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Contents

1 Executive Summary

The ICES/NAFO Working Group on Harp and Hooded Seals (WGHARP) met during 2630 September 2016 Copenhagen, Denmark. The WG received presentations related to catch and abundance estimates, and ongoing research of White Sea/Barents Sea, Greenland Sea and Northwest Atlantic Ocean harp and hooded seal stocks. The WG concluded their meeting on 30 September 2016. In attendance were scientists representing Canada (2), Greenland (1), Norway (3), UK (1), USA (1), and Russia (2), as well as observers from NAMMCO (1) and Denmark (1) (Annex 1).

Reported catches for harp seals in 2016 were 1442, 28, and 146 614 animals from the Greenland Sea, White Sea, and NW Atlantic populations respectively. Total hooded seal catches were 18 pups from the NE Atlantic and 1 856 animals from the NW Atlantic population including Greenland harvests.

Current research on the Greenland Sea harp seal has focused on the animal welfare aspects of different killing methods. Data collection has ended and analyses are underway. Software-based seal detection methodology has been developed. Evaluating the seal detection scheme using a validation dataset, an accuracy of 99.7% was obtained. False positives occur and therefore a semi-automatic approach was implemented, where a human reader checks if detections correspond to actual seal pups, and can modify the results if necessary.

No new survey information was available for any stock. For the Greenland Sea harp seal population a population model estimates a 2017 abundance of 543 800 (95% CI: 366 500719 400) 1+ animals and 106 500 (95% CI: 76 500136 400) pups. The total population estimate is 650 300 (95% CI: 471 200829 300) seals. Using current catch levels, the model projects an increase in the 1+ population of 58% over the next 15 years. The equilibrium catch level (which maintains constant population size) is 21 500 (100% 1+ animals). If pups are hunted, two pups balance one 1+ animal. A catch of 26 000 animals (100% 1+) will reduce the population, but with a 0.8 probability that the population remains above N70 over a 15 year period. Catch estimates are lower than previous advice due to changes in fecundity rates used in the projection. Because future fecundity rates are not known, an average of the fecundity rates observed over the past decade was used in the projections. This resulted in an average fecundity rate of 0.84, which is lower than the rate observed in 2016 (F=0.91)

In the White Sea, poor ice conditions were observed in 2015 and 2016. There was no suitable ice for pupping inside the White Sea, but seals with pups were observed on the ice at the entrance to the White Sea. Ice also accumulated in the southeastern Barents Sea. If poor ice conditions are encountered in the White Sea during 2017, the southeast Barents Sea will be searched to see if pupping also occurs in this area.

The model estimates of abundance for White Sea harp seals in 2017 is 1 197 000 (95% CI: 1 042 8001 351 200) 1+ animals and 211 000 (185 100 – 236 900) pups. Total estimate is 1 408 000 (95% CI: 1 251 6801 564 320). The last reproductive rates available are based on data from 2006. The WG was concerned about using the last observed fecundity rate of 0.84 in future projections. Instead, an average of fecundity rates observed over the last 10 years, was used in the projections (F_{future} = 0.76). The harp seal population in the Barents Sea/White Sea is considered data poor because of the time elapsed since the last series of reproductive samples were obtained. For this reason, the catch option to reduce the population to N70 was not examined for this stock. Because the stock is

Data Poor, this means that the Potential Biological Removal (PBR) approach for estimating catch quotas should be considered. However, in simulations based on the population model, using this approach resulted in a projected population decline of 25% over the next 15 years. The WG concluded that the PBR catch level was not suitable for providing advice on future catch quotas and recommended that equilibrium catch levels be used. The equilibrium catch level is 10 090 seals (100% 1+ animals). The model indicates an increase of 12% for the 1+ population over 15 years with no catch.

For Northwest Atlantic harp seals a population model was used to examine changes in the size of the population between 1952 and 2014, and then extrapolated into the future to examine the effect of different harvest simulations on the modelled population. The working group examined the level of catches necessary to reduce the harp seal population to 6.8 million or 5.4 million animals assuming catches consisted of 90% Young of the Year (YOY) or 50% YOY, and occurred over different time periods (5, 10,and 15 years). Then, once the herd was reduced, the level of catch possible that would maintain a 95% probability of remaining above the Limit Reference Level. The impacts of the different catch options on the projected population were tested under two scenarios. The first scenario (Model A) assumed that reproductive rates and Greenland catches were similar to that seen over the past 10 years. The second scenario, referred to as Model B, assumed that both future reproductive rates and Greenland catches behave in a density-dependent manner. The predicted changes in the population trajectory were affected very strongly by the age composition of the harvest used to reduce the population, the speed at which the reduction was achieved and on model assumptions concerning density-dependence.

The results of the modelling exercise indicated that more animals would need to be removed if the population reduction was to be achieved rapidly, or with a harvest comprised primarily of YOY. Under Model A, once the target level was achieved, the catch levels that would ensure a 95% probability of remaining above the Critical Reference Limit were much lower than the harvest levels allowable during the reduction phase. Under Model B, the numbers of animals needed to be removed to achieve the reduction target of 6.8 million animals, were similar to the numbers of animals needed to reduce the population to the same level, but under Model A. However, with Model B and a reduction target of 6.8 million animals, much higher harvests were allowed over the 15 years following the reduction due to the increased reproductive rates and reduced Greenland catch that were assumed. Under all scenarios, the uncertainty associated with estimates of population size increased considerably as time since the last survey also increased. The objective of the exercise was to have a 95% likelihood of remaining above the limit reference point (2.4 million) rather than to maintain the population at the reduction target level. As a result, in some scenarios, high catches could be taken after the initial reduction. However, these would result in a continued reduction in the population. If the management objective had been to maintain the population at the reduction target level, the ‘post reduction’ catches would have been much smaller.

These simulation results are very sensitive to model assumptions and should be considered for illustration only.

The summer (June–July) diet of Greenland Sea hooded seals was studied in the West Ice in 2008 and 2010, based on analysis of gastrointestinal contents of 179 animals obtained in dedicated surveys. Polar cod dominated the diet. The importance of the squid *Gonatus fabricii* was lower in this study compared with previous hooded seal studies in the area.

The estimated 2017 abundance of Greenland Sea hooded seals was 66 860 1+ animals (95% CI: 45 860–87 860) and 13 600 (9 25017 950) pups. The estimated total 2017 population is 80 460 (95% CI: 59 020101 900). All model runs indicate a population currently well below the Limit Reference Level. Following the precautionary approach framework developed by WGHARP, no catches should be taken from this population. Previously, ICES recommended that no harvest of Greenland Sea hooded seals should be permitted, with the exception of catches for scientific purposes. Eighteen animals, including 10 pups were taken for scientific purposes by Norway in 2016.

2 Opening of the meeting

The ICES/NAFO Working Group (WG) on Harp and Hooded Seals (WGHARP) met during 2630 September, 2016 at ICES headquarters, in Copenhagen, Denmark. The WG received presentations related to estimates of catch, abundance, biological parameters and current research of relevance to White Sea/Barents Sea, Greenland Sea and Northwest Atlantic Ocean harp and hooded seal stocks. The WG provided catch options for the West Ice/Greenland Sea harp and hooded seals and White Sea/Barents Sea harp seals. The WG also discussed the implications of possible management objectives proposed for the Northwest Atlantic harp seal population. In attendance were scientists from Canada (2), Greenland (1), Norway (3), UK (1), USA (1) NAMMCO (1), Denmark (1), and Russia (2), (Annex 1).

3 Adoption of the agenda

The agenda for the meeting, as shown in Annex 2, was adopted at the opening of the meeting on 26 September 2016.

4 Terms of reference

WGHARP – Group on Harp and Hooded Seals

The **ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP)** chaired by Mike Hammill, Canada, will meet in ICES HQ, Copenhagen, Denmark, 26–30 September, 2016 to:

Harp and hooded seals: Northeast Atlantic stocks:

a) Address the special request from Norway on the Management of Harp and Hooded Seal stocks in the Northeast Atlantic by assessing the status and harvest potential of the harp seal stocks in the Greenland Sea and the White Sea/Barents Sea, and of the hooded seal stock in the Greenland Sea. ICES should also assess the impact on the harp seal stocks in the Greenland Sea and the White Sea/Barents Sea of an annual harvest of:

- i) current harvest levels;
- ii) sustainable catches (defined as the fixed annual catches that stabilizes the future 1 + population);
- iii) catches that would reduce the population over a 15-year period in such a manner that it would remain above a level of 70% of the maximum population size, determined from population modelling, with 80% probability.

b) Evaluate new model developments and comparisons with the old assessment model

Harp seals: Northwest Atlantic stock:

c) Explore the impact of proposed harvest strategies that would maintain the North Atlantic harp seal population at a precautionary level of a PA framework, using the Canadian levels as a case study, and that would have a low risk of decreasing below the critical level.

Note - The terms of reference regarding item b were not addressed at the meeting.

5 Harp seals (*Pagophilus groenlandicus*)

5.1 Stock Identity

No new information

5.2 The Greenland Sea Stock

5.2.1 Information on recent catches and regulatory measures

Catches

Based on advice from WGHARP (ICES 2013) the 2015–2016 TAC for harp seals in the Greenland Sea was set at 21 270 1+ animals (where 2 pups balanced one 1+ animal), i.e. the estimated removal level that would reduce the population by 30% to N70 over the next 10 year period (see ICES 2013)(Annex 8, Table 1). The total removals of Greenland Sea harp seals in 1946–2016 are shown in Annex 7, Table 1. No Russian vessels have hunted in this area since 1994. Total catches (performed by one vessel each year) of harp seals were 2237 (including 2,144 pups) in 2015 and 1442 (including 426 pups) in 2016 (Annex 7, Table 1).

The group was informed, that up to the 2014 season, Norwegian seal hunts were subsidized by the Norwegian government. For the 2015 season these subsidies were completely removed. They were reinstated in 2016, however on a considerably lower scale than in previous years.

5.2.2 Current research

Sealing methods

A project including collection of material to assess efficiency and animal welfare issues in the Norwegian commercial seal hunt was started in 2013, continued in 2014 and field efforts ended after the commercial harp seal hunt in the Greenland Sea in April/May 2015. Analyses of the collected material are in progress.

Identification of seals on digital imagery

Pup production of harp and hooded seals are based primarily on photographic surveys, which are time-consuming to analyse manually. Software-based detection methodology using artificial intelligence (deep learning) has been developed as a collaboration between the Norwegian Computing Centre and Institute of Marine Research, Norway and Fisheries and Oceans, Canada. Deep learning has revolutionized image analysis over the last four years in terms of its ability to extract content and information from images. The developed deep learning scheme is based on a deep convolutional neural network and initial tests of the proposed deep learning based seal detection scheme shows that seals can be detected with a very high accuracy. By evaluating the proposed method on a validation dataset, an accuracy of 99.7% was obtained. False positives occur and therefore a semi-automatic approach was implemented, where a reader may evaluate the detected seal pups and modify the results if necessary.

A new method for estimating the pup production using a geospatial point process is under development. If successful, this may lead to improvements in estimates of variance associated with the pup abundance surveys.

5.2.3 Biological parameters

Mean age of maturity (MAM) was estimated at 6.15±0.6 years for a sample of 197 Greenland Sea harp seals collected early in the moulting period in 2014 (Frie SEA246). This estimate is not significantly different from the long term average of 5.6 years estimated for the period 1964-1990, but is significantly different from the 2009 estimate (7.6 years). The ovary-based pregnancy rate for the 2014 sample was 0.91±0.02, which is significantly higher than estimates for the period 1991-2009, but similar to values from 1964 and 1978. The estimated MAM for 2014 was only 0.5 years lower than the mean age of primiparity (MAP) estimated for the same sample, due to near absence of first time ovulators. Further comparisons of MAM and MAP for Greenland Sea harp seals suggest that first time ovulators were poorly represented in samples from 1990, 1991 and 2009. The difference between MAM and MAP for these samples was close to 1 year implying an unrealistically high pregnancy rate of 100% for first time ovulators. In comparison, the difference between MAM and MAP for samples collected in 1959-64, 1978, 1987, 1990 was 1.5 years. The timing of sampling in 2009 and 2014 was similar to, or slightly later than in 1978, suggesting that a seasonal delay of ovulation in young females is not the main reason for the low occurrence of first time ovulators in the more recent Greenland Sea samples. Mark-recapture analyses for the Greenland Sea (Øien and Øritsland, 1995) have previously suggested temporal emigration of some cohorts up to the time of first pupping, which could explain the absence of the first time ovulators in the 2014 Greenland Sea sample.

5.2.4 Population assessment

No new survey information is available. The next survey is planned for March 2018.

The current abundance of harp seals in the Greenland Sea was estimated using a population dynamics model that incorporates historical catch records, historical fecundity rates, and age specific proportions of mature females. The model is fitted to independent estimates of pup production (Øigard and Haug SEA240). It is a deterministic age-structured population dynamics model with 3 unknown parameters (pup mortality, mortality of 1 year and older seals, initial population size). This model is the same as used previously by the WG to provide advice for this stock.

Model Input

Two types of reproductive data are used: information on the proportion of females that are mature at a given age (i.e. maturity ogive) and the proportion of mature females that are pregnant at a given year (i.e. fecundity rate). Historical data on the maturity curve are sparse, consisting of only three curves (Table 1). One curve is from the period 19591990, one is from 2009 and the last one is from 2014. For the periods with missing data (19902009 and 2009–2014), a linear transition between the available maturity curves is assumed. Figure 1 shows the maturity curves from Table 1, along with the linear interpolation between the curves in years with missing data.

Table 1. Estimates of proportions of mature females ($p_{i,t}$). The P_1 estimates are from the period 1950 - 1990 (ICES, 2009), the P_2 estimates are from 2009 (ICES, 2011) and the P_3 estimates are from 2014 (Frie, SEA246).

AGE	1	2	3	4	5	6	7	8	9	10	11	12	13
P1	0	0	0.06	0.29	0.55	0.74	0.86	0.93	0.96	0.98	0.99	1.00	1.00
P2	0	0	0	0	0.06	0.28	0.55	0.76	0.88	0.95	0.98	0.99	1.00
P3	0	0	0	0	0.33	0.71	0.89	0.96	0.99	0.99	1.00	1.00	1.00

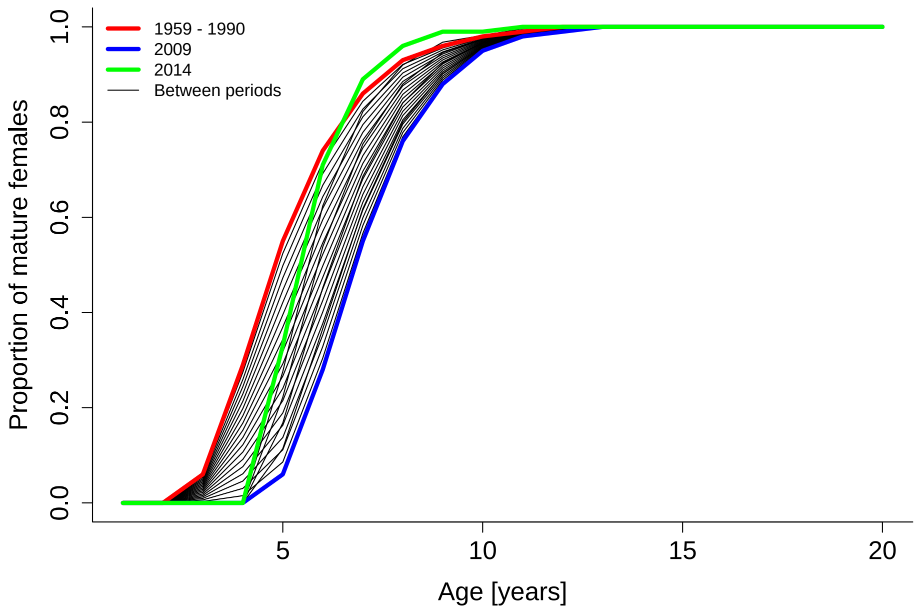

Figure 1. Proportion of mature females and the interpolated values for years without data among Greenland Sea harp seals in three periods. Values are taken from Table 1.

The model uses historical values of the fecundity rates *F* rates that are obtained through sampling during the commercial hunt (Table 2). Data are available from a Russian long term dataset (19591991) (Frie *et al.*, 2003) as well as Norwegian data for 2008 and 2009 (ICES, 2011). A new pregnancy rate for 2014 was presented (Frie, SEA246). The long term dataset on pregnancy rates relies on the assumption that pregnancy in the previous cycle can be estimated based on the presence/absence of a large luteinised *Corpus albicans* (LCA) in the ovaries of females sampled in April-June (ICES, 2009). A similar approach has previously been used for estimation of pregnancy rates of ringed seals (Stirling, 2005). In periods where data are missing, a linear transition between estimates was assumed. Figure 2 shows the available historical pregnancy rates and the interpolated values for years with missing data. As opposed to being part of the data to which the model is fit by maximum likelihood, these rates are treated as fixed values (with no variance) by the population dynamics model.

Table 2. Estimates of proportion of Greenland Sea harp seal females giving birth. It is assumed that the fecundity rate and pregnancy rate are the same. Data from (ICES, 2011) and (Frie, SEA246).

YEAR	FECUNDITY RATE	STANDARD DEVIATION
1964	0.92	0.04
1978	0.88	0.03
1987	0.78	0.03
1990	0.86	0.04
1991	0.83	0.05
2008	0.80	0.06
2009	0.81	0.03
2014	0.91	0.03

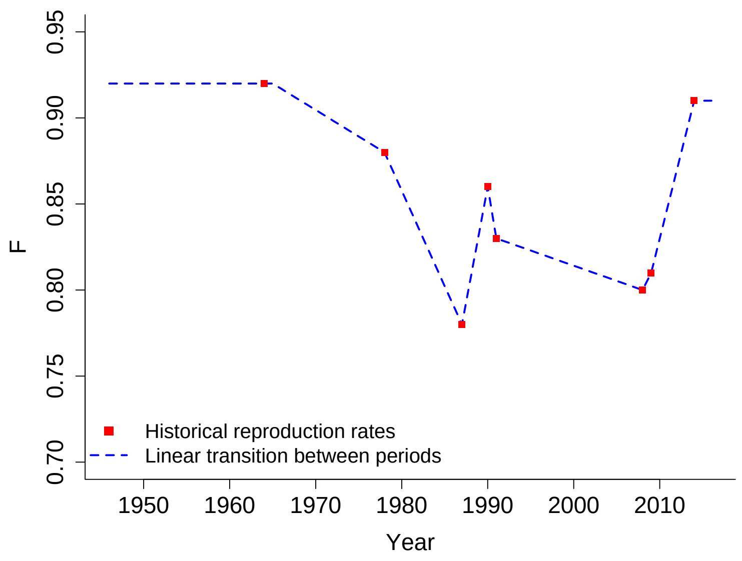

Figure 2. Historical fecundity rates *F* of mature females Greenland Sea female harp seals and the interpolated values for years with missing data. Values are taken from Table 2.

Pup production estimates are available from mark-recapture estimates (1983-1991) and aerial surveys conducted (20022012) (Table 3). Catch levels for the period 1946–2016 are listed in Appendix 7, Table 1).

Table 3. Estimates of Greenland Sea harp seal pup production (ICES 2011, Øigård *et al.*, 2010; Øigård *et al.*, *2014a;* ICES 2013). The data from 19831991 are mark––recapture estimates; those from 2002, 2007 and 2012 are from aerial surveys.

Year	Estimated Number of Pups	Coefficient of Variation.
1983	58 539	0.104
1984	103 250	0.147
1985	111 084	0.199
1987	49 970	0.076
1988	58 697	0.184
1989	110 614	0.077
1990	55 625	0.077
1991	67 271	0.082
2002	98 500	0.179
2007	110 530	0.250
2012	89 590	0.137

Population model

The population model used to assess the abundance for the Greenland Sea harp seal population is a deterministic age-structured population dynamics model (Øigard and Haug SEA240).

For initiation of the model it is assumed that the population had a stable age structure in year y_0 = 1945, i.e.

$$N_{i,y_0} = N_{y_0} s_{1+}^{i-1}(1 - s_{1+}),\ i = 1,\ldots, A-1, \quad (1)$$

$$N_{A,y_0} = N_{y_0} s_{1+}^{A-1} \quad (2)$$

Here A is the maximum age group containing seals aged A and higher, set to 20 years (ICES, 2013), and N_{y_0} is the estimated initial population size in the first year (y_0). The model is parameterized by the natural mortalities M_0 and M_{1+} for the pups and seals 1 year and older seals, respectively. These mortalities determine the survival probabilities $s_0 = \exp(-M_0)$ and $s_{1+} = \exp(-M_{1+})$.

The model has the following set of recursion equations:

$$\begin{aligned} N_{1,y} &= (N_{0,y-1} - C_{0,y-1})s_0, \\ N_{a,y} &= (N_{a-1,y-1} - C_{a-1,y-1})s_{1+}, \quad a = 2,\ldots, A-1, \\ N_{A,y} &= \left[(N_{A-1,y-1} - C_{A-1,y-1}) + (N_{A,y-1} - C_{A,y-1})\right]s_{1+}. \end{aligned} \quad (3)$$

Data are not available to estimate age-specific mortality rates. Therefore it is assumed that the mortality rates are constant across ages within the 1+ group. The $C_{a,y}$ are the age-specific catch numbers, but catch records are available only as the number of pups and number of 1+ seals caught. To obtain $C_{a,y}$ in (3) we assume that the age-distribution in the catch follows the estimated age distribution of the population (Skaug *et al.*, 2007):

$$C_{a,y} = C_{1+,y}\frac{N_{a,y}}{N_{1+,y}}, \quad a = 1,\ldots, A, \quad (4)$$

where $N_{1+,y} = \sum_{y=1}^{A} N_{a,y}$, with $N_{a,y}$ being the number of individuals at age a in year y.

The modelled pup abundance is given by

$$N_{0,y} = \frac{F_y}{2} \sum_{a=1}^{A} p_{a,y} N_{a,y}, \tag{5}$$

where $N_{a,y}/2$ is the number of females at age a in year y, F_y is the fecundity rate and $p_{a,y}$ are the age specific proportions of mature females in year y.

Assuming normality for the pup production counts, their contribution to the log-likelihood function is

$$\sum_t -\log(cv_{0,y}) - \frac{1}{2}\frac{(N_{0,y} - n_{0,y})^2}{cv_{0,y} n_{0,y}}, \tag{6}$$

where $n_{0,y}$ and $cv_{0,y}$ denotes the survey pup production count and corresponding coefficient of variation (CV) for year y, respectively (Table 3).

The model calculates a coefficient D_{1+}, which describes the increase or decrease in the 1+ population trajectory over a 15-year period,

$$D_{1+} = \frac{N_{1+,2032}}{N_{1+,2017}}. \tag{7}$$

The coefficient is used for finding the equilibrium catch levels. The equilibrium catch level is defined as the constant catch level that results in the population size in 2032 being the same as in 2017, i.e. the catch level that gives $D_{1+} = 1$.

The population dynamics model is a Bayesian type model as priors are imposed on the parameters. A vague normal prior is assumed for the initial population size N_{y_0} and a truncated normal prior for both the pup mortality M_0 and the mortality for the 1+ group M_{1+} (Table 4).

The combined likelihood-contributions for these priors are

$$-\frac{1}{2}(\mathbf{b}-\mathbf{m})^{\mathrm{T}} \Sigma^{-1}(\mathbf{b}-\mathbf{m}) - \frac{1}{2}\ln|\Sigma| - \frac{3}{2}\ln(2\pi), \tag{8}$$

where $\mathbf{b} = (N_{0,y}, M_0, M_1)^{\mathrm{T}}$ is a vector containing the parameters estimated by the model, T denotes the vector transpose, **m** is a vector containing the respective mean values of the normal priors for the parameters in **b**, and Σ is a diagonal matrix with the variance of the respective prior distributions on the diagonal. The mean of the prior for M_0 was set at three times the mean of M_{1+}.

All parameter estimates are found by minimizing the likelihood function using the statistical software ADModel Builder (Fournier *et al.*, 2012). ADModel Builder calculates standard errors (SE) for the model parameters, as well as the derived parameters such as present population size and D. It uses a quasi-Newton optimization algorithm with bounds on the parameters, and calculates estimates of standard errors of model parameter using the "delta-method" (Skaug *et al.*, 2007). The catch data enter the model through Eq. (3), but do not contribute to the objective function. Handling of data and visualizations were done in R (R Core Team, 2015).

The estimated population sizes and parameters used in the model, along with the normal priors, used are presented in Table 4. The model trajectory indicates a substantial increase in the population abundance from the 1970s to the present (Figure 3). The model estimates are stable for various choices of initial values. Although the priors for M_0, and M_{1+} are relatively non-informative, increasing the mean of the prior to 0.3 and 0.1, respectively, caused a 0.1% change in the total population estimate. Due to the limited data available, mortality cannot be estimated independently and the model estimates of M_0 and M_{1+} are highly correlated (-0.95).

The model estimates a 2017 abundance of 543 800 (95%CI: 366 500719 400) 1+ animals and 106 500 (95%CI: 76 500136 400) pups. Total estimate is 650 300 (95%CI: 471 200829 300) seals.

Table 4: Greenland Sea harp seals: Estimated and derived mean values and standard deviations of the parameters used in the model. Priors used are shown in brackets. N_{max} is the historically largest total population estimated by the model, N_{70} is 70% of N_{max}, N_{lim} is 30% of N_{max}, and N_{min} is the estimated population size using 20th percentile of the lognormal distribution.

Parameters	Model estimates	
	Mean	SD
N0y	283 600 (900 000)	25 611 (900 000)
M0	0.27 (0.24)	0.19 (0.2)
M1+	0.12 (0.08)	0.02 (0.1)
N_{max}	650 300	-
N_{70}	455 210	-
N_{lim}	195 090	-
N_{min}	567 879	-
$N_{0,2017}$	106 500	15 305
$N_{1+,2017}$	543 800	90 050
$N_{Total,2017}$	650 300	91 338

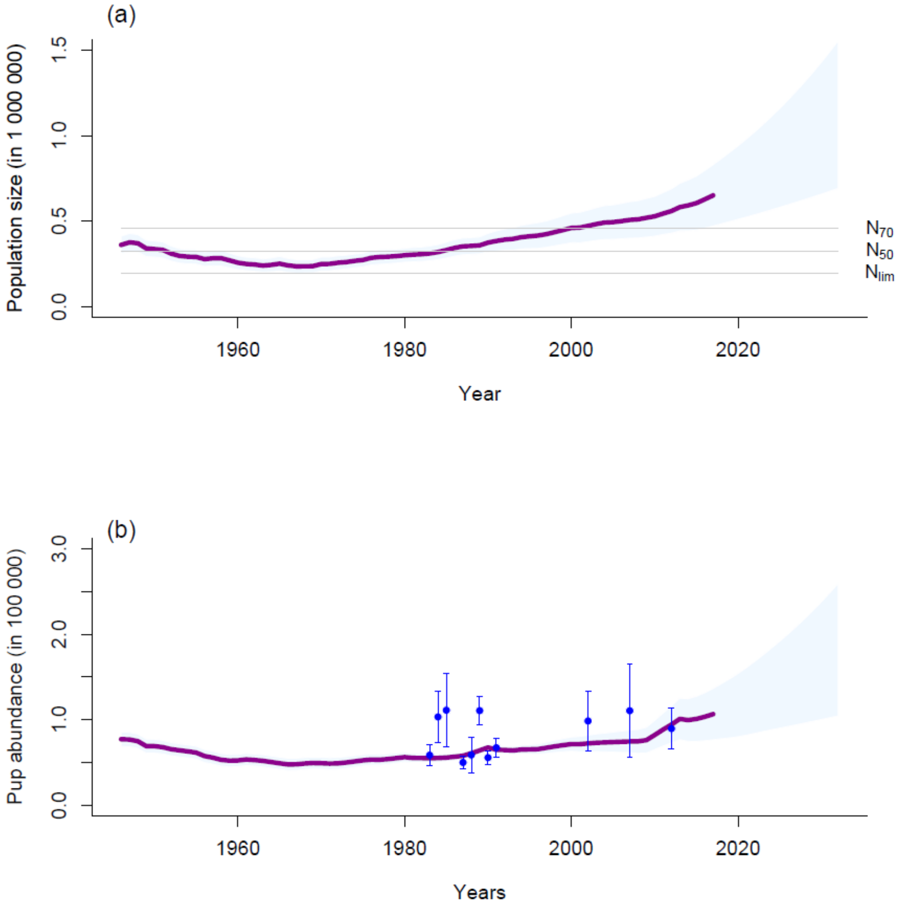

Figure 3. Greenland Sea harp seals: Modelled population trajectories for pups and total population (full lines), 95% confidence intervals. Future projections are illustrated by confidence bands. N_{70}, N_{50}, and N_{lim} denote the 70%, 50% and 30% of the estimated maximum population size, respectively. Observed pup production estimates and 95% confidence intervals are shown in blue.

Catch options

The most recent reproductive rates available are based on data from 2014 (Frie, SEA 246) and pup production estimates are based on data from 2012 (ICES, 2013), i.e. less than 5 years old. Based on this, the WG considers the harp seal population in the Greenland Sea as data rich and catch advice can be provided with the use of an appropriate population model. Hammill and Stenson (2010) explored the impact of extrapolating catches on our ability to monitor changes in the population given the precision and frequency of pup production surveys. They found that catches should be projected over a period of at least 15 years to determine their impact on the population. In 2013 the WG recommended that in future, the impact of the various catch scenarios should be explored over a 15 year period rather than 10 years used previously (ICES, 2013). The impact of various catch scenarios are therefore explored over a 15 year period. The catch scenarios are:

1) Current catch level (average of the catches in the period 2012 – 2016).
2) Equilibrium catches.
3) Catches that would reduce the population to N_{70} with probability 0.8 over a 15-year period.

Current catch level is defined as the average catch level of the last 5 years, i.e. the average catch level of the period 2012–2016. For pups there has been zero catch in this period, and for the 1+ group 9 seals. The equilibrium catch level is defined as the (fixed) annual catch level that stabilizes the future 1+ population under the estimated model. The proportion of pups in catch used was 0% and 80.4%. Option 3 is the highest harvest level that would ensure with 80% probability that the population size does not fall below N_{70} over a 15 year period.

The WG was concerned about the uncertainty in the pregnancy rates and felt that using the last observed fecundity rate in the projections was not appropriate given observed historical variation. They considered that it was more appropriate to use an average of the fecundity rates observed over the past decade in projections of the population size. This is consistent with the practice used for other harp seal stocks. The fecundity rate used for projections was $F_{future} = 0.84$.

The estimates for the various catch options are given in Table 5. Using current catch levels the model projects an increase in the 1+ population of 58% over the next 15years. The equilibrium catch level is 21 500 (100% 1+ animals). If pups are hunted, two pups balance one 1+ animal. A catch level of 26 000 animals (100% 1+) will reduce the population to N_{70} with an 0.8 probability that the population remains above this level over a 15 year period.

Table 5. Catch options with relative 1+ population size (D_{1+}) in 15-years (2032) for harp seals in the Greenland Sea.

Catch option	Proportion pups in catches	Pup catch	1+ catch	Total catch	D1+ (95% CI)
Current level	80.4%	5 992	1 465	7 456	1.58 (1.30-1.86)
Equilibrium	0%	0	21 500	21 500	1.00 (0.61-1.40)
Reduce to N70a)	0%	0	26 000	26 000	0.85 (0.40-1.29)

[a)] **Catches that would reduce the population to 70% of current level with 0.8 probability over 15 years.**

The available data on fecundity are limited. The population model does not consider the uncertainty in the estimated fecundity rates. Instead it treats the available data on fecundity and age specific maturity as known quantities. Therefore the confidence intervals around model projections are underestimated. The **WG recommends** that the model should be modified to account for the uncertainties of these reproductive data.

5.3 The White Sea and Barents Sea Stock

5.3.1 Information on recent catches and regulatory measures

Due to a sharp decline in pup production observed after 2003, ICES (2013, 2014) recommended that removals be restricted to the estimated sustainable equilibrium level which was 17,400 and 19,200 1+ animals (where 2 pups balanced one 1+ animal) in 2015 and 2016, respectively. The Joint Norwegian-Russian Fisheries Commission has followed this request of which 7,000 seals of this TAC was allocated to Norway and the remaining quota allocated to Russia in both years (Annex 8, Table 2). A ban on all pup catches prevented Russian hunting in the White Sea during the period 20092014. This ban was removed before the 2015 season. However, the availability of ice was too restricted to permit sealing, resulting in no commercial Russian harp seal catches in the

White Sea in 2015 (Annex 7, Table 2). This was also the case in 2016. Also, no Norwegian vessels hunted in the southeastern Barents Sea (the East Ice) in 2015 and 2016. In September 2016, 28 harp seals (1+ animals) were taken for scientific purposes north of Svalbard – presumably from the White Sea / Barents Sea population (Appendix 7, Table 2;).

5.3.2 Current research

Ice conditions and possible influence on harp seal pupping

Information on ice conditions in the White Sea and southeastern part of the adjacent Barents Sea area was obtained from satellite imagery, ice-charts and ship captains during January-April 2015 and 2016 to examine possible impacts of ice conditions on harp seal pupping.

In 2015, the remote sensing data showed extensive ice cover, throughout the White Sea and in the adjacent southeastern part of the Barents Sea during February. Ice conditions considered optimum for harp seal pupping were present at this time. During March the ice had largely disappeared from the main 'basin' of the White Sea. Heavier ice remained in the entrance to the White Sea and in southeastern part of the Barents Sea (Fig 4), but warm temperatures and warm southerly winds contributed to ice destruction and by mid-March there was very little ice remaining in the White Sea, with ice cover being restricted along the coast at the entrance to the White Sea and in the southeastern Barents Sea. A large patch of whelping animals was seen in each of these areas. Pup mortality was considered to be relatively high.

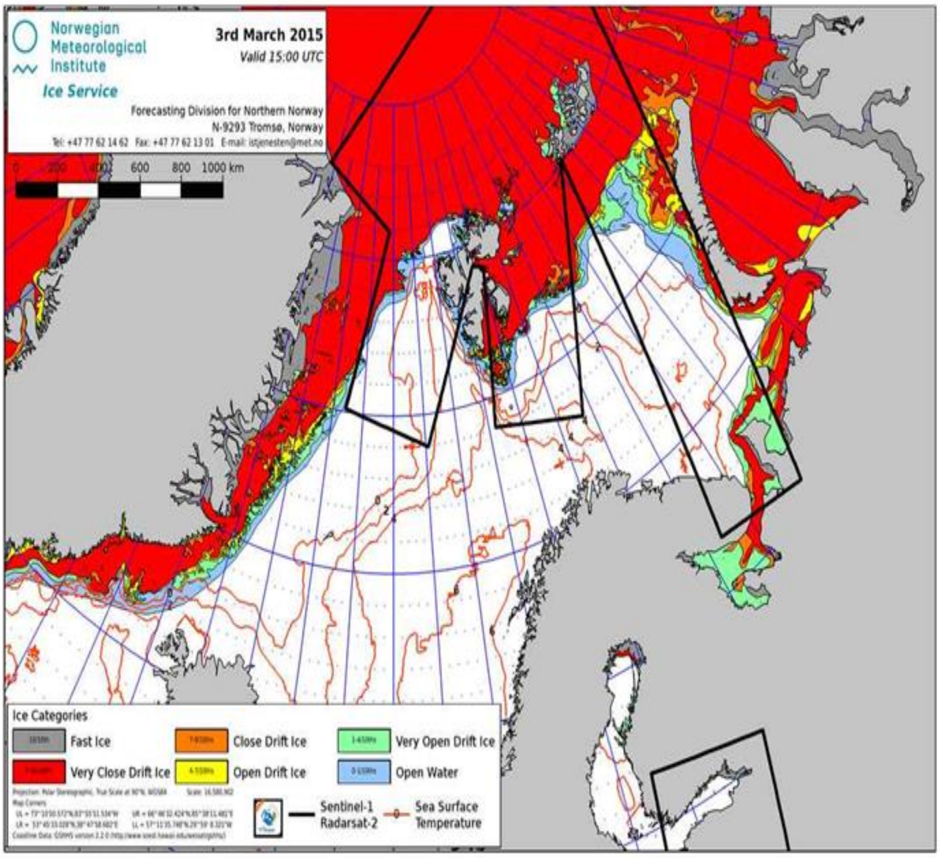

Figure 4. Map showing ice cover in the White Sea and southeastern Barents Sea on 3 March 2015. Ice map is from the Norwegian Meteorological Institute, TromsØ Norway.

In 2016, suitable ice conditions in the White Sea were observed in January, but the ice deteriorated rapidly and by March suitable ice for harp seal pupping was only observed along the coast at the entrance to the White Sea and in the eastern Barents Sea. Total ice cover was lower than in 2015, but more suitable ice for pupping appeared to be present. Consequently, mortality was considered to be lower in 2016 compared to 2015.

Working papers on the age of maturity and pregnancy rates of harp seals in the White Sea and estimates of abundance using cohort and stock production models were made available to the working group but were not discussed in detail because the authors were unable to be present (Shafikov SEA244 ; Korzhev and Zabavnikov SEA242).

5.3.3 Biological parameters

For the Barents/White Sea stock an even more pronounced underrepresentation of first time ovulators was observed. Estimates of MAM and MAP were virtually identical for all available samples from the early 1960s to 2006. The implications of this depend on the underlying reason for the small numbers of first time ovulators in the samples. If the main reason was a seasonal delay in timing of first ovulation, MAM will be overestimated, but estimates of MAP would be reliable. If the main reason was spatio-temporal segregation of reproductive classes, MAP may be underestimated due to underrepresentation of nulliparous females. More information on the seasonal distribution of first time ovulators is needed to understand why they are not being seen in the sample collections.

The WG noted that biological material sufficient for establishing an ogive was last collected in 2006, and that data for calculations of fertility rates have not been collected from this area since 2011. The WG **recommends** that efforts be made to obtain samples, to evaluate reproductive rates for use in the population model and body condition information as well.

5.3.4 Population assessment

No new survey information.

A new survey is planned for March 2017

Population Assessment

The population dynamics model has the same structure as that used to model Greenland Sea harp and hooded seals. It incorporates historical catch records, fecundity rates, age specific proportions of mature females, and fits to estimates of pup production to estimate the population trajectory.

Two types of reproductive data are used in the model: information on the proportion of females that are mature at a given age (i.e. maturity ogive) and the proportion of mature females that are pregnant at a given year (i.e. fecundity rate). Estimates of age specific proportions of mature females are available for four historical periods; 1962-1972, 19761985, 19881993, and 2006 (Table 6; Frie *et al.*, 2003; ICES, 2009; ICES, 2013). For years with no data a linear interpolation of the age specific proportions of mature females between two periods is assumed (Figure 5; ICES, 2013).

Table 6. Estimates of proportions of mature Barents Sea / White Sea harp seal females (p) at ages 215 in four historical periods: P_1 = 1962-1972 P_2 = 1976-1985; P_3 = 1988-1993; P_4 = 2006;. Data from ICES (2014).

AGE	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P1	0	0.01	0.17	0.64	0.90	0.98	0.99	1.0	1.0	1.0	1.0	1.0	1.0	1.0
P2	0	0	0	0.24	0.62	0.81	0.81	0.95	0.98	0.99	0.99	1.0	1.0	1.0
P3	0	0	0.02	0.08	0.21	0.40	0.59	0.75	0.85	0.91	0.95	0.97	0.98	0.99
P4	0.01	0.02	0.05	0.11	0.25	0.55	0.90	0.99	1.0	1.0	1.0	1.0	1.0	1.0

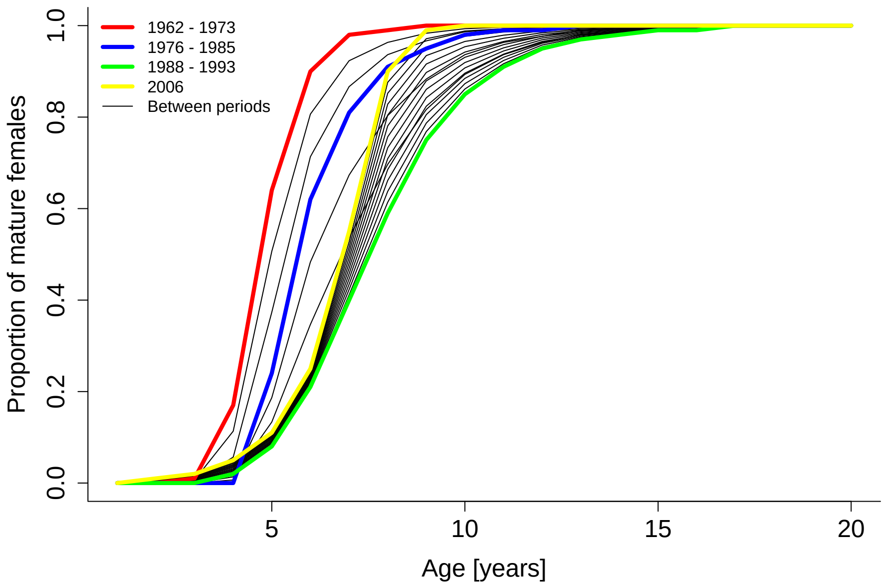

Figure 5: Proportion of mature females and the interpolated values for years without data among Barents Sea / White Sea harp seals. Values are from Table 6.

The model also uses historical values of the fecundity rates that are obtained through sampling during commercial hunt. Barents Sea / White Sea population fecundity data are available as mean estimates in the period 19901993, and from 2006 and 2011 (Table 7; Kjellqwist *et al.*, 1995; ICES, 2008; Frie SEA246). The population dynamics model sets fecundity with no variance. For periods where there are no pregnancy rate data, values were interpolated assuming a linear transition from 0.84 in 1990 to 0.68 in 2006, increasing again to 0.84 from 2006 to 2011. Prior to 1990 a constant pregnancy rate was assumed and set at 0.84. After 2011, the WG was concerned about the uncertainty in the pregnancy rates and felt that using the last observed fecundity rate in the projections was not appropriate given observed historical variation. They considered that it was more appropriate to use an average of the observed fecundity rates in the projections.

Table 7. Estimates of proportion of Barents Sea / White Sea harp seal females giving birth. Data from ICES (2011) and Frie (SEA246)

Year	Fecundity rate	Standard Deviation
19901993	0.84	0.05
2006	0.68	0.06
2011	0.84	0.10

Pup production estimates are available from surveys conducted in 19982013 (Table 8) (ICES 2011; 2014). The catch records comes from commercial hunt and distinguish between the number of pups (0-group) and the numbers of 1+ animals caught per year, but contain no additional information about the age composition of the catches. The modelling period begins in 1946, because catch data prior to then are unreliable (Iversen, 1927; Rasmussen, 1957; Sergeant, 1991).

Table 8. Timing of Russian surveys, estimated numbers of pups and coefficients of variation (CV) for harp seals in the Barents Sea / White Sea. Numbers and CVs are drawn from ICES (2011) and ICES (2014). All unspecified surveys were flown using multispectral sensing systems

Year	Survey Period	Estimated Number of Pups	Coefficient of Variation
1998	12 & 16 March	286,260	0.150
2000	1012 March - photo	322,474a	0.098
	18 March -	339,710b	0.105
2002	20 March	330,000	0.103
2003	18 & 21 March	328,000c	0.181
2004	22 March – photo	231,811	0.190
	22 March -	234,000	0.205
2005	23 March	122,658	0.162
2008	1920 March	123,104	0.199
2009	1416 March	157,000	0.108
2010	2023 March	163,022	0.198
2013	1521 March	128,786	0.237

First 2000 estimates represented the sum of 291,745 pups (SE = 28,708) counted plus a catch 30,729 prior to the survey for a total pup production of 322,474.

Second 2000 estimate represents the sum of 308,981pups (SE = 32,400) counted plus a catch of 30,729 prior to the survey for a total pup production of 339,710.

2003 estimate represents the sum of 298,000 pups (SE = 53,000) counted, plus a catch of 35,000 prior to the survey for a total pup production of 328,000.

The estimated population sizes, and priors used are presented in Table 9. Figure 6 shows the model fit to the observed pup production estimates and the modelled total population trajectory. The fit to the early pup production estimates is poor, and the model does not capture the dynamics of the survey pup production estimates. The model indicates that harp seal abundance in the Barents Sea/White Sea declined from 1946 to the early 1960s, increased from the early 1960s to early 1980s, but then declined again until around 2007. The model suggests an increase in population size since 2007.

The model estimates are stable for various choices in priors. Although the priors for M_0, and M_{1+} are relatively non-informative, increasing the mean of the prior to 0.3 and 0.1, respectively, caused a 0.1% change in the total population estimate. Due to the limited data available, mortality cannot be estimated independently and the model estimates of M_0 and M_{1+} are highly correlated (-0.95).

Because the fecundity rates are fixed values in the model, there is no uncertainty associated with this parameter, meaning that the uncertainty of the modelled abundance is underestimated.

The 2017 model estimates of abundance is 1 197 000 (95% CI: 1 042 8001 351 200) 1+ animals and 211 000 (95% CI: 185 100236 900) pups. Total estimate is 1 408 000 (95% CI: 1 251 6801 564 320).

Table 9: Barents Sea/White Sea harp seals: Estimated and derived mean values and standard deviations of the parameters used in the model. Priors used are shown in brackets. N_{max} is the historically largest total population estimated by the model, N_{70} is 70% of N_{max}, N_{lim} is 30% of N_{max}, and N_{min} is the estimated population size using 20th percentile of the lognormal distribution.

Parameters	Model estimates	
	Mean	SD
Ny0	1 701 500 (1 000 000)	141 450 (2 000 000)
M0	0.27 (0.27)	0.05 (0.05)
M1+	0.13 (0.09)	0.006 (0.05)
N_{max}	2 115 300	-
N_{70}	1 480 710	-
N_{lim}	634 590	-
N_{min}	1 332 826	-
$N_{0,2017}$	211 000	13 200
$N_{1+,2017}$	1 197 000	78 650
$N_{Total,2017}$	1 408 000	79 750

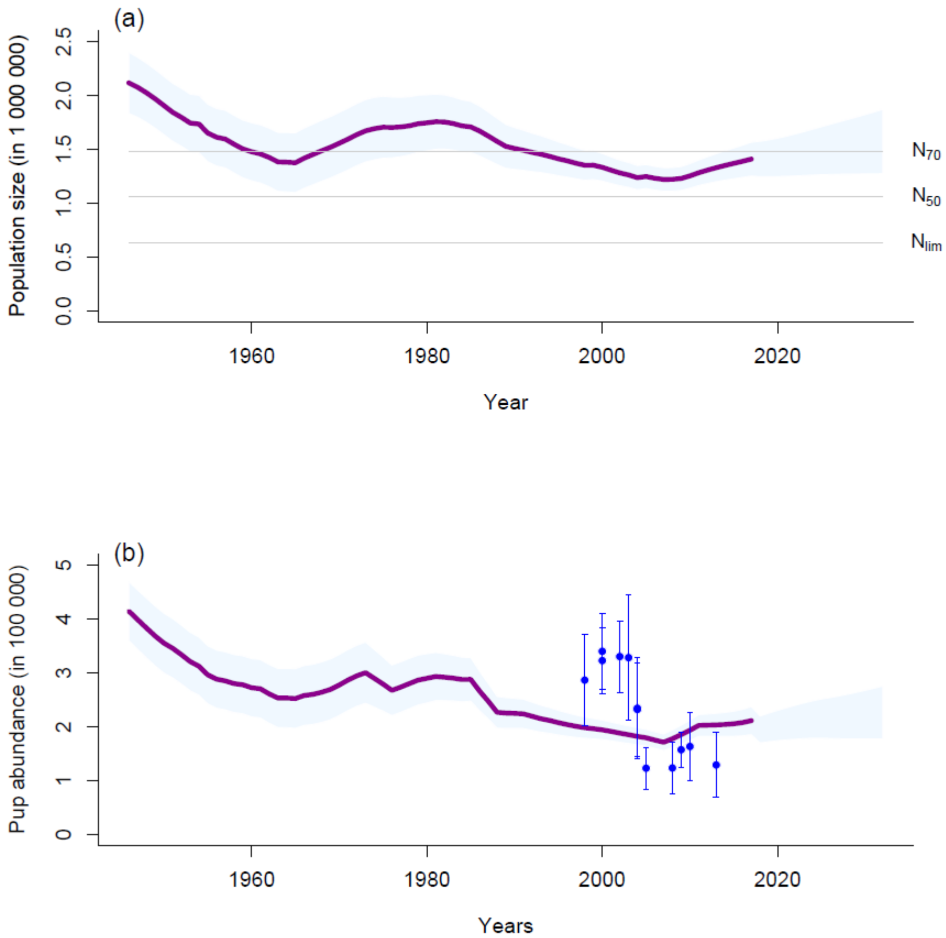

Figure 6: Barents Sea/White Sea harp seals: Modelled population trajectories for pups and adults (full lines), 95% confidence intervals. Future projections are illustrated by confidence bands. N_{70}, N_{50}, and N_{lim} denote the 70%, 50% and 30% of the historical maximum population size, respectively. Observed pup production estimates and 95% confidence intervals are shown in blue.

Catch options

The various catch scenarios requested are:

1) Current catch level (average of the catches in the period 2012 – 2016).
2) Equilibrium catch level.
3) Catches that would reduce the population to N_{70} with probability 0.8 over a 15-years period.

Current catch level is defined as the average catch level of the last 5 years, i.e. the average catch level of the period 20122016. For pups there has been zero catch in this period, and for the 1+ group 9 seals were caught in 2012 and none for the other years. Because of this we have set the current catch level to be zero for both the pups and the 1+ group. The equilibrium catch level is defined as the (fixed) annual catch level that stabilizes the future 1+ population under the estimated model over a period of 15years. It was assumed that no pups were taken in the catch

The last reproductive rates available are based on data from 2006 (ICES, 2011), i.e. more than 5 years old. The WG was concerned about using the last observed fecundity rate of 0.84 in future projections. An average of the most recent observed fecundity rates, i.e. observed fecundity rates the last 10 years, was used for the population projections. The averaged fecundity rate used for future projections was $F_{future} = 0.76$.

The harp seal population in the Barents Sea / White Sea is considered data poor because of the time elapsed since the last series of reproductive samples were obtained. As a result the catch option 3 (Catches that would reduce the population to N70 with probability 0.8 over a 15-years period) was not examined.

Since the populations is classified as data poor and is above a critical limit (N_{lim}) the Potential Biological Removal (PBR) approach for estimating catch quotas should be considered in addition to the requested catch options.

The PBR has been defined as:

$$PBR = \frac{1}{2} R_{\max} F_r N_{\min},$$

where R_{max} is the maximum rate of increase for the population, F_r is the recovery factor with values between 0.1 and 1, and N_{min} is the estimated population size using 20th percentile of the lognormal distribution. R_{max} is set at a default of 0.12 for pinnipeds.

Given the still unexplained drop in pup production first observed in 2004 and that the pup production since then seems to remain low, we used a recovery factor F_r of 0.5 as in the previous assessment. The PBR catch option assumes that the age structure of the removals is proportional to the age composition of the population, i.e. 14% pups in catch. A catch consisting of a larger proportion of pups would be more conservative, but a multiplier to convert age 1+ animals to pups is inappropriate for the PBR.

Setting future harvests at the PBR level resulted in a 33% reduction of the 1+ population over the next 15 years. Since the model indicates a decline of the population using a PBR catch level with a recovery of $F_r = 0.5$, we also used a smaller recovery rate of $F_r = 0.25$. The model indicated a reduction of 10% of the 1+ population over the next 15 years using this PBR catch level. The precision of the 2017 model estimate is fairly high with a CV of 0.07. The WG feels that the uncertainty of the population dynamics model is underestimated and a CV of 0.07 is too low. Because of this, the resulting PBR catch level is likely to be overestimated. Increasing the CV when calculating the PBR catch level, i.e. increasing the uncertainty about the model estimate of the 2017 abundance, will lower the PBR catch quota. However, using FR=0.5, and an N_{min}, that assumed a substantial increase of the CV to 0.30 still resulted in a PBR that caused the estimated 1+ population to decrease by 25% over the next 15 years. The WG concluded that the PBR catch level was not suitable for providing advice of future catch quotas and recommended that equilibrium catch levels be used.

The estimates for the various catch options are given in Table 10. The model indicates an increase of 12% for the 1+ population over 15 years with no catch. Equilibrium catch level is 10 090 seals (100% 1+ animals). If pups are hunted two pups balance one 1+ animal.

Table 10. Catch options with relative 1+ population size (D_{1+}) in 15-years (2032) for harp seals in the Barents Sea / White Sea.

Catch option	Proportion pups in catches	Pup catch	1+ catch	Total catch	Change of the 1+ population over 15 years (95% CI)
Current level	0%	0	0	0	1.12 0.99-1.25
Equilibrium	0%	0	10 090	10 090	1.00 (0.87-1.13)
PBR, Fr = 0.50	14%	5598	34 387	39 985	0.67 (0.52-0.81)
PBR, Fr = 0.25	14%	2799	17 193	19 992	0.90 (0.76-1.03)
PBR, Fr = 0.50, CV = 0.3	14%	4 619	28 371	32 990	0.75 (0.61-0.87)

In this assessment, the equilibrium catch, is much lower than that estimated in the previous assessment. This is because of the lower pregnancy rates assumed in the projections and this highlights the need for new samples.

Furthermore, uncertainty in the reproductive data needs to be incorporated into the assessment model.

5.4 The Northwest Atlantic Stock

5.4.1 Information on recent catches and regulatory measures

Canada

Between 2003 and 2010 the harp seal quota in Canada ranges from 270 000 to 330 000. In 2011 the quota was raised to 400 000. Since then it has been 'rolled over' annually (Annex 8, Table 3). The TAC includes allocations for aboriginal harvesters (currently 6 840), development of new products (20 000) and personal use (2 000). There is no specific allocation or quotas for catches in Arctic Canada.

Following a peak catch of 365 971 harp seals in 2004, catches have declined significantly (Annex 7, Table 4). Despite the high quotas, catches have remained below 80 000 since 2009. In 2015, catches dropped to a low of 35 304 (8.8% of the TAC) due primarily to the lack of markets. Although still low, catches increased to approximately 66 865 (16.7% of the TAC) in 2016. Catches in the Canadian Arctic are not known but are thought to be small (<1000).

The vast majority of harp seals taken in the Canadian commercial hunt are young of the year, accounting for >98% of the catch during the past decade. However, in 2016, a small meat hunt for adult seals occurred during late February and early March. The actual age structure of the hunt in 2016 will not be available until Statistics Branch completes their examination of the purchase slips. For this reason the age is listed as unknown. The age structure of the 2015 catches may also change once this check is completed.

Greenland

Greenland catches of harp seals have been reported up to 2014. Catches over the past decade have varied from 59 769 in 2012 to 95 954 in 2006 with an average catch on 78 749 (Annex 7 Table 5). The reported catch for 2013 and 2014 was 81 196 and 63 059, respectively. Along the west coast where the majority of seals were caught, the % adults reported varied between ¼ and ⅓ of the catch.

The most recent catch reports differ slightly from previous reports. However, the reasons for these changes are not clear. Therefore, tables presented here include the previous reported catches for the period up to 2011. They will be updated if necessary once the reason for any changes are clarified (Annex 7, Table 6).

Total reported catches for Canada and Greenland are summarized in Annex 7, Table 3. In Annex 7, Table 7 presents estimated total removals including bycatch in Canadian and US fisheries, and estimates of struck and lost (Stenson and Rosing-Asvid SEA 245). It also assumes that Canadian catches in 2016 were all young of the year.

5.4.2 Current research

Female harp seal attendance to their pups, and nursing patterns, under varying environmental conditions were examined at the Front whelping patch to determine if these patterns change in response to changing weather conditions (Perry *et al.*, 2016). The behaviour of 158 harp seal females and pups was recorded every three minutes during daylight hours; air and water temperature, and windspeed were recorded at the beginning of each observation session. GAMM models were used to examine the importance of time and environmental conditions in predicting attendance and nursing patterns. The best model for predicting attendance included time of day, air temperature, windspeed, and the interaction between wind and air temperature. The best model for predicting nursing included windspeed, air temperature, and time of day. Females were more likely to attend their pups during the afternoon when solar radiation appeared to be high, but reduced attendance during high winds and/or low temperatures. The likelihood of attending females nursing during these poor weather conditions was greater than when conditions were better. Thus, females were less likely to be present when weather conditions were poor but when present, they were more likely to be provisioning their pups. This strategy may help these females defray the thermoregulatory demands on their limited resources while ensuring that their young attain weights that are likely to increase post-weaning survival and hence maternal fitness.

5.4.3 Biological Parameters

The long term monitoring of late-term pregnancy rates, fecundity and abortion rates of Northwest Atlantic harp seals has continued with annual samples being collected off the coast of Newfoundland and Labrador.

Stenson *et al.* (2016) described a study of late term pregnancy and abortion rates in Northwest Atlantic harp seals based upon samples collected off the coast of Newfoundland, Canada. Since the 1950s, pregnancy rates have declined while interannual variability has increased. Using a beta regression model to explore the importance of biological and environmental conditions, they found that while the general decline in fecundity is a reflection of density-dependent processes associated with increased population size, including the late term abortion rates captured much of the large interannual variability. Change in the abortion rate is best described by a model that incorporates ice cover in late January and capelin, a major prey of harp seals, biomass obtained from the previous fall. A previous study has shown that capelin abundance is correlated with ice conditions suggesting that late January ice conditions could be considered a proxy for environmental conditions that influence a number of prey species.

Preliminary data on the condition of harp seals collected off the coast of southern Labrador and NE Newfoundland between 1979 and 2012 presented to the WG indicates that there appears to be a positive correlation between annual average condition and annual pregnancy rates. There appears to be a negative, nonlinear, relationship between annual average condition and annual abortion rates. There also appears to be a strong correlation between mean winter (December – February) blubber thickness and annual pregnancy rates.

5.4.4 Population Assessment

No new information on current abundance was presented. However, the importance of the assumption used to describe the density-dependent relationship in the NWA harp seal model was illustrated as part of the advice to Canada (see below).

A new pup production survey is planned for March 2017.

6 Hooded seals (*Cystophora cristata*)

6.1 The Greenland Sea Stock

6.1.1 Information on recent catches and regulatory measures

Concerns over low pup production estimates resulted in a recommendation from ICES that no harvest of Greenland Sea hooded seals should be permitted, with the exception of catches for scientific purposes (ICES, 2008) (Annex 8, Table 1). This advice was immediately implemented (Annex 8, Table 1). The total removals of Greenland Sea hooded seals in 1946-2016 are shown in Annex 6, Table 1. Total catches for scientific purposes (all taken by Norway, Russian sealers did not operate in the Greenland Sea) in 2014 were 11 (whereof 5 pups) in 2015 and 18 (whereof 10 pups) in 2016.

6.1.2 Current research

Diet

Hooded seals are important predators in drift ice areas of the Greenland Sea (the West Ice) during spring and summer. Their summer (June-July) diet was studied in the West Ice in 2008 and 2010, based on analysis of gastrointestinal contents of 179 animals obtained in dedicated surveys (Enoksen *et al.*, *in press*). Polar cod dominated the diet. The importance of the squid *Gonatus fabricii* was lower in this study compared with previous hooded seal studies in the area, and krill only occurred sparsely. In addition to the hooded seals, samples of 20 harp seal digestive tracts and 70 harp seal faeces were also obtained during the 2010 survey. The diet composition of the harp seals was dominated by amphipods (primarily *Themisto* sp.) and deviated significantly from the hooded seal diet, implying that the degree of food competition was relative low. The occurrence of polar cod, *Themisto* sp. and krill in the diets of the two seal species coincides well with the geographical and vertical distribution of these three prey items and the previously recorded dive depths of the seals. The presence of demersal fish such as sculpins and snailfish in the diet of some hooded seals was more likely a result of increased availability rather than changes in prey preference, as these seals were collected above shallower waters.

Morphometric data

Morphometric parameters of female hooded seals collected in the Greenland Sea (GS) 19582010 were compared to female Northwest Atlantic (NWA) hooded seals from the period 195676. Reproductive data available for a subset of the NWA dataset have previously been shown to exhibit the highest reproductive rates recorded for hooded seals, while reproductive rates for the GS hooded seals have been low during this period of dramatic decline in population size. One of the central findings of the study is that length-at-age of parous females was consistently lower in GS females compared to the NWA hooded seals. Length-at-age of GS hooded seals furthermore declined significantly in the late 1970s and remained low up to the late 1990s. The most recent sample from 2008-10 showed a return to the 1958 level. A similar pattern of decline and subsequent increase occurred for average length of primiparous females (ALPP). ALPP for the period 1958-75 and 2008-10 was not different from value for the NWA samples, but a significant drop in ALPP was observed during the period 1980-1999. The drop in length-at-age and ALPP in the late 1970s occurred after signs of marked boom and bust dynamics of fisheries for potential hooded seal prey species like redfish and Greenland halibut. Conversely the later increase in length-at-age and ALPP in the 200810 occurred after a documented recovery of redfish and Greenland halibut in the Norwegian Sea area and around Svalbard. These two species have, however, not been documented in diet studies of GS hooded seals, which have focused on the diet in the pack ice areas, dominated by high arctic species like polar cod (*Boreogadus saida*) and the squid *Gonatus fabricii*. The geographical distribution of these high Arctic species has likely declined during the warm period after 2000, but the density of prey available to the hooded seals close to the pack ice could have increased.

6.1.3 Biological parameters

No new information

6.1.4 Population assessments

No new surveys have been completed

The same population model used for the Greenland Sea harp seal population is used in this assessment of the Greenland Sea hooded seal population.

Maturity curves were constructed based on female reproductive material collected over the period 199094 and 200810 (Table 11, ICES 2011).

Table 11. Estimates of proportions of mature females ($p_{i,t}$). The P1 estimates are from ICES (2008) and the P2 estimates are from ICES (2011). Mature females had at least one CL or CA in the ovaries.

AGE	1	2	3	4	5	6	7	8	9	10	11
P1	0	0.05	0.27	0.54	0.75	0.87	0.93	0.97	0.98	0.99	1.00
P2	0	0	0.06	0.60	0.89	0.97	0.99	1.00	1.00	1.00	1.00

The record of historical fecundity rate is sparse, but the observed fecundity rates are all around 0.7 (ICES, 2013). A fixed fecundity rate of F = 0.7 was used for all years when modelling the Greenland Sea hooded seal population.

Pup production estimates are available from aerial surveys conducted in 1997, 2005, 2007, and 2012 (Table 12, ICES, 2011, Salberg *et al*., 2008, Øigård *et al*., 2014). Catch levels for the period 1946 – 2016 are presented in Annex 6, Table 1.

Table 12. Estimates of Greenland Sea hooded seal pup production, based on data from ICES (2011), Salberg *et al*., 2008 and Øigård *et al*., 2014.

YEAR	ESTIMATED NUMBER OF PUPS	COEFFICIENT OF VARIATION.
1997	23 762	0.192
2005	15 250	0.228
2007	16 140	0.133
2012	13 655	0.138

The estimated population, along with the parameters for the normal priors used are presented in Table 13. The mean of the prior for M0 was set to be three times the mean of M1+.

The population trajectory is shown in Figure 7. The model indicates a substantial decrease in abundance from the late 1940s and up to the early 1980s. In the most recent two decades, the population appears to have stabilized at a low level.

A 2017 abundance of 66 860 1+ animals (95% CI: 45 86087 860) and 13 600 (95% CI: 9 25017950) pups is obtained. The estimated total 2017 population of hooded seals in the Greenland Sea is 80 460 (95% CI: 59 020101 900). For comparison the total estimated population of hooded seals on the Greenland Sea was 82 830 seals in 2013 and 85 790 in 2011 (ICES, 2011; 2013).

Table 13: Greenland Sea hooded seals: Estimated mean values and standard deviations of the parameters used in the model. Priors used are shown in brackets. N_{max} is the historically largest total population, N70 is 70% of N_{max}, N_{lim} is 30% of N_{max}, and N_{min} is the estimated population size using 20th percentile of the lognormal distribution.

PARAMETERS	MEAN	SD
N0y	1 086 890	394 940
M0	0.34	0.02
M1+	0.17	0.05
N_{max}	1 302 800	-
N_{70}	911 960	-
N_{lim}	390 840	-
N_{min}	75 241	-
$N_{0,2017}$	13 600	2 218
$N_{1+,2017}$	66 860	10 714
$N_{Total,2017}$	80 460	10 941

Catch options

All model runs indicate a population currently well below Nlim (30% of largest observed population size). Following the precautionary approach framework developed by WGHARP (ICES2005), no catches should be taken from this population.

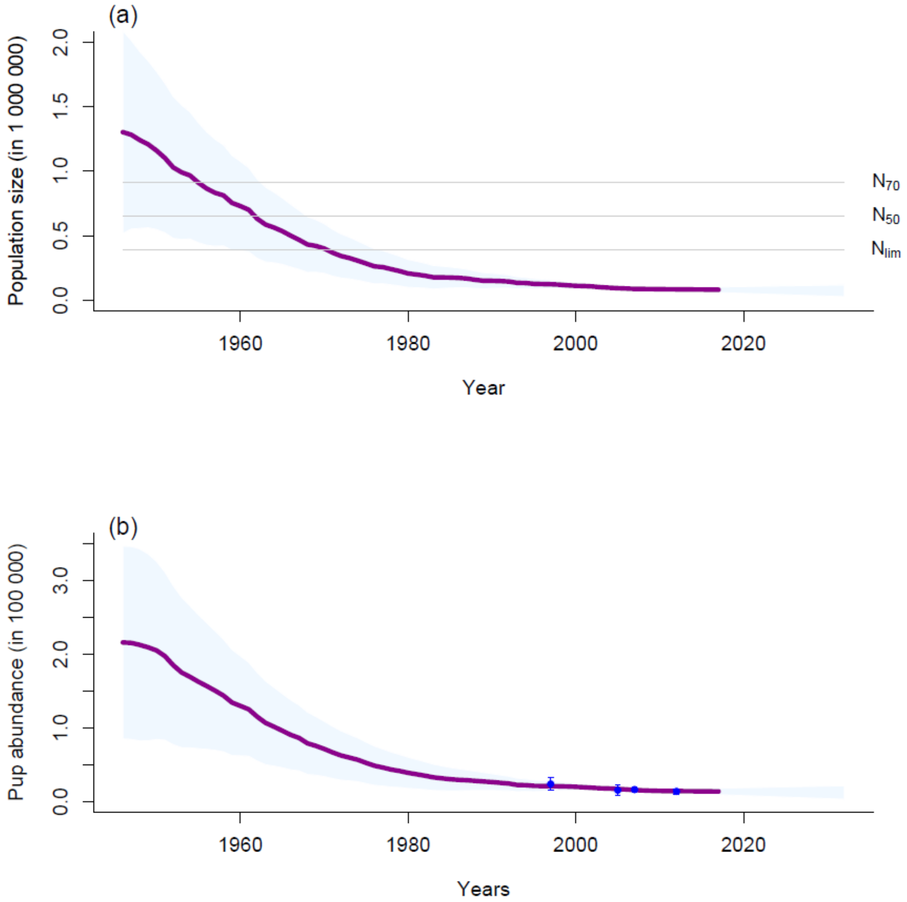

Figure 7: Greenland Sea hooded seals: Modelled population trajectories for adults (a) and pups (b) (mean=solid line, 95% confidence intervals= shaded area). Projections are illustrated by confidence bands. N_{70}, N_{50}, and N_{lim} denote the 70%, 50% and 30% of the historical maximum population size, respectively. Observed pup production estimates and 95% confidence intervals are shown in blue.

6.2 The Northwest Atlantic Stock

6.2.1 Information on recent catches and regulatory measures

Under the Canadian Atlantic Seal Management Strategy (Hammill and Stenson 2007), Northwest Atlantic hooded seals are considered to be data poor. Under this approach, TACs are set using PBR. Prior to 2007, the TAC for hooded seals was set at 10 000 (Annex 8, Table 4). As a result of new data on the status of the population (Hammill and Stenson 2006) the quota was reduced to 8 200 in 2007 where it has remained. The killing of young of the year hooded seals (bluebacks) is prohibited in Canada.

Canadian catches of hooded seals (1+ only) have remained extremely low in recent years (Annex 6, Table 2). Catches have remained less than 50 since 2005 with most years being less than 10. Reported catches in 2015 and 2016 were 1 and 13 respectively.

Greenland catches of hooded seals since 2009 have been between 1 00 and 2 100, which is much lower than catches prior to 2005 which were generally between 5 0007 000 animals (Annex 6, Table 3). A total of 1 520 hooded seals were reported taken in 2013 while 1 846 were reported caught in 2014. With the exception of 1 seal taken in 2014, all of these animals were considered to be from the Northwest Atlantic hooded seal population.

6.2.2 Current Research

The WG noted that the collection of small numbers of hooded seals has continued in Canada. When analysed, these samples may provide some new data on diets, condition and reproductive rates. However, sample sizes are small.

6.2.3 Population Assessments

No new information. Canada is exploring the possibility of obtaining a minimum pup production from photos obtained during the 2012 harp seal survey.

7 Advice Requests

7.1 Request for advice submitted to ICES by Norway

In October, 2015, Norway requested management advice on the status of harp and hooded seal stocks in the Greenland Sea and the harp seal stock in the White Sea/Barents Sea.

ICES was asked to assess the impact on the harp seal stocks in the Greenland Sea and in the White Sea/Barents Sea of an annual harvest of:

1) current harvest levels,
2) sustainable catches (defined as the fixed annual catches that stabilizes the future 1+ population)
3) catches that would reduce the population over a 15-years period in such a manner that it would remain above a level of 70% of the maximum population size, determined from population modelling, with 80% probability.

The advice on status and impacts of different harvest options are provided in previous sections of this report. Section 4.2.5 provides advice on Greenland sea harps, section 4.3.4 on White sea harps and section 5.1.4 on Greenland sea hooded seals.

7.2 Request for advice submitted to NAFO by Canada

In 2014 Canada requested that WGHARP explore the impact of proposed harvest strategies that would maintain the Northwest Atlantic harp seal population at a precautionary level of a PA framework and that would have a low risk of decreasing below the critical level. Specifically, the WG was asked to:

1) Identify the catches necessary to reduce the NWA harp seal population to 5.4M animals assuming:
    a) Catches consisting of 90% Young of the Year (YOY) or 50% YOY
    b) Reductions over periods of 5, 10, and 15 years
2) Identify the catches necessary to reduce the population to 6.8M assuming:
    a) Catches consisting of 90% YOY or 50% YOY
    b) Reduction over periods of 5, 10, and 15 years
3) Identify sustainable future catches possible at each of these reduced populations, assuming there is a 95% probability of remaining above the Limit Reference Point (defined as 2.4 million).

This request was considered at the 2014 meeting but it was not completed at that time. It was agreed that the advice would be provided at the 2016 meeting.

To examine the impacts of the different population reduction scenarios, Hammill *et al.* (SEA243) projected the 2014 NWA harp seal population model into the future, using as a starting point, the estimates of 2014 population size, pup production, natural mortality (M), and carrying capacity (K).

Assumptions associated with future reproductive rates and levels of the Greenland catch are necessary. Therefore, the impacts of the different Canadian catch options on the projected population under two major scenarios that represent a continuation of the current state (Model A) and an alternate model that responds to the impact of removals by assuming density-dependent compensation, i.e. decreased catches and increased reproductive rates when populations are reduced (Model B). In Model A, it was assumed that future reproductive rates, and Greenland catches were based upon the observed rates from the past 10 years (Table 14). In Model B, both future reproductive rates and Greenland catches behaved in a density-dependent manner, i.e. as the population declines, Greenland catches decline and pregnancy rates increase to an asymptotic value, whereas when the population increases, Greenland catches increase to an asymptotic value and reproductive rates decline.

In both scenarios, it is assumed that the age structure and mortality from bycatch and the Canadian Arctic harvest remain constant at 2013 levels and that the proportion of seals struck and loss, for the different harvests remain unchanged.

Table 14. Comparison of model assumptions

	MODEL A	MODEL B
Greenland catches	Fixed at average over past 10 years	Catches vary with population size when less than 7.1 million harp seals
Ice related mortality	Selected randomly from a vector of recently observed rates	Same
Pregnancy rates	Selected from a vector of recently observed rates	Density-dependent – decreases as population approaches carry capacity Proportion pregnant varied to account for changes in food supply (based upon recent observations)
Mortality rates of YOY	Density-dependent – increases as population approaches carry capacity	Same

Once the target population level was achieved, the model was further projected forward to determine the level of catches that will respect the management plan (i.e. 95% likelihood of population remaining above the Limit Reference Level) for an additional 15 years which ensures that catches are sustainable while they propagate through the population age structure. Therefore, the total length of the projection varied with each reduction scenario (i.e. total of 20, 25 and 30 years). However, since the management objective changed following the reduction, the mean estimated population did not necessarily remain at the target level.

The predicted changes in the population trajectory were affected very strongly by the age composition of the harvest used to reduce the population, the speed with which the reduction was achieved and whether the scenario used a population whose dynamics were assumed to be similar to what has been seen in the past 10 years (Model A) or assumed to vary in a density-dependent manner (Model B).

Model A Scenario

A large number of animals would need to be removed if the population reduction was to be achieved rapidly, or with a harvest comprised primarily of YOY (Table 15). For a population whose future dynamics are described by current conditions (Model A), up to 610,000 animals would need to be removed if the population was to be reduced to 6.8 million within 5 years. Fewer animals need to be removed annually if the removals were spread over a longer time period, or if animals aged 1+ years comprised a larger proportion of the harvest (Table 15). It was not possible to achieve a target population of 5.4 million seals within 5 years (Table 15) if YOY comprised 90% or more of the harvest.

Once the target level was achieved, the catch levels that would ensure a 95% probability of remaining above the Limit Reference Level were much lower than the harvest levels allowable during the reduction phase (Table 15).

Large removals were needed to reduce the population within 5 years, particularly if a large proportion of YOY were taken in the harvest. These removals had a longer term impact on the population than those that were spread over a longer time period, or had a larger proportion of older seals. In the 5 year scenario to reduce the population to 6.8 million animals, the population continued to decline during the subsequent monitoring period, although there was still a 95% probability of the population remaining above the Limit Reference Level.

Model B

The estimated number of removals needed to reduce the population to 6.8 million was similar under the two modelling scenarios. Higher harvests were estimated over the following 15 years, while still ensuring that the population had a 95% probability of remaining above the reference limit point, under the assumptions of Model B, (i.e. density-dependent responses). This is because of the compensation assumed in reproductive rates and catches.

The catch levels needed to reduce the population to 5.4 million were much higher under the assumptions of Model B (i.e. density-dependence), compared to the assumptions used in Model A (Table 16). However, as in Model A, harvests had to be reduced considerably once the target was reached to allow the population to remain above the Limit Reference Level (Table 16).

Once the target population level was reached, the continuing catches that had a 95% likelihood that the population remained above the Limit Reference Level were estimated. The management objective did not require the population to remain at the target level and in some scenarios the population continued to decline. As a result, catches may have to be reduced further following the 15 year simulation period as the population was predicted to decline during the post reduction period.

Table 15. Annual removals (000's) needed to reduce the population from current levels to 6.8 or 5.4 million within a period of 5, 10 or 15 years. Catches were assumed to comprise 90%, or 50% young of the year (YOY). Continuing annual removals (000's) represent the total removals allowed that would maintain a 95% likelihood that the population would remain above the Limit Reference Level (N_{30}) for 15 years. Simulations examined removal impacts assuming future reproductive rates and Greenland harvests were similar to those seen over the past decade (Model A).

SCENARIO	90%YOY		50%YOY	
	REDUCTION	CONTINUING	REDUCTION	CONTINUING
6.8 M				
5 Y	610	350	270	190
10 Y	450	250	220	150
15 Y	400	230	190	100
5.4 M				
5 Y	*		480	90
10 Y	670	100	320	40
15 Y	540	40	260	20

*** indicates target impossible to achieve in time frame and age composition**

Table 16. Annual removals (000's) needed to reduce the population from current levels to 6.8 or 5.4 million within a period of 5, 10 or 15 years, assuming future reproductive rates and Greenland harvest follow a density-dependent manner (Model B). Catches were assumed to comprise 90%, or 50% young of the year (YOY). Annual continuing removals (000's) represent the total removals allowed that would maintain a 95% likelihood that the population would remain above the Limit Reference Level (N_{30}) for 15 years.

FIXED	90%YOY		50%YOY	
	REDUCTION	CONTINUING	REDUCTION	CONTINUING
6.8 M				
5 Y	560	560	250	280
10 Y	420	500	200	260
15 Y	370	500	180	270
5.4 M				
5 Y	*		560	250
10 Y	860	400	400	200
15 Y	770	300	350	170

*** indicates target impossible to achieve in time frame and age composition**

Under all scenarios, the uncertainty associated with estimates of population size increased considerably as time since the last survey also increased.

The management objective for this exercise was to have a 95% likelihood of remaining above the Limit Reference Level (2.4 million) rather than to maintain the population at the reduction target level. As a result, in some scenarios, high catches could be taken after the initial reduction. However, these would result in a continued decline in the population. If the management objective had been to maintain the population at the reduction target level, the 'post reduction' catches would have been much smaller. For example, in the scenario where the population is reduced to 6.8 million over 5 years and the assumptions used for Model B, the catches that would maintain the population would be ~390,000 (vs 560,000)

These simulation results are very sensitive to model assumptions and should be considered for illustration only. For example, we assumed that the density-dependent relationship could be described using a theta=2.4. Using the same level of harvest but assuming a density-dependent relationship using a theta=1 results in a much lower catch to maintain the population at the same level (Fig 8).

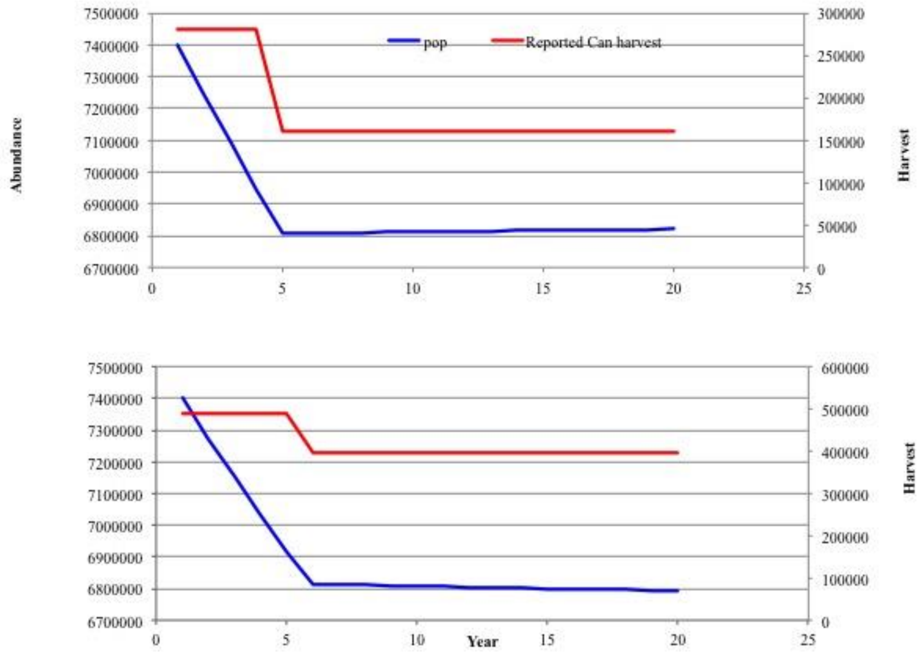

Fig 8. Comparison of catch levels that would result in a constant population after the reduction has occurred, under the assumption that the density-dependent relationship can be described using Theta = 1 (top) or Theta = 2.4 (bottom). Scenario assumes that the population is reduced to 6.8 million within 5 years.

The impact of these scenarios on the Greenland hunt will depend upon the assumptions used. Under Model A, it is assumed that the hunt remains the same as it currently is, even if the total abundance is reduced. Under Model B, the availability of animals is the main force driving harvest levels in Greenland and catches decline as the population is reduced. Under this scenario, there would appear to be little impact on number of animals available to Greenland hunters if the herd was reduced to 6.8 million. However, a reduction in the herd to 5.4 million animals could result in a 25% reduction in availability of animals to Greenland hunters. Clearly, the age composition of the catch (90% or 50% YOY) and rate of the reduction would have an impact on the number of YOY available to Greenland hunters during the reduction period. However, while the proportion of YOY in the population was slightly higher if density-dependence was assumed, both scenarios resulted in estimates of YOY that were similar to that seen in the past, once the initial reduction is completed.

The WG emphasizes that these simulation results are very sensitive to model assumptions and should be considered for illustration only. It also notes that these scenarios do not include the potential impacts of an unusual mortality event.

Furthermore, the estimated carrying capacity is based upon historical conditions that may no longer apply. This will impact our assumptions about density-dependent compensation in reproductive rates (particularly for the 6.8 million scenario).

The two models represent two unlikely situations, one assumes reproductive rates and catches do not respond to changes in total population while the other assumes full compensation in reproductive rates and catches as the population declines. Based upon historical changes in reproductive rates, we expect that some density-dependent compensation will occur, but recent environmental changes suggest that full compensation may not result.

Other business

If necessary, the WG will work by correspondence during 2017. The next meeting is proposed for September 2018 in Greenland or Norway.

8 Adoption of the report

The WG adopted the report on 21 November 2014, at the close of the meeting.

Annex 1: List of participants

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Annex 2: Agenda

Monday, 26 September 2016

10:00pm to noon

- Introductory Comments
- Discussion of Terms of References
- Varia

Noon to 1:30 pm lunch

1:30pm to 5:00pm – Harp Seals: Harp Seals: Greenland Sea Stock

- Biological parameters
- Population model new developments
- Current harvests
- Catch options

5:00pm Break for Day

Tuesday, 27 September 2016

9:00 am to noon – Harp Seals: Harp Seals: Greenland Sea Stock

- Continue Monday discussions on population model

Noon to 1:00pm – Lunch

1:00pm to 5:00pm - White Sea and Barents Sea Stock

- Biological parameters
- New estimates
- Population assessment ()

5:00pm Break for Day

Wednesday, 28 September 2016

9:00am to noon -- Harp Seals: Northwest Atlantic Stock

- Biological parameters
- Population assessment
- Population Model development
- Population modelling development and simulation scenarios
- Impacts on Greenland harvest

Noon to 1:00pm – lunch

1:00pm to 3:00pm --

- Discussion of way forward?

3:30pm to 4:30pm –Hooded seals NE Atlantic

- Biology,
- Catches
- New research

4:30pm Break for Day

Thursday, 29 September 2016

9:00am to 10:00am-Hooded seals NW Atlantic

- biology
- Catches
- New research

10:00 to noon

- Write report

Noon to 1:00pm – Lunch

1:00pm to 3:00pm –

- Write report

3:30pm – 4:30

- Review report

4:30 Break for Day

Friday, 30 September 2016

9:00 am to noon

- Review/complete report
- Next meeting
- Other business

12:00 end meeting

Annex 3: WGHARP terms of reference for the next meeting

The **Working Group on Harp and Hooded Seals (WGHARP)** (Chair: Mike Hammill) proposed to meet in Greenland or Norway in late September 2018 to:

- Review results of new surveys as available for harp seals in the White Sea and southeastern portion of Barents Sea
- Review results from the biological samples obtained from the harp seals
- Provide advice on other issues as requested

WGHARP will report September 2018 for the attention of the ACOM.

Annex 4: Recommendations

Recommendation	Action By	Recipient
The WG recommends that efforts be made to obtain samples, to evaluate reproductive rates for White Sea harp seals, particularly in years when an aerial survey is completed. These are required for use in the population model.	2017	Norway/Russia
The WG recommends that efforts be made to incorporate bycatch and age composition information from the 'seal invasion years' in the mid to late 1980s be incorporated into the White Sea harp seal model as additional catch data.	2018	Norway/Russia
The WG recommends that new aerial surveys be conducted to estimate pup production of harp seals in the White Sea\Barents Sea and NW Atlantic in 2017 and Greenland Sea in 2018	March 2017/2018	Russia/Norway/Canada
The WG recommends that during all aerial surveys, staging surveys also be conducted to determine the correction for pups not available to be photographed when the aerial survey is flown. This should be done for all populations of harp and hooded seals.	Continuing	Canada/Norway/Russia
The WG recommends that satellite telemetry tagging studies be undertaken of the White Sea\Barents Sea harp seal population	2017	Norway/Russia
The WG recommends that uncertainties in reproductive rates be incorporated into the Greenland and White Sea harp seal population models	2018	Norway
The WG recommended that if possible the Greenland Sea and White Sea harp seal mark-recapture data be re-examined and updated with new information if available.	2018	Norway
The WG recommended that the Greenland Sea assessment takes into account catches from east Greenland	2018	Norway
The WG recommends that all new data on hooded seals be examined to increase understanding of current status of these populations	2018	Canada/Norway

Annex 5: References

Working Papers

Number	Author	Title
SEA238	Tore Haug, and Vladimir Zabavnikov	Norwegian and Russian catches of harp and hooded seals in the Northeast Atlantic in 2015-2016
SEA239	Øigård,T.A,and T. Haug	The 2017 abundance of harp seals (Pagophilus groenlandicus) in the Barents sea / White sea
SEA240	Øigård,T.A,and T. Haug	The 2017 abundance of harp seals (Pagophilus groenlandicus) in the Greenland Sea
SEA241	Øigård,T.A,and T. Haug	The 2017 abundance of hooded seals (Cystophora cristata) in the Greenland Sea
SEA242	Korzhev,V. and V. Zabavnikov	Estimation of the White Sea Harp Seal Population (Phoca groenlandica) Number by Cohort and Stock-Production (ASPIC) Models in Present Stage
SEA243	Hammill,M.O. G.B. Stenson and A. Mosnier.	Impacts of Theoretical Harvest Reduction Scenarios and Sustainable Catches of NWA harp seals?
SEA244	I. Shafikov	Estimation of Females Age Maturity and Barrenness Coefficient for the White Sea Harp Seal Population (Phoca groenlandica)
SEA245	Stenson, G. and A. Rosing-Asvid	Recent Catches of Harp and Hooded Seals in Canada and Greenland
SEA 246	Frie, A.K.	A 2014 update and reassessment of reproductive parameters of Northeast Atlantic harp seals (Pagophilus groenlandicus)

Other References

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Annex 6: Catches of hooded seals including catches taken according to scientific permits

Table 1. Catches of hooded seals in the Greenland Sea ("West Ice") from 1946 through 2016. Totals include catches for scientific purposes.

	Norwegian catches			Russian catches			Total catches		
Year	Pups	1 year and older	Total	Pups	1 year and older	total	Pups	1 year and older	Total
1946–50	31152	10257	41409	-	-	-	31152	10257	41409
1951–55	37207	17222	54429	-	-	-b	37207	17222	54429
1956–60	26738	9601	36339	825	1063	1888b	27563	10664	38227
1961–65	27793	14074	41867	2143	2794	4937	29936	16868	46804
1966–70	21495	9769	31264	160	62	222	21655	9831	31486
1971	19572	10678	30250	-	-	-	19572	10678	30250
1972	16052	4164	20216	-	-	-	16052	4164	20216
1973	22455	3994	26449	-	-	-	22455	3994	26449
1974	16595	9800	26395	-	-	-	16595	9800	26395
1975	18273	7683	25956	632	607	1239	18905	8290	27195
1976	4632	2271	6903	199	194	393	4831	2465	7296
1977	11626	3744	15370	2572	891	3463	14198	4635	18833
1978	13899	2144	16043	2457	536	2993	16356	2680	19036
1979	16147	4115	20262	2064	1219	3283	18211	5334	23545
1980	8375	1393	9768	1066	399	1465	9441	1792	11233
1981	10569	1169	11738	167	169	336	10736	1338	12074
1982	11069	2382	13451	1524	862	2386	12593	3244	15837
1983	0	86	86	419	107	526	419	193	612
1984	99	483	582	-	-	-	99	483	582
1985	254	84	338	1632	149	1781	1886	233	2119
1986	2738	161	2899	1072	799	1871	3810	960	4770
1987	6221	1573	7794	2890	953	3843	9111	2526	11637
1988	4873	1276	6149c	2162	876	3038	7035	2152	9187
1989	34	147	181	-	-	-	34	147	181
1990	26	397	423	0	813	813	26	1210	1236
1991	0	352	352	458	1732	2190	458	2084	2542
1992	0	755	755	500	7538	8038	500	8293	8793
1993	0	384	384	-	-	-	0	384	384
1994	0	492	492	23	4229	4252	23	4721	4744
1995	368	565	933	-	-	-	368	565	933
1996	575	236	811	-	-	-	575	236	811
1997	2765	169	2934	-	-	-	2765	169	2934
1998	5597	754	6351	-	-	-	5597	754	6351

Year	Norwegian catches			Russian catches			Total catches		
	Pups	1 year and older	Total	Pups	1 year and older	total	Pups	1 year and older	Total
1999	3525	921	4446	-	-	-	3525	921	4446
2000	1346	590	1936	-	-	-	1346	590	1936
2001	3129	691	3820	-	-	-	3129	691	3820
2002	6456	735	7191	-	-	-	6456	735	7191
2003	5206	89	5295	-	-	-	5206	89	5295
2004	4217	664	4881	-	-	-	4217	664	4881
2005	3633	193	3826	-	-	-	3633	193	3826
2006	3079	568	3647	-	-	-	3079	568	3647
2007	27	35	62	-	-	-	27	35	62
2008	9	35	44	-	-	-	9	35	44
2009	396	17	413	-	-	-	396	17	413
2010	14	164	178	-	-	-	14	164	178
2011	15	4	19	-	-	-	15	4	19
2012	15	6	21	-	-	-	15	6	21
2013	15	7	22	-	-	-	15	7	22
2014	24	0	24	0	0	0	24	0	24
2015	5	6	11	0	0	0	5	6	11
2016	10	8	18	0	0	0	10	8	18

a For the period 1946–1970 only 5-year averages are given.

b For 1955, 1956 and 1957 Soviet catches of harp and hooded seals reported at 3,900, 11,600 and 12,900, respectively. These catches are not included.

c Including 1048 pups and 435 adults caught by one ship which was lost.

Table 2. Canadian catches of hooded seals off Newfoundland and in the Gulf of St Lawrence, Canada (“Gulf” and “Front”), 19462016a,b. Catches from 1995 onward includes catches under personal use licences. YOY refers to Young of Year. Catches from 19901996 were not assigned to age classes. With the exception of 1996, all were assumed to be 1+.

	Large Vessel Catches				Landsmen Catches				Total Catches			
Year	YOY	1+	Unk	Total	YOY	1+	Unk	Total	YOY	1+	Unk	Total
1946-50	4029	2221	0	6249	429	184	0	613	4458	2405	0	6863
1951-55	3948	1373	0	5321	494	157	0	651	4442	1530	0	5972
1956-60	3641	2634	0	6275	106	70	0	176	3747	2704	0	6451
1961-65	2567	1756	0	4323	521	199	0	720	3088	1955	0	5043
1966-70	7483	5220	0	12703	613	211	24	848	8096	5431	24	13551
1971-75	6550	5247	0	11797	92	56	0	148	6642	5303	0	11945
1976	6065	5718	0	11783	475	127	0	602	6540	5845	0	12385
1977	7967	2922	0	10889	1003	201	0	1204	8970	3123	0	12093
1978	7730	2029	0	9759	236	509	0	745	7966	2538	0	10504
1979	11817	2876	0	14693	131	301	0	432	11948	3177	0	15125
1980	9712	1547	0	11259	1441	416	0	1857	11153	1963	0	13116
1981	7372	1897	0	9269	3289	1118	0	4407	10661	3015	0	13676
1982	4899	1987	0	6886	2858	649	0	3507	7757	2636	0	10393
1983	0	0	0	0	0	128	0	128	0	128	0	128
1984	206	187	0	393d	0	56	0	56	206	243	0	449
1985	215	220	0	435d	5	344	0	349	220	564	0	784
1986	0	0	0	0	21	12	0	33	21	12	0	33
1987	124	4	250	378	1197	280	0	1477	1321	284	250	1855
1988	0	0	0	0	828	80	0	908	828	80	0	908
1989	0	0	0	0	102	260	5	367	102	260	5	367
1990	41	53	0	94d	0	0	636e	636	41	53	636	730
1991	0	14	0	14d	0	0	6411e	6411	0	14	6411	6425
1992	35	60	0	95d	0	0	119e	119	35	60	119	214
1993	0	19	0	19d	0	0	19e	19	0	19	19	38
1994	19	53	0	72d	0	0	149e	149	19	53	149	221
1995	0	0	0	0	0	0	857e	857	0	0	857e	857
1996	0	0	0	0	0	0	25754e	25754	0	22847f	2907	25754
1997e	0	0	0	0	0	7058	0	7058	0	7058	0	7058
1998e	0	0	0	0	0	10148	0	10148	0	10148	0	10148
1999e	0	0	0	0	0	201	0	201	0	201	0	201
2000e	2	2	0	4d	0	10	0	10	2	12	0	14
2001e	0	0	0	0	0	140	0	140	0	140	0	140
2002e	0	0	0	0	0	150	0	150	0	150	0	150
2003e	0	0	0	0	0	151	0	151	0	151	0	151
2004e	0	0	0	0	0	389	0	389	0	389	0	389

2005e	0	0	0	0	0	20	0	20	0	20	0	20
2006e	0	0	0	0	0	40	0	40	0	40	0	40
2007e	0	0	0	0	0	17	0	17	0	17	0	17
2008e	0	0	0	0	0	5	0	5	0	5	0	5
2009e	0	0	0	0	0	10	0	10	0	10	0	10
2010e	0	0	0	0	0	0	0	0	0	0	0	0
2011e	0	0	0	0	0	2	0	2	0	2	0	2
2012e	0	0	0	0	0	1	0	1	0	1	0	1
2013e	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	7	0	7	0	7	0	7
2015	0	0	0	0	0	1	0	1	0	1	0	1
2016	0	0	0	0	0	13	0	13	0	13	0	13

a For the period 1946–1970 only 5-years averages are given.

b All values prior to 1990 are from NAFO except where noted; recent years are from Stenson (2009) and DFO Statistics Branch.

c Landsmen values include catches by small vessels (< 150 gr tons) and aircraft.

d Large vessel catches represent research catches in Newfoundland and may differ from NAFO values.

e Statistics no longer split by age; commercial catches of bluebacks are not allowed

f Number of YOY based upon seizures of illegal catches

Table 3. Catches of hooded seals in West and East Greenland 1954–20014.

	West Atlantic Population					
Year	West	KGHB	Southeast	Total	NE	All Greenland
1954	1097	-	201	1298	-	1298
1955	972	-	343	1315	1	1316
1956	593	-	261	854	3	857
1957	797	-	410	1207	2	1209
1958	846	-	361	1207	4	1211
1959	780	414	312	1506	8	1514
1960	965	-	327	1292	4	1296
1961	673	803	346	1822	2	1824
1962	545	988	324	1857	2	1859
1963	892	813	314	2019	2	2021
1964	2185	366	550	3101	2	3103
1965	1822	-	308	2130	2	2132
1966	1821	748	304	2873	-	2873
1967	1608	371	357	2336	1	2337
1968	1392	20	640	2052	1	2053
1969	1822	-	410	2232	1	2233
1970	1412	-	704	2116	9	2125
1971	1634	-	744	2378	-	2378
1972	2383	-	1825	4208	2	4210
1973	2654	-	673	3327	4	3331
1974	2801	-	1205	4006	13	4019
1975	3679	-	1027	4706	58a	4764
1976	4230	-	811	5041	22a	5063
1977	3751	-	2226	5977	32a	6009
1978	3635	-	2752	6387	17	6404
1979	3612	-	2289	5901	15	5916
1980	3779	-	2616	6395	21	6416
1981	3745	-	2424	6169	28a	6197
1982	4398	-	2035	6433	16a	6449
1983	4155	-	1321	5476	9a	5485
1984	3364	-	1328	4692	17	4709
1985	3188	-	3689	6877	6	6883
1986	2796a	-	3050a	5846a	-a	5846a
1987	2333a	-	2472a	4805a	3a	4808a
1988–92c						
1993	4983	-	1967	6950	32	6982
1994	5060	-	3048	8108	34	8142
1995	4429		2702	7131	48	7179
1996	6066	-	3801	9867	24	9891
1997	5250		2175	7425	67	7492
1998	5051		1270	6321	14	6335

	West Atlantic Population					
Year	West	KGHb	Southeast	Total	NE	All Greenland
1999	4852	-	2587	7439	16	7455
2000	3769	-	2046	5815	29	5844
2001	5010	-	1496	6506	8	6514
2002	3606	-	1189	4795	11	4806
2003	4351	-	1992	6343	10	6353
2004	4133	-	1690	5823	20	5843
2005	3092	-	1022	4114	14	4128
2006	4194	-	550	4744	3	4747
2007	2575	-	712	3287	7	3294
2008	2085	-	519	2604	2	2606
2009	1627	-	358	1982	1	1986
2010	1871		266	2137	7	2144
2011	1827		225	2052	9	2061
2012	1318	-	347	1665	6	1671
2013	1190	-	330	1520	0	1520
2014	1457	-	388	1845	1	1846

a Provisional figures: do not include estimates for non-reported catches as for the previous years.

b Royal Greenland Trade Department special vessel catch expeditions in the Denmark Strait 1959–68.

c For 1988 to 1992 catch statistics are not available.

Annex 7: Catches of harp seals including catches taken according to scientific permits

Table 1. Catches of harp seals in the Greenland Sea ("West Ice") from 1946 through 2016a. Totals include catches for scientific purposes. Catches are from Haug, and Zabavnikov (SEA238)

	Norwegian catches			Russian catches			Total catches		
Year	Pups	1 year and older	Total	Pups	1 year and older	Total	Pups	1 year and older	Total
1946–50	26606	9464	36070	-	-	-	26606	9464	36070
1951–55	30465	9125	39590	-	-	-b	30465	9125	39590
1956–60	18887	6171	25058	1148	1217	2365b	20035	7388	27423
1961–65	15477	3143	18620	2752	1898	4650	18229	5041	23270
1966–70	16817	1641	18458	1	47	48	16818	1688	18506
1971	11149	0	11149	-	-	-	11149	0	11149
1972	15100	82	15182	-	-	-	15100	82	15182
1973	11858	0	11858	-	-	-	11858	0	11858
1974	14628	74	14702	-	-	-	14628	74	14702
1975	3742	1080	4822	239	0	239	3981	1080	5061
1976	7019	5249	12268	253	34	287	7272	5283	12555
1977	13305	1541	14846	2000	252	2252	15305	1793	17098
1978	14424	57	14481	2000	0	2000	16424	57	16481
1979	11947	889	12836	2424	0	2424	14371	889	15260
1980	2336	7647	9983	3000	539	3539	5336	8186	13522
1981	8932	2850	11782	3693	0	3693	12625	2850	15475
1982	6602	3090	9692	1961	243	2204	8563	3333	11896
1983	742	2576	3318	4263	0	4263	5005	2576	7581
1984	199	1779	1978	-	-	-	199	1779	1978
1985	532	25	557	3	6	9	535	31	566
1986	15	6	21	4490	250	4740	4505	256	4761
1987	7961	3483	11444	-	3300	3300	7961	6783	14744
1988	4493	5170	9663c	7000	500	7500	11493	5670	17163
1989	37	4392	4429	-	-	-	37	4392	4429
1990	26	5482	5508	0	784	784	26	6266	6292
1991	0	4867	4867	500	1328	1828	500	6195	6695
1992	0	7750	7750	590	1293	1883	590	9043	9633
1993	0	3520	3520	-	-	-	0	3520	3520
1994	0	8121	8121	0	72	72	0	8193	8193
1995	317	7889	8206	-	-	-	317	7889	8206
1996	5649	778	6427	-	-	-	5649	778	6427
1997	1962	199	2161	-	-	-	1962	199	2161
1998	1707	177	1884	-	-	-	1707	177	1884

Year	Norwegian catches			Russian catches			Total catches		
	Pups	1 year and older	Total	pups	1 year and older	Total	Pups	1 year and older	Total
1999	608	195	803	-	-	-	608	195	803
2000	6328	6015	12343	-	-	-	6328	6015	12343
2001	2267	725	2992	-	-	-	2267	725	2992
2002	1118	114	1232	-	-	-	1118	114	1232
2003	161	2116	2277				161	2116	2277
2004	8288	1607	9895				8288	1607	9895
2005	4680	2525	7205				4680	2525	7205
2006	2343	961	3304				2343	961	3304
2007	6188	1640	7828				6188	1640	7828
2008	744	519	1263				744	519	1263
2009	5177	2918	8035	-	-	-	5117	2918	8035
2010	2823	1855	4678	-	-	-	2823	1855	4678
2011	5361	4773	10134	-	-	-	5361	4773	10134
2012	3740	1853	5593	-	-	-	3740	1853	5593
2013	13911	2122	16033	-	-	-	13911	2122	16033
2014	9741	2245	11986				9741	2245	11986
2015	2144	93	2237	-	-	-	2144	93	2237
2016	426	1016	1442	-	-	-	426	1016	1442

a For the period 1946–1970 only 5-year averages are given.

b For 1955, 1956 and 1957 Soviet catches of harp and hooded seals reported at 3,900, 11,600 and 12,900, respectively (Sov. Rep. 1975). These catches are not included.

c Including 1431 pups and one adult caught by a ship which was lost.

Table 2. Catches of harp seals in the White and Barents Seas ("East Ice"), 1946–2016a,b (Haug and Zabavnikov SEA 238)

	Norwegian catches			Russian catches			Total catches		
Year	Pups	1 year and Older	Total	Pups	1 year and Older	Total	Pups	1 year and Older	Total
1946–50			25057	90031	55285	145316			170373
1951–55			19590	59190	65463	124653			144243
1956–60	2278	14093	16371	58824	34605	93429	61102	48698	109800
1961–65	2456	8311	10767	46293	22875	69168	48749	31186	79935
1966–70			12783	21186	410	21596			34379
1971	7028	1596	8624	26666	1002	27668	33694	2598	36292
1972	4229	8209	12438	30635	500	31135	34864	8709	43573
1973	5657	6661	12318	29950	813	30763	35607	7474	43081
1974	2323	5054	7377	29006	500	29506	31329	5554	36883
1975	2255	8692	10947	29000	500	29500	31255	9192	40447
1976	6742	6375	13117	29050	498	29548	35792	6873	42665
1977	3429	2783	6212c	34007	1488	35495	37436	4271	41707
1978	1693	3109	4802	30548	994	31542	32341	4103	36344
1979	1326	12205	13531	34000	1000	35000	35326	13205	48531
1980	13894	1308	15202	34500	2000	36500	48394	3308	51702
1981	2304	15161	17465d	39700	3866	43566	42004	19027	61031
1982	6090	11366	17456	48504	10000	58504	54594	21366	75960
1983	431	17658	18089	54000	10000	64000	54431	27658	82089
1984	2091	6785	8876	58153	6942	65095	60244	13727	73971
1985	348	18659	19007	52000	9043	61043	52348	27702	80050
1986	12859	6158	19017	53000	8132	61132	65859	14290	80149
1987	12	18988	19000	42400	3397	45797	42412	22385	64797
1988	18	16580	16598	51990	2501e	54401	51918	19081	70999
1989	0	9413	9413	30989	2475	33464	30989	11888	42877
1990	0	9522	9522	30500	1957	32457	30500	11479	41979
1991	0	9500	9500	30500	1980	32480	30500	11480	41980
1992	0	5571	5571	28351	2739	31090	28351	8310	36661
1993	0	8758f	8758	31000	500	31500	31000	9258	40258
1994	0	9500	9500	30500	2000	32500	30500	11500	42000
1995	260	6582	6842	29144	500	29644	29404	7082	36486
1996	2910	6611	9521	31000	528	31528	33910	7139	41049
1997	15	5004	5019	31319	61	31380	31334	5065	36399
1998	18	814	832	13350	20	13370	13368	834	14202
1999	173	977	1150	34850	0	34850	35023	977	36000
2000	2253	4104	6357	38302	111	38413	40555	4215	44770

	Norwegian catches			Russian catches			Total catches		
Year	Pups	1 year and Older	Total	Pups	1 year and Older	Total	Pups	1 year and Older	Total
2001	330	4870	5200	39111	5	39116	39441	4875	44316
2002	411	1937	2348	34187	0	34187	34598	1937	36535
2003	2343	2955	5298	37936	0	37936	40279	2955	43234
2004	0	33	33	0	0	0	0	33	33
2005	1162	7035	8197	14258	19	14277	15488	9405	22474
2006	147	9939	10086	7005	102	7107	7152	10041	17193
2007	242	5911	6153	5276	200	5476	5518	6111	11629
2008	0	0	0	13331	0	13331	13331	0	13331
2009	0	0	0	0	0	0	0	0	0
2010	0	105	105	5	5	10	5	110	115
2011	0	200	200	0	0	0	0	200	200
2012	0-	0-	0-	0	9	9	0	9	9
2013	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0
2016	0	28	28	0	0	0	0	28	28

[a] For the period 1946–1970 only 5-year averages are given.

[b] Incidental catches of harp seals in fishing gear on Norwegian and Murmansk coasts are not included (see Table 6).

[c] Approx. 1300 harp seals (unspecified age) caught by one ship lost are not included.

[d] An additional 250–300 animals were shot but lost as they drifted into Soviet territorial waters.

[e] Russian catches of 1+ animals after 1987 selected by scientific sampling protocols.

[f] Included 717 seals caught to the south of Spitsbergen, east of 14o E, by one ship which mainly operated in the Greenland Sea.

Table 3. Reported catches of harp seals in the Northwest Atlantic for 19522016. Estimated catches are indicated by shading. The Greenland catches are made up of the Table 5 West Greenland catches and 1/2 of the SE Greenland. The other half of the SE Greenland and the NE Greenland are assigned to the West Ice population (Stenson and Rosing-Asvid SEA245).

Year	Front & Gulf	Canadian Arctic	Greenland	NW Atlantic Total
1952	307,108	1,784	16,400	325,292
1953	272,886	1,784	16,400	291,070
1954	264,416	1,784	19,150	285,350
1955	333,369	1,784	15,534	350,687
1956	389,410	1,784	10,973	402,167
1957	245,480	1,784	12,884	260,148
1958	297,786	1,784	16,885	316,455
1959	320,134	1,784	8,928	330,846
1960	277,350	1,784	16,154	295,288
1961	187,866	1,784	11,996	201,646
1962	319,989	1,784	8,500	330,273
1963	342,042	1,784	10,111	353,937
1964	341,663	1,784	9,203	352,650
1965	234,253	1,784	9,289	245,326
1966	323,139	1,784	7,057	331,980
1967	334,356	1,784	4,242	340,382
1968	192,696	1,784	7,116	201,596
1969	288,812	1,784	6,438	297,034
1970	257,495	1,784	6,269	265,548
1971	230,966	1,784	5,572	238,322
1972	129,883	1,784	5,994	137,661
1973	123,832	1,784	9,212	134,828
1974	147,635	1,784	7,145	156,564
1975	174,363	1,784	6,752	182,899
1976	165,002	1,784	11,956	178,742
1977	155,143	1,784	12,866	169,793
1978	161,723	2,129	16,638	180,490
1979	160,541	3,620	17,545	181,706
1980	169,526	6,350	15,255	191,131
1981	202,169	4,672	22,974	229,815
1982	166,739	4,881	26,927	198,547
1983	57,889	4,881	24,785	87,555
1984	31,544	4,881	25,829	62,254
1985	19,035	4,881	20,785	44,701
1986	25,934	4,881	26,099	56,914
1987	46,796	4,881	37,859	89,536
1988	94,046	4,881	40,415	139,342
1989	65,304	4,881	42,971	113,156
1990	60,162	4,881	45,526	110,569
1991	52,588	4,881	48,082	105,551
1992	68,668	4,881	50,638	124,187

YEAR	FRONT & GULF	CANADIAN ARCTIC	GREENLAND	NW ATLANTIC TOTAL
1993	27,003	4,881	56,319	88,203
1994	61,379	4,881	59,684	125,944
1995	65,767	4,881	66,298	136,946
1996	242,906	4,881	73,947	321,734
1997	264,210	2,500a	68,816	335,526
1998	282,624	1,000a	81,272	364,896
1999	244,552	500a	93,117	338,169
2000	92,055	400a	98,458	190,914
2001	226,493	600a	85,428	312,521
2002	312,367	1,000	66,744	380,102
2003	289,512	1,000	66,149	356,661
2004	365,971	1,000	70,586	437,557
2005	323,826	1,000	91,696	422,525
2006	354,867	1,000	92,210	448,077
2007	224,745	1,000	82,836	308,581
2008	217,850	1,000	80,556	299,406
2009	76,668	1,000	72,142	149,810
2010	69,101	1,000	90,014	160,115
2011	40,389	1,000	74,013	115,402
2012	71,460	1,000	59,769	132,229
2013	90,703	1,000	81,196	169,700
2014	54,830	1,000	63,059	133,827
2015	35,304	1,000	78,749b	115,053
2016	66,865	1,000	78,749b	146,614

[a] **Rounded**

[b] **Average of catches 2005–2014**

Table 4. Reported Canadian catches of Harp seals off Newfoundland and in the Gulf of St Lawrence, Canada ("Gulf" and "Front"), 1946–2016a,b. Catches from 1995 onward include catches under the personal use licences. YOY = Young of Year, (Stenson and Rosing-Asvid SEA245).

	Large Vessel Catch				Landsmen Catch				Total Catches			
Year	YOY	1+	Unk	Total	YOY	1+	Unk	Total	YOY	1+	Unk	Total
1946-50	108256	53763	0	162019	44724	11232	0	55956	152980	64995	0	217975
1951-55	184857	87576	0	272433	43542	10697	0	54239	228399	98273	0	326672
1956-50	175351	89617	0	264968	33227	7848	0	41075	208578	97466	0	306044
1961-65	171643	52776	0	224419	47450	13293	0	60743	219093	66069	0	285162
1966-70	194819	40444	0	235263	32524	11633	0	44157	227343	52077	0	279420
1971-75	106425	12778	0	119203	29813	12320	0	42133	136237	25098	0	161336
1976	93939	4576	0	98515	38146	28341	0	66487	132085	32917	0	165002
1977	92904	2048	0	94952	34078	26113	0	60191	126982	28161	0	155143
1978	63669	3523	0	67192	52521	42010	0	94531	116190	45533	0	161723
1979	96926	449	0	97375	35532	27634	0	63166	132458	28083	0	160541
1980	91577	1563	0	93140	40844	35542	0	76386	132421	37105	0	169526
1981d	89049	1211	0	90260	89345	22564	0	111909	178394	23775	0	202169
1982	100568	1655	0	102223	44706	19810	0	64516	145274	21465	0	166739
1983	9529	1021	0	10550	40529	6810	0	47339	50058	7831	0	57889
1984	95	549	0	644e	23827	7073	0	30900	23922	7622	0	31544
1985	0	1	0	1e	13334	5700	0	19034	13334	5701	0	19035
1986	0	0	0	0	21888	4046	0	25934	21888	4046	0	25934
1987	2671	90	0	2761	33657	10356	22	44035	36350	10446	0	46796
1988	0	0	0	0	66972	13493	13581	94046	66972	27074	0	94046
1989	1	231	0	232e	56345	5691	3036	65072	56346	8958	0	65304

	Large Vessel Catch				Landsmen Catch				Total Catches			
Year	YOY	1+	Unk	Total	YOY	1+	Unk	Total	YOY	1+	Unk	Total
1990	48	74	0	122e	34354	23725	1961	60040	34402	25760	0	60162
1991	3	20	0	23e	42379	5746	4440	52565	42382	10206	0	52588
1992	99	846	0	945e	43767	21520	2436	67723	43866	24802	0	68668
1993	8	111	0	119e	16393	9714	777	26884	16401	10602	0	27003
1994	43	152	0	195e	25180	34939	1065	61184	25223	36156	0	61379
1995	21	355	0	376e	33615	31306	470	65391	34106	31661	0	65767
1996	3	186	0	189e	184853	57864	0	242717	184856	58050	0	242906
1997	0	6	0	6e	220476	43728	0	264204	220476	43734	0	264210
1998	7	547	0	554e	0	0	282070	282070	7	547	282070	282624
1999	26	25	0	51e	221001	6769	16782	244552	221027	6794	16782	244603
2000	16	450	0	466e	85035	6567	0	91602	85485	6583	0	92068
2001	0	0	0	0	214754	11739	0	226493	214754	11739	0	226493
2002	0	0	0	0	297764	14603	0	312367	297764	14603	0	312367
2003	0	0	0	0	280174	9338	0	289512	280174	9338	0	289512
2004	0	0	0	0	353553	12418	0	365971	353553	12418	0	365971
2005	0	0	0	0	319127	4699	0	323826	319127	4699	0	323826
2006	0	0	0	0	346426	8441	0	354867	346426	8441	0	354867
2007	0	0	0	0	221488	3257	0	224745	221488	3257	0	224745
2008	0	0	0	0	217565	285	0	217850	217565	285	0	217850
2009	0	0	0	0	76668	0	0	76668	76668	0	0	76668
2010	0	0	0	0	68654	447	0	69101	68654	447	0	69101
2011	0	0	0	0	40371	18	0	40371	40371	18	0	40371
2012	0	0	0	0	71319	141	0	71460	71319	141	0	71460

	Large Vessel Catch				Landsmen Catch				Total Catches			
Year	YOY	1+	Unk	Total	YOY	1+	Unk	Total	YOY	1+	Unk	Total
2013	0	0	0	0	90703	0	0	90703	90703	0	0	90703
2014	0	0	0	0	54829	1		54830	54829	1	0	54830
2015	0	0	0	0	35302	2	0	35304	35302	2	0	35304
2016	0	0	0	0	0	0	66865	66865	0	0	66865	66865

a For the period 1946-1975 only 5-years averages are given.

b All values prior to 1990 are from NAFO except where noted, recent data from Stenson (2009) and DFO Statistics Branch.

c Landsmen values include catches by small vessels (< 150 gr tons) and aircraft.

d NAFO values revised to include complete Quebec catch (Bowen, W.D. 1982)

e Large vessel catches represent research catches in Newfoundland and may differ from NAFO values

Table 5. Catches of harp seals in Greenland, 1954–1987 (List-of-Game), and 1993–2014 (Piniarneq), and % adults according to the hunters' reports (Stenson and Rosing-Asvid SEA245).

	West Greenland		South East Greenland		North East Greenland		All Greenland
Year	Catch numbers	% adults	Catch numbers	% adults	Catch numbers	% adults	Catch numbers
1954	18,912		475		32		19,419
1955	15,445		178		45		15,668
1956	10,883		180		5		11,068
1957	12,817		133		40		12,990
1958	16,705		360		30		17,095
1959	8,844		168		7		9,019
1960	15,979		350		16		16,345
1961	11,886		219		13		12,118
1962	8,394		211		10		8,615
1963	10,003	21	215	28	20	50	10,238
1964	9,140	26	125	40	7	86	9,272
1965	9,251	25	76	65	2	100	9,329
1966	7,029	29	55	55	6		7,090
1967	4,215	38	54	35	10		4,279
1968	7,026	30	180	47	4		7,210
1969	6,383	21	110	62	9		6,502
1970	6,178	26	182	70	15	100	6,375
1971	5,540	24	63	48	5		5,608
1972	5,952	16	84	48	6	100	6,042
1973	9,162	19	100	20	38	79	9,300
1974	7,073	21	144	29	27	95	7,244
1975	5,953	13	125	20	68	72	6,146
1976	7,787	12	260	48	27	55	8,074
1977	9,938	15	72	16	21	81	10,031
1978	10,540	16	408	14	30	36	10,978
1979	12,774	20	171	19	18	25	12,963
1980	12,270	17	308	14	45		12,623
1981	13,605	21	427	15	49		14,081
1982	17,244	16	267	20	50	60	17,561
1983	18,739	19	357	56	57	30	19,153
1984	17,667	16	525	19	61		18,253
1985	18,445	2	534	0	56	52	19,035
1986	13,932b	10	533b	18	37b	65	14,502b
1987	16,053b	21	1060b	24	15b	60	17,128b
1988-1992	For 1988 to 1992 comparable catch statistics are not available.						
1993	55,792	50	1,054	30	40	93	56,886
1994	56,941	50	864	30	88	65	57,893
1995	62,296	53	906	36	61	52	63,263
1996	73,287	52	1,320	35	69	59	74,676

	West Greenland		South East Greenland		North East Greenland		All Greenland
Year	Catch numbers	% adults	Catch numbers	% adults	Catch numbers	% adults	Catch numbers
1997	68,241	49	1,149	28	201	58	69,591
1998	80,437	51	1,670	30	110	73	82,217
1999	91,321	50	3,592	12	104	65	95,017
2000	97,229	44	2,459	15	113	76	99,801
2001	84,165	42	2,525	18	73	68	86,763
2002	65,810	46	1,849	19	66	86	67,725
2003	64,735	44	2,828	24	44	77	67,607
2004	69,273	41	2,625	27	207	29	72,105
2005	90,308	35	2,775	18	38	58	93,121
2006	91,191	33	2,038	16	89	78	93,318
2007	81,485	32	2,702	21	85	53	84,272
2008	78,747	32	3,617	15	50	90	82,414
2009	70 869	32	2 546	9	83	75	73 498
2010	89 045	25	1 938	12	35	34	91 018
2011	73 277	30	1 472	16	74	26	74 823
2012	59,124	21	1,290	11	154	23	59,923
2013	80,102	24	2,188	15	186	28	82,099
2014	62,147	29	1,824	13	28	32	63,811

a Seals exhibiting some form of a harp.b These provisional figures do not include estimates for non-reported catches as for the previous years.

Table 6. Estimated catches of harp seals in Greenland, 1975–1987 and 1993–1995. Figures in bold are non-corrected figures from Table 5 (Stenson and Rosing-Asvid SEA245).

Year	West Greenland	South East Greenland	North East Greenland	Total Greenland
1975	6,689	125	68	6,882
1976	11,826	260	50	12,136
1977	12,830	72	50	12,952
1978	16,434	408	50	16,892
1979	17,459	171	50	17,680
1980	15,101	308	45	15,454
1981	22,760	427	49	23,236
1982	26,793	267	50	27,110
1983	24,606	357	57	25,020
1984	25,566	525	61	26,152
1985	20,518	534	56	21,108
1986	25,832	533a	50	26,415
1987	37,329	1060a	50	38,439
1993	55,792	1,335	40	57,167
1994	58,811	1,746	88	60,645
1995	65,533	1,529	61	67,123

a Provisional figures; do not include estimates for non-reported catches.

Table 7. Estimated total removals of harp seals in the Northwest Atlantic for 19522016, (Stenson and Rosing-Asvid SEA245).

YEAR	REPORTED	BYCATCH	STRUCK AND LOST	TOTAL
1952	325,292	0	129,230	454,522
1953	291,070	0	95,095	386,165
1954	285,350	0	112,084	397,434
1955	350,687	0	100,938	451,625
1956	402,167	0	64,218	466,385
1957	260,148	0	96,381	356,529
1958	316,455	0	176,883	493,338
1959	330,846	0	94,426	425,272
1960	295,288	0	140,697	435,985
1961	201,646	0	34,532	236,178
1962	330,273	0	125,277	455,550
1963	353,937	0	86,250	440,187
1964	352,650	0	88,959	441,609
1965	245,326	0	64,414	309,740
1966	331,980	0	83,382	415,362
1967	340,382	0	65,438	405,820
1968	201,596	0	46,718	248,314
1969	297,034	0	66,051	363,085
1970	265,548	68	50,313	315,929
1971	238,322	490	29,870	268,682
1972	137,661	621	22,031	160,313
1973	134,828	465	37,486	172,779
1974	156,564	182	42,899	199,645
1975	182,899	285	43,681	226,865
1976	178,742	1,092	47,991	227,825
1977	169,793	1,577	44,094	215,464
1978	180,490	2,919	65,474	248,883
1979	181,706	3,310	50,585	235,601
1980	191,131	2,717	60,048	253,896
1981	229,815	3,921	53,222	286,958
1982	198,547	3,785	54,740	257,071
1983	87,555	4,962	40,131	132,648
1984	62,254	4,108	39,591	105,952
1985	44,701	4,857	32,069	81,627
1986	56,914	8,178	36,178	101,269
1987	89,536	13,096	55,099	157,731
1988	139,342	8,545	75,895	223,781
1989	113,156	10,256	59,775	183,187
1990	110,569	3,621	77,978	192,168
1991	105,551	9,689	65,400	180,640
1992	124,187	25,476	82,629	232,292
1993	88,203	26,472	72,665	187,340

YEAR	REPORTED	BYCATCH	STRUCK AND LOST	TOTAL
1994	125,944	47,255	102,049	275,248
1995	136,946	20,395	104,635	261,975
1996	321,734	29,201	146,607	497,542
1997	335,526	18,869	126,654	481,048
1998	364,896	4,641	126,725	496,262
1999	338,169	16,111	113,033	467,313
2000	190,914	11,347	110,354	312,615
2001	312,521	19,475	109,069	441,065
2002	380,102	9,329	98,009	487, 440
2003	356,661	5,367	91,233	453, 261
2004	437,557	12, 593 a	102,612	552 ,761
2005	422,525	12, 325 a	115, 767	550, 616
2006	448,077	12, 355 a	119, 884	580, 316
2007	308,581	12, 447 a	98, 750	419, 778
2008	299,406	12, 704 a	93 ,292	405, 402
2009	149,810	12, 775 a	77, 177	239, 762
2010	160,115	12, 575 a	95, 074	267, 764
2011	115,402	12,571 a	77 ,156	205, 129
2012	132,229	12,571 a 12 571	64,664	209,463
2013	169,700	12,571 a	86,970	272,442
2014	133,827	12,571 a	66,946	198,406
2015	115,053	12,571 a	81,609	209,232
2016	146,614	12,571 a	83,268b	242,454

[a]Average bycatch 19992003 in Canadian and US fisheries

Annex 8: Summary of harp and hooded sealing regulations

Table 1. Summaries of Norwegian harp and hooded sealing regulations for the Greenland Sea ("West Ice"), 1985–2016 (Haug and Zabavnikov SEA 238)

			Quotas				Allocations	
Year	Opening Date	Closing Date	Total	Pups	Female	Male	Norway	Soviet & Russian
Hooded Seals								
1985	22 March	5 May	(20,000)[2]	(20,000)2	03	Unlim.	8,000[4]	3,300
1986	18 March	5 May	9,300	9,300	03	Unlim.	6,000	3,300
1987	18 March	5 May	20,000	20,000	03	Unlim.	16,700	3,300
1988	18 March	5 May	(20,000)[2]	(20,000)2	03	Unlim.	16,700	5,000
1989	18 March	5 May	30,000	0	03	Incl.	23,100	6,900
1990	26 March	30 June	27,500	0	0	Incl.	19,500	8,000
1991	26 March	30 June	9,000	0	0	Incl.	1,000	8,000
1992-94	26 March	30 June	9,000	0	0	Incl.	1,700	7,300
1995	26 March	10 July	9,000	0	0	Incl.	1,700[7]	7,300
1996	22 March	10 July	9,0008				1,700	7,300
1997	26 March	10 July	9,0009				6,200	2,800[11]
1998	22 March	10 July	5,00010				2,200	2,800[11]
1999-00	22 March	10 July	11,200[12]				8,400	2,800[11]
2001-03	22 March	10 July	10,300[12]				10,300	
2004-05	22 March	10 July	5,600[12]				5,600	
2006	22 March	10 July	4,000				4,000	
2007-1614			0	0	0	0	0	0
Harp Seals								
1985	10 April	5 May	(25,000)[2]	(25,000)2	0[5]	0[5]	7,000	4,500
1986	22 March	5 May	11,500	11,500	0[5]	0[5]	7,000	4,500
1987	18 March	5 May	25,000	25,000	0[5]	0[5]	20,500	4,500
1988	10 April	5 May	28,000	0[5,6]	0[5,6]	0[5,6]	21,000	7,000
1989	18 March	5 May	16,000	-	0[5]	05	12,000	9,000
1990	10 April	20 May	7,200	0	0[5]	05	5,400	1,800
1991	10 April	31 May	7,200	0	0[5]	05	5,400	1,800
1992-93	10 April	31 May	10,900	0	0[5]	05	8,400	2,500
1994	10 April	31 May	13,100	0	0[5]	05	10,600	2,500
1995	10 April	31 May	13,100	0	0[5]	05	10,6007	2,500
1996	10 April	31 Ma8	13,100[9]				10,600	2,500[11]
1997-98	10 April	31 May	13,100[10]				10,600	2,500[11]
1999-00	10 April	31 May	17,500[13]				15,000	2,500[11]
2001-05	10 April	31 May	15,000[13]				15,000	0
2006-07	10 April	31 May	31,200[13]				31,200	0
2008	5 April	31 May	31,200[13]				31,200	0
2009	10 April	31 May	40,000				40,000	0
2010	10 April	31 May	42,000				42,000	0

Year	Opening Date	Closing Date	Quotas Total	Pups	Female	Male	Allocations Norway	Soviet & Russian
2011	10 April	31 May	42,000				42,000	0
2012-13	10 April	31 May	25,000				25,000	0
2014-16	10 April	31 May	21,270				21,270	0

[1] Other regulations include: Prescriptions for date for departure Norwegian port; only one trip per season; licensing; killing methods; and inspection.

[2] Basis for allocation of USSR quota.

[3] Breeding females protected; two pups deducted from quota for each female taken for safety reasons.

[4] Adult males only.

[5] 1 year+ seals protected until 9 April; pup quota may be filled by 1 year+ after 10 April.

[6] Any age or sex group.

[7] Included 750 weaned pups under permit for scientific purposes.

[8] Pups allowed to be taken from 26 March to 5 May.

[9] Half the quota could be taken as weaned pups, where two pups equalled one 1+ animal.

[10] The whole quota could be taken as weaned pups, where two pups equalled one 1+ animal.

[11] Russian allocation reverted to Norway.

[12] Quota given in 1+ animals, parts of or the whole quota could be taken as weaned pups, where 1,5 pups equalled one 1+ animal.

[13] Quota given in 1+ animals, parts of or the whole quota could be taken as weaned pups, where 2 pups equalled one 1+ animal.

[14] Hooded seals protected, only small takes for scientific purposes allowed.

Table 2. Summary of sealing regulations for the White and Barents Seas ("East Ice"), 1979–2016.[1]

	Opening Dates			Quota-Allocation		
Year	Soviet/Rus.	Norway	Closing Date	Total	Soviet/Rus.	Norway
1979–80	1 March	23 March	30 April3	50,000[4]	34,000	16,000
1981	-	-	-	60,000	42,500	17,500
1982	-	-	-	75,000	57,500	17,500
1983	-	-	-	82,000	64,000	18,000
1984	-	-	-	80,000	62,000	18,000
1985-86	-	-	-	80,000	61,000	19,000
1987	-	-	20 April3	80,000	61,000	19,000
1988	-	-	-	70,000	53,400	16,600
1989–94	-	-	-	40,000	30,500	9,500
1995	-	-	-	40,000	31,250	8,7505
1996	-	-	-	40,000	30,500	9,500
1997-98	-	-	-	40,000	35,000	5,000
1999	-	-	-	21,400[6]	16,400	5,000
2000	27 Febr	-	-	27,700[6]	22,700	5,000
2001-02	-	-	-	53,000[6]	48,000	5,000
2003	-	-	-	53,000[6]	43,000	10,000
2004-05				45,100[6]	35,100	10,000
2006	-	-	-	78,200[6]	68,200	10,000
2007	-	-	-	78,200[6]	63,200	15,000
2008	-	-	-	55,100[6]	45,100	10,000
2009	-	-	-	35,000	28,000[7]	7,000
2010				7,000	0	7,000
2011				7,000	0	7,000
2012-13				7,000	0	7,000
2014				7,000	0	7,000
201516				19,200	12,200	7,000

[1] **Quotas and other regulations prior to 1979 are reviewed by Benjaminsen (1979).**

[2] **Hooded, bearded and ringed seals protected from catches by ships.**

[3] **The closing date may be postponed until 10 May if necessitated by weather or ice conditions.**

[4] **Breeding females protected (all years).**

[5] **Included 750 weaned pups under permit for scientific purposes.**

[6] **Quotas given in 1+ animals, parts of or the whole quota could be taken as pups, where 2,5 pups equalled one 1+ animal**

[7] **Quota initially set at 28,000 animals, but then was reconsidered and set to 0.**

Table 3. Major management measures implemented for harp seals in Canadian waters, 1961–2016.

YEAR	MANAGEMENT MEASURE
1961	Opening and closing dates set for the Gulf of the St Lawrence and Front areas.
1964	First licensing of sealing vessels and aircraft. Quota of 50,000 set for southern Gulf (effective 1965).
1965	Prohibition on killing adult seals in breeding or nursery areas. Introduction of licensing of sealers. Introduction of regulations defining killing methods.
1966	Amendments to licensing. Gulf quota areas extended. Rigid definition of killing methods.
1971	TAC for large vessels set at 200,000 and an allowance of 45,000 for landsmen.
1972 – 1975	TAC reduced to 150,000, including 120,000 for large vessel and 30,000 (unregulated) for landsmen. Large vessel hunt in the Gulf prohibited.
1976	TAC was reduced to 127,000.
1977	TAC increased to 170,000 for Canadian waters, including an allowance of 10,000 for northern native peoples and a quota of 63,000 for landsmen (includes various suballocations throughout the Gulf of St Lawrence and northeastern Newfoundland). Adults limited to 5% of total large vessel catch.
1978–1979	TAC held at 170,000 for Canadian waters. An additional allowance of 10,000 for the northern native peoples (mainly Greenland).
1980	TAC remained at 170,000 for Canadian waters including an allowance of 1,800 for the Canadian Arctic. Greenland was allocated additional 10,000.
1981	TAC remained at 170,000 for Canadian waters including 1,800 for the Canadian Arctic. An additional allowance of 13,000 for Greenland.
1982–1987	TAC increased to 186,000 for Canadian waters including increased allowance to northern native people of 11,000. Greenland catch anticipated at 13,000.
1987	Change in Seal Management Policy to prohibit the commercial hunting of whitecoats and hunting from large (>65 ft) vessels (effective 1988). Changes implemented by a condition of licence.
1992	First Seal Management Plan implemented.
1993	Seal Protection Regulations updated and incorporated in the Marine Mammal Regulations. The commercial sale of whitecoats prohibited under the Regulations. Netting of seals south of 54°N prohibited. Other changes to define killing methods, control interference with the hunt and remove old restrictions.
1995	Personal sealing licences allowed. TAC remained at 186,000 including personal catches. Quota divided among Gulf, Front and unallocated reserve.
1996	TAC increased to 250,000 including allocations of 2,000 for personal use and 2,000 for Canadian Arctic.
1997	TAC increased to 275,000 for Canadian waters.
2000	Taking of whitecoats prohibited by condition of license
2003	Implementation of 3 year management plan allowing a total harvest of 975,000 over 3 years with a maximum of 350,000 in any one year.
2005	TAC reduced to 319,517 in final year of 3 year management plan
2006	TAC increased to 335,000 including a 325,000 commercial quota, 6,000 original initiative, and 2,000 allocation each for Personal Use and Arctic catches
2007	TAC reduced to 270,000 including 263,140 for commercial, 4,860 for Aboriginal, and 2,000 for Personal Use catches
2008	TAC increased to 275,000 including a 268,050 for commercial, 4,950 for Aboriginal and 2,000 for Personal Use catches Implementation of requirement to bleed before skinning as a condition of licence

Year	Management Measure
2009	TAC increased to 280,000 based upon allocations given in 2008 plus an additional 5,000 for market development Additional requirements related to humane killing methods were implemented
2010	TAC increased to 330,000
2011	TAC increased to 400,000

Table 4. Major management measures implemented for hooded seals in Canadian waters for 1964–2016.

YEAR	MANAGEMENT MEASURE
1964	Hunting of hooded seals banned in the Gulf area (below 50oN), effective 1965.
1966	ICNAF assumed responsibility for management advice for Northwest Atlantic.
1968	Open season defined (12 March–15 April).
1974–1975	TAC set at 15,000 for Canadian waters. Opening and closing dates set (20 March–24 April).
1976	TAC held at 15,000 for Canadian waters. Opening delayed to 22 March. Shooting banned between 23:00 and 10:00 GMT from opening until 31 March and between 24:00 and 09:00 GMT thereafter (to limit loss of wounded animals).
1977	TAC maintained at 15,000 for Canadian waters. Shooting of animals in water prohibited (to reduce loss due to sinking). Number of adult females limited to 10% of total catch.
1978	TAC remained at 15,000 for Canadian waters. Number of adult females limited to 7.5% of total catch.
1979–1982	TAC maintained at 15,000. Catch of adult females reduced to 5% of total catch.
1983	TAC reduced to 12,000 for Canadian waters. Previous conservation measures retained.
1984–1990	TAC reduced to 2,340 for Canadian waters.
1987	Change in Seal Management Policy to prohibit the commercial hunting of bluebacks and hunting from large (>65 ft) vessels (effective 1988). Changes implemented by a condition of licence.
1991–1992	TAC raised to 15,000.
1992	First Seal Management Plan implemented.
1993	TAC reduced to 8,000. Seal Protection Regulations updated and incorporated in the Marine Mammal Regulations. The commercial sale of bluebacks prohibited under the Regulations.
1995	Personal sealing licences allowed (adult pelage only).
1998	TAC increased to 10,000
2000	Taking of bluebacks prohibited by condition of license.
2007	TAC reduced to 8,200 under Objective Based Fisheries Management based on 2006 assessment
2008	Implementation of requirement to bleed before skinning as a condition of license
2009	Additional requirements implemented to ensure humane killing methods are used

Annex 9: Technical minutes from the Review Group for the ICES WGHARP REPORT 2016 (Norwegian request)

27 Oct 2016 revised 30 Oct 2016

Participants: Karin Harding (Chair), Mario Acquarone and Sinéad Murphy;

Working Group: WGHARP 2016

Chair WG:

Secretariat:

The Review Group considered the following stocks:

- Harp seal Greenland Sea
- Harp seal White Sea/Barents Sea
- Hooded Seal Greenland Sea

And the following special requests:

- Assess the status and harvest potential of the three stocks

Especially assess the impact of

1) current harvest levels,
2) sustainable catches (defined as the fixed annual catches that stabilizes the future 1+ population)
3) catches that would reduce the population over a 15-years period in such a manner that it would remain above a level of 70% of the maximum population size, determined from population modelling, with 80% probability.

General

The Review Group (RG) acknowledges the immense effort expended by the Working Group (WG) to produce the report. The report is well written and well thought through and the best data and literature available on the species of concern have been used. However, the RG has some comments on the methodology and suggestions for complementary methods and literature that we hope can be valuable in future developments of the model framework and, consequently, in the population assessments.

Introduction

The report describes the biological status of pinniped stocks in the high Arctic. These populations inhabit one of the most difficult habitats to survey in the world, the polar drift ice. Despite incomplete datasets, the authors have used every piece of information available to them to put together a picture of seal abundance, growth rate and the potential for harvest. We acknowledge the difficulty of this task.

The RG would like to stress the following points

There are no reliable estimates of population abundance from surveys for these populations, but there are indications of abundance given as data on pup production and harvest data. There are also biological data on pinniped life history. These pieces of information are tied together in a population dynamics model and this is how abundance is estimated. Therefore, every model assumption is vital.

Our main points are the following

- The basic population dynamic model is sound but can be further improved by applying the precautionary principle in each step in selecting parameter values. As it now stands the basic intrinsic rate of increase (r) is not given explicitly for different parameter values. There is a risk that the model is over optimistic in its estimates of sustainable catches.
- How is uncertainty in population abundance included in estimates of sustainable catches?

For single-stock summary sheet advice:

Stock 4.2 The Greenland Harp Seal stock

Short description of the assessment: extremely useful for reference of ACOM!

1) Assessment type:
2) Assessment: abundance, potential for catches
3) Forecast:presented (for future population size given different hunting regimes)
4) Assessment model: Population projection model fitted to some empirical data on reproduction and pup production. 2. Bayesian model trying to fit the population model to data on pup production, initial population sizes.
5) Consistency:
6) Stock status: Seem to be at safe levels 650 300 (95% CI: 471 200 – 829 300) according to the model
7) Man. Plan.: Current harvest is at historically low levels and seem to be at the safe side 1 442 in 2016. However, in 2013 as many as 16 033 animals were hunted (whereof 2 245 were older than pups). Suggested quotas of about 20 000 seals might cause rapid decline depending on population parameters.

General comments

This is an ambitious and very professional section. However, the RG still has some points of concern.

Technical comments

A. The Population model and parameter values chosen

The main construction of the population model is good and straightforward. But there are a number of question marks in the parameterization. The most important aspect of a population model is which inherent rate of population increase it assumes/obtains through model parameterizations. This growth rate (often termed r in the literature) will govern everything in model predictions and affect which catches the population is thought to sustain. The models intrinsic r (for different settings of parameter values) is not clearly stated in the report.

High growth rate (*r*) allows for higher catches. High growth rates result from: (1). Early female sexual maturity (2). High pregnancy rates (3). Low mortality rates. In order to apply a pre-cautionary principle, it is therefore important not to over/ misestimate these parameters, i.e. propose a high growth rate in data poor populations, but to try to stay on the safe side.

1) Age at sexual maturity is well documented by the WG and is nicely included year by year in the estimation of historical population size. However, for the projection this number is kept constant. <u>Suggestion:</u> For future projections it would be best to allow age at maturity to vary within the same range as the historical data has varied and randomize if it is a ''good year'' or a ''bad year'' (See Caswell 2011), as it is now it seems an average value is used for all future years.

2)

2.1) Fertility rate in this case pregnancy rate) was estimated by examining females that were caught within a few weeks or months of the breeding season for the presence or absence of a large partially luteinized *Corpus albicans*. This may overestimate pup production as females that just ovulated and did not become pregnant, and females that had pregnancies ending in abortions may leave signs that look like successful breeding. A lower value should be assumed.

2.2) An average pregnancy rate is used for future projected population size. Suggestion: For future projections randomize good-years and bad-years pregnancy rates from the historical distribution.

3)

3.1) Mortality rates are unknown. But assumed to be 0.3 for pups and 0.1 for adults. These parameters are crucial to the resulting *r*. A *literature* review of survival rates of phocid seals indicate that pup mortality can be even higher than 30% especially in bad years it can be close to 100% (Härkönen *et al.*, 2002, Kjellqvist *et al.*, 1995). Subadult survival (ages 1-5 years) is often higher compared to adult survival. Suggestion: A next version of the model could include more realistic age-dependent mortality rates from literature data on other phocids.

3.2) One more detailed question: Why is survival (*s*) not assumed to be 1-mortality (M) but s=exp(-M)? (See Page 15 ICES WGHARP REPORT 2016 submitted 141016) This procedure overestimates *s* survival a bit? For M=0.5 *s* becomes 0.60, but the sum must be one. Suggestion: Correct or explain in the report.

Suggested test of the model: How rapidly does this model population increase with catches set to zero. Are the parameter values realistic? No seal population can increase more than about 10-12% and stay within known constraints of pinniped biology (Harkonen *et al.*, 2002). One way to double check the settings is to incorporate the basic data in a Leslie matrix and study the growth rate as parameter by parameter is changed (e.g. Caswell 2011, Harding *et al.*, 2002, Harding *et al.*, 2007).

B. Assumptions related to the catch

1) It is assumed that the age structure of the catch 1+ is the same as the age distribution in the population 1+. Is this a good assumption or is the sex and age ratio of the catches 1+ de facto likely to be biased? Any empirical data on this? If it is biased towards adult females, catches are more costly to the population (in terms of the effect on population growth rate) than the model suggests and consequently the applied hunting scenarios suggest that the population tolerate a too high hunting pressure. Suggestion: If there is information of the age and sex structure of the hunt we suggest this is incorporated in future modelling. Otherwise it can be investigated theoretically in the model (applying different test-structure of the catches systematically and record the effect on *r*)

2) If age and sex structure is unknown we approve of the approach the WG takes to assume the age structure of catches of 1+ to follow the age structure of the population flexibly for each year (eqn 4) as the baseline example.

3) The value of a pup for population growth rate relative to older seals is assumed to be 1:2. This simplification will underestimate the cost of the hunt

since adult females are worth about 2.7 for future population growth. The exact value will depend on the population growth rate and the values can be found by a Leslie matrix approach and its left eigenvector (Harding *et al.*, 2007).

C. Model projections and catch levels

In the model projection the scenario called ''current catch levels" uses an average number of the last five years (average 7 458 during 2012-1016). It is reported that continuing current catch levels (and with the assumed population parameter values above) we will see an increase by 58% in 15 years. This is however only a 3% annual growth rate in an exponentially growing population (N15 = N0*e^r15). 3% is not a safe growth rate for a pinniped population in models of risk assessment and does not allow for any other events not included in the model, such as failing food supply or an epidemic disease. A positive growth rate is a population's only guarantee from rapid decline and extinction. Thus the current catch level scenario seems not so safe. Also bearing in mind that multiple parameters included are chose at the higher end (all points mentioned above).

In this light, a hunt of 21 500 (100% 1+) animals in the so called Equilibrium Scenario (Table 5) sounds very high and a sharp decline can be the result. Especially since population abundance estimates are poor it can take many years before a drop in population size can be documented. The RG advises that hunting should not exceed 7 500 pups. However a new population assessment with revised approach is preferred, before any new catches are performed. Consequently, the RG also suspects that the catch option ''Reduce to N70a" with a catch of 26 000 (1+) animals will cause a sharper and quicker decline than projected.

Conclusions

The harp seal biology in the Greenland Sea seems to be characterized by large long term fluxes in age at sexual maturity and pregnancy rate. Most likely these fluxes also affect annual survival rates (not included in the model). The WG has made an impressive job in constructing a model framework that make use of the pieces of information that exist. However, we are worried that parameterization at several points has been chosen in a way that happened to produce a too optimistic result of the potential harvest on this population. We give concrete suggestions for model improvements and test in the text above. Our recommendation is to systematically go through each parameter value within its biologically realistic range and register its effect on the growth rate (*r*) in a form of sensitivity analysis.

For single-stock summary sheet advice:

Stock 5.1 The Greenland Sea Hooded Seal Stock

1) Assessment type: Population status assessed by modelling
2) Assessment: Historical abundance, reference levels, potential for catches
3) Forecast: No population forecast is presented.
4) Assessment model: Population projection model fitted to some empirical data on reproduction and catches. 2. Bayesian model fitting the population model to data on pup production, initial population sizes.
5) Consistency:

6) Stock status: Have undergone a dramatic decline during the last 70 years from about 1 M to about 80 000. Current estimates of pup production show a continued decline.

7) Man. Plan.: The historical hunt has been around 3 000-8 000 annually since 1989 and up to 2006, thereafter a sharp drop in catches has occurred and the last years about 20 seals are hunted annually. The WG suggest no further hunting on this stock and the RG agree with this conclusion.

General comments

This section on hooded seals is well written and gives a good background to the biology and historical catch levels. However, the population is poorly studied and the lack of abundance and age structure/natural mortality data are striking. Nevertheless, the WG has made the best of the situation and produced a population model with parameter values of life history, catches and pup production tuned to hooded seals.

Brief summary

The hooded seal is a top predator in the Arctic drift ice. Parameter values given in the report (pregnancy rate 0.7, age at maturity about 6 years, mortality about 0.34 (pups) and 0.17 (1+) indicate that the population has a very low intrinsic rate of increase compared to most phocid seals. Hooded seals seem to be one more of these slow growing top predators that are so easy to overexploit and also vulnerable to large-scale changes in prey abundance.

The estimated total 2017 population of hooded seals in the Greenland Sea is 80 460 (95% CI 59 020 – 101 900). In the 1950s the population is estimated to have been around 1 M (Fig 5). An annual harvest of over 20 000 seals during the 1970s most likely contributed to the stock collapse. The lack of recovery last years as judged from pup production data are worrying and may indicate a change in the entire foodweb, as suggested by the WG. Estimated pup production was about 13 000 in 2016 and in 1997 23 000 pups.

Technical comments

A. The Population model and parameter values chosen

The same model as for the Greenland harp seal has been used but parameters are chosen to mimic the hooded seal population. The RG approve of the general model approach. However, just as with the Greenland harp seals all conclusions depend on parameter values. This stock is not suggested to be further hunted and thus an improvement of the population model is not as urgent as for species that may be harvested. If for other management reason the hooded seal population dynamics is to be further understood the RG suggest a similar approach as we suggested for harp seals. Suggestion: Vary age at sexual maturity and pregnancy rates and assumed mortality rates among years according to a stochastic good year/bad year distribution with data on variability from the past and when necessary with data from other phocid species (to give biological realistic limits for parameters). Perform a Leslie matrix analysis and a sensitivity analysis to see how the intrinsic growth rate (r) depend on the life history parameters. This can guide future research on the population.

Recommendations on catches

The RG full agrees with the WG: ''All model runs indicate a population currently well below N_{lim} (30% of largest observed population size). Following the precautionary approach framework developed by WGHARP (ICES2005), no catches should be taken from this population.''

For single-stock summary sheet advice:

Stock 4.3 The White Sea and Barents sea Harp Seal Stock

Short description of the assessment: extremely useful for reference of ACOM!

1) Assessment type:
2) Assessment: abundance, potential for catches
3) Forecast: presented (for future population size given different hunting regimes)
4) Assessment model: Population projection model fitted to some empirical data on reproduction and catches. 2. Bayesian model fitting the population model to data on pup production, initial population sizes.
5) Consistency:
6) Stock status: Estimated to 1 408 000 (95% CI 1 251 680 – 1 564 320) according to the model, a sharp decline in reproductive rates since 2003.
7) Man. Plan: Current harvest is practically null (9 adult seals in 2012 and no pups. 28 animals in 2016). Suggested quotas for equilibrium takes of about 10 000 adult seals could be excessive due to the high growth rates used in the model contrasting with the low pup production since 2004, and the fact that this population is data-poor. Additionally, the reduction of the whelping habitat due to rapid decrease of suitable sea ice could further jeopardize reproductive success.

General comments

This section summarize the existing data on the stock in a clear and well-structured manner. However, the data points are few and with large variances. A well thought through population model is used, however due to a likely error in parameterization and scattered data the model does not capture recent declining trends in pup production and the model results must be treated very cautiously. The RG have some points of concern.

1) The growth rate used in the modelling (12% over 15 years) might be too high since annual variation in pregnancy rate and stochastic variation in pup survival is not included.
2) This stock is data poor, as also the WG points out.
3) Hunting (1+) is more costly for the population growth rate than the 1:2 ratio used especially if the population is declining. The estimated Equilibrium catch of 10 090 might be too high since the current trend in pup production is not captured by the projection model. The RG agrees with the WG that better data on abundance, pup production and intrinsic rate of increase are required for future assessments.

Technical comments

A. The Population model and parameter values chosen

The population model used for the Barents Sea/White Sea harp seals is the same as the one used for the Greenland Sea population and we refer to the section on this population for detailed comments and suggestions for ways to improve the parameterization. We also express our concern in accordance with the WG that this population is data poor.

Reproductive data

The model is fed two types of reproductive data: maturity ogive and fecundity rate. A complete dataset for either of these parameters is not available for the whole period (1962-present). Fecundity is used with no variance and pregnancy rate is interpolated linearly for years with no data. WG expressed concerns about the uncertainty in pregnancy rates and the variations in fecundity rates. We agree with these concerns and confirm that the use of the last observed fecundity rate is not advisable. Suggestion: vary pregnancy rate in a stochastic fashion to mimic the variability in harp seal reproductive data. It is also noted that age sexual maturity is very late in this population, we have here one slower growing late maturing Arctic marine mammal and a growth rate above 6% will be highly unlikely. A Leslie matrix approach could be one way forward to obtain likely life history values and growth rates (*r*) (See for example Harding *et al*., 2002, 2007).

Pup production values:

As pointed out by the WG data from commercial operations is unreliable and only surveys conducted in the period 1998-2013 can be used. The latter also provide a measure of the variation in the data. Poor sea ice conditions were observed in 2015 and 2016 which may have led to high pup mortality – particularly more during 2015 (See Page 19 ICES WGHARP REPORT 2016 submitted 141016). Data from this period are not included in the model and thus increased pup mortality in recent years has not been accounted for.

Model estimates:

The model does not fit well to the early pup production, when data were not reliable, but does not fit either to the data from the later better surveys. Assuming the robustness of the model chosen these observations indicate that the life history data do not completely reflect the values for this population, and that some factors influence survival. Suggestion: Treat the model outcome with extreme caution.

Catch levels:

The catch levels for the years since 2012 are assumed zero since the takes have been minimal. For the equilibrium catch to stabilize the population over 15 years only 1+ animals have been considered. The resulting advice for equilibrium catch was 10 090 animals 1+. The RG noted that this advice is based on a too high intrinsic growth rate, it is reported that the population grow with 12% annually without hunting (p 27 at the bottom). Such high growth rates are only seen for pinnipeds with a sexual maturity at about 3 to 4 years, 95% pregnancy rate and 96% adult survival rates (thus unlikely for harp seals in the White Sea/Barents Sea.) This may also be the reason why the model is hard to fit to the pup production data involving an unexplained drop. The RG also noted that the removal of adults only might affect the population more than a combination of adults and pups and more than 1:2 ratio. Suggestion: As above for modelling.

The request to provide advice on catch levels that would reduce the population to N70 was not addressed using the model because of the lack of data, instead a PBR approach was provided. A precautionary recovery factor was employed and a simplified, adult/pup composition of the catch was assumed. The results were evaluated by the WG and deemed the approach not suitable, and the RG agrees.

Recommendation: The RG recommends no further hunting on this population until new data on pup production shows that declining trend has been broken. Furthermore, the RG suggest the population model to systematically test parameter values to find a realistic intrinsic growth rate, this might lead to better model fit, and new Equilibrium catch levels if any.

Conclusions

The dramatic changes in ice conditions in recent years seem to have had a strong influence on harp seal biology in the Barents Sea/White Sea and especially age at sexual maturity, pregnancy rate and pup production. The WG has made an excellent job in extracting useful data from the heterogeneous dataseries for use in the model framework. However, we are worried that the values chosen for the reproductive parameters and the pup production do not reflect the actual values mainly because this population is data poor. We pointed out some strategies for improvement of the model in the text above. We also recommend a precautionary approach when allocating a catch quota for this population which means no catches before a new assessment has been performed.

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