STATUS OF NORTHWEST ATLANTIC HARP SEALS, *PAGOPHILUS GROENLANDICUS*

Image: Harp seal

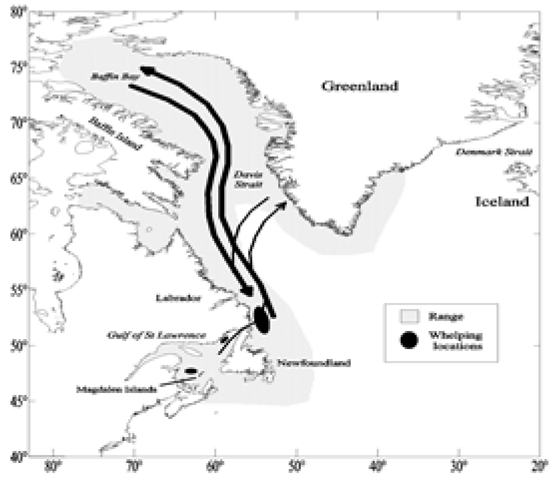


Figure 1. Range, migratory pathways and whelping locations of harp seals in the northwest Atlantic.

Context:

The harp seal is an abundant, medium-sized seal which migrates annually between Arctic and sub-Arctic regions of the north Atlantic. Three populations are recognized: the White Sea/Barents Sea, the Greenland Sea and the Northwest Atlantic. The northwest Atlantic population summers in the eastern Canadian Arctic and Greenland. In the fall, these seals migrate southward to Atlantic Canadian waters where they give birth on the pack ice in the Gulf of St. Lawrence ("Gulf") or off northern Newfoundland ("Front") during late February or March, then return to the north.

Northwest Atlantic harp seals are hunted throughout their range. They are harvested for subsistence purposes by Inuit in Labrador, Arctic Canada and Greenland, and a commercial harvest occurs in the Gulf and at the Front. Approximately 80,000 animals are taken during subsistence harvests, mainly in Greenland. The commercial harvest removed over 300,000 seals per year between 2002 and 2006, but has declined to less than 100,000 seals per year since 2009 due to difficult ice conditions and weaker markets. Over 95 % of the commercial harvest consists of young of the year. Approximately 12,000 seals are estimated to be removed incidentally during commercial fishing activities.

Subsistence harvests are currently not regulated while the commercial harvest is regulated by a five-year (2014-18) management plan.

Science was requested to evaluate the risk that the population will drop below 50 % and 70 % of the maximum population observed (N_{max}) at a Total Allowable Catch (TAC) of 300,000, 400,000, 500,000 and 600,000 with a composition of: 30 % adults / 70 % beaters; 10 % adults / 90 % beaters; 5 % adults / 95 % beaters. Science was also asked to identify the 'triggers' that could be used to indicate a need to reassess the population and multi-year TAC before the end of the management plan.

This Science Advisory Report (SAR) is from the October 7-11, 2013 Annual Meeting of the National Marine Mammal Peer Review Committee (NMMPRC). Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- Northwest Atlantic harp seals are harvested in Canadian and Greenland waters. Canadian commercial catches have declined from a peak reported catch of 355,000 in 2006 to 91,000 in 2013. Greenland catches have fluctuated, between 66,100 and 92,200 animals since 2003. Catches in the Canadian Arctic remain low (< 1,000). Additional removals include bycatch, as well as estimates of animals killed, but not recovered (struck and loss). Total annual removals have been less than 250,000 animals since 2009.
- Females age 8 years and older (8 +) account for approximately 70 % of the pup production. Pregnancy rates for these ages were high throughout the 1960s, but have declined particularly since the early 2000s.
- Harp seals require stable ice as a platform for resting, pupping and rearing their young. The annual extent of ice cover in Atlantic Canada has varied considerably over the last 44 years, particularly in the Gulf of St Lawrence (Gulf), where overall total ice cover has declined. An estimate of mortality of young of the year caused by poor ice conditions has been incorporated into the assessment. If the frequency of winters with poor ice cover observed over the past decade continues or increases, continued breeding in the southern Gulf may be markedly reduced or cease.
- Photographic and visual aerial surveys flown in the Gulf, Strait of Belle Isle, and off Newfoundland (Front) during 27 February – 16 March, 2012 resulted in pup production estimates of 115,500 (SE=15,000), 74,100 (SE=12,400) and 601,400 (SE=66,900), respectively. Combining these estimates resulted in an estimated total pup production of 790,000 (SE=69,700, CV=8.8%).This estimate is significantly lower than that estimated in 2008, in part due to lower reproductive rates.
- The population assessment model used as input data the time series of pup production estimates, including the 2012 estimate, as well as reproductive rates, estimates of ice-related mortality and harvest information to 2013. The model estimated 2012 pup production to be 929,000 (SE=148,000) and a total population of 7,445,000 (SE=698,000). Projecting the model to 2014 results in an estimated pup production of 853,000 (SE=202,000) and a total population size of 7,411,000 (SE=656,000). The population appears to be relatively stable, showing little change in abundance since 2004.
- The Atlantic Seal Management Strategy identifies three reference levels based upon the maximum observed population, which is referred to as N_{max}. The first reference level is a precautionary level called N_{70} that is set at 70 % of N_{max}. A secondary precautionary reference level, known as N_{50}, is set at 50 % of N_{max}, and a critical limit reference level, known as N_{30}, is set at 30 % of N_{max}. Based upon the current model, N_{max} was estimated to be 7.8 million, N_{70}=5.5 million, N_{50}=3.9 million and N_{30}=2.3 million animals.
- Assuming that the Greenland harvest, reproductive rates (average=0.34), and ice-related mortality remain within the range of values observed over the last 5 years, harvests of 125,000, 100,000, and 75,000 animals consisting of 95 %, 90 % and 70 % Young-of-the-Year (YOY), respectively, would result in an 80% likelihood of remaining above N_{70}. Harvests of 250,000, 225,000 and 150,000 seals consisting of 95 %, 90 % and 70 % YOY, respectively is estimated to have an 80 % likelihood of remaining above N_{50}.
- Assuming a harvest of 95 % young of the year and reproductive rates similar to those seen over the past 5 years, the probabilities that the population would decline below N_{70}, with catches of 300,000, 400,000, 500,000 and 600,000 would be 0.68, 0.91, 0.98 and 1,

respectively. The probability for similar catches to result in the population declining below N_{50} would be 0.29, 0.6, 0.85, and 0.96 respectively. The probability of the population declining below these thresholds would be greater if the proportion of young in the catch declines to 90 % or 70 %.

- Assuming that the Greenland harvest, reproductive rates (average=0.48) and ice-related mortality remained within the range of values observed over the last 10 years, then a harvest of 325,000, 275,000, and 175,000 animals would have an 80 % probability of the population remaining above N_{70} for an age composition of the harvest of 95 %, 90% and 70 % YOY respectively. Harvests of 450,000, 375,000 and 225,000 animals would have an 80 % probability of respecting N_{50} assuming age compositions of the harvest of 95 %, 90 % and 70% YOY.
- Given reproductive rates observed over the past 10 years and a catch of 95 % YOY, the probabilities that catches of 300,000, 400,000, 500,000 and 600,000 would result in the population declining below N_{70} were 0.16, 0.35, 0.59 and 0.80 respectively. The probabilities that the population would decline below N_{50} were 0.04, 0.11, 0.28, and 0.49. Harvests consisting of lower proportion of YOY would have lower probabilities of maintaining a population above the respective reference levels.
- Assuming a similar approach to incorporating uncertainty in the population estimates, harvest levels set based on N_{50} increased the risk of falling into the critical zone when compared to using the current approach of using N_{70}. Overall, it is likely that the risk of falling below the precautionary thresholds (N_{70} and N_{50}) and, subsequently, the critical limit (N_{30}) is underestimated. For example, if future reproductive rates are more similar to rates that have been observed over the last 5 years, a harvest level based upon an assumption of 10 year average rates would result in an overharvest by 40-50 %.
- The status of the harp seal population is assessed every 4-5 years coincident with a new estimate of pup production. Since the harvest targets YOY, and females are not fully recruited until they are 8-10 years old, a decline in pup production, resulting from very high exploitation rates or unusual mortality will not be detected for a minimum of 10-15 years. Setting a harvest level based upon N_{50} will result in a higher risk that the population will fall into the critical zone before such declines can be detected.
- Reproductive rates of females have been declining since the 1980s in response to increased population size and an increase in the occurrence of late term abortions. The abortion rate appears to be influenced by prey availability and ice conditions, either as a direct influence on pupping habitat or as a proxy for other ecosystem changes. These ecosystem changes are predicted to continue. Therefore, it is likely that reproductive rates will remain low.
- Several factors should be monitored to determine if a multiyear TAC should be re-evaluated. In general, significant changes in any of the major assumptions used in the projections should trigger a new analysis; the most important being annual reproductive rates. Significant changes in the age structure of the harvest or mortality, particularly Greenland harvest or pup mortality associated with poor ice conditions, should also result in a re-analysis.

INTRODUCTION

Background

Aerial surveys to estimate pup production were carried out in March 2012. Data on recent reproductive rates and removals were also available. Using these data, the current status of the Northwest Atlantic harp seal population was assessed. The estimates of total population presented here are based upon a population model that incorporates pup production estimates, as well as reproductive rates, Canadian harvest information and ice related mortality to 2013, and Greenland harvest information to 2011.

Northwest Atlantic harp seals have been managed under the Atlantic Seal Management Strategy. They are considered to be a data-rich population and have been managed for the last decade to maintain an 80 % probability that the population remains above a precautionary reference level (N_{70}) which was defined to be 70 % of the maximum estimated population size.

Species Biology

The Northwest Atlantic population of harp seals summers in the Canadian Arctic and Greenland. In the fall, most of these seals migrate southward to the Gulf of St. Lawrence ("Gulf"), or to the area off southern Labrador and northern Newfoundland ("Front") where they give birth in late February or March on medium to thick first year pack ice. Male and female harp seals are similar in size with adults averaging 1.6 m in length and 130 kg in weight prior to the breeding season. Females nurse a single pup for about twelve days, after which they mate and then disperse. The pup, known as a whitecoat, moults its white fur at approximately three weeks of age after which it is referred to as a beater. Older harp seals form large concentrations on the sea ice off northeastern Newfoundland and in the northern Gulf of St. Lawrence to moult in April and May. Following the moult, seals disperse and eventually migrate northward. Small numbers of harp seals may remain in southern waters throughout the summer while a portion of the population remains in the Arctic.

The Hunt

Harp seals have been hunted commercially since the early 18th century. The largest catches were documented off Newfoundland with catches of over 700,000 animals in the early 1800s. A ban on the importation of whitecoat pelts implemented by the European Economic Community in 1983 severely reduced the market, ending the traditional large-vessel hunt, and subsequent catches were low, averaging ~ 50,000 per year until 1996 (Fig. 2). Catches increased in the mid-1990s with an average of 262,000 seals taken annually between 1996 and 2002. From 2003-05, a multiyear quota was set at 975,000 seals. A total of 985,312 animals were taken over the three years of this plan (Table 1). Catches in recent years have been extremely low (< 100,000), due to a combination of poor ice conditions, reduced effort and alternative fisheries. Young of the year (YOY) seals that have moulted their whitecoat ('beaters') make up over 95 % of the harvest since 2000.

The largest subsistence harvest occurs in Greenland. Over the last decade catches have varied between a low of 66,000 in 2003 to as many as 90,000 in 2010 (Table 1). Seals of all ages are taken in Greenland with the majority being over one year of age. Catches in the Canadian Arctic are not well documented, but appear to be low with likely fewer than 1,000 harp seals taken annually in recent years.

Table 1. Canadian commercial (plus TAC) and Greenland catches of harp seals (,000s), 2000-13.

Canada-TAC

2003-5	2006	2007	2008	2009	2010	2011	2012	2013
975[1]	335	270	275	280	330	400	400	400

Canada - Catch

2003-5	2006	2007	2008	2009	2010	2011	2012	2013
985.3	354.9	224.7	217.8	76.7	69.1	40.4	71.5	90.7

Greenland - Catch

2003-5	2006	2007	2008	2009	2010	2011	2012	2013
66.1	92.2	82.8	80.6	72.1	90.0	74.0	NA	NA

[1] Taken over three years.

Other Sources of Human-Induced Mortality

In addition to reported catches, some seals are killed, but not recovered or reported (referred to as ‘struck and lost’). Estimates of the additional mortality caused by struck and lost for young seals during the large vessel, whitecoat hunt (prior to 1983) are considered to be low (~ 1%). Since then, loss rates of YOY seals, which make up the majority of the current harvest in Canada, appear to be 5 % (or less) while losses of older seals are higher (assumed to be 50 % of those killed). This higher figure is also applied to all catches in the Canadian Arctic and Greenland when estimating total removals (Fig. 3).

Harp seals are also taken as bycatch in fishing gear. The Newfoundland lumpfish fishery is thought to be responsible for the largest bycatch mortality of seals. Estimates are not available for seals caught in other fisheries in Canada. The highest bycatch of harp seals was estimated to occur during 1992-96 with average catches of 29,431 animals per year. By 2003, bycatch was estimated to be less than 5,500. Estimates of bycatch levels in the last decade are not available and so the average annual level during the previous decade (12,000) has been assumed. A small number of harp seals (< 500/yr) are also taken in fishing gear in the northeastern United States.

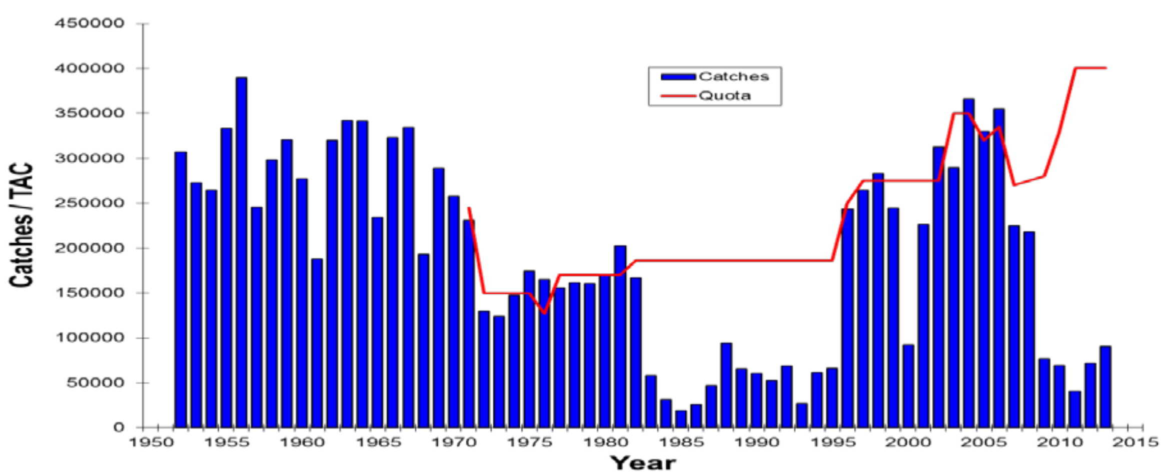


Figure 2. Canadian commercial Catch and TAC of harp seals, 1952-2013.

To estimate the total removals, reported catches in Canada and Greenland are combined with estimates of bycatches and struck and lost. Between 1996 and 2004, higher catches in Canada and Greenland resulted in average annual removals of 468,500. Estimated total annual removals have been less than 250,000 since 2009 (Fig. 3). Young of the year have declined from approximately 67 % of the total removals during the years 2001-08 to around 42 % since 2009.

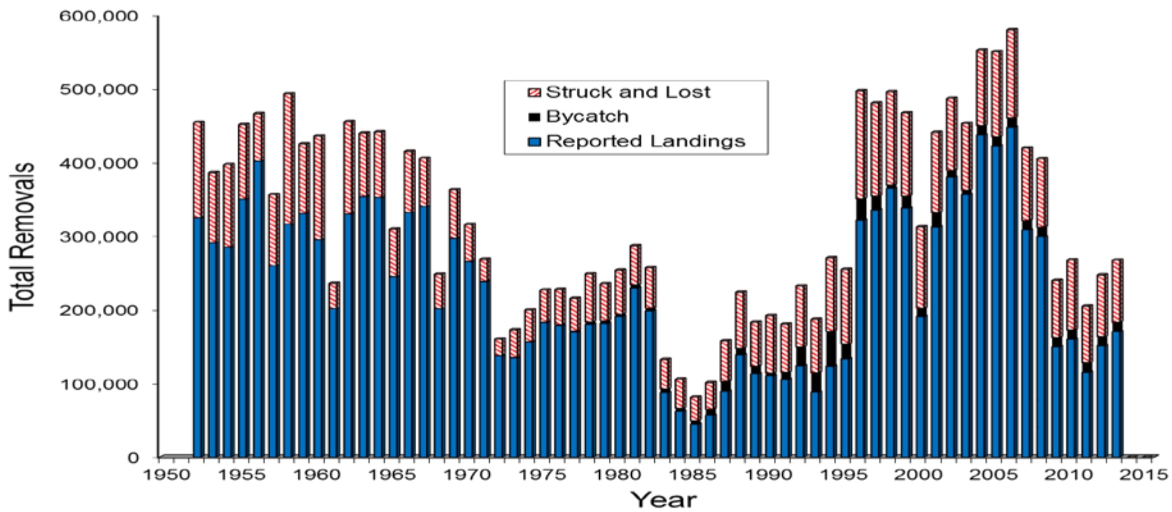


Figure 3. Total removals of Northwest Atlantic harp seals, 1952-2013.

ASSESSMENT

Resource Status

The number of harp seal pups born in a year is estimated periodically from surveys flown in the spring when the seals are gathered on the ice to have their pups. Estimates of total population are based on a population model that incorporates estimates of pup production with information on annual reproductive rates, catches in Canada and Greenland, bycatch, struck and lost, and information on unusual pup mortality due to poor ice conditions.

In the past, pup production has been estimated from catch data, mark-recapture experiments, and aerial surveys. Estimates for the mid to late 1970's ranged from approximately 250,000 to 500,000. The Royal Commission on Seals and Sealing in Canada concluded that pup production in 1978 was about 300,000-350,000 and the total population was about 1.5-1.75 million. Aerial surveys, off the Front and in the Gulf of St. Lawrence, indicate that pup production has increased from 577,900 in 1990 to a maximum of 1.6 million in 2008 (Table 2).

Photographic and visual aerial surveys were flown in the Gulf of St. Lawrence, Strait of Belle Isle, and off Newfoundland (Front), to determine harp seal pup production between 27 February and 16 March, 2012. Estimated pup production in the southern Gulf was 115,500 (SE=15,300) animals. Surveys of the Strait of Belle Isle and at the Front resulted in estimates of 74,100 (SE=12,400) and 601,400 (SE=66,900) pups, respectively. Combining these areas resulted in an estimated total 2012 pup production of 790,000 (SE=69,700, CV=8.8 %) (Table 2). This estimate is approximately one half of the number of pups estimated in 2008, but similar to the numbers estimated to have been born in 1994, 1999 and 2004 (Fig. 6). Overall, the proportion of pups born in the southern Gulf of St Lawrence has declined from a high of 28 % in 1994 to 15 % in 2012 (Table 2).

Table 2. Northwest Atlantic harp seal pup production estimates from aerial surveys completed since 1990 (with SE) and the proportion of pups in each component. Northern Gulf component in 2012 was part of the 'Strait' concentration.

Pup Production Estimates

Year	Southern Gulf	Northern Gulf	Front	Total
1990	106,000 (23,000)	4,400 (1,300)	467,000 (31,000)	578,000 (39,000)
1994	198,600 (24,200)	57,600 (13,700)	446,700 (57,200)	702,900 (63,600)
1999	176,200 (25,400)	82,600 (22,500)	739,100 (96,300)	997,900 (102,100)
2004	261,000 (25,700)	89,600 (22,500)	640,800 (46,900)	991,400 (58,200)
2008	287,000 (27,600)	172,600 (22,300)	1,185,000 (112,500)	1,644,500 (117,900)
2012	115,500 (15,300)	74,100 (12,400)	601,400 (66,900)	791,000 (69,700)

Proportions

Year	Southern Gulf	Northern Gulf	Front
1990	0.18	0.01	0.81
1994	0.28	0.08	0.64
1999	0.18	0.08	0.74
2004	0.26	0.09	0.65
2008	0.17	0.11	0.72
2012	0.15	0.09	0.76
Average	0.20	0.08	0.72
SD	0.05	0.03	0.07

The reproductive rates of female harp seals are important factors in determining the dynamics of this population. The mean age at which females become sexually mature was 5.8 years in the mid-1950s, declining to ~ 4.5 years of age from the late 1970s through the mid-1980s, then increasing to 5.7 years by the mid-1990s. It has remained high since then. Annual age-specific pregnancy rates were estimated by smoothing the raw pregnancy-rate data over the period 1954–2013 (Fig. 4). Pregnancy rates among 4 to 6 year olds were low during the 1950s and early 1960s, after which they increased to reach maximum levels in the 1980s, and then declined. Animals aged 8 + years account for over 70 % of the total pup production. Reproductive rates of these animals were high until the 1980s, but have generally declined since then, although there is considerable variability among years (Fig. 4). The general decline in fecundity is thought to be a reflection of density dependent processes associated with increased population size. The large inter-annual variability is influenced by the occurrence of late term abortions in some years.The occurrence of abortions appear to be related to prey availability and mid-winter ice conditions, either directly as an indicator of breeding habitat or as a proxy for ecosystem productivity. Climate change models predict that ice conditions will continue to deteriorate suggesting that reproductive rates may, on average, remain low.

Harp seals require stable ice as a platform for resting, pupping and rearing their young. The annual extent of ice cover in Atlantic Canada has varied considerably over the last 44 years, particularly in the Gulf, where overall total ice cover has declined (Fig. 5). This decline reduces early YOY survival and mortality of young of the year associated with very poor ice conditions has been incorporated into the assessment since 2003. If the frequency of winters with poor ice cover continues or increases, pup production in the Gulf will likely decline.

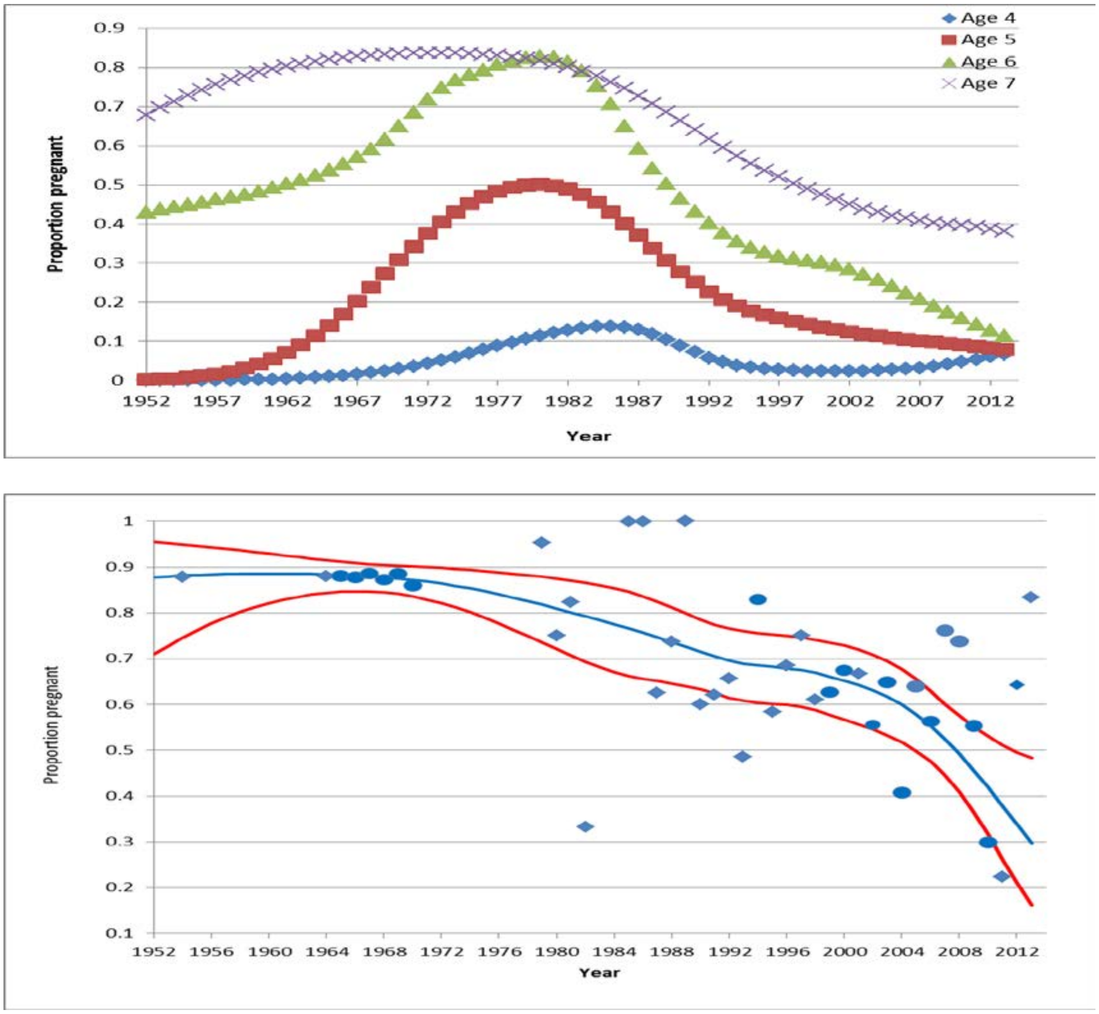
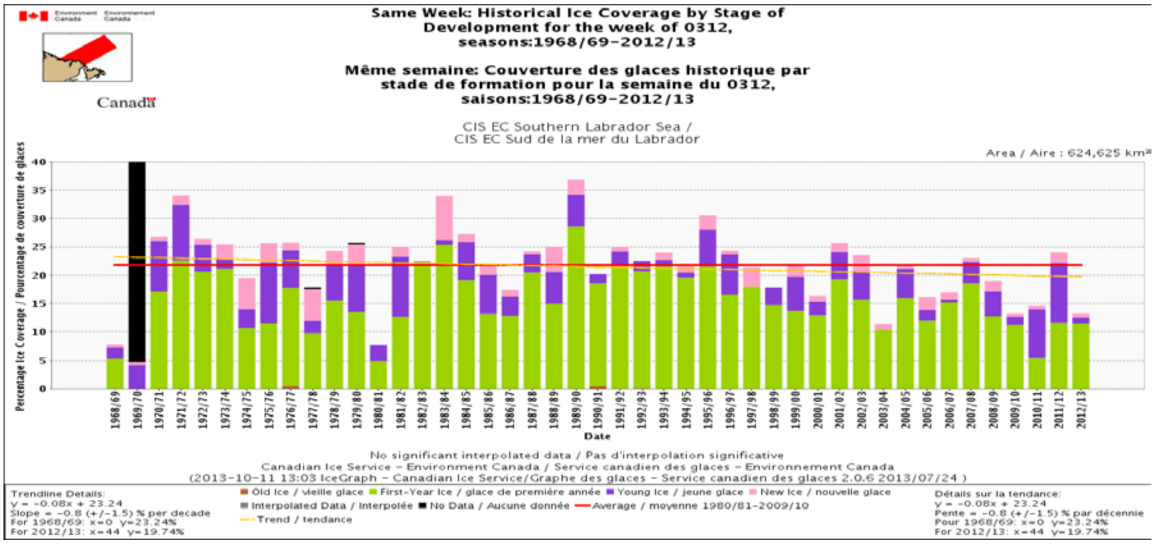


Figure 4. Smoothed estimates of age-specific pregnancy rates of northwest Atlantic harp seal females age 4 to 7 years old (top). Observed and smoothed reproductive rates ± 95 % confidence intervals of female harp seals aged 8 + years, 1952-2013 (bottom).Circles represent samples of more than 40 animals.

The Northwest Atlantic harp seal population has increased significantly over the past four decades. The general decline in reproductive rates over this period, as well as a decline in size at age suggests that the population is approaching its environmental carrying capacity (K). It is likely that juvenile survival is also declining, but mortality rate data are not available. These density dependent changes are affecting the dynamics of this population although it is very difficult to determine the exact relationship between the current population and the carrying-capacity. Attempts to estimate K are further complicated by periodic large harvests, interannual variably in reproductive rates which affect the dynamics of the population, and the time interval of 4-5 years between pup production surveys. At the 2011 assessment, catch information going back to the 18th Century were used to reconstruct the trajectory of the population back to the period when commercial harvesting began. This approach assumed that the population was stable and at its environmental carrying capacity just prior to commercial exploitation. This reconstruction resulted in an estimated pre-exploitation population of 10.8 million (range=7.6-15.4 million) animals.



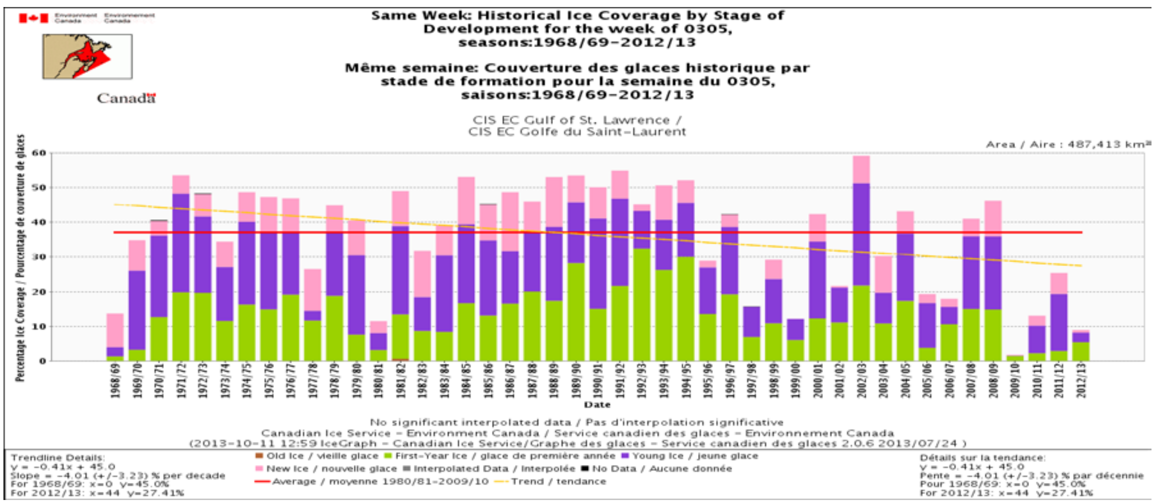


Figure 5. Changes in the amount of first year, young, new ice and total ice cover off southeast Labrador (Front, top) and in the Gulf (bottom).

The population model estimates the starting population size, the adult mortality rate (M) and, for the first time, the environmental carrying capacity. It incorporates a time series of pup production estimates up to 2012, as well as reproductive rates, ice-related mortality and harvest information to 2013 to predict 2014 pup production and total population size (Fig. 6 and 7). The model provides a 2012 estimated pup production of 929,000 (SE=148,000), a total population of 7,445,000 (SE=698,000) and a K=10.8 million (SE=564,000). Projecting to 2014, results in an estimated pup production of 853,000 (SE=202,000) and a total population of 7,411,000 (SE=656,000) animals. The population appears to be relatively stable, showing little change in abundance since 2004 (Figs. 6 and 7).

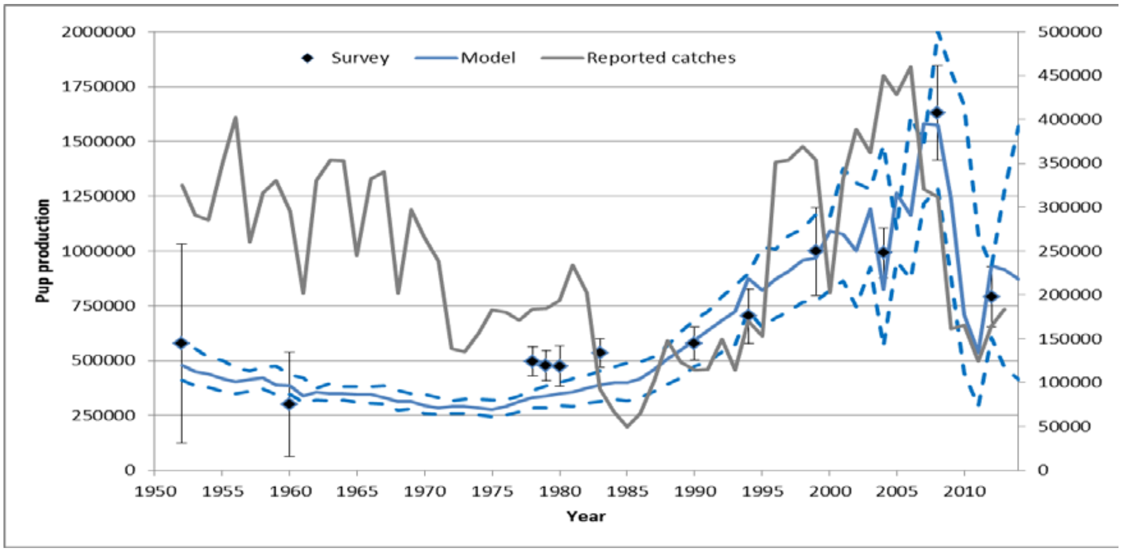


Figure 6. Independent (± 95 % CI) and model (± 95 % CI, line) estimates of pup production, 1952-2014 (left Y-axis), as well as reported catches,1952-2013 (right Y-axis).

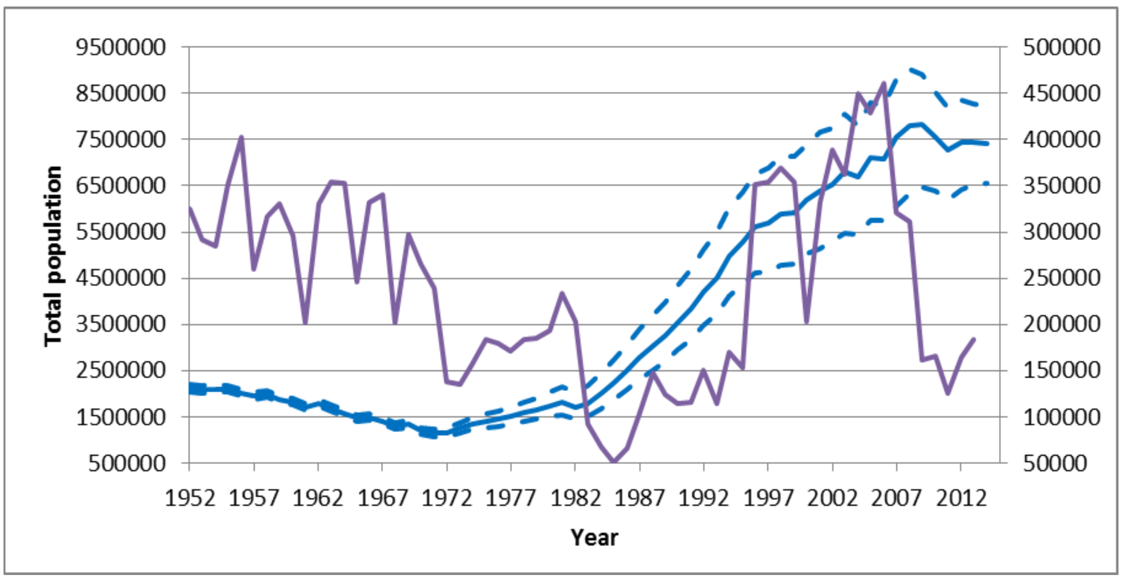


Figure 7. Estimates of total population for Northwest Atlantic harp seals (±95%CI) 1952-2014 (left Y-axis), and reported harvests for 1952-2013 (right Y-axis).

Catch options

Science was requested to evaluate the risk for a five year management plan (2014-18), that the population will drop below 50 % and 70 % of N_{max} at a constant annual TAC of 300,000, 400,000, 500,000 and 600,000 with a composition of: 30 % adults / 70 % beaters; 10 % adults/ 90 % beaters; 5 % adults / 95 % beaters. The Atlantic Sea Management Strategy identifies 3 reference levels as a proportion of the maximum population size estimated (N_{max}). Based upon the population model, N_{max} was estimated to be 7.8 million seals, with the precautionary level, N_{70}=5.5 million, a secondary precautionary level, N_{50}=3.9 million and the critical reference level, N_{30}=2.3 million animals.

In the projections to evaluate the impact of different levels of harvest it was assumed that the Greenland harvest, reproductive rates and ice-related mortality remained within the range of values observed over the last decade. The estimated probabilities of remaining above N_{70}, N_{50} and the Critical Reference level (N_{30}) are affected by the age composition of the harvest and herd productivity. The probability of the population remaining above N_{70}, N_{50} and N_{30} were estimated assuming that reproductive rates during the next 5 years are similar to a) the reproductive rates observed over the last 5 years (2009-13, average pregnancy rate of 34 % of females aged 8 + years) which is a period of low productivity; b) reproductive rates observed over the last 10 years (2004-12, average pregnancy rate of 48 % of females aged 8 + years) which is a period with higher productivity (Table 3).

Assuming that reproductive rates remained within the range of values observed over the last 5 years (low productivity), harvests of 125,000, 100,000, and 75,000 animals consisting of 95 %, 90 % and 70 % YOY, respectively, would have an 80 % likelihood of remaining above N_{70}. Harvests of 250,000, 225,000, and 150,000 seals consisting of 95 %, 90 % and 70 % YOY, respectively, would have an 80 % likelihood of remaining above N_{50}.

Assuming that reproductive rates remained within the range of values observed over the last 10 years (high productivity), harvests of 325,000, 275,000, and 175,000 animals consisting of 95%, 90% and 70% Young of the Year (YOY), respectively would have an 80% likelihood of remaining above N_{70}. Harvests of 450,000, 375,000, and 175,000 seals consisting of 95%, 90% and 70% YOY, respectively would have an 80% likelihood of remaining above N_{50}.

The probability that harvests of 100,000 to 600,000 animals would fall below N_{70}, N_{50} and N_{30} is also affected by herd productivity and age composition of the harvest (Table 4).

Several factors should be monitored to determine if a multiyear TAC should be re-evaluated. In general, significant changes in any of the major assumptions used in the projections should trigger a new analysis. The most important of these assumptions is associated with annual monitoring of reproductive rates; changes in reproductive rates either leading to an increase or to a decrease in average assumed rates over three years, will have an important impact on the trajectory of the population. Significant changes in the age structure of the harvest, the level of Greenland harvest or a major unusual mortality event would also result in a need to re-evaluate the TAC. Given the importance of ice conditions for pup survival, a series of years (e.g. three consecutive winters) with significantly below average ice conditions, particularly at the Front where approximately 70 % of pup production occurs, could indicate a need to reassess the population and re-evaluate a multiyear TAC.

Table 3. Probability of respecting N_{70}, N_{50} and N_{30} at different harvest levels and age compositions of 95 % YOY, 90 %YOY and 70 % YOY. Projections assumed that future reproductive rates were similar to those observed between 2009-13 (34 % pregnant, Low productivity) and also assumed that future reproductive rates were similar to the higher rates observed between 2008-13 (48 % pregnant, Higher productivity). The numbers in bold represent the harvest level that is closest to the Management objective of maintaining an 80% likelihood of remaining above the reference level

Probability of Respecting – Low Productivity

Age	Harvest	N70	N50	N30
95%	125,000	**0.83**	0.97	0.99
95%	250,000	0.47	**0.83**	0.96
90%	100,000	**0.85**	0.97	0.99
90%	225,000	0.43	**0.80**	0.96
70%	75,000	**0.81**	0.97	1
70%	150,000	0.44	**0.81**	0.96

Probability of Respecting – Higher Productivity

Age	Harvest	N70	N50	N30
95%	325,000	**0.81**	0.95	0.99
95%	450,000	0.53	**0.81**	0.95
90%	275,000	**0.81**	0.94	0.99
90%	375,000	0.54	**0.82**	0.95
70%	175,000	**0.83**	0.96	0.99
70%	225,000	0.62	**0.87**	0.96

Table 4. Probability of falling below N_{70}, N_{50} and N_{30} at different harvest levels and age compositions of 95 % YOY, 90 %YOY and 70 % YOY. Projections assumed that future reproductive rates were similar to those observed between 2009-13 (34 % pregnant, Low productivity) and also assumed that future reproductive rates were similar to the higher rates observed between 2008-13 (48 % pregnant, Higher productivity).

Probability of Falling Below – Low Productivity

Age	Harvest	N70	N50	N30
95%YOY	300,000	0.68	0.29	0.07
95%YOY	400,000	0.91	0.60	0.21
95%YOY	500,000	0.98	0.85	0.43
95%YOY	600,000	1.00	0.96	0.68
90%YOY	300,000	0.82	0.45	0.14
90%YOY	400,000	0.97	0.81	0.42
90%YOY	500,000	1.00	0.97	0.76
90%YOY	600,000	1.00	1.00	0.94
70%YOY	300,000	1.00	0.94	0.72
70%YOY	400,000	1.00	1.00	0.99
70%YOY	500,000	1.00	1.00	1.00
70%YOY	600,000	1.00	1.00	1.00

Probability of Falling Below – Higher Productivity

Age	Harvest	N70	N50	N30
95%YOY	300,000	0.16	0.04	0.01
95%YOY	400,000	0.35	0.11	0.03
95%YOY	500,000	0.59	0.28	0.08
95%YOY	600,000	0.80	0.49	0.19
90%YOY	300,000	0.25	0.07	0.02
90%YOY	400,000	0.53	0.23	0.07
90%YOY	500,000	0.81	0.52	0.22
90%YOY	600,000	0.95	0.80	0.51
70%YOY	300,000	0.76	0.45	0.20
70%YOY	400,000	0.98	0.90	0.71
70%YOY	500,000	1.00	1.00	0.98
70%YOY	600,000	1.00	1.00	1.00

Sources of Uncertainty

The annual reproductive rate data have a significant impact on our ability to fit the model to the observed data. As well, assumptions about future rates have a significant impact on modelled population trajectories and impacts of different harvest levels. Animals aged 8 years of age and older contribute the most to the total pup production, and it is therefore important to have adequate numbers of samples from this age class to describe the productivity of the herd. Despite our efforts, very few samples have been obtained in recent years and as a result, there is considerable uncertainty in recent reproductive rates.

Additional uncertainty is associated with subsistence catches in the Canadian Arctic and Greenland. The reported Greenland harvest has been equal to, or greater than, the Canadian commercial catch in many years over the last decade (Table 1) and is not limited by quotas. Given the level of harvest and the higher proportion of older animals taken, the Greenland harvest has an important impact on the population dynamics of Northwest Atlantic harp seals.

Removals include estimates of seals caught in fishing gear (bycatch) and the number that are killed, but not recovered (Struck and Lost). These estimates are not well known and may be overestimated. The majority of bycatch occurs in the Newfoundland lumpfish fishery. Catches in this fishery have declined in recent years and the current level of bycatch is unknown. Similarly, no recent data on struck and loss rates, particularly in the Arctic, are available. Errors in estimating either, or both, of these sources of removals are unlikely to significantly change the overall population estimates, but would result in higher estimates of 1 + mortality. Future projections will not be affected by these changes assuming the same levels of struck and lost, bycatch and mortality are used in both the projections and fitting models.

The current assessment model estimates natural mortality rates to fit observed data on reproductive rates and pup production. The model assumes that mortality is constant for seals one year of age and older and does not change over the projection period. However, natural mortality is likely to vary over the time and with age. Independent estimates of mortality are needed to verify model predictions and to improve information concerning the dynamics of this population.

Since 1990, harp seals have been assessed every 4-5 years when new pup production survey results became available. Since the harvest targets YOY, which are not fully recruited until they are 8-10 years old, changes in pup production, resulting from very high exploitation rates or unusual mortality will not be detected for a minimum of 15-20 years. Reducing the frequency of surveys will increase the uncertainty and require more conservative harvest levels to ensure the population remains viable. The impact of proposed harvest levels should be extended to cover the lifespan of the species (~ 30 years) to determine the consequences of removals on the full age structure.

The dynamics of the Northwest Atlantic harp seal are described assuming that density dependent factors are acting on reproductive rate and first-year survival. Currently, it is assumed that the population is limited by food resources, but changes in other factors such as ice cover may become more important in the future. As the population increases, reproductive rates and first-year survival are expected to decline as per capita resources also decline. The relationship between available resources, or environmental carrying capacity and how the population parameters respond to changes in these resources is very uncertain, and will be difficult to determine with an interval of 4-5 years between pup surveys.

CONCLUSION

Fitting the population model to the estimates of pup production up to 2012, annual estimates of age-specific reproduction rates, removals and ice related mortality to 2013 resulted in a 2014 population estimate of 7.4 million. The population appears to be relatively stable, showing little change in abundance since 2004.

Pregnancy rates of harp seals have been declining since the late 1980s. This decline can be explained by an increase in population (i.e. density dependent) and density independent (ice conditions, prey availability) factors. These ecosystem conditions are predicted to continue. Therefore, it is likely that reproductive rates will remain low.

The impact of different harvest scenarios was examined. Population trajectories and impacts of different TAC levels on the population and the probability that harvests will respect management objectives are very sensitive to assumptions concerning future productivity of the herd. Future reproductive rates are not known, consequently two potential scenarios that could be considered to represent low and higher productivity were presented. Recent conditions indicate that herd productivity has declined and is likely to remain low.

Several factors should be monitored to determine if a multiyear TAC should be re-evaluated. In general, significant changes in any of the major assumptions used in the projections should trigger a new analysis; the most important being annual reproductive rates. For example if reproductive rates remained below the average rate over 3 years or ice related mortality remains above normal over 3 years, then the TAC should be re-evaluated. Other changes include significant changes in the age structure of the harvest, level of Greenland harvests or ice conditions should also result in a re-analysis.

OTHER CONSIDERATIONS

Subsistence harvests in Greenland and Arctic Canada are currently not regulated. Harvest levels in these areas, particularly in Greenland, can have a significant impact on the population dynamics of this population.

There has been an increase in the frequency of lighter ice cover winters, particularly in the Gulf over the past decade. If this trend continues, the contribution of Gulf pup production will decline and this herd may decline as a significant component of the Northwest Atlantic harp seal population. Although this is unlikely to occur before the next assessment, the current allocation of 30 % of the commercial quota to the Gulf may need to be re-examined if poor ice conditions continue. In the past decade, declines in ice conditions in the Gulf have been obvious while changes in the ice at the Front have been less so. However, climate change models predict that the area off southern Labrador will be the next area of major change. Increases in YOY mortality due to poor ice conditions at the Front will have a significant impact on the ability of the population to withstand any given level of harvest. Therefore, ice conditions should be monitored annually and a reassessment carried out if a series of 3 or more years of extremely poor ice conditions persist.

SOURCES OF INFORMATION

This Science Advisory Report is from the 7-11 October, 2013 Annual Meeting of the National Marine Mammal Peer Review Committee (NMMPRC). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2010. Current Status of Northwest Atlantic Harp Seals, *Pagophilus groenlandicus*. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/074.

DFO. 2012. Current Status of Northwest Atlantic Harp Seals, (*Pagophilus groenlandicus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/070.

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