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Harvest advice for Eastern Hudson Bay belugas

Avis sur le prélèvement de bélugas de l'est de la baie d'Hudson

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ABSTRACT

The number of Eastern Hudson Bay (EHB) animals in the summer harvest in the Hudson Strait area remains low. For this assessment it was assumed that all animals killed in EHB, 10% of animals killed in spring and summer in Hudson Strait, 20% of animals killed in fall in Hudson Strait and Ungava Bay are EHB beluga.

A population model incorporating removals was fitted to aerial survey estimates of abundance using Bayesian methods estimated the 1985 population at 4, 200 animals (se=1,500; 95% Credibility Interval 2,200-7,700). The model estimated that the population had declined to 3,300 in 2009 (se=1,325; 95% Credibility Interval 1,600-6,500). Nevertheless, at current harvest levels, the population has probably been stable or has increased slightly the last few years. The model estimated struck and loss at 63% (se=31).

The analyses indicated that removing 15 EHB animals per year would have a moderate level of risk (0.3 to 0.35) of the population declining depending on level of the total harvests reported for 2009. The lower risk would be associated with a reported 2009 catch of 38 EHB animals, whereas the slightly higher risk would result if the 2009 harvest were taken. Removing 55 animals would have a higher probability of causing a decline in the population of 0.5 to 0.55 in 2010, again depending on the final 2009 harvest.

The total number of animals that can be harvested without causing a decline in the EHB beluga whale population will depend on how catches are distributed between Eastern Hudson Bay, Ungava Bay and Hudson Strait during spring/summer and catches in Hudson Strait during fall.

RÉSUMÉ

Le nombre d’animaux à l’est de la baie d’Hudson (EBH) est demeuré bas lors de la capture d’été dans le détroit d’Hudson. Pour réaliser cette évaluation, il a été présumé que tous les animaux tués dans l’EBH, que 10 % des animaux tués au printemps et en été dans le détroit d’Hudson, et que 20 % des animaux tués en automne dans le détroit d’Hudson et la baie d’Ungava étaient des bélugas de l’EBH.

Un modèle de population intégrant des données fondées sur les prélèvements et adapté aux estimations de l’abondance obtenues à partir des relevés aériens en utilisant des méthodes bayésiennes a permis d’évaluer la population de 1985 à 4 200 individus (erreur-type = 1 500; intervalle de crédibilité de 95 % = 2 200-7 700). La modélisation a permis d’estimer que la population avait diminué pour atteindre 3 300 individus en 2009 (erreur-type = 1 325; intervalle de crédibilité de 95 % = 1 600-6 500). Néanmoins, aux niveaux de captures actuels, la population a probablement été stable ou a augmenté légèrement au cours des dernières années. La modélisation a estimé le nombre de bêtes abattues et perdues à 63 % (erreur-type = 31).

Les analyses ont indiqué qu'un prélèvement de 15 individus de l'EBH en 2010 représenterait un niveau de risque moyen (de 0,3 à 0,35) que la population décline, dépendamment du nombre total de captures déclarées pour 2009. Le risque le plus bas serait associé à un nombre de prises déclarées en 2009 de 38 animaux de l'EBH, tandis qu'on obtiendrait un niveau de risque légèrement plus élevé si tout le TPA (Total des Prises Autorisées) de 2009 était pris. L'enlèvement de 55 individus se traduirait par une probabilité plus importante de provoquer une diminution de la population de l'ordre de 0,5 à 0,55 en 2010, toujours selon le nombre total de captures de 2009.

Le nombre total d'individus qui peuvent être capturés sans provoquer une diminution de la population de bélugas de l'EBH dépendra de la répartition des prises entre l'est de la baie d'Hudson, la baie d'Ungava et le détroit d'Hudson au cours du printemps, de l'été, et de l'automne.

INTRODUCTION

Systematic aerial surveys flown in the mid-1980's to assess beluga (*Delphinapterus leucas*) abundance along the Ungava and Hudson Bay coast of Quebec (Smith and Hammill 1986) led to restrictions on harvesting through a combination of quotas and seasonal and regional closures to allow the stocks to recover (Reeves and Mitchell 1989). Concern for belugas in the waters adjoining Nunavik also led COSEWIC (Committee on the Status of Endangered Wildlife in Canada) to designate belugas in Ungava Bay and Eastern Hudson Bay (EHB) belugas as 'Endangered' (COSEWIC 2004). Continued subsistence hunting underlines a need to monitor changes in the EHB beluga population.

Bayesian fitting is well adapted to data-poor situations, allowing the incorporation of existing knowledge of parameter values, even if uncertain, and also accommodating conflicts between different uncertainties. Bayesian methods of fitting models have the advantage of allowing extraneous estimates to be input as prior distributions, while also permitting the data to refine parameter estimates by updating the prior to a different posterior distribution if the data contains information. Furthermore, predictions, and their estimated uncertainties, can be based on the full multivariate posterior distribution of the parameter estimates. This is a significant advantage in the present case where we are fitting to little data and parameter estimates are highly correlated.

Here, we fitted a population model using Bayesian methods to aerial survey estimates, incorporating information on numbers of animals harvested and the stock composition of the harvest to monitor changes in the population over time and to provide scientific advice pertinent to managing a small beluga population which is subjected to a subsistence harvest (Hammill et al. 2009).

MATERIALS AND METHODS

The model fitted was built as a simple stock-production model. It was fitted by Bayesian methods, so prior information on, or guesses as to, the values of stock-dynamic parameters were included as prior distributions.

Numbers in each year were a constant multiple of the previous year's, with removals deducted:

$$N_t = N_{t-1} \cdot \exp(r) \cdot \varepsilon 1_t - R_t$$

The instantaneous rate of growth, *r*, was given a Normal prior with mean 0.03 and standard deviation 0.1, but limited to the range –0.1 – +0.3. Process error terms $\varepsilon 1$ were lognormally distributed with zero mean and uniform variance in log space. The sparse survey data tells us nothing about the process error, and an informative prior was assigned for the precision[1] parameter of the lognormal distribution with CV quartiles at 5.5% and 8.7%.

Removals were calculated as catches corrected for animals struck and lost.

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[1] The 'precision' parameter for a lognormal distribution is the reciprocal of the variance of the corresponding normal distribution in log space. In real space, it may be looked upon as something like the reciprocal of the square of the coefficient of variation.

$$R_t = C_t \cdot (1 + SL)$$

where the struck-and-lost correction *SL* was given a moderately informative log-normal prior[2] with quartile points at 0.43 and 0.85.

Survey catchability was assumed to be 1, and survey estimates were linked to population size by a multiplicative error term

$$\ln(S_t) = \ln(N_t) + \varepsilon 2_t$$

where the error terms ε were normally distributed with mean zero and the 'precision' was given a moderately informative prior, gamma(2.5,0.4) with quartiles approximately equivalent to survey coefficients of variation (CV) of 35% and 55% or approximate symmetrical 95% CI on the CV 24%–99% .

The model was extended into the future for 10 years at 5 different catch levels, producing predictions of stock trajectories expressed both as stock numbers and as the probability of stock decrease since 2008.

The model was coded for BUGS and run on the WinBUGS platform. Typically, trajectory models of this kind produce highly correlated chains in MCMC sampling, so every 200th point was kept from chains of 10 000 000. The model converged easily and ran fast enough (Hammill et al. 2009).

Data

The data comprised 5 total-count estimates from aerial surveys flown in 1985, 1993, 2001, 2004 and 2008 and series of annual reports of landed catches (Summarized in Hammill et al. 2009; Lesage et al. 2009)(Table 1,2). The proportions of those landings that were EHB-summering animals were estimated from genetic analyses and the input catch series correspondingly revised (Table 2). These were set so that the proportion of animals reported landed were: 100% in the Hudson Bay arc area by Nunavik hunters, 12% of Sanikiluaq landings, 21% of Hudson Strait landings and 12.6% of Ungava Bay landings (Hammill et al. 2004). In recent years, the genetic data has shown changes in these proportions. In 2009, discussions led to recommendations that directed more of the harvest to the spring, when the proportion of EHB animals in the harvest is lower. Therefore, 10% of the animals killed during spring and summer were assumed to belong to the EHB population, while 20% of the fall harvest in Hudson Strait was considered to consist of EHB animals (Table 3,4).

Survey counts were corrected for a decline in detection with distance from the survey platform using standard line-transect methods (Gosselin et al. 2009). Corrections were also applied for 'unavailable' animals using: $N_t = N_{survey} / P_0 + N_{estuary}$, where the estimated proportion (P_0) of animals visible from an aerial survey platform is 0.478 (SE 0.0625) (Kingsley and Gauthier 2002). Belugas detected in estuaries ($N_{estuary}$) were assumed to represent total counts. Although estimates of uncertainty were available for each survey estimate, they were

[2] A negative binomial model was not used as it is a single-parameter model and variance and mean are tightly related.

incorporated into the fitting process only by guiding the formulation of the prior distribution of the survey error (see above).

RESULTS

Composition of the harvest

Previous assessments have used a harvest composition of EHB animals in the harvest of 21% from Hudson Strait and 13% in the harvest from Ungava Bay. Samples collected since 2004 indicate that the proportion of EHB animals in the Hudson Strait harvest have declined to 9% (Table 3). Although data are lacking on the timing of the hunt for the years prior to 2004, there is a marked difference in the sampled proportion of EHB animals in the fall hunt compared to the spring hunt (Table 4). The number of EHB animals in the summer harvest in the Hudson Strait area remains low. For this assessment it was assumed that all animals killed in EHB, 10% of animals killed in spring and summer in Hudson Strait, 20% of animals killed in fall in Hudson Strait and Ungava Bay are EHB beluga.

The model incorporating removals and fitted to aerial survey estimates of abundance, resulted in a 1985 population estimate of 4, 200 animals (se=1,500; 95% Credibility Interval 2,200-7,700). The model estimated that the population had declined to 3,300 in 2009 (se=1,325; 95% Credibility Interval 1,600-6,500). At current harvest levels the population has probably been stable or has increased slightly the last few years (Fig. 1). The estimated rate of increase of 3.0% (se=2.9) which is within the range expected for other cetaceans with similar life histories. Struck and loss was estimated at 63% (se=31).

Removing 15 EHB animals per year will have a moderate level of risk of 0.3 to 0.35 depending on total harvests reported for 2009 (Fig. 2). A lower risk would be associated with a reported 2009 catch of 38 EHB animals (Table 2), whereas a slightly higher risk would be associated with the 2009 harvest if it is taken in full. Removing 55 animals would have a higher probability of causing a decline in the population of 0.5 to 0.55 in 2010, depending on the final 2009 harvest.

DISCUSSION

Our impressions of this population are based on only five aerial survey estimates. Additional uncertainty is associated with the estimated maximum rate of increase of the population, the factor applied to correct for diving animals, and estimates of struck and loss. We also made certain assumptions about the values and distributions of these parameters by linking model parameters to defined statistical distributions, and re-sampling from these distributions during different model runs, instead of representing them by single values. The true values and distribution of the model parameters (λ_{max}, N_{1854}, θ, and b) of the Nunavik beluga population are not known.

The model estimates a high level of struck and loss. Although levels this high have been reported, this term also includes the effects of under-reporting (of which struck and loss is a subset), and if we are under-estimating the proportion of EHB animals taken in the hunt, then this under-estimate will be in part reflected in the value for the estimated struck and loss term. Nonetheless, a high struck and loss value points to one area where research is needed, either to improve estimates of the declared harvest or to reduce the number of whales struck and lost. This would also result in an increase in numbers of whales available to communities, without increasing overall harvest rates. Or conversely, a reduction in struck and loss rates could reduce the harvest impact on this population, without necessarily reducing the harvest through lower quotas.

Under the current management plan overall harvest rates have declined and the model suggests that the rate of decline in the Nunavik beluga population has also slowed or stopped. The model indicates a removal of more than 55 animals from the EHB population would have a 50% or higher risk of causing a decline in the population using the catch data information available in mid-May, which indicated that about 38 EHB animals had been taken up to then. If the remaining quota is taken, then a harvest of 55 EHB whales in 2010, will have a 55% probability of causing a decline in the population. If no further harvesting had occurred after mid-November, then reducing the harvest of EHB animals to 45 whales would have a 45% probability of causing a decline in the population, while reducing the harvest to 25 EHB whales would result in about a 35% probability of the population declining. Different approaches could be used to reduce the impact of the harvest on the EHB population, while ensuring access to animals in Hudson Strait. A spring/summer harvest in Hudson Strait, with no harvest in EHB would have the lowest impact on the EHB population, followed by a fall harvest in Hudson Strait only, again with no harvest allowed in EHB. If harvesting does occur in EHB, then numbers taken in Hudson Strait must be reduced, but the size of this reduction would depend on whether hunting occurs in the spring/summer or the fall (Fig. 3).

The population has been listed as endangered by COSEWIC, but has not yet been listed by the government of Canada. Canada is also a signatory of the United Nations *Agreement on Straddling and Highly Migratory Fish Stocks* (UNFA), which came into force in 2001, and commits Canada to use the Precautionary Approach in managing straddling stocks as well as, in effect, domestic stocks. In 2003, the Privy Council Office, on behalf of the Government of Canada published a framework applicable to all federal government departments that set out guiding principles for the application of precaution to decision making about risks of serious or irreversible harm where there is a lack of full scientific certainty. In 2006, the Department of Fisheries and Oceans developed its own Precautionary Approach framework. This identifies three zones of risk: a healthy zone, cautious zone and a critical zone, depending on the status of the resource. When a population is in the healthy zone, then socioeconomic concerns are considered to be the most important when setting harvest levels. However, if the population declines, into what is identified as the cautionary zone, then conservation is to assume an increasingly important role in the decision making process; if the population declines further and falls into the critical zone, then onservation is to become a priority and harvest levels should be reduced to minimum levels or stopped to allow the population to recover. The threshold separating the healthy zone from the cautious zone is referred to as a precautionary level, while the threshold separating the cautious zone from the critical zone is referred to as a limit reference level. There is some flexibility around where the precautionary and limit reference levels should be established. One possibility would be to borrow from the approach used to manage Atlantic seals and to set the precautionary level at 70% of the estimate of pristine population size. If the pristine population size was 12,500 (DFO 2005), then the precautionary threshold separating the healthy zone from the cautious zone would be set at around 70% of the pristine population size ie at a level of 8 800 animals. A limit reference level which separates the cautious zone from the critical zone would be set at about 2,800 animals for EHB beluga if we used the framework developed by DFO for fish, or it would be set at about 3700 animals using the framework developed for seals. At a current population size of 3,300 animals the EHB population would fall into the lower end of the cautious zone or would fall just inside the critical zone in the Precautionary Framework, depending on where the limit reference level is set (Fig. 4).

In 2009, management of beluga in Nunavik, fell under the responsibility of the Nunavik Marine Wildlife Management Board. As a result the Board will be responsible for providing Total Allowable Take recommendations to the Department. The current approach to management of beluga in Nunavik is not clear. Therefore it is important that the board develop a precautionary framework that will allow management of Nunavik beluga and recovery of this stock.

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Table 1. Final aerial survey estimates of beluga populations in eastern Hudson Bay. The 1985 survey data were adjusted to account for differences between strip-transect and line-transect methods (Hammill et al. 2004). Aerial survey estimates have been corrected for diving animals (Kingsley and Gauthier 2002) and corrected for estuary animals by adding in estuary counts in EHB of 474, 18, 39 , 5 and 0, for 1985, 1993, 2001, 2004 and 2008 respectively (Hammill et al. 2009).

Year	Distance line-transect (m) (SE)	Estimate corrected for diving animals
1985	*2,294*	4279 (620)
1993	1,314 (489)	2727 (1,012)
2001	1,418 (635)	2922 (1,368)
2004	2045 (698)	4269 (1,499)
2008[1]	1,265 (570)	2646 (1,959)

Table 2. Number of eastern Hudson Bay animals removed from the population assuming that following herd composition for EHB (100%), Sanikiluaq (12.6%), Hudson Strait (21%), and Ungava Bay (12.6%). In 2009, 10% of animals harvested from the Hudson Strait and Ungava Bay area during the spring and summer were assumed to belong to EHB. The proportion increased to 20% for the fall harvest. [1] Preliminary numbers converted to EHB animals, assuming all animals killed in EHB, 10% of animals killed in spring and summer, and 20% of animals killed in fall are EHB beluga.

Year	Harvest	Year	Harvest	Year	Harvest
1985	84	1996	101	2007	59
1986	69	1997	98	2008	53
1987	81	1998	102	2009	38[1]
1988	76	1999	106		
1989	144	2000	104		
1990	77	2001	129		
1991	144	2002	49		
1992	99	2003	54		
1993	105	2004	43		
1994	128	2005	41		
1995	103	2006	29		

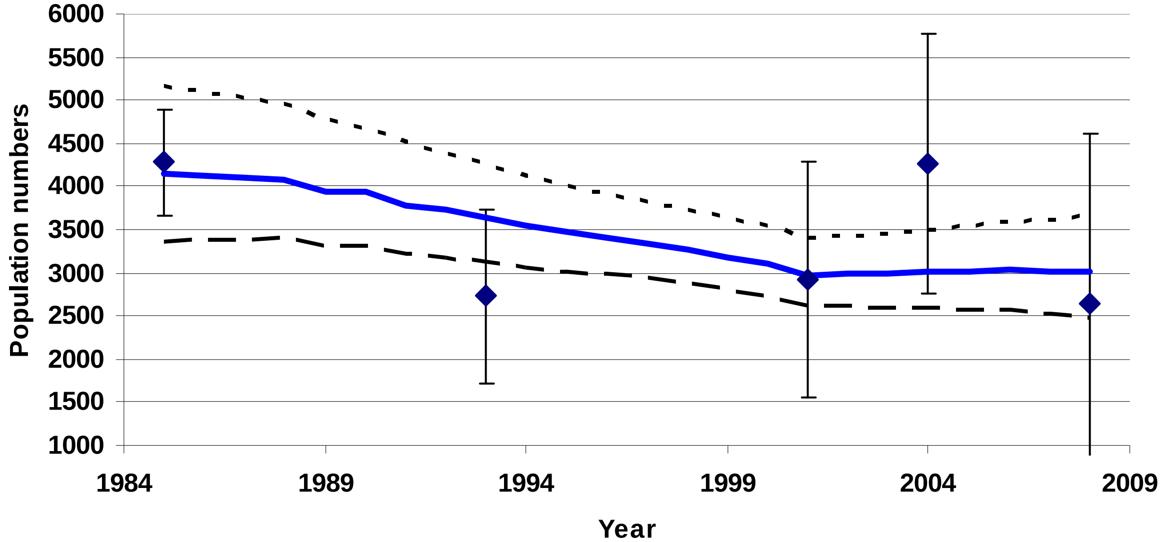
Table 3. Proportion of EHB animals in harvest from Hudson Strait.

Hudson Strait	EHB	non-EHB	Total	Average %EHB
1997	3	11	14	21.4
1998	15	27	42	35.7
1999	4	32	36	11.1
2000	14	17	31	45.2
2001	11	44	55	20
2002	2	38	40	5
2003	5	46	51	9.8
Average				21.1
se				14.6
2004	41	8	33	19,5
2005	28	1	26	3,6
2006	30	2	28	6,7
2007	34	2	32	5,9
Average				8,9
se				7,2
Global Average				10.1
Global se				7.5

Ungava Bay	EHB	non-EHB	Total	%EHB
1997	2	7	9	22.2
1998	0	4	4	0.0
1999	1	12	13	7.7
2000	0	10	10	0.0
2001	1	11	12	8.3
2002	3	5	8	37.5
2003	3	21	24	12.5
Average				12.6
se				13.4
2005	9	1	8	11,1
2006	2	18	20	10,0
2007	2	6	8	25,0
Average				15,4
se				8,4
Global Average				15.4
Global se				8.4

Table 4. Seasonal changes in the number of EHB (%) beluga whales in the Hudson Strait catch.

Pre-2004	EHB	Non-EHB	Total	Percent
Fall	21	101	122	17.2
Spring	5	54	59	9.2
Summer	2	30	32	6.0
2004 and later				
Fall	7	17	24	29.2
Spring	4	83	87	4.6
Summer	1	18	19	5.3



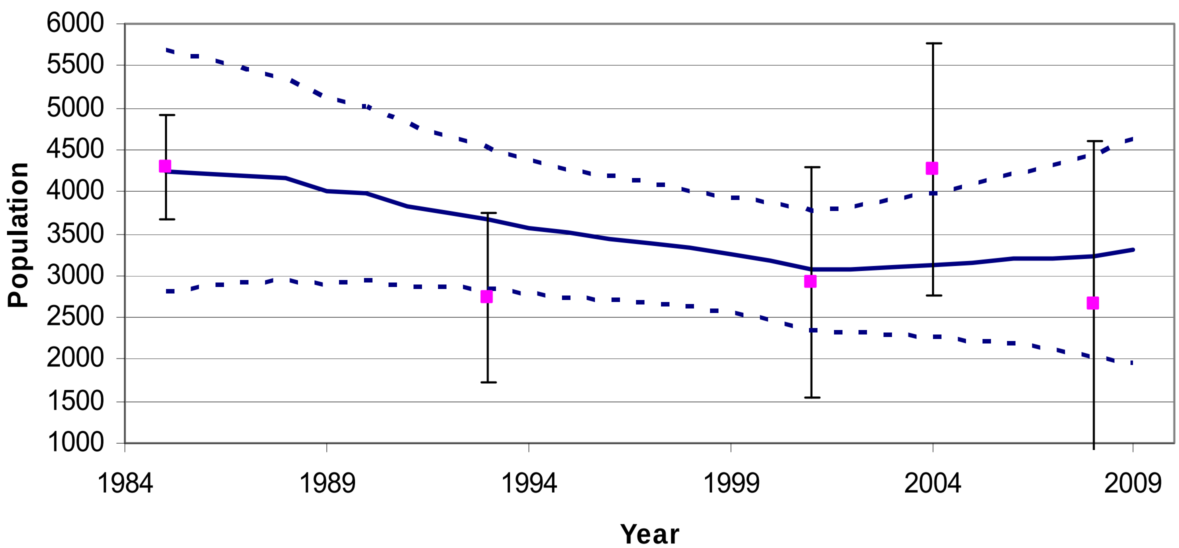


Figure 1. Aerial survey and model estimates (± SE) of eastern Hudson bay beluga abundance fitted to aerial survey estimates corrected for animals at the surface. The top graph is the plot used in at the assessment (Hammill et al. 2009), the bottom graph is the result of fitting the model to new catch data from the 2009 harvest.

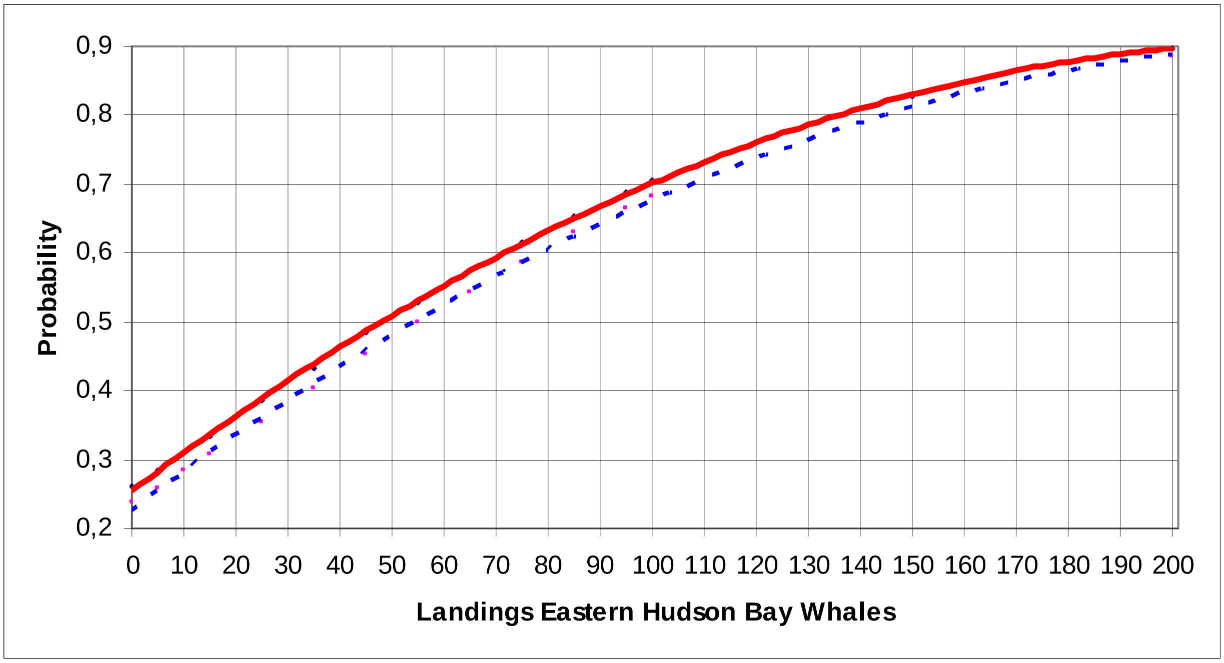
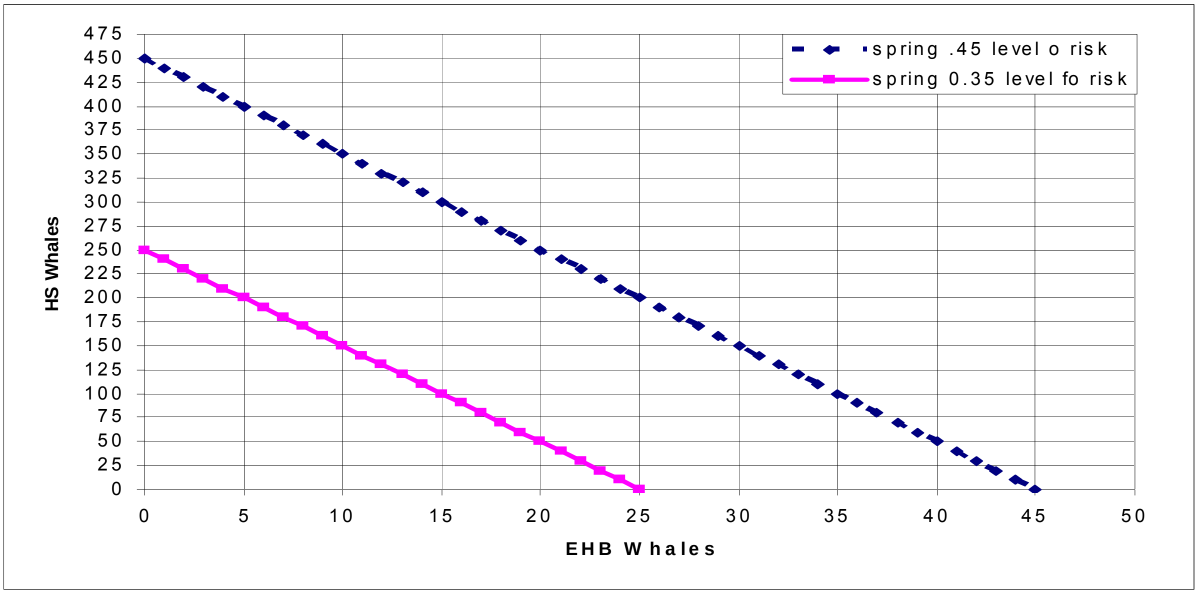


Figure 2: Eastern Hudson Bay belugas. Probability of stock decrease at different catch levels estimated by a Bayesian stock-production model assuming deterministic stock dynamics. The solid line represents the probability of a decline if all of the Total Allowable Take was taken in 2009 (approx 53 EHB beluga whales). The dotted line represents the probability of decline if only 38 EHB beluga whales were taken, which was the case in mid-November based on the reported harvest statistics.



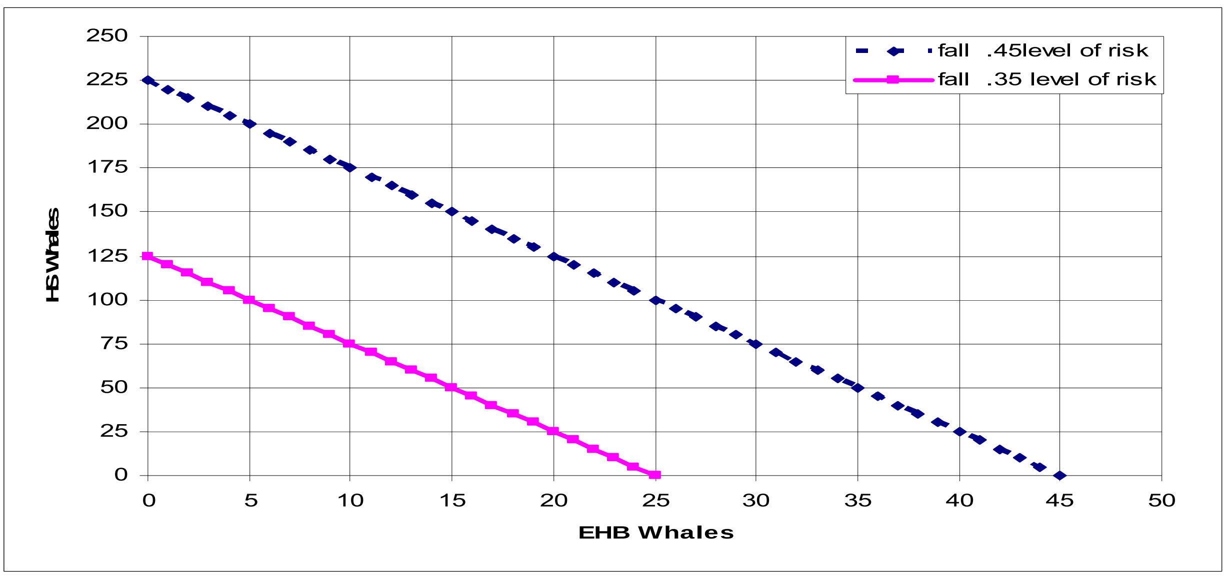


Figure 3. Numbers of EHB animals expected to be taken (x-axis) from a given harvest in Hudson Strait (y-axis) during the spring (top) or during the fall (bottom). The dotted line indicates numbers of animals that can be removed with the expectation of a probability of decline of 0.45 (or 45%). The lower solid line represents harvest levels that would have a lower risk of decline of only 0.35 (ie 35% probability of decline). Harvesting at these levels would be more likely to allow some population recovery.

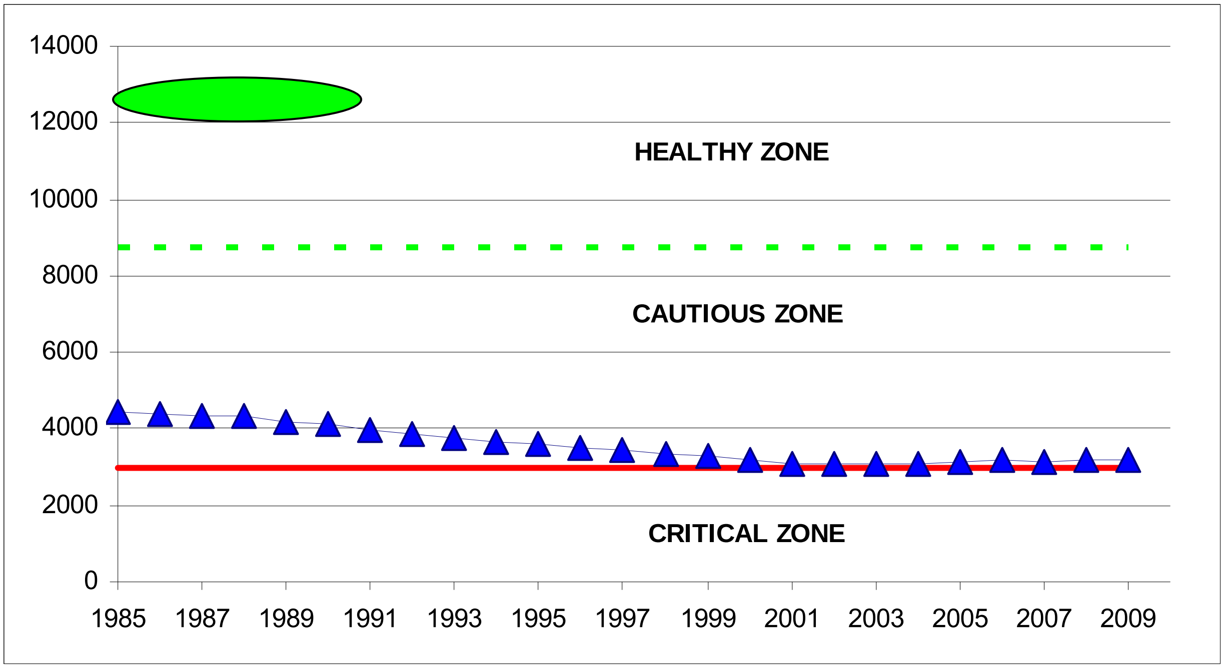


Figure 4. Current estimates of the EHB population size within the context of a Precautionary Approach framework. The oval represents the estimate of pristine population size during the 1850s. The dotted line represents a precautionary level that separates the healthy zone from the cautious zone. The cautious zone is a region where conservation is to assume a greater role when establishing harvest levels. The solid line represents a reference limit threshold that forms the separation between the cautious and critical zones. For a population in the critical zone, conservation should be a priority and harvesting should be reduced to allow population recovery.