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Final Report to the Nunavut Wildlife Management Board

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Summary:

This document reports on final results of the Davis Strait polar bear population inventory conducted by the Department of Environment, Government of Nunavut and its partners from 2005 to 2007. The results reported here combine capture information from the present study with similar data collected since 1974 in Davis Strait by other researchers (M. Taylor, I. Stirling). Using the long term mark-recapture-recovery data set allowed us to more accurately estimate survival of the polar bears, as they are a long-lived species. As a result we are able to produce an accurate population estimate and also survival estimates over time. We estimated the population size to be approximately 2,142 polar bears in 2007. We conclude that survival of polar bears has significantly increased since the 1970's likely due to combined effects of increased harp seal abundance and relatively low harvest rate. However, survival rates have now plateaued since the early 2000's and the population is at a point of decline. We surmise that the decline in abundance is as a result of concomitant declines in harp seals, density effects and a lag effect of decreasing ice conditions. We recommend that the current target goal of 1,650 bears (Government of Nunavut MOU with communities harvesting from Davis Strait) should be evaluated with respect to current management and conservation goals, and past and future population dynamics. Consequences of various harvest scenarios are included in this report.

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ᐆᒪᔪᓐᓇᕐᓂᖏᑦ ᐅᔾᔨᕐᓇᖅᑐᒻᒪᕆᖏᒃ ᐅᓄᖅᓯᕚᓪᓕᖅᓯᒪᓂᖏᓐᓂᒃ 1970-ᖏᓐᓂ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᓯᒪᑎᓪᓗᒋᑦ. ᐱᔾᔪᑕᐅᓚᐅᖅᓯᒪᔪᖅ ᖃᐃᑦᓖᑦ ᐅᓄᖅᓯᕚᓪᓕᖅᓯᒪᓚᐅᖅᓯᒪᓂᖏᓐᓂᒃ ᐊᒻᒪ ᖃᔅᓱᓐᓇᑦᑐᐃᑦ ᐱᔭᐅᖃᑦᑕᕐᓂᑰᓂᖏᓐᓄᑦ. ᑭᐊᓯᓂ, ᐆᒪᔪᑦ ᐅᓄᖅᓯᕖᓪᓕᐊᓂᖏᑦ ᐅᓄᕈᓐᓃᖅᐸᓪᓕᐊᓂᖏᑦ ᐊᑕᐅᓯᖅᓯᓕᑲᓚᐅᖅᑐᑦ ᑕᐃᒪᙵᑦ 2000 ᐱᒋᐋᓴᓚᐅᖅᓯᒪᑎᓪᓗᒍ ᐊᒻᒪ ᐅᓄᕐᓂᖅᓴᖏᑦ ᒫᓐᓇ ᐅᓄᕈᓐᓃᖅᐸᓪᓕᐊᖔᓕᕐᒥᔪᑦ. ᓇᓚᐅᑦᑖᖅᐳᒍᓪᓕ ᐅᓄᕈᓐᓃᖅᐹᓪᓕᕐᓂᖏᓐᓂᒃ ᐅᓄᕐᓂᓇᓚᐅᖅᑕᖏᓐᓄᑦ ᐱᔾᔪᑕᐅᓇᓱᒋᓪᓗᑎᒍᑦ ᐊᑕᐅᑦᑎᒃᑯᑦ ᐅᓄᕈᓐᓃᖅᐹᓪᓕᕋᓱᒋᓪᓗᑎᒍᑦ ᖃᐃᑦᓖᕐ, ᐅᓄᕐᓂᓇᓱᖏᓐᓄᑦ ᐊᒃᑐᐃᓂᓇᓱᐅᔪᖅ ᐊᒻᒪ ᐱᕙᓪᓕᐊᓂᖓᓄᓪᓗ ᓯᑯᐃᖅᓵᓕᖃᑦᑕᓕᕐᓂᖓᓄᑦ. ᐱᕐᑯᔨᕗᖔᓕᐅᕐᑯᔨᕗᒍᓪᓕ ᒫᓐᓇᓕᓴᖅ ᑎᑭᑕᐅᓇᓱᒃᑐᖅ 1,650 ᓇᓄᐃᑦ (ᓄᓇᕗᑦ ᒐᕙᒪᖓᑕ ᑎᑎᖅᑲᑦ ᑐᑭᓯᐅᒪᕐᖃᑎᒌᖕᓂᕐᒧᑦ ᓄᓇᓕᖕᓂᒃ ᐊᖑᓇᓱᒃᐸᒃᑐᓂᒃ ᕿᑭᖅᑖᓗᐸ ᑲᓛᕐᑖᓪᓗ ᓄᓇᖓᑕ ᐃᑭᕋᓴᖓᓂ) ᖃᐅᔨᓵᖑᔭᓇᐊᖅᑲᕐᓂᖏᓐᓂᒃ ᐃᒃᐱᒋᔭᐅᑦᑎᐊᕐᓗᓂ ᒫᓐᓇᓕᓴᐃᑦ ᐊᐅᓚᑦᑎᓂᕐᒧᑦ ᐊᑐᓗᐊᖅᑕᐃᓕᒪᓂᕐᒧᓪᓗ ᑎᑭᑕᐅᓇᓱᒃᑐᑦ, ᑭᖑᓂᑦᑎᓐᓂᓪᓗ ᓯᕗᓂᑦᑎᓐᓂᓪᓗ ᖃᔅᓯᐅᓂᓇᓱᖏᓐᓄᑦ. ᓴᖅᑮᔭᓕᕐᓂᖓ ᖃᓄᐃᓕᖓᓕᕐᓂᓇᓱᖓ ᐊᔾᔨᒌᙱᑦᑐᑦ ᐊᖑᓇᓱᒃᑕᐅᕙᒃᑐᑦ ᐊᔾᔨᓕᐅᖅᓯᒪᔪᑦ ᐃᓚᓕᐅᔾᔭᐅᓯᒪᔪᑦ ᑖᕙᓂ ᐅᓂᒃᑳᒥᒃ.

Introduction:

Polar bears (*Ursus maritimus*) were assessed as a *species of special concern* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2008). The species is also considered vulnerable by the IUCN/World Conservation Union (Aars et al., 2005) and *threatened* under the United States Endangered Species Act (US Department of the Interior, 2008). Threats to the species include anthropogenic harvest (Taylor et al., 2008), increased development in the Arctic (Durner et al., 2006) and bio-accumulation of environmental contaminants (Sonne et al., 2006). However, the most significant threat to polar bear abundance and distribution is the decline in optimal habitat – annual ice over the continental shelf (Amstrup et al., 2007, Durner et al., 2009). Annual ice provides best access to ringed seals (*Phoca hispida*), the primary prey of polar bears, and other prey including harp seals (*Phoca groenlandica*), walrus (*Odobenus rosmarus*) and bearded seals (*Erignathus barbatus*).

Declines in body metrics of polar bears attributed to declines in various measures of ice cover have been found in the south Beaufort Sea and western Hudson Bay subpopulations (Regehr et al., 2007, Rode et al., 2007). Reductions in annual survival rates (and therefore population growth) of senescent and subadult bears have been statistically correlated with earlier ice break-up in western Hudson Bay (Regehr et al., 2007). Further, biologically significant trends in declining survival and population size have been found in the southern Hudson Bay and southern Beaufort sea populations (Obbard et al., 2007, Regehr et al., 2006); it has been suggested that these changes are also linked to reductions in ice cover.

Considering the impacts of harvest and/or changing environmental conditions, the Canadian Federal and Provincial/Territorial Polar Bear Technical Committee considers six of Canada's 13 subpopulations (Figure 1) as declining in size, two as data deficient and five as either stable or increasing (PBTC, 2009). Two of the subpopulations considered to be increasing are being managed for recovery (i.e., harvest is set below intrinsic rate of increase) from previously depleted states (Gulf of Boothia and M'Clintock Channel). It appears however, that one subpopulation of polar bears, Davis Strait (Figure 2), has naturally increased according to both Aboriginal Traditional Knowledge (ATK; M. Kotierk, unpublished data and comments provided by local hunting and trapping organizations in Iqaluit, Pangnirtung, Kimmirut (Nunavut) and Nain (Labrador) and professional knowledge (e.g., I. Stirling, M. Taylor, A. Simpson)). Davis Strait is one of the most southerly sub-Arctic subpopulations of polar bears in the world and concentration of summer time annual sea ice has declined since 1984 (Stirling and Parkinson, 2006) (Figure 3). The anecdotal increase in the population size of polar bears, over the same period of decreasing ice metrics, suggests other factors may be influencing polar bear survival in Davis Strait. The ecological circumstances for polar bears in Davis Strait may differ (Theiman et al. 2008) from that for other subpopulations of polar bears where empirical relationships between declining habitat and declining demographic parameters have been established (Obbard et al., 2007, Regehr et al., 2006, Regehr et al., 2007).

For the purposes of this report, our primary objective was to conduct a rigorous population inventory of the Davis Strait polar bear population to generate a modern population estimate and other demographic parameters. We compare estimates of annual survival and recruitment to those in the 1970's, when the last population inventory was conducted (Stirling et al. 1980, Stirling and Killian 1980).

Project Objectives:

To estimate:

i. population size;
ii. sex/age/family status population composition;
iii. recruitment and survival rates; and
iv. population status and sustainable harvest

Materials and Methods:

Study Area

The Davis Strait subpopulation of polar bears is defined as occurring on the ice between Canada and Greenland, south of 66° N, extending to the southern reaches of Labrador (Taylor et al., 2001). From approximately August through mid November the area is ice-free. At this time bears concentrate on offshore islands and a narrow coastal strip of Labrador, Hudson Strait, the Ungava Coast of Quebec, and the southern coast of Baffin Island east of Kimmirut, Nunavut into the heads of Frobisher Bay and Cumberland Sound, and the east coast of Baffin Island north to Cape Dyer (Figure 2). Polar bears belonging to the Davis Strait subpopulation do not occur in Greenland during the ice-free season.

Data collection

Detailed here are the field methods for the hitherto unpublished data collected from 2005 – 2007. We conducted the marking in the ice-free season from August through October. We used a Bell 206L Helicopter to survey the entire coastline of the study area, including off-shore islands. Inland transects were also flown. Every bear observed was captured, providing that the capture was safe for bears and crew (Figure 2). Bears were immobilized with Pneudarts (dependent young) or Palmer darts with Zoletil (tiletamine hydrochloride and zolazepam hydrochloride) at approximately 5 mg/kg. Each immobilized bear was given a unique capture number (ear tags and lip tattoo). Capture numbers were recorded for the recaptured bears. The data collected from each bear included straight line body length, greatest breadth of zygomatic arch, chest girth, an index of body condition, approximate age, sex and location and date of capture. A premolar tooth was collected to determine age from cementum layers.

We covered the entire coastline and offshore islands of Davis Strait; areas of the map where there are no dots indicate no bears were seen or captured, not that these areas were not searched. We began searching for polar bears at Nain, NL, but generally did not capture the first bear until just south of Saglek Fiord. On the Ungava coast, we ceased searching for polar bears near Quaqtaq, Nunavik; only a few bears were seen north of Kangirsuk, Nunavik. We searched east from Kimmirut, as bears west of Kimmirut would be considered part of the Foxe Basin Population. In Cumberland Sound and Frobisher Bay, we ceased searching after we no longer saw a bear after an hour of searching towards the heads of the bays. We ceased searching at the northern end of the study area at Cape Dyer, Nunavut, north of this point would be considered a part of the Baffin Bay subpopulation. We also conducted many inland transects to tag bears that may be inland. Family groups are generally found more inland in some populations (Regehr et al., 2007), however in Davis Strait we found this less common, likely because of the steep terrain along the coast in most areas. However, we did make forays in low land inland areas and valleys.

We compiled harvest data from Davis Strait in Greenland, Quebec, Nunavut and Newfoundland and Labrador from 1974 until 2007. Conservation officers recorded numbers from lip tattoos and/or ear tags that were submitted by harvesters. We assume all tagged bears were recorded as the quota is well regulated and harvest reporting has occurred for several decades. In addition, hunters receive compensation for the submission of samples from harvested bears. Any violation of this assumption would negatively bias the estimates of natural survival. It is not expected that harvesters preferentially shoot tagged animals, as the ear tags are very small and white.

We used all recovery events of bears marked in Davis Strait, whether harvested within the population or other subpopulations (e.g., Foxe Basin and Baffin Bay).

Mark-recapture-recovery analysis

We estimated recapture, recovery and survival probability using Burnham's likelihood (Burnham, 1993), which is an extension of the Cormack-Jolly-Seber open-population model (Seber, 1982). The Burnham model combines live recaptures and dead recoveries of marked animals in the estimation of demographic parameters. The parameters estimated from the likelihood are: total apparent survival (*S*) of marked animals; live recapture probability (*p*); site fidelity (*F*); and recovery probability of marked animals (*r*). The probability of recovery is the probability of the bear being harvested and reported. We implemented the likelihood in RMark. We built our capture histories with all initial captures, however we only included recapture events during the period during which capture effort was systematic (2005 - 2007), so as to not bias estimates of recapture probability with years of unsystematic effort. Preliminary analysis suggested that there were insufficient data to use models in which the fidelity parameter was allowed to vary, and thus in all models presented in this paper, we fixed *F* at one. This results in the Jolly-Seber assumption that any emigration from the study area is permanent (Burnham, 1993).

We used a five age-class model to estimate the other demographic parameters (*S, r* and *p*): cubs-of-the-year (COY), yearlings (1 year old); subadults (2 – 4 years old); adults (5 – 20) and senescent animals (21+). Bears were assigned age-classes based on 1) known age 2) age derived from pre-molar teeth in the laboratory or 3) estimated age in the field. We had laboratory or known ages for 1,874 of 2,943 capture and recovery events; remaining ages were estimated in the field.

We initially examined models for the estimation of *p*, which allowed the parameter to vary with age-class, time and sex. Preliminary models coalesced to support that variation in *p* to be best explained by variation among three groups: 1) adult females and dependent young; 2) subadult males and females; and 3) adult males. The recapture probability of adult females with dependent young and those dependent young are obviously correlated; however we found that the most parsimonious model also included solitary adult females in this group. There was no sex difference in recapture probability between male and female subadults, leaving the second parameter to be estimated for the recapture of adult males. We also found that recapture probability was lower for 2005 than 2006 and 2007, likely as a result of refined searching techniques. As a result, only two models for *p* are presented here: *p(~femandyoung + subadult)* and *p(~femandyoung + subadult + time).* Recapture probability was fixed at zero from 1974 to 2004, during which capture effort was not systematically applied to the entire population.

We built models to best estimate *S* and *r* by evaluating variation with the following factors: sex, age-class, time, and group- and time-covariates. Preliminary analyses showed that the interactive term *non-juv:male* was supported; the final models presented in this report were built with variations of this parameter. *Non-juv:male* indicates that survival and recovery varied among sex but only for independent bears (subadults, adults and senescent adults); there was no difference in survival or recovery between male and female dependent young.

We sought to describe any temporal variation in survival and recovery not by time but by environmental covariates which may have varied over the duration of the study. However, we included a factor, *time period* (1974 – 1978; 1979 – 1983, 1984 – 1988, 1989 – 1993, 1994 – 1998, 1999 – 2007) when building models to examine variation that could not be explained with the temporal covariates. Time covariates included both demographic and environmental variables: a time series of abundance estimates of harp and hooded seals in the North Atlantic; annual metrics of summer ice concentration; annual Arctic Oscillation and average adult age of bears in the population.

In the western Hudson Bay polar bear subpopulation, timing of ice break-up was an important covariate explaining variation in juvenile, senescent and subadult survival (Regehr et al., 2007). Ice conditions in Davis Strait are also changing (Figure 3) and may impact the polar bear population (Stirling and Parkinson, 2006). Here we use the mean weekly estimate of total ice concentration in Davis Strait from 14 May to 15 October (Archives of the Canadian Ice Service, http://ice-glaces.ec.gc.ca/) as a metric of ice conditions. This covariate *ice* (Figure 3), encompasses variation in the length of the ice-free season; we could not use freeze-up or break-up date as these metrics are highly variable in Davis Strait. There is no significant linear trend in this metric during the course of the study (1974 – 2008); however there is a significant polynomial trend, and as such we used the second order of this covariate in the mark-recapture analysis. A break-point regression indicated that a break point in the time series occurs between 1983 and 1984, with two significant and opposite trends in summertime ice concentration from 1974 – 1983 and 1984 - 2007 ($y = 0.01x – 20.33$, $R^2 = 0.39$, $p = 0.05$; $y_2 = 9.61 – 0.004x$, $R^2 = 0.55$, $p = 0.00$, Figure 3)

Harp seals are known to be an important food source for polar bears in southern Davis Strait (Iverson et al., 2006), and the North Atlantic populations of harp seals has increased (DFO, 2005, Stenson et al., 2002) as a result of a European ban on the import of white pelts. It has been suggested that that the increase in these seals has contributed to increases in polar bear abundance in Davis Strait. The covariate *seal* (Figure 4) were time series data on harp and hooded seals abundance estimates provided by the Department of Fisheries and Oceans (G. Stenson, unpublished data). These were estimates of total population size were derived from models incorporating empirically-derived estimates of pup production, other reproductive rates and human-caused mortality (DFO, 2005). No time series of abundance for any seals species exist in the Nunavut region. However, ATK suggests that harp seals have been increasing in the southeastern Baffin region (Minutes from authors meeting with Iqaluit and Pangnirtung Hunting and Trapping Organization, January 2009).

This report also produces a population estimate for Davis Strait polar bears, which is much larger than previous estimates (Stirling et al., 1980, Stirling and Killian, 1980). This increase is also supported by ATK (Pangnirtung, Kimmirut and Iqaluit Hunting and Trapping Organization boards, personal communications). As a result of this increase in density we sought to evaluate whether survival of polar bears in Davis Strait varies with population density. However, there are only two point population estimates for polar bears in Davis Strait, and no population density index exists. The average age of captured adult polar bears in Davis Strait has increased over the last three decades (Figure 5; β = 2.058 ± 0.453, F = 20.66, p 0.00, df = 812; mean age in 1970’s, 9.20 ± 4.55 and in 2000’s, 11.26 ± 5.06; research in both the 1970’s and the 2000’s was conducted for the purpose of population inventory and thus the sample is representative of the population) indicating the significant change in the demographic make-up of the population. We therefore use the annual mean adult age*,* as a proxy of increasing population density to understand variation in survival over time. Survival rates may also vary directly with average age of the adult population itself. The covariate *adult age* (Figure 5) is the mean age of captured adult male and female polar bears in Davis Strait.

We explored the use of harvest numbers as an additional parameter to fit recovery (*r*) models. However, recovery of marked bears did not vary with harvest and thus this parameter was not retained in the final set of models presented here.

After preliminary analysis, we ran 504 models and the most general model, which represented combinations of the above covariate and age-sex class effects on total survival, recapture and recovery probability. We selected models using Akaike’s Information Criterion (Burnham and Anderson, 2002) (AIC).

We estimated fit of the data to our most general estimable model. We used the *median* $\hat{c}$ approach to calculate overdispersion by exporting the model from RMark into program MARK:

*S(Time period +age-class*Sex),r(Time period + age-class + nonjuv: male)p(femandyoung + subadult +time)F(1).*

We found no overdispersion ($\hat{c}$ = 1), and no adjustments were made to parameter estimates.

Natural survival

The Burnham model provides maximum-likelihood estimates of total survival; this parameter includes mortality due to human harvest of polar bears. We are interested in natural survival to evaluate selective forces on polar bears separate from the effect of human harvest. We estimated natural survival (S_n) such that:

$$S_n = S + (1-S)r$$

This formulation assumes that all harvested, marked bears are reported. The variance of S_n was estimated using the delta method (Seber, 1982) and the covariance matrix for r and S_n; the calculations were implemented in RMark.

Abundance estimate

We estimated abundance using the Horvitz-Thompson approach (McDonald and Amstrup, 2001, Taylor et al., 2002), by dividing the number of animals marked and recaptured in a particular year by the estimated recapture probabilities in that year for each sex and age class. The abundance estimates are summed over sex and age classes. The variance of the abundance estimate was constructed using the delta method (Taylor et al., 2002) using the variances for the number of marks and the covariance matrix for p_i.

Recruitment

We calculated recruitment rates using all data from adult females captured between 2005 and 2007, and did not calculate age-specific litter production rates, as all ages have not been finalized. We produce reproductive parameters as did Stirling and Killian (1980) and Stirling et al. (1980) for Davis Strait polar bears, for comparative purposes. We calculated *litter-produced rate* such that:

$$\frac{(\text{Adult females aged X} + 1 \text{ with COY}) + (\text{Adult females aged X} + 2 \text{ with yearling})}{(\text{Adult females aged X} + 1) + (\text{Adult females aged X} + 2)}$$

We also calculated mean *COY litter size* and *yearling litter size*, by dividing the number of cubs by the number of litters for each year. We calculate *Natality as litter-produced rate* multiplied by mean *COY litter size*. We present an average for the three years of study (2005 – 2007). We also calculated *litter production rate* as per Taylor et al. (1987) for use in population viability analyses (PVA, RISKMAN; Taylor et al. 2001b) such that:

$$\frac{\text{(Adult females with COY in year t)}}{\text{(Solitary Adult females in year t - 1)}}$$

We also present *litter production rate* discounted by annual total survival of adult females (0.929). While this value is not used in RISKMAN, as RISKMAN already incorporates annual survival in population projections, it does reflect actual *litter production rate*, by incorporating the probability of the solitary adult female surviving the year to have COY in following year.

We also present age-specific recruitment parameters from a standing-age distribution built using 587 ages (2005 capture season): mean *COY* and *yearling litter size*; *litter production rate* for 5-year olds, 6-year olds and 6 + adult year old females; and the average age of first reproduction. We produced these parameters using VITAL RATES (1.0.092; Taylor et al. 2000).

Results:

Capture and harvest recovery of polar bears

Live capture and recapture data used in this analysis consisted of 2,037 events in Davis Strait from 1974 – 2007. Intensive mark-recapture work was conducted on the spring sea-ice from 1974 – 1979 (Stirling et al., 1980, Stirling and Killian, 1980) and in the ice-free season from 2005 – 2007 (Tables 1, 2). Other capture data were collected in both the spring and fall (1993 and 1997 – 1999) for studies concentrating on radio and satellite telemetry (Taylor et al., 2001a). During other years, there were incidental captures. Figure 2 shows the spatial distribution of captures and harvest of marked bears (recoveries) from 2005 – 2007. We incorporated recovery events of 139 harvested bears that were marked in Davis Strait as dead encounters from 1974 – 2008. We used recovery of any bears marked in Davis Strait, including those recovered in neighboring populations; of 139 recovered bears 8 were recovered in the Foxe Basin population and 25 in the Baffin Bay population. We did not include recovery of bears marked in other populations.

Mark-recapture-recovery modeling

We ran 505 Burnham models in RMark as described in the methods section (Table 3ab). We present model-averaged estimates of all parameters, estimated over 504 models. We also present model-averaged estimate of the derived parameter, natural survival. When presenting results on effects of covariates, we present model-specific estimates.

Probabilities of recapture and recovery

Recapture estimates (*p*; Table 4) for 2005 – 2007 were high with recapture rates higher in 2006 and 2007 than 2005; adult males were captured at a higher rate (0.44 ± 0.07 (SE) in 2005 and 0.48 ± 0.03 in 2006-07) than adult females and young (0.27 ± 0.06 in 2005 and 0.30 ± 0.02 in 2006-07), and subadult bears (0.33 ± 0.07 in 2005 and 0.37 ± 0.03 in 2006-07).

In the most supported model, recovery rates, *r*, varied by dependent status (β = -1.03 ± 0.5, juveniles; Table 5) and sex of non-juveniles (β = 0.58 ± 0.24 (SE), males and β = -1.40 ± 0.20, females). There is also support for variability of recovery over time (Table 5, Figure 6), with the probability of recovery peaking in the time period 1984 – 1989. We tested for an effect of season, and found negligible differences between fall and spring recovery of marked polar bears (first appearance in a model with ΔAIC = 1.95, Table 3a). Recovery rates for adult and subadult polar bears in 2007 were 0.26 ± 0.10 and males and 0.16 ± 0.06 for females.

Survival

We provide total and natural survival estimates for the males and females of the five identified age-classes for 2007 (Table 6).

The most supported model (Table 3a) included no time covariates explaining variation in survival, but there was an effect of *time period* (Figure 7), age class and sex of non-juveniles on total survival. Point estimates of total survival in general have increased over time, peaking in the early 2000's (Figure 8). Support for the top model was ambiguous as the next most supported model had ΔAIC of 0.05; 22 models had ΔAIC < 2.0. In models with ΔAIC < 2.0, the time covariates of *seal, adult age*, and *ice* largely supplant *time period* in explaining variation in total survival.

The most important time covariates affecting polar bear survival were the abundance of harp seals and average age of adults in the population. *Seal* primarily affected subadult survival (β = 2.96 ± 1.3 (SE), subadults, β = 0.31 ± 0.44 non-subadult); as harp and hooded seals increased in the North Atlantic population, polar bear survival increased. Simultaneously, average *adult age* is negatively correlated with survival, primarily for subadults (β = -3.00 ± 1.3 for subadults, β = -0.10 ± 0.54 for non-subadults).

The impact of total concentration of summer-time ice concentration is complex. *Ice* as a second-order variable first appears in a model of ΔAIC = 0.69 (Table 3a). Survival of polar bears increases as mean summer ice concentration declines from 35% to 20% (from 1974 – mid 1990's). However, as mean summer ice concentrations have now decreased from 20% to less than 10%, survival declines with ice concentration (Figure 8).

Recruitment

Recruitment parameters generated from 2005 – 2007 data (Table 7) generally show lower productivity of Davis Strait adult females in the 2000's (n = 267 litters) compared to the 1970's. However, recruitment parameters were measured in the spring from 1974 – 1979, thus comparisons are not appropriate.

Using the standing age distribution from 587 random captures in 2005 (Table 8). Mean COY litter size is 1.59 (0.19, SE) and yearling litter size is 1.45 (0.01). Litter production rate for 5-year old females was 0.56 (0.13), for 6-year olds, 0.44 (0.37) and for older females, 0.39 (0.02). Average age of first reproduction was 4.99 (0.78). We documented two four-year old females with cubs-of-the-year in 2005.

Abundance

Our estimate of total polar bear abundance in Davis Strait for 2007 is 2,142 (95% CI, 1811 – 2,534).

Discussion:

Abundance

Our estimate of abundance indicates an increase in polar bears in Davis Strait. The last empirical estimate in the late 1970's of approximately 800 - 900 animals was a combination of numbers estimated in southeast Baffin (Stirling et al., 1980) and northern Labrador (Stirling and Killian, 1980). These mark-recapture estimates were derived from captures on the spring time sea ice, where all bears were not available for capture, and thus were likely biased low. In addition, parts of the Hudson Strait, including Akpatok Island, the Ungava Coast, Resolution Island and the coast west of Kimmirut were not included in the earlier studies. These regions are now considered part of the Davis Strait subpopulation (Taylor et al., 2001). As a result it is unwise to compare scientific figures of abundance between these two studies. However, both professional scientific opinions combined with local knowledge and ATK in the area coalesces in support for a significant increase in abundance of polar bears in the region over the last three decades. This increase in abundance is also corroborated by our estimated rates of increasing survival over time.

Recruitment

Litter production rates, assuming overwinter survival of the adult female (0.42 ± 0.05 (SE)) are relatively low compared with similar estimates of recruitment to the fall of polar bear productivity in other populations. For example, Taylor et al. (2005) estimated the litter production rates for females older than 6 years old to be 1.0 ± 0.16, i.e., every solitary adult female in the fall produces a litter the following spring. In western Hudson Bay, litter production rates for adult females in the fall are 0.790 ± 0.18.

Survival

Natural survival rates of polar bears, as measured in the autumn, are low compared with other populations, measured in the fall. As an example, adult female survival is 0.928 (0.024) in Davis Strait, compared with 0.953 (0.020) in Baffin Bay, and 0.940 (0.01) in western Hudson Bay (PBTC 2009). Point estimates of survival have declined since the early 2000's, likely the period of the fastest increase in abundance of polar bears in Davis Strait. The increase in survival over time was most influenced by the increase in harp seals. This relationship was most important for subadult polar bears, perhaps indicating the existence of intra-specific competition for food-resources. As age of Davis Strait polar bears has increased, survival has decreased, possibly indicating an effect of increasing density. Polar bear survival increased even through periods of decreasing ice conditions, likely because of the overriding importance of seal abundance. However, we now see that with mean total ice concentration between May and October decreasing below 20%, the relationship of polar bear survival and this ice metric is negative. Over the last 10 years, mean ice concentration has not exceeded 16.8% during this period of the year, and there has been a significant negative trend in this metric over the last 23 years.

Status

Using recruitment rate and natural survival rates generated from this study, the unharvested population growth rate for 2007 is 0.94 ± 0.0005 (SE). However, the results from the RISKMAN PVA suggest that growth rates stabilize to 0.99 ± 0.0005 (Table 9). Without harvest the likelihood of any decline over the next 10 years is 81%. Note that the population viability analysis assumes that recruitment or survival parameters remain constant over the period of simulation. We conclude that the population, having increased substantially over the last three decades is now at the point of decline. This is likely because of a combined effect of density dependence, declining harp seals, and a lag effect of declining ice condition.

Management Implications:

Population viability analysis suggests that the Davis Strait population is now in a state of decline from the population size of 2,142 in 2007. However, this population size is an increase in polar bear numbers from the past, and the increase is likely due to the increase in harp seals and the relatively low harvest rate over the last three decades (the last 5 years, 65 bears/year represents 2.8% harvest rate).

Using 65 bears harvested per year, which is the combined quota from Nunavut (46), Newfoundland and Labrador (6), Greenland (2) and the 5-year mean harvest from Quebec of 11, the likelihood of any decline from 2,142 by 2016 is 100% (Figure 10).

The current target number established in the Nunavut MOUs with the communities of Pangnirtung, Iqaluit and Kimmirut is 1,650. Under current harvest regimes, a population of 1,650 will likely be reached by 2012. By 2016, the end of our 10-year simulation, the population would be expected to be approximately 1,400 bears.

Under a scenario of no harvest, by 2016, the population would be expected to be approximately 1,950 bears.

Polar bear harvest can be set at any level depending on the conservation and management goals of the jurisdictions. If the goal is to increase harvest opportunities, and decrease potential human-bear conflicts as the on-shore season is predicted to increase (Stirling and Parkinson 2006), an increase of harvest to 85 bears per year shared among jurisdictions with quotas (addition of 20 bears), by 2016, the population would be predicted to be about 1,200 bears.

It is important to emphasize that all population viability analyses used in this report do not taken into consideration any change in vital rates over the course of the 10 year simulation. This means that population predictions could be biased low (i.e., if a decline in population resulted in increases in vital rates from release from effects of density-dependence) or high (i.e., if vital rates decline with continued decreases in summertime ice concentration).

Reporting to Communities/Resource Users:

In January of 2009, we presented the results herein to the HTOs in the communities of Pangnirtung, Iqaluit and Kimmirut, Nunavut. There is a planned meeting in Nain in May of 2009 with stakeholders from Newfoundland & Labrador and Nunatsiavut.

References:

Aars, J., Lunn, N. J. & Derocher, A. E. (2005) Polar Bears. *14th Working Meeting of the IUCN/SSC Polar Bear Specialist Group*. Seattle, Washington, USA.

Amstrup, S. C., Marcot, B. G. & Douglas, D. (2007) Forecasting the range-wide status of polar bears at selected times in the 21st century. USGS Administrative Report, pp. 132.

Burnham, K. P. (1993) A theory for combined analysis of recovery and recapture data. *Marked individuals in the study of bird populations* (eds. J. D. Lebreton & P. M. North), pp. 199-213. Birkhauser, Basel, Switzerland.

Burnham, K. P. & Anderson, D. R. (2002) *Model selection and multimodel inference: A practical information-theoretic approach,* Springer, New York.

COSEWIC (2008) COSEWIC assessment and update status report on the polar bear *Ursus maritimus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa., pp. vii + 75 pp.

Department of Fisheries and Oceans. 2005. Stock assessment of northwest Atlantic harp seals (*Pagophilus groenlandicus*). Department of Fisheries and Oceans, Canada.

Durner, G. M., Amstrup, S. C. & Ambrosius, K. J. (2006) Polar bear maternal den habitat in the Arctic National Wildlife Refuge, Alaska. *Arctic,* **59,** 31-36.

Durner, G. M., Douglas, D. C., Nielson, R. M., Amstrup, S. C., McDonald, T. L., Stirling, I., Mauritzen, M., Born, E. W., Wiig, O., DeWeaver, E., Serreze, M. C., Belikov, S. E., Holland, M. M., Maslanik, J., Aars, J., Bailey, D. A. & Derocher, A. E. (2009) Predicting 21st-century polar bear habitat distribution from global climate models. *Ecological Monographs,* **79,** 25-58.

US Department of the Interior (2008) Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Polar Bear (*Ursus maritimus*) Throughout Its Range; Final Rule.

Iverson, S. J., Stirling, I. & Lang, S. L. C. (2006) Spatial and temporal variation in the diets of polar bears across the Canadian Arctic: indicators of changes in prey populations and environment. *Top Predators in Marine Ecosystems* (eds., I. L. Body, S. Wanless & C. J. Camphyuysen). Cambridge University Press, Cambridge.

McDonald, T. L. & Amstrup, S. C. (2001) Estimation of population size using open capture-recapture models. *Journal of Agricultural, Biological, and Environmental Statistics,* **6,** 206 - 220.

Obbard, M. E., McDonald, T. L., Howe, E. J., Regehr, E. V. & Richardson, E. (2007) Polar bear population status in southern Hudson Bay, Canada. USGS Administrative Report, pp. 36.

Polar Bear Technical Committee (2009). Status Report of the Canadian Federal and Provincial/Territorial Polar Bear Technical Committee. Yukon, Whitehorse.

Regehr, E. V., Amstrup, S. C. & Stirling, I. (2006) Polar Bear Population Status in the Southern Beaufort Sea. USGS Administrative Report, pp. 20.

Regehr, E. V., Lunn, N. J., Amstrup, S. C. & Stirling, I. (2007) Effects of earlier sea ice breakup on survival and population size of polar bears in western Hudson Bay. *Journal of Wildlife Management,* **71,** 2673 - 2683.

Rode, K. D., Amstrup, S. C. & Regehr, E. V. (2007) Polar bears in the southern Beaufort Sea III: Stature, Mass and Cub Recruitment in Relationship to time and sea ice extent between 1982 and 2006. USGS Administrative Report, pp. 32.

Seber, G. A. F. (1982) *The estimation of animal abundance and related parameters,* MacMillan Publishing Co., Inc., New York.

Sonne, C., Leifsson, P. S., Dietz, R., Born, E. W., Letcher, R. J., Hyldstrup, L., Riget, F. F., Kirkegaard, M. & Muir, D. C. G. (2006) Xenoendocrine pollutants may reduce size of sexual organs in East Greenland polar bears (*Ursus maritimus*). *Environmental Science & Technology,* **40,** 5668-5674.

Stenson, G. B., Hammill, M. O., Kingsley, M. C. S., Sjare, B., Warren, W. G. & Myers, R. A. (2002) Is there evidence of increased pup production in northwest Atlantic harp seals, *Pagophilus groenlandicus*. *Journal of Marine Science,* **59,** 81 - 92.

Stirling, I., Calvert, W. & Andriashek, D. (1980) Population ecology studies of the polar bear in the area of southeastern Baffin Island. Canadian Wildlife Service Occasional Paper 44. 31 pp.

Stirling, I. & Killian, H. P. L. (1980) Population ecology studies of the polar bear in northern Labrador. Canadian Wildlife Service Occasional Paper 42. 19 pp.

Stirling, I. & Parkinson, C. L. (2006) Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. *Arctic,* **59,** 261-275.

Taylor, M. K., Akeeagok, S., Andriashek, D., Barbour, W., Born, E. W., Calvert, W., Cluff, H. D., Ferguson, S., Laake, J., Rosing-Asvid, A., Stirling, I. & Messier, F. (2001a) Delineating Canadian and Greenland polar bear (*Ursus maritimus*) populations by cluster analysis of movements. *Canadian Journal of Zoology-Revue Canadienne De Zoologie,* **79,** 690-709.

Taylor, M.K., M. Kuc, M. Obbard, H. D. Cluff, B. Pond. (2002b) RISKMAN: Stochastic and deterministic population modeling RISK MANagement decision tool for harvested and unharvested populations. Government of Nunavut.

Taylor, M.K., M. Kuc, D. Abraham (2000). Vital Rates: Population parameter analysis program for species with three year reproductive schedules. Government of Nunavut.

Taylor, M. K., Laake, J., Cluff, H. D., Ramsay, M. & Messier, F. (2002) Managing the risk from hunting for the Viscount Melville Sound polar bear population. *Ursus,* **13,** 185-202.

Taylor, M. K., Laake, J., McLoughlin, P. D., Cluff, H. D., Born, E. W., Rosing-Asvid, A. & Messier, F. (2008) Population parameters and harvest risks for polar bears (*Ursus maritimus*) of Kane Basin, Canada and Greenland. *Polar Biology,* **31,** 491-499.

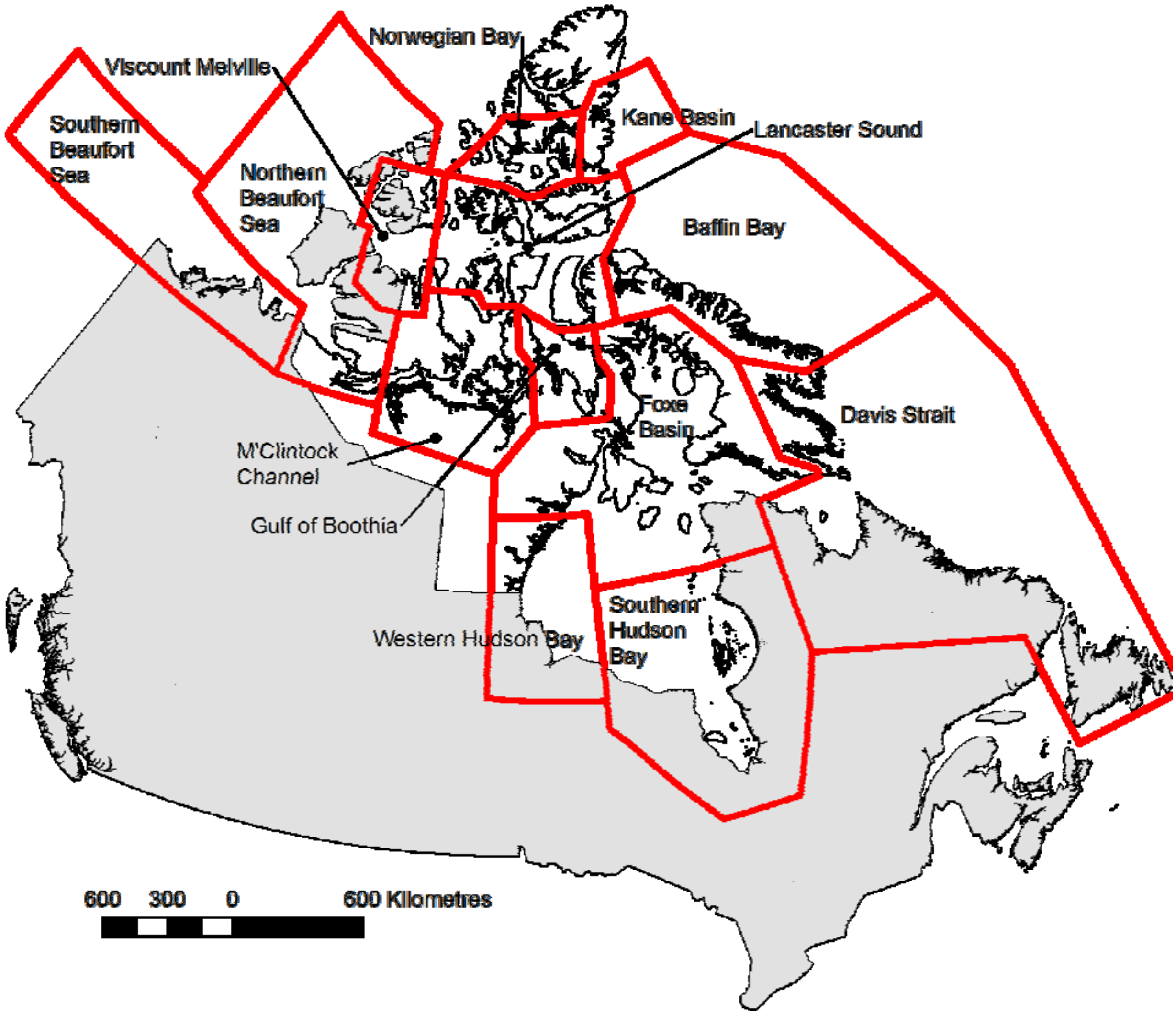

Figure 1. Thirteen polar bear management zones (subpopulations) in Canada.

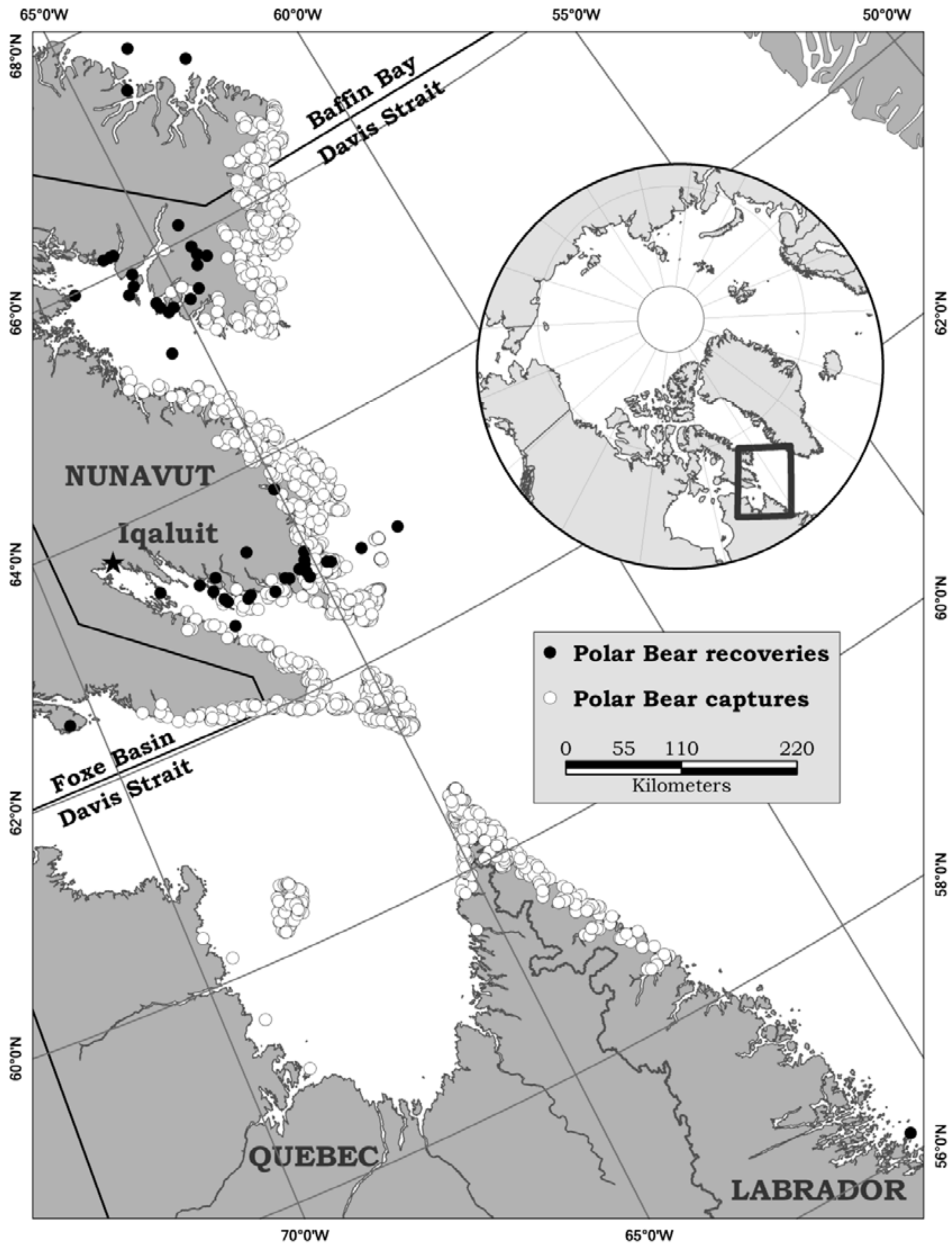

Figure 2. Polar bears captured (n = 2,142) and recovered (marked bears, harvested) in 2005 – 2007 in the Davis Strait subpopulation. Only those recoveries where locations were provided are mapped (n = 36 of 55 recovered).

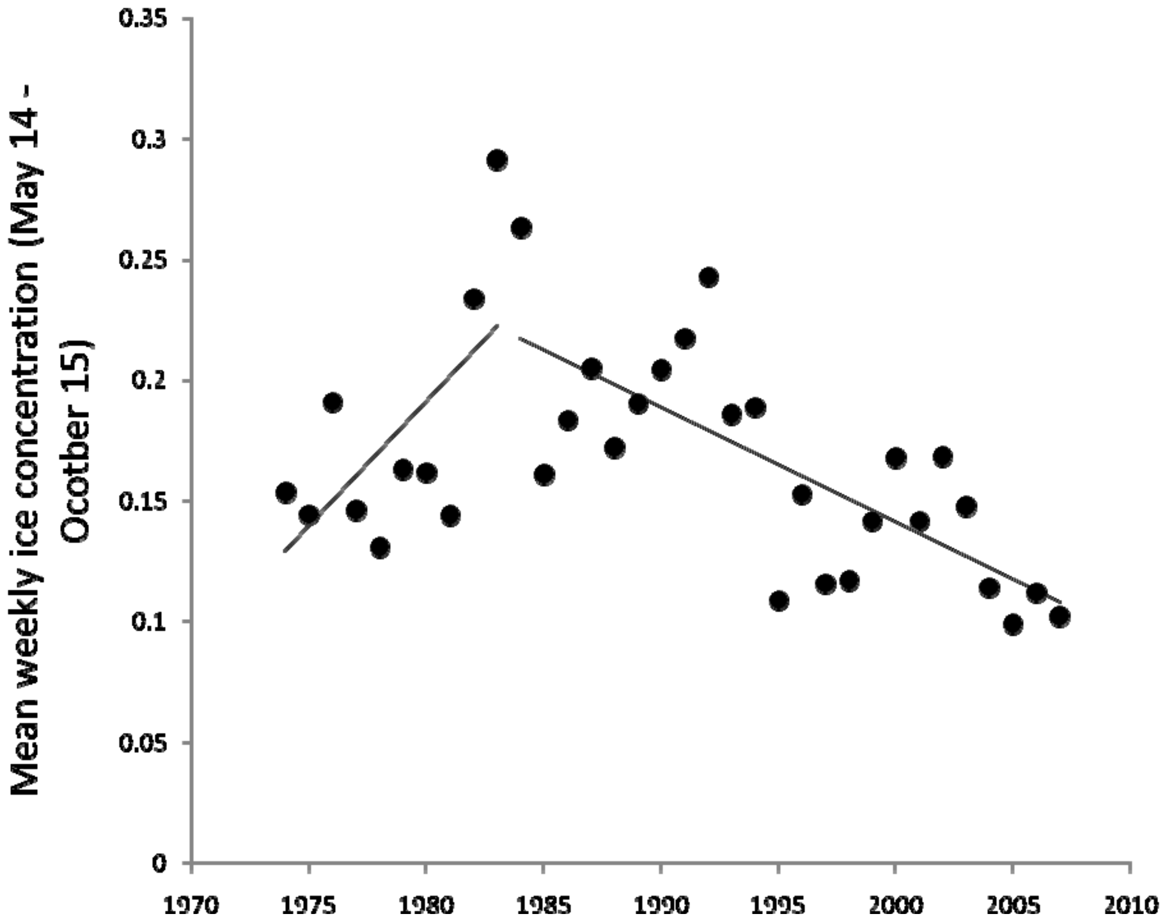

Figure 3. Mean weekly total ice concentration in Davis Strait between May and October (Canadian Ice Service). A breakpoint regression, estimates a break point after 1983, marking a change in trend in ice-concentration; y = 0.01x – 20.33, R^2 = 0.39, p = 0.05; y_2 = 9.61 – 0.004x, R^2 = 0.55, p = 0.00.

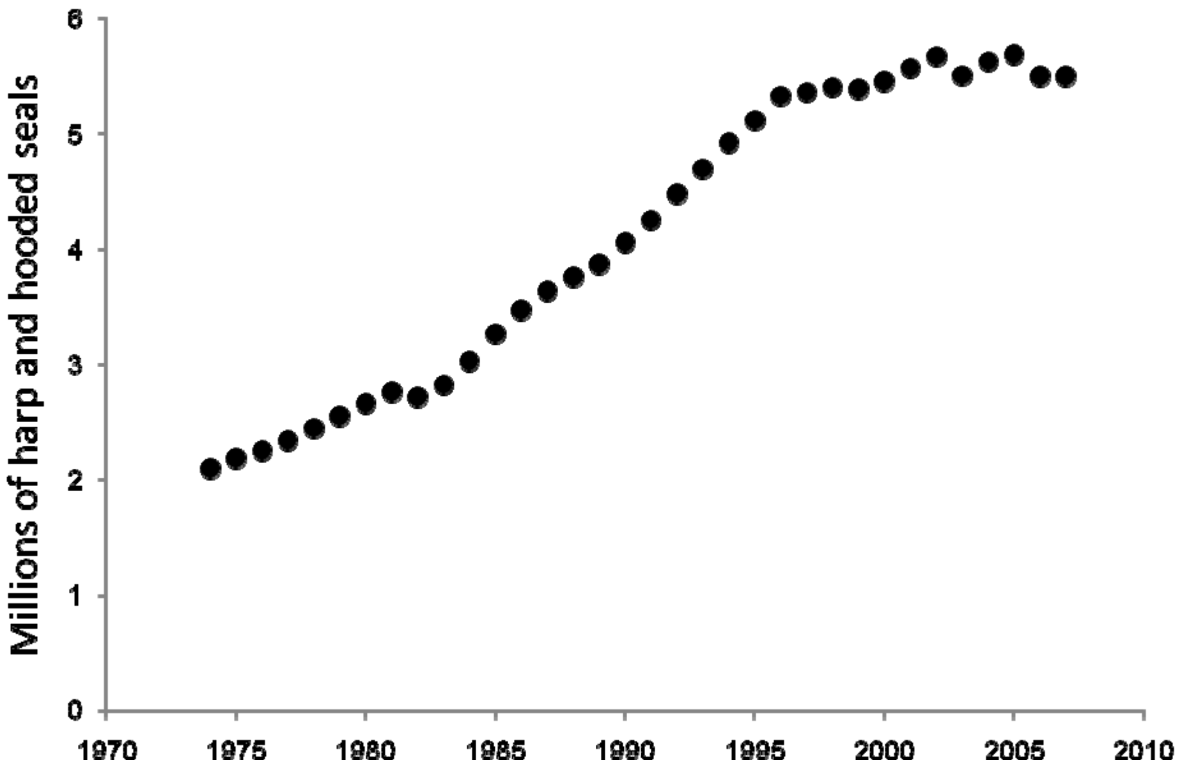

Figure 4. Estimated hooded and harp seals in the North Atlantic population (DFO 2005).

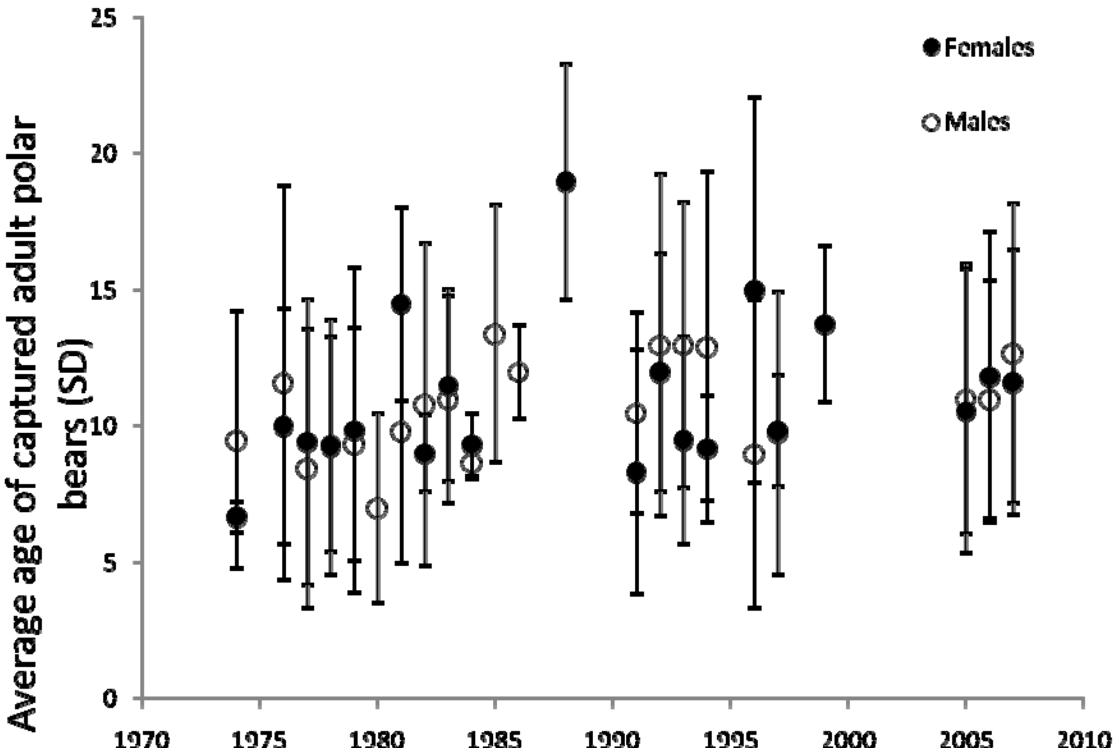

Figure 5. Average age (SD) of adult male and female polar bears captured in Davis Strait from 1974 – 2007.

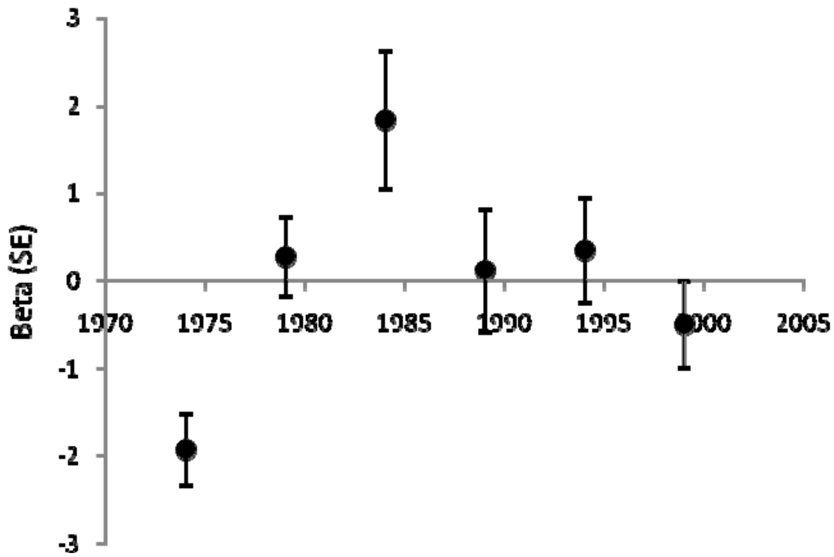

Figure 6. Beta estimates (SE) of the recovery parameter (*r*) over time. Estimates from Burnham model, ΔAICc = 0.05 (Table 3a).

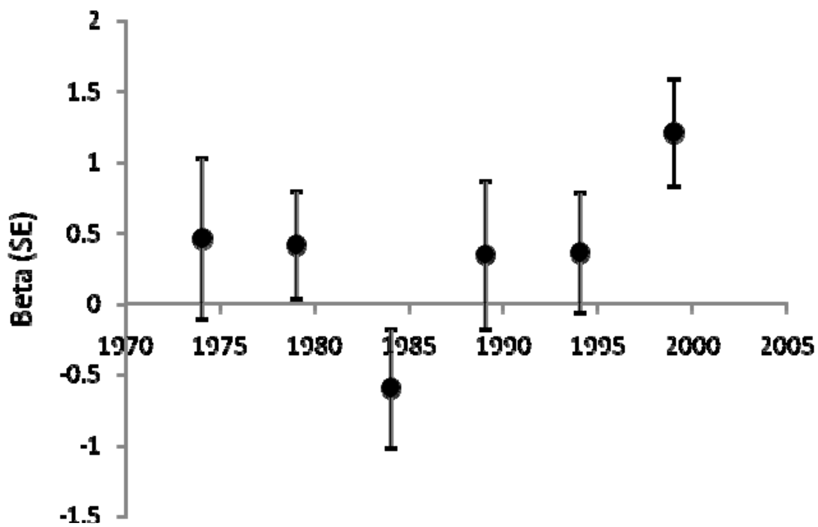

Figure 7. Beta estimates (SE) of total survival (*S*) over time, from most supported Burnham model (Table 3a).

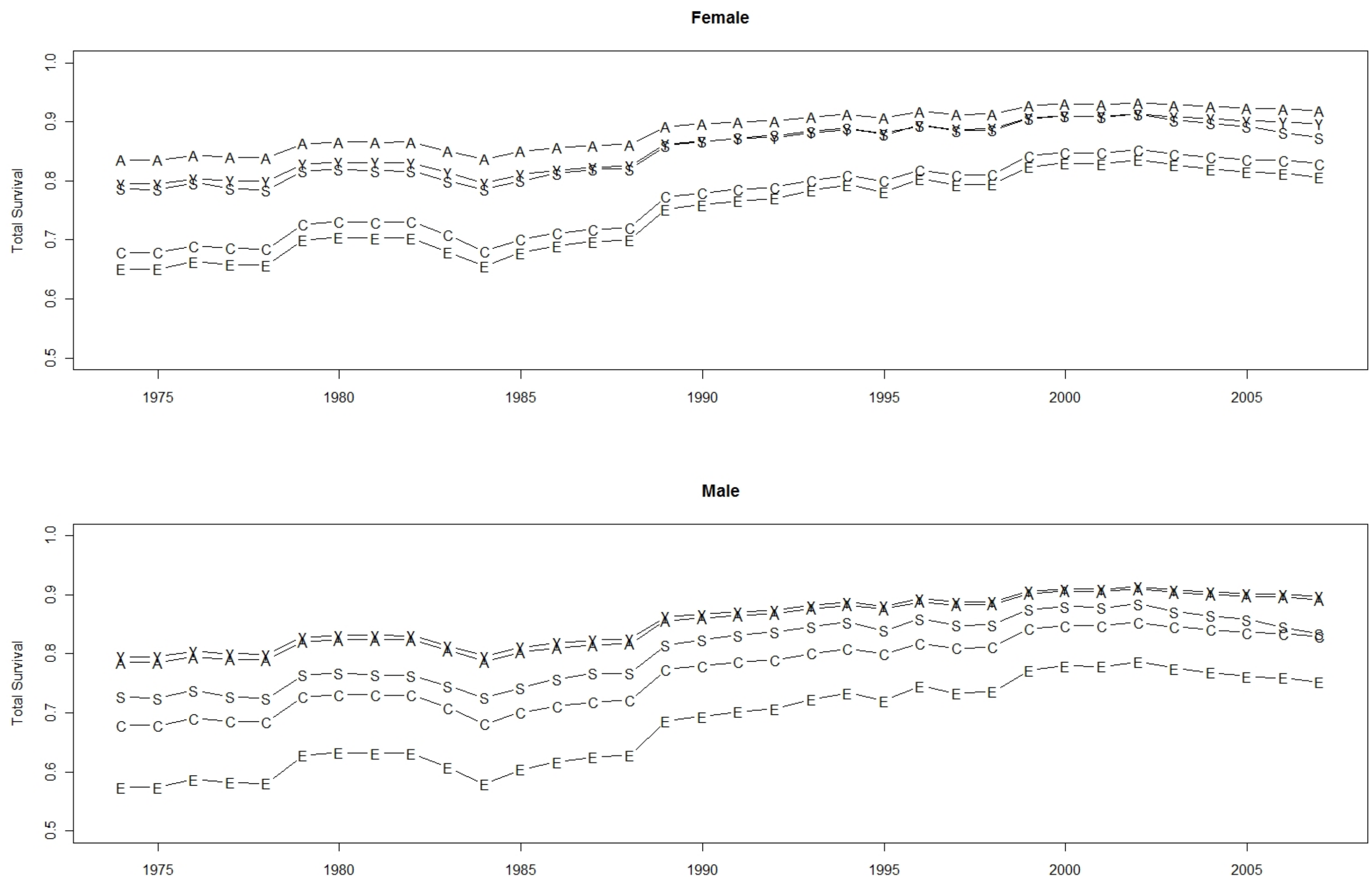

Figure 8. Point estimates of total survival of all sex-age classes (C, cub-of-the-year; Y, yearling; S, subadult; A, adult; E, senescent) over time.

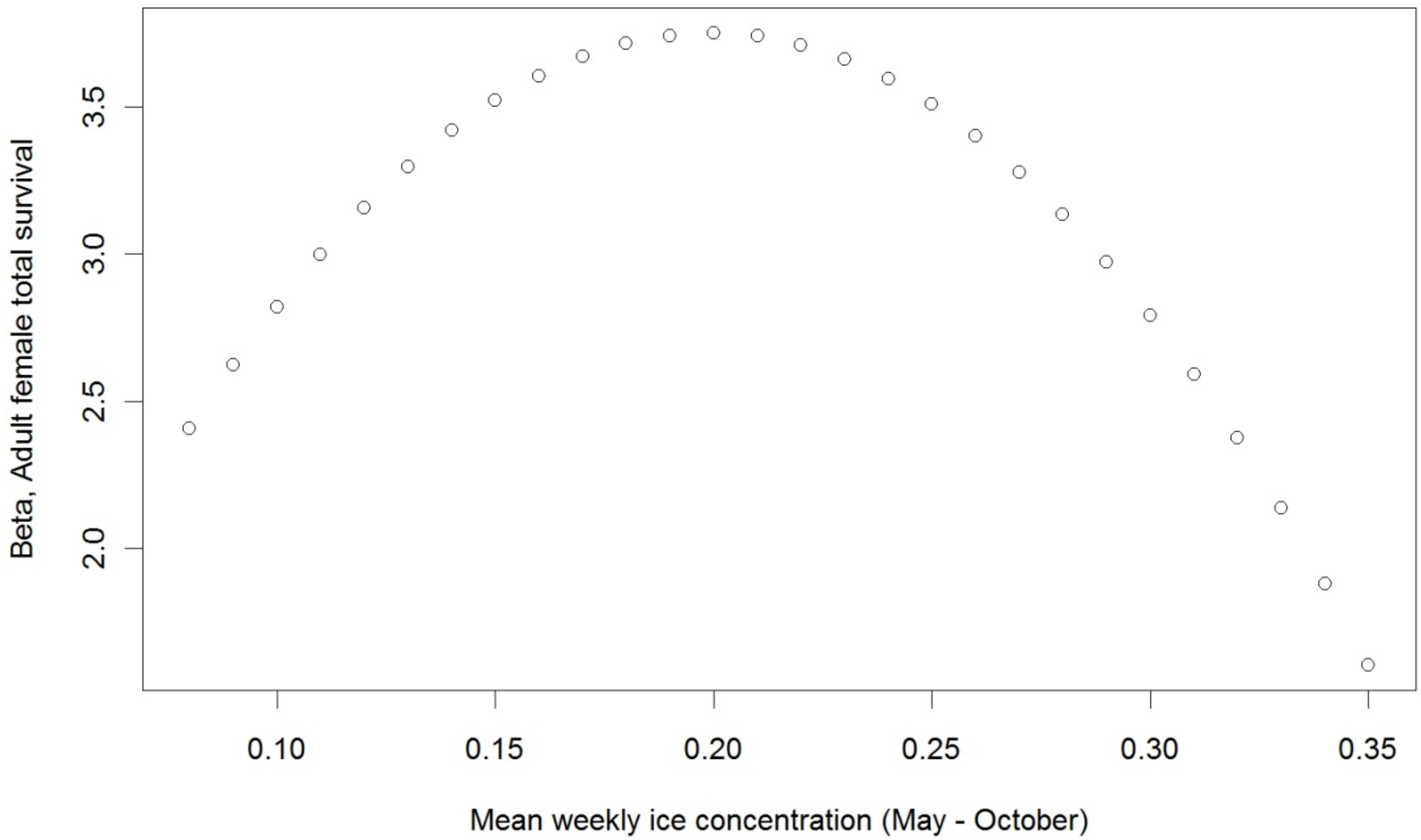

Figure 9. Beta estimates of adult female total survival with variation in mean summer ice concentration, $y = 37.65x - 94.47x^2$, from Burnham model, ΔAIC = 0.69 (Table 3a).

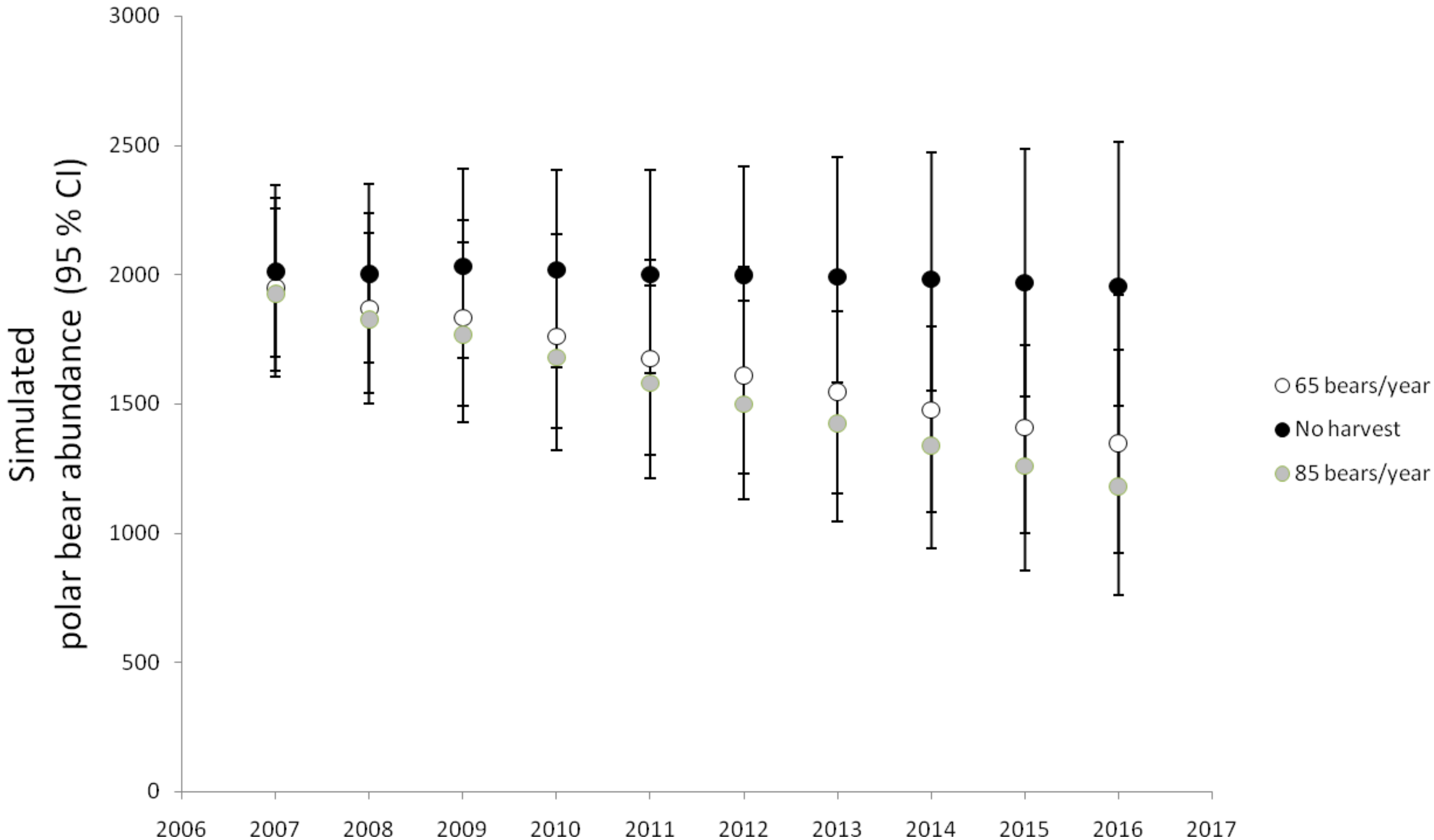

Figure 10. Simulated polar bear abundance (95% CI) under various management regimes using RISKMAN PVA and vital rates estimated in the current study.

Table 1. Polar bears caught and released in the different jurisdictions of the Davis Strait Population from 2005 – 2007.

	Labrador			Nunavut			Quebec			Davis Strait (Total)		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Adult	34	83	90	381	437	466	8	16	18	423	536	574
Subadult	2	11	19	97	136	117	5	8	5	104	155	141
Yearling	3	15	24	36	56	73	2	2	4	41	73	99
COY	1	23	12	49	52	47	5	2	2	55	77	61
Total	40	132	147	563	681	714	20	28	29	623	841	886

Table 2. Polar bears of different reproductive status caught (frequency by total caught) in the Davis Strait Population from 2005 – 2007.

Sex/Age-class/Family status	2005	2006	2007
Female COY	20 (0.03)	40 (0.05)	28 (0.03)
Female yearling	15 (0.02)	34 (0.04)	56 (0.06)
Female subadult (2-5)	61 (0.10)	74 (0.09)	74 (0.08)
Female adult with no cubs	81 (0.13)	99 (0.12)	152 (0.17)
Female adult with 1 COY	22 (0.04)	22 (0.03)	14 (0.02)
Female adult with 2 COY	16 (0.03)	27 (0.03)	17 (0.02)
Female adult with 1 yearling	14 (0.02)	24 (0.03)	23 (0.03)
Female adult with 2 yearlings	13 (0.02)	25 (0.03)	25 (0.03)
Male COY	35 (0.06)	37 (0.04)	34 (0.04)
Male yearling	26 (0.04)	39 (0.05)	42 (0.05)
Male subadult (2-5)	43 (0.07)	81 (0.10)	67 (0.08)
Male adult	277(0.45)	339 (0.40)	346 (0.39)
Total	623	841	878

Table 3a. Mark-recapture-recovery models (ΔAICc < 2.0) for total survival (*S*), recovery (*r*) and recapture (*r*) for polar bears in Davis Strait (1974 – 2007). Fidelity (*F*) was fixed at 1 for all of these models. Definitions of abbreviations are in Table 3b.

Model	Parameters	AICc	ΔAICc	Model Weight	Deviance
S(~Time period + ageclass + nonjuv:male)p(~femandyoung + subadult)r(~juv + nonjuv:male)	16	3911.70	0.00	0.038	708.64
S(~ageclass + juv + nonjuv:male + seal:as.factor(subadult) + adult age:as.factor(subadult))p(~femandyoung + subadult)r(~Time period + nonjuv:male)	20	3911.75	0.05	0.037	700.59
S(~ageclass + juv + nonjuv:male + seal:as.factor(subadult) + adult age:as.factor(subadult))p(~femandyoung + subadult)r(~Time period + juv + nonjuv:male)	21	3912.09	0.39	0.032	698.89
S(~ageclass + juv + nonjuv:male + seal:as.factor(subadult) + adult age:as.factor(subadult))p(~femandyoung + subadult + time)r(~Time period + nonjuv:male)	21	3912.19	0.50	0.030	699.00
S(~ageclass + nonjuv:male + seal)p(~femandyoung + subadult)r(~Time period + juv + nonjuv:male)	17	3912.33	0.64	0.028	707.25
S(~ageclass + nonjuv:male + ice + I(ice^2) + seal)p(~femandyoung + subadult + time)r(~Time period + nonjuv:male)	19	3912.38	0.69	0.027	703.25
S(~ageclass + nonjuv:male + ice + I(ice^2) + seal)p(~femandyoung + subadult)r(~Time period + nonjuv:male)	18	3912.40	0.70	0.027	705.29
S(~ageclass + nonjuv:male + ice + I(ice^2) + seal)p(~femandyoung + subadult)r(~Time period + juv + nonjuv:male)	19	3912.46	0.77	0.026	703.33
S(~ageclass + nonjuv:male + ice + I(ice^2) + seal)p(~femandyoung + subadult + time)r(~Time period + juv + nonjuv:male)	20	3912.52	0.82	0.025	701.35
S(~ageclass + nonjuv:male + seal)p(~femandyoung + subadult)r(~Time period + nonjuv:male)	16	3912.57	0.87	0.025	709.52
S(~Time period + ageclass + nonjuv:male)p(~femandyoung + subadult + time)r(~juv + nonjuv:male)	17	3912.59	0.89	0.025	707.51
S(~ageclass + nonjuv:male + seal + adult age)p(~femandyoung + subadult)r(~Time period + nonjuv:male)	17	3913.32	1.63	0.017	708.24

Model	Parameters	AICc	ΔAICc	Model Weight	Deviance
S(~ageclass + nonjuv:male + seal)p(~femandyoung + subadult + time)r(~Time period + juv + nonjuv:male)	18	3913.34	1.64	0.017	706.23
S(~ageclass + juv + nonjuv:male + ice + I(ice^2) + seal)p(~femandyoung + subadult + time)r(~Time period + nonjuv:male)	20	3913.37	1.67	0.017	702.20
S(~ageclass + juv + nonjuv:male + ice + I(ice^2) + seal)p(~femandyoung + subadult)r(~Time period + nonjuv:male)	19	3913.43	1.73	0.016	704.30
S(~ageclass + nonjuv:male + seal)p(~femandyoung + subadult + time)r(~Time period + nonjuv:male)	17	3913.56	1.87	0.015	708.48
S(~ageclass + nonjuv:male + seal + adult age)p(~femandyoung + subadult)r(~Time period + juv + nonjuv:male)	18	3913.58	1.89	0.015	706.48
S(~ageclass + nonjuv:male + seal:as.factor(subadult))p(~femandyoung + subadult)r(~Time period + nonjuv:male)	17	3913.62	1.92	0.015	708.54
S(~ageclass + nonjuv:male + seal + adult age)p(~femandyoung + subadult + time)r(~Time period + nonjuv:male)	18	3913.63	1.93	0.015	706.52
S(~Time period + ageclass + nonjuv:male)p(~femandyoung + subadult)r(~Season + juv + nonjuv:male)	17	3913.65	1.95	0.015	708.56
S(~ageclass + nonjuv:male + adult age)p(~femandyoung + subadult)r(~Time period + juv + nonjuv:male)	17	3913.67	1.97	0.014	708.59
S(~Time period + ageclass + juv + nonjuv:male)p(~femandyoung + subadult)r(~juv + nonjuv:male)	17	3913.69	2.00	0.014	708.61

Table 3b. Definitions of factor and covariates used in mark-recapture-recovery models (Table 3a).

Descriptor	Description
Time period	1974 – 1978; 1979 – 1983; 1984 – 1988; 1989 – 1993; 1999 -2007. There is some variation in survival and recovery that we were unable to account for with time covariates. However, not able to estimate all parameters with a time effect
ageclass	Cub-of-the-year; yearling, ages 2 – 4; ages 5 – 20; age 20+
nonjuv:male	Interaction of sex within the non-juvenile age classes (subadult, adult, senescent)
Femandyoung	Variable creates a dichotomy between adult females and young (including solitary adult females) v.s. all other bears
subadult	Variable creates a dichotomy between bears of age 2 – 4 v.s. all other bears
juv	Variable creates a dichotomy between cubs-of-the-year and yearlings v.s. all other bears
Adult age	Index of average adult age of polar bears in Davis Strait over the years of the study. This is a proxy index for increasing polar bear density.
seal	Population estimates of hooded and harp seals in the North Atlantic population from 1974 – 2007.
ice	Average of biweekly measures (Canadian Ice Service) of total concentration of ice in Davis Strait from 1974 – 2007.
time	Allowing for *p* to vary between 2005 and 2006/2007; *p* is fixed at 0 for all other years
seal:as.factor(subadult)	Interaction between the seal covariate and whether a bear is a subadult or not
Adultage: as.factor(subadult)	Interaction between the adult age covariate and whether a bear is a subadult or not

Table 4. Model-averaged recapture estimates for groups and years that explain most variation in recapture probability (*p*). Recapture probability was fixed at 0 for 1974 – 2004.

Age and sex class	Year	Estimate	SE
Adult female and young	2005	0.265	0.055
Adult female and young	2006 & 2007	0.297	0.023
Subadult	2005	0.334	0.069
Subadult	2006 & 2007	0.371	0.034
Adult male	2005	0.437	0.072
Adult male	2006 & 2007	0.478	0.029

Table 5. Model-averaged recovery estimates for groups of bears, harvest seasons and time period.

Dependency	Sex	Season	Estimate	SE	Years
Juvenile	-	Fall	0.106	0.053	1974 - 1978
Juvenile	-	Spring	0.105	0.053	1974 - 1978
Juvenile	-	Fall	0.138	0.062	1979 - 1983
Juvenile	-	Spring	0.138	0.063	1979 - 1983
Juvenile	-	Fall	0.343	0.204	1984 - 1988
Juvenile	-	Spring	0.343	0.205	1984 - 1988
Juvenile	-	Fall	0.109	0.066	1989 - 1993
Juvenile	-	Spring	0.108	0.066	1989 - 1993
Juvenile	-	Fall	0.121	0.064	1994 - 1998
Juvenile	-	Spring	0.120	0.064	1994 - 1998
Juvenile	-	Fall	0.082	0.036	1999 - 2007
Juvenile	-	Spring	0.082	0.036	1999 - 2007
Non-Juvenile	F	Fall	0.146	0.055	1974 - 1978
Non-Juvenile	F	Spring	0.145	0.054	1974 - 1978
Non-Juvenile	M	Fall	0.255	0.077	1974 - 1978
Non-Juvenile	M	Spring	0.254	0.076	1974 - 1978
Non-Juvenile	F	Fall	0.186	0.053	1979 - 1983
Non-Juvenile	F	Spring	0.186	0.052	1979 - 1983
Non-Juvenile	M	Fall	0.314	0.063	1979 - 1983
Non-Juvenile	M	Spring	0.313	0.061	1979 - 1983
Non-Juvenile	F	Fall	0.417	0.187	1984 - 1988
Non-Juvenile	F	Spring	0.416	0.188	1984 - 1988
Non-Juvenile	M	Fall	0.576	0.196	1984 - 1988
Non-Juvenile	M	Spring	0.575	0.197	1984 - 1988
Non-Juvenile	F	Fall	0.149	0.069	1989 - 1993
Non-Juvenile	F	Spring	0.148	0.068	1989 - 1993

Dependency	Sex	Season	Estimate	SE	Years
Non-Juvenile	M	Fall	0.259	0.105	1989 - 1993
Non-Juvenile	M	Spring	0.259	0.103	1989 - 1993
Non-Juvenile	F	Fall	0.164	0.060	1994 - 1998
Non-Juvenile	F	Spring	0.163	0.059	1994 - 1998
Non-Juvenile	M	Fall	0.283	0.085	1994 - 1998
Non-Juvenile	M	Spring	0.282	0.083	1994 - 1998
Non-Juvenile	F	Fall	0.116	0.044	1999 - 2007
Non-Juvenile	F	Spring	0.116	0.043	1999 - 2007
Non-Juvenile	M	Fall	0.206	0.060	1999 - 2007
Non-Juvenile	M	Spring	0.206	0.059	1999 - 2007

Table 6. Model-averaged estimates of total survival (S) and natural survival (S_n) for polar bears in Davis Strait in 2007.

Age-class	Total Survival (95% CI)		Natural Survival (95% CI)	
	Female	Male	Female	Male
Cub	0.83 (0.69 – 0.97)		0.84 (0.70 – 0.98)	
Yearling	0.90 (0.79 – 1.00)		0.90 (0.81 – 1.0)	
Subadult (2 – 4)	0.87 (0.76 – 0.98)	0.83 (0.71 – 0.96)	0.89 (0.78 – 0.99)	0.87 (0.75 – 0.98)
Adult (5 – 20)	0.92 (0.86 – 0.98)	0.89 (0.83 – 0.96)	0.93 (0.87 – 0.99)	0.91 (0.85 – 0.98)
Senescent (21 +)	0.81 (0.64 – 0.97)	0.75 (0.56 – 0.94)	0.83 (0.67 – 0.98)	0.80 (0.63 – 0.97)

Table 7. Recruitment parameters (SE) for female polar bears in Davis Strait.

Study	Litter Size				Litter Produced Rate*	Natality*	Litter Production Rate†	Litter Production Rate (discounted by survival) ††	Number of litters
	Cub	Cub of the Year	Yearling	Two-year old					
Labrador 1976 – 1979 (spring)	1.50	-	-	-	0.16	0.24			6
Southeast Baffin 1974 – 1979 (spring)	1.61	1.82 (0.16)	1.57 (0.40)	1.43 (0.40)	0.30	0.54			32
Davis Strait 1974 -1979** (spring)	1.59	-	-	-	0.28	0.49			38
Davis Strait 2005 - 2007*** (fall)	1.48	1.47 (0.16)	1.48 (0.04)	-	0.21	0.31	0.42 (0.05)	0.39 (0.06)	267

* Calculations as per Stirling and Killian (1980) for the purpose of comparing 1970s's and 2000's data.

** Weighted average between regions

*** Average mean litter sizes used data from adult females with ages and cubs. Sample size for litter produced rate represents the sample of all adult females with ages (whether with cubs or not).

†LPR, Litter Production Rate, as used in RISKMAN PVA analysis (Taylor et al. 1987). RISKMAN PVA incorporates survival rates independently.

†† LPR, Litter Production Rate, discounted by total annual survival of adult females (0.929) in 2005-07. This parameter takes into account female survival between subsequent falls.

Table 8. Standing-age distribution of polar bears caught in 2005 in Davis Strait (*n* = 587).

Age	Male	Unencumbered female	Female w/1 COY	Female w/2 COY	Female w/1 YRL	Female w/2 YRL
0	34	22	0	0	0	0
1	25	19	0	0	0	0
2	5	8	0	0	0	0
3	15	15	0	0	0	0
4	15	7	0	1	0	0
5	24	26	2	1	0	0
6	27	12	2	2	3	0
7	25	21	1	2	0	1
8	20	6	2	1	1	1
9	20	7	0	1	1	2
10	20	5	3	0	0	1
11	24	4	1	0	0	1
12	18	4	1	0	0	1
13	12	3	1	2	1	1
14	8	3	1	2	0	0
15	14	3	0	0	0	0
16	12	3	1	1	2	0
17	9	2	1	0	1	0
18	8	3	1	0	1	1
19	2	2	0	1	2	0
20	2	0	0	0	0	0
21	2	1	0	1	0	0
22	3	0	0	0	0	1
23	1	0	0	1	0	0
24	8	1	2	0	0	0

Table 9. Estimated un-harvested growth rate (RIKSMAN, PVA) of the Davis Strait polar bear population using natural survival rates, recruitment rates and standing age-distribution (*n* = 587 ages from 2005) estimated for 2007.

Year	Growth rate	SE
2007	0.941	0.001
2008	0.994	0.001
2009	1.01	0.001
2010	0.996	0.001
2011	0.990	0.001
2012	0.999	0.001
2013	0.999	0.001
2014	0.995	0.001
2015	0.994	0.001
2016	0.996	0.001