A REVIEW OF ICE CONDITIONS AND THE HARP SEAL TOTAL ALLOWABLE CATCH (TAC) FOR 2010

Context

Harp seals, *Pagophilus groenlandicus*, are the most abundant pinniped in the northwest Atlantic with an estimated total population size in 2009 of 6,851,600 (95% CI=5,978,500 to 7,697,200) (Hammill and Stenson 2009).

Ice conditions, measured primarily as ice cover have been declining over the last decade. Conditions in 2010 in the Gulf of St. Lawrence and off the southeastern coast of Labrador are about 80% below expected levels, which is the lowest level ever seen since 1969, the start of the ice cover database (1969 in the Gulf, 1971 at the Front) maintained by Environment Canada. The very poor conditions are expected to result in higher mortality of young harp seals before they become independent, which in combination with harvesting could have longer term negative impacts on the population. The objective of this response is to examine the impact of this potential high young of the year mortality on the population when it occurs in combination with a Canadian commercial harvest of 330,000. In this analysis we have adopted an extremely conservative and pessimistic approach in assuming that mortality would be high (70% of animals born), there would be an immediate drop in productivity of the herd as seen over the past decade (decline in reproductive rates of 3%). It has also been assumed that ice related mortality would persist in subsequent years (M_{ice}=12%), and finally, in spite of current poor market conditions it was assumed that the entire harvest of 330,000 would be taken each year of the projection period.

Background

The harp seal population is estimated using a population model that incorporates information on age-specific reproduction rates, removals from different sources corrected for animals struck but not recovered and changes in ice conditions which can affect the survival of young animals until they are fully independent. The model is fitted to independent estimates of pup production obtained from aerial surveys to obtain an estimate of the total population size (Hammill and Stenson 2009).

Harp seals are taken in the Canadian commercial hunt, the Greenland and Arctic subsistence hunts and as bycatch in commercial fisheries. In the Canadian commercial harvest, reported harvests have averaged 294,168 animals since 1996, or 86% of the quota (Table 1). Quota overruns ranging from 1 to 13 percent have occurred in 5 of the last 14 years (Table 1).

The Canadian commercial harp seal harvest has been managed under an Objective Based Fisheries Management (OBFM) since 2003. OBFM incorporates the principle of the Precautionary Approach (DFO 2003, 2006; Hammill and Stenson 2007) and under this approach, precautionary reference levels are identified and are associated with agreed-upon management actions that are to be implemented if the population declines below the threshold levels (DFO 2003). Under OBFM, the management objective is to set harvests that will ensure that the probability of the population falling below a precautionary reference level called N_{70} is less than

20%. The line representing this probability is referred to as L_{20}. The 2006-2010 management plan set N_{70} at 4.1 million animals (DFO 2006). With the most recent assessment, the 2009 population is estimated to be 6.9 million animals (DFO 2009), which would reset N_{70} to 4.8 million animals. The limit reference level for this population, also known as a conservation reference level (N_{30}), has also been adjusted to 2.1 million animals. In evaluating the impacts of different harvest levels on the population, reported harvests by Canadian and Greenlandic hunters, losses of animals struck but not landed or reported, bycatch in fishing gear, changes in reproductive rates, and unusual mortality due to poor ice conditions are taken into account (Hammill and Stenson 2009). The current management plan ends after the 2010 harvest season (DFO 2006).

At the National Marine Mammal Peer Review meeting held in November 2009, the impact of several different harvest scenarios on the harp seal population were examined to determine whether they respected the objectives of the current management plan which ends after the 2010 hunt. These runs indicated that scenarios with a 2010 harvest of 250,000, 275,000 or 300,000 animals would respect the management plan (DFO 2009). Subsequent to this review, ice conditions in Atlantic Canada are substantially poorer than normal and Fisheries and Aquaculture Management (FAM) has requested advice to examine the impacts of an annual harvest of 330,000 over the next three years. For this advice we include potential impacts on the population assuming a projection over the next 20 years. Previous simulations have indicated, that the population can withstand very high harvests for 10 years or more, but there is also a very high probability of population collapse due to the lagged effects as the harvested cohorts mature and enter into the breeding population, usually at the age of 5-6 years of age. Once this collapse occurs, recovery cannot be expected for 15 years or more (Hammill and Stenson 2009)

Harp seals require ice for giving birth and rearing their young. Once weaned, the young also need to be able to haul-out onto the ice to rest. Without access to stable ice, neonate mortality is expected to be high (Sergeant 1991). The 2009/10 winter has been characterized by mild temperatures and high winds which has prevented the formation of stable pack ice in both the Gulf of St. Lawrence and off the southeast coast of Labrador (‘Front’). Total ice cover Atlantic Canada is the lowest that has been recorded ever since the start of the Environment Canada database (Fig. 1).This is expected to lead to higher than normal mortality among the young of the year. Examination of the total extent of ice over the past 40 years indicates that there is a declining trend in accumulated ice, in both in the Gulf and the south-western Labrador Sea (Canadian Ice Service data). Therefore there is an increased likelihood of increased mortality in future years.

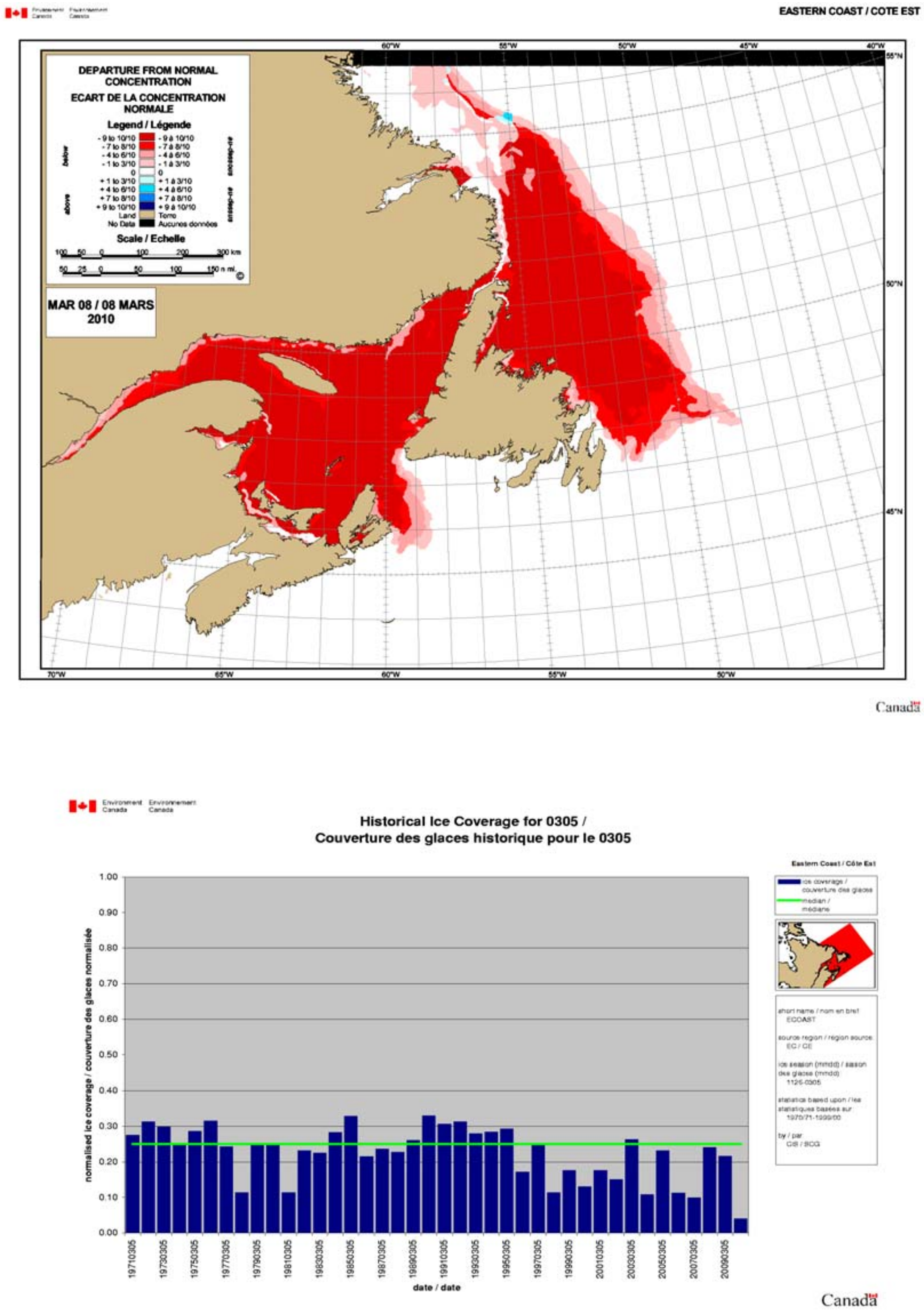

Figure 1. Deviation in 2010 from normal ice cover of Atlantic Canada for 8 March.Red indicates that ice cover is 90% less than normal (top). Proportion of the study area (Gulf of St. Lawrence and the Front) covered by ice on 5 March, 1971-2010 (bottom). Atlantic Canada ice cover in 2010 is the lowest year in the time series.

Analysis and responses

The impact of a harvest of 330,000 animals on the population was examined and compared with the effects of a harvest of 330,000 animals with ice-related mortality of 70% of the pups born in 2010. In both scenarios, the full quota of 330,000 was taken in all years during the scenario period (2010-2030). This analysis incorporated some changes to the population model compared with scenarios examined at the November 2009 peer review meeting (Table 2). Changes included a 3% reduction in age-specific reproductive rates beginning in 2010. This reduction was similar to that observed among adults between 1997 and 2007 (Stenson et al 2009). Quota over-runs have occurred in the past. These over-runs are one component of what is known as implementation error. Implementation error in this case, the quota over-run, results from the delay between when information is received on current catch levels, and the time taken to implement the closure of the hunt. Implementation error has been incorporated in the population model since 2003 as a multiplier applied towards the reported catch with a mean over-run of 5% in every year (range 0 to 10%). In this evaluation, implementation error was increased to an average of 10% in every year (range 0-20%). This increase encompassed the largest quota over-run, observed in 2002 of 13% (Table 1). Variability in harvests in the Arctic and from by-catch were also increased to reflect our uncertainty in these values and to encompass the range observed in the data (Stenson 2009)

The projection was run assuming that the age structure of the subsistence catch in the Canadian Arctic, bycatch in fishing gear and the age structure of the Greenland harvest remained unchanged. The age composition of the Canadian commercial catch was changed from 97% young of year (YOY) to 95% YOY to reflect a possible increase in the number of older animals harvested for meat.

Table 1. Total Allowable Catch (TAC), reported commercial harvest, and Greenland subsistence harvest between 1996 and 2009.

Year	Total Allowable Catch (Canada commercial hunt)	Canada	Percent of TAC	Greenland
	Quota	Catch	%	
1996	250,000	242,000	96.8	
1997	275,000	264,000	96	
1998	275,000	282,000	103	
1999	275,000	244,000	89.7	
2000	275,000	92,000	33	
2001	275,000	226,000	82	
2002	275,000	312,000	113	
2003	325,000	289,512	89	66,149
2004	350,000	365,971	104	70,586
2005	319,517	323,826	101	91,696
2006	335,000	354,867	106	92,210
2007	270,000	224,745	83	81,447
2008	275,000	217,850	79	N/A
2009	280,000	76,195[1]	27	N/A
Av.	307,788	294,168	86	80,160

[1] Catch data for 2009 were revised since the National Marine Mammal Peer Review meeting held in Halifax, November, 2009 based upon new data from DFO, Statistics Branch

Table 2. Values for parameters modified for the simulation runs compared with values presented at the assessment.

Variable	Assessment value (Nov 2009)	Scenario value (March 2010)
Implementation error- (error associated with quota over-runs)	Uniform distribution 1.0-1.1, with a mean of 1.05	Uniform distribution 1.0 to 1.2, with a mean of 1.1
Proportion of pups in the Canadian commercial catch	97%	95%
Arctic catches	Uniform 999 to 1,001, with mean of 1,000 animals	Uniform 750-1,500, mean of 1,125
Bycatch	Uniform 10,599 to 10,601, with a mean of 10 ,600	Uniform 8,000 to 14,000 with a mean of 12,000
Greenland catch	Uniform 70,000-100,000, with mean of 85,000	Same as assessment
Ice Survival (1-mortality) in 2010. Young of year (YOY)	Uniform distribution, with mean=0.88	0.88 or 0.3 in 2010, then 0.88 for future years depending on scenario
Ice Survival during all projection years from 2011 onwards	Sample from values (mean=0.88) (1,0.9,0.8,0.7,1)	no change
Reproductive rates in 2010 and future	Same as 2009	No change or reduced by 3%, starting in 2010
Constant harvest during 20 years	250,000, 275,000, or 300,000	330,000

Projections

The base model assumed a harvest of 330,000 in all years beginning in 2010. The TAC was assumed to be taken in each year. In the model, natural mortality of YOY is set at 3 times the adult mortality rate. Although ice-related mortality (M_{ice}) is a component of natural mortality, it is treated separately because it appears to be a sporadic event that occurs prior to the hunt. From 2011-2030, M_{ice} was expected to be, on average, higher than normal in all projections with a mean of 12% (i.e. survival=88%)(Table 2). At the last assessment (November 2009:DFO 2009), data were presented indicating that there had been a decline in pregnancy rates of about 3% over the period 1999-2007 (Stenson et al. 2009). This follows a decade of greater decline. Therefore, a second run examined the impact on the population of an additional reduction in reproductive rates of 3%, beginning in 2010, with a constant harvest of 330,000. A third run examined the impact of a combination of a harvest of 330,000 animals and a very high mortality of young of the year animals occurring prior to the hunt. This mortality was assumed to be 70% of the animals born in 2010, then in subsequent years this ice related mortality dropped to an average of 12% (i.e. Survival=0.88). In the final run, the impact of a harvest of 330,000 animals, a 3% reduction in reproductive rates and a high mortality of 70% of the young of the year in 2010, followed by an average ice mortality of 12% (i.e., Survival=0.88) from 2011 and all subsequent years was examined.

Under the base scenario, with a harvest of 330,000, pup production peaks at 1.1 million animals in 2009, then shows little change until 2014 before increasing again, with a continuous increase in pup production until the end of the projection period in 2030 (Fig. 2). The little change in pup production reflects lagged effects of the high harvests during the 2001-2005 period when an average of 303,000 animals was removed during the commercial hunt in each year (Table 1). The total population shows a period of little growth, from 2005 until 2009, with the population remaining around 6.5 to 6.9 million animals between 2005 and 2009, then begins to increases markedly in 2010 reflecting the decline in harvest levels from 2006 through 2009. From 2010 on, the population continues to increase (Fig. 3).

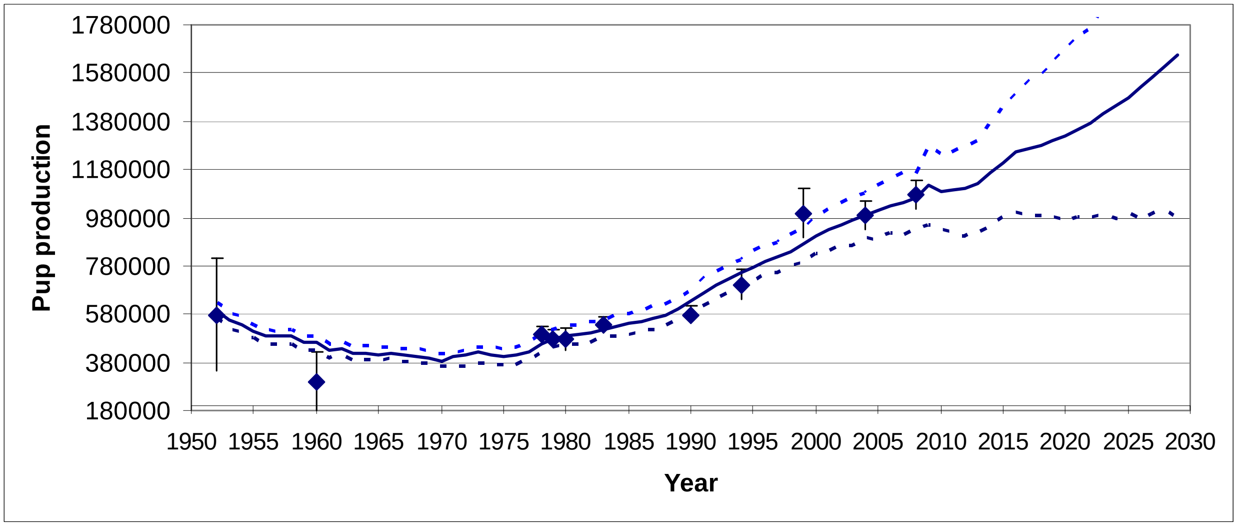

Figure 2. Predicted pup production (mean ±95% C.I.) of Northwest Atlantic harp seals, assuming a Canadian commercial harvest of 330,000 per year starting in 2010 and average ice-related mortality of young animals of 12% (range 0-30%), (SAR 2009).

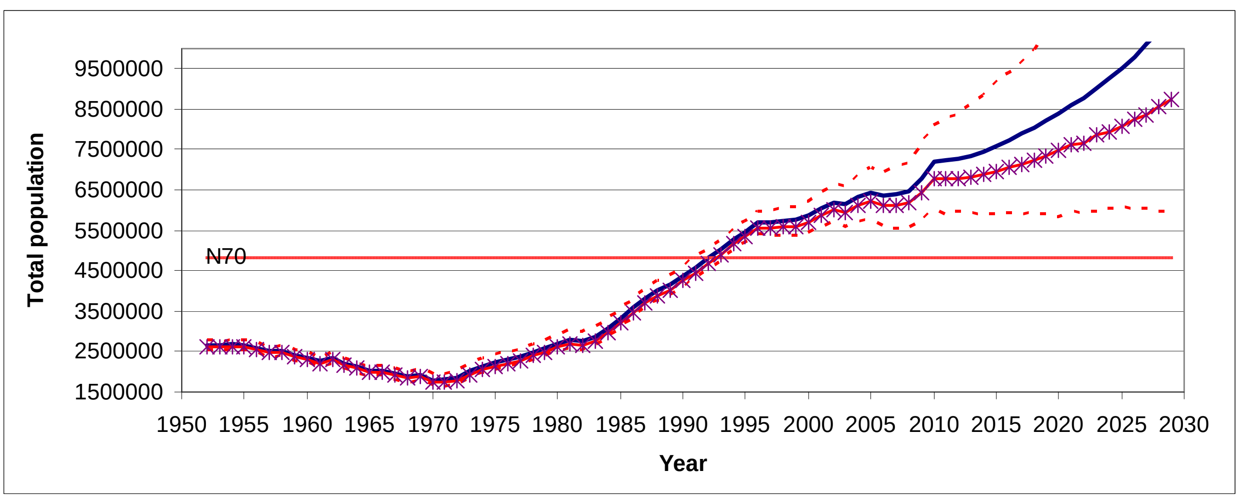

Figure 3. Predicted total population size (mean ±95% C.I.) (solid ±dotted lines) and L_{20} (solid line with crosses) of Northwest Atlantic harp seals, assuming a Canadian commercial harvest of 330,000 per year starting in 2010 and average ice-related mortality of young animals of 12% (range 0-30%), (SAR 2009).

Reduce Reproductive Rates

We examined the impact of a knife edge decline in reproductive rates beginning in 2010, and an annual harvest of 330,000, and average 12% ice-related mortality over the next 20 years (Fig. 4, 5). This reduction in reproductive rates had a slight impact on the rate of population growth compared to the initial base scenario. Pup production showed little change initially, but increased to 1.48 million by the end of the projection period. Total population size also increased but at a slower rate than the base run, increasing to approximately 9.5 million animals by the end of the simulation. Under this scenario, L_{20} also showed an increasing trend throughout the projection period (Fig. 3).

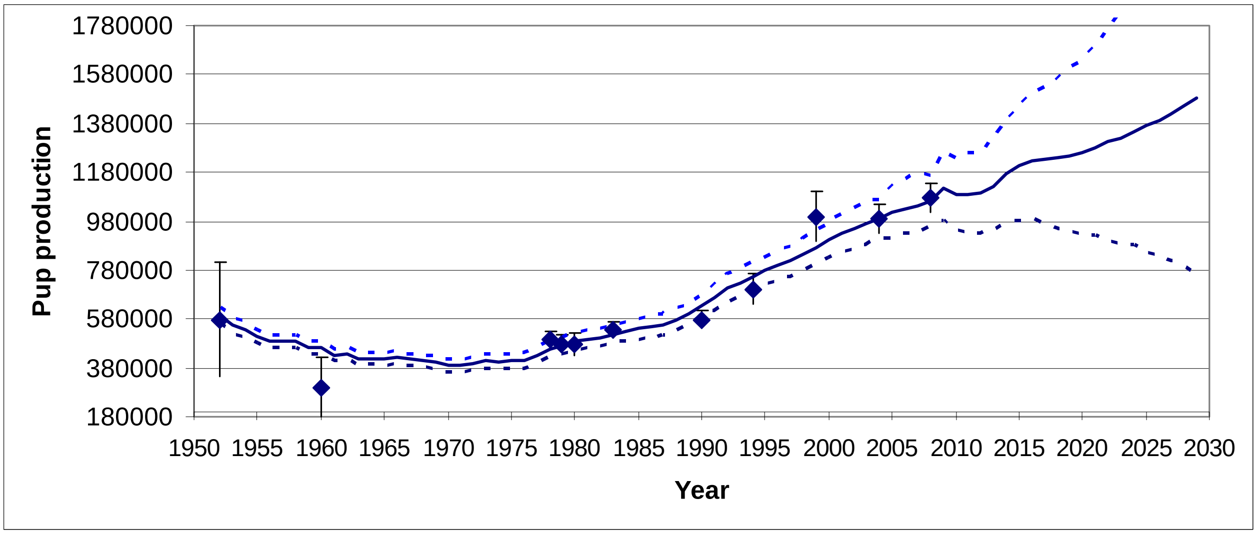

Figure 4. Predicted change in pup production (mean ± 95% C.I.) of Northwest Atlantic harp seals, assuming a Canadian commercial harvest of 330,000 per year starting in 2010, a 3 % reduction in reproductive rates as observed between 1997 and 2007, and an average ice-related mortality of young animals of 12%.

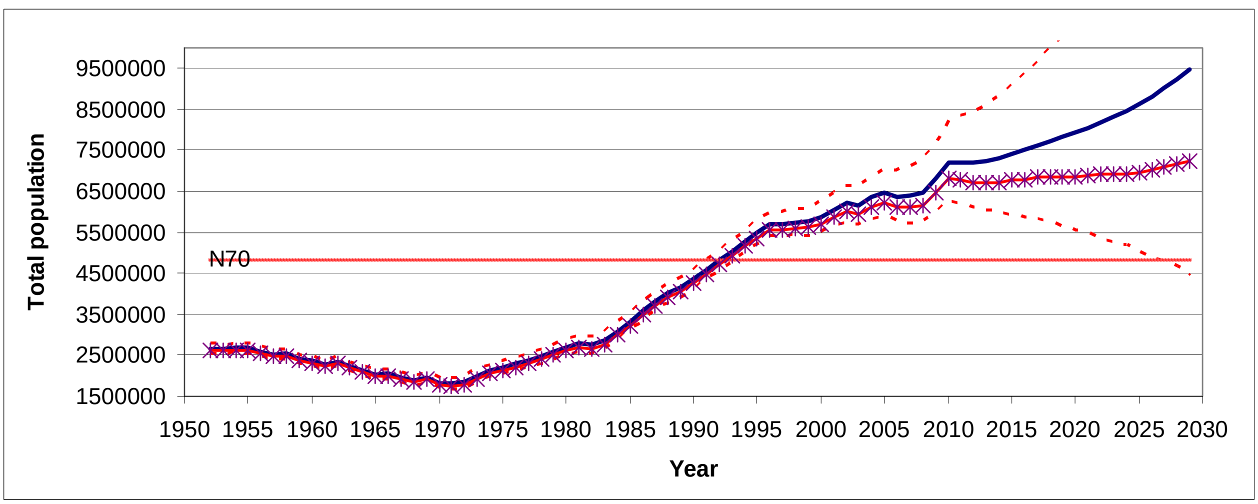

Figure 5. Predicted change in total population size (mean ±95% C.I.) and L_{20} (solid line with crosses) of Northwest Atlantic harp seals, assuming a Canadian commercial harvest of 330,000 per year starting in 2010, an average ice-related mortality of young animals of 12% and a 3 % reduction in reproductive rates as observed between 1997 and 2007.

Increased Ice Related Mortality in 2010

The scenario with an annual harvest beginning in 2010 of 330,000 animals, combined with an extremely high ice-related mortality among YOY of 70% in 2010 applied across the whole herd, then averaging 12% starting in 2011 and every year thereafter was examined (Fig. 6,7). The initial high mortality in 2010 had a greater impact on pup production and total population size, than did the 3% decline in reproductive rates. Pup production in 2010 would be expected to be about 1.09 million animals. A 70% mortality would result in only 327,300 animals being available to harvesters. If harvesters removed 330,000 animals, of which 95% would be young of the year, then only 13,800 animals would be left. In spite of almost total mortality/removal of the 2010 cohort, pup production would continue to increase reaching 1.3 million animals by the end of the projection period. Total population size would also increase to 8.2 million animals by 2030. L_{20} shows a very slight decline from 6.8 million animals in 2010 to about 6.0 million animals by 2030 (Fig. 7).

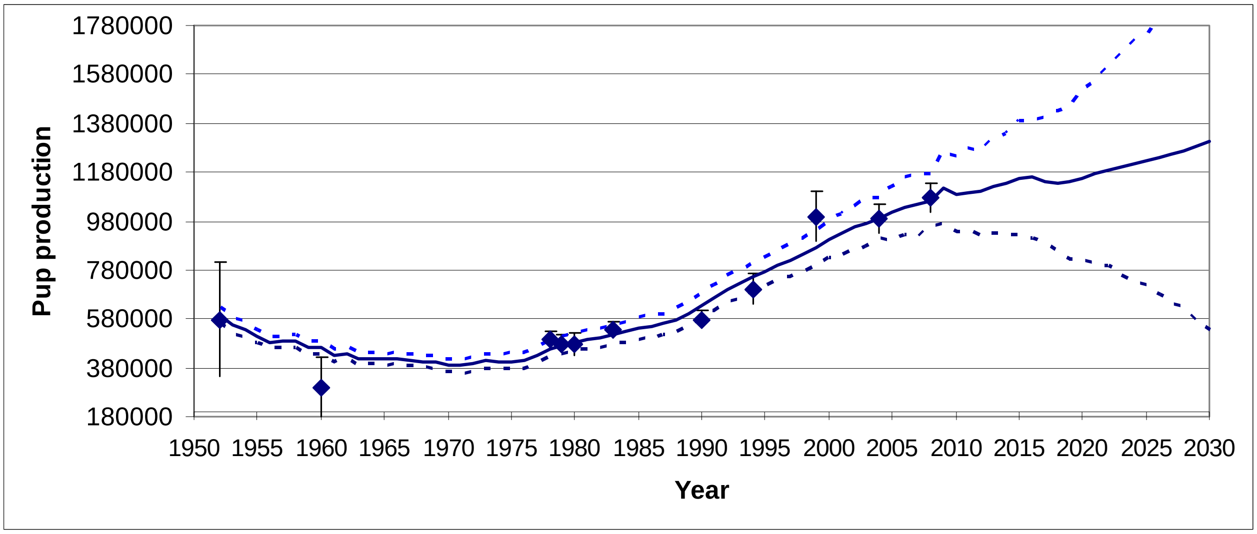

Figure 6. Changes in predicted pup production assuming a Canadian commercial harvest of 330,000 animals, per year starting in 2010, an ice -related mortality of 70% in 2010, and an average of 12% in each year thereafter.

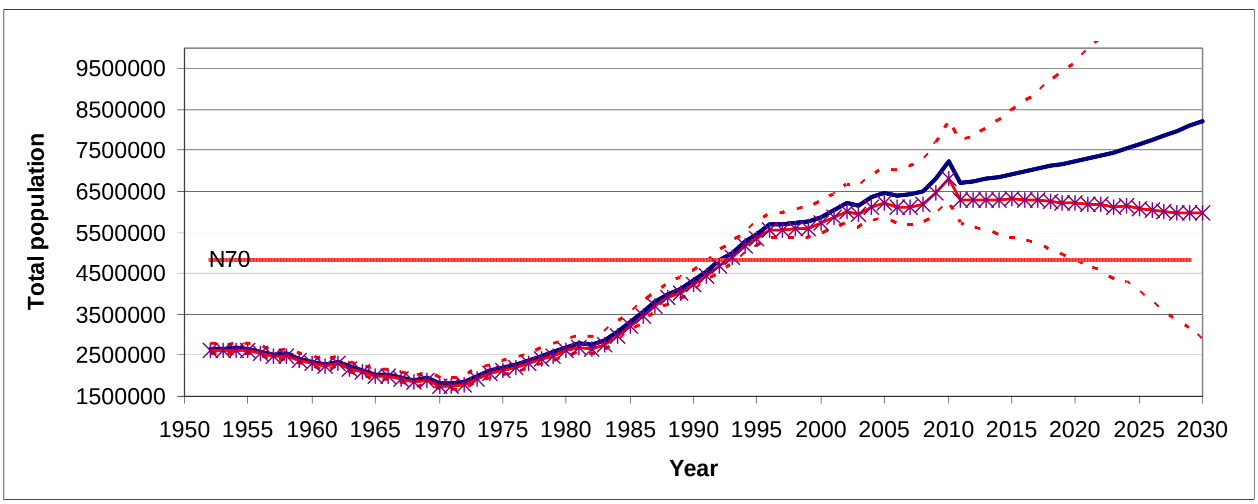

Figure 7. Changes in predicted total population size assuming a Canadian commercial harvest of 330,000 animals, per year starting in 2010, an ice-related mortality of 70% in 2010, and an average of 12% in each year thereafter.

Under a scenario with increased ice related mortality of 70% in 2010, followed by an average mortality of 12% in subsequent years, and a 3% decline in reproductive rates starting in 2010, both pup production and total population size are both likely to continue increasing, but at much lower rates than observed in previous scenarios. Pup production would only increase slightly to 1.3 million animals by 2030, while total population size would increase to nearly 8.2 million animals by 2030. L_{20} declines from 6.8 million animals in 2010 to about 5.8 million animals by 2030, but remains well above the precautionary level of 4.8 million animals (Fig. 9).

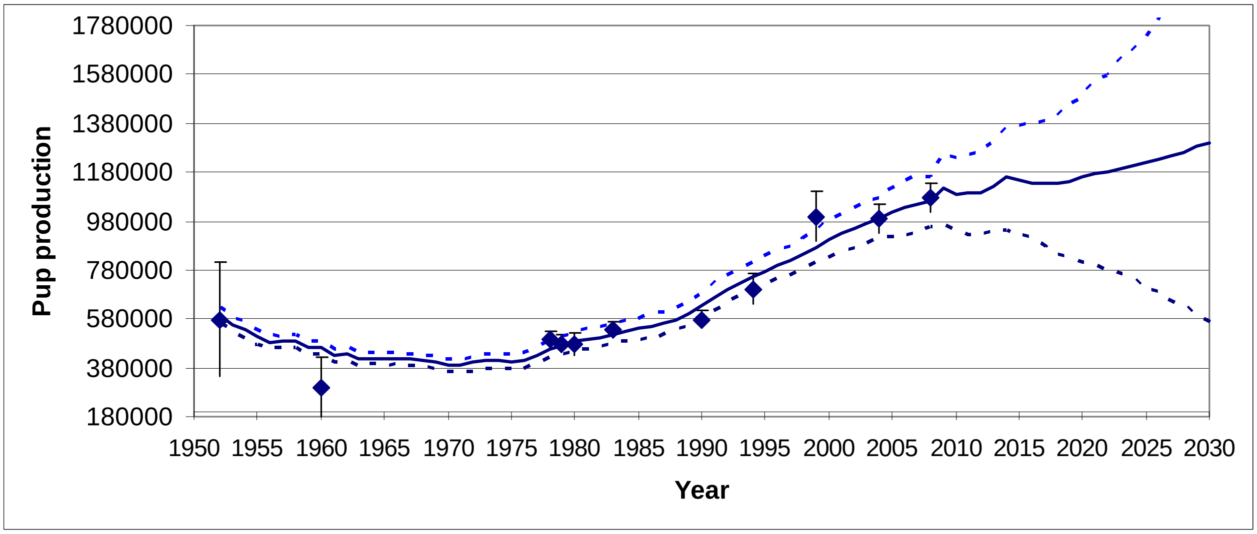

Figure 8. Changes in predicted pup production (mean + 95% C.I.) assuming a Canadian commercial harvest of 330,000 animals, per year starting in 2010, an ice -related mortality of 70% in 2010, and an average of 12% in each year thereafter and a reduction in reproductive rates of 3% beginning in 2010.

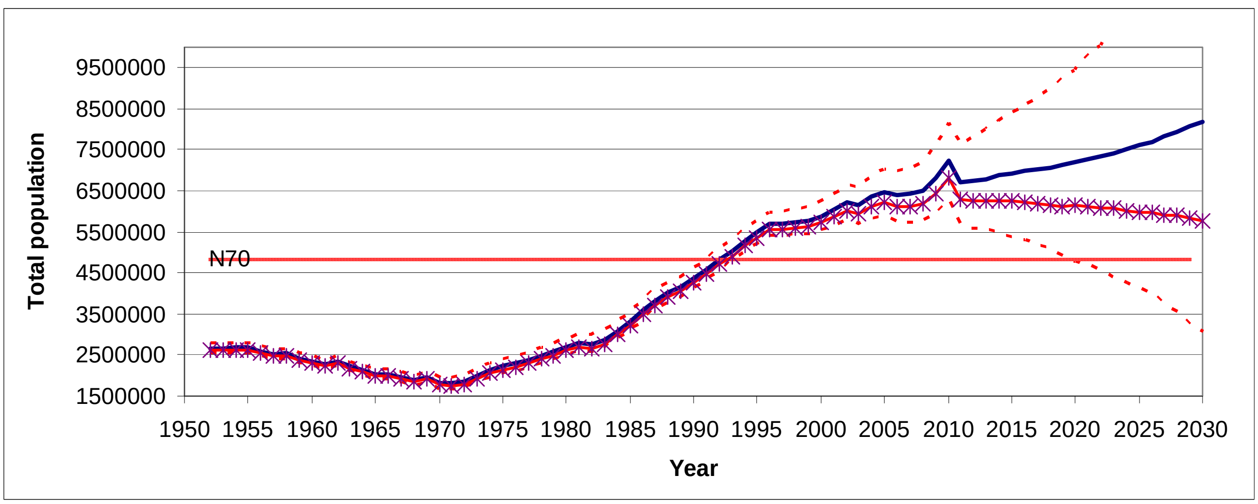

Figure 9. Changes in predicted total population size assuming a Canadian commercial harvest of 330,000 animals, per year starting in 2010, an ice -related mortality of 70% in 2010, and an average of 12% in each year thereafter and a reduction in reproductive rates of 3% beginning in 2010. Mean, C.I. and L20 lines shown as in previous graphs.

As the model projects changes in the population into the future there is an increase in the uncertainty associated with the model predictions. This is reflected by the increasing differences in the spread between the mean and the L_{20} lines. However, it is anticipated that over the next 15 years, that there will likely be 3-5 additional surveys, depending on whether surveys are flown every 4-5 years. This will allow verification of the model predictions and reduce the uncertainty associated with our estimates of the population.

In this analysis it was assumed that the TAC would remain constant at 330,000 and would be taken in full in each year. Assuming that the current phase of the hunt began in 1996 with the expansion in markets, annual harvests have averaged about 86% of the TAC since 1996. In some years (5/14), TAC over-runs have occurred (1-13%). Given current market conditions and observations of past hunt conditions, the probability of the TAC being attained or exceeded is very low. Nonetheless, the projections have incorporated an average TAC over-run of 10% (ie implementation error: range 0-20%), which contributes to the uncertainty associated with the predicted trajectory of the populations.

Conclusions

One of the primary considerations in the development of the Objective Based Fisheries Management (OBFM) approach to the management of Atlantic seals was to take into account our uncertainty about the population and to maintain some buffer in the event of unusual or unexpected events. Use of the L_{20} is predicated upon the idea that on 8 out of 10 occasions the population is actually higher than the stated level, or conversely, the population would only be lower than L20 levels on 2 out of 10 occasions. As predictions are made further into the future, our uncertainty increases and this is captured by the increasing divergence between the mean and the L20 population levels. This characteristic reflects the fact that attempting to predict the impacts of different TAC levels on a population becomes increasingly uncertain as the number of years since the last assessment increase will become increasingly uncertain. This is particularly true for harp seals because the fishery removes primarily juveniles. This removal will not be reflected in the pup production until 5 years later when these animals mature and begin producing pups themselves. Because the assessment relies on pup counts which are only flown every 4-5 years, there could be an additional delay in detecting any changes in the population. The amount of delay in detecting a change because of these two factors is uncertain, but would be at least 10 years and possibly more, depending on when the assessment is completed and the precision of the estimate.

In 2010, pupping is expected to begin in the Gulf of St. Lawrence by the last week of February and at the Front about one to two weeks later. Currently ice conditions are very poor, and there is a high likelihood of increased mortality among young of the year. This mortality is expected to occur prior to the start of hunting in late March (Gulf) or in April (Front). Even under a scenario where this mortality would be as high as 70% of the YOY in 2010 and higher than normal in subsequent years, and that there is a decline in age-specific reproductive rates as was observed between 2000 and 2007, a harvest of 330,000 is unlikely to lead to a decline in the population. Although L_{20} is observed to decline it remains above the precautionary threshold of 4.8 million animals over the next 20 years. Continued monitoring of pup production and reproductive rates is critical to determine how this population responds to harvests and changing environmental conditions.

We have tried to formulate a pessimistic scenario to evaluate the impacts of poor ice conditions of the Northwest Atlantic harp seal population. Although we have assumed that mortality of YOY will be extensive in 2010, it is possible that not all of these animals pupped on unsuitable ice and instead a larger proportion might find better ice further north along the Labrador coast. We also assumed that reproductive rates would decline, although this may not be the case, particularly if mortality is in fact higher than expected. Finally, we have assumed that the TAC would be taken in full. However, history has shown that in many years, the TAC has not been taken in full, and given current market conditions and the difficulties in finding concentrations of animals in some areas, there is unlikely to be a high harvest in 2010. Although it appears that the extremely poor ice conditions observed in 2010 will not have a serious impact on the harp seal population, several years of poor conditions are more likely to have a longer term effect on harp seal abundance or distribution in Atlantic Canada.

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