REPORT OF THE JOINT ICES/NAFO/NAMMCO WORKING GROUP ON HARP AND HOODED SEALS (WGHARP)

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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Martin Biuw • Sophie Smout

Authors

Martin Biuw • Albert Chacon • Anne Kirstine Frie • Mike Hamill • Charmain Hamilton • Tore Haug • John-André Henden • Daniel Howell • Shelley Lang • Kimberly Murray • Arnt Salberg • Sophie Smout • Garry Stenson • Lars Witting

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Contents

i Executive summary

The main objective of the working group was to review recent surveys of Greenland Sea harp and hooded seal pup production and examine harvest scenarios for these populations as well as harp seals in the White Sea. No new survey to estimate pup production of Barents Sea/White Sea harp seals was completed. No new survey information was available for the Northwest Atlantic.

The 2022 Greenland Sea aerial survey images were analyzed manually and with the aid of automatic detection methodology (deep learning). For assessment purposes, this report only refers to the manual counts. Correction factors based on staging surveys were applied according to established methodology. The 2022 Greenland Sea harp seal pup production estimate for harp seals was 92,769 (CV = 20.2%), which is significantly higher than the 2018 estimate but similar to that based on the 2012 survey. The hooded seal pup production estimate for 2022 was 13,509 (CV=12.9%), slightly but not significantly higher than the 2018 estimate.

Subsequent to the recent benchmark meeting, model development indicated that the model estimates of adult population size for the Greenland Sea population of harp seals is highly sensitive to the standard deviation on the prior for initial population size. The WG therefore concluded that the current version of the assessment model could not be used to explore harvest scenarios based on estimates of current or projected total population size. Moreover, given the fact that the estimate of current total population size is unreliable, it also did not allow for robust calculation of Potential Biological removals (PBR). Tentatively, two different approaches are presented that might be used to inform sustainable harvest levels until the model has been further improved and reviewed: 1) an adaptive management approach based on population trends and 2) PBR based on a conservative population estimate that is a simple scaling of the observed levels of pup production, based on plausible values of adult:pup ratios.

The Greenland Sea hooded seal population shows continued decline, and remains below the Lower Reference Limit despite no hunting since 2007.

In a recent review of the status of the Northwest Atlantic harp seal population, model fit to aerial survey estimates of pup production and annual reproductive rates was poor compared to previous assessments indicating underlying problems relating to model assumptions and/or structure. A new hierarchical Bayesian state-space model was fitted to the same data on pup production, annual fecundity, human removals, and environmental conditions used in the previous assessment to produce annual estimates of pup production and total abundance from 1952 - 2019. Data on age structure based upon random samples were also included, and the process model incorporated environmental stochasticity and several other improvements. The new model estimates were similar to the previous model through 1990 but then diverged, indicating that the population peaked in 1997 at 6.6 million animals, almost a decade earlier than modelled in previous assessments. After a period of decline due to high catches and poor ice conditions, the new model provides an abundance estimate of 4.7 (95% Credibility Interval (CI) 3.7-5.7) million in 2019, compared to an estimate of 7.6 (95% CI 6.6-8.8) million in the last assessment. The lower estimates of recent abundance reflect higher and more variable juvenile mortality after 2000 due to a combination of density-dependent and density-independent factors operating on juvenile survival. The new model also suggests a decline in equilibrium abundance (K) levels from 7.6 (95% CI=7.4 to 7.8) million Northwest Atlantic harp seals prior to 2000 to 6.8 (95% CI=6.7 to 6.9) million animals post-2000.

ii Expert group information

Expert group name	Joint ICES/NAFO.NAMMCO Working Group on Harp and Hooded Seals [WGHARP]
Expert group cycle	Biennial
Year cycle started	1984
Reporting year in cycle	1/1
Chair(s)	Martin Biuw, Norway
	Sophie Smout, United Kingdom
Meeting venue(s) and dates	21–25 August 2023, Tromsø, Norway

1 ToRs for working group on harp and hooded seals

The **ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP)** chaired by Martin Biuw, Norway, and Sophie Smout, UK, will meet at Tromsø, Norway, on 21-25 August 2023 to:

a) Review new pup production estimates based on the 2022 surveys of NW Atlantic and Greenland Sea harp seals and Greenland Sea hooded seals;
b) Review results from the biological samples obtained from the NW Atlantic, Greenland Sea and Barents Sea / White Sea stocks;
c) Review the status of populations using the method agreed at the WKBSEALS2023 benchmark as described in the stock annex and produce a report of the work carried out, providing summaries of the following where relevant: i) Input data and examination of data quality; ii) estimates of population size, pup production, and harvest potential; iii) The state of the population against relevant reference points;
d) Review the main result from WGIBAR and WGIEAGS;
e) Comment on relevant sections of the published ecosystem and fisheries overviews for the Greenland Sea and the Barents Sea.

2 Summary of the WKBSEALS benchmark process

Motivation for benchmark

WKBSEALS aimed to benchmark three different stocks of two Arctic pinniped species; harp seals (*Pagophilus groenlandicus*) in the Barents Sea/ White Sea (BS/WS) and the Greenland Sea (GS), as well as hooded seals (*Cystophora cristata*) in the Greenland Sea. This represents the first ICES benchmark for marine mammals. The meeting was run as a hybrid meeting, with most participants present at the ICES Headquarters in Copenhagen and some participating via Teams. The motivation for conducting a benchmark was the conclusion by the 2019 meeting of the joint NAFO/ICES/NAMMCO working group on harp and hooded seals (WGHARP), that the current assessment model fails to produce realistic estimates of population dynamics to form the basis for harvest advice using the harvest control rules (HCR) agreed upon in 2005 (ICES, 2006). One reason for the poor model performance is its stiffness. It currently estimates only three parameters; initial population size in 1946, along with constant mortalities for pups and 1+ animals. The argument for keeping the model relatively simple, and therefore inflexible, has been the relative sparsity of input data. WKBSEALS aimed to evaluate an updated model that allows for increased flexibility and the inclusion of environmental drivers on vital rates.

The benchmark was tasked with evaluating proposed developments to the assessment model used for two stocks of harp seals (WS/BS) [seh.27.1] and GS [seh.27.125a14]) and one stock of hooded seals (GS sez.27.2514]) in the Northeast Atlantic. The benchmark concluded that there were sufficient data to produce an assessment model for the Greenland Sea stock of harp seals, but that data were insufficient for the Barents Sea / White Sea harp seal stock and too weak a signal for the Greenland Sea hooded seals for viable assessments for these stocks.

There has been no pup production survey for WS/BS harp seals since 2013. In the absence of more re-cent survey data, the benchmark concludes that viable assessment of current stock status or catch advice cannot be produced. Furthermore, the most recent available pup production estimates indicated a poor status. There have been limited catches since 2019, and the benchmark recommends that a pup survey and subsequent revised assessment is required prior to the resumption of any substantial commercial hunt. The model version with capelin abundance informing model dynamics does perform well in the time period for which data exist.

For the GS harp seal stock, the benchmark proposes a revised assessment model using cod and capelin alongside a first order autocorrelation (AR1) process to drive the model dynamics. Owing to the provisional nature of the recent pup survey, Reference Points were not calculated but could well be considered at WGHARP 2023 when the final data are available. The historical modelled population absolute level is uncertain, but the overall recent trend is relatively flat and has not been adversely affected by recent catches. Although a harvest is taken, advice is not currently given through ICES. An existing HCR is used (ICES 2005) for advice outside ICES, and there is a desire to conduct a HCR evaluation to produce a basis for future ICES advice.

The benchmark notes the current low level of the GS hooded seal stock, and that no commercial hunting has been conducted since 2007. No commercial hunting should be considered unless a clear upward trend in the pup abundance estimate can be observed, taking account of the uncertainty in these data. In the event of such an improving trend being observed, a new revised assessment would be needed prior to the resumption of hunting in order to give information on stock status and potential harvest levels.

The benchmark also performed a preliminary evaluation of the existing catch-at-age data for the different stocks. There was sufficient sign of signal in the data consistent with population structure (exponential decay with age, sign of recruitment failure tracking between years) to consider the possibility for using these data for model tuning. The benchmark strongly encourages such work.

3 Harp Seals

3.1 Stock identity

No new information was presented.

3.2 Background

During WGHARP in 2019, there was concern regarding the ability of the official assessment model fitted to survey-based pup production estimates, using data on historical catch levels and reproductive rates. Specifically, for the Barents Sea / White Sea stock, the official model was not able to account for the observed rapid drop in pup production between 2003 and 2005, while for the Greenland Sea stock the model could not account for the variable pup production estimates based on mark-recapture experiments in the 1990s. Based on these concerns, WGHARP recommended in 2019 that alternative formulations be tested to improve the fit of the assessment models, with the inclusion of environmental data. The revised model, reviewed by the WKBSEALS benchmark in 2023, incorporates biomass estimates of potential prey and competitors as potential drivers on an 'abortion term'. The aim was to account for foetal and pup mortality that occurs between implantation and the time of the pup production survey.

3.3 The Greenland Sea Stock

3.3.1 Information on recent catches and regulatory measures

Based on advice from ICES (ICES 2019) the 2020–2023 Total Allowable Catch (TAC) for harp seals in the Greenland Sea was set at 11,548 animals of all ages (Biuw et al. SEA 255). The total removals of Greenland Sea harp seals in 1946–2023 are shown in Annex 7, Table 1. No Russian vessels have hunted in this area since 1994. In 2021 there was no commercial hunt in the area, only 10 harp seals (including 5 pups) were taken for scientific purposes. Total catches in the other years (performed by three vessels in 2020 and one vessel in 2022 and 2023) were 10,284 (including 2,341 pups) in 2020, 1,421 (including 1,347 pups) in 2022, and 1,877 (including 1,793 pups) in 2023 (Annex 7, Table 1).

The WG 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, although on a considerably lower scale than in previous years. This level of support was also maintained in 2020–2023.

3.3.2 Current research

Estimates of pup production of harp and hooded seals are based primarily on photographic surveys (see section 3.3.4), which are time-consuming to analyze manually. Software-based automatic detection methodology using artificial intelligence (deep learning) is being developed through a collaboration between the Norwegian Computing Center, Institute of Marine Research, Norway and Fisheries and Oceans, Canada. Deep learning has revolutionized image analysis in recent years in terms of its ability to extract content and information from images. Using the Faster R-CNN object detection architecture, we have applied it to the photographs acquired on the West Ice 2022 survey. The detector was pre-trained on data from the surveys in

Canada in 2008, 2012 and 2017 and the West Ice in 2007, 2012 and 2018, and then fine-tuned on the assigned calibration images (250 images where 84 of them contained seal pups). We counted a total of 2,688 harps seal pups and 280 hooded seal pups on the 2719 images obtained from the 29 transects. This resulted in an estimated pup production of 87,263 (SE 16,216) harps and 8,958 (SE 1,280) hoods, without correcting for pup staging. In general, the automatic abundance estimation was quite good, at least for harp seals. However, a pre-train-then-finetune approach was necessary to obtain an acceptable performance.

3.3.3 Biological parameters

Preliminary information was given on age at maturity and pregnancy rate based on reproductive data collected from 176 females captured between 14 April and 10 May, 2019. Mean age at maturity (MAM) for this sample was estimated at 6.4 years, which was almost identical to the MAM of 6.2 (±0.3 SD) years estimated for the previous sample collected in 2014. The pregnancy rate estimated for the 2019 sample was 0.85 (0.04 SE), somewhat lower than the 2014 estimate of 0.91 (0.03 SD). These estimates are based on presence/absence of a large luteinized corpus albicans in postbreeding females and thus pertain to the pregnancy rate in the reproductive cycle prior to capture (see also ICES, 2011). The pregnancy rate estimated for 2019 was based on 96 parous females.

3.3.4 Pup Production

Surveys in 2022

In the period 18–30 March 2022, reconnaissance and aerial surveys were performed in the Greenland Sea pack-ice (the West Ice), to assess the pup production of the Greenland Sea populations of harp and hooded seals (Biuw et al., SEA 256). One fixed-wing aircraft, stationed in Akureyri (Iceland), was used for reconnaissance flights and photographic surveys along-transects over the whelping areas. A helicopter, operated from the expedition vessel (Research Icebreaker Kronprins Haakon) also flew reconnaissance flights, and was subsequently used for monitoring the distribution of seal patches and age-staging of the pups.

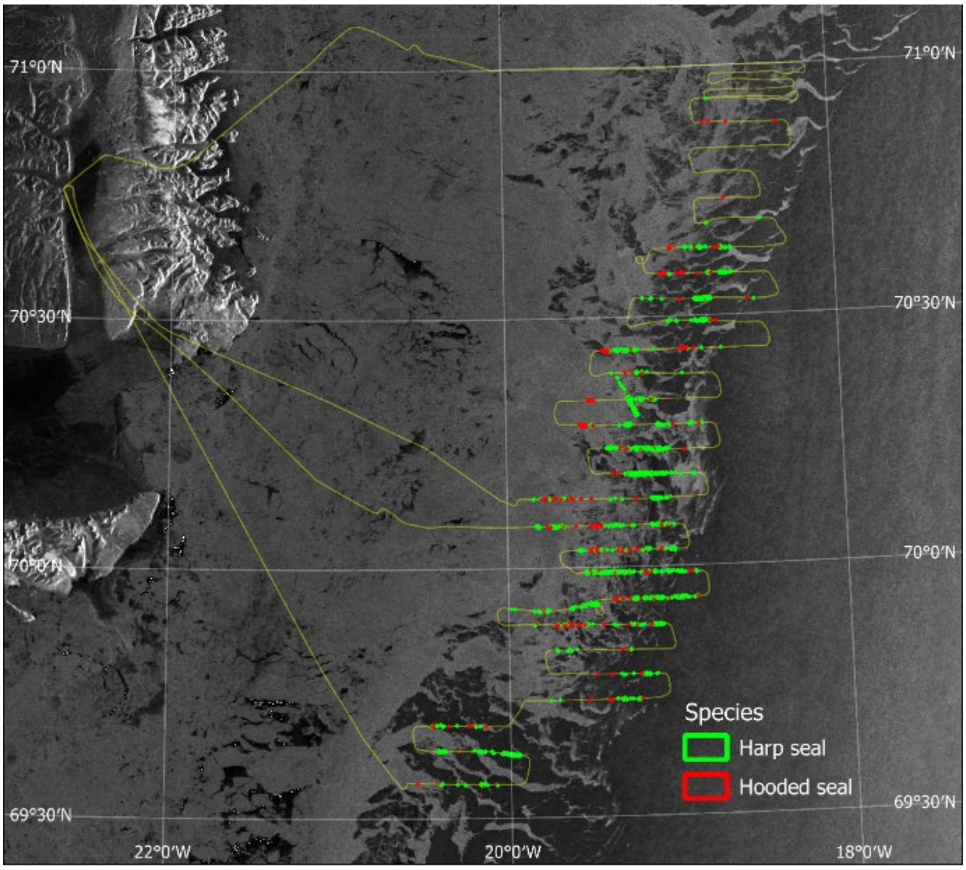

Figure 3.1. Photo surveys in the West Ice on March 28 in 2022 overlaid on a satellite image of ice conditions during that same date. The thin yellow line represents the flight path, and aerial images were taken along the straight E/W transect lines. Green and red markers represent respectively harp and hooded seals.

Reconnaissance surveys were flown by the helicopter (18–22 March). Due to poor weather conditions, the first reconnaissance flight with the fixed-wing aircraft was delayed until the 25 March, when it managed to cover the region from 71°30′N / 17°47′W in the northeast, to 70°00′N / 19°54′W in the southwest. As was observed in 2018, the ice cover was narrow and the edge closer to the Greenland coast compared to previous survey years. The reconnaissance surveys were adapted to the actual ice configuration, usually flown at altitudes ranging from 160–300 m, depending on weather conditions. Repeated systematic east-west transects with a 10 nm spacing (sometimes 5 nm) were flown from the eastern ice edge and usually 20–30 nautical miles (sometimes longer) over the drift ice to the west.

On 28 March, two photographic surveys were flown to cover the entire whelping patch area which was a little more than 86 nm in south-north direction. Due to limited fuel capacity of the aircraft, the spacing between transect lines was ~3nm. In total, 2492 photos were taken during the surveys.

Pup staging surveys were carried out on March 22nd, 23rd, 25th, 28th and 30th. The model achieved a good fit to the observed recalculated stages based on the staging surveys. For harp seals, this resulted in an estimated correction factor of 0.99 for the day of the photographic surveys, suggesting that only about 1% of all pups born may have been unavailable for photography. For hooded seals, the corresponding correction factor was 0.86, suggesting roughly 14% of pups would have been missed during aerial surveys. These correction factors were used to scale the pup production estimates.

The corrected pup production estimates were 92,769 (CV = 20.2%) for harp seals. The harp seal pup production estimate is significantly higher than the 2018 estimate, and similar to that based on the 2012 survey (89,590; CV = 13.7%). For hooded seals, the 2022 estimate is slightly but not significantly higher than the 2018 estimate.

3.3.5 Population Assessment

A population dynamics model that incorporates historical catch records, historical fecundity rates, age specific proportions of mature females, and environmental data on capelin and cod in the Icelandic and Greenland Sea Ecosystem was developed to estimate current abundance of harp seals in the Greenland Sea. The model is fitted to independent estimates of pup pro-duction (Annex 5, Biuw et al., SEA 256). It is a stochastic age-structured population dynamics model with eight unknown parameters (pup mortality, mortality of 1-year and older seals, initial population size, the effect of capelin and cod biomass (βcap and βcod) and an AR[1] process (φ and σ) on the pre-survey pup mortality rate). This model is the hence not the same as used previously by the WG to provide harvest scenarios and determine stock status for this stock (ICES 2016, 2019).

Two types of reproductive data are used: information on the proportion of females that are mature at a given age (i.e. maturity curve) and the proportion of mature females that are pregnant at a given year (i.e. fecundity rate) (Tables 3.1 and 3.2). The historical data of the maturity curve is sparse, consisting of only three curves (Figure 3.2 and Table 3.1). One curve is from the period 1959–1990, one is from 2009, and the last is from 2014. For the periods with missing data (e.g., 1990–2009 and 2009–2014), a linear transition between the available maturity curves is assumed.

Pup production estimates are available from mark-recapture estimates (1983–1991) and aerial surveys (2002–2022) (Table 3.3). Catch data come from commercial hunts and distinguish between the number of pups (0-group) and the numbers of 1-year and older animals (1+) caught per year but contain no additional information about the age composition of the catches. Catch data prior to 1946 are unreliable and they make no distinction between pups and older seals. Because of this the model began in 1946. Catch levels for the period 1946–2023 are listed in Annex 7, Table 1.

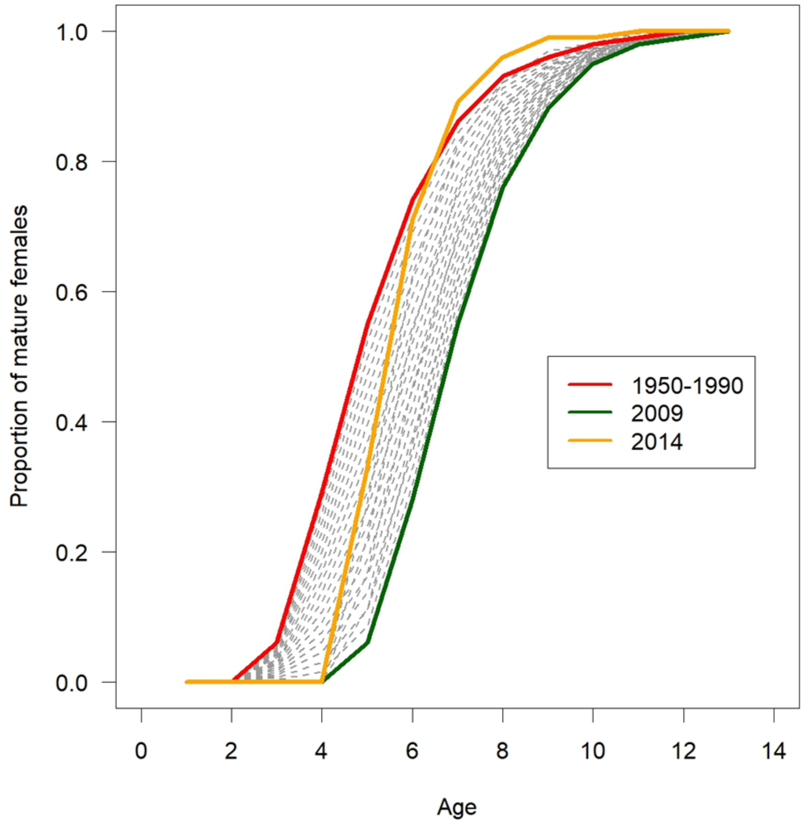

Figure 3.2. Shows the maturity curves for harp seal females from the Greenland Sea. The colored curves depict the years and periods with data (Red line = 1950-1990, Green line = 2009, Orange line= 2014) and the grey lines show curves for all other years, based on linear interpolation between the years and periods with data.

Table 3.1. Estimates of proportions of mature females (pi,t). The P1 estimates are from the period 1950-1990 (ICES, 2009), the P2 estimates are from 2009 (ICES, 2011) and the P3 estimates are from 2014 (ICES, 2016).

Age	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y	11y	12y	13y
p_1	0.00	0.00	0.06	0.29	0.55	0.74	0.86	0.93	0.96	0.98	0.99	1.00	1.00
p_2	0.00	0.00	0.00	0.00	0.06	0.28	0.55	0.76	0.88	0.95	0.98	0.99	1.00
p_3	0.00	0.00	0.00	0.00	0.33	0.71	0.89	0.96	0.99	0.99	1.00	1.00	1.00

Table 3.2. Estimates of the fecundity rate (proportion) of Greenland Sea harp seal females. Data from ICES (2011, 2016).

Year	Fecundity	SD
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

Table 3.3. Estimates of Greenland Sea harp seal pup production (ICES, 2019). Data from 1983-1991 are mark-recapture estimates; those from 2002, 2007, 2012, 2018 and 2022 are from aerial surveys.

Year	Estimated number of pups	CV
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	67 274	0.082
2002	98 500	0.179
2007	110 530	0.250
2012	89 590	0.137
2018	54 181	0.170
2022	92 769	0.202

Population model

For initialization of the population model (ICES, 2019) it is assumed that the population had a stable age structure in year y_0 = 1945, i.e.

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

$$N_{A,y_0} = N_{y_0} s_{1+}^{A-1}. \tag{2}$$

Here A is the maximum age group containing seals aged A and higher, set to 20 years (ICES, 2013), and N_{y0} is the estimated initial population size in the first year ($y0$).

The model is parameterized by the natural mortalities $M0$ and $M1+$ for the pups and seals 1 year and older respectively. These mortalities determine the survival probabilities

$s0 = exp(-M0)$ and $s1+ = exp(-M1+)$.

The model has the following set of recursion equations:

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

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):

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

Where $N_{1+,y}$ is the sum of all individuals in all age classes above 1 and $N_{a,y}$ is the number of individuals in age class a in year y.

The modelled pup abundance is given by

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

where $N_{0,y}$ is the number of pups in year y, F_y is the fecundity rate, $p_{a,y}$ is the proportion of mature females at age a in year y, $N_{a,y}$ is the total number of adults of age a in year y and A_y denote the pre-survey pup mortality rate.

For Greenland Sea harp seals, the chosen model includes a submodel for the pre-survey pup mortality rate (A_y) :

$$\text{logit}(A_y) = \text{logit}(A_{normal}) - \beta_{res}Cap_y^{res} + \beta_{comp}Cod_y^{comp} + \omega_y,$$

,

where Cap_y^{res} represents a standardized index of standing stock biomass (SSB) of Greenland Sea capelin as a resource , Cod_y^{comp} represents a standardized index of biomass of Greenland Sea cod (i.e., 3+ age-classes) as a competitor, and where ω_y constitutes an AR(1) process given by

$$\begin{aligned} \omega_y &= \phi\omega_{y-1} + \varepsilon_y, \\ \varepsilon_y &\sim N(0,\sigma^2). \end{aligned}$$

Since Cap_y^{res}, Cod_y^{comp} and ω_y all vary around 0, A_y, varies around A_{normal}. Hence, A_{normal} can be interpreted as the pre-survey pup mortality rate under normal environmental conditions.

This pre-survey pup mortality rate then modifies the fecundity rate in the equation for pup production in the population model. Note that in the model, fecundity rates are more reflective of pregnancy rates, and that A_y is seen as a cumulative measure of several different causes of mortality of pups, such as reabsorption of the fetus, late-term abortions, stillborn pups and early mortality from birth to the time surveys are conducted. Hence, the product of fecundity, maturity and A_y better reflects the realized reproductive rate.

The estimated parameters in the model and their priors are presented in **Table 3.4** and **3.5**. The model trajectory indicates a slow population decrease in the population abundance from the 1940s to the early 1990s, followed by an estimated increase until about 2010, again followed by a slow decline to the present (Figure 3.3).

The WG noted that the proposed model from the benchmark, i.e. the model with a high prior for the standard deviation of the initial population size, provided an estimated N1+ population size that greatly exceeded the pup to adult ratios commonly estimated for this and comparative species. While believing the trend in population size over time, the level was deemed unrealistic. The model's N1+ population level is labile with regards to the choice of the standard deviation of the prior on initial population size in 1946, since increasing the standard deviation of the prior in effect increases the mean. This happens because the prior is bounded at the lower end by the catches, as the model is forces to have a minimum population size that could have sustained the catch levels. As a consequence, we present estimates and results from two versions of the model; one with a high prior standard deviation and one with a low prior standard deviation.

The model with a high prior for the standard deviation (Table 3.5) estimates a 2023 abundance of 2 090 690 (CI= [148 057, 29 522 392]) 1+ animals and 90 176 (CI= [62 023, 131 107]) pups, yielding a total population estimate of 2 180 866 (CI= [210 080, 29 653 499]) seals and an adult to pup ratio of ~23:1. The model with a low prior for the standard deviation (Table 3.5) estimates a 2023 abundance of 1 044 774 (CI= [483 351, 2 258 307]) 1+ animals and 92 596 (CI= [64 185, 133 582]) pups, yielding a total population estimate of 1 137 370 (CI= [547 536, 2 391 889]) seals and an adult to pup ratio of ~11:1. Note that the population estimates from the new models are considerably higher than those predicted using the previous standard assessment model.

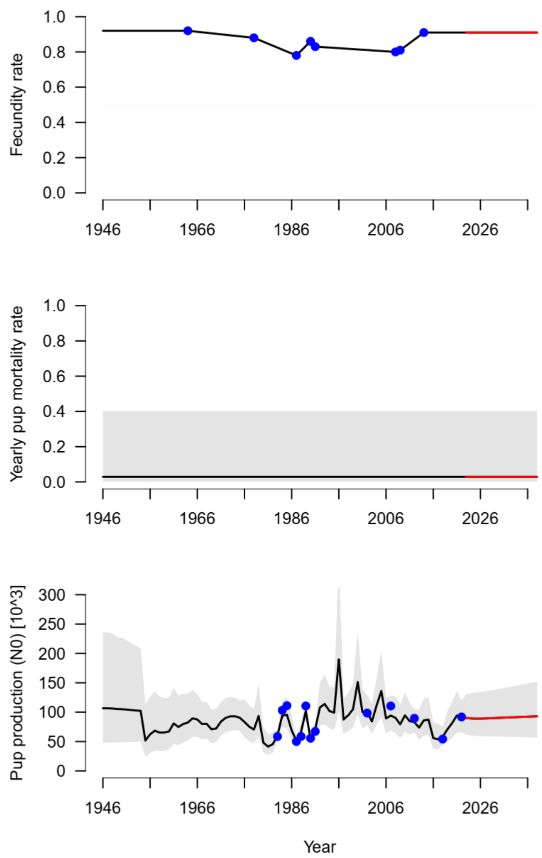

Figure 3.3. Shows the output from the current best population model with a high standard deviation of the prior for initial population size (Table 3.4 and 3.5), where abortion (i.e. pre-survey pup mortality (A_y)) rates (upper right panel) are modelled as a function of capelin standing stock biomass (SSB) at *y*, cod biomass (BM) at *y* and an additional AR(1) process. In all panels, black lines indicate estimated values, and the grey areas indicate the 95% confidence bands. In the upper left panel, blue points indicate estimates of fecundity, while in the lower left panel blue points indicate estimated pup production. Note that the red line segments indicate a period of forecast of 15 years, based on average values of vital rates and drivers. Note also, the different scale of the y-axis in the different panels.

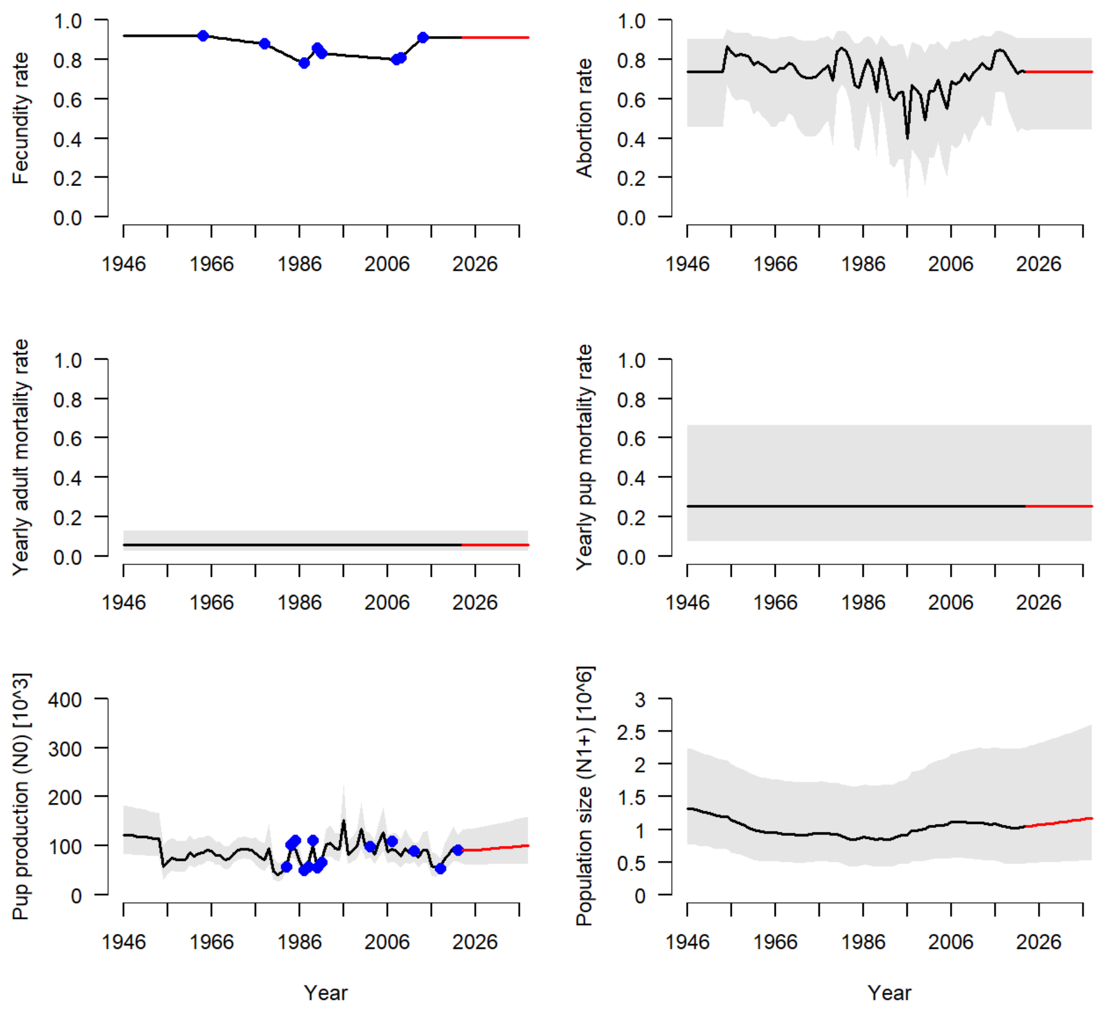

Figure 3.4. Shows the output from the current best population model with a low prior for the standard deviation of initial population size (Table 3.4 and 3.5), where abortion (i.e. pre-survey pup mortality (A_y)) rates (upper right panel) are modelled as a function of capelin standing stock biomass (SSB) at *y*, cod biomass (BM) at *y* and an additional AR(1) process. In all panels, black lines indicate estimated values, and the grey areas indicate the 95% confidence bands. In the upper left panel, blue points indicate estimates of fecundity, while in the lower left panel blue points indicate estimated pup production. Note that the red line segments indicate a period of forecast of 15 years, based on average values of vital rates and drivers. Note also, the different scale of the y-axis in the different panels.

Table 3.4. Estimated mean and standard deviations for the parameters in the model for Greenland Sea Harp Seals. Note that h.Sd refers to the models with a high standard deviation on the prior for initial population size, while l.Sd refers to the model with a low standard deviation on prior for the initial population size (see Table 3.5).

Parameter	Estimate h.Sd	SD	Estimate l.Sd	SD
$N_{1+,y0}$ (in millions)	2.43	2.46	1.31	0.36
$M_{0,normal}$	0.26	0.20	0.29	0.20
$M_{1,normal}$	0.03	0.04	0.06	0.03
A_{normal}	0.89	0.17	0.74	0.12
β^A_{cap}	1.91	0.57	2.21	0.63
β^A_{cod}	1.59	0.66	1.84	0.71
ϕ	0.28	0.23	0.29	0.23
σ	0.15	0.06	0.18	0.07

Table 3.5 Mean and standard deviation of the normal priors for model parameters. Note that while the mean of the priors are identical, h.Sd refers to the standard deviation for the priors usen in the model with high prior Sd for initial population size, while l.Sd refers to the priors used in the model with low prior Sd for initial population size.

Parameter	Mean	h.Sd	l.Sd
$N_{1+,y0}$	10^6	$2 \cdot 10^7$	$5 \cdot 10^5$
$M_{0,normal}$	0.27	0.2	0.2
$M_{1,normal}$	0.09	0.1	0.1
A_{normal}	0.09	0.1	0.1
β^A_{cap}	0.00	0.2	0.2
β^A_{cod}	0.00	0.2	0.2
ϕ	0.50	0.3	0.3
σ	0.00	0.5	0.5

3.3.6 Catch scenarios

Different model formulations give different absolute estimates of population based on the choice of standard deviation of the prior on initial population size. As a consequence, it is difficult to obtain a robust estimate of N0. It is the intention of WGHARP to improve the assessment model and resolve this problem such that the model can be used directly to provide advice on acceptable removals. In particular, the benchmark recommended that the inclusion of catch-at-age data should be prioritised, as this may be used to tune the population age structure and provide information about adult mortality rates. As an interim solution, we present two alternative approaches that may inform discussion about appropriate maximum harvest levels.

Adaptive management based on trends

There are several lines of evidence suggesting that the population is relatively stable, and that recent catches have not resulted in substantial population decline. There is no clear trend in the pup production data in recent decades, though there are fluctuations between surveys. Based on the life history of harp seals where the age of maturity is about 6 years, and females live and reproduce over periods longer than 20 years, it is appropriate to examine the recent decade of pup production, which depends on mature animals, in relation to catches carried out during the period between 10 and 20 years earlier when those animals would have been pups. To inform observations during the decade 2014-2023, we therefore considered catches between 2004-2013 which on average were 7397 (to the nearest whole number). It may therefore be appropriate to set a precautionary catch level at or below this level.

Potential Biological Removal (PBR) based on scaled pup production estimates

A standard approach to calculating safe levels of removals for marine mammals makes use of the PBR equation[1,2,3]

PBR = 0.5 R * Nmin * F

R is the maximum net productivity rate using a default value of 0.12 for pinnipeds.

N_{min} denotes the 20th percentile (lower 60% confidence limit) of the log-normal distribution resulting from a point estimate of abundance and its CV (see Wade & Angliss 1997, Wade 1998, Harkonen et al. 2011, NMFS 2016, Annex 5 [Tinker et al., SEA 257]). Here we estimate N_{min} from pup production, described below.

F is a recovery factor, to compensate for uncertainties that might prevent population recovery. This value was set a 0.25, which is considered precautionary for seals.

As WGHARP considered the model estimate of adult population size unrealistic (resulting in unlikely adult to pup ratios of 23:1 and 11:1 for respectively the high and low sd on the prior for initial population size), it instead recommended that *Nlim* should be based on the 20th percentile of the 2022 pup production estimate, multiplied by some number to convert to an estimate of total population size.

Here, the lower 20% centile for pup production was calculated using the equation

$$pp_{\ min} = \widehat{pp}/exp(0.842\sqrt{(ln(1 + CV^2))})$$

where $\widehat{pp}$ is the estimated level of pup production (92 769) and *CV* is the coefficient of variation, based on the surveys (0.202).

Outputs of Northwest Atlantic harp seal population models show a range of 4 to 8 for the ratio of adults to pups with an average of 5.6, and the WG decided to use a 'rounded down' value of 5 which can be considered plausible and conservative[4,5]. This yields an estimated N_{lim} of $N_{min} = 5pp_{\ min}$.

Using the standard PBR equation with a recovery factor F = 0.25 then yielded an estimated PBR of 5 879 (to the nearest whole number).

Carryover

WGHARP suggests that catches not taken from the annual quota in year t could be carried over to year t+1, but not any further. This level of carryover has been tested for several species of marine mammals using simulation methods, and have been found to be sustainable with no negative impacts on the stock (e.g., Hammill & Stenson, 2003; Doniol-Valcroze et al., 2014; Richard & Young, 2015; Hammill et al., 2016).

3.4 The Barents Sea/White Sea Stock

3.4.1 Information on recent catches and regulatory measures

Following the apparently rapid decline in White Sea harp seal pup production observed from 2003 to 2005, pup production appeared to stabilize at this low level until 2013 when the most recent pup production survey was conducted. Due to the poor fit of the previous population model to the pup production estimates, and in particular its inability to account for the rapid drop in the early 2000s, ICES (2019) recommended a quota of 21 172 animals of all ages for the period 2020-2023, calculated using PBR (ICES, 2019; Biuw et al SEA-255). The Joint Norwegian-Russian Fisheries Commission has followed this request and allocated 7,000 seals of this TAC to Norway in all years. A ban implemented on all pup catches prevented a Russian hunt in the White Sea during the period 2009-2013. This ban was removed before the 2014 season. However, the availability of ice has been too restricted to permit sealing, resulting in no commercial Russian harp seal catches in the White Sea after 2014 and including the period 2020-2023 (Annex 7 Table 2). While no Norwegian vessels visited the hunting area in the southeastern Barents Sea (the East Ice) in 2020, 2022 and 2023, one Norwegian vessel hunted in the area in 2021, with a total catch of 5,061 (including 49 pups) of harp seals (Biuw et al SEA-255). Total catches from 1946-2023 are given in Annex 7 Table 2.

3.4.2 Current research

No information on ongoing research on this stock was provided at the meeting.

3.4.3 Biological parameters

Two types of reproductive data are available: information on the proportion of females that are mature at a given age (i.e. maturity curve) and the proportion of mature females that are pregnant in a given year (i.e. fecundity rate) (Tables 3.6 and 3.7). Estimates of age specific proportions of mature females are available for five historical periods; 1962–1972, 1976–1985, 1988– 1993, 2006 and 2018 (Table 3.6; ICES, 2019). For years with no data, a linear interpolation of the age specific proportions of mature females between two periods is assumed (Figure 3.4; ICES, 2016).

The population dynamics model assumes the observed fecundity is a known quantity (i.e. without error) as opposed to being part of the data to which the model is fit. For periods with missing pregnancy rates, a linear transition was assumed, i.e., a linear transition from 0.84 in 1990 to 0.68 in 2006, from 0.68 in 2006 to 0.84 in 2011, and from 0.84 in 2011 to 0.86 in 2018. In the periods before 1990, the pregnancy rate was assumed constant at 0.84 and after 2018 it was assumed to be constant at 0.91.

Note that reproductive data was collected in 2021, but while presented at the meeting this was not ready to be implemented in the model. Preliminary information was given on age at maturity and pregnancy rates based on these reproductive data collected from 306 females between 20 April and 6 May, 2021. Mean age at maturity (MAM) for this sample was estimated at 6.6 years, which was close to the MAM of 6.9 (±0.5 SD) years estimated for the previous sample collected in 2018. The pregnancy rate estimated for the 2021 sample was 0.72 (0.03 SD), which was significantly lower than the 2018 estimate of 0.91 (0.03 SD) ($P<0.01$). As for the Greenland Sea harp seals, the estimated pregnancy rates were based on presence/absence of a large luteinized corpus albicans in postbreeding females (ICES, 2011). The pregnancy rate estimated for 2021 was based on 217 parous females.

3.4.4 Pup production

Pup production estimates are available from surveys conducted at 1- to 3-year intervals between 1998 and 2013 (Table 3.8). No updated pup production estimates were available at this meeting.

3.4.5 Population assessment

The modified population model used to assess the abundance of the Barents Sea/White Sea harp seal population is identical to the one used for the Greenland Sea harp population presented above, except that the effect of cod on the pre-survey pup mortality rate (Ay) is set to zero. This is based on model runs performed during the benchmark meeting, which showed that this parameter was estimated as being close to zero. The model is therefore referred to as a "capelin-only" model.

The estimated parameters and their priors are presented in Table 3.9 and Table 3.10. Unlike the Greenland Sea Harp seal model, the Barents / White Sea model's N1+ population level was not shown to be very sensitive to the standard deviation of the prior for initial population size.

The estimated population sizes for 2023 are presented below, and Figure 3.5 shows the model fit to the observed pup production estimates along with the modelled total population trajectory. The model estimates seven parameters. As opposed to the previous model (ICES, 2016, 2019), the new model has a very good fit to the pup production estimates. In particular, the model does capture the apparent drop in pup production that occurred from 2003 to 2005. The modelled total N1+ population suggests that harp seal abundance in the Barents Sea/White Sea increased from the mid-1960s until the early 2000's, followed by a gradual decline until present. This decline is expected to continue in the near future (Figure 3.5). The estimated total population size in 2023 is 1 361 993 (CI= [456 582, 4 161 381]) seals, where 1 276 522 (CI= [440 884, 3 696 003]) constitutes 1+ animals and 85 471 (CI= [15 698, 465 378]) constitutes the number of pups.

Table 3.6. Estimates of proportions of mature females ($p_{i,t}$). The P1 estimates are from the period 1962-1972 , P2 estimates are from 1976-1985, P3 estimates are from 1988-1993, while the P4 and P5 estimates are from 2014 and 2018 respectively (ICES 2011; 2016; 2019)

Age	2y	3y	4y	5y	6y	7y	8y	9y	10y	11y	12y	13y	14y	15y
p_1	0.00	0.01	0.17	0.64	0.90	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
p_2	0.00	0.00	0.00	0.24	0.62	0.81	0.91	0.95	0.98	0.99	0.99	1.00	1.00	1.00
p_3	0.00	0.00	0.02	0.08	0.21	0.40	0.59	0.75	0.85	0.91	0.95	0.97	0.98	0.99
p_4	0.01	0.02	0.05	0.11	0.25	0.55	0.90	0.99	1.00	1.00	1.00	1.00	1.00	1.00
p_5	0.00	0.00	0.00	0.00	0.52	0.77	0.89	0.95	0.97	0.99	0.99	0.99	1.00	1.00

Table 3.7. Estimates of proportion of Barents Sea / White Sea harp seal females giving birth. Data from (ICES, 2011, 2016, 2019).

Year	Fecundity	SD
1990	0.84	0.06
1991	0.84	0.06
1992	0.84	0.06
1993	0.84	0.06
2006	0.68	0.06
2011	0.84	0.06
2018	0.91	0.03
2021		

Table 3.8. Estimates of Barents Sea / White Sea harp seal pup production. Numbers and CVs are drawn from ICES (2011) and ICES (2014).

Year	Estimated number of pups	CV
1998	286 260	0.150
2000	322 474	0.098
2000	339 710	0.105
2002	330 000	0.103
2003	328 000	0.181
2004	231 811	0.190
2004	234 000	0.205
2005	122 658	0.162
2008	123 104	0.199
2009	157 000	0.108
2010	163 032	0.198
2013	128 786	0.237

Table 3.9. Parameter estimates with standard deviation for the current best model for Harp seals in the East Ice. Note that the cod-coefficient, , is set to zero in the model and therefore does not contribute to the fit.

Parameter	Estimate	SD
$N_{1+,y0}$ (in millions)	1.34	0.40
$M_{0,normal}$	0.26	0.20
$M_{1,normal}$	0.09	0.03
A_{normal}	0.19	0.24
β_{Cap}	1.43	0.92
β_{Cod}	0	0
Φ	0.99	0.0006
Σ	0.31	0.92

Table 3.10. Priors for the parameters used for the current best model for Harp seals in the East Ice. Note that the cod-coefficient, is set to zero in the model and therefore does not contribute to the fit.

Parameter	Mean	SD
$N_{1+,y0}$	10^6	$5 \cdot 10^5$
$M_{0,normal}$	0.27	0.2
$M_{1,normal}$	0.09	0.1
A_{normal}	0.09	0.1
β_{Cap}	0.00	0.2
β_{Cod}	0.00	0.2
Φ	0.50	0.3
Σ	0.00	0.5

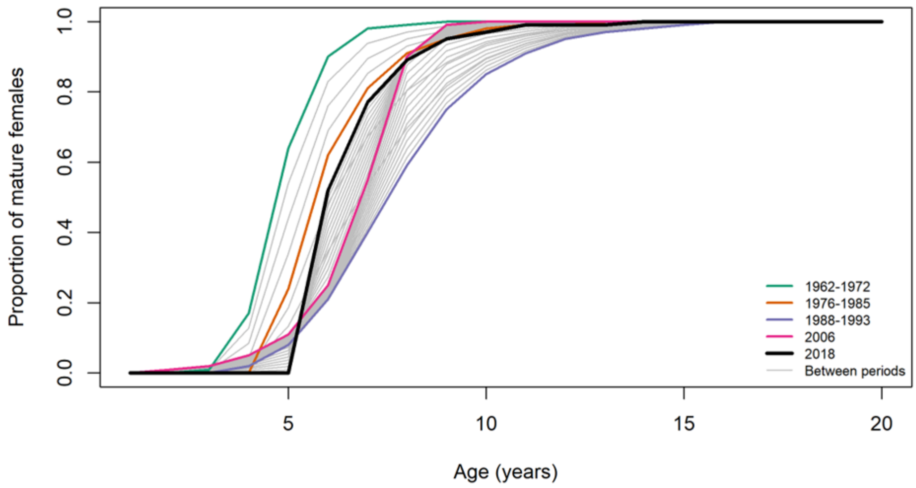

Figure 3.4. Proportion of mature females among Barents Sea / White Sea harp seals in four periods. Values are taken from Table 1.

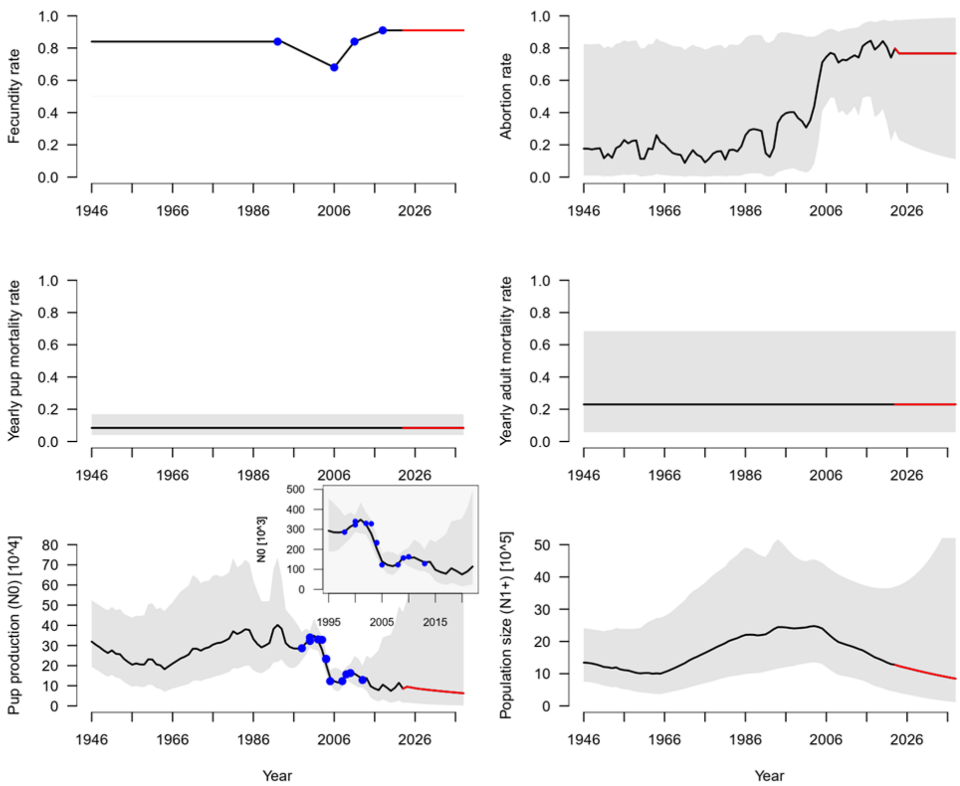

Figure 3.5. Shows the output from the current best population model, where pre-survey pup mortality rates (A_y) (upper right panel) are modelled as a function of capelin biomass at *y-1* and an additional AR(1) process. In all panels, black lines indicate estimated values, and the grey areas indicate the 95% confidence bands. In the upper left panel, blue points indicate estimates of fecundity. The inset in the lower left panel shows the fit of the model to the period with pup production estimates (blue points). Note that the red segments indicate a period of forecast of 15 years, based on average values of vital rates and drivers. Note also, the different scale of the y-axis in the different panels.

3.4.6 Catch Scenarios

The WG noted that the model version with capelin abundance informing model dynamics does perform well in the time period for which data exist. However, no new pup production estimates are available for this stock since 2013, and as a result, the model could not reliably assess current levels of this population. WGHARP recommends that a pup survey and subsequent revision of the population assessment model is required prior to its use for recommending catch levels for a commercial hunt. Aside from its importance as a basis for setting catch levels, a reliable population assessment model is also urgently needed to support ecosystem-based management in this system in which harp seals are important consumers.

3.5 The Northwest Atlantic Stock

3.5.1 Information on recent catches and regulatory measures

Canada

Catches

After 2005, the TAC was set annually to ensure that the population did not decline below the precautionary reference level (i.e. N70 or 70% of the maximum population size) within a 15-year period (e.g. Hammill and Stenson 2007, 2009; Hammill et al. 2014). Using this approach, the TAC for harp seals was set at 400,000 in 2011 (Annex 8 Table 3). Although the harp seal population was reassessed in 2013 (Hammill et al. 2014) and 2019 (Hammill et al. 2021), the TAC has remained at 400,000 (Annex 8, Table 3). Since 2017, the TAC has not been formally announced. Catches are monitored 'with respect to the scientific recommendations'.

After more than a decade of high catches (1996-2008), harp seal catches in Canada have remained below 100,000 since 2009 (Annex 7 Table 5). Catches declined to 35,382 (8% of the TAC) in 2015 after which they increased to 81,742 in 2017. Since 2017, catches have declined, averaging ~ 28,000 per year for 2019, 2021 and 2022. Catches were very low in 2020 as a result of limited harvest activity in some areas due to COVID-19 restrictions, and are not included in this average. Preliminary results for 2023 show a slight increase in harvest levels to a catch of ~ 40,000 (Annex 7, Table 4). Since the late 1990s, an average of 95% of the catch has been comprised of young of the year (YOY), with beaters accounting for 100% of the harvest in some years (Annex 7 Table 5).

Catches in the Canadian Arctic are not well documented but appear to be low (Stenson and Upward 2020). We currently assume that approximately 1,000 harp seals per year are taken in the Canadian Arctic.

Bycatch

Sjare et al. (2005) provided estimates of harp seal bycatch in the Newfoundland lumpfish fisheries from 1970–2003. These estimates were based upon reported landings of lumpfish roe (Stenson and Upward 2020; Annex 7, Table 8) and estimates of seal bycatch rates obtained from a bycatch logbook monitoring program that was carried out by DFO, Marine Mammal Section from 1989 to 2003. The data were split into three areas; Northeast Coast (NAFO Divisions 3K and 3L except subdivision 3Lq), South Coast (3Pn, 3Ps and 3Lq) and the West Coast (4R). Harp seal bycatch per tonne of lumpfish roe were calculated for each area based on the logbook data on the weight of lumpfish roe landed and the number of seals caught per trip (Table 6). These estimates were used to hind-cast from 1988 to 1970 based on lumpfish roe landings over that time period and the average number of seals taken per tonne of roe from 1989 to 1991.

In the absence of logbook data on bycatch rates for 2004 onward, Stenson and Upward (2020) used the bycatch rates estimated by Sjare et al. (2005) and updated lumpfish roe landing data (Table 5) to revisit the bycatch estimates for 1970-2018. Following the method of Sjare et al. (2005) they used the average of the bycatch rates from 1989 to 1991 from each area to hind-cast the 1970-1988 period and the average rates from 1999 to 2003 (i.e. the last 5 years) for the subsequent years. Sjare et al. (2005) estimated the proportion of YOY seals caught from 1989 to 2000 using age class records provided by fishers over that time period. As in Sjare et al. (2005), Stenson and Upward (2020) applied the average age classes from 1989 to 1991 to the 1970-88 period and the averages for 1996 to 2000 to 2000 onward (Table 7). Bycatch values for 2019-2022 (Table 8) were estimated following the method of Stenson and Upward (2020).

Bycatch was low until the early 1990s due to limited effort in the fishery (Annex 7 Table 8). However, in the mid-1990s effort increased dramatically and catches rose to over 45,000 seals. By the late 1990s, bycatch dropped dramatically. However, it rose again briefly before drop-ping again in the early 2000s. Another peak (~35,000) in bycatch occurred in the mid-2000s before declining. Since 2010, bycatch has remained low. In 2022 it was estimated to be 1898 seals.

In addition to estimated bycatch in the Newfoundland lumpfish fishery, we also include estimates of bycatch in the northeast US fisheries (Hayes et al. 2021). Only small numbers of harp seals are caught in the US fisheries (Annex 7 Table 8).

Greenland

Greenland catches of harp seals have been reported up to 2022. Catches over the past decade have varied from 54,660 in 2012 to 29,680 in 2022 with an average catch of 52,524 for that period (Annex 7 Tables 4, 6). The reported catch for 2020 and 2021 was 50,162 and 30,677, respectively. Along the west coast where the majority of seals were caught, the percentage of adults reported varied between ¼ and ⅓ of the catch.

Total reported catches for Canada and Greenland are summarized in Annex 7, Table 4. Annex 7, Table 8 presents estimated total removals including bycatch in Canadian and US fisheries, and estimates of struck and lost.

3.5.2 Current research

No new information was presented.

3.5.3 Biological Parameters

Since the 1950s, pregnancy rates of Northwest Atlantic harp seals have declined while inter-annual variability has increased. Stenson et al. (2016) found that pregnancy rates were influenced by both density- dependent and independent factors. While the general decline in pregnancy rates reflected density-dependent processes associated with increased population size, including late term abortion rates captured much of the large interannual variability observed at high population levels. Changes in the abortion rate were best de-scribed by a model that incorporates ice cover in late January and capelin biomass obtained from the previous fall. A previous study (Buren et al. 2014) showed that capelin abundance is correlated with ice conditions suggesting that late January ice conditions should be considered a proxy for environmental conditions that may influence a number of prey species.

Stenson et al. (2016) hypothesized that the impact of changing prey availability influences reproductive rates through changes in body condition and growth. To test this hypothesis, Canadian scientists have recently examined growth rates and body condition of harp seals collected off the coast of Newfoundland Canada over the past four decades (Stenson et al. 2020a).

Comparing lengths and weights of seals among decades indicated that growth-rates and asymptotic weights of harp seals have declined significantly since the 1980s. The average body condition of females prior to pupping varied greatly among years, although the condition of pregnant females did not change among years. Annual pregnancy rates were positively correlated with improved condition while abortion rates declined rapidly with only slight improvements in condition. As with abortion rates, condition was related to capelin biomass and midwinter ice cover. These data indicate that changes in abundance and environment influence reproductive rates in harp seals through changes in body condition and suggest that females must maintain a certain level of body condition if they are to complete their pregnancy successfully.

3.5.4 Pup Production

A new pup production survey for the NWA harp seal population was conducted in March 2022. Whelping patches were located in the Southern Gulf of St Lawrence (NW of the Magdalen Islands), Northern Gulf of St. Lawrence and off of NE Newfoundland (the Front). The majority of pup production occurred on the Front. Ice conditions were poor in 2022 and multiple storms during the survey period resulted in significant ice breakup over the course of the sur-vey. Counts for the survey are underway and are approximately 70% complete. The survey analyses are expected to be completed by winter 2025.

3.5.5 Population Assessment

In a recent review of the status of the Northwest Atlantic harp seal population, model fit to aerial survey estimates of pup production and annual reproductive rates was poor compared to previous assessments indicating underlying problems relating to model assumptions and/or structure. A new hierarchical Bayesian state-space model framework was developed and fitted to the same data on pup production, annual fecundity, human removals, and environmental conditions to produce annual estimates of pup production and total abundance from 1952 - 2019. An additional data set of age structure based upon random samples was also included and the process model incorporated environmental stochasticity and several other improvements.

The new, Stochastic model structure resembles the Deterministic model previously used in the harp seal assessments, in that the process model tracks annual fecundity, survival, and abundance of multiple age classes. However, instead of treating certain parameters as fixed constants, the model attempts to estimate parameter values, allowing for data-driven estimates of age specific survival, density-dependent effects, mortality from ice anomalies, and effects of environmental conditions on fecundity and survival (Annex 5, Tinker et al. SEA-257).

3.5.5.1 Data Inputs

Pup production estimates

The model was fit to 13 independent estimates of pup production (1951-2017), derived using a combination of mark-recapture (m-r) and aerial-survey methods (Stenson et al. 2020b)

Reproductive Rates

Female reproduction rates at age were determined using reproductive tracts and jaws from harp seals sampled around Newfoundland and southern Labrador since 1979 (Annex 5, Tinker et al. SEA-257).

Catches

The sources of mortality directly due to humans are the commercial and personal use seal hunt in two areas of Atlantic Canada (referred to as the 'Front' and 'Gulf'), the subsistence/commercial harvests in Greenland and the Canadian Arctic, and incidental catches in commercial fishing gear (i.e., bycatch). Data on the levels of various components of this mortality are available since 1952 (Annex 7, table 8).

Environmental Factors

Poor ice conditions result in increased mortality of YOY during their first month of life (Stenson & Hammill 2014). A standard ice cover anomaly was developed using cover information obtained from Environment Canada (https://iceweb1.cis.ec.gc.ca/IceGraph/page1.xhtml?lang=en) and was incorporated into the model. To account for some ecosystem variability, the Newfoundland Climate Index (Figure 3.6) is included as a factor affecting reproduction and juvenile survival.

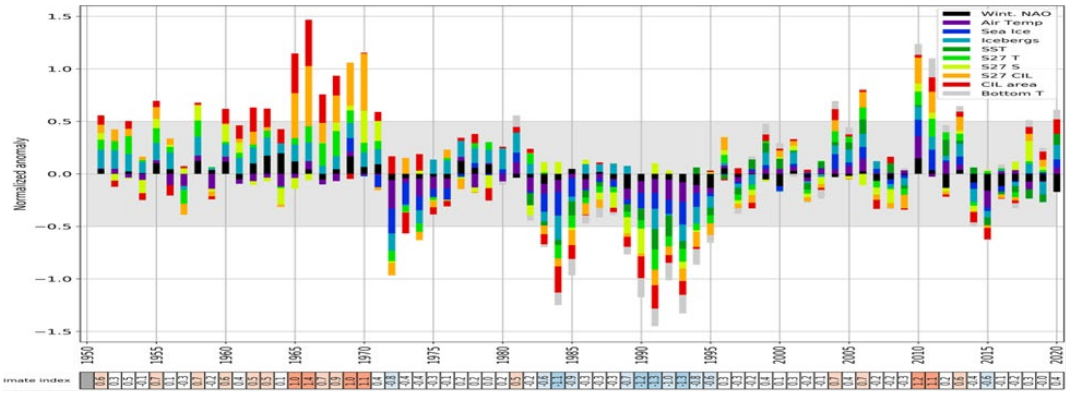

Figure 3.6. Variability (1950-2020) in the Newfoundland Climate Index (NCI) developed by Cyr and Galbraith (2021).

Age Structure

Age data were obtained from seals collected for reproductive rates or during other sampling programs carried out by DFO. Seals of all ages have been collected although there was a suggestion that younger ages may be under, or over, represented in some annual samples. The model was fitted to the age frequency distribution of animals 5 years and older.

3.5.5.2 Model description

The methods for analyzing the harp seal population can be described in three parts: 1) the process model, a series of equations that describe demographic transitions and which, when solved, predict dynamics in the variables of interest (e.g. population abundance) based on the values of the input parameters; 2) the data model, which describes how empirical data sets are related to the predicted dynamics of the process model; 3) model fitting, which describes how input parameters are estimated.

The population is age-structured, such that a population vector n(i,t) describes the number of individuals in age class i (i = 1, 2… 36) at year t, and N(t) is the sum of n(i,t) across age classes.

Model fitting

The observed data variables constrain the possible values of unknown parameters in the process model, allowing us to estimate posterior distributions for these parameters using standard Markov Chain Monte Carlo (MCMC) methods using R (R Core Team 2022) and Stan software (Carpenter et al. 2017) to code and fit the model.

3.5.5.3 Results

The Stochastic model incorporated the age distribution data from the Newfoundland sample collection program into the model structure. Early in the time series, the age structure of this data set was dominated by animals aged 4–7 years, but beginning in the late 1990s, there is a decline in recruitment to the breeding population. Since 2010 there has been a slight increase in recruitment of younger animals to the sampled age structure, although animals aged 20+ years old continue to dominate the time series.

When all of the estimated environmental and demographic effects, as well as harvest/bycatch mortality, are combined, the model results indicate that human removals represent the single most important driver of juvenile mortality up until 1985. However, since 1985, density dependent mortality and unexplained stochastic deviations have been a more substantial source of juvenile mortality, followed by anthropogenic removals between 1996 and 2006 (Figure 3.x). Mortality attributable to ice anomalies and climate effects (NCI) are also important in some years, particularly in more recent decades (Figure 3.7).

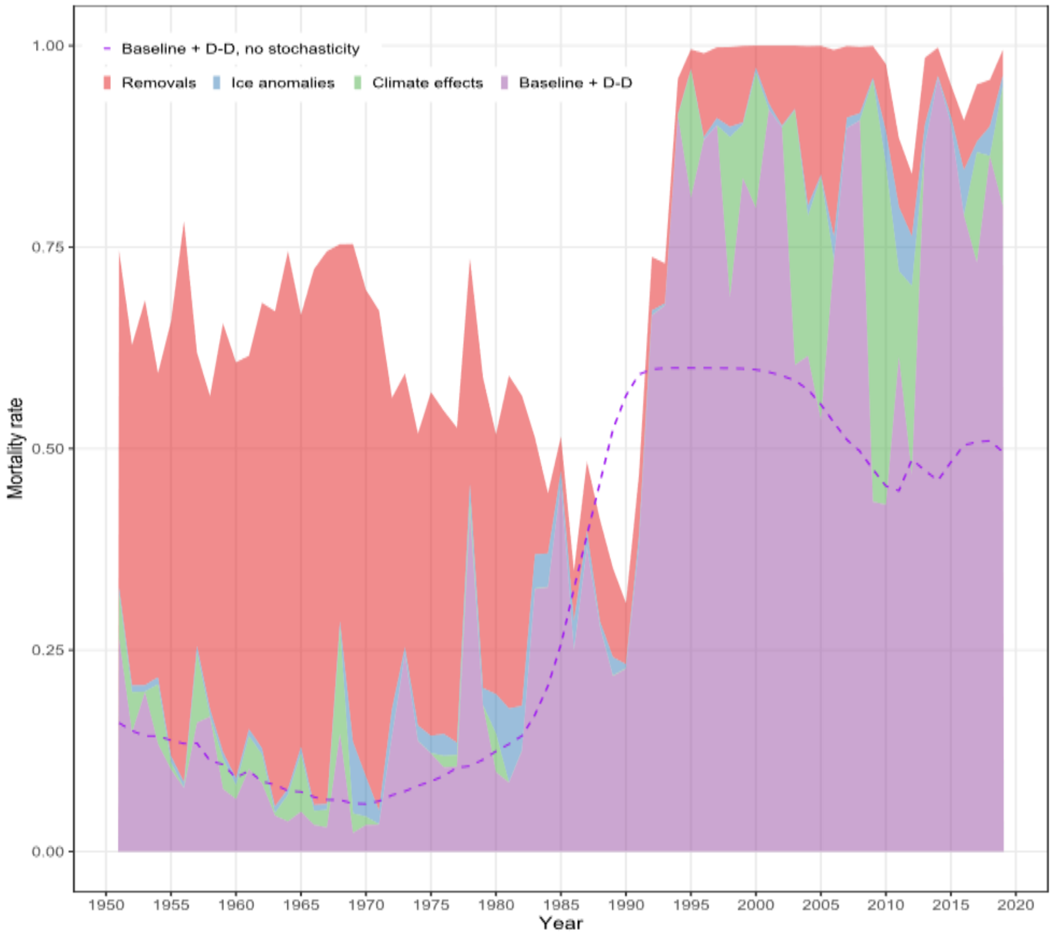

Figure 3.7. Plot showing relative contributions of various sources of mortality to the total combined mortality rate for juveniles (also referred to as YOY). Mortality factors compared include removals from harvesting (taking into account struck and loss and incidental catches), mortality attributable to poor ice conditions, mortality attributable to climate effects, and baseline plus density-dependent mortality (including stochastic variation). The dashed line indicates what the expected value of baseline plus density-dependent mortality would be if stochastic variation were excluded.

The various sources of mortality and fecundity are combined in the process model to generate projections of population dynamics. Using the Stochastic model, the 2019 estimate of pup production is 776,000 (95% CI 558,000- 1,011,000) and the total estimated abundance is 4,667,000 (95% CI: 3,712,000- 5,679,000). When compared with observed data or equivalent projections from the deterministic model, the Stochastic model projections more closely adhered to variation in the three empirical time series: most observed data points (or their standard error bars) intersected the 95% CI bounds of the Stochastic model projections (Figure 3.8).

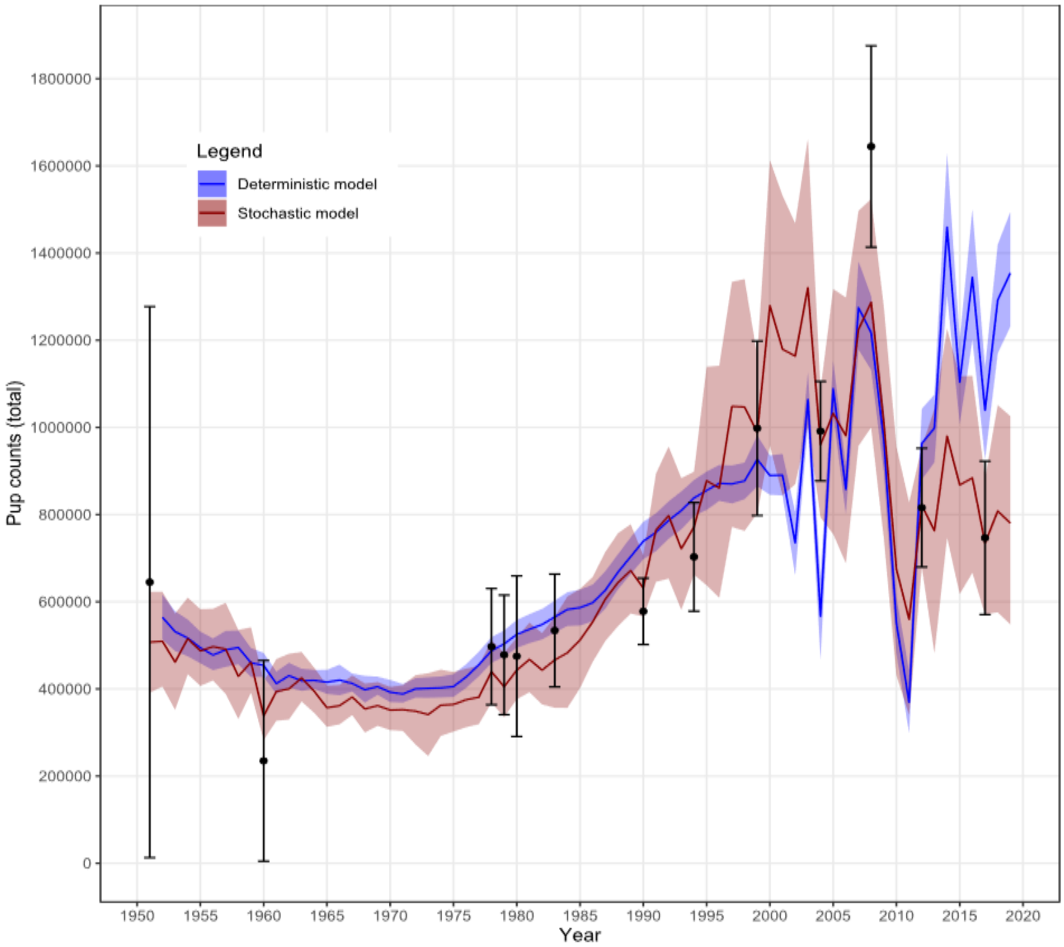

Figure 3.8. Plot showing temporal variation in model-estimated pup (YOY) production with observed data plotted for comparison: points indicate mean estimated pup abundance for a given survey; error bars show 95% CI associated with the survey estimate. Model projections are plotted for the Stochastic Bayesian model (red) and the Deterministic model (blue). Solid lines represent mean estimated values; shaded bands indicate the associated 95% CI.

Total abundance is estimated by the model as a latent variable, although there are no empirical data to compare with. The estimated trends in total population abundance (adults plus YOY) based on the Stochastic Bayesian model are shown in Figure 3.8, with corresponding estimates from the Deterministic model shown for comparison. The two models are generally consistent in their projections from 1951 through approximately 1990 but deviate after that point.

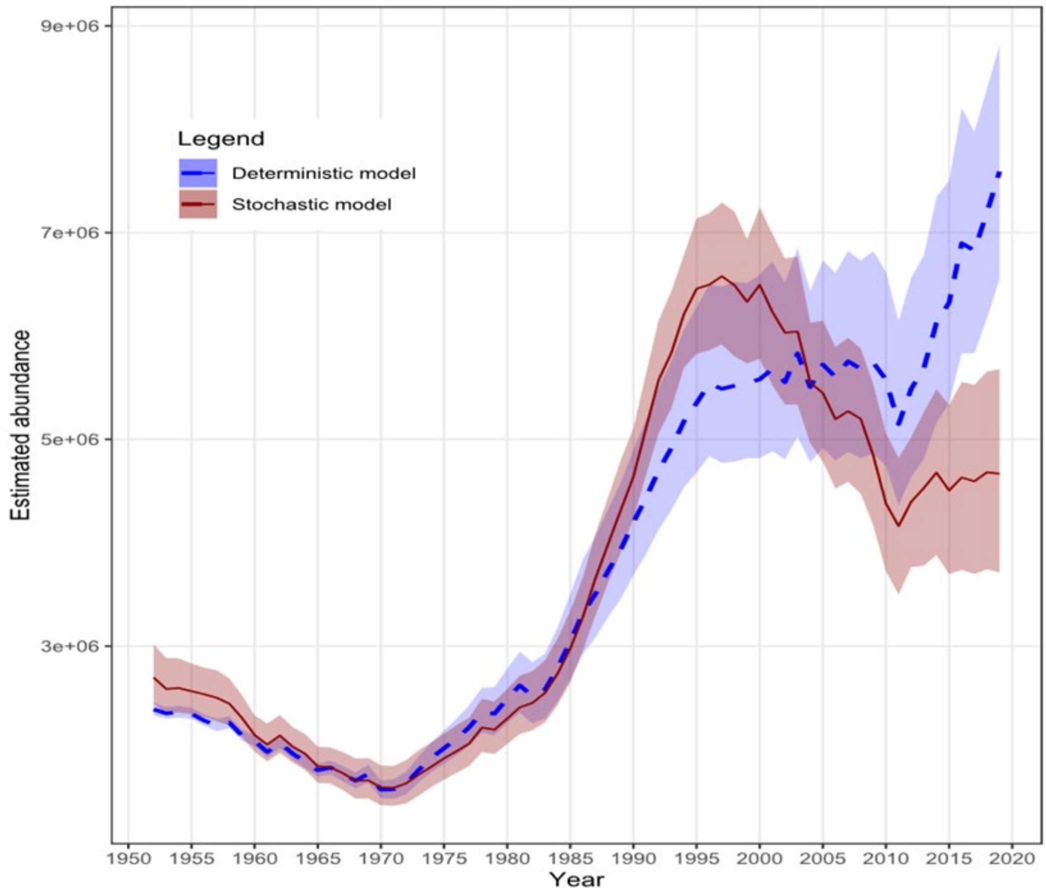

Figure 3.9. Plot showing temporal variation in model-estimated abundance for the Stochastic Bayesian model, with a start age of 5 years (red) and the deterministic model (blue). Solid and dashed lines represent mean estimated values for the Stochastic and Deterministic models, respectively, while shaded bands indicate the associated 95% CI.

3.5.5.4 Discussion

Previous runs of the Deterministic population model had suggested that abundance declined through the 1950s and 1960s to an estimated minimum of approximately 2 million animals in 1972, before recovering to an estimated 7.6 (95% CI=6.55-8.82) million animals in 2019 (Annex 5, Tinker et al. SEA-257).

The Stochastic model provided a 2019 pup production estimate of 780 thousand and a total abundance estimate of 4.7 million, which is approximately 62 % of the estimated 2019 total abundance of 7.6 million produced by the Deterministic model (Hammill et al. 2021). The higher estimate from the Deterministic model reflects multiple differences in the two models, perhaps most importantly the limiting assumption of the Deterministic model that juvenile mortality is fixed over the entire time series. Once harvesting declined, the fixed mortality rate of the deterministic model forces an increase in population abundance. In the Stochastic model, juvenile mortality from density-dependent and density-independent factors (including poor ice conditions and climate forcing) were not fixed and, thus, captured the effects of increased mortality after 2000. In the absence of high harvests, these sources of natural mortality are (and likely will continue to be) the major factors driving the dynamics of this population (Figure 14). Recent assessments of grey seals also resulted in downward revisions to estimates of total abundance of a similar order of magnitude due to significant changes in how juvenile mortality is incorporated into assessment models. Both of these cases highlight the importance of improving our understanding of this key parameter (Annex 5, Tinker et al. SEA-257).

In summary, the Stochastic model improves upon the Deterministic model in several ways, including: 1) variables that were treated as fixed constants in the Deterministic model are now treated as estimated parameters in the Stochastic model, allowing for data-driven estimates of annual age-specific survival, density-dependent effects, mortality from ice anomalies, and effects of environmental conditions on fecundity and survival; 2) the Stochastic model allows for environmental stochasticity in fecundity and survival; 3) multiple causes of death - baseline mortality, age and density-dependent effects, pup mortality due to poor ice cover, harvest/bycatch mortality - are incorporated as competing risks using a proportional hazards formulation, allowing for a more consistent and mathematically coherent treatment of these effects; and 4) model fitting is conducted using a hierarchical Bayesian state-space approach that allows for more robust characterization of uncertainty, disentanglement of process error from observer error, and incorporation of multiple data sources with different distributions and variance structures (Buckland et al. 2004, Wang 2009, Williams et al. 2017). Use of the Stochastic model for future assessments, and for exploring potential consequences of a changing climate, will help strengthen and support management of this iconic species.

4 Hooded Seals

4.1 The Greenland Sea Stock

4.1.1 Information on recent catches and regulatory measures

Concerns over low pup production estimates in 2007 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, from 2007 (see ICES 2006) (Annex 6, Table 1). This advice was immediately implemented (Annex 6, Table 1), and has been maintained due to subsequent low pup production estimates in 2018 (ICES 2019). The total removals of Greenland Sea hooded seals in 1946–2023 are shown in Annex 6, Table 1. Catches for scientific purposes were taken in 2021 (12 pups, and 4 1+ animals) and 2022 (10 pups, and 4 1+ animals) (Biuw et al SEA-255).

4.1.2 Current Research

No new information was presented.

4.1.3 Biological parameters

Maturity curves were constructed based on female reproductive material collected over the period 1990–1994 and 2008–2010 (ICES, 2011) (Table 3.11). The record of historical fecundity rate is sparse, but previous analyses have indicated that fecundity rates remained around F = 0.7 during the period 1958–1999 (ICES, 2013). This is lower than the estimate of F = 0.9 estimated for the period 2008-2010 (ICES, 2011). WGHARP in 2016 (ICES, 2016) ran the population model for a range of fecundity rates, and found that while they resulted in relatively large variations in historical population sizes, the effects were non-significant in terms of estimated population sizes in recent decades. Here we present estimates for the model that was run using F = 0.7. This is within the range of expected fecundities and in accordance with the most recent assessments (ICES, 2016, 2019).

Table 4.1. Estimates of proportions of mature females (pi,t). The P1 estimates are from ICES (2008) and the P2 estimates are from ICES (2011). Mature females had at least one Corpus Luteum or Corpus Albicans in the ovaries.

Age	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y	11y
p_1	0.00	0.05	0.27	0.54	0.75	0.87	0.93	0.97	0.98	0.99	1.00
p_2	0.00	0.00	0.06	0.60	0.89	0.97	0.99	1.00	1.00	1.00	1.00

4.1.4 Pup Production

Pup production was estimated from reconnaissance and aerial surveys performed in the Greenland Sea pack-ice (the West Ice) in the period 18–30 March 2022 (Annex 5, see section 3.1.2.2 and Biuw et al., SEA 256). The resulting estimate was 13,509 (CV=12.9%) for hooded seals. This is slightly but not significantly higher than the 2018 estimate.

4.1.5 Population Assessment

The population model used to assess the abundance for the Greenland Sea hooded seal population is a deterministic age-structured population dynamics model. It uses historical catch records, fecundity rates, age specific proportions of mature females (Table 3.12, Figure 3.10), and estimates of pup production (Table 3.13) to estimate the population trajectory. The base model is the same as described for Greenland Sea harp seals (above) (ICES, 2016, 2019), except that no environmental variables have been included and hence the pre-survey pup mortality rate is set to zero. The influence of Greenland halibut and redfish were assessed but did not contribute to the fit of the model to the pup production estimates.

Unlike the Greenland Sea Harp seal model, the N1+ population level estimated by the model for Greenland Sea Hooded seals was not shown to be very sensitive to the standard deviation of the prior for initial population size.

The estimated population parameters, along with the parameters for the normal priors used are presented in Table 3.14 and Table 3.15. The population size and pup production trajectories are shown in Figure 3.11. The model indicates a substantial de-crease in the population abundance from the late 1940s until the early 1980s. In the two most recent decades, the population size appears to have been stable at a low level, or possibly decreasing slowly. Using a fecundity rate of F = 0.7, we estimated a 2023 abundance of 63 957 (49 645 – 82 396) 1+ animals and 12 875 (10 617 – 15 613) pups. The total 2023 population of hooded seals in the Greenland Sea is therefore estimated to be 76 832 (60 262 – 98 009). This is lower than previous total population size estimates of hooded seals in the Greenland Sea, of 85 790 seals in 2011 (ICES, 2011), 82 830 seals in 2013 (ICES, 2013), 80 460 in 2017 (ICES, 2016) and 77 331 in 2019 (ICES, 2019).

Table 4.2. Estimates of proportions of mature females (pi,t). The P1 estimates are from ICES (2008) and the P2 estimates are from ICES (2011). Mature females had at least one Corpus Luteum or Corpus Albicans in the ovaries.

Age	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y	11y
p_1	0.00	0.05	0.27	0.54	0.75	0.87	0.93	0.97	0.98	0.99	1.00
p_2	0.00	0.00	0.06	0.60	0.89	0.97	0.99	1.00	1.00	1.00	1.00

Table 4.3 Estimates of Greenland Sea hooded seal pup production, based on data from ICES (1998), ICES (2011), Salberg et al., (2008), Øigård et al., (2014), ICES (2019), Annex 5 [Biuw et al.,WP SEA 256].

Year	Estimated number of pups	CV
1997	23 762	0.192
2005	15 250	0.228
2007	16 140	0.133
2012	13 655	0.138
2018	12 977	0.140
2022	13 509	0.129

Table 4.4 Parameter estimates with standard deviation for the current best model for Hooded seals in the West Ice.

Parameter	Estimate	SD
$N_{1+,y0}$ (in millions)	1.12	0.22
$M_{0,normal}$	0.31	0.21
$M_{1,normal}$	0.17	0.02

Table 4.5 Mean and standard deviation of the normal priors for model parameters

Parameter	Mean	Sd
$N_{1+,y0}$	10^6	$2 \cdot 10^7$
$M_{0,normal}$	0.27	0.2
$M_{1,normal}$	0.09	0.1

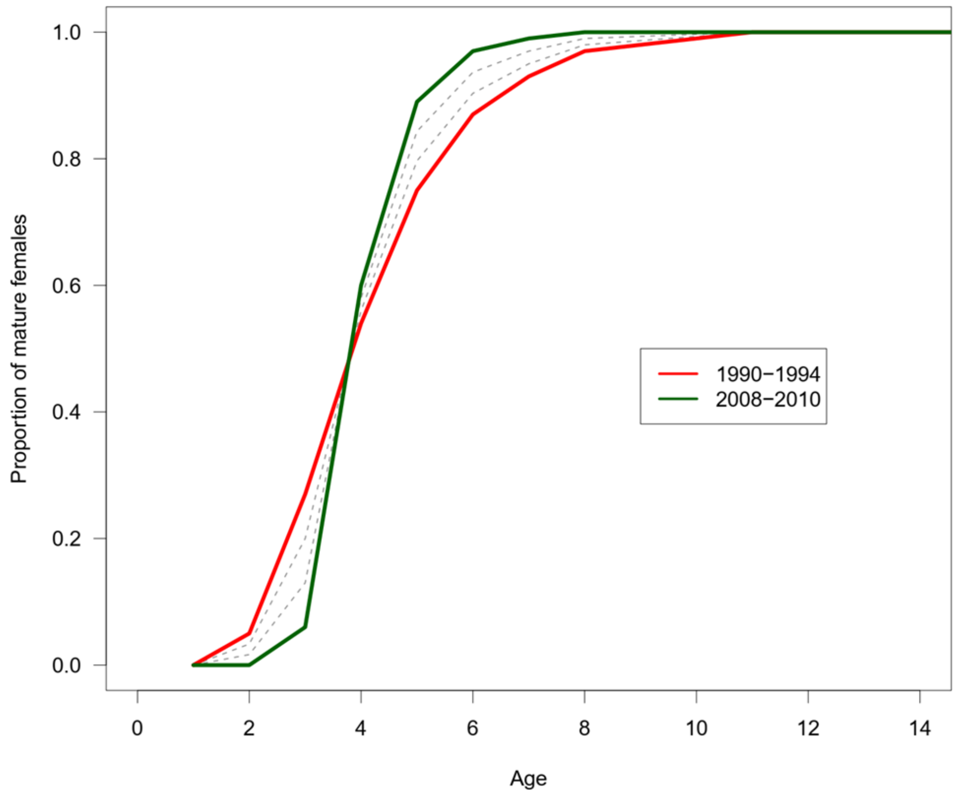

Figure 4.1. Shows the maturity curves for hooded seal females from the Greenland Sea. The colored curves depict the years and periods with data (Red line = 1990-1994, Green line = 2008-2010) and the grey lines show curves for all other years, based on linear interpolation between the years and periods with data. Note that the red curve is used for all years prior to 1990 and the green curve is used for all years post-2010.

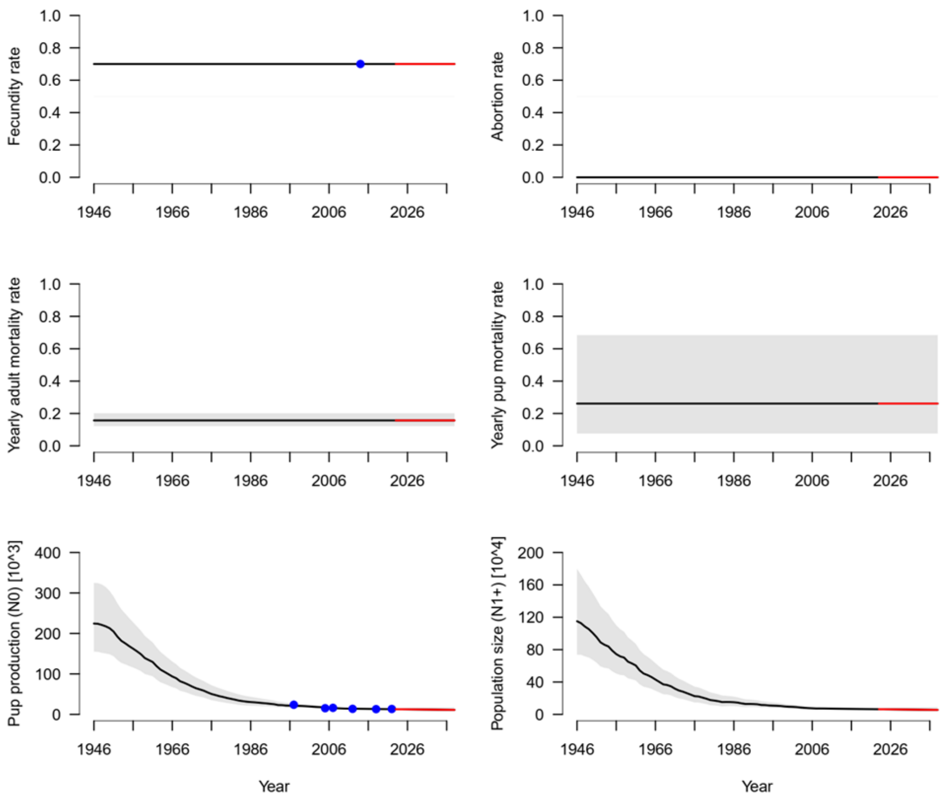

Figure 4.2. Shows the output from the standard population model. In all panels, black lines indicate estimated values, and the grey areas indicate the 95% confidence bands. In the upper left panel, blue points indicate estimates of fecundity, while in the lower left panel blue points indicate estimated pup production. Note that the red line segments indicate a period of forecast of ~15 years, based on average values of vital rates and a harvest level of zero. Note also, the different scale of the y-axis in the different panels. Note also that pre-survey pup mortality rates are set to zero in the standard model (see model description above).

4.1.6 Catch Scenarios

Model runs indicate a population currently well below Nlim (30% of largest observed population size). Following the precautionary approach framework developed by WGHARP (ICES 2003, 2005, 2008), no commercial catches should be taken from this population.

4.2 The Northwest Atlantic Stock

4.2.1 Information on recent catches and regulatory measures

Under the Canadian Atlantic Seal Management Strategy (Hammill and Stenson 2007, 2009), Northwest Atlantic hooded seals are considered to be data poor. Under this approach, TAC is set by considering a PBR approach. 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. Hooded seals have not been assessed since 2006 and, as a result, there has been no change to the TAC. The TAC has not been formally announced since 2016.

The number of hooded seals taken annually in Canadian waters remains low, with a total catch for 2020 through 2022 of 35 animals (Annex 6 Table 2; Lang et al. SEA-263). All animals harvested were 1+, as the harvesting of bluebacks is prohibited in Canada (Lang et al. SEA-263; Annex 8 Table 4).

Only preliminary catch statistics are available for Greenland, indicating a total catch of 5 619 hooded seals for the period 2018-2022 (see Annex 6, Table 3)

4.2.2 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.

4.2.3 Biological parameters

There are no new data on biological parameters.

4.2.4 Population Assessments

The last hooded seal surveys in the NW Atlantic were competed in 2004 and 2005 (Hammill and Stenson 2006, Stenson et al. 2006). Harp seal surveys were carried out in the NW Atlantic in 2012 and 2017 during which hooded seals were also photographed. Efforts are underway to determine if hooded seal pup production can be estimated from the 2012 and/or 2017 harp seal surveys as it is believed that these surveys may have covered the majority of the hooded seal whelping patches on the Front.

A survey to determine pup production of NW Atlantic is tentatively planned for March 2025.

5 Ecosystem Context

A presentation was given on the work of the working groups (WGs) on integrated eco-system assessments (IEA) of ICES Ecoregions using the Greenland Sea working group (WGIEAGS) as the main example. There are 17 ICES ecoregions and most of them now have an associated IEA WG. These groups have three-year work plans and deter-mine their own terms of reference. One mandatory delivery, however, is the ecosystem overview (EO), which has status of advice within ICES (see: https://www.ices.dk/advice/ESD/Pages/default.aspx). The EO use risk-based methods to describe ecosystem components, dynamics and anthropogenic pressures and impacts. This information is further condensed into wire diagrams showing the relative strengths of pressures from human activities on different ecosystem components. Some ICES IEA groups also aim to deliver a more detailed integrated assessment of ecosystem status and change based on various additional methodologies. Since there is no direct funding of the ICES IEA groups, this work often draws heavily on publications from re-search projects. An example is Heide-Jørgensen et al. (2022) on ecosystem regime change in the southern Greenland Sea, which is an important component of WGIEAGS report at the end of the group's first three-year term in 2023. Members of WGHARP participate in the work of WGIEAGS as well as similar groups for the Barents Sea (WGIBAR), The Norwegian Sea (WGINOR) and The Central Arctic Ocean (WGICA), but so far not in the IEA group for the Northwest Atlantic (WGNARS). WGHARP agreed to maintain and develop their interactions with the ICES IEA groups and other similar groups such as the NAFO WG.ESA.

6 Biologging

A portion of the meeting was devoted to biologging studies and the potential for collaborative satellite tagging projects going forward. Tiphaine Jeanniard du Dot (Centre d'Etudes Biologiques de Chizé, CNRS - La Rochelle Université) presented results from a study of 116 adult hooded seals tagged from 1992-2019 in the Northwest Atlantic (Gulf and Front) and Greenland Sea, to investigate changes in suitable habitat over the past 3 decades, as well as diet in-formed by stable isotopes from tissue samples. Results were used to predict future locations of suitable habitats in response to a global warming scenario. Results suggested that animals shifted their foraging locations to maintain preferred habitat preferences despite changes in environmental conditions. Different foraging habitats existed between animals breeding in the Gulf compared to the Front and the Greenland Sea, and suitable habitat was predicted to de-crease in the Gulf but increase in the Greenland Sea.

Martin Biuw presented research which demonstrated the potential to measure body condition of seals with novel satellite tags. Traditional tags provide data on the location and behaviour of animals. They have also been used to provide additional insight to the consequences of foraging success, survival, and reproductive success by understanding where animals gain lipid stores by inferring body condition based upon changes in drift rate from dive data. A new approach is to directly measure body condition based on descent/ascent rates from flipper movements and short sections of gliding. The new satellite tag (Wildlife Computers, BD-SRDL) extracts parameters during glide periods which are then used to compute the density of the animal given the ratio of drag and mass to buoyancy. Ultimately this allows one to investigate temporal and spatial changes in lipid density, and correlate these with individual behaviour and/or population demographics.

A discussion followed on strategies and design for collaborative research with this type of tag on harp and hooded seals. Specifically, which species, age class, and timing (breeding or moult) to prioritize. Tagging during the moult is preferred as the tag lasts longer, though this poses logistical challenges in that animals may not have fully moulted and therefore must be held until the moult is completed and are more difficult to catch than during the pupping pe-riod. There is interest in both species related to their impacts on the ecosystem, and their population and movement responses to ecosystem change. The conservation of hooded seals is a priority given their reduced population size, while interest in harp seals may be motivated by concerns about competition with fisheries. Juvenile survival is a major issue for both species and for population models, so there is a need for information on juveniles. These tags would also provide valuable information on the condition of mature females which could be used to approximate reproductive rates. The group agreed for a smaller group to put together a strategy document to outline the goals for a cross-Atlantic collaborative tagging study on both species, aimed at understanding impacts on population recovery and ecosystem dynamics. International bodies such as NAMMCO could be approached to support the development of the strategic document.

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Annex 1: List of participants

Name	Address	Email
Sophie Smout Co-Chair	Sea Mammal Research Unit , Scottish Oceans Institute, University of St Andrews UK	scs10@st-and.ac.uk
Martin Biuw Co-Chair	Institute of Marine Research Norway	martin.biuw@hi.no
Anne Kirstine Frie	Institute of Marine Research Norway	anne.kirstine@hi.no
Tore Haug	Institute of Marine Research Norway	tore.haug@hi.no
John-André Henden	Institute of Marine Research Norway	John-Andre.Henden@hi.no
Arnt-Børre Salberg	Norwegian Computing Center Norway	salberg@nr.no
Mike Hammill	Unaffiliated Canada	cystophora.cristata@gmail.com
Garry Stenson	Unaffiliated Canada	GarryBStenson@gmail.com
Shelley Lang	Fisheries and Oceans Canada Canada	shelley.lang@dfo-mpo.gc.ca
Charmain Hamilton	Fisheries and Oceans Canada Canada	charmain.hamilton@dfo-mpo.gc.ca
Kimberly Murray	Northeast Fisheries Science Center USA	kimberly.murray@noaa.gov
Lars Witting	Greenland Institute of Natural Resources Greenland	larsw@natur.gl
Aqqalu Rosing-Asvid	Greenland Institute of Natural Resources Greenland	aqro@natur.gl
Daniel Howell	Institute of Marine Research Norway	daniel.howell@hi.no
John-Tyler Trochta	Institute of Marine Research Norway	john.tyler.trochta@hi.no
Albert Chacón	NAMMCO	albert@nammco.no
Geneviève Desportes	NAMMCO	genevieve@nammco.no
Ruth Fernandez	ICES Secretariat	Ruth.Fernandez@ices.dk

Annex 2: Agenda

Meeting of WGHARP, 21-25 August 2023
IMR, Fram Centre, Tromsø, Norway

Monday, August 21st

- Introductory Comments
- Housekeeping
- Discussion of Terms of Reference & a brief mention of some key issues from the Benchmark Meeting
- Information from ICES and NAMMCO
- Greenland Sea – Updated pup production estimates
  - Presentation of survey
  - Machine Learning approach
  - Harp seal pup production
  - Hooded seal pup production

- Northwest Atlantic
    - Overview of harp and hooded seal survey data. Plans for analysis and data collection
  - Harp seal population model

Tuesday, August 22nd

- Report from the BKSEALS benchmark meeting
  - Presentation of benchmark ToRs, agenda and participants
  - Review of work leading up to benchmark meeting
  - Report of main output and BKSEALS recommendations
  - Discussion of reference points and limits

- Biological Parameters, all stocks
- Harp seals: Barents Sea / White Sea Stock
    - Catches
    - Stock-specific model structure, parameters and resource data
    - Review of historical age distribution data
    - Population assessment

- Harp Seals: Greenland Sea Stock
    - Review and update

- Hooded seals: Greenland Sea NE Atlantic
    - Catches
    - Stock-specific model structure, parameters and resource
    - Review of historical age distribution data
    - Population assessment

- Biological parameters
- Management Strategy Evaluation framework
- Discussion and summary of suggestions for future developments
  - Reporting from this meeting

- Recommendations -priorities **for work for next WGHARP**

Thursday, August 24th

- Suggestions for coordinated satellite tracking studies
    - Presentation of results and plans from French collaborators
    - Presentation of new tags estimating changes in body condition
- Discussion of way forward
- Next meeting
- AOB
- Write and review report

Friday, August 25th

- Review/complete report
- Next meeting
- Other business

12:00 end meeting

Annex 3: Draft Resolution for next meeting

The ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP) chaired by Sophie Smout, UK, and Martin Biuw, Norway, will meet at St Andrews, Scotland, in the first week of September 2025 to:

a) Evaluate new model developments and comparisons with previous assessment models;

b) Review results of new abundance surveys for harp and hooded seals, if available;

c) Review results from the biological samples obtained;

d) Address potential special requests on the management of harp and hooded seal stocks by assessing their status and harvest potential;

WGHARP will report to ACOM and NAMMCO.

Annex 4: Recommendations to NAMMCO

Recommendation	Recipient
New pup aerial survey of harp seals in the White Sea (Action by 2024)	NAMMCO
The WG recommends that the population model(s) used to describe the dynamics of North Atlantic harp and hooded seals, in particular the Greenland Sea, Barents /White Sea be further developed, including consultation to agree model priors, additional environmental/biological variables into the model structure, especially if new information becomes available. Inclusion of catch at age data is a priority. (Action by 2025)	NAMMCO
The WG recommends that ICES and/or NAMMCO convene an online workshop on the potential to use multi-species modelling to support the work of WGHARP	NAMMCO
The WG recommends continued communication and collaboration with the regional integrated assessment and ecosystem modelling communities, and bycatch working group (Action by 2025)	NAMMCO, NAFO
The WG recommends that efforts continue to obtain reproductive samples. These are required for use in the population model. (Continuing Action)	NAMMCO
The WG recommends that satellite imaging studies be undertaken of the White Sea\Barents Sea harp seal population during the pupping season, to suggest possible re-distribution of the seals outside traditional whelping patches (Action by 2025)	NAMMCO

Annex 5: Working Documents

Number	Author	Title
SEA 255	Biuw, M., J-A. Henden, T. Haug and V. Zabavnikov	Norwegian and Russian catches of harp and hooded seals in the Northeast Atlantic 2020-2023.
SEA256	Biuw M., J-A. Henden, A-B. Salberg, K.T. Nilssen, L. Lindblom, M. Poltermann, M. Kristiansen, and T. Haug	Estimation of pup production of harp and hooded seals in the Greenland Sea in 2022
SEA257	Tinker, M.T., G.B. Stenson, A. Mosnier, and M.O.Hammill	Estimating abundance of Northwest Atlantic harp seal using a bayesian modelling approach
SEA260	J-A. Henden, M. Biuw, A.K. Frie, and M. Aldrin	The 2023 abundance of harp seals (*Pagophilus groenlandicus*) in the Barents Sea/White Sea
SEA261	J-A. Henden, M. Biuw, A.K. Frie, and M. Aldrin	The 2023 abundance of harp seals (*Pagophilus groenlandicus*) in the Greenland Sea
SEA262	J-A. Henden, M. Biuw, A.K. Frie, and M. Aldrin	The 2023 abundance of hooded seals (*Cystophora cristata*) in the Greenland Sea
SEA263	S.L.C. Lang, C.D. Hamilton, and G.B. Stenson	Updated Estimates of Harp Seal Bycatch and Total Removals of NW Atlantic Harp and Hooded Seals in Canadian waters

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 2023. Totals include catches for scientific purposes.

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
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
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
2017	14	3	17	0	0	0	14	3	17
2018	9	8	17	0	0	0	9	8	17
2019	14	9	23	0	0	0	14	9	23
2020	0	0	0	0	0	0	0	0	0
2021	12	4	16	0	0	0	12	4	16
2022	10	4	14	0	0	0	10	4	14
2023	0	0	0	0	0	0	0	0	0

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 3900, 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"), 1946–2023. Catches from 1995 onward includes catches under personal use licences. YOY refers to Young of Year. Catches from 1990–1996 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	94[d]	0	0	636[e]	636	41	53	636	730
1991	0	14	0	14[d]	0	0	6411[e]	6411	0	14	6411	6425
1992	35	60	0	95[d]	0	0	119[e]	119	35	60	119	214

1993	0	19	0	19[d]	0	0	19[e]	19	0	19	19	38
1994	19	53	0	72[d]	0	0	149[e]	149	19	53	149	221
1995	0	0	0	0	0	0	857[e]	857	0	0	857e	857
1996	0	0	0	0	0	0	25754[e]	25754	0	22847[f]	2907	25754
1997	0	0	0	0	0	7058	0	7058	0	7058	0	7058
1998	0	0	0	0	0	10148	0	10148	0	10148	0	10148
1999	0	0	0	0	0	201	0	201	0	201	0	201
2000	2	2	0	4[d]	0	10	0	10	2	12	0	14
2001	0	0	0	0	0	140	0	140	0	140	0	140
2002	0	0	0	0	0	150	0	150	0	150	0	150
2003	0	0	0	0	0	151	0	151	0	151	0	151
2004	0	0	0	0	0	389	0	389	0	389	0	389
2005	0	0	0	0	0	20	0	20	0	20	0	20
2006	0	0	0	0	0	40	0	40	0	40	0	40
2007	0	0	0	0	0	17	0	17	0	17	0	17
2008	0	0	0	0	0	5	0	5	0	5	0	5
2009	0	0	0	0	0	10	0	10	0	10	0	10
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	2	0	2	0	2	0	2
2012	0	0	0	0	0	1	0	1	0	1	0	1
2013	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	1	0	1	0	1	0	1
2017	0	0	0	0	0	12	0	12	0	12	0	12
2018	0	0	0	0	0	79	0	79	0	79	0	79

2019[g]	0	0	0	0	0	30	0	30	0	30	0	30
2020	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	3	0	3	0	3	0	3
2022	0	0	0	0	0	32	0	32	0	32	0	32
2023	0	0	0	0	0	0	0	0g	0	0g	0	0

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 DFO Statistics Branch.
c Landsmen values include catches by small vessels (<150 gr tonnes) and aircraft.
d Large vessel catches represent research catches in Newfoundland and may differ from NAFO values.
e Statistics not split by age; commercial catches of bluebacks are not allowed
f Number of YOY based upon seizures of illegal catches
g Preliminary data

Table 3. Catches of hooded seals in West and East Greenland 1954–2023

Year	West Atlantic Population				NE	All Greenland
	West	KGHb	Southeast	Total		
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

Year	West Atlantic Population				NE	All Greenland
	West	KGHb	Southeast	Total		
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	4982	-	1967	6950	32	6981
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
1999	4852	-	2587	7439	16	7455
2000	3769	-	2046	5815	29	5844
2001	5010	-	1496	6506	8	6514
2002	3606	-	1189	4795	11	4806

Year	West Atlantic Population				NE	All Greenland
	West	KGHb	Southeast	Total		
2003	4351	-	1992	6343	10	6353
2004	4136	-	1690	5823	17	5843
2005	3092	-	1022	4114	14	4128
2006	4238	-	559	4744	3	4800
2007	2570	-	710	3287	7	3287
2008	2083	-	519	2604	2	2604
2009	1628	-	359	1982	1	1988
2010	1872		266	2137	7	2145
2011	1835		225	2052	9	2069
2012	1352	-	349	1665	6	1707
2013	1185	-	330	1520	0	1515
2014	1460	-	388	1845	1	1849
2015	1719	-	229	1948	0	1948
2016	1247	-	267	1514	1	1515
2017	1309	-	217	1526	0	1526
2018d						992
2019 d						1605
2020 d						909
2021 d						1169
2022 d						944

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 1959–1968.
c For 1988 to 1992 catch statistics are not available.
d Preliminary catch statistics (totals only)

Table 4. Catches of moulting hooded seals in the Denmark Strait, 1945-1978.

Year	Norway sealing	Greenland sealing[a]	Norway scient. sampling
1945	3275	-	
1946	17 767	-	
1947	16 080	-	

Year	Norway sealing	Greenland sealing[a]	Norway scient. sampling
1948	16 170	-	
1949	1494	-	
1950	17742	-	
1951	47 607	-	
1952	16 910	-	
1953	2907	-	
1954	18 291	-	
1955	10 230	-	
1956	12 840	-	
1957	21 425	-	
1958	14 950	-	
1959	6480	414	
1960	7930	0[b]	
1961	-	803	
1962	-	988	
1963	-	813	
1964	-	360	
1965	-	-	
1966	-	782	
1967	-	371	
1968	-	20	
1969	-	-	
1970	-	-	797
1971	-	-	
1972	-	-	869
1973	-	-	
1974	-	-	1201
1975	-	-	

Year	Norway sealing	Greenland sealing[a]	Norway scient. sampling
1976	-	-	323
1977	-	-	
1978	-	-	1201

a) Performed by KGH (Royal Greenland Trade Department) on behalf of the local inhabitants of Ammassalik, Southeast Greenland.
b) The vessel was lost 23 June on its first trip that year; previous information on a catch of 773 seals is thus in error (probably confused with the 1961-catch.

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 2023. Totals include catches for scientific purposes. Catches are from Biuw et al. (SEA255)

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
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
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
2017	1934	66	2000	-	-	-	1934	66	2000
2018	1218	1485	2703	-	-	-	1218	1485	2703
2019	2168	3645	5813	-	-	-	2168	3645	5813
2020	2341	7943	10284	0	0	0	2341	7943	10284
2021	5	5	10	0	0	0	5	5	10
2022	1347	74	1421	0	0	0	1347	74	1421
2023	1793	84	1877	0	0	0	1793	84	1877

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 3900, 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 Barents and White Seas ("East Ice"), 1946–2023 (Annex 5, Biuw *et al.*, SEA 255)

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
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
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
2017	0	1	1	0	0	0	0	1	1
2018	21	2220	2241	0	0	0	21	2220	2241
2019	34	568	602	0	0	0	34	568	602

2020	0	0	0	0	0	0	0	0	0
2021	49	5012	5061	0	0	0	49	5012	5061
2022	0	0	0	0	0	0	0	0	0
2023	0	0	0	0	0	0	0	0	0

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. Incidental catches and death of harp seals at the Norwegian and Murman coasts[1]. There are no data since 1991.

Year	Norwegian coast	Murman coast	Total
1978	.		.
1979	2023	1114	3137
1980	3311		
1981	2013		
1982	517		
1983	855		
1984	1236		
1985	1225		
1986	4409		
1987	56 222		
1988	21 538		
1989	314		
1990	368		
1991	-		

[1]) Norwegian data are recorded catches, since 1981 recorded for compensation under regulations for damage to fishing gear.

Table 4. Reported catches of harp seals in the Northwest Atlantic for 1952-2023. Estimated catches are indicated by shading. The Greenland catches are made up of the Table 6 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.

Year	Front and Gulf	Canadian Arctic	Greenland	NW Atlantic Total
1952	307 108	1784	16 400	325 292
1953	272 886	1784	16 400	291 070
1954	264 416	1784	19 150	285 350
1955	333 369	1784	15 534	350 687
1956	389 410	1784	10 973	402 167
1957	245 480	1784	12 884	260 148
1958	297 786	1784	16 885	316 455
1959	320 134	1784	8 928	330 846
1960	277 350	1784	16 154	295 288
1961	187 866	1784	11 996	201 646
1962	319 989	1784	8 500	330 273
1963	342 042	1784	10 111	353 937
1964	341 663	1784	9203	352 650
1965	234 253	1784	9289	245 326
1966	323 139	1784	7057	331 980
1967	334 356	1784	4242	340 382
1968	192 696	1784	7116	201 596
1969	288 812	1784	6438	297 034
1970	257 495	1784	6269	265 548
1971	230 966	1784	5572	238 322
1972	129 883	1784	5994	137 661
1973	123 832	1784	9212	134 828
1974	147 635	1784	7145	156 564
1975	174 363	1784	6752	182 899
1976	165 002	1784	11 956	178 742
1977	155 143	1784	12 866	169 793
1978	161 723	2129	16 638	180 490

1979	160 541	3620	17 545	181 706
1980	169 526	6350	15 255	191 131
1981	202 169	4672	22 974	229 815
1982	166 739	4881	26 927	198 547
1983	57 889	4881	24 785	87 555
1984	31 544	4881	25 829	62 254
1985	19 035	4881	20 785	44 701
1986	25 934	4881	26 099	56 914
1987	46 796	4881	37 859	89 536
1988	94 046	4881	40 415	139 342
1989	65 304	4881	42 971	113 156
1990	60 162	4881	45 526	110 569
1991	52 588	4881	48 082	105 551
1992	68 668	4881	50 638	124 187
1993	27 003	4881	56 319	88 203
1994	61 379	4881	57 373	123 633
1995	65 767	4881	62 749	133 397
1996	242 906	4881	73 947	321 734
1997	264 210	2500[a]	68 816	335 526
1998	282 624	1000[a]	81 273	364 897
1999	244 552	500[a]	93 120	338 172
2000	92 055	400[a]	98 463	190 918
2001	226 493	600[a]	85 428	312 521
2002	312 367	1000	66 735	380 102
2003	289 512	1000	66 149	356 661
2004	365 971	1000	70 587	437 558
2005	323 826	1000	91 688	422 517
2006	354 867	1000	94 034	449 901
2007	224 745	1000	82 826	308 571

2008	217 850	1000	80 444	299 294
2009	76 668	1000	71 862	149 530
2010	69 101	1000	90 909	160 006
2011	40 389	1000	73 462	114 851
2012	71 460	1000	54 660	127 120
2013	97 922	1000	65 241	164 163
2014	59 666	1000	63 028	123 694
2015	35 382	1000	61 767	98 149
2016	68 360	1000	56 730	124 880
2017	81 742	1000	48 593	130 258
2018	61 022	1000	58 614[b]	120 636
2019[c]	32 602	1000	58 614[b]	91 652
2020[c]	2 406	1000	50 162	53 568
2021[c]	28 975	1000	30 677	60 652
2022[c]	31 597	1000	29 680	62 277
2023[c]	40 001	1000	-	41 001

[a] Rounded
[b] Average of catches 2013–2017
[c] Preliminary data

Table 5. Reported Canadian catches of Harp seals off Newfoundland and in the Gulf of St. Lawrence, Canada (“Gulf” and “Front”), 1946–2023. Catches from 1995 onward include catches under the personal use licences. YOY = Young of Year.

	Large Vessel Catch				Landsmen Catch[c]				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[d]	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	644[e]	23827	7073	0	30900	23922	7622	0	31544
1985	0	1	0	1[e]	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	232[e]	56345	5691	3036	65072	56346	8958	0	65304
1990	48	74	0	122[e]	34354	23725	1961	60040	34402	25760	0	60162
1991	3	20	0	23[e]	42379	5746	4440	52565	42382	10206	0	52588
1992	99	846	0	945[e]	43767	21520	2436	67723	43866	24802	0	68668
1993	8	111	0	119[e]	16393	9714	777	26884	16401	10602	0	27003
1994	43	152	0	195[e]	25180	34939	1065	61184	25223	36156	0	61379
1995	21	355	0	376[e]	33615	31306	470	65391	34106	31661	0	65767
1996	3	186	0	189[e]	184853	57864	0	242717	184856	58050	0	242906
1997	0	6	0	6[e]	220476	43728	0	264204	220476	43734	0	264210
1998	7	547	0	554[e]	0	0	282070	282070	7	547	282070	282624
1999	26	25	0	51[e]	221001	6769	16782	244552	221027	6794	16782	244603
2000	16	450	0	466[e]	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	40389	40371	18	0	40389
2012	0	0	0	0	71319	141	0	71460	71319	141	0	71460
2013	0	0	0	0	94,310	3,612	0	97,922	94,310	3,612	0	97,922
2014	0	0	0	0	59,616	50	0	59,666	59,616	50	0	59,666
2015	0	0	0	0	35,302	80	0	35,382	35,302	80	0	35,382
2016	0	0	0	0	51,854	7,087	9,419[f]	68,360	51,854	7,087	9,419	68,360
2017	0	0	0	0	58,234	10,062	13,446[f]	81,742	58,234	10,062	13,446	81,742
2018	0	0	0	0	53,222	4,728	3,072[f]	61,022	53,222	4,728	3,072	61,022
2019[g]	0	0	0	0	30265	1685	652[f]	32602	30265	1685	652[f]	32602

2020[g,h]	0	0	0	0	333	1676	397[f]	2406	333	1676	397[f]	2406
2021[g]	0	0	0	0	25368	31	3576[f]	28975	25368	31	3576[f]	28975
2022[g]	0	0	0	0	27204	492	3901[f]	31597	27204	492	3901[f]	31597
2023[g]	0	0	0	0	0	0	40001[f]	40001	0	0	40001[f]	40001

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 DFO Statistics Branch.
c Landsmen values include catches by small vessels (< 150 gr tonnes) 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
f Unspecified catches will be assigned to age class at a later date
g Preliminary data

Table 6. Catches of harp seals in Greenland, 1954–1987 (List-of-Game), and 1993–2017 (Piniarneq), and % adults [a] according to the hunters' reports [b].

Year	West Greenland		South East Greenland		Northeast Greenland		All Greenland
	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	8844		168		7		9,019
1960	15 979		350		16		16 345
1961	11 886		219		13		12 118
1962	8394		211		10		8615
1963	10 003	21	215	28	20	50	10 238
1964	9140	26	125	40	7	86	9272
1965	9251	25	76	65	2	100	9329
1966	7029	29	55	55	6		7090
1967	4215	38	54	35	10		4279
1968	7026	30	180	47	4		7210
1969	6383	21	110	62	9		6502
1970	6178	26	182	70	15	100	6375
1971	5540	24	63	48	5		5608
1972	5952	16	84	48	6	100	6042

Year	West Greenland		South East Greenland		Northeast Greenland		All Greenland
	Catch numbers	% adults	Catch numbers	% adults	Catch numbers	% adults	Catch numbers
1973	9162	19	100	20	38	79	9300
1974	7073	21	144	29	27	95	7244
1975	5953	13	125	20	68	72	6146
1976	7787	12	260	48	27	55	8074
1977	9938	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	55 784	50	1054	30	40	93	56 878
1994	56 919	50	864	30	88	65	57 871
1995	62 296	53	906	36	61	52	63 263
1996	73 288	52	1320	35	68	60	74 676
1997	68 241	49	1149	28	201	58	69 591
1998	80 438	51	1670	30	109	73	82 217
1999	91 324	49	3592	12	101	67	95 017
2000	97 233	44	2459	15	109	79	99 801
2001	84 165	42	2525	18	73	68	86 763
2002	65 810	45	1849	19	66	86	67 725
2003	64 735	44	2828	24	44	77	67 607
2004	69 274	40	2625	27	206	28	72 105

Year	West Greenland		South East Greenland		Northeast Greenland		All Greenland
	Catch numbers	% adults	Catch numbers	% adults	Catch numbers	% adults	Catch numbers
2005	90 300	35	2775	18	38	58	93 113
2006	92 995	33	2077	17	89	78	95 161
2007	81 476	32	2699	21	85	53	84 260
2008	78 728	32	3432	11	7	29	82 167
2009	70 577	32	2569	9	260	6	73 406
2010	88 936	25	1938	12	35	34	90 909
2011	72 640	30	1644	16	74	26	74 358
2012	53 833	30	1653	12	147	90	55 633
2013	64 147	29	2188	15	186	28	66 521
2014	62 116	28	1824	13	28	32	63 968
2015	60 959	31	1616	18	57	46	62 632
2016	54 346	31	2348	14	36	36	56 730
2017	46 476	33	2079	16	38	5	48 593

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 8. Estimated total removals of harp seals in the Northwest Atlantic for 1952–2019

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	451 627
1956	402 167	0	64 218	466 383
1957	260 148	0	96 381	356 529
1958	316 455	0	176 883	493 340
1959	330 846	0	94 426	425 274
1960	295 288	0	140 697	435 983
1961	201 646	0	34 532	236 181
1962	330 273	0	125 277	455 550

Year	Reported	Bycatch	Struck and Lost	Total
1963	353 937	0	86 250	440 185
1964	352 650	0	88 959	441 607
1965	245 326	0	64 414	309 740
1966	331 980	0	83 382	415 361
1967	340 382	0	65 438	405 821
1968	201 596	0	46 718	248 315
1969	297 034	0	66 051	363 086
1970	265 548	77	50 313	315 938
1971	238 322	525	29 870	268 719
1972	137 661	623	22 031	160 315
1973	134 828	467	37 486	172 782
1974	156 564	183	42 899	199 647
1975	182 899	285	43 681	226 865
1976	178 742	1,095	47 991	227 828
1977	169 793	1,633	44 094	215 518
1978	180 490	3,376	65 474	249 342
1979	181 706	3,603	50 585	235 895
1980	191 131	2814	60 048	253 994
1981	229 815	4181	53 222	287 216
1982	198 547	3817	54 740	257 102
1983	87 555	5009	40 131	132 694
1984	62 254	4143	39 591	105 987
1985	44 701	4987	32 069	81 757
1986	56 914	6109	36 178	99 199
1987	89 536	10 910	55 099	155 547
1988	139 342	8398	75 895	223 634
1989	113 156	8643	59 775	181 574
1990	110 569	2769	77 978	191 317
1991	105 551	8703	65 400	179 654

Year	Reported	Bycatch	Struck and Lost	Total
1992	124 187	23 035	82 629	229 852
1993	88 203	26 975	72 665	187 845
1994	123 633	47 604	99 738	270 974
1995	133 397	20 593	101 086	255 075
1996	321 734	29 641	146 607	497 981
1997	335 526	19 048	126 654	481 229
1998	364 897	4 557	126 726	496 181
1999	338 172	16 167	113 036	467 376
2000	190 918	11 521	110 358	312 799
2001	312 521	20 064	109 069	441 653
2002	380 102	9543	98 009	487 655
2003	356 661	5445	91 233	453 340
2004	437 558	35 870	102 613	576 040
2005	422 517	26 378	115 759	564 652
2006	449 901	21 656	121 707	593 264
2007	308 571	9450	98 740	416 759
2008	299 294	7280	93 180	399 755
2009	149 530	2275	76 897	228 700
2010	160 006	3957	94 965	258 930
2011	114 851	2114	76 605	193 570
2012	127 120	2886	59 554	189 561
2013	164 163	177	74 817	239 157
2014	123 694	1166	67 216	192 075
2015	98 149	1039	64 705	163 895
2016	124 880	603	67 075	192 559
2017	130 258	226	63 686	194 169
2018	120 636	612	67 455	188 703
2019	91 652	711[a]	63 313	155 677

[a] Average bycatch 2014–2018 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"), 1985–2023 (Biuw et al., SEA 255)

Year	Opening Date	Closing Date	Quotas				Allocations	
			Total	Pups	Female	Male	Norway	Soviet and Russian
Hooded Seals								
1985	22 March	5 May	(20 000)[2]	(20 000)[2]	03	Unlim.	8000[4]	3300
1986	18 March	5 May	9300	9300	03	Unlim.	6000	3300
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	6900
1990	26 March	30 June	27 500	0	0	Incl.	19 500	8000
1991	26 March	30 June	9000	0	0	Incl.	1000	8000
1992-94	26 March	30 June	9000	0	0	Incl.	1700	7300
1995	26 March	10 July	9000	0	0	Incl.	1700[7]	7300
1996	22 March	10 July	9000[8]				1700	7300
1997	26 March	10 July	9000[9]				6200	2800[11]
1998	22 March	10 July	5000[10]				2200	2800[11]
1999-00	22 March	10 July	11 200[12]				8400	2800[11]
2001-03	22 March	10 July	10 300[12]				10 300	
2004-05	22 March	10 July	5600[12]				5600	
2006	22 March	10 July	4000				4000	
2007-2023			0	0	0	0	0	0
Harp Seals								
1985	10 April	5 May	(25 000)[2]	(25 000)[2]	0[5]	0[5]	7000	4500
1986	22 March	5 May	11 500	11 500	0[5]	0[5]	7000	4500
1987	18 March	5 May	25 000	25 000	0[5]	0[5]	20 500	4500
1988	10 April	5 May	28 000	0[5,6]	0[5,6]	0[5,6]	21 000	7000

1989	18 March	5 May	16 000	-	0[5]	05	12 000	9000
1990	10 April	20 May	7200	0	0[5]	05	5400	1800
1991	10 April	31 May	7200	0	0[5]	05	5400	1800
1992-93	10 April	31 May	10 900	0	0[5]	05	8400	2500
1994	10 April	31 May	13 100	0	0[5]	05	10 600	2500
1995	10 April	31 May	13 100	0	0[5]	05	10 600[7]	2500
1996	10 April	31 May[8]	13 100[9]				10 600	2500[11]
1997-98	10 April	31 May	13 100[10]				10 600	2500[11]
1999-00	10 April	31 May	17 500[13]				15 000	2500[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
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
2017-19	10 April	31 May	26 000				26 000	0
2020-23	10 April	31 May	11 548				11 548	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"), 1979–2023.[1]

Year	Opening Dates		Closing Date	Quota-Allocation		
	Soviet/Rus.	Norway		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	9500
1995	-	-	-	40 000	31 250	8750[5]
1996	-	-	-	40 000	30 500	9500
1997-98	-	-	-	40 000	35 000	5000
1999	-	-	-	21 400[6]	16 400	5000
2000	27 February	-	-	27 700[6]	22 700	5000
2001-02	-	-	-	53 000[6]	48 000	5000
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]	7000
2010				7000	0	7000
2011				7000	0	7000
2012-13				7000	0	7000

Year	Opening Dates		Closing Date	Quota-Allocation		
	Soviet/Rus.	Norway		Total	Soviet/Rus.	Norway
2014				7000	0	7000
2015-16				19 200	12 200	7000
2017-19				10 090	3 090	7000
2020-23				21 172	14 172	7000

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, 1961–2019.

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 1800 for the Canadian Arctic. Greenland was allocated additional 10 000.
1981	TAC remained at 170 000 for Canadian waters including 1800 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.

Year	Management Measure
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 2000 for personal use and 2000 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, 6000 original initiative, and 2000 allocation each for Personal Use and Arctic catches
2007	TAC reduced to 270 000 including 263 140 for commercial, 4860 for Aboriginal, and 2000 for Personal Use catches
2008	TAC increased to 275 000 including a 268 050 for commercial, 4950 for Aboriginal and 2000 for Personal Use catches Implementation of requirement to bleed before skinning as a condition of licence
2009	TAC increased to 280 000 based upon allocations given in 2008 plus an additional 5000 for market development Additional requirements related to humane killing methods were implemented
2010	TAC increased to 330 000.
2011	TAC increased to 400 000.
2017	TAC no longer announced. Catches monitored

Table 4. Major management measures implemented for hooded seals in Canadian waters for 1964–2019.

Year	Management Measure
1964	Hunting of hooded seals banned in the Gulf area (below 50°N), 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 2340 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 8000. 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 8200 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.
2017	TAC no longer announced. Catches monitored.