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Beluga in Northern Quebec: Impact of harvesting on population trends of beluga in eastern Hudson Bay.

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Abstract

A five-year management plan implemented in 1995 limited beluga harvests to 90 animals by hunters from eastern Hudson Bay communities, 100 beluga by communities in Hudson Strait and 50 animals by communities in Ungava Bay as long as harvesting occurs outside of the bay. However, throughout the plan harvesting by Hudson Strait and Hudson Bay communities consistently exceeded the quota. Modelling changes in population size suggest that the eastern Hudson Bay population has declined markedly during the past 5 years, possibly to as low as 1,100 (SE=500) animals. If current harvest levels continue then the lower 95% confidence limit suggests that this population could be extirpated as early as 2003. A reduction in harvests to 40 animals would be sustainable. A harvest of 20 animals would likely allow the herd to increase at a rate of 2% per year. However, there is considerable uncertainty associated with modelling estimates owing to a lack of population survey information, uncertainty associated with beluga population parameters, stock composition of beluga harvests in Hudson Strait, the proportion of animals visible at the surface during aerial surveys and under-reporting of harvests.

Résumé

Un plan de gestion d'une période de cinq ans est entré en vigueur en 1995 afin de limiter la chasse du béluga à 90 animaux pour les communautés de l'est de la Baie d'Hudson, à 100 pour les communautés du détroit d'Hudson et à 50 pour les communautés de la Baie d'Ungava en autant que la chasse se fasse à l'extérieur de la baie. Cependant, tout au long du plan, les communautés du Détroit d'Hudson et de la Baie d'Hudson ont constamment dépassé leurs quotas. La modélisation des changements de l'effectif de la population suggère que la population de l'est de la Baie d'Hudson a diminué considérablement au cours des cinq dernières années et pourrait être de l'ordre de 1,100 (écart type=500) animaux. Si le présent taux de captures se maintient, la limite inférieure de confiance de 95% suggère que cette population pourrait disparaître dès 2003. Une réduction des captures à 20 animaux devrait permettre au troupeau de croître à un taux de 2% par année. Cependant, il y a une importante incertitude liée aux estimés du modèle en raison des relevés de population insuffisants et des incertitudes associées aux paramètres de population des bélugas, à la composition des stocks de bélugas capturés dans le Détroit d'Hudson, à la proportion des animaux visibles à la surface lors des relevés aériens et à la sous-déclaration des prises.

Introduction

Beluga in northern Quebec and adjoining waters belong to one of at least three populations based on the summer distribution of animals; an Ungava Bay stock, an eastern Hudson Bay stock and a western Hudson Bay stock. Separate stocks may also occur in James Bay and along the Ontario coast of Hudson Bay. Genetic analyses have confirmed that the eastern and western Hudson Bay beluga stocks can be distinguished between each other (DeMarch et al. 2001; Brennin et al. 1997; Brown Gladden et al. 1997). The majority of animals from these populations or stocks appear to overwinter together in Hudson Strait (Finley et al 1982), although the possibility of smaller groups wintering in Hudson Bay cannot be excluded (Jonkel 1969).

The Ungava Bay and eastern Hudson Bay (EHB) populations were classified as endangered and threatened respectively by COSEWIC in 1989, primarily as a result of aerial surveys flown in 1985. These surveys provided population estimates of 1,200 (SE=300) in James Bay, and 1,000 (SE=200) beluga in eastern Hudson Bay, while too few animals were seen in Ungava Bay to estimate abundance using standard survey techniques (Smith and Hammill 1986).

Attempts were made to reduce hunting after the 1985 surveys. A series of management plans were implemented, with the current plan starting in 1996. This plan limited harvesting to 240 animals, 50 by Ungava Bay communities if harvesting occurred outside of the Bay, 100 by communities in Hudson Strait and 90 by communities along eastern Hudson Bay. Other measures which included seasonal closures were also incorporated into the plan (Anonymous 1996).

In 2001, the government of Canada is expected to present the Species at Risk Act (SARA) to the House of Commons. Once signed into law, the new Act requires that recovery plans be established for species considered as endangered or threatened by COSEWIC. The Act also prohibits the harvesting of animals that will interfere with its recovery.

With the termination of the current management plan in March 2001, a new plan is needed along with recommendations for harvest levels in the Nunavik region prior to the start of hunting in May 2001. Consultations concerning a new management plan began in February 2001. As part of the consultation process some advice on permissible harvest levels was needed. Here I make suggestions for harvest levels for the 2001 season keeping in mind uncertainties concerning the current size and trend of the EHB population, uncertainties related to the proportion of EHB belugas in the Hudson Strait harvest, our absence of information on the stock identity of beluga in James Bay, and the need to allow EHB beluga population to rebuild as per SARA. The impacts of harvesting on Ungava Bay beluga were not examined explicitly because of the low number of animals in this population (<200).

Materials and Methods

It is assumed that population growth can be represented by: $N_{t+1}=(N_t\, e^{rt})-h$, where N is the estimated number of beluga at time t, and t+1, h is removals from the population and r is the maximum rate of increase. Catch data are available from harvest studies, and DFO catch statistics obtained from each of the harvesting communities (Fig 1; Table 1) (Lesage et al. 2001). Beluga harvests from the Nunavik Hudson Bay communities comprise eastern Hudson Bay animals, while Hudson Strait communities harvest an unknown proportion of animals from both the eastern and western Hudson Bay stocks. The impacts of different harvest compositions on the eastern Hudson Bay stock were examined.

Information on abundance and population parameters is more limited. Visual strip transect surveys completed in 1985, estimated a visible population rounded to the nearest 100, of 1,000 animals (SE=200) in eastern Hudson Bay. Numbers of animals seen in Ungava Bay were too few to provide an estimate for this area (Smith and Hammill 1986). A second series of aerial surveys flew the same transect lines in August 1993, but used line transect techniques instead of strip transect methods (Kingsley 2000). The estimated visible population was 3,300 belugas (SE=800) in James Bay, and 1,000 animals (SE=400) in eastern Hudson Bay. Again, too few animals were seen in Ungava Bay to estimate population size, but Kingsley (2000) indicates that numbers are likely less than 200 animals.

Correction factors are required to account for animals under the water, and consequently not visible, when the survey plane passes overhead. Correction factors from satellite telemetry of 1.42 (Martin and Smith 1992) have been suggested for the high Arctic, and 1.66 (SE=0.12) for Hudson Bay based on the amount of time 3 satellite transmitter equipped beluga spent in water less than 4 m deep (Hammill and Doidge In prep). However, it is difficult to link the proportion of time that animals spend near the surface to what might be visible from an aerial survey platform. Gauthier (1999) examined the question of visibility of beluga during aerial surveys in the St Lawrence River Estuary and proposed a correction factor of 2.09 (SE=0.16), which I use here. The correction factor was assumed to be normally distributed.

Beluga are medium sized odontocetes , whose life history is characterized by early reproduction (age 4-7 y), low reproductive rates (crude birth rate: 0.26-0.47) and long lifespan (Longevity =35 y) (Sergeant 1973; Burns and Seaman 1985; Doidge 1990; Heide-Jorgensen and Teilman 1994; Kingsley et al. 1995). Unfortunately, little information is available on the natural rate of increase in beluga populations. Doidge (1990) compared results from two aerial surveys and suggested an annual growth rate of 3.6% for western Hudson Bay beluga. However, he suggested caution in using this result because of methodological differences between surveys. Kingsley et al (1995) suggested a somewhat lower maximum annual growth rate of 2.6% for beluga in eastern Hudson Bay. Rates of increase from other species with similar life-histories were examined for their suitability to be applied to an exploited beluga population (Table 2). Estimated rates of increase for odontocetes vary from 0.02 in spotted dolphins to a high 0.111 for harbour porpoise. Life-history parameters of beluga suggest a rate of increase falling in between that of the killer whale and the harbour porpoise. A rate of increase of 0.03-0.04, similar to Narwhal, Pothead and spotted dolphins would appear to be reasonable. The rate of increase was incorporated into the model assuming a uniform distribution with upper and lower limits of 0.04 and 0.03 respectively.

The model was fitted by minimizing the mean sum of squares (MSS) from the aerial survey estimates from 1985 and 1993 surveys (Smith and Hammill 1986; Kingsley 2000) estimates using the software Risk Optimizer (Palisade Corporation 2000). Runs were constrained to values that lay within 2 standard deviations of the 1985 and 1993 survey estimates. The model starts with an initial population and samples (Latin Hypercube) from the defined functions, values for the expected proportion of harvest from the EHB population and the expected rate of increase for each year. Sampling is repeated 500 times (replicates) and generates a distribution of 500 MSS. These constitute a simulation. The model calculates the MSS, stores the value and randomly selects a new initial population size to carry out a new simulation. After 1000 simulations, the model retains the simulation which generated the smallest MSS.

For the eastern Hudson Bay population of beluga it was assumed that: (i) animals in James Bay do not belong to the eastern Hudson Bay population; (ii) eastern Hudson Bay harvests are from the EHB beluga population. Harvesting also occurs in Hudson Strait, but it is not known what fraction of this harvest is made up of animals belonging to the eastern and western Hudson Bay populations. Therefore simulations assuming that: (1) all animals harvested in Hudson Strait belonged to the western Hudson Bay stock; (2) all animals harvested in Hudson Strait belonged to the eastern Hudson Bay stock; (3) the fraction of the harvest belonging to the eastern Hudson Bay stock was normally distributed with a mean proportion of 0.5 (se=0.15) were run.

Levels of harvesting that could be sustained in the eastern Hudson Bay population were examined. Harvesting levels were set to maintain current estimated population sizes (replacement yield) in 2000 and also to establish harvest levels that would allow the population to increase. Uncertainty in the population trajectory was examined by drawing 1000 random samples of r, the fraction of the total harvest coming from the eastern Hudson Bay population and the correction factor for animals not visible at the surface and plotting the corresponding trajectories using the software @Risk (Palisade Corporation 2000).

Results

Three factors were allowed to vary in the model: rate of increase, the correction factor applied to the aerial survey estimates to account for animals not visible at the surface and the fraction of the harvest in Hudson Strait that is made up of animals from the eastern Hudson Bay population. Of the three factors, the model was most sensitive to changes in the proportion of EHB animals in the Hudson Strait harvest, followed by changes in the aerial survey correction factor and then the rate of increase (Fig. 2).

The fraction of the harvest by Hudson Strait communities that belongs to the eastern HB beluga population has a major impact on our perspective of the population (Fig 3). Assuming that none of the animals taken in Hudson Strait belong to the eastern Hudson Bay population, then the population may have changed little since the surveys flown in 1985 and 1993. Fitting the model to the survey data resulted in an estimated population of 2,100 (SE=200) animals in 1985 and around 1,900 (SE=300) in 2000 (Figure 3a). If we assume that all animals harvested in Hudson Strait belong to the EHB stock, then the population declined slightly from approximately 2,600 (SE=200) in 1985 to about 1,700 (SE=300) animals in 1993, and then more rapidly to 400 (SE=400) beluga in 2000 (Fig 3b). However, it is unlikely that the harvest consists of all EHB or all WHB animals and this proportion may vary from year to year. Assuming that a proportion (Mean=0.5, SE=0.15) of the Hudson Strait harvest consisted of EHB animals, then the population has declined from 2,300 (SE=200) animals in 1985 to 1,100 (SE=500) beluga in 2000 (Fig 3c).

The impacts of future harvesting on the EHB beluga population were examined assuming that a variable proportion (Mean=0.5, SE=0.15) of animals harvested during the period 1985 to 2000 in Hudson Strait belonged to the EHB population. If the present quota of 140 whales for the Hudson Strait and eastern Hudson Bay communities was maintained, then the population would continue to decline, approaching extirpation as early as 2003 (Fig 3c). Reducing total removals, which includes both animals landed and animals killed but not recovered, from the EHB population to 40 animals per year beginning in 2001, would likely result in the population levelling off at 1,100 animals (SE=500), and may even allow the population to increase very slowly (Fig 4a). Reducing the removal of EHB animals from all sources to 20 animals per year would allow the population to begin increasing at a rate of about 2% per year (Fig 4b). During the meeting, it was learned that under the current management plan, harvests by Puvirnituq and Akulivik hunters have occurred primarily in the Hudson Strait area near Ivujivik (Lesage et al. 2001). The genetic analyses of skin samples from Hudson Strait communities, although limited due to the number of samples, indicated that the proportion of eastern Hudson Bay animals in the Hudson Strait harvest may only be 30% (de March et al. 2001). Incorporating these changes into the harvest estimates from 1996-2000 indicate that the 2000 population would have declined to 1,500 (SE=500) and could disappear by 2006 (Fig. 5). A harvest of 40 animals would likely result in the population levelling off and possibly increasing slightly (Fig. 6a). Reducing the harvest of EHB animals from all sources to 20 animals per year would allow the population to begin increasing at a rate of about 2% per year (Fig. 6b).

Discussion

Only two systematic aerial surveys, which used two different techniques (strip transect and line transect; Smith and Hammill 1986; Kingsley 2000) have been flown to estimate beluga abundance in eastern Hudson Bay. Unfortunately, the last survey was flown in 1993, which increases the level of uncertainty associated with changes in the population over the last eight years. The absence of a regular time series of abundance data means that a greater reliance is placed on the accuracy of the harvest statistics and literature values for r_{max} to model changes in the population. If the harvest statistics under-report removals from the EHB population, then the beluga population will be much smaller than estimated by the current model. Changes in population size were modelled by applying a variable rate of increase (r=0.03-0.04) based on maximum rates of increase observed in other species with similar life-histories to beluga. Doidge (1990) reports a similar rate for western Hudson Bay beluga, but cautions that the estimate is based on comparisons between two surveys that used different methods. Data from the literature suggest that the maximum rate of increase for beluga should be around 3-4% and the rate of 4% is an accepted standard in some jurisdictions (Wade 1998). However, the possibility of other rates either closer to 2% (Kingsley et al 1995) or a higher rate of 0.05 cannot be excluded (Reilly and Barlow 1986). If the rate of increase is closer to 2% then the population could disappear as early as 2003. If the maximum rate of increase in beluga was actually closer to 0.05, then the population would not be expected to disappear until 2009 if harvests continue at current levels.

The correction factor (2.09) (Gauthier 1999) used to adjust aerial survey estimates to account for animals under the water is much higher than estimates from satellite telemetry data. If this correction factor has been overestimated, then eastern Hudson Bay beluga are much less abundant than the model suggests.

Finally, the lack of information on the proportion of animals belonging to the eastern Hudson Bay stock that are harvested in Hudson Strait has a major impact on our impressions of what is happening to this population. Genetic information has indicated that beluga belonging to both the eastern and western Hudson Bay beluga populations are harvested by Hudson Strait communities. However, more samples are needed, particularly from communities at the western entrance to the strait, which harvest the greatest number of animals, before this concern can be addressed.

In the absence of a time series of survey data it is necessary to look at other information to determine if changes in abundance have occurred. Comparisons between the 1985 (Smith and Hammill 1986) and 1993 (Kingsley 2000) surveys, which flew along the same transect lines indicate that fewer animals are found in inshore areas in the more recent study. Fewer whales were also counted on the 1993 survey lines (N=150 whales) compared to the 1985 survey (N=200 whales), in spite of a 57% wider effective transect width in the 1993 survey. Shore based observations conducted during 1983 and 1984 (Caron and Smith 1990) reported maximum counts of 100+ beluga in the Nastapoka during July and August, compared to sightings of 40-60 animals at a time in 1993 (Doidge 1994) and from community agents during 1995-97. Maximum counts (Hammill and Doidge unpublished), during a study to capture beluga to deploy satellite transmitters at the Nastapoka River were less than 25 animals during a 3 week period in August 1998 and a one month period in July 1999. At Little Whale River a maximum of 25 beluga were seen during the first week of August 1999 compared to maximum counts of 100 or more animals during the last week of July 1993 (Doidge 1994). Individually the changes observed in these indices may reflect changes in whale distribution owing to increases in vessel traffic in inshore areas, or sampling error associated with individual surveys. However, when the indices are taken together, along with the information that there has been a decline in the median age of the harvest in the estuaries, and a reduction in the proportion of worn teeth (older animals) in the catch (Lesage et al. 2001), then it would appear that that the eastern Hudson Bay beluga population has declined and that current harvest levels are not sustainable.

Different catch levels were examined for their impact on the predicted 2001 population estimate. If all assumptions associated with modelling are satisfied then the current population probably numbers around 1,100 animals, which could support removals of 40 animals. However, owing to the uncertainties associated with our knowledge of this population, total harvests from the EHB population of beluga should be reduced to 20 animals per year. This is unlikely to result in any further decline in the population and may even allow them begin rebuilding at an annual rate of about 2% per year.

Recommendations

During 1995 to 2000, northern Quebec beluga were managed under a five year management plan (Anonymous 1996). Owing to the combination of the 5-year plan and Program Review, this plan was not supported by a research program to monitor changes in population parameters, enforcement of harvest quotas and regular meetings with clients to discuss concerns related to the resource. It is recommended that this resource be managed on a shorter term and that the management plan be supported by a more rigorous research effort to allow both managers and hunters to incorporate new information into the management plan. It would also indicate to hunters that DFO is maintaining an active interest in the resource.

Beluga populations recover very slowly from overharvesting. A regular program to monitor population changes should have been implemented to monitor changes in population size. Regular monitoring would have provided cross validation of harvest statistics, assumptions about the composition of harvests from Hudson Strait and would have provided an earlier warning to an apparent decline in the EHB beluga stock. It is important that a new survey of this population be completed as soon as possible. This survey should also re-evaluate beluga abundance in Ungava and James Bays.

Recent research activities (satellite telemetry, genetics) have shown that an inshore/offshore movement of beluga can occur quite rapidly, and that animals from the Nastapoka River make extensive use of offshore areas of the Hudson Bay arc (Hammill and Doidge In prep). Skin samples provided by hunters have underlined differences between eastern and western Hudson Bay beluga. Although one management strategy might be to encourage a shift in hunting effort towards Hudson Strait in order to protect the EHB beluga stock, a major effort to obtain skin samples for genetic analyses from villages hunting at the western portion of Hudson Strait is required to determine stock composition of the harvest. Until this information is obtained, it must be assumed that Hudson Strait harvests contain some animals from the EHB population. The aerial surveys also indicate that large numbers of beluga may also occur in James Bay. These animals may belong to the eastern Hudson Bay beluga population or they may form a separate stock. Understanding the stock relationships between these two groups could have a substantial impact on our views of the eastern Hudson Bay population.

The general model developed here assumes that harvesting takes animals proportional to their representation in the population. Previous modelling efforts (Kingsley et al. 1995) have shown that harvests could be increased slightly if harvesting is directed towards young males, and if females with calves are protected. Unfortunately, during hunting it is often difficult to distinguish animals. Nevertheless, every effort should be undertaken to stress protection from hunting of females and females with calves. Although harvest data (age structure, sex ratio) do exist, a greater effort to collect this data are needed along with regular monitoring of reproductive rates, information that could also be obtained from the harvest. This would permit the development of a more detailed model incorporating abundance, age structure and reproductive rate information.

Current harvesting is concentrated in nearshore and estuarine areas, where a strong decline in numbers has occurred. It is recommended that the duration of the current closure to hunting in the key areas of Little Whale, Nastapoka Rivers and Richmond Gulf be extended in order to provide animals a respite from hunting. This will maintain an abundant resource that is available to inshore hunters when numbers have increased.

Owing to low numbers and uncertainty associated with the presence status of the EHB beluga population it is recommended that harvesting from this population be reduced to 20 animals. However, these estimates are based on aerial surveys flown over eight years ago. These surveys also indicate that there were a considerable number of animals near the Belcher Islands. Analyses of the stock composition of the Belcher Island harvest indicate that very few animals from the eastern Hudson Bay stock are taken (deMarch et al. 2001). Thus it might be possible that the survey provides an abundance estimate for the eastern Hudson Bay beluga and another stock(s) that overlap(s) in this area. In this case, the size of the eastern Hudson Bay population may be even smaller than suggested by the modelling conducted in this study.

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Literature cited

Anonymous. 1996. Northern Quebec belugas. 5 year management plan: 1996-2000. Fisheries and Oceans Canada, Laurentian Region.

Barlow,J. and P.Boveng. 1991. Modeling age specific mortality for marine mammal populations. Mar. Mamm. Sci. 7:50-65.

Brault, S. and H. Caswell. 1993. Pod-specific demography of killer whales (*Orcinus orca*). Ecology 74:1444-1454.

Brennin, R., B.W. Murray, M.K. Friesen, L.D. Maiers, J.W. Clayton, and B.N. White. 1997. Population genetic structure of beluga whales (*Delphinapterus leucas*): mitochondrial DNA sequence variation within and among North American populations. Can. J. Zool. 75: 795-802.

Brown Gladden, J.G., N.M. Ferguson, and J.W.Clayton. 1997. Matriarchal genetic population structure of Morth American beluga whales *Delphinapterus leucas* (Cetacea: Monodontidae). Molecular Ecol. 6: 1033-1046.

Burns, J.J. and G.A. Seaman. 1985. Investigations of Belukha whales, in coastal waters of western and northern Alaska. II Biology and Ecology. Final report NOAA Outer Continental Shelf Environmental Assessment Program. 129 p. Alaska Dept. of Fish and Game, Fairbanks, Alaska.

Caron, L.M. and T.G. Smith. 1990. Philopatry and site tenacity of belugas, (*Delphinapterus leucas*) hunted by the inuit at the Nastapoka Estuary, eastern Hudson Bay. Can. Bull. Fish. Aquat. Sci. 224:69-79.

Caswell, H. S. Brault, A.J. Read, and T.D. Smith. 1998. Harbor porpoise and fisheries: An uncertainty analysis of incidental mortality. Ecol. Appl. 8:1226-1238.

Chivers,S.J. and A.C. Myrick. 1993. Comparison of age at sexual maturity and other reproductive parameters for two stocks of spotted dolphin, *Stenella attenuata*. Fish. Bull. 91:611-618.

de March, B.G.E., L.D. Maiers, M.O. Hammill, and D.W. Doidge. 2001. Stock discrimination of belugas (*Delphinapterus leucas*) hunted in eastern Hudson Bay, northen Québec, Hudson Strait, and Sanikiluaq (Belcher Islands), using mitochondrial DNA and 15 nuclear microsatellite loci. Can. Stock. Ass. Secr. Res. Doc. 2001/050.

Doidge, D.W. 1990. Age and stage based analysis of the population dynamics of beluga whales, *Delphinapterus leucas,* with particular reference to the northern Quebec population. Unpubl. PhD thesis, Renewable Resources, McGill university, Montreal, QC.

Doidge, D.W. 1994. Landbased observations of beluga whales at the Little Whale and Nastapoka rivers, eastern Hudson Bay, Summer 1993. Funded by Fisheries and Oceans Aboriginal Fisheries Strategy. 30 pp.

Finley, K.J., G.W. Miller, M. Allard, R.A. Davis, and C.R. Evans. 1982. The belugas (*Delphinapterus leucas*) of northern Quebec: distribution, abundance, stock identity, catch history and management. Can. Tech. Rep. Fish. Aquat. Sci. 1123. 57 pp.

Gauthier, I. 1999. Estimation de la visibilité aérienne des bélugas du Saint-Laurent et les conséquences pour l`évaluation es effectifs. Mémoire de maîtrise, Université du Québec à Rimouski, Rimouski, QC, Canada, 104pp.

Hammill, M.O. and D.W. Doidge. In prep. Movement and diving behaviour of beluga from the Nastapoka River. Working paper.

Heide-Jorgensen, M.P. and J. Teilman. 1994. Growth, reporduction, age structure and feeding habits of white whales (*Delphinapterus leucas*) in west Greenland waters. Medd. Om. Gronland, Bioscience. 39:195-212.

Jonkel, C.J. 1969. White whales wintering in James Bay. J. Fish. Res. Board Can. 26:2205-2207.

Kaysuya, T., D.E. Sergeant and K. Tanaka. 1988. Re-examination of life history parameters of long-finned pilot whales in Newfoundland waters. Sci. Rep. Whales Res. Inst. 39:103-119.

Kingsley, M.C.S. 2000. Numbers and distribution of belugas in Hudson Bay, James Bay and Ungava Bay in Canada during the summer of 1993. Fish. Bull. 98: 736-747.

Kingsley, M.C.S. 1989. Population dynamics of the narwhal (*Monodon monoceros*): an initial assessment (Odontoceti: Monodontidae). J. Zool., Lon. 219:201-208.

Kingsley, M.C.S., P. Richard, and S. Innes. 1995. The effect of management options on the dynamics of beluga populations. Unpubl. MS 26 pp.

Lesage, V., W.D. Doidge, and R. Fibich. 2001. Harvest statistics for beluga in Nunavik, 1974-2000. Can. Stock. Ass. Secr. Res. Doc. 2001/022. 52 pp.

Martin, A.R. and T.G. Smith. 1992. Deep diving in wild, free-ranging beluga whales, *Delphinapterus leucas*. Can. J. Fish. Aquat. Sci. 49: 462-466.

Olesiuk, P.F., M.A. Bigg, and G.M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rept. Of the Int. Whaling Com. Spec. Issue 12:209-243.

Palisade Corporation Inc. 2000. Guide to Risk Optimizer: simulation optimization for Microsoft Excel. Windows version Release 1.0. Newfield, NY, USA.

Palisade Corporation Inc. 2000. @Risk advanced risk analysis for spreadsheets. Windows version Release 1.0. Newfield, NY, USA.

Reilly, S.B. and J. Barlow. 1986. Rates of increase in dolphin population size. Fish. Bull. 84:527-533.

Sergeant, D.E. 1973. Biology of white whales (*Delphinapterus leucas*) in western Hudson Bay. J. Fish. Res. Board Can. 30:1065-1090.

Smith, T.G. and M.O. Hammill. 1986. Population estimates of white whale, *Delphinapterus leucas*, in James Bay, Eastern Hudson Bay and Ungava Bay. Can. J. Fish. Aquat. Sci. 43:1982-1987.

Table 1. Beluga harvest statistics for Nunavik villages from 1984-2000 (Lesage et al. 2001).

YEAR	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
Kuujjuarapik	35	40	10	11	0	8	8	12	16	12	22	14	15	11	14	14	8
Umiujaq	-	-	3	15	12	18	12	24	24	19	18	21	19	19	18	24	19*
Inukjuak	58	11	7	11	17	17	11	20	16	13	19	20	22	21	18	19	35
Puvirnituk	-	-	0	16	23	41	22	50	22	23	23	36	38	33	36	27	29
Akulivik	4	11	12	12	12	19	9	18	16	16	20	18	15	24	17	22	12
Eastern Hudson Bay total	97	62	32	65	64	103	62	124	94	83	102	109	109	108	103	106	103
Ivujivik	69	35	5	24	19	118	-	31	2	37	-	38	34	22	44	37	36
Salluit	29	22	24	20	16	53	17	28	19	37	46	40	32	46	54	33	28
Kangiksujuaq	26	32	22	28	28	28	24	39	28	29	34	22	25	25	22	27	26
Quaqtaq	46	32	21	21	15	35	18	29	22	32	35	28	23	31	32	24	26
Hudson Strait total	170	121	72	93	78	234	59	127	71	135	115	128	114	124	152	121	116
Kangirsuk	3	7	9	8	7	11	10	12	3	12	10	12	16	16	13	19	12
Aupaluk	2	3	3	1	2	3	5	9	0	3	6	6	8	8	4	13	8
Tasiujaq	4	9	14	4	11	9	3	2	2	7	12	11	6	14	17	21	13
Kuujjuak	5	2	10	5	2	8	3	3	4	12	9	10	5	13	10	8	7
Kangiksualujjuaq	5	3	5	2	1	0	0	7	0	4	11	2	9	7	3	7	11
Ungava Bay total	19	24	41	20	23	31	21	33	9	38	48	41	44	58	47	68	51
Nunavik total	286	207	145	178	165	368	142	284	174	256	265	278	267	290	302	295	258

Table 2. Population parameters for odontocete populations.

Parameter	Beluga	Narwhal	Killer whale	Pilot whale	Harbour porpoise	Spotted dolphin
Longevity (y)	35		80	46	20	33-45
Age first birth (y)	4-7	6	14	7	4.5	13
Crude birth rate (y)	0.26-0.47	0.3-0.38	0.154	0.37-0.40	0.4-0.83	0.33-0.4
Max. rate of increase	0.03-0.038	0.03-0.04	0.025-0.029	0.028	0.096-0.111	0.02-0.04
Sources	Doidge 1990; Burns and Seaman 1985	Kingsley 1989	Olesiuk et al 1990; Brault and Caswell 1993	Kasuya et al 1998	Caswell et al 1998.	Barlow and Boveng 1991: Chivers and Myrick 1993.

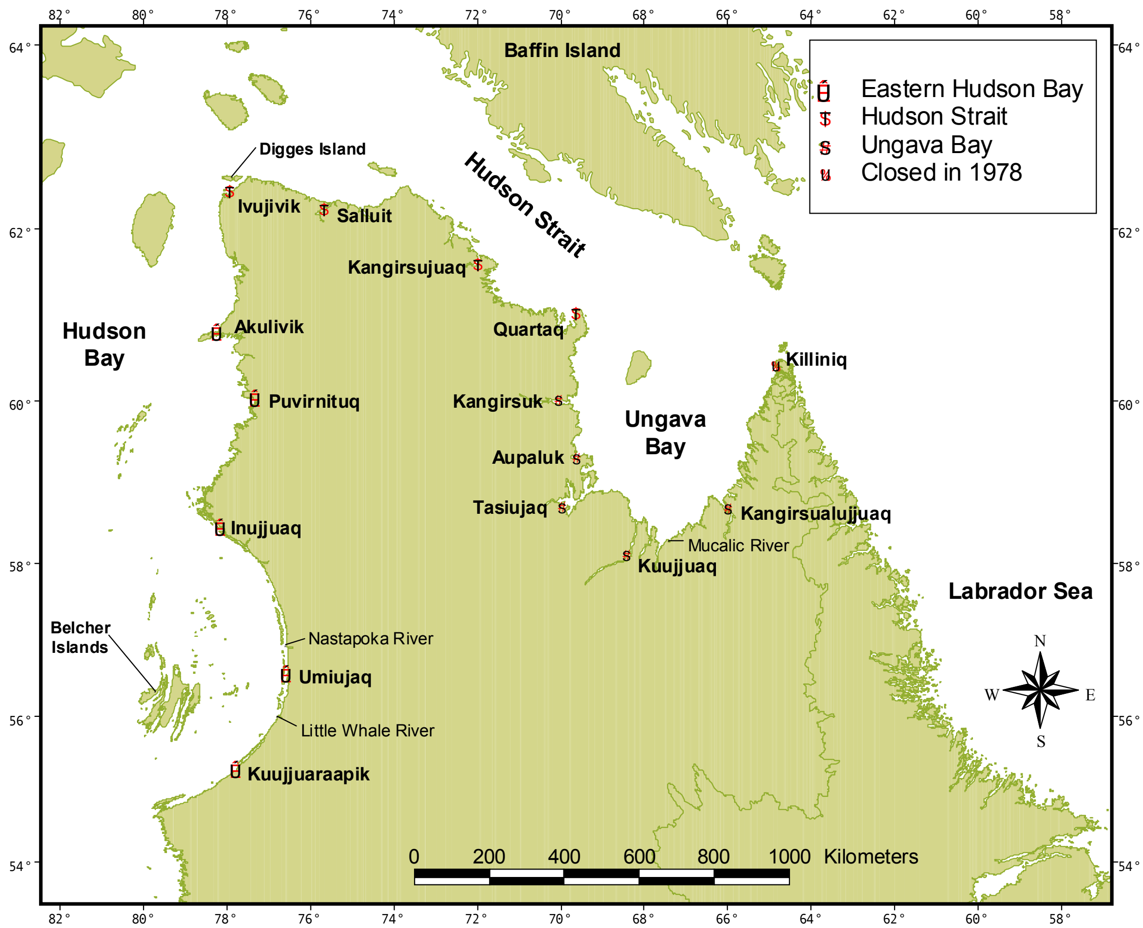

Figure 1. Location of communities in northern Quebec (Nunavik).

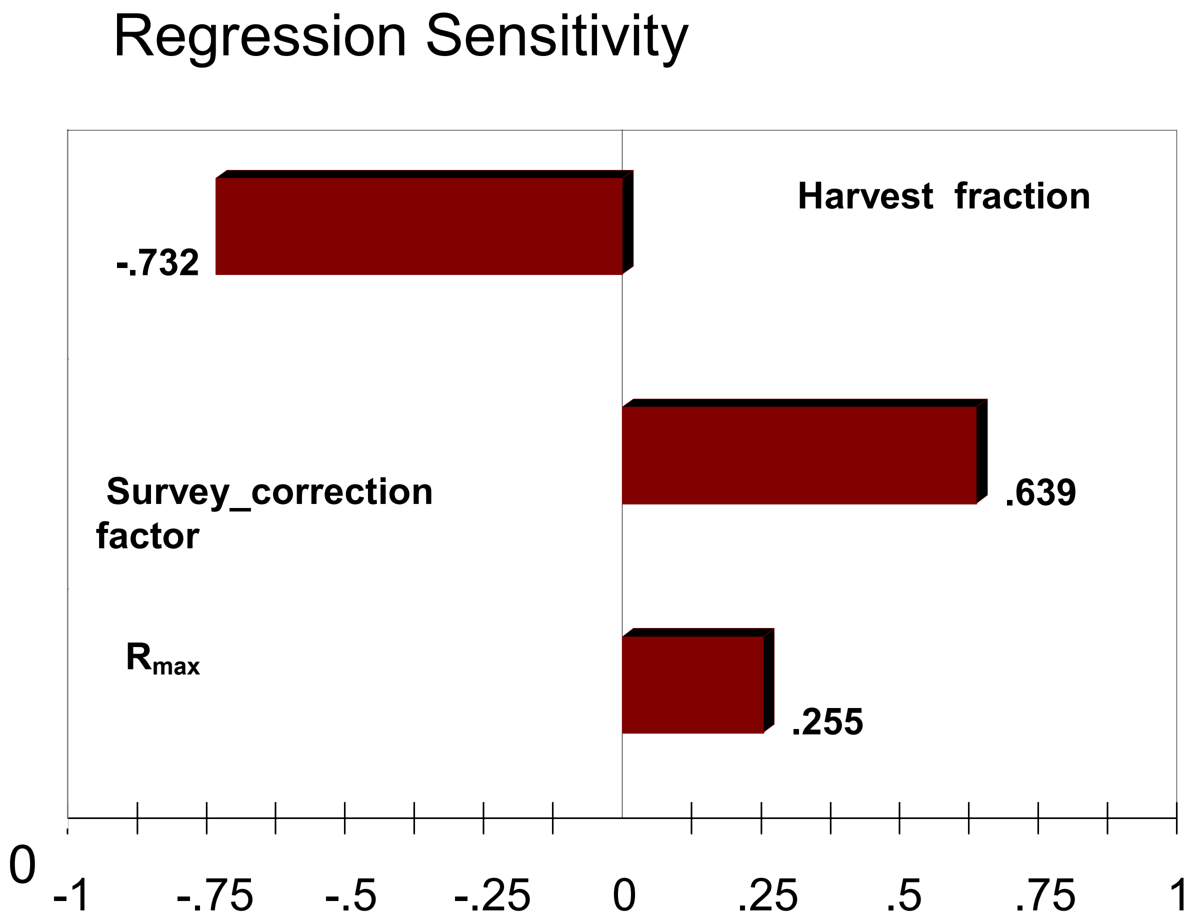

Figure 2. Sensitivity of model population estimates to changes in input parameters.

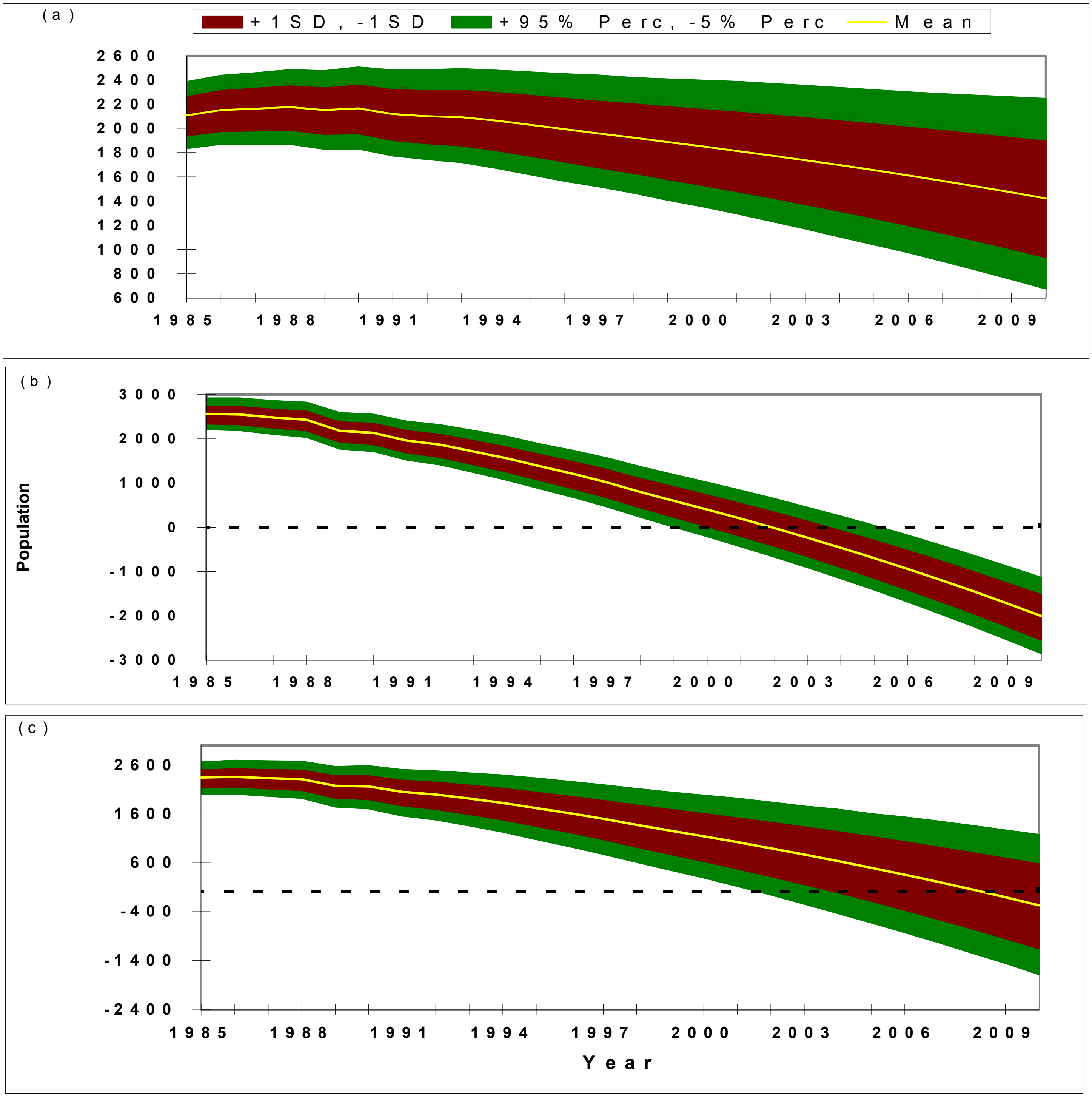

Figure 3. Trajectory of EHB beluga population from 1985 to 2010 assuming r=0.03-0.04, harvesting levels in 2000 continue and (a) no EHB animals are harvested in Hudson Strait harvests (b) all of animals harvested in Hudson Strait come from the EHB population and (c) 0.5 (se=0.15) of the Hudson Strait harvest is made up of EHB animals.

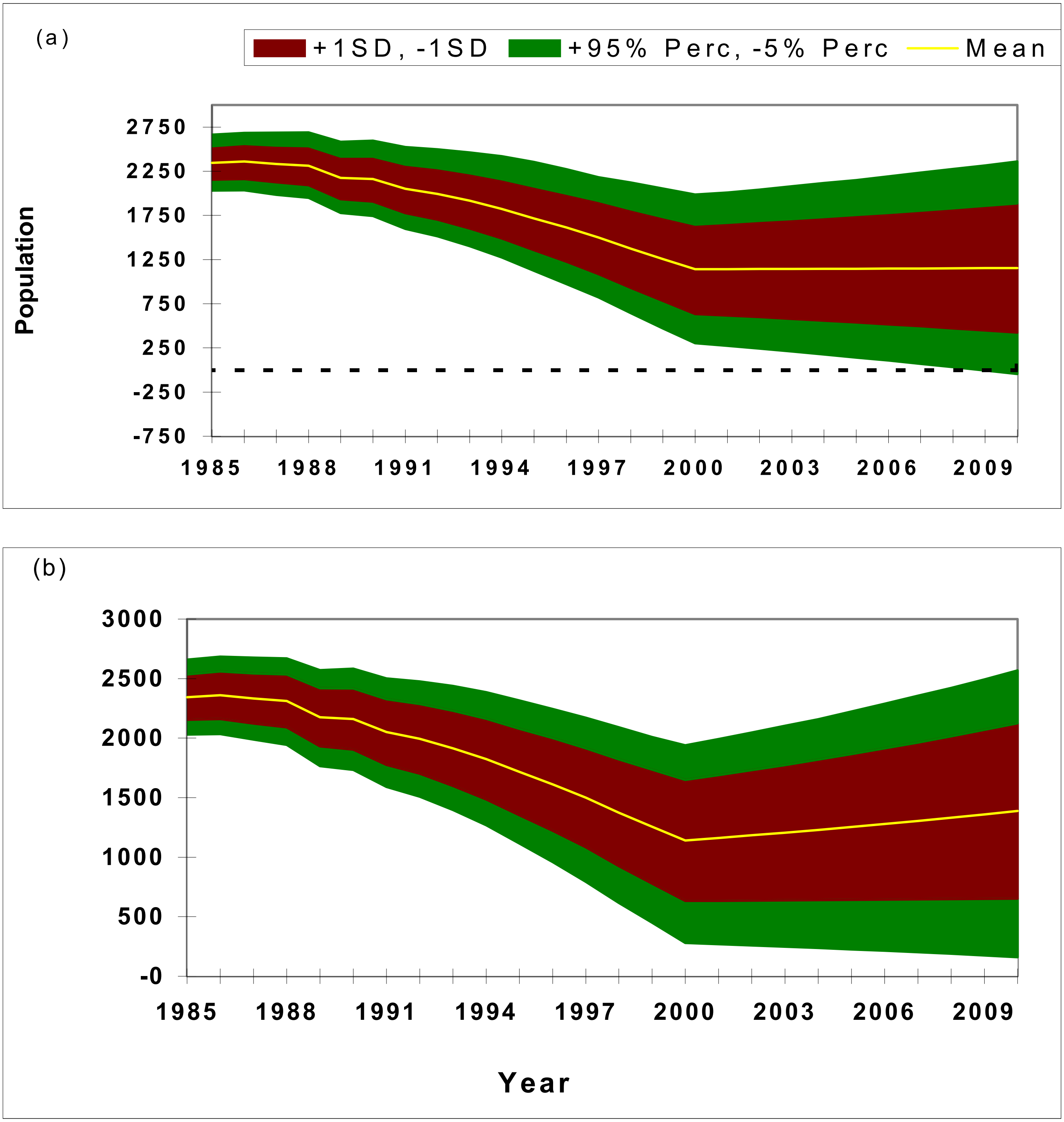

Figure 4. (a) Expected impacts of harvesting on the EHB population: (a) a total harvest of 40 animals; (b) a total harvest of 20 animals.

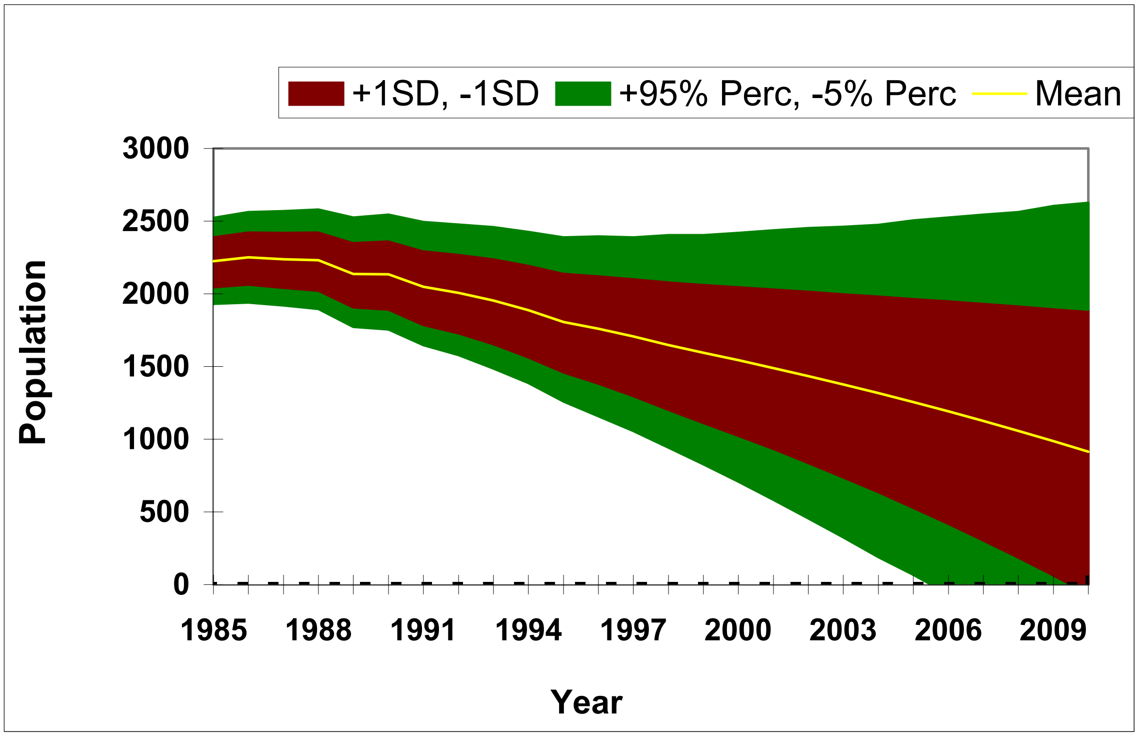

Figure 5. Estimated changes in beluga abundance in eastern Hudson Bay, assuming that animals hunted by the communities of Puvirnituq and Akulivik since 1996 were taken in the Hudson Strait area and that the proportion of eastern Hudson Bay beluga in the Hudson Strait this harvest is 30%.

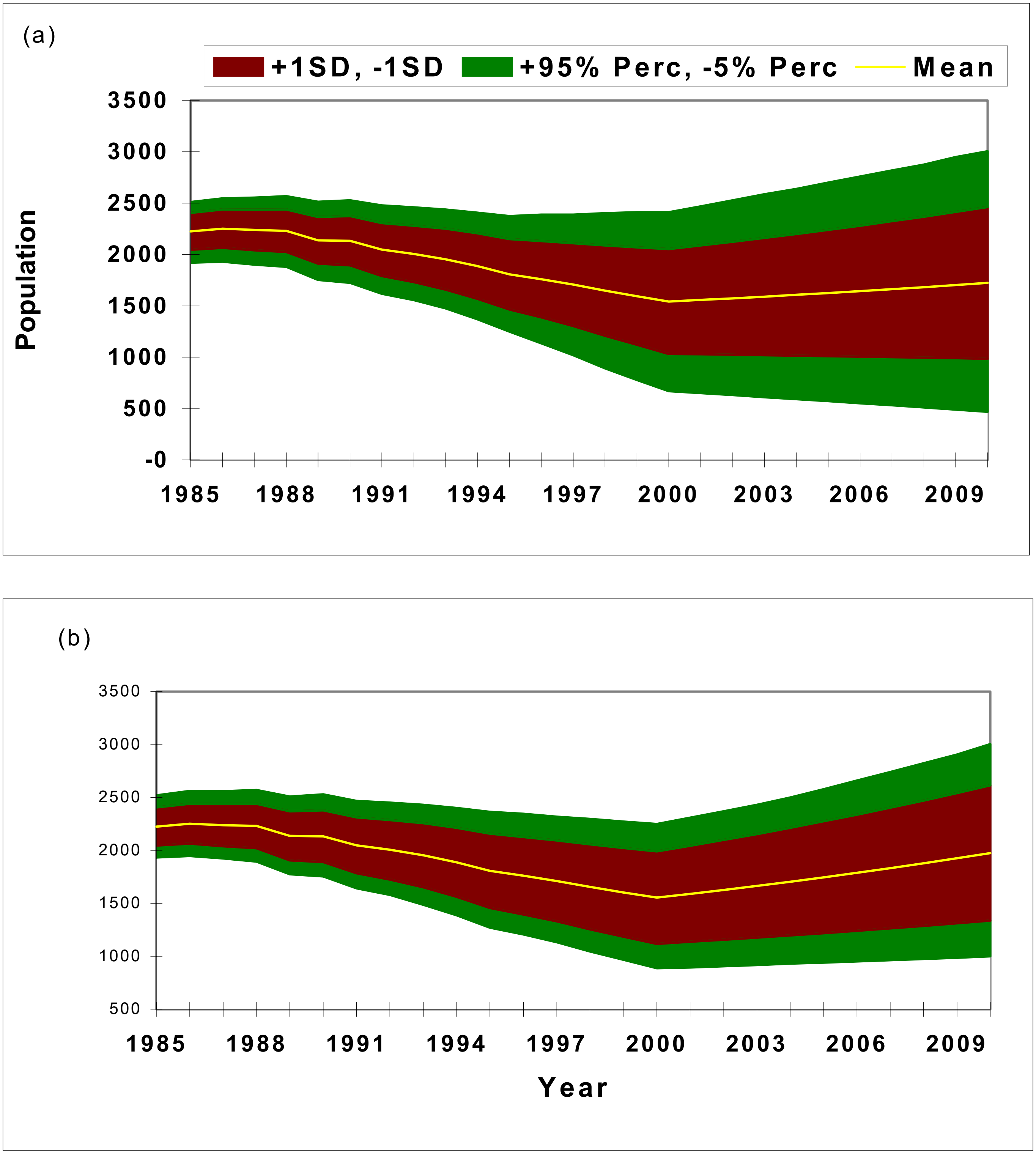

Figure 6. Estimated changes in beluga abundance in eastern Hudson Bay, assuming that animals hunted since 1996, by the communities of Puvirnituq and Akulivik were taken in the Hudson Strait area and that the proportion of eastern Hudson Bay beluga in the Hudson Strait harvest is 30%. (a) A quota of 40 whales, (b) a quota of 20 whales.