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Possible Impacts of Ice Related Mortality on Trends in the Northwest Atlantic harp seals population.

By

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Abstract

The harp seal is a medium sized highly migratory phocid distributed over continental shelf regions of the north Atlantic. The Northwest Atlantic population currently numbers around 5.5 million animals and is harvested commercially and for subsistence purposes. Harp seals use pack ice to haul out on, to give birth and nurse their young. After weaning the young of the year (YOY) remain with the ice, which they use as a resting platform. The harp seal population is assessed approximately every 4 years using a population model that relies upon independent estimates of pup production obtained from aerial surveys. Since the current harvest is focused on YOY animals, the impact of any unusual mortality will not be reflected in the assessment for at least two decades later. In the Gulf of St. Lawrence, poor ice conditions, which are thought to lead to increased mortality among young animals, have been observed in 6 of the last 10 years. A factor to account for increased mortality during poor ice years has been incorporated into the assessment model since 2004, but the impacts of this factor on model predictions has not been evaluated. Under scenarios of a constant harvest, an annual mortality of 30% or higher, due to ice, in a single year would result in significant changes in the population trajectory within a decade, but these changes would not be noticed as detectable changes in pup production for at least 20 years. Repeated ice-related mortality of 10% had limited impact unless it occurred in 6 or more winters within a decade. Changes in the population and pup production due to increased YOY mortality could not be detected until 15 or more years had passed even under high levels of mortality or variability among years, by which time significant changes in the population can occur. For management considerations, taking into account possible changes in natural mortality due to ice would not appear to be important in the short-term, but will have more important longer term implications.

Introduction

The harp seal (*Pagophilus groenlandicus*) is a medium sized highly migratory phocid distributed over continental shelf regions of the north Atlantic. The Northwest Atlantic population summers in the Arctic but moves south in fall to overwinter and reproduce off northeastern Newfoundland and in the Gulf of St. Lawrence (Fig. 1). Harp seals use pack ice to haul out on, to give birth and nurse their young. After weaning the young of the year (YOY) remain with the ice, which they use as a resting platform, for several weeks. The presence of stable pack ice appears to be essential for these two stages in the early development of the young seal. Very young animals have not developed sufficient blubber for insulation, and if forced to spend time in the water become rapidly fatigued and drown or die from hypothermia. Weaned animals also appear to tire quickly and suffer high mortality when a stable ice platform is not available. Harp seals rarely haul-out on land.

Expert reviews provided by the Intergovernmental Panel on Climate Change (IPCC) make it clear that climate change will induce temperature changes and associated adjustments in ocean circulation, ice coverage and sea level. (McCarthy et al. 2001). Such changes are expected to impact marine ecosystems, through changes in population parameters, predator-prey relationships and distribution (Simmonds and Isaac 2007). Sea ice cover in the area occupied by overwintering harp seals appears to vary periodically, with positive and negative extremes approximately 6 yr apart (Johnston et al. 2005). The spatial analysis of extreme anomalies reveals that changes occur primarily in the Gulf of St. Lawrence, but have also occurred off the east coast of Newfoundland, suggesting that both areas react similarly to seasonal shifts and climatic variation (Johnston et al. 2005).

Using ice-cover in the Gulf of St. Lawrence as an index of haul-out ice conditions, the period 1985-97 was characterized by unusually good ice conditions when compared to the longterm mean (Fig. 2). Over the last decade, the frequency of below average ice cover has increased markedly. In years, where there is very little ice-cover, mortality (M_{ice}) of nursing and weaned YOY is likely quite high. In 1981, there was very little ice cover during the whelping (early March) and weaning periods, and M_{ice} is considered to have been particularly high in that year. Among cohort samples collected in later years, this year class appears to have disappeared. Although the loss of this cohort may have resulted from the poor ice, high harvest levels at that time may have been a contributing factor (Sergeant 1991). Other evidence for high M_{ice} in the Gulf includes the reports of large numbers of carcasses on the beaches or large numbers of drifting carcasses in the water from the public. Although these observations show that M_{ice} might be high at the whelping or at the post-weaning stages, it is difficult to quantify. Current assessments include an estimate forM_{ice}, but these have been based on 'expert opinion' rather than actual data. Here we examine the impact of including increased YOY mortality in the population model and its impact on our assessment of the Northwest Atlantic harp seal population.

Methods and Model structure

The impact of M_{ice} was examined by comparing modeled base population trajectories with those obtained when mortality of YOY was included in the assessment. The base trajectory was generated with a constant harvest of 200,000 animals beginning in 2008, and no ice mortality. This was compared with trajectories obtained from a constant harvest of 200,000, and M_{ice} that: (1) lasted for only a few years; (2) changed in magnitude; (3) was increasingly variable.

The main tool used to monitor the population is a population model that is tuned to independent estimates of pup production obtained approximately every 4 years from aerial surveys. These surveys are normally associated with a coefficient of variation of ≤ 10%. Increased mortality due to ice was considered to have a significant impact on pup production (and indirectly the population) if the predicted pup production differed by more than 20% from the base trajectory.

The basic population model is the same as that used to assess status of Northwest Atlantic harp seals Hammill and Stenson (2005). The basic population model has the form:

for a=1: $n_{a,t} = ((n_{a-1,t-1} * w) - c_{a-1,t-1})\, e^{-(\gamma)m}$ *(1)*

for $1 < a < A$: $n_{a,t} = (n_{a-1,t-1}\, e^{-(\gamma)m/2} - c_{a-1,t-1})\, e^{-(\gamma)m/2}$ (2)

for $a = A$, where A is age 25 years:

$$n_{A,t} = (n_{A-1,t-1}\, e^{-(\gamma)m/2} - c_{a-1,t-1})\, e^{-(\gamma)m/2} \quad (3)$$

and for $a = 0$; $n_{0,t} = \sum n_{A,t} P_{A,t}$ (4)

where $n_{a,t}$ = population numbers-at-age a in year t,
$c_{a,t}$ = the numbers caught at age a in year t,
$P_{a,t}$ = per capita pregnancy rate of age a parents in year t, assuming a 1:1 sex ratio.
m = the instantaneous rate of natural mortality.
γ = a multiplier to allow for higher mortality of first year seals. Assumed to equal 3, for consistency with previous studies.
w = is the proportion of pups surviving an unusual mortality event arising from poor ice conditions or weather prior to the start of harvesting.
A = the 'plus' age class i.e. older ages are lumped into this age class and accounted for separately, set as age 25 .

The model is fit to survey estimates of pup production by adjusting the starting population size in 1960 and the adult mortality rate to minimize the mean sum of squares differences between the predicted number of pups and the survey estimates. A projection model is used to predict future changes in the population assuming that the initial population size and adult mortality rates follow a Normal distribution, and that harvests in Greenland follow a Uniform distribution between 70,000 and 100,000 animals. The model was projected forward from 2008 using a constant Canadian reported harvest of 200,000 animals. The impacts of additional mortality due to ice were compared with the base run of no ice mortality. Most pup surveys have a coefficient of variation (CV) of ≤ 10%. Therefore, only runs falling outside a zone approximately 2 x the 10% CV zone were considered to have a significant impact.

Results

The Northwest Atlantic harp seal population has increased from approximately 2 million animals in 1960 to about 5.8 million animals in 2005 (Fig. 3). The management objective is to ensure an 80% probability that the population will remain above a precautionary level called N70, or 4.07 million animals. The last survey was flown in 2004. Pup production has increased from about 500,000 in 1960 to nearly 1,000,000 animals in 2004.

All runs including the baseline run, and simulations for changes in duration, magnitude and variability of ice related mortality (M_{ice}) were implemented in the simulations beginning in 2008. However, all simulations showed a decline in the population from 2009-2013 (Fig. 4-6). This reflects the impacts of ice and harvests over the last decade as they work themselves through the population. Different levels of M_{ice} used in this study began to take effect in the population by about 2013, when the first cohorts subject to the new harvest/M_{ice} regime reached maturity and entered into the breeding population.

A single event resulting in mortality of 30% of the pups or more resulted in a significant change in the population. However, no significant change in pup production from the base run was detectable for approximately 20 years. Incorporating a10% ice related mortality into the model resulted in a significant change in pup production and total population if it occurred in 6 or more years within a single decade.

Including M_{ice} of 10% had little impact on our perception of the population in the short-term (<10 y) (Fig. 4). M_{ice} that persisted for 6 or more consecutive years had significant longer term impacts on the population trajectory. However, these effects would not have been detected until more than 20 years later.

Increasing magnitudes of ice-related mortality were examined next for their impact on the pup production trajectory (Fig. 5). The impact of any level of additional mortality will not be identified for at least 10 years, after which mortalities greater than 20% may result in pup productions that are significantly different from projections assuming no ice mortality.

The impacts of variability in M_{ice} on the population was examined assuming a uniform distribution with a mean value for M_{ice} of 10%, and a CV of 10-60% (Fig. 6). In the short-term, variable mortalities cannot be distinguished. Variable values for M_{ice} did not have a detectable impact on changes in the population trajectory within the first decade. However, a variable M_{ice} did have a noticeable effects on the trend in pup production within approximately 15 years, quite possibly at a CV of as little as 10%. Higher variability has a greater impact on the population, but by the time this is recognized based upon surveys (~15- 20 years), pup production could be significantly lower.

Discussion

Marine mammals life history strategies are characterized by long lifespan, delayed age of maturity, low reproductive rates and high juvenile mortality. Among pinnipeds, the nursing periods are quite short, and weaning is abrupt, leaving the young animals to develop swimming and foraging skills on their own. Few studies have examined mortality rates, but they are expected be high initially and decline as animals mature. Mortality due to poor ice conditions during the nursing and post-weaning fasting stages are one component of natural mortality that would be expected to vary between years, particularly in the Gulf of St. Lawrence. Harp seals are also subject to commercial and subsistence harvests. Between 2003 and 2007, an average of 390,000 seals were harvested annually and in the Canadian commercial harvest approximately 95% of the harvest consists of animals less than three months old (Stenson 2005).

The primary tool for monitoring harp seals consists of aerial surveys to determine pup production, which through extensive reconnaissance cover all known Northwest Atlantic harp seal pupping areas (Stenson et al. 2003). Flown every 4-5 years during the nursing period, the surveys typically have a coefficient of variation of 10% or less, which is fairly precise, particularly considering the large area to be covered (Hammill and Stenson 2005). Although the surveys may be capable of detecting relatively small changes in pup production, the fact that the large commercial harvest and high natural mortality are operating primarily in the first few months of life, means their impacts will not be felt in the population until at least 5 years later, when these cohorts enter into the breeding population and begin to produce young themselves. This has two implications for managers, the first being that there is considerable inertia within the population as previous harvest and ice mortality conditions work themselves through the population and secondly, there will be a delay of 5 or more years before new harvest and natural mortality regimes will be reflected in the population.

Ice-cover in the Northwest Atlantic shows considerable inter-annual variability (Johnston et al. 2005), which may impact on the natural mortality rates of young harp seals during the nursing or post-weaning fast periods. The simulations initiated new harvest regimes and mortality conditions beginning in 2008, but as indicated above, the impact of this new harvest (N=200,000) and mortality related to ice conditions, were not reflected in the population before 2013, at least 5 years after the start of simulation period. None of the simulations appeared to have a significant impact on our perceptions of the population over a short-term view of 5-10 years and a change in pup production could not be distinguished. However, over a longer-term view of 20 or more years, the pup production trajectories started to differ significantly from the baseline projections.

In these simulations, changes in pup production were simulated over a 40 year time frame, assuming that reproductive rates, reported harvests and M_{ice} remained constant or only changed in the direction set as part of the simulation exercise. In a practical sense, inter-annual changes in harvest levels may vary by more than 10% and such changes would have a more significant impact on the population trajectory than would small changes in M_{ice}. It is likely that regular monitoring would detect the changes in pup production and that fitting the model to new estimates of pup production could result in lower estimates of the modelled population, thus tracking the short-term changes in the population fairly well. However, failure to consider M_{ice}, would result in a poorer fit of the model to the survey estimates, particularly if M_{ice} was significant or highly variable. Considering M_{ice} would also contribute to understanding future trends as the inertia from previous harvest and environmental conditions moves through the population.

This study has shown that it is important to consider M_{ice} in the assessment of Northwest Atlantic harp seals. Although low levels of increased mortality are not likely to have an impact on the population, over the longer term increased mortality from variable ice conditions can have a significant impact on the trajectory of the population. This underlines the need for caution and consideration of uncertainty in the assessment when setting suitable harvest levels. This point needs to be underlined because although the impacts may not be felt for 10 or more years, the normal decision cycle of managers, scientists and politicians involved in the decision making process is considerably less than that.

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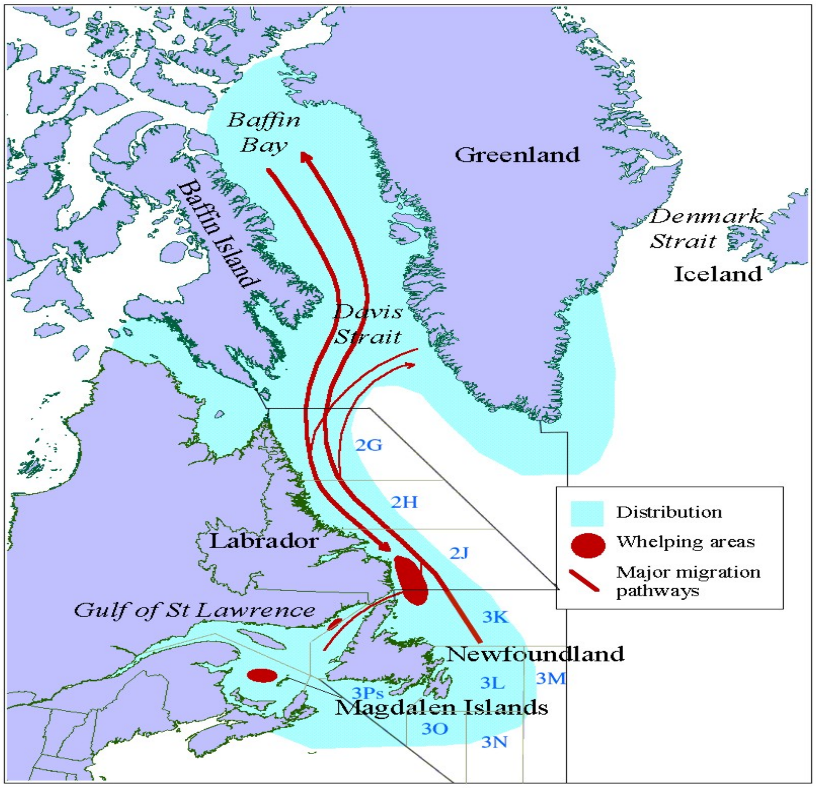

Figure 1. The Northwest Atlantic harp seal summers in the Arctic but moves south in fall to overwinter and reproduce on the drifting pack-ice off northeastern Newfoundland and in the Gulf of St. Lawrence

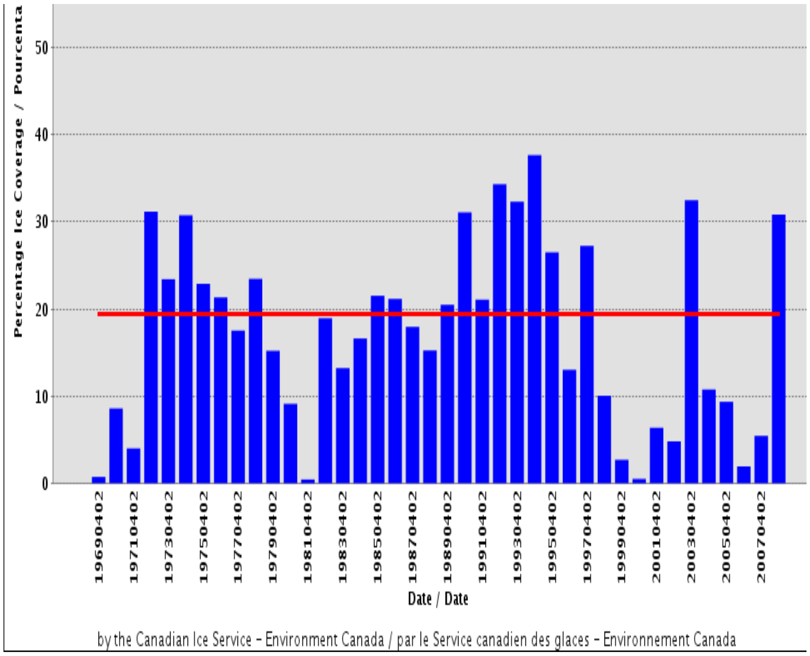

Figure 2. Total ice cover in the Gulf (percent) on April 2, 1969 -2008. The period 1985-97 was characterized by unusually good ice conditions as compared to the longterm mean. Over the last decade, the frequency of below average ice cover has increased markedly.

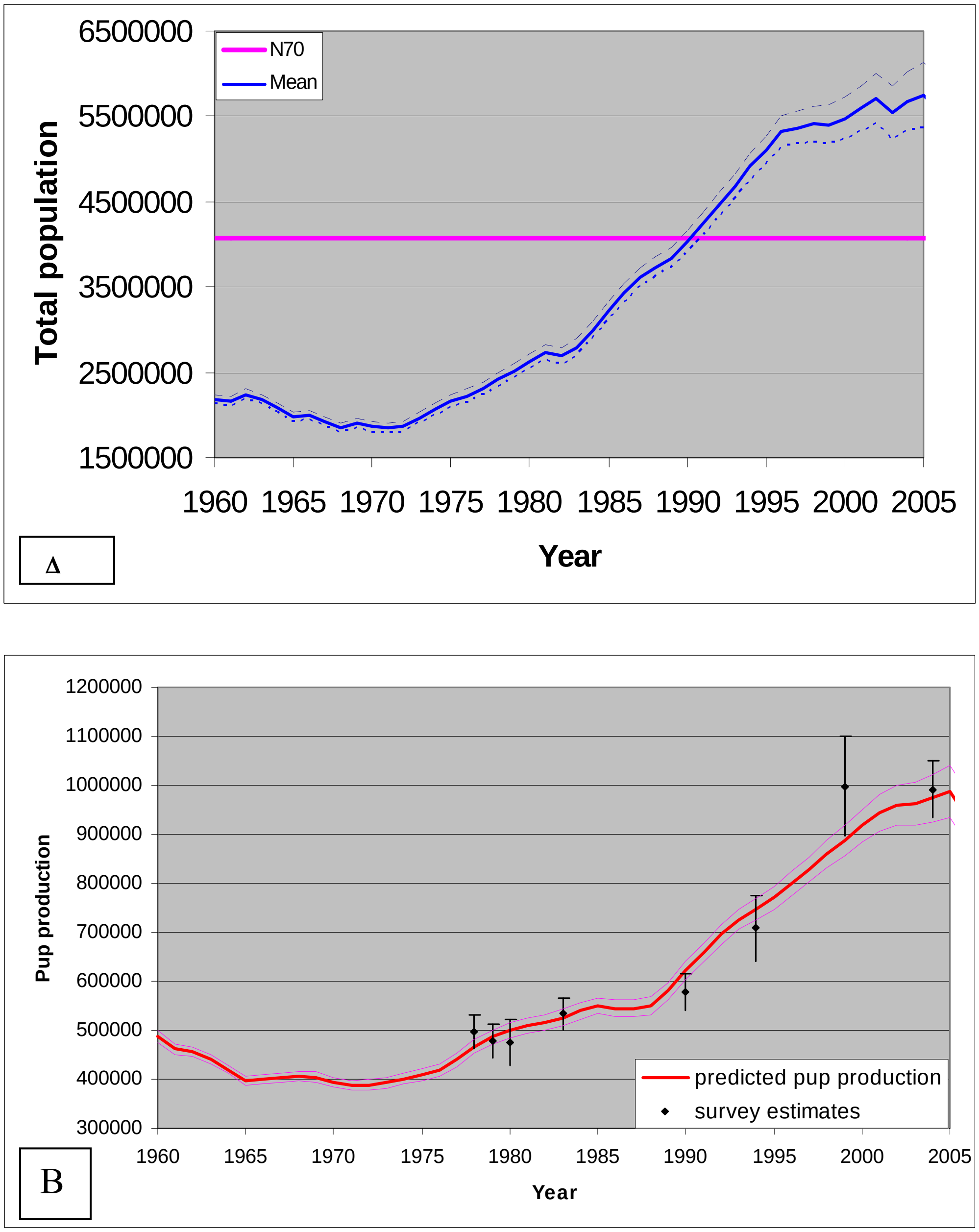

Figure 3. Changes in the Northwest Atlantic harp seal total population size (**A**) and in pup production (B) between 1960 and 2005 (mean ± 1SE) . N70 represents the precautionary reference level of 4.07 million animals, where the management objective is to maintain an 80% probability that the population will be above N70. The survey estimates (mean ± 1SE) are based on mark-recapture estimates (prior to 1990), and aerial survey estimates (1990 and later).

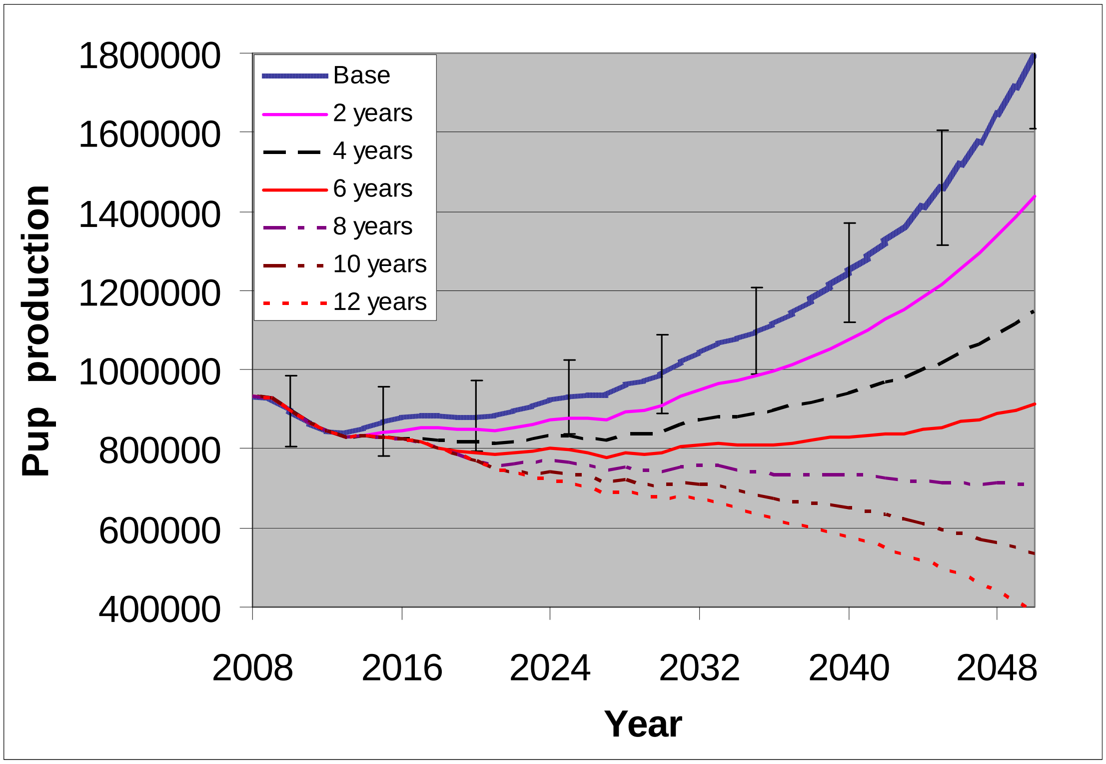

Figure 4. Baseline and M_{ice} trajectories from 2008 to 2050. The base run includes 10% cv bars plotted at 5 year intervals. M_{ice} was set at 10% and lasted for 2 to 12 years.

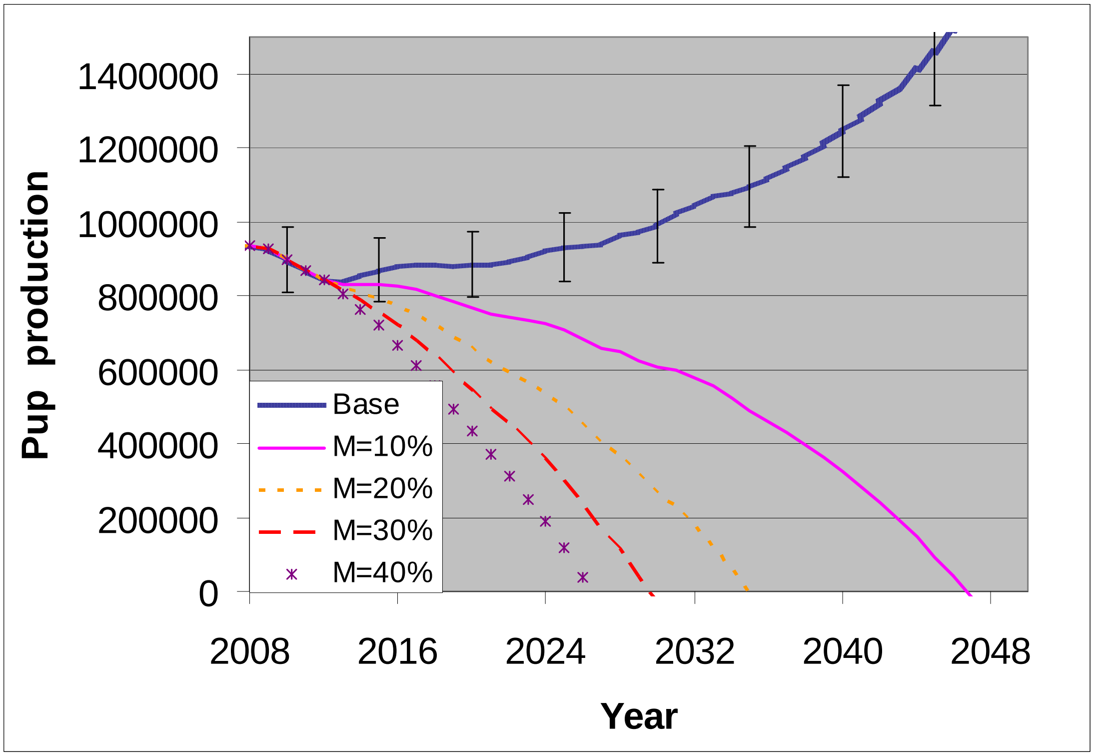

Figure 5. Impacts of different annual levels of M_{ice} on pup production. The base pup production projection with cv error bars of 10%, assumes no additional M_{ice} .

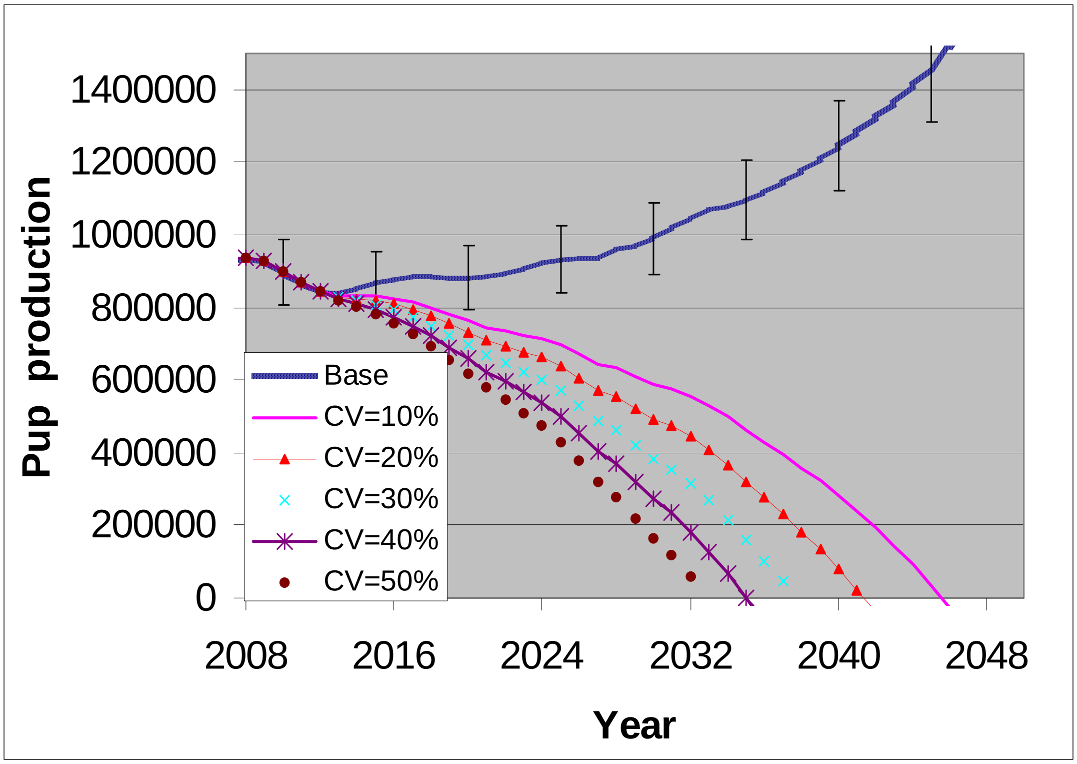

Figure 6. Impacts on pup production with mean M_{ice}=10%, but CV=10-50% . The base pup production projection with CV error bars of 10%, assumes no M_{ice} . In the short-term there is little to be gained by taking into account M_{ice} . However, longterm projections should consider accounting for ice mortality .