ECOREGION   Barents and Greenland seas
SUBJECT   Status and harvest potential of the Harp seal stocks in the Greenland Sea and the White Sea/Barents Sea, and of the Hooded seal stock in the Greenland Sea

Advice summary

The harp seal stocks in the Greenland Sea and the White Sea/Barents Sea are increasing, and advice using three catch scenarios is provided for both stocks. The hooded seal stock in the Greenland Sea is well below N_{lim} (equal to 30% of the largest estimated population size), and thus the ICES advice is that no catch be allowed from this stock.

Request

In September 2010 the Norwegian Royal Ministry of Fisheries and Coastal Affairs requested ICES to:

Assess the status and harvest potential of harp seal stocks in the Greenland Sea and White Sea/Barents Sea and of the hooded seal stocks in the Greenland Sea, and

Assess the impact on the harp seal stocks in the Greenland Sea and the White Sea/Barents Sea of an annual harvest of:

1. *Current harvest levels,*
2. *Sustainable catches (defined as the fixed annual catches that stabilizes the future 1+ population),*
3. *Catches that would reduce the population over a 10-year period in such a manner that it would remain above a level of 70% of current level with 80% probability.*

ICES advice

The advice is structured as an update of relevant parts of the advice provided by ICES in 2008 (ICES, 2008a).

The request concerns three stocks of seals: Greenland Sea harp seals, White Sea/Barents Sea harp seals, and Greenland Sea hooded seals. The distribution of the stocks is shown in Figure 1.

Figure 1   Locations of North Atlantic harp and hooded seal stocks. Green spots indicate the whelping and moulting areas for the White Sea (also called the East Ice) stock of harp seals, the Greenland Sea or West Ice stocks of harp and hooded seals (West Ice), and the northwest Atlantic stocks (Front and Gulf areas) of harp and hooded seals. Dark blue indicates the entire distributional area.

Greenland Sea harp seals

The estimated size of the Greenland Sea harp seal stock in 2011 is 649 570 (SE = 138 028) animals, comprising 553 100 (SE = 136 030) age 1+ seals, and 96 470 (SE = 23 401) young of the year. In 2011, the existing population model was modified to incorporate historical reproductive rate data. This resulted in a smaller stock than that reported in 2008. However, this revised estimate is still the largest in the time series. All model predictions indicate an increase in stock size of 1+ animals on a ten-year scale, with the 10-year increase ranging from 31% to 49%, assuming no harvesting or other unanticipated pressure.

The Greenland Sea harp seal stock is considered to be 'data-rich' and above the N_{70} level (i.e., more than 70% of the known maximum stock size measured). Thus, it is appropriate to provide catch advice using the assessment model.

The analysis of catch options indicates the following:

- If the recent average catch (2007–2011) of 6 388 animals (63.4% pups) is maintained, the stock is expected to increase by 23% over 10 years.
- Sustainable catches are 25 410 animals (of which 63.4% are pups) or 16 737 (100% 1+ animals).
- Annual catches that would reduce the population over a 10-year period but would still maintain the stock above 70% of the current level with 80% probability are 35 000 animals (of which 63.4% are pups) or 25 000 (100% 1+ animals).

ICES regards 70% of the unexploited population size as the stock size associated with the maximum sustainable long-term average catch. This stock size (N_{70}) is estimated at 454,699 animals. The maximum sustainable long-term average catch is about 25 000 animals (of which 63.4% are pups) annually.

The current size of the Greeland Sea harp seal stock (i.e., 649 570 animals) is a record-high. Therefore N_{lim} (equal to 30% of the largest estimated population size) is estimated as 194 871 animals. ICES advises that this estimate of N_{lim} be regarded as the minimum sustainable size of the Greenland Sea harp seal stock. At or below this stock size, ICES recommends that there should be no catch.

White Sea/Barents Sea harp seals

The estimated size of the White Sea/Barents Sea stock is 1 364 700 animals (SE = 68 503). A recent survey estimated 163 032 (SE = 32 342) pups in the White Sea/Barents Sea , which is slightly higher than the estimates obtained from surveys conducted between 2005 (122 658; SE = 19 625) and 2009 (157 000; SE = 16 956). However, the recent pup estimate is considerably lower than survey estimates prior to 2004. The number of pups has substantially declined, presumably because of reduced reproductive rates.

The original population model for the White Sea/Barents Sea harp seal stock provides a poor fit to the pup production survey data. Incorporating fecundity data produced a lower estimate and a conservative projected population. Based on current data availability and the previously agreed criteria (three surveys within the past 15 years; one survey within the past five years; recent data on reproductive rates), the Barents Sea/White Sea harp seal stock is considered to be 'data-rich', and above the N_{70} level. Catch advice is provided using the modified assessment model.

- If the recent average catch (2007–2011) of 5 056 animals[1] (74.6% pups) is maintained, the stock is expected to increase by 11% over 10 years.
- Sustainable catches are 26 535 animals (of which 74.6% are pups) or 15 827 (100% 1+ animals).
- Annual catches that would reduce the population over a 10-year period but would still maintain the stock above 70% of the current level with 80% probability are 37 800 animals (of which 74.6% are pups) or 25 000 (100% 1+ animals)[2].

Greenland Sea hooded seals

The available historical data on pregnancy rates are unreliable. Hence, the assessment model was run using a range of pregnancy rates, in addition to a run using the original model assuming constant reproduction rates. All model runs indicate a current stock size well below N_{lim} of 233 700 animals (30% of the N_{max} estimate of 777 900 animals).

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[1] It should be noted that the average catch in the last three years has been 105 animals.

A population model, incorporating a reproduction rate of $F = 0.9$, produced a 2011 stock estimate of 67 770 1+ animals and 18 040 pups. The estimated total stock size of hooded seals in the Greenland Sea is therefore 85 810 animals (SE = 13 981).

- Following the precautionary harvest strategy previously developed by ICES (see ICES, 2006a) and given that the current stock size of 85 810 animals is well below N_{lim} (233 700 animals), ICES recommends that no harvest be allowed from the Greenland Sea hooded seal stock.

Background

Greenland Sea harp seals

State of stock/exploitation

The adult population is at the highest level estimated in the historical time-series. Based on previous (1983–1991) mark–recapture data and recent (2002, 2007) aerial survey data, the stock in 2007 is estimated to be 649 566 (SE = 138 028) seals. The Greenland Seal harp seal stock is considered data rich, and above the N_{70} level (i.e., more than 70% of the known maximum stock size measured).

The recent average annual catch (2007–2011) has been 6 388. The 2008 catches were 10 134 animals (including 5 361 pups) or 24% of the allocated quota of 42 225 seals. The quota has been implemented such that parts of, or the whole quota, could be taken as weaned pups, assuming two pups equaled one 1+ animal. Russia has not participated in this hunt since 1994.

Population estimates

Estimates of total population size are obtained from an age-structured model that incorporates information on reproduction (Tables 1 and 2) and catches (Table 3). In recent years catches have been much lower than the allocated quota (Table 4). The model is fitted to independent estimates of pup production (Table 5).

As suggested by ICES (2009), the model incorporates historical values of the reproductive rates (*F)* available from a Russian long-term data set and new Norwegian data from 2009 (Table 1). Hence, the pregnancy rate is no longer estimated, but considered a known quantity. In periods where data are missing, a linear transition between estimates is assumed. The proportion of mature females at age *i*, p_i, is no longer assumed to be constant for all years. The model utilizes two maturity curves; one for the period 1959 –1990 and the other for 2009 (Table 2). In the period 1990–2009, where data are missing, a linear transition between the two curves was assumed.

The estimated population sizes are presented in Table 6, along with the parameters for the normal priors used in the two model scenarios. The mean of the prior for M_0 was taken to be three times that of the mean of M_{1+}. The model estimates seem to be stable for various choices of precision of the prior of M_0 and M_{1+}. Changes in the mean of the priors of M_0 and M_{1+} had little effect on the model estimates.

All model runs seem to indicate a substantial increase in population size from the 1970s up to the present time (Figure 2). The model which included time-varying reproductive rates provides a 25% lower population estimate than the original model. All model predictions indicate an increase in the stock size of 1+ animals over the next ten years, with increases ranging from 31% to 49%, assuming no hunt.

In the time-varying model, the 2011 stock size estimates are 553 100 1+ animals and 96 470 pups. The total 2011 stock size of harp seals in the Greenland Sea is estimated at 649 566 (95% C.I. = 379 031–920 101).

Catch options

ICES was requested to provide advice on the implications of various catch options for harp seals in the Greenland Sea:

The projected stock sizes at different catch options, using the new and modified population model, are given in Table 7. If current catch levels are maintained, a 23% increase of the stock size is projected over 10 years. Sustainable catches are 25 410 (63.4% pups) or 16 737 (100% 1+ animals). An annual catch level of 35 000 (assuming 63.4% pups) or 25 000 (assuming 100% 1+ animals) would reduce the stock over a 10-year period such that the stock remains above 70% of the current level with 80% probability.
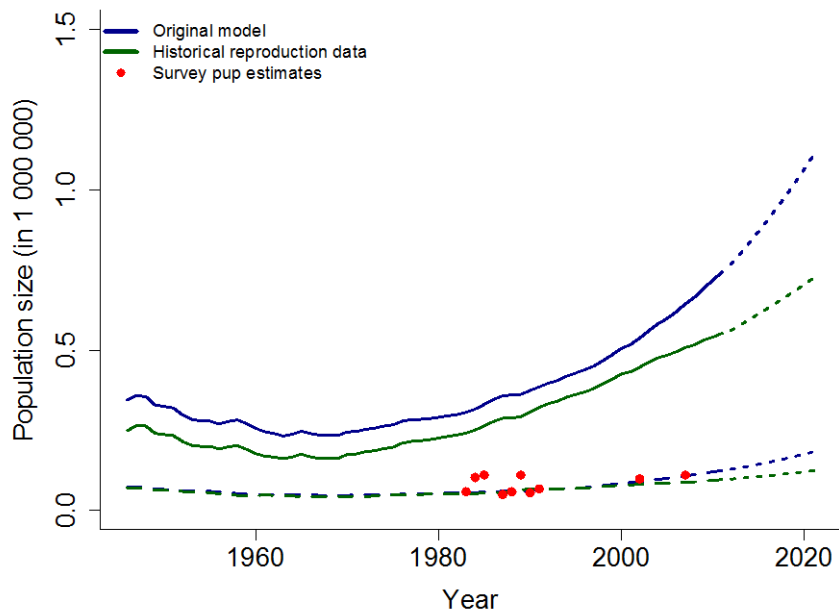
Figure 2   Greenland Sea harp seals: Estimated model trajectories for various reproduction rates. Full lines show 1+ abundance, dashed-dotted lines show pup abundances, and dashed lines show predictions from the original and the time-varying models. Red dots are estimated pup production.

Table 1   Reproduction rates, F_t, for harp seals in the Greenland Sea.

Year	Pregnancy rate	Standard Deviation
1964	0.92	0.04
1978	0.88	0.03
1987	0.78	0.03
1990	0.86	0.04
1991	0.83	0.05
2008	0.80	0.06
2009	0.81	0.03

Table 2   Estimates of proportions of mature females ($p_{i,t}$). The P_1 estimates are from the period 1959–1990 and the P_2 estimates are from 2009.

AGE	1	2	3	4	5	6	7	8	9	10	11	12	13
P_1	0	0	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	0	0	0	0.06	0.28	0.55	0.76	0.88	0.95	0.98	0.99	1.00

Table 3 Catches of harp seals in the Greenland Sea ("West Ice") from 1946 through 2011[a]. 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	26606	9464	36070	-	-	-	26606	9464	36070
1951–55	30465	9125	39590	-	-	-[b]	30465	9125	39590
1956–60	18887	6171	25058	1148	1217	2365[b]	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	9663[c]	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				5177	2918	8035
2010	2823	1855	4678				2823	1855	4678
2011	5361	4773	10134				5361	4773	10134

[a] The period 1946–1970 shows only 5-year averages.
[b] For 1955, 1956, and 1957 Soviet catches of harp and hooded seals were reported at 3900, 11,600 and 12,900, respectively. These catches are not included.
[c] Including 1431 pups and one adult caught by a ship which was lost.

Table 4 Summaries of Norwegian harp and hooded sealing regulations[1] for the Greenland Sea ("West Ice"), 1985–2011.

Year	Opening Date	Closing Date	Quotas				Allocations	
			Total	Pups	Female	Male	Norway	Soviet & Russia
Hooded Seals								
1985	22 March	5 May	(20,000)[2]	(20,000)[2]	0[3]	Unlim.	8,000[4]	3,300
1986	18 March	5 May	9,300	9,300	0[3]	Unlim.	6,000	3,300
1987	18 March	5 May	20,000	20,000	0[3]	Unlim.	16,700	3,300
1988	18 March	5 May	(20,000)[2]	(20,000)[2]	0[3]	Unlim.	16,700	5,000
1989	18 March	5 May	30,000	0	0[3]	Incl.	23,100	6,900
1990	26 March	30 June	27,500	0	0	Incl.	19,500	8,000
1991	26 March	30 June	9,000	0	0	Incl.	1,000	8,000
1992–94	26 March	30 June	9,000	0	0	Incl.	1,700	7,300
1995	26 March	10 July	9,000	0	0	Incl.	1,700[7]	7,300
1996	22 March	10 July	9,000[8]				1,700	7,300
1997	26 March	10 July	9,000[9]				6,200	2,800[11]
1998	22 March	10 July	5,000[10]				2,200	2,800[11]
1999–00	22 March	10 July	11,200[12]				8,400	2,800[11]
2001–03	22 March	10 July	10,300[12]				10,300	
2004–05	22 March	10 July	5,600[12]				5,600	
2006	22 March	10 July	4,000				4,000	
2007–11[14]			0	0	0	0	0	0
Harp Seals								
1985	10 April	5 May	(25,000)[2]	(25,000)[2]	0[5]	0[5]	7,000	4,500
1986	22 March	5 May	11,500	11,500	0[5]	0[5]	7,000	4,500
1987	18 March	5 May	25,000	25,000	0[5]	0[5]	20,500	4,500
1988	10 April	5 May	28,000	0[5,6]	0[5,6]	0[5,6]	21,000	7,000
1989	18 March	5 May	16,000	-	0[5]	0[5]	12,000	9,000
1990	10 April	20 May	7,200	0	0[5]	0[5]	5,400	1,800
1991	10 April	31 May	7,200	0	0[5]	0[5]	5,400	1,800
1992–93	10 April	31 May	10,900	0	0[5]	0[5]	8,400	2,500
1994	10 April	31 May	13,100	0	0[5]	0[5]	10,600	2,500
1995	10 April	31 May	13,100	0	0[5]	0[5]	10,600[7]	2,500
1996	10 April	31 May[8]	13,100[9]				10,600	2,500[11]
1997–98	10 April	31 May	13,100[10]				10,600	2,500[11]
1999–00	10 April	31 May	17,500[13]				15,000	2,500[11]
2001–05	10 April	31 May	15,000[13]				15,000	0
2006–07	10 April	31 May	31,200				31,200	0
2008	5 April	31 May	31,200				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

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

[2] Basis for allocation of USSR quota.

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

[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, small takes are allowed for scientific purposes only.

Table 5   Survey estimates of Greenland Sea harp seal pup production.

YEAR	ESTIMATE	C.V.
1983	58,539	0.10
1984	103,250	0.15
1985	111,084	0.20
1987	49,970	0.08
1988	58,697	0.18
1989	110,614	0.08
1990	55,625	0.08
1991	67,271	0.08
2002	98,500	0.18
2007	110,530	0.25

Table 6   Greenland Sea harp seals: Model estimates and standard deviation of the parameters used in the model for various choices of the reproduction rate F. Priors used are shown in brackets.

Parameters	Traditional NE model		Time-varying NE model	
	Mean	SE	Mean	SE
N_{t_0}	344 670 (900000)	63 755 (900000)	249 777	37 992
M_0	0.22 (0.24)	0.2 (0.2)	0.28	0.2
M_{1+}	0.10 (0.08)	0.02 (0.1)	0.11	0.02
F	0.79 (0.81)	0.02 (0.2)	NA	NA
$N_{0,2011}$	124 800	24 922	96 470	23 401
$N_{1+,2011}$	744 700	185 400	553 100	136 030
$N_{Total,2011}$	869 500	187 068	649 570	138 028

Table 7   Catch options with relative population size (D1+) and 95% confidence intervals over 10 years for harp seals in the Greenland Sea. The model with historical reproduction parameters is used when evaluating these catch options.

Option #	Catch level	Proportion of pups in catches	Pup catch	1+ catch	Total catch	D_{1+} Lower CI	Point	Upper CI
1	Current harvest	63.4%	4 046	2 341	6 387	0.92	1.23	1.54
2	Sustainable harvest	63.4%	16 110	9 300	25 410	0.61	1.00	1.40
3	Sustainable harvest	0%	0	16 737	16 737	0.65	1.02	1.40
5	Reduce to N_{70}	63.4%	22 190	12 810	35 000	0.45	0.89	1.32
6	Reduce to N_{70}	0%	0	25 000	25 000	0.46	0.88	1.31

White Sea/Barents Sea harp seals

State of stock/exploitation

Pup production in the White Sea/Barents Sea herd declined by approximately 50% between the 2004 and 2005 surveys. Pup production has remained low since then. Fitting the population model to the aerial survey data results in an estimated 2011 stock of 1 364 700 animals.

The average annual catch (2007–2011) has been 5056 animals, but catches have been much lower in the last three years, averaging 105 animals per year. This represents less than 1% of the quota allocated between Russia and Norway (45 100 and 10 000 seals, respectively). All of the 2010 harvest was taken by Norway.

Population estimates

Estimates of total population size are obtained from an age-structured model that incorporates information on reproduction (Tables 8 and 9) and catches (Table 10). In recent years catches have been much lower than the allocated quota (Table 11). The model is fitted to independent estimates of pup production (Table 12).

The model incorporates reproductive rates (*F*) as an input. Three approaches to incorporate reproductive rates into the model were examined.

- A constant maturity curve, p_4, and a constant pregnancy rate, *F*, estimated from the most recent reproductive sample from 2006 (see Tables 8 and 9).

- An adjusted model with time varying maturity curve, $p_{i,t}$, and a time-varying pregnancy rate, F_t (see Tables 8 and 9).The values used for the maturity curve are historical estimates and the latest estimate from 2006. Only four maturity curves are available. Where estimates were missing a linear interpolation was applied to estimate the maturity curve. A linear transition was also used for periods with missing pregnancy rates (i.e. a linear transition from 0.84 in 1990 to 0.68 in 2006). In the periods before 1990 the pregnancy rate was assumed constant at 0.84. In the periods after 2006 the pregnancy rate was assumed constant at 0.68.

- The pregnancy rate was assumed to be correlated with the condition of seals. This improved the fit of the model to the observed changes in pup production. But before this model can be used in the assessment further work is required to examine the functional relationship between changes in condition and changes in reproductive rates.

The estimated population sizes and the parameters for the normal priors used in the two first model scenarios are presented in Table 13. The mean of the prior for M_0 was taken to be three times that of the mean of M_{1+}. The model estimates seem to be stable for various choices of precision of the priors of M_0 and M_{1+}. Also changes in the mean of the priors of M_0 and M_{1+} did not affect the model estimates much.

Neither the original model nor the modified model using historical reproductive rate data were able to capture the observed survey pup production estimates properly. The model incorporating historical reproductive data provides a 2011 stock size of 1 172 000 (95% C.I. = 1 039 240–1 304 760) 1+ animals and 192 700 pups. The total estimated population is 1 364 700 (95% C.I. = 1 230 384–1 498 916) (Table 13; Figure 3).

Catch options

Based on current data availability and the criteria agreed to previously (three surveys within the past 15 years, one survey within the past five years, recent data on reproductive rates), the Barents Sea/White Sea harp seal stock is considered to be data rich and above the N_{70} level (i.e. more than 70% of known maximum stock size measured). Catch advice is provided using the assessment model incorporating time-varying reproductive rates.

The estimates for the three requested catch options are given in Table 14. By incorporating the full range of reproductive data available, the model provides a new (and lower) estimate of the total population. The catch options provided are, therefore, also lower than the catch options estimated in 2009. At current catch levels a stock increase of about 11% is predicted over the next 10 years. Sustainable catches are 26 535 (of which 74.6% are pups) or 15 827 (100% 1+ animals). Annual catches of 37 800 (of which 74.6% are pups) or 25 000 (100% 1+ animals) over a 10-year

period would reduce the stock such that the stock would remain above a level of 70% of the current level with 80% probability[2].
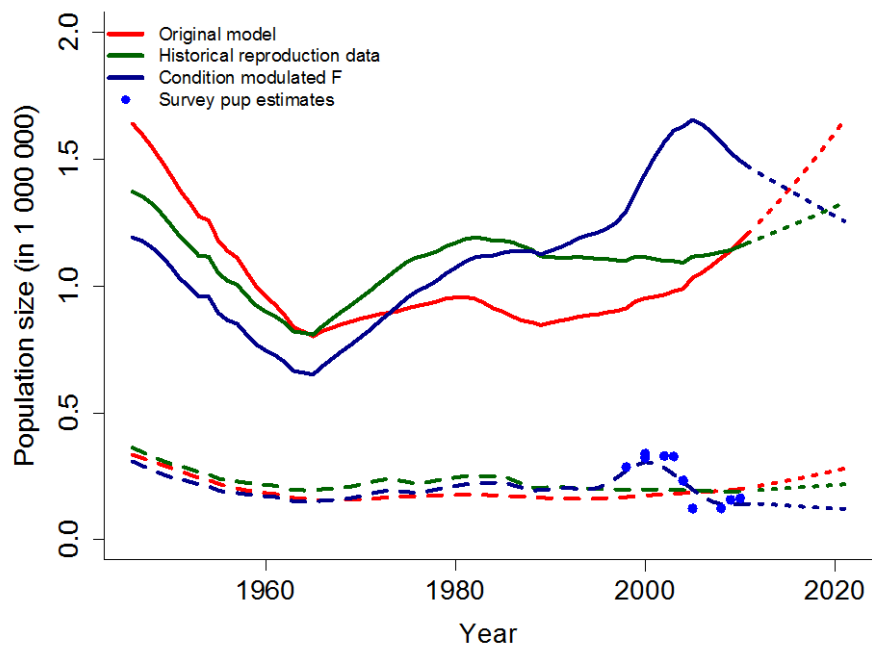

Figure 3   Modelling the Barents Sea/White Sea harp seal population: Population trajectories for pups (dashed lines) and the 1+ population (full lines) for all three scenarios. The model with reproduction varying with condition was examined, but further work is needed using this approach, and additional results are not included here. The dotted lines show model predictions, blue dots are survey pup production estimates.

Table 8   Estimates of proportions of mature females (p) at ages 2–15 in four historical periods: P_1 = 1962–1972; P_2 = 1976–1985; P_3 = 1988–1993; and P_4 = 2006–2009.

Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P_1	0	0.01	0.17	0.64	0.90	0.98	0.99	1.0	1.0	1.0	1.0	1.0	1.0	1.0
P_2	0	0	0	0.24	0.62	0.81	0.81	0.95	0.98	0.99	0.99	1.0	1.0	1.0
P_3	0	0	0.02	0.08	0.21	0.40	0.59	0.75	0.85	0.91	0.95	0.97	0.98	0.99
P_4	0.01	0.02	0.05	0.11	0.25	0.55	0.90	0.99	1.0	1.0	1.0	1.0	1.0	1.0

Table 9   Estimates of proportion of females giving birth.

Year	Estimated F
1990–93	0.84
2006	0.68

[2] Note that the White Sea/ Barents Sea stock is approximately double the size of the Greenland Sea stock. However, because fecundity is lower in the White Sea/Barents Sea, the catch advice is similar in both areas.

Table 10   Annual catches of harp seals in the White and Barents seas ("East Ice"), 1946–2008[a,b].

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	6212[c]	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	17465[d]	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	2501[e]	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	8758[f]	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

[a] The period 1946–1970 shows only 5-year averages.
[b] Incidental catches of harp seals in fishing gear on Norwegian and Murmansk coasts are not included.
[c] Approx. 1300 harp seals (unspecified age) caught by a ship which was 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 14°E, by a ship operating mainly in the Greenland Sea.

Table 11   Summary of sealing regulations for the White and Barents seas ("East Ice") harp seals, 1979–2011.

Year	Opening dates		Closing date	Quota allocation		
	Soviet/Rus.	Norway		Total	Soviet/Rus.	Norway
1979–80	1 March	23 March	30 April[1]	50,000[2]	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 April[1]	80,000	61,000	19,000
1988	-	-	-	70,000	53,400	16,600
1989–94	-	-	-	40,000	30,500	9,500
1995	-	-	-	40,000	31,250	8,750[3]
1996	-	-	-	40,000	30,500	9,500
1997–98	-	-	-	40,000	35,000	5,000
1999	-	-	-	21,400[4]	16,400	5,000
2000	27 February	-	-	27,700[4]	22,700	5,000
2001–02	-	-	-	53,000[4]	48,000	5,000
2003	-	-	-	53,000[4]	43,000	10,000
2004–05				45,100[4]	35,100	10,000
2006	-	-	-	78,200[4]	68,200	10,000
2007	-	-	-	78,200[4]	63,200	15,000
2008	-	-	-	55,100[4]	45,100	10,000
2009	-	-	-	35,000	28,000	7,000
2010				7,000	0	7,000
2011				7,000	0	7,000

[1] The closing date may be postponed until 10 May if necessitated by weather or ice conditions.
[2] Breeding females protected (all years).
[3] Included 750 weaned pups under permit for scientific purposes.
[4] Quotas given in 1+ animals; parts of or the whole quota could be taken as pups, where 2.5 pups equal one 1+ animal.

Table 12   Timing of Russian surveys, estimated numbers of pups, and coefficients of variation (CV) in the White Sea/Barents Sea.

Year	Survey period	Estimated number of pups	Coefficient of variation
1998	12 & 16 March	286,260	0.150
2000	10–12 March – photo	322,474[a]	0.098
	18 March – multispectral	339,710[b]	0.105
2002	20 March	330,000	0.103
2003	18 & 21 March	328,000[c]	0.181
2004	22 March – photo	231,811	0.190
	22 March – multispectral	234,000	0.205
2005	23 March	122,658	0.162
2008	19–20 March	123,104	0.199
2009	14–16 March	157,000	0.108
2010	20–23 March	163,032	0.198

a. The first 2000 estimate is the sum of 291 745 pups (SE = 28 708) counted plus a catch of 30 729 prior to the survey, leading to a total pup production of 322 474.
b. The second 2000 estimate is the sum of 308 981 pups (SE = 32 400) counted plus a catch of 30 729 prior to the survey, leading to a total pup production of 339 710.
c. The 2003 estimate is the sum of 298 000 pups (SE = 53 000) counted plus a catch of 35 000 prior to the survey, leading to a total pup production of 328 000.

Table 13   Barents Sea/White Sea harp seals: Model estimates and standard deviation of the parameters used in the model for various choices of the reproduction rate F. Priors used are shown in brackets.

Parameters	Traditional model		Time-varying model		Model with historical values of $p_{i,t}$ and condition modelled F_t	
	Mean	SE	Mean	SE	Mean	SE
N_{t_0}	1 639 253 (1 000 000)	128 090 (200 000)	1 372 033	122 590	1 181 366	105 220
M_0	0.33 (0.30)	0.05 (0.05)	0.35	0.05	0.30	0.05
M_{1+}	0.10 (0.09)	0.03 (0.008)	0.11	0.01	0.09	0.01
$N_{0,2011}$	205 000	10 785	192 700	10 216	142 700	8 879
$N_{1+,2011}$	1 212 000	70 029	1 172 000	67 737	1 485 000	97 722
$N_{Total,2011}$	1 417 000	70 855	1 364 700	68 503	1 627 700	98 125

Table 14   Catch options with relative population size (D1+) in 2021 for harp seals in the Barents Sea/White Sea.

Option #	Catch level	Proportion of pups in catches	Pup catch	1+ catch	Total catch	D_{1+} Lower CI	Point	Upper CI
1	Current	74.6%	3 771	1 285	5 056	1.00	1.11	1.23
2	Sustainable	74.6%	19 795	6 740	26 535	0.89	1.00	1.12
3	Sustainable	0%	0	15 827	15 827	0.90	1.01	1.13
5	Reduce to N_{70}[a]	74.6%	28 199	9 601	37 800	0.83	0.95	1.06
6	Reduce to N_{70}[a]	0%	0	25 000	25 000	0.84	0.95	1.06

Greenland Sea hooded seals

State of stock/exploitation

Concerns over low pup production estimates resulted in advice from ICES that no harvest of Greenland Sea hooded seals should be permitted, with the exception of catches for scientific purposes, from 2007 on (ICES, 2006b). This advice was immediately implemented.

Results from the 2007 pup survey suggest that pup production (16 140 pups, CV = 0.13) remains low and was significantly lower than observed in the 1997 survey (24 000 pups, CV = 0.28). Model explorations indicate a substantial decrease in stock size from the late 1940s and up to the early 1980s. The results suggest that the stock may have stabilized at a low level over the past 20 years, but the current trajectory remains uncertain.

The stock is estimated to be well below N_{lim}. As a result, ICES recommended in 2008 (ICES, 2008a) that there be no catch of Greenland Sea hooded seals. There was no catch in 2007–2008. ICES continues to advise that there shall be no catch of Greenland Sea hooded seals.

Population estimates

The population model used to assess the stock size is an age-structured population dynamics model. The model is similar to the model assessing the stock of the Barents Sea/White Sea harp seal population and has been modified to incorporate historical maturity curves and historical pregnancy rates (Table 15). The available data on pregnancy rates are unreliable. Hence, the model was run for a range of pregnancy rates. All runs indicate a population currently well below N_{lim} of 233 700 (30% of the N_{max} estimate of 777 900).

The model incorporates catches into the model structure (Table 16). In recent years there have been no catches except for the removal of animals for scientific reasons (Table 4). The model is fitted to independent estimates of pup production to estimate the current total population (Table 17).

The model incorporated the only measured historical reproductive rate which consists of one estimate from the 1990s. Consequently, the model was run for a range of pregnancy rates. In addition to a run using the original model assuming constant reproductive rates, three additional scenarios, with F = 0.5, F = 0.7, and F = 0.9 were also run. The estimated population sizes, along with the parameters for the normal priors used in the model scenarios, are presented in Table 18. The mean of the prior for M_0 was taken to be three times that of the mean of M_{1+}. The model estimates seem to be stable for various choices of precision of the priors of M_0 and M_{1+}. Also, changes in the mean of the prior of M_0 and M_{1+} did not affect the model estimates much.

Using a reproduction rate of F = 0.9, the 2011 stock estimates of 67 770 1+ animals and 18 040 pups are obtained. The total 2011 stock of hooded seals in the Greenland Sea is estimated at 85 810 (95% C.I. = 58 407–113 212) seals of all ages (Figure 4).

Catch options

The Greenland Sea hooded seal stock in 2007 was well below N_{lim}. It is recommended that no harvest be allowed for Greenland Sea hooded seals at this time.
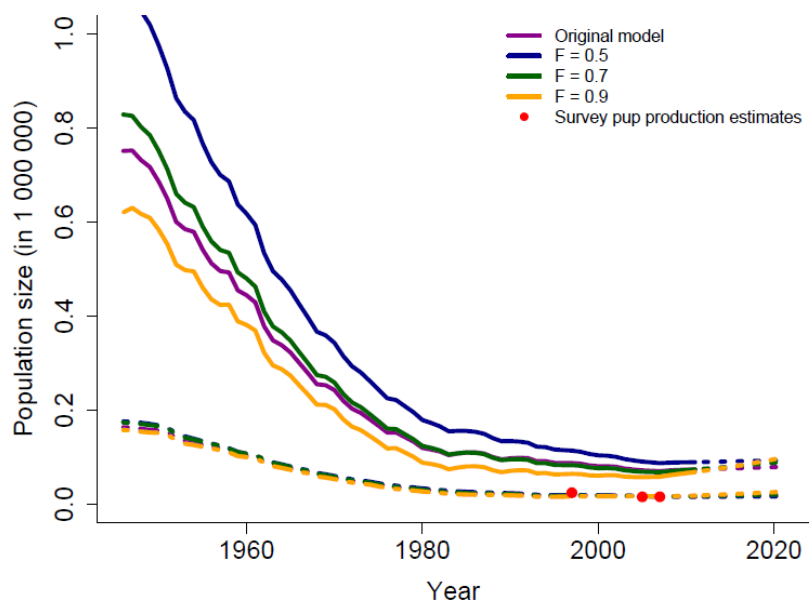
Figure 4   Greenland Sea hooded seals: Estimated model trajectories for various model scenarios. Full lines show 1+ abundance, dashed-dotted lines show pup abundances, and dashed lines show model predictions. Red dots are results from aerial pup production estimations.

Table 15   Estimates of proportions of mature females ($p_{i,t}$). The P_1 estimates are from data collected in 1990–1994 and the P_2 estimates are from 2008 and 2010.

Age	1	2	3	4	5	6	7	8	9	10	11
P_1	0	0.05	0.27	0.54	0.75	0.87	0.93	0.97	0.98	0.99	1.00
P_2	0.02	0.11	0.45	0.82	0.95	0.99	1.00	1.00	1.00	1.00	1.00

Table 16   Catches of hooded seals in the Greenland Sea ("West Ice") from 1946 through 2008[a]. 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	1888[b]	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	6149[c]	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

[a] The period 1946–1970 shows only 5-year averages.
[b] For 1955, 1956, and 1957 Soviet catches of harp and hooded seals combined are reported at 3900, 11,600 and 12,900, respectively. These catches are not included.
[c] Including 1048 pups and 435 adults caught by a ship which was lost.

Table 17   Survey estimates of Greenland Sea hooded seal pup production.

Year	Estimate	c.v.
1997	24,000	0.28
2005	15,200	0.25
2007	16,140	0.13

Table 18   Model estimates and standard deviation of the parameters used in the model for the original and for various choices of the reproductive rate F. Priors used are shown in brackets. D is the ratio of the projected 2021 population to the current population.

Parameters	Original		F = 0.5		F = 0.7		F = 0.9	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
N_{t_0}	751 323 (90 000)	465 170 (90 000)	1 102 995 (90000)	582 510 (90000)	828 739	498 990	620 564	379 970
M_0	0.33 (0.33)	0.05 (0.05)	0.33 (0.33)	0.05 (0.05)	0.34	0.05	0.34	0.05
M_{1+}	0.15 (0.11)	0.03 (0.05)	0.13 (0.11)	0.03 (0.05)	0.16	0.05	0.16	0.04
F	0.86 (0.88)	0.1 (0.1)	NA	NA	NA	NA	NA	NA
$N_{0,2011}$	15 340	2 967	15 690	2 563	16 710	3 120	18 040	3 723
$N_{1+,2011}$	73 340	13 963	88 860	14 280	73 440	13 336	67 770	13 476
$N_{Total,2011}$	88 680	14 275	104 550	14 500	90 150	13 695	85 810	13 981
D_{1+}	1.08	0.34	1.05	0.23	1.22	0.36	1.46	0.54

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