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**Date:** April 17, 2003

**To:** Glenda Fraton  
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**This fax contains** 3 **page(s), including the cover sheet.**

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**Comments:**

Please see attached answers to the MVEIRB wildlife Information Requests.

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Northwest  
Territories Resources, Wildlife and Economic Development

April 17, 2003

Glenda Fraton  
Environmental Assessment Officer  
Mackenzie Valley Environmental Impact Review Board  
2nd Floor Scotia Center, 5102-50<sup>th</sup> Ave  
Yellowknife, NT X1A 2N7

Dear Ms Fraton:

**Information Requests to the Government of the Northwest Territories.  
WILDLIFE REPORTS**

On April 4, 2003, the Mackenzie Valley Environmental Impact Review Board provided a set of questions to the Government of the Northwest Territories. This letter addresses the first wildlife question posed.

Q 1 Please place on the record a copy of McLoughlin et al 2003a and 2003b.

The Government of the Northwest Territories has forwarded electronic versions of the following reports:

McLoughlin, P.D., M.K. Taylor, H.D. Cluff, R.J. Gau, R. Mulders, R.L. Case, S. Boutin, and F. Messier. 2003a. Demography of barren-ground grizzly bears. Canadian Journal of Zoology. 81: 294-301. 775-A

McLoughlin, P.D., M.K. Taylor, H.D. Cluff, R.J. Gau, R. Mulders, R.L. Case, S. Boutin, and F. Messier. Arctic. In Press. 775B.

If you have any concerns or questions in regards to the above please feel free to contact me at (867) 873-7315.



- 2 -

Sincerely,

A handwritten signature in black ink, appearing to read "Gavin More".

Gavin More.  
Environmental  
Assessment Analyst.

# Demography of barren-ground grizzly bears

Philip D. McLoughlin, Mitchell K. Taylor, H. Dean Cluff, Robert J. Gau,  
Robert Mulders, Ray L. Case, Stan Boutin, and François Messier

**Abstract:** Between May 1995 and June 1999, we equipped 81 barren-ground grizzly bears (*Ursus arctos*) with satellite radio collars within a study area of 235 000 km<sup>2</sup>, centred 400 km northeast of Yellowknife, Northwest Territories, Canada. We used data from radiotelemetry to estimate survival rates, reproductive parameters, and the finite rate of increase of the population ( $\lambda$ ). The annual survival rate of adult females was estimated at 0.979 (95% confidence intervals (CI) = 0.955–0.998), while the survival rate of adult males was 0.986 (95% CI = 0.942–1.0). The cub survival rate was 0.737 (95% CI = 0.600–0.844) and the yearling survival rate was 0.683 (95% CI = 0.514–0.821). Cub litter size averaged 2.23 (SE = 0.13,  $n$  = 35), while yearling litter size decreased to a mean of 1.86 (SE = 0.12,  $n$  = 35). The mean litter size of females with 2-year-olds was 1.85 (SE = 0.15,  $n$  = 20). The mean birth interval was 2.8 years (SE = 0.3 years,  $n$  = 17). The mean reproductive interval, which is calculated by excluding the loss of whole litters from the sample, was 3.9 years (SE = 0.4 years,  $n$  = 9). Mean litter size divided by mean birth interval yielded an annual natality rate of 0.81 cubs per adult female per year. The mean age at first parturition was 8.1 years (SE = 0.5 years,  $n$  = 10). We believe the population to be currently stable or slightly increasing ( $\lambda$  = 1.033, 95% CI = 1.008–1.064).

**Résumé :** De mai 1995 à juin 1999, nous avons muni de colliers émetteurs satellites 81 grizzlis (*Ursus arctos*) de la toundra, dans une zone de 235 000 km<sup>2</sup> dont le centre est situé à 400 km de Yellowknife, Territoires du Nord-Ouest, Canada. Les données radio-téléométriques nous ont permis de faire l'estimation des taux de survie, des paramètres reproducteurs, et du taux fini de la croissance de la population ( $\lambda$ ). La survie annuelle des femelles a été évaluée à 0,979 (intervalle de confiance (IC) 95 % = 0,955–0,998), alors que celle des mâles adultes a été estimée à 0,986 (IC 95 % = 0,942–1,0), celle des jeunes à 0,737 (IC 95 % = 0,600–0,844) et celle des oursons de 1 an à 0,683 (IC 95 % = 0,514–0,821). Le nombre moyen d'oursons dans une portée est de 2,23 (erreur type = 0,13,  $n$  = 35), alors que le nombre moyen de petits de 1 an est de 1,86 (erreur type = 0,12,  $n$  = 35). Le nombre moyen d'oursons dans la portée d'une mère qui a déjà deux oursons est de 1,85 (erreur type = 0,15,  $n$  = 20). L'intervalle moyen entre les naissances est de 2,8 ans (erreur type = 0,3 ans,  $n$  = 17). L'intervalle reproducteur moyen, qui est calculé en excluant les portées entièrement perdues de l'échantillon, est de 3,9 ans (erreur type = 0,4 ans,  $n$  = 9). Le nombre moyen de petits dans une portée divisé par l'intervalle moyen entre les naissances donne un taux de natalité annuel de 0,81 ourson par femelle adulte par an. L'âge moyen des femelles à la première mise bas est de 8,1 ans (erreur type = 0,5 ans,  $n$  = 10). Nous considérons que cette population est actuellement stable ou qu'elle croît légèrement ( $\lambda$  = 1,033, IC 95 % = 1,008–1,064).

[Traduit par la Rédaction]

## Introduction

Grizzly bears (*Ursus arctos*), like many long-lived animals, are highly susceptible to overexploitation. Late age at maturity, small litter sizes, and long interbirth intervals maintain low intrinsic rates of increase for the species. Because of this, all populations of grizzly bears in Canada are classified as be-

ing of "special concern" to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002).

Barren-ground grizzly bears inhabiting the Arctic coastal plain, however, may be particularly sensitive to overexploitation because they live at low densities in an area of low productivity and high seasonality (Ferguson and McLoughlin 2000; McLoughlin et al. 2000). We would predict, relative to other

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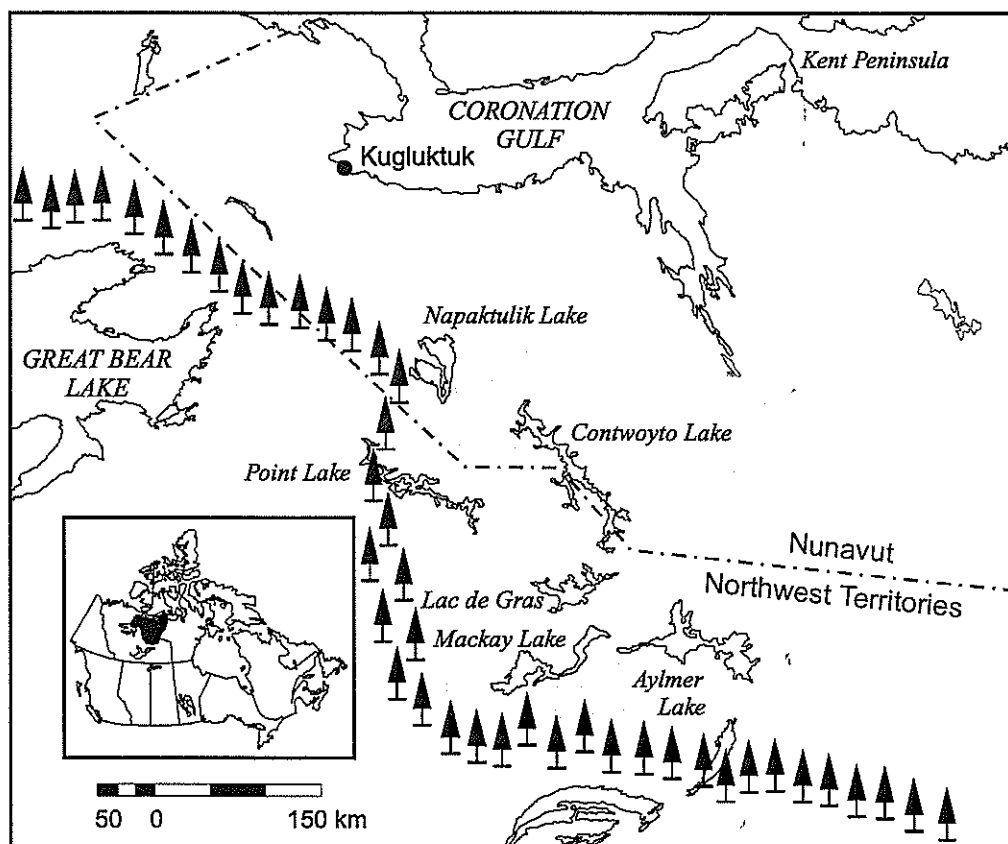
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Fig. 1. Bounds of the study area (shaded region) in Canada's central Arctic. The treeline indicates the northernmost extent of coniferous forest.



grizzly bear populations, low reproduction resulting from delayed age at first parturition, longer birth and reproductive intervals, and smaller litter sizes. Of all grizzly bear populations, barren-ground populations may be most susceptible to direct mortality associated with human activity.

To address concerns about potential effects of increasing human activity on barren-ground grizzly bears inhabiting Canada's central Arctic (Fig. 1), the Government of the Northwest Territories and the University of Saskatchewan initiated a program of research into the ecology of bears in the region. Here we describe age distributions, survival rates, reproductive parameters, and rate of increase for the population. The significance of these parameters to the life history of barren-ground grizzly bears and their conservation is discussed.

## Methods

### Study area

The study area was located in Canada's central Arctic, encompassing approximately 235 000 km<sup>2</sup> of mainland Nunavut and the Northwest Territories (Fig. 1). The study area (65°N, 112°W) was delineated by the communities of Kugluktuk, the Kent Peninsula, Aylmer Lake, Mackay Lake, and Great Bear Lake. The region is characterized by short cool summers and long cold winters. Summer temperatures average 10°C and winter temperatures are commonly below

−30°C. The area is semi-arid, with annual precipitation around 300 mm, about half of which falls as snow (BHP Diamonds Inc., Yellowknife, Northwest Territories, Canada, 1995, Ecological mapping: 1995 baseline study update). Drainages support willow (*Salix* spp.) and dwarf birch (*Betula glandulosa*) shrubs as tall as 3 m, and birch shrublands (<0.5 m in height) dominate the uplands. Shrubs such as blueberry (*Vaccinium uliginosum*), cranberry (*Vaccinium vitis-idaea*), and crowberry (*Empetrum nigrum*) are also common and their berries are important foods to grizzly bears (Gau et al. 2002). Ungulate prey include caribou (*Rangifer tarandus*) of the Bathurst herd, which migrate annually through the study area. Muskoxen (*Ovibos moschatus*) occur sporadically in the northern half of the study area.

### Animals and telemetry

We used a Bell 206B or Hughes 500 helicopter to search for and capture grizzly bears. A Piper SuperCub, Scout, or Aviat Husky aircraft was also used to search for animals. We captured most grizzly bears in spring (15 May – 5 June) by following tracks in snow (Case and Buckland 1998). We immobilized bears with an injection of tiletamine hydrochloride and zolazepam hydrochloride (Telazol®, Ayerst Laboratories Inc., Montréal, Quebec, Canada) delivered by a projected dart. We marked animals with uniquely numbered ear tags and permanent lip tattoos. Bears were weighed using a load-

cell scale (Norac Systems International Inc., Saskatoon, Saskatchewan, Canada) while suspended in a cargo net from a helicopter. Only bears weighing  $\geq 110$  kg (males) and  $\geq 90$  kg (females) were fitted with a radio prior to release.

We used satellite and VHF radiotelemetry (Telonics, Mesa, Arizona, U.S.A., and Service Argos Inc., Landover, Maryland, U.S.A.) to obtain demographic data on study animals. Satellite collars were equipped with a VHF beacon permitting relocations of radio-marked bears from an aircraft and, eventually, the retrieval of collars. Most collars were designed to transmit approximately 2–5 locations every 2 days (8-h duty cycle) from 1 May to 1 November. During other months, collars were programmed to transmit locations every 8 days to minimize loss of battery power.

### Survival

We calculated annual survival rates using only confirmed natural mortalities and known legal or illegal kills. We did not use data from bears for which monitoring could not be maintained between recaptures (i.e., through the loss of a radio ( $n = 1$ )), as this may lead to inflated estimates of survival rates because only surviving bears with whom contact was lost can be recaptured (White and Garrott 1990; Hovey and McLellan 1996).

We used Pollock et al.'s (1989) staggered-entry modification of Kaplan and Meier's (1958) survivorship model to estimate survival rates because of its broad basis in survival theory and widespread use among bear researchers (e.g., Amstrup and Durner 1995; Hovey and McLellan 1996). We determined cumulative survival rates at seasonal intervals as in Amstrup and Durner (1995) by determining the number of new radios applied, total number of radios at risk, total number of radios censored (including missing radios), and total number of deaths from tables of tracking histories. Pollock et al.'s (1989) model estimates a cumulative survival rate, variance, SE, and confidence interval (CI) for an entire period of study (here 11.5 years for adult females and 4.5 years for adult males). We converted estimates of survival rate for the duration of monitoring to a mean annual survival rate with 95% CI by taking the 11.5th and 4.5th roots of the total survival point and estimates of 95% confidence limits for adult females and adult males, respectively (Amstrup and Durner 1995).

The annual survival rates ( $S$ ) for cubs and yearlings were calculated as in Eberhardt et al. (1994) as 1 minus the division of cub deaths ( $D_c$ ) and number of cubs observed ( $R_c$ ):

$$[1] \quad S = 1 - D_c/R_c$$

We calculated SE and 95% CI as in Tr  nt and Rongstad (1974). By using this estimate we assumed that the disappearance of a cub (including yearlings) occurring at some time between one spring census and the next equated to the cub's death (Case and Buckland 1998). To avoid introducing bias, in our calculations of cub survival rate, we used only records of cubs of mothers that were radio-tracked for the entire year and into the next active season. Records of cubs whose mothers were tracked <1 year were ignored, regardless of whether the cubs died.

### Reproduction

We recorded reproductive histories of captured female grizzly bears in spring of each year by visually relocating animals from fixed-wing aircraft (e.g., presence or absence of accompanying young, ages of accompanying young). Litter size was determined from the number of cubs first observed with a female in spring or early summer. We defined the birth interval as the number of years between the births of cubs, including intervals shortened by whole-litter loss. The reproductive interval was the number of years between successful litters (i.e., those litters for which at least 1 cub survived to 2-year-old status). Natality was estimated by dividing mean litter size by mean birth interval, and represents the average number of cubs produced per female per year in the population. From reproductive histories we determined the mean age at first parturition. We also determined the mean age at first parturition leading to the successful rearing of at least 1 cub to 2 years of age.

### Population rate of increase

The finite rate of population increase ( $\lambda$ ) was estimated from reproductive rates and female survival rates obtained from confirmed natural plus confirmed human-caused mortality. We used an approximation of Lotka's equation proposed by Eberhardt (1985) and presented in Eberhardt et al. (1994):

$$[2] \quad \lambda^a - S_{\text{adult}}\lambda^{a-1} - l_a m [1 - (S_{\text{adult}}/\lambda)^{w-a+1}] = 0$$

where  $S_{\text{adult}}$  is the mean annual adult female survival rate,  $l_a$  is survival to mean age at first parturition ( $a$ ),  $w$  is the maximum age considered, and  $m$  is the number of female cubs per adult female per year (i.e., the natality rate multiplied by 0.5). The parameter  $w$  was fixed at 25 years. We solved for  $\lambda$  by iteration until the absolute value of [2] was <0.0001. We obtained 95% CI for  $\lambda$  (Eberhardt et al. 1994) by first generating random samples of  $S_{\text{adult}}$ ,  $l_a$ ,  $m$ , and  $a$  from distributions of survival and reproductive parameters. Sample rates were then used to calculate  $\lambda$ . The process was repeated 1000 times and the resulting frequency distribution of  $\lambda$  values was used to provide approximate 95% confidence limits by excluding 2.5% at each end of the distribution (Manly 1997).

## Results

### Captures of animals

From May 1988 to June 1999, 283 barren-ground grizzly bears were immobilized on 330 occasions. Of the 283 individuals, 106 were adult females and 53 were adult males. Among subadults (aged 3–4 years), 12 were females and 20 were males; 3 subadults of unknown sex were also captured. We identified 41 cubs (17 females, 14 males, 10 of unknown sex), 39 yearlings (9 females, 10 males, 20 of unknown sex), and 9 two-year-olds (3 females, 6 males). During the period 1988–1991, 15 VHF radio collars were placed on females in the Kugluktuk region of the study area (Fig. 1; Case and Buckland 1998). From 1995 to 1998, we placed 89 satellite radio collars on 81 bears (38 adult females, 4 subadult females, 35 males, 4 subadult males). For 23 of these bears

(mostly females), "break-away" VHF radio collars were attached after satellite radio collars were removed.

### Survival

Three adult females died of natural causes during 146 bear-years of observation (1988–1999), providing a survival rate of 0.979 (95% CI = 0.955–0.998). These females were all suspected to have been killed, or at least scavenged, by other grizzly bears. Mounds of torn-up vegetation, characteristic of grizzly bear caches, and bear scats containing bear fur and bones were found in the areas where the animals died. One female was found dead near her den, which had been excavated by another grizzly bear. In addition to natural mortalities, an adult female suffocated in a landslide during a capture operation in 1999. The survival rate including this capture-related death was 0.972 (95% CI = 0.946–0.993).

One adult male was suspected to have died a natural death (cause unknown) during 58 bear-years of observation (1995–1999): the natural survival rate was 0.986 (95% CI = 0.942–1.0). Two adult males are suspected to have died as a result of illegal harvest during the monitoring period. In both circumstances, satellite radio collars belonging to the bears were found in the field, opened with all nylon-coated fastening nuts removed. Both collars were in good condition. The survival rate including these suspected illegal harvests was 0.974 (95% CI = 0.914–1.0).

Small sample sizes precluded a meaningful analysis of subadult female survival rates. From 5 bear-years for which subadult females were monitored after being released from capture, one harvest mortality and one suspected illegal mortality (recovered collar with missing nylon-coated nuts, as above) were observed. No natural mortalities were observed.

Forty-two of 57 cubs (74%) survived to their next year, yielding a mean survival rate of 0.737 (95% CI = 0.600–0.844). This estimate does not include data for 2 cubs that were euthanized after their mother died during a capture operation. Twenty-eight of 51 yearlings (55%) survived to be observed with their mothers in the spring census of the year in which they were 2 years old. The mean yearling survival rate was 0.683 (95% CI = 0.514–0.821).

### Reproduction

We obtained data on the reproductive histories of 56 female grizzly bears of various ages (Table A1). The earliest age at which a female produced a cub was 5 years. This cub disappeared the following summer, however. Reproduction appeared to continue throughout life, although it may have diminished at older ages. The oldest female in the study produced a cub at age 26 and was observed with a yearling just prior to her death the next year. Although this female was reproductively active after age 22, she contributed little more to the population, as 2 litters were lost as cubs and her last cub likely had a low chance of survival on its own. Another female, however, produced a cub at age 22, weaned the cub successfully, and produced another cub at age 25, at which time her radio was removed. A third female also produced 2 cubs at age 22, of which only 1 survived to yearling status before her radio was removed at age 23.

Litter size observed in mid-May averaged 2.23 cubs (SE = 0.13,  $n = 35$ ). We observed 6 litters of 1 cub, 16 pairs of twins, 12 sets of triplets, and 1 litter of 4 cubs. Yearling lit-

ter size decreased to a mean of 1.86 (SE = 0.12,  $n = 35$ ). The mean litter size for females with 2-year-olds was 1.85 (SE = 0.15,  $n = 20$ ).

The mean birth interval was 2.8 years (SE = 0.3 years,  $n = 17$ ) and the mean reproductive interval was 3.9 years (SE = 0.4 years,  $n = 9$ ). The longest reproductive interval was 6.0 years. We calculated an annual natality rate of 0.81 cubs per adult female per year. The number of female cubs per adult female per year, to use as  $n$  in [2], was 0.405.

The mean age at first parturition ( $a$ ) was 8.1 years (SE = 0.5 years,  $n = 10$ ). The youngest age at first parturition was 5 years, indicating that successful mating took place as early as 4 years of age. The mean age at first parturition, where at least 1 cub in a litter was successfully raised to at least age 2, was 8.2 years (SE = 0.7 years,  $n = 5$ ).

### Population rate of increase

Because data on subadult female survival were sparse, to determine the survival rate to age at first reproduction ( $l_a$ ) for use in [2], we used the mean between yearling survival rates ( $S_{\text{yearling}} = 0.683$ ) and adult annual survival rates ( $S_{\text{adult}} = 0.979$ ) for ages 2–4 (i.e.,  $S_{\text{sub}} = 0.831$ ), and adult annual survival rates for ages 5–7. Our estimate of  $l_a$  (i.e.,  $S_{\text{cub}} \times S_{\text{yearling}} \times S_{\text{sub}}^3 \times S_{\text{adult}}^3$ ) was 0.271. From iterations of eq. 2 with reproduction and survival rates and CIs given above, we estimated the population's finite rate of increase,  $\lambda$ , as 1.033 (95% CI = 1.008–1.064).

### Discussion

Ferguson and McLoughlin (2000) concluded that in areas of high altitude (>1000 m) and high latitude (>65°N), populations of grizzly bears respond to extremes in environmental conditions with risk-spreading adaptations. For example, seasonality explains 43% of the variation in age at maturity for Arctic-interior populations of grizzly bears in North America (Ferguson and McLoughlin 2000). Populations in these extreme environments are limited by resources; hence, life-history responses should limit reproductive effort. Reproductive females allocate resources to offspring that reduce the risk of cub mortality. If females allocate their resources sequentially in reproductive bouts, they should allocate them to a safer, less productive option in risky environments of extreme variability. The Arctic is characterized by less predictable year-to-year variation and greater interannual (i.e., seasonal) variation (Ferguson and Messier 1996; McLoughlin et al. 2000). Changes in the timing of reproduction in life history, such as a greater age at maturity, a longer interbirth interval, greater longevity (Cohen 1970; Philippi and Seger 1989; Sajah and Perrin 1990), and reduced offspring size and number (McGinley et al. 1987), minimize the effects of a stochastic environment so the geometric fitness is greater (Yoshimura and Jansen 1996).

The grizzly bear population in Canada's central Arctic is near the northern- and eastern-most extent of grizzly bear range in North America. The population is characterized by relatively low density and living in an area of low productivity and high seasonality (Ferguson and McLoughlin 2000; McLoughlin et al. 2000). We anticipated low reproduction resulting from delayed age at first parturition, longer birth and reproductive intervals, and smaller litter size.

As expected, age at first parturition was late compared with that of other grizzly bear populations (Case and Buckland 1998; Ferguson and McLoughlin 2000); however, birth and reproductive intervals were shorter than for most northern populations, and similar to intervals of southern interior populations. Further, litter sizes of this study were among the largest recorded for grizzly bears in Canada and Alaska (Case and Buckland 1998). Natality, which reflects both litter size and birth interval, indicated that cub production in the central Arctic was higher than in most other grizzly bear populations, including southern populations (Case and Buckland 1998). These data suggest that factors other than adaptations to low primary productivity and high seasonality are governing the life history of grizzly bears in Canada's central Arctic.

Although it is not reflected by the relatively high survival rates obtained for adult males, there has been a strongly male-biased harvest (approximately 13.4 bears per year, of which ~30% are females) in the study area for over 40 years (McLoughlin and Messier 2001). As a result, it is possible that male density in the study area is substantially lower than female density. Female reproduction may be enhanced by reduced numbers of males because of reduced risks from intraspecific predation (Miller 1990; McLellan 1994), unless the killing of adult males invites immigration of predatory subadult males (Wielgus and Bunnell 2000). Reduced intraspecific predation may directly affect life history through changes to mortality schedules. Where resources are scarce or unpredictable (i.e., the central Arctic), lower rates of intraspecific predation may indirectly influence life history by allowing females with cubs to exploit higher quality habitats from which they were once excluded by predatory males. Here, life-history traits such as adult female size, offspring size, litter size, and reproductive interval may be affected. Body mass of adult females (mean = 126 kg,  $n = 60$ ; from Ferguson and McLoughlin 2000) in the central Arctic averages 10–20 kg more than that in adjacent barren-ground grizzly bear populations (Ferguson and McLoughlin 2000). An increase in body size may account for the larger litters observed in this study, and potentially plays a role in shortening reproductive intervals by resulting in larger offspring at birth and (or) increasing milk production.

We believe the population of grizzly bears in the study area to be stable or slightly increasing ( $\lambda = 1.033$ ); however, there is uncertainty about this estimate because of our inability to adequately estimate all required parameters. Our estimated subadult survival rate (0.831), which is the mean between yearling and adult female survival rates (excluding capture mortality) for ages 2–4, has the greatest potential for error. Nonetheless, we believe this figure to be conservative: the rate is at the low end of the range of subadult female survival rates reported by Wielgus (2002) for grizzly bear populations in the Rocky Mountains (mean = 0.868, SD = 0.054).

Although we note stability in the population under study, we caution that there is a definite risk of future population decline if annual harvest rates are increased from historic levels. Modelling studies using data presented here show that by only slightly increasing historic rates of harvest from a mean of 13.4 bears per year precipitates a negative population trajectory (McLoughlin and Messier 2001). Unreported illegal mortality may already be contributing to a higher risk

of population decline. In this study, we retrieved from the field three discarded satellite radio collars, all in excellent condition but opened, with all fastening nuts removed. On no other occasions did we find collars with any fastening nuts loose or missing, even those that had suffered considerable abuse. We suspect that the bears which wore these collars were illegally harvested. We consider the population to be vulnerable to population decline, especially in the context of increasing human activity (diamond mining, outfitting) in the study area.

## Acknowledgements

Numerous private-sector and government sponsors have contributed to the barren-ground grizzly bear research program, including the West Kitikmeot/Slave Study Society, BHP Diamonds Inc., BHP Minerals, Diavik Diamond Mines Inc., the Government of the Northwest Territories, the University of Saskatchewan, RESCAN Environmental Services Ltd., Axyx Environmental Consulting Ltd., the Nunavut Wildlife Management Board, the Federal Department of Indian Affairs and Northern Development, the Polar Continental Shelf Project, the Northwest Territories Centre for Remote Sensing, Echo Bay Mines Ltd., Air Tindi Ltd., First Air Ltd., Big River Air Ltd., Canadian Helicopters Ltd., Nunasi Helicopters, Helicopter Wildlife Management Ltd., the Northern Scientific Training Program, and the Natural Sciences and Engineering Research Council of Canada.

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## Appendix A

Table A1. Reproductive histories of female grizzly bears (*Ursus arctos*) followed by satellite and VHF radiotelemetry determined in spring and early summer from 1988 to 1999, showing reproductive status in spring of the observation year, with notes on cub survival to the next spring.

Bear ID No.	Year captured	Age at capture (years)	Reproductive status in spring of observation year, with notes on cub survival to next spring									
			1	2	3	4	5	6	7	8	9	10
G501	1988	6	NC	NC	2 cubs	2 yearlings	2 2-year-olds	1 cub <sup>a</sup>	2 cubs	2 yearlings		
G502	1988	22	NC	NC	1 cub <sup>a</sup>	1 cub <sup>b</sup>	NO	1 yearling <sup>c</sup>	Died			
G505	1988	7	NC	NC	NC	3 cubs	3 yearlings	3 2-year-olds	NC	NC	NO	3 cubs
G507	1988	4	NC	Killed								
G511	1989	8	NC	3 cubs <sup>a,d</sup>	1 yearling	1 2-year-old	4 cubs <sup>a</sup>	3 yearlings	3 2-year-olds			
G514	1989	9	1 yearling <sup>e</sup>	2 cubs	2 yearlings <sup>f</sup>	1 2-year-old	1 3-year-old	3 cubs	3 yearlings	NO		
G517	1989	6	NC	NC	NC	2 cubs	2 yearlings <sup>d,f</sup>	NC	NC			
G522	1990	14	2 yearlings	2 2-year-olds								
G524	1990	10	2 yearlings <sup>a,f</sup>	NC	2 cubs	2 yearlings	2 2-year-olds	NC	NO			
G529	1990	13	NC									
G534	1990	6	NC	NC	3 cubs	3 yearlings <sup>f</sup>	2 2-year-olds	NC	NO			
G535	1990	15	NC	2 cubs	2 yearlings	2 2-year-olds	Died					
G541	1991	6	NC	NC	2 cub <sup>a</sup>	1 yearling <sup>f</sup>	NC	NO	2 yearlings			
G543	1991	16	2 cubs <sup>a</sup>	1 yearling <sup>f</sup>	NC	2 cubs	2 yearlings	NO	2 yearlings			
G549	1991	13	3 cubs	3 yearlings <sup>f</sup>	2 2-year-olds	3 cubs	3 yearlings	NO	2 yearlings			
G591	1995	3	NC									
G592	1995	5	1 cub	1 yearling <sup>e</sup>	NO	NO	NO	NC				
G597	1995	11	1 2-year-old	NC								
G601	1995	19	3 cubs <sup>a</sup>	2 yearlings								
G602	1995	10	1 yearling									
G604	1995	6	NC	NC								
G605	1995	10	3 2-year-olds	NC								
G606	1995	5	NC	NC								
G608	2000	5	NC									
G611	1995	5	NC	Capture mortality								
G614	1995	4	NC	NC								
G627	1995	5	NC									
G634	1996	16	NC									
G638	1996	10	NC	2 cubs <sup>a,d</sup>	NC	3 cubs						
G639	1996	11	2 2-year-olds	NC	NC	2 cubs						
G640	1996	14	1 yearling	1 2-year-old	1 3-year-old	3 cubs						
G641	1996	7	NC									
G642	1996	6	NC	NC	NC	NC						
G643	1996	7	NC	NC	NC	3 cubs						
G646	1996	22	1 cub	1 yearling	1 2-year-old	1 cub						
G648	1996	6	NC	NC								
G649	1996	8	1 2-year-old	NC								

G650	1996	19	3 cubs	3 yearlings	2 3-year-olds	2 cubs
G652	1996	14	2 yearlings	2 2-year-olds	NC	NC
G660	1996	2	NC	NC	NC	NC
G663	1997	19	NC	NC	NC	NC
G681	1997	9	NC	NC	NO	1 yearling
G683	1997	6	NC	2 cubs <sup>a</sup>	2 cubs <sup>a</sup>	1 yearling
G684	1997	21	NC	NC	NC	1 yearling
G685	1997	3	NC	NC	NC	1 yearling
G686	1997	16	2 cubs <sup>a</sup>	1 yearling	NC	NC
G695	1998	7	NC	NC	NC	NC
G699	1998	10	NC	NC	NC	NC
G701	1998	25	NC	NC	NC	NC
G702	1998	16	2 yearlings	2 2-year-olds	NC	NC
G705	1998	4	NC	NC	NC	NC
G707	1998	9	1 yearling	1 yearling	NC	NC
G721	1998	7	2 yearlings	2 2-year-olds	NC	NC
G724	1998	2	NC	Suspected mortality	2 cubs <sup>g</sup>	2 cubs <sup>g</sup>
G726	1998	11	NC	NC	Capture mortality	Capture mortality
G731	1998	9	NC	NC	2 cubs	2 cubs
G746	1999	Unknown	2 2-year-olds	2 2-year-olds	NC	NC
G755	2000	Unknown	2 yearlings <sup>d,e</sup>	2 yearlings <sup>d,e</sup>	NC	NC

Note: NC, no cubs present; NO, not observed.

<sup>a</sup>Cub went missing during the year and was presumed dead.

<sup>b</sup>Cub must have died for the bear to give birth to another cub the following spring. Bear was observed last with a cub and accompanying adult bear (male?).

<sup>c</sup>Death of mother told us of death of yearling.

<sup>d</sup>At least 2 cubs in litter were lost.

<sup>e</sup>Yearling went missing during the year and was presumed dead.

<sup>f</sup>Death of yearling if we assume that they are dead if not found during spring census with mother when they are 2 years old.

<sup>g</sup>Cubs were euthanized as a result of capture mortality of G726.

**POPULATION VIABILITY OF BARREN-GROUND GRIZZLY BEARS IN  
NUNAVUT AND THE NORTHWEST TERRITORIES**

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**Abstract:** We modelled probabilities of population decline as a function of annual kill for a population of barren-ground grizzly bears (*Ursus arctos*) inhabiting Nunavut and the Northwest Territories, Canada. Our results suggest the population is at risk of decline, especially if annual removal rates increase from the 42-year mean of 13.4 bears/year. Adding six bears to the mean annual kill results in >40% chance of a decrease in population size by one-quarter over the next 50 years, compared to a 10% chance with the current level of human-caused mortality.

Additional mortalities may result from increased problem activity at mine sites or hunt and exploration camps, given recent increases in human activity in the region, and may already be present as unreported mortality. We believe any increase in current harvest quotas would considerably impact conservation prospects for the population.

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**Key words:** Arctic, demography, grizzly bear, harvest, Northwest Territories, Nunavut,, population viability, PVA, *Ursus arctos*.

The life history traits of grizzly bears (*Ursus arctos*) generally preclude populations from being resilient when threatened by human disturbance. Late age at maturity, small litter sizes, and long interbirth intervals maintain low intrinsic rates of increase for the species. Because of this, all grizzly bear populations in Canada are considered to be of 'special concern' to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC. 2000. List of species at risk. Canadian Wildlife Service, Ottawa, Ontario, Canada). However, grizzly bears show great diversity in life history strategy (Ferguson and McLoughlin, 2000), and we can predict that not all populations of grizzly bears will be equally resilient (or susceptible) to anthropogenic disturbances.

Barren-ground grizzly bears inhabiting Canada's central Arctic (Fig. 1) may be at particular risk to population decline because they are located near the northern- and easternmost extent of grizzly bear range in North America, and the population is characterized by relatively low density and small bears that live in areas of low productivity and high seasonality (Ferguson and McLoughlin, 2000; McLoughlin et al., 2000). Consequently, we can expect generally low reproduction, relative to other grizzly bear populations, resulting from delayed age at first parturition, longer birth and reproductive intervals, and smaller litter sizes. Of all grizzly bear populations, direct mortality associated with human activity may be most pronounced in the viability of barren-ground grizzly bear populations.

In 1995, to address concerns about the potential effects of increasing human activity on barren-ground grizzly bears inhabiting Canada's central Arctic, the Government of the Northwest Territories and the University of Saskatchewan initiated a multi-faceted research program into the ecology of barren-ground grizzly bears (e.g., Gau, 1998; McLoughlin, 2000; McLoughlin, et al. 1999, 2002). As part of this program, we described the demography of grizzly bears in the region (McLoughlin and Messier, 2001). Here we model population viability of barren-ground grizzly bears in Nunavut and the Northwest Territories.

## **METHODS**

### **Study Area**

The study area was located in Canada's central Arctic, encompassing approximately 235,000 km<sup>2</sup> of Low Arctic tundra in mainland Nunavut and the Northwest Territories (Fig. 1). McLoughlin et al. (2002) provides a detailed description of the landscape typical of grizzly bear range in the Low Arctic.

### **Animals and Vital Rates**

From May 1988 to June 1999, 283 barren-ground grizzly bears were immobilized by capture crews on at least 330 occasions for the purpose of obtaining information on vital rates of the population. Reproductive histories of grizzly bears were determined by visual relocations of radio-collared animals in spring of each year; survival was determined by monitoring activity sensors on collars and via annual visual relocations (McLoughlin and Messier, 2001). For the period 1988–1991, 15 females were monitored in the Kugluktuk region of the study area (Case and Buckland, 1998). From 1995 to 1998, 81 bears ( $n = 38$  adult females,  $n = 4$  subadult females,  $n = 35$  males,  $n = 4$  subadult males) were monitored throughout the whole of the study area, including the Kugluktuk region, for which interchange of individuals with the central and eastern portions of the study area was high (McLoughlin, 2000). Vital rates presented in McLoughlin and Messier (2001) form the basis of analyses presented herein (survival rates and reproductive data).

### **Modeling Population Viability**

Population viability analysis uses measures of vital rates for populations and effects of demographic and environmental stochasticity on population growth to evaluate probabilities of population persistence for a specified period of time (Boyce, 1992). The usual approach for estimating persistence is to develop a probability distribution for the number of years before population models for a species 'go extinct', or fall below a specified threshold. The percentage of area under this distribution where the population persists beyond a specified time period is equated to persistence. For a review of PVA, including its merits and shortfalls, we refer the reader to White (2000).

Here we use A WINDOWS© compatible program named RISKMAN (see, e.g., Eastridge and Clark, 2001) to model population viability for grizzly bears in the central Canadian Arctic. The model is available freely from M. K. Taylor upon written request. RISKMAN differs from other simulation models in several ways. First, it provides an option to accurately model the population dynamics of species with multi-year reproduction schedules, such as grizzly bears (Taylor et al., 1987). Second, RISKMAN allows sex and age specific harvests to occur that take into account differential sex and age class vulnerability to harvest and differential hunter sex and age class selectivity. Third, the program provides a stochastic option that uses the variance of input parameters and the structure identified by the simulation options that are selected. Monte Carlo techniques are used to generate a distribution of results, and RISKMAN uses this distribution to estimate the variance of summary parameters (e.g., population size at a future time, population growth rate, and proportion of runs that result in a population decline set at a pre-determined level by the user). The model incorporates individual heterogeneity by relying on a life table approach (Caughley, 1977), rather than a Leslie matrix (Leslie, 1945) to model population dynamics. Individuals simultaneously survive and reproduce with the Leslie matrix



approach, whereas the life table approach has the females survive first, then they reproduce (Taylor and Carley, 1988). Having females survive first enables heterogeneity in female survival to influence reproduction for any given year, which may be important for accuracy in models of population viability (White, 2000).

### **Model Input**

Input required to run our PVA was obtained from calculations and tables presented in McLoughlin and Messier (2001), and are reproduced here in Table 1. We calculated the proportion of females with new litters having one, two, or three cubs-of-the-year in their litters to be 0.17, 0.46, and 0.37, respectively. The mean proportion of females that were available for mating in the previous year (i.e., possessed no cubs, or cubs that were at least two-years-old), and then gave birth to a litter, was 0.20 (SE = 0.11) for females aged 5–7, and 0.60 (SE = 0.08) for females  $\geq 8$  years. In our simulations we used a minimum age of reproduction of five years, and a maximum of 25 years. Maximum age was set at 30 years.

Finite rate of population increase is not a required input by RISKMAN as it is calculated by the program itself. Although there are provisions to model density-dependent effects in RISKMAN, we had no data to model such effects here (McLellan, 1994; Boyce, 1995; Mills et al., 1996; Wielgus, 2002).

The mean removal rate of bears inhabiting the study area was calculated as 13.4 bears/year, and reflects kills that are for sport, subsistence, and the protection of life and property. Estimates of unknown, illegal kills are not included in this estimate. We assume here that harvest in each year will be composed of the relative sex/age strata depicted in McLoughlin and Messier (2001) and Government of the Northwest Territories harvest records, 1958–2000 (data on file).

We used an initial population estimate of 800 bears, which was an extrapolation from counts of uniquely identified (tagged and untagged) bears observed for the central portion of the study area (McLoughlin and Messier, 2001). We ran simulations using SE of population size of 300, 200, and 150 to reflect our uncertainty about this mean, and to appreciate the sensitivity of our model outcomes to sampling error in initial population size.

We were unable to separate environmental stochastic effects in vital rates from measurement errors for all rates as annual variability in rates for cubs-of-the-year, yearlings and subadults was unavailable. This likely had the effect of generating conservative probabilities of persistence (White, 2000; M. Boyce, University of Alberta, *personal communication*). Effects of catastrophes were not incorporated into models (Ewans et al., 1987), nor were potentially detrimental effects of inbreeding (Lacy, 1993; Lindenmayer et al., 1995). We assumed annual random deviates of parameter values were independent for lack of data on temporal variability, although it is possible and perhaps likely parameters were correlated (White, 2000).

## Models

We ran RISKMAN models to evaluate the potential risk from harvest to generate a decline in the grizzly bear population. We estimated the probability of the grizzly bear population declining by 25%, 50%, and 75% of the current population size over a specified time interval of 50 years from present. To examine the risks of increasing current harvest, or to account for possible risks of unreported illegal harvest, we ran simulations with the mean annual harvest rate increased by six bears annually. This higher harvest level reflects recent requests by communities in the study area to increase the annual sport hunt of grizzly bears from 10 to 16 animals. To account for uncertainty in our survival data, we ran simulations that decreased estimates of rate of increase by including bears that went missing during our monitoring program as unconfirmed mortalities.

RISKMAN is designed to provide Monte Carlo estimates of the uncertainty of simulation results using the variance of input parameters. Our rationale for model structure and approach to variance is summarized in Taylor et al. (2001). We ran 2,800 stochastic simulations for each year of a simulation to provide a distribution of model outcomes (i.e., population numbers at survey time) from which risks of population declines were estimated.

## RESULTS

The number of simulation runs leading to set thresholds of population decline was sensitive to SE of initial population size (Figs. 2–4). However, we believed SE = 200 to best describe the SE associated with our estimate of population size (Fig. 3). Translated into a 95% confidence interval, a SE of 200 would result in an interval of approximately 400–1200 about our initial population size of 800 bears.

Using the highest estimates available for natural survival rates and a population SE = 200, we estimated the probabilities of the initial population declining by 25%, 50%, and 75% over the next 50 years were 0.10, 0.07, and 0.05, respectively (Fig. 3). These results were based upon past harvest records detailing the selectivity/vulnerability of different age strata, and a mean of 13.4 bears removed from the population each year due to sport and subsistence hunting, and those kills associated with defence of life or property. These results can be regarded as the ‘best case’ and also most likely scenario, given our current understanding of grizzly bears in the region.

Increasing the kill by six bears annually from 13.4 bears/year dramatically increased risks of population decline. With a mean of 19.4 bears/year being removed from the population we estimated that the probabilities of the current population declining by 25%, 50%, and 75% over the next 50 years would be 0.42, 0.32, and 0.18, respectively (Fig. 5).

By including missing bears for which no collar was recovered in McLoughlin and Messier (2001) as unconfirmed natural mortalities in the simulations, and retaining a mean of 13.4 bears/year removed from the population due to harvest, we estimated that the probabilities of the current population declining by 25%, 50%, and 75% over the next 50 years were 0.99, 0.99, and 0.98, respectively (Fig. 6). We caution that this situation is likely underestimating natural survival, but we have included it here for completeness. Six of seven missing adults disappeared two years after their initial capture and beyond the lifespan of their satellite radio-collars, likely impeding our ability to include them in the spring, 1997 census (McLoughlin and Messier, 2001).

## DISCUSSION

Although we believe the population to be currently stable or slightly increasing ( $\lambda = 1.033$ , 95% C.I. 1.008–1.064; McLoughlin and Messier 2001), our results suggest that the population is at risk of decline, especially if the annual kill is increased from the mean of 13.4 bears/year. Even if we ignore missing radios in our study as possible deaths, our risk analyses suggest that the population of grizzly bears in the central Arctic has the potential to decrease substantially within our lifetimes. By adding only six animals to the mean removal rate, there is greater than a 40% chance of a decrease in population size by one-quarter over the next 50 years, up from a 10% chance with current estimates of kill rate. These six bears could easily come from increased problem activity at mine sites or hunting and exploration camps, and may already be present as unreported mortality. In this study we retrieved from the field three discarded satellite radio-collars, all in excellent condition but opened with all fastening nuts removed. On no other occasions did we find collars with any fastening nuts loose or missing, even those that suffered considerable abuse. We suspect the bears that wore these collars were illegally harvested;

however, these harvests were not included in the harvest records used in our RISKMAN analyses (harvest records from 1958–2000 include only two illegal harvests; data on file).

We consider grizzly bears in the central Arctic to be in danger of experiencing sustained negative population growth, especially in the context of increasing human activity in the study area. Industrial development in the region is proceeding at a rapid pace, primarily due to the recent discovery of diamond-bearing kimberlite pipes in the region. Coinciding with increased industrial development, the prevalence of hunting camps in the region is increasing. Some outfitters in the study area are becoming increasingly vocal about raising the current quota for the sport harvest of grizzly bears.

We believe any increase in current harvest quotas would considerably impact the population. Mortality of females (and especially females with cubs) must be minimized from all sources of harvest. Removal rates used in our risk assessments are based upon past patterns of harvest; thus, selectivity/vulnerability rates used in our analyses assume that removed bears from the population will primarily be subadults or adult males. If females with cubs contribute more to the reported harvest than in the past (i.e., as problem kills at mine sites or camps), risks of population decline will increase.

To refine our models, uncertainty in our input parameters would need to be decreased, especially regarding subadult survival (of which  $\lambda$  may be quite sensitive; Hovey and McLellan 1996) and population size (of which model results were sensitive to SE). Both subadult survival and population size, however, are difficult and costly to estimate. Estimating subadult survival would require a tracking study of two- and three-year old bears captured prior to their dispersal from their mother. Subadult bears in the central Arctic travel over extremely large distances ( $>20,000 \text{ km}^2$ ; McLoughlin, 2000), and would need to be tracked using expensive satellite radio-

collars. Most two- and three-year old bears, however, are probably too small and grow too rapidly to be collared safely.

Estimating population size would be even more costly, and would likely involve a lengthy mark-recapture program. Although expensive, an estimate of population size using mark-recapture methods would provide not only an objective and more precise estimate of the number of bears in the central Arctic, but also the means for obtaining new estimates of survival and population rate of increase (i.e., by using the Cormack-Jolly-Seber method; Krebs 1989). Comparing rates of increase with those contained in this study and McLoughlin and Messier (2001) would provide an excellent opportunity to identify the direction of growth for the population. For this reason, perhaps it would be wise to delay estimating population size using mark-recapture methods for some time in the future (e.g., 5–10 years). This would permit enough time to lapse between studies to better gauge the effects of current management practices on maintaining the population's rate of increase.

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## TABLES

Table 1. Natural survival rates ( $\bar{X}$ , SE) calculated using methods of Trent and Rongstad (1974) and used to develop population models in RISKMAN (originally presented in Messier and McLoughlin, 2001). Parameters include survival of cubs ( $S_c$ ), yearlings ( $S_y$ ), subadult females ( $S_{sf}$ ), subadult males ( $S_{sm}$ ), adult females ( $S_{af}$ ), and adult males ( $S_{am}$ ). Rates are presented for confirmed mortalities only and when missing radios (i.e., unconfirmed mortalities,  $n = 7$ ) are incorporated into survival estimates.

	Confirmed mortalities		Unconfirmed mortalities	
	only		included	
	Mean	SE	Mean	SE
$S_c$	0.737	0.060	0.737	0.060
$S_y$	0.683	0.074	0.683	0.074
$S_{sf}$	0.831	0.148	0.814	0.131
$S_{sm}$	0.833	0.150	0.816	0.133
$S_{af}$	0.979	0.012	0.945	0.019
$S_{am}$	0.983	0.017	0.948	0.029

**FIGURE CAPTIONS**

Fig. 1. Bounds of the study area (shaded region) in Canada's central Arctic. The treeline indicates the northernmost extent of coniferous forest in the study area.

Fig. 2. The cumulative proportion of RISKMAN population simulation runs having reached reductions of 25%, 50%, and 75% from initial population size as a function of time (future projection). RISKMAN population simulations were performed using the highest survival rates available and an annual removal rate of 13.4 bears/year. Initial population size of 800 bears was estimated with a SE = 300.

Fig. 3. The cumulative proportion of RISKMAN population simulation runs having reached reductions of 25%, 50%, and 75% from initial population size as a function of time (future projection). RISKMAN population simulations were performed using the highest survival rates available and an annual removal rate of 13.4 bears/year. Initial population size of 800 bears was estimated with a SE = 200.

Fig. 4. The cumulative proportion of RISKMAN population simulation runs having reached reductions of 25%, 50%, and 75% from initial population size as a function of time (future projection). RISKMAN population simulations were performed using the highest survival rates available and an annual removal rate of 13.4 bears/year. Initial population size of 800 bears was estimated with a SE = 150.

Fig. 5. Increasing mean harvest rates from 13.4 bears/year to 19.4 bears/year dramatically increases the risks of population decline. We show the cumulative proportion of RISKMAN population simulation runs having reached reductions of 25%, 50%, and 75% from initial population size as a function of time (future projection). RISKMAN population simulations were conducted using the highest survival rates available, as in Fig. 3. Initial population size of 800 bears was estimated with a  $SE = 200$ .

Fig. 6. RISKMAN projection simulations with a mean of 13.4 bears/year removed from the population due to harvest (as in Fig. 3), but we included missing bears for which no collar was recovered as unconfirmed mortalities in the simulations ( $n = 7$ ). Presented are the cumulative proportion of RISKMAN population simulation runs having reached reductions of 25%, 50%, and 75% from initial population size as a function of time (future projection). Initial population size of 800 bears was estimated with a  $SE = 200$ .

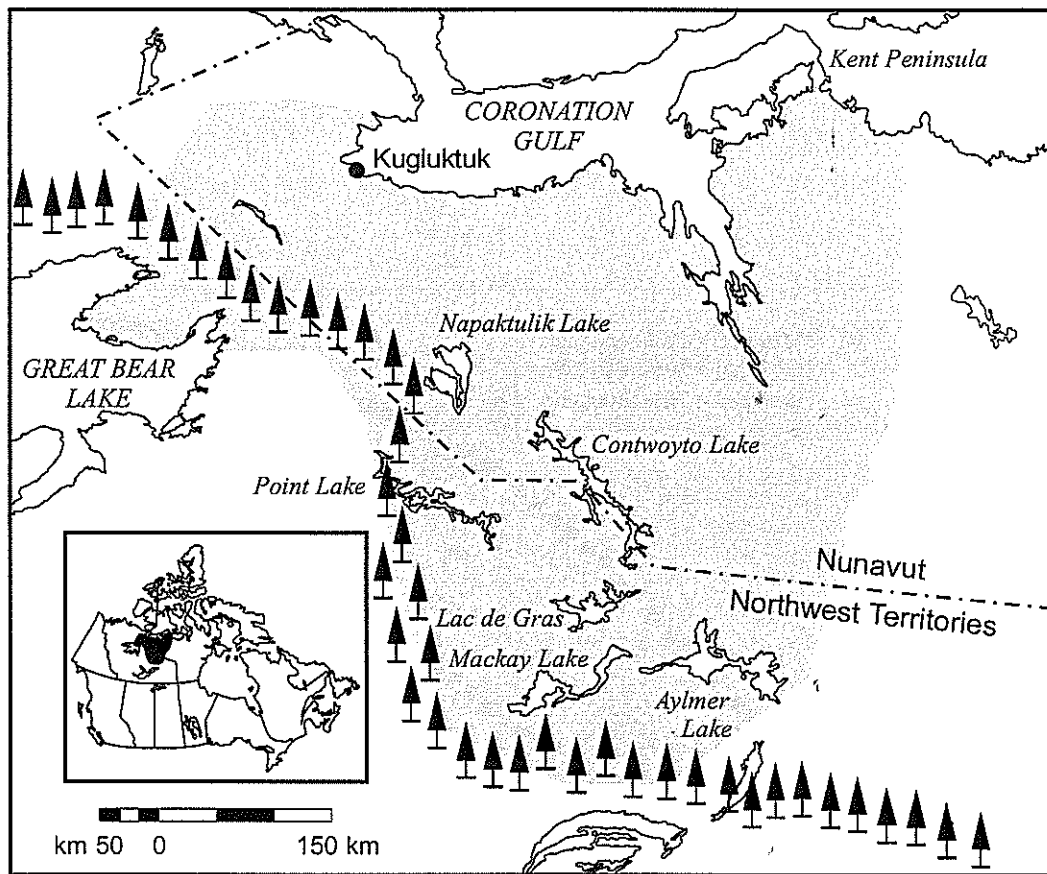


Fig. 1

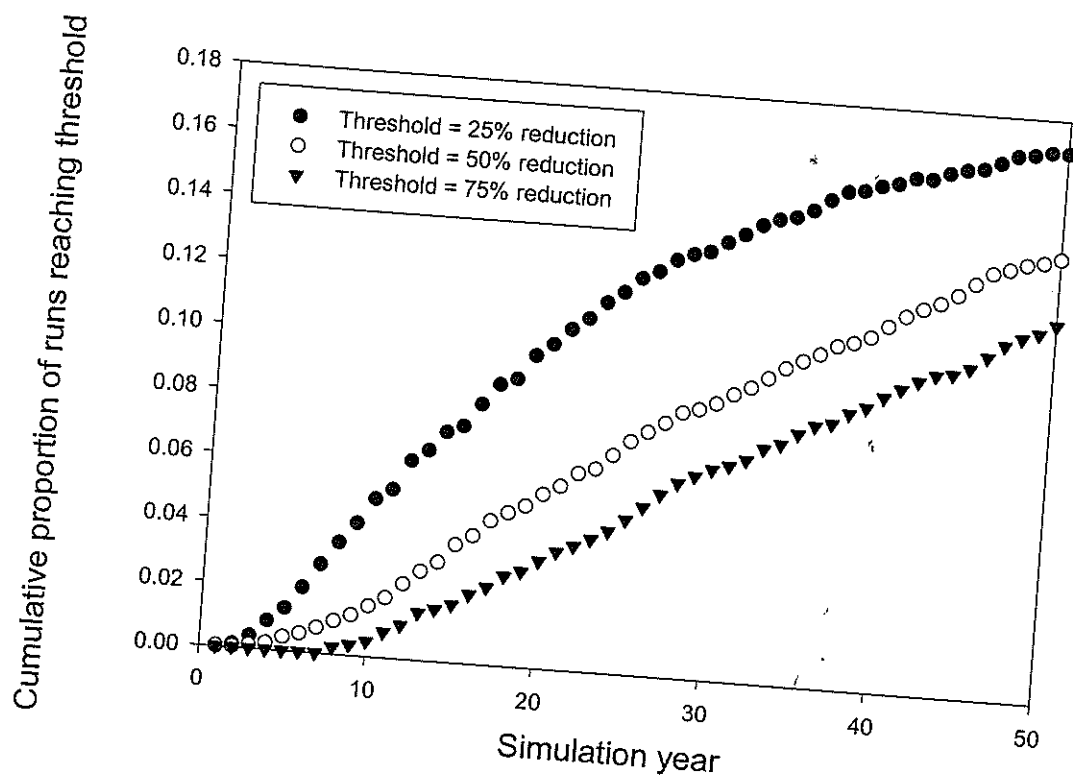


Fig. 2.

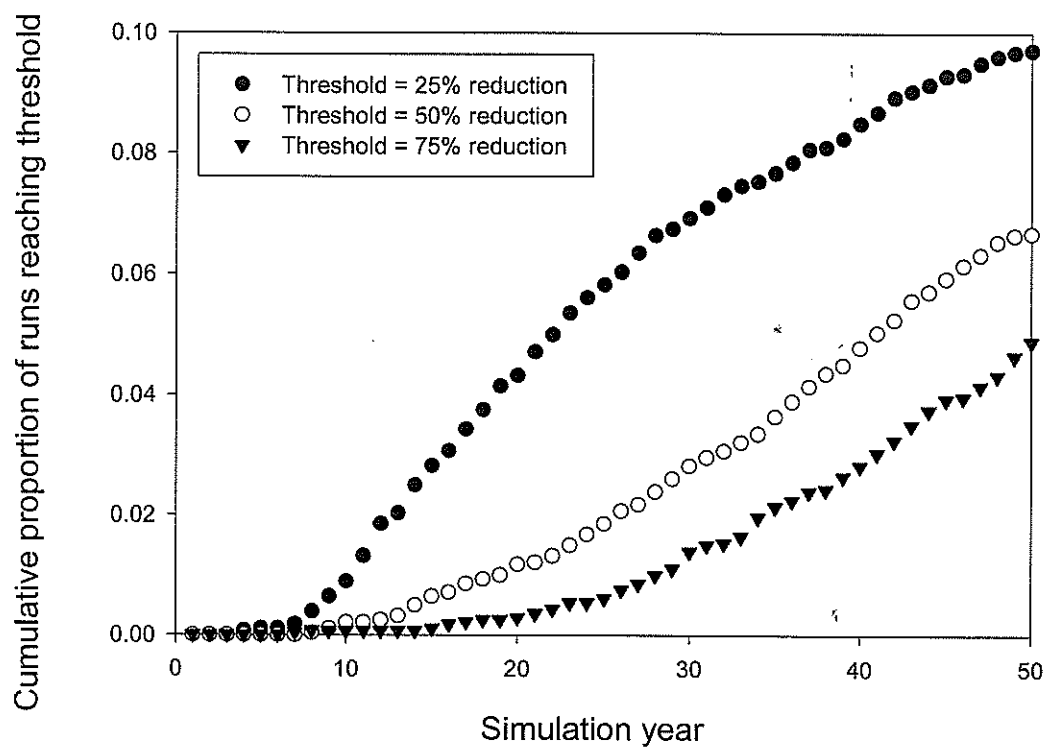


Fig. 3.



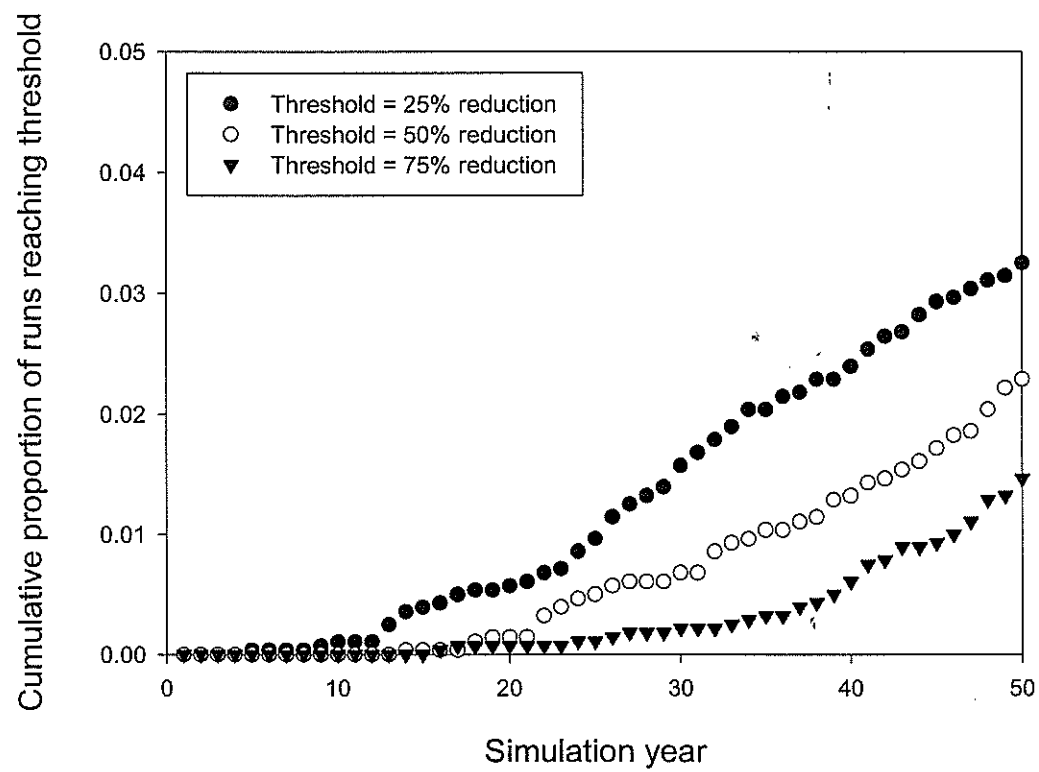


Fig. 4.

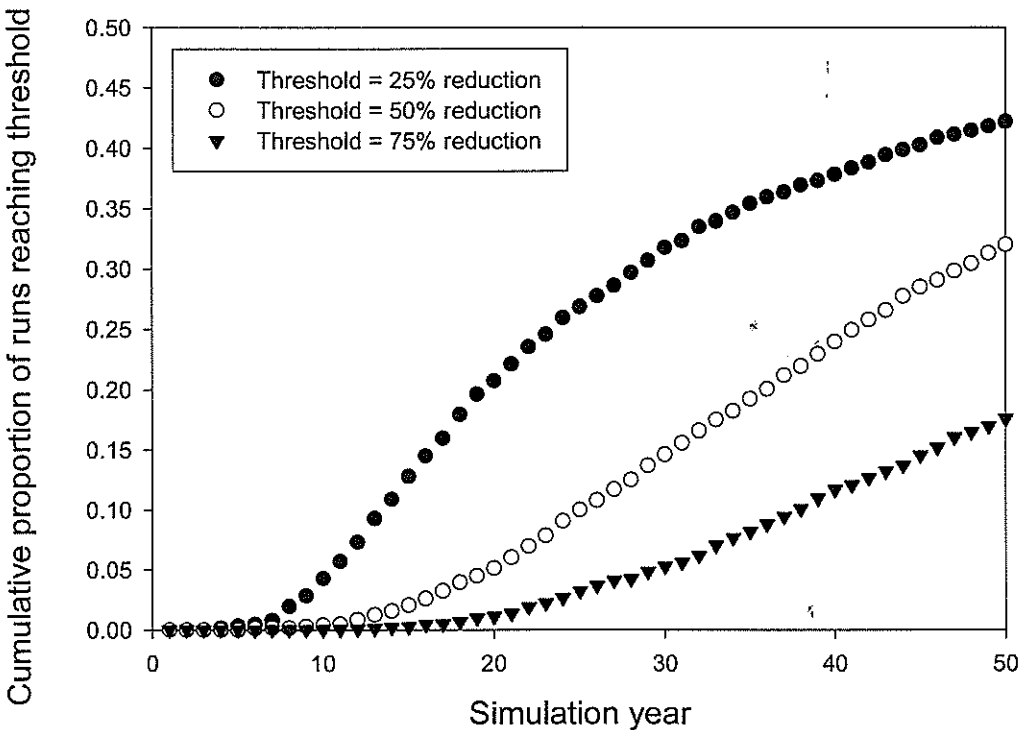


Fig. 5.

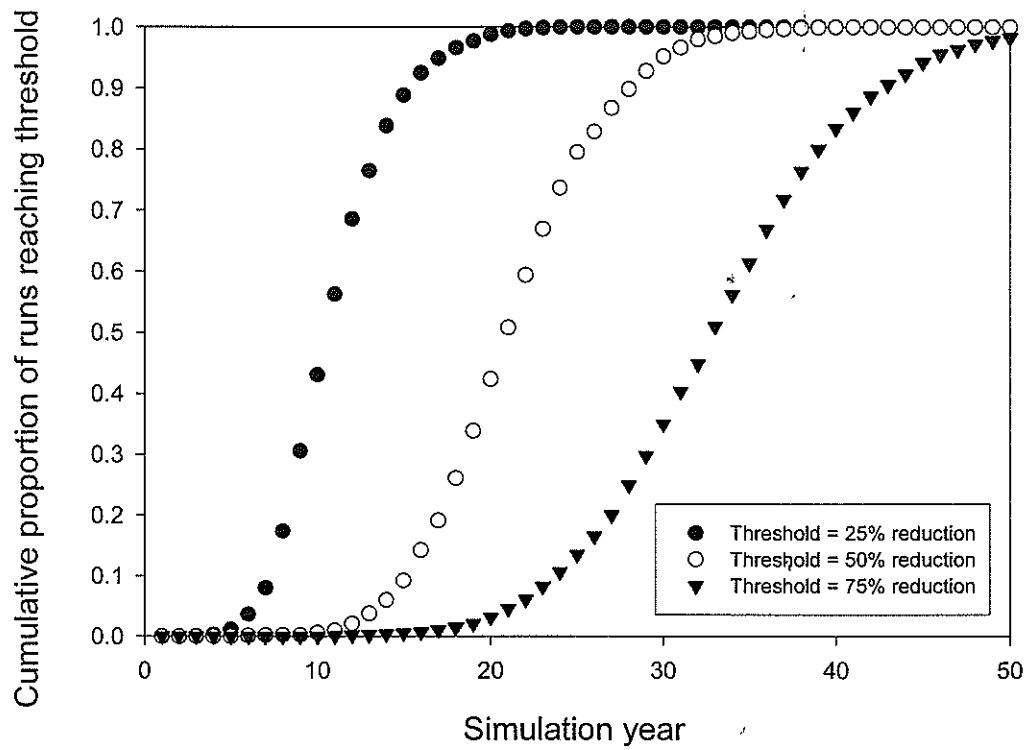


Fig. 6.