Using reproductive data to model American black bear cub orphaning in Manitoba due to spring harvest of females

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Abstract: Animal rights groups have lobbied for the cancellation of Manitoba's spring hunting season for American black bear (*Ursus americanus*), contending that hundreds of cubs are orphaned each year. We developed a mathematical model to estimate the number of black bear cubs that may be orphaned in Manitoba because of the spring hunting season. The model used information from annual questionnaires mailed to resident hunters, Outfitter Declaration Forms from operators who provide services to non-resident clients, and analysis of reproductive tracts (>200 for both spring and fall seasons) and tooth samples (>1,100). To accurately reflect the number of cubs orphaned each spring, the model accounted for cub losses (both litter reduction and total litter loss) prior to a female being harvested using values from the literature. Although the data was not used in the model, evidence from the examination of reproductive tracts suggests that total litter loss of hunter killed bears can be determined by examining the condition of the uterus and ovaries. The model estimated that on average, 41 cubs were orphaned for each of the spring seasons between 1996 and 2000. This number represents <2% of the estimated number of cubs that may die annually in Manitoba from natural causes.

Key words: American black bear, cub mortality, cub orphaning, lactation, litter loss, Manitoba, model, reproduction, spring hunt, *Ursus americanus*

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Some animal rights groups have called for the cancellation of the spring bear hunting season in Manitoba (Bray 1999). They contend that in the spring, female bears accompanied by cubs of the year are vulnerable to harvest by hunters. They also claimed that orphaned cubs of harvested females all die from starvation. Manitoba Wildlife and Ecosystem Protection Branch's (MWEPB) position is that the spring hunting season is a valuable wildlife management tool that helps regulate the bear population in advance of the problem bear season in July–September. Manitoba has taken several steps to reduce the likelihood of hunters harvesting female black bears with cubs, including enacting legislation prohibiting hunters from harvesting female bears with cubs of the year, allowing the use of bait to enable hunters to observe their target and verify that it is not a female with cubs, distributing hunting pressure by allocating non-resident hunting opportunities to specific areas within game management areas, and providing a variety of information and education materials that encourage hunters to carefully examine each bear before harvesting it. Outfitters, who are authorized to outfit non-resident (non-Canadian) bear hunters, have also instituted measures to reduce the harvest of females with cubs including instructional sessions to help clients distinguish females from males, a no-shooting policy for the first 2 days of a week-long hunting package to enable a hunter to observe which animals visit a baiting station, sharing information with clients when a female with cubs uses a particular bait, and a 10-minute no-firing rule which allows time for any cubs to appear.

In response to the arguments presented by those opposed to the spring harvest in Manitoba, MWEPB developed a model to estimate the number of black bear cubs orphaned due to spring hunting. The objective of this paper is to report on: (1) the usefulness of reproductive data collected from hunter-killed samples in the spring, (2) the results of a literature search for the

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values used in the model for cub mortality, and (3) the application of these data in the model.

Study area

Manitoba has 5 distinct ecoregions: prairie (11%), boreal plain (19%), boreal shield (38%), boreal taiga (20%), and the Hudson plain (12%). The province was divided into 61 game hunting areas (GHAs), administrative units used to manage the harvest of game species. A population estimate was derived for each GHA based on black bear densities reported in the literature for ecoregion type (ranging from 0.65–2.6/km^2 [0.25 to >1/mile^2]). We estimated that the black bear population ranged between 25,000 and 30,000 animals for 1996–2000 (Pastuck 2001).

Methods

Data sources

Due to the secretive nature of black bears, traditional monitoring techniques are not effective, and managers rely on harvest information to manage black bear populations. The black bear hunting season in Manitoba comprised spring and fall segments, and baiting was legal. The spring segment commenced the last week of April for all black bear hunting zones and closed between the second and the last Saturday of June, depending on latitude.

Manitoba instituted a low-cost, low-effort data collection program in the early 1990's to monitor the harvest of black bears. Hunters were asked to provide the first upper pre-molar tooth, the reproductive tract from female bears, and information on hunter effort and success. For a sample to be eligible for analysis, it had to include a tooth for which an age determination could be made and the reproductive tract with both ovaries and uterine horns intact.

Aging

Teeth were aged using the cementum aging model described by Matson et al. (1993). To properly assign an age to a tooth collected in the spring, kill date is critical because in Manitoba, summer deposition (lightly stained cellular cementum in histological sections viewed with transmitted light) is first seen along the outer edge of a tooth by mid–late May. In some populations, there is reduced summer cementum deposition in years when females successfully rear cubs and lactate, resulting in adjacent bands of darkly stained cementum (winter) to be closely spaced, i.e., a paired appearance. Reconstructing reproductive history from dental cementum was successfully demonstrated for black bears in Arizona (Carrel 1994), Minnesota (Rogers 1975, Coy and Garshelis 1992), and California (Coy and Garshelis 1992), but not for bears in New York (O'Pezio 1980) or Maine (Coy and Garshelis 1992). This technique was used in this study to determine the age of first "prolonged lactation" and subsequent lactation intervals. For analysis purposes, we pooled the female-harvest data into 4 age classes to reflect sexual maturity and birthing experience: infantile (1-year olds), first-time breeders (2- to 5-year olds), having had at least one litter (6- to 9-year olds), and experienced breeders ($\geq$10 years old).

Reproductive status was determined by evaluating the ovaries for follicles and uterus for placental scars. The endotheliochorial placenta of carnivores is usually surrounded by a histotrophic band of tissue in which there is hemorrhage from maternal capillaries. Blood cells are phagocytized here as it provides iron and other nutrients to the fetus. Although most of the blood escaping into this tissue is phagocytized by adjacent placental cells, some is taken up by local endometrial macrophages where it is converted into large, yellowish granules of hemosiderin, an insoluble form of tissue iron. Parts of the endometrium containing large numbers of hemosiderin-laden macrophages are darker than the surrounding tissue, and these dark areas are known as placental scars, usually measuring 7–10 mm. In bears, the characteristic zonary placenta found in most carnivores is interrupted on the mesometrial side; thus, the placenta forms a curved disc and the surrounding band of tissue is ring shaped (Mossman 1987). The resulting placental scars are therefore ring shaped and their presence in the endometrium provides evidence of previous pregnancies. In bears, Erickson et al. (1964) found scars to persist for more than a year after parturition, although their appearance fades over time.

We developed a standard procedure for searching the uterus for scars in collaboration with P.F. Flood (Department of Veterinary Biomedical Sciences, University of Saskatchewan, Saskatoon, Saskatchewan, Canada). The reproductive tract was thawed and the mesometrium was removed with scissors at its attachment to the uterus. The uterus was then opened along the line of mesometrial attachment and flattened, endometrium upwards, on a standard slide viewing box that had been laid on its back with the illuminated surface upward. Each uterus was evaluated for uterine placental scar numbers and age assessment according to the intensity of pigmentation. Ovaries were evaluated macroscopically for ovarian follicular (spring) or corpora lutea (fall) development.

The appearance of the scars was strongly influenced by the handling of the sample. If the uterus was removed from the carcass in under two hours and cooled rapidly, they were coral colored. If the uterus remained in the carcass for longer, the scars became progressively darker, turning dark brown after a few hours and bluish black by about twelve hours. The change in color was thought to be caused by microbial production of hydrogen sulphide in the carcass. The scars were deemed to be new (T, from the previous winter) if they had a vibrant appearance and were a complete or almost complete ring. Scars were deemed old (L, from the winter before last) if they were dull in appearance and the ring was incomplete. Typically, T-scars and L-scars were easily distinguished, but on occasion, there were very faint scars, often requiring the use of a light box for confirmation, that are believed to be from pregnancies that occurred ≥2 years before the bear was killed. Because these old scars may often go unrecognized and cannot be accurately aged, they were recorded but not included in the main analysis.

Females having evidence of consecutive-year birthing (C-scars, tracts that have both T and L scars) were included to account for all females with new scars. The sample size of new scars for any year was increased for comparative purposes by combining data obtained during the year of harvest (T-scars) with data from bears killed in the subsequent year (L-scars, dental evidence of lactation). These data were not used in the model.

The following additional reproductive conditions were noted: number of sites where fetuses did not appear to develop to full term (scar sites <3 mm, believed to be aborted or resorbed fetuses); consecutive-year births; no scars but tooth indication of prior lactation; no scars and no evidence of lactation (≤5 years of age; or >5 years of age).

The thickness of the uterine wall (normal, slightly thickened, or thick-walled and convoluted) and the sizes of ovarian follicles (none [all <1 mm], small [1–2 mm], medium [2–4 mm], large [4–6 mm], and mature [>6 mm]) were recorded. Mature antral follicles were counted when present. Females with L-scars frequently had both thickened uterine walls and medium or larger follicles.

All T-scar and randomly chosen L-scar uteri were mounted, endometrium upward, onto jumbo craftsticks and affixed by crimping open-ended paperclips to prevent the sample from curling. These and corresponding ovaries were preserved in 1-liter containers filled with 10% buffered formalin. The bleaching effect from formalin also gives clarity to placental scar sites. Most remaining scarred tracts and corresponding ovaries were flattened and placed in individual bags, vacuum-sealed, labeled, and refrozen. M.L. Connor (Department of Animal Science, University of Manitoba, Winnipeg, Manitoba, Canada) microscopically examined a sample of 1997 and 1998 tracts to confirm macroscopic assessments.

Mail surveys

All resident hunters were mailed questionnaires to determine hunter success rates, effort per kill, proportion of females in the harvest, and number of bears observed by hunters at baiting sites. Outfitters were required to complete and submit an Outfitter Declaration Form (ODF) on behalf of their clients. This form asked similar questions as the resident questionnaire.

Literature review for model development

We reviewed literature to verify the assumptions used in the following model were valid and to obtain data on cub mortality where there was no or limited information specific to Manitoba. For this report, we used the lower end of the reported range of estimated cub mortality that best represented Manitoba's habitat. These values were 25% for total litter loss (reported range, 18–47%) and 20% for litter reduction (mortality rates of cubs in multi-cub litters during the spring). If the mean of reported cub mortality had been used in the model, the estimate of orphaned cubs would have been lower.

The mathematical model

We developed the following model to estimate the number of cubs potentially orphaned due to spring bear hunting in Manitoba:

$$N_o = [K_t P_f P_i (1 - P_{tll}) L_b] - [P_{mcl}(K_t P_f P_i (1 - P_{tll}) L_b) M_{mcl}] \quad [1]$$

N_o is the estimated number of black bear cubs orphaned as a result of females with cubs being shot during the spring hunting season.

K_t is the total number of bears harvested during the spring season. The total annual kill of black bears was divided into spring (K_t) and fall. This information was obtained from questionnaires from resident Manitoba black bear hunters and from ODFs from Manitoba outfitters. Both questionnaires and ODFs asked whether the hunter harvested a bear, the gender of the bear, season the bear was harvested.

P_f is the proportion of the spring kill which was female, calculated from questionnaire and ODF data. This

Table 1. Results of reproductive tract analysis from spring harvested black bears in Manitoba, Canada, 1996–2000.

Scar and tract		Year					
Codes	Description	1996	1997	1998	1999	2000	Total
T	scars from fetus attached in the year of harvest	18	19	9	5	6	57
L	scars from fetus attached in the year prior to harvest	40	27	58	63	61	249
C	scars from 2 consecutive years, T and L combined	1	2	4	3	2	12
A	T or L scars suggesting fetuses did not fully develop (< 3 cm, believed aborted or resorbed)	3	1	2	9	7	22
P	no visible scars, cementum deposition indicating prior successful cub rearing	9	4	6	17	5	41
N	no visible scars, no cementum deposition indicating prior successful cub rearing (age > 6)	6	8	12	13	7	46
V	no visible scars or cementum deposition indicating successful cub rearing (age < 6)	53	77	82	76	105	393
Total		130	138	173	186	193	820

proportion, multiplied by the spring kill (K_t), estimated the number of females killed each spring.

P_i is the proportion of spring-killed females with new placental scars (evidence of fetal attachment in the year of harvest and which had a non-zero probability of having cubs of the year). This proportion was calculated from female reproductive tracts submitted by hunters (T – scars + the T component of C-scars, Table 1). Number of females killed each spring (K_tP_f) multiplied by ($K_tP_fP_i$) estimates the number of females killed that could have been accompanied by cubs.

P_{tll} is proportion of spring-shot females which had total litter loss (lost all cubs from causes other than the spring hunt). The proportion of spring-killed females with total litter loss (P_{tll}) was estimated from literature. These females would not have been accompanied by cubs when they were shot. Therefore, the proportion of shot, implanted females that could have live cubs is $1 - P_{tll}$. Number of females killed which could have been accompanied by cubs ($K_t P_f P_i$) multiplied by $1 - P_{tll}$, estimates the number of females which would probably still have live litters at the time they were shot ($K_tP_fP_i\,[1 - P_{tll}]$).

L_b is the mean litter size at birth, calculated from examining reproductive tracts and determining the average number of placental scars in females (Table 2). Number of females with live cubs ($K_tP_fP_i(1 - P_{tll})$) multiplied by the average litter size at birth (L_b) estimated the number of orphaned cubs if all cubs in litters with more than 1 cub survived from birth [$K_tP_fP_i(1 - P_{tll})L_b$]. Litter reduction (loss of one or more, but not all, of the cubs in a litter) occurs from natural causes in black bear litters. The equation must account for this loss, otherwise, the number of cubs orphaned is overestimated. This litter reduction loss is estimated by [$P_{mcl}\,(K_tP_fP_i(1 - P_{tll})L_b)\,M_{mcl}$].

P_{mcl} is proportion of multi-cub litters (P_{mcl}), calculated from the analysis of reproductive tract samples (Table 3). Implanted females with >1 placental scar were considered to have had multi-cub litters. Proportion of multi-cub litters (P_{mcl}) multiplied by the estimated number of orphaned cubs if all cubs in a litter with more than 1 cub survived from birth ($K_tP_fP_i(1 - P_{tll})L_b$), the product estimated the number of cubs in multi-cub litters (P_{mcl} ($K_tP_fP_i\,(1 - P_{tll})L_b$)).

M_{mcl} is mortality rate of cubs in multi-cub litters prior to the lactating female being harvested during the spring season, as estimated from the literature. The product of mortality rate of cubs in multi-cub litters prior to the lactating female being harvested during the spring season (M_{mcl}) and the estimate of cubs in multi-cub litters ($P_{mcl}[K_tP_fP_i(1 - P_{tll})L_b]$) results in estimated litter reduction, [$P_{mcl}(K_tP_fP_i[1 - P_{tll}]L_b)M_{mcl}$]. When the estimate of litter reduction [$P_{mcl}(K_tP_fP_i[1 - P_{tll}]L_b)\,M_{mcl}$] was subtracted from the estimate of orphaned cubs if all cubs in litters with >1 cub survived from birth [$K_tP_fP_i(1 - P_{tll})L_b$], the difference was equal to the estimated number of black bear cubs orphaned as a result

Table 2. T and C scar[a] analysis of spring harvested female black bears in Manitoba, Canada, 1996–2000.

	Age in years *n* scars/*n* tracts						
Year	**1.5**	**2–5**	**6–9**	**10+**	**Total age ≥2 years**	**$\bar{x}$ scars**	**Tracts analyzed**
1996	0/1	25/9	17/8	5/2	47/19	2.47	130
1997	0/2	15/6	24/9	17/6	56/21	2.67	138
1998	0/1	6/3	6/3	19/7	31/13	2.38	173
1999	0/4	5/2	4/2	12/4	21/8	2.63	186
2000	0/3	9/4	9/4	0/0	18/8	2.25	193
Totals	0/11	60/24	60/26	53/19	173/69	2.51	820
Scars (mean)		2.50	2.31	2.79			

[a]Placental scars indicating fetal attachment in year of harvest.

of females with cubs being shot during the spring hunting season (N_o).

Equation [1] can be simplified to:

$$N_o = [K_t P_f P_i (1 - P_{tll}) L_b][1 - (P_{mcl} M_{mcl})] \quad [2]$$

In this form, the relationship of the parameters in the equation is not as easily explained as in the expanded form.

Equation assumptions

The model required the following assumptions to be valid: (1) the proportion of females in the spring with total litter loss, as determined from literature, was reasonable for black bears in Manitoba, (2) the mortality rate of cubs in multi-cub litters prior to the lactating female being harvested during the spring season, based on the literature, was reasonable for black bears in Manitoba, and (3) samples of female bear reproductive tracts submitted by hunters were representative of all hunter-harvested bears.

Results

Model

We estimated that, on average, 41 cubs per year (range = 20–67) were orphaned due to spring hunting from 1996 to 2000 in Manitoba (Table 4). Reproductive data indicated that on average, 55% of female bears harvested in the spring were between the ages of 2 and 5. Analysis of the reproductive tracts of these females showed that most (86%) had never had a litter (381 of 444) and 14% had ≥1 (63 of 444), most having had 1 litter. Estimated mean litter size at birth was 2.5 cubs, with 61 of 69 litters (88%) being multi-cub litters. Age-specific mean litter sizes were 2.5 for 2 to 5-year old females (24 of 444 tracts), 2.3 for 6 to 9-year old females (26 of 188 tracts), and 2.8 for bears ≥10 years old (19 of 177 tracts).

Harvest

In Manitoba, >95% of all bears harvested were taken over bait. As resident hunter numbers declined (1,574 in 1996 to 1,243 in 1999), non-resident license sales increased (1,443 in 1996 to 1,988 in 2000), maintaining constant hunting pressure. For the study period (1996–2000), an average of 1,383 resident hunters harvested 419 bears (range = 399–495)/year with 62% of the harvest occurring in the spring season, while 1,636 non-resident hunters killed 1,167 bears (range = 965–1,438) with 73% from the spring season.

Age

Tooth submissions from spring-harvested bears increased from 592 in 1996 to 961 in 2000, and the submission of complete reproductive tracts increased from 130 to 193. Non-residents traditionally submitted more samples than residents. Overall, hunters submitted an average of 65% of all teeth and >50% of all reproductive tracts, based on the estimated harvest obtained from questionnaire returns. The proportion of females represented in the reported harvest remained near 28% (range = 26–32%), while females represented 31% (range = 28–35%) of tooth submissions. Mean ages of harvested females (7.06, range = 6.28–8.14) were consistently higher than males (5.38, range = 4.88–5.99).

Reproductive tracts

We examined 1,063 complete reproductive tracts, and of these, 820 tracts were from the spring seasons. Only 8% (69 of 820) showed evidence of having a litter the previous winter (T-scars), and 30% (249 of 820) had evidence of having a litter the year before harvest (L-scars). Most harvested female bears which had given birth to cubs during the previous winter were taken in the latter half of the spring hunting season, with a mean harvest date of May 26. The earliest evidence of mature follicles in the samples examined was May 13, and the latest was September 23. In the latter cases, the females were either immature or senescent (≥26 years old).

The histological evaluation of the ovarian and uterine tissues was, for the most part, consistent with the

Table 3. Black bear litter sizes based on new scars from spring harvested females in Manitoba, Canada, 1996–2000.

	Estimated litter size					
Year	1	2	3	4	5	Total
1996	3	6	8	2	0	19
1997	1	8	9	3	0	21
1998	1	6	6	0	0	13
1999	1	1	6	0	0	8
2000	2	2	4	0	0	8
Total	8	23	33	5	0	69

macroscopic assessment of the reproductive tract and the tooth as indicators of reproductive status (M.L. Connor, unpublished data). Uteri from tracts collected in May through mid-June had scars of various sizes and pigmentation. Microscopic examination of very recent sites (T-scars) revealed erythrocyte fragmentation and an overall pinkish coloration. Vascular components were clear with identifiable lumen. In older scars, (interpreted to be L-scars), golden-brown larger granules were concentrated throughout the mucosa. Vascular components were not extensive. Histology of ovaries from these tracts appeared to be consistent with assessment of scar tissue evaluation for bears presumed to have been pregnant and aborted or those that lost their young in early lactation (M.L. Connor, unpublished data).

Of the 1,063 (spring and fall) reproductive tracts examined in Manitoba, evidence of placental scaring from 2 consecutive years (C) was found in <2% ($n = 17$) of the samples, whereas evidence of fetuses not developing to full term was found in 2% ($n = 22$) of the samples. Combined T and L scar information for the study yielded sample size increases of 35 to 128 for age of first reproduction and 69 to 422 for mean litter sizes and frequency of multi-cub litters (Table 5). The increased sample sizes changed the respective estimates only slightly: 4.51 to 4.56; 2.51 to 2.56; and 0.88 to 0.92.

We found evidence to suggest females were still lactating if they had very little new cementum, placental scars from the previous winter, and ovaries with no follicles >2 mm. If, however, a female had new scars, more than minimal amounts of new cementum, and follicles >2 mm with thickened uterine walls, the bear was classified as non-lactating and was presumed to have lost its litter. Although data of this kind were recorded, they were not used in the analysis because of insufficient corroborative evidence from confirmed family groups.

Discussion

Reproductive biology of black bears

Not all females reproduce every year. This is because some females have not reached sexual maturity or may be in too poor physical condition to mate, to implant blastocysts, or to carry embryos to full term. In addition, females with cubs are not available for breeding. In Pennsylvania, Alt (1982) found that on average 35% (range = 33–58%) of the females were traveling with cubs. Kolenosky (1990) had similar reproductive rates for east-central Ontario, 38% (range = 13–58%).

Food quality and availability largely influence reproductive potential in a density-independent manner (Beecham 1980, McLaughlin et al. 1994, Miller 1994, Samson and Huot 1995). Jolicoeur and Lemieux (1994) considered 35 kg to be the threshold body mass for females to come into estrus in Quebec, assessed the probability of a female of that weight ovulating to be 36%, and found no follicular development in females <35 kg. Rogers (1976) found that in Minnesota, 94% of 34 adult females >80 kg on October 1 had young the following spring, whereas none of the 17 females <67 kg produced young; those between 67 kg and 80 kg had intermediate reproductive success. For Ontario, Kolenosky (1990) found reproducing females averaging 97 kg, whereas non-producing adult females averaged 70 kg.

Survival of cubs in the den is typically high, but some mortality occurs. Miller (1994) reported an in-den mortality rate of 5%, attributed to poor condition of females entering the den and insufficient milk to sustain cubs until den emergence. Oftedal et al. (1993) reported that a female black bear with three cubs must produce at least 32 kg of milk to feed the cubs while in the den, in the absence of feeding or drinking (other than the excreta of the cubs, and water from snow melting into the den). Hellgren (1998) suggested that lactation is an enormous physiological drain, citing body mass losses of 27% for lactating females during hibernation, whereas the loss for non-lactating females was only 20%. Jolicoeur and Lemieux (1994) observed the absence of milk in females with a body weight <44.5 kg upon den emergence. The low lactation rate (6%) of 4-year-old females, observed by Jolicoeur and Lemieux (1994) indicates the difficulty of young females reaching the threshold fall weight required to successfully raise a litter.

The act of nursing likely inhibits the release of gonadotrophins, including luteinizing and follicle-stimulating hormones, which are needed for the female to come into estrus (McNeilly 1988). Suckling almost always inhibits ovulation. This hormonal mechanism could

Table 4. Parameter values for model predicting black bear cubs orphaned in Manitoba, Canada, during the spring bear hunting season, 1996–2000.

Parameter	Description	1996	1997	1998	1999	2000	Mean
K_t	total bears harvested during spring season	902	1003	1129	1,103	1,396	1,107[a]
P_f	proportion of females in spring kill	0.287	0.272	0.317	0.258	0.257	0.278[a]
P_l	proportion of females with placental scars (evidence of fetal attachment, year of harvest)	0.146	0.152	0.075	0.043	0.041	0.091[b]
P_{tll}	proportion of spring-shot females with total litter loss prior to harvest	0.25	0.25	0.25	0.25	0.25	0.25[c]
L_b	mean litter size at birth	2.47	2.67	2.38	2.63	2.25	2.51[b]
P_{mcl}	proportion of cubs in multi-cub litters	0.842	0.952	0.923	0.875	0.750	0.870[b]
M_{mcl}	mortality rate of cubs in multi-cub litters prior to the female harvested, spring season	0.20	0.20	0.20	0.20	0.20	0.20[d]
N_o	estimated cubs orphaned, spring season	58.23	67.23	39.07	19.91	21.10	41.11

[a]Calculated from hunter questionnaire and ODF data.
[b]Calculated from reproductive tract samples.
[c]Bunnell and Tait (1985).
[d]Miller (1994).

account for the alternate-year breeding cycle of adult females (Wimsatt 1963). However females that lose their cubs of the year before the end of the breeding season can and frequently do come into estrus, breed, and produce cubs the following winter (Baker 1912, Rausch 1961, Erickson et al. 1964, Hensel et al. 1969, Alt 1982, Higgins 1997, Powell et al. 1997). This raises an interesting question: can a female that has weaned its cubs before the end of breeding season come into estrus?

Overall cub mortality—annual rates

Cub mortality is usually reported as an annual rate and is expressed as either total litter loss, where all cubs in the litter die, or litter reduction, where some of the cubs in a litter die. Because few studies have monitored radiotransmitted cubs (LeCount 1987; Elowe and Dodge 1989; Higgins 1997; Echols 2000; G.B. Kolenosky and S.M. Strathearn, 1987, Survival and movements of orphan and non-orphan black bear cubs in east-central Ontario, Ontario Ministry of Natural Resources, Maple, Ontario, Canada), there is little data on cub mortality at different periods of the year. Most authors monitor cub mortality by conducting successive-year den checks to compare the difference in the observed yearlings versus observed cubs. Generally, reported mortality rates are mean values from several years of study, which can vary from year to year within individual populations. Bunnell and Tait (1985) estimated a first-year cub mortality rate of 25–30% for black bears in North America, but rates of 18% in Minnesota (Garshelis 1994) and 47% in east-central Ontario (Kolenosky 1990) have been documented for regions similar to Manitoba. In years when food is scarce, cub mortality tends to be at the higher limit of the range (around 50%), while in food-rich years, it would be closer to the lower end of the range, around 20% (Kolenosky and Strathearn 1987).

Seasonal mortality—den emergence until breeding season

Black bear researchers generally agree that most cub mortality occurs prior to the first of July. Though they did not report on litter reduction specifically, McLaughlin et al. (1994) suggested that most litter losses occur soon after emergence from the den, when cubs depend on the female's nutritional resources and are less able to avoid predators. Kolenosky (Ontario Ministry of Natural Resources, retired, British Columbia, Canada, personal communication, 2002) suggested that average cub mortality is a good estimate of the mortality rate of individual cubs in multi-cub litters (litter reduction).

Higgins-Vashon (Maine Department of Inland Fisheries and Wildlife, Bangor, Maine, USA, personal communication, 2001) suggested that the mortality rate of cubs in multi-cub litters is slightly less than the mortality rate of cubs in litters of only one. She added that mortality rates reported in the literature are most often a combination of these data sets. This difference could be explained in part because young, inexperienced females are generally those with one-cub litters. Therefore, the mortality rate of cubs in multi-cub litters would generally be less than overall mortality rates reported. Miller (1994) reported no difference in the likelihood of losing all

Table 5. Black bear litter sizes based on scar data from spring and fall harvested females in Manitoba, Canada, 1996–2000.

	Frequency						
Year	1	2	3	4	5	Total	% with >1 scar
1996-T[a]	4	9	12	2	0	27	0.852
1997-L[b]	2	19	14	4	4	43	0.860
1997-T	1	9	10	3	0	23	0.957
1998-L	8	31	30	5	2	76	0.868
1998-T	2	9	7	0	0	18	0.889
1999-L	2	28	25	12	2	69	0.942
1999-T	2	2	7	0	0	11	0.818
2000-L	6	27	31	8	0	72	0.917
2000-T	2	3	5	1	0	11	0.818
2001-L	5	32	33	2	0	72	0.931
Totals	34	169	174	37	8	422	0.919

[a]New scars from winter of the year of harvest.
[b]Old scars from year prior to year of harvest.

Table 6. Estimated black bear cubs that die from natural causes in Manitoba, Canada, 1996–2000.

Parameters	Values	Factor
Estimated bear population	25,000[a]	A
Estimated number of females (0.55[b] × A)	13,750	B
Estimated number of females that breed annually (0.33[c] × B)	4,540	C
Number of cubs born each year (2.56[d] × C)	11,622	D
Annual mortality rate of cubs (estimated from the literature)	0.18[e]–0.47[f]	E
Estimated number of cubs which die in the wild, annually (D × E)	2,092–5,462	

[a]Pastuck (2001).
[b]Hristienko, unpublished data.
[c]Alt (1982), range = 33–58%.
[d]Calculated from T scars from current year + L scars from subsequent year.
[e]Garshelis (1994).
[f]Kolenosky (1990).

or a portion of a litter in Alaska. If true, his reported mortality rate of 20% for cubs between den emergence and June estimates the mortality rate of cubs in multi-cub litters (litter reduction) and total litter loss for that period.

We have no reason to believe that the literature-reported estimates of 25% for total litter loss and 20% for litter reduction do not represent Manitoba. Instead of relying on literature or expensive studies to estimate total and partial litter loss for use in this model, one may be able to use the size of follicles (>2 mm) and the status of the uterus (thickened walls) to determine this variable. In Alaska, Rausch (1961) found no follicles >2 mm in the ovaries of 2 adult females that died (on 28 Jun and 6 Jul) after giving birth to 3 cubs each the previous winter. In 3 samples collected from females with cubs that had been euthanized as problem animals or were road-killed in Manitoba, none had follicles >2 mm between early July and mid August. In some years, mature follicles (>6 mm) were found in 40% of the ovaries examined from females that reproduced the previous winter. Before this technique can be used with confidence, it should be verified by a statistically valid sample of reproductive tracts from females that died before July 1 and were known to be lactating or accompanied by cubs. Female bears dispatched for being a nuisance or road kills would be potential sources, assuming the female did not hide its cubs before it died.

Perspective on cub orphaning

Comparing the estimates of orphaned cubs to those that die from natural causes (starvation, cannibalism, abandonment, predation, disease, human-related, accidents) adds perspective to the situation. To ensure that our estimate of cub mortality due to natural causes was not inflated or excessive, we used the low end of the population estimate.

Manitoba's black bear population for 1996 through 2000 was estimated to be between 25,000 and 30,000 (Pastuck 2001). Assuming that at birth there is an equal sex ratio and considering that the harvest is heavily skewed toward males (72:28, H. Hristienko, unpublished data), we chose 55% to represent the estimated number of females in the population. Using 33% of females available to breed in a year (Alt 1982), we estimated that 11,622 cubs were born each year based on an average litter size of 2.56. With annual mortality rates for cubs of 18–47%, an estimated 2,092–5,462 cubs died annually from natural causes (Table 6). The 41 cubs that may have been orphaned during each spring hunting season represent <2% of those that may die annually from natural causes.

Fate of orphaned cubs

There is evidence that not all cubs orphaned in spring starve to death. Some cubs survive on their own. Kolenosky and Strathearn (unpublished report 1987) reported on 49 orphaned cubs in Ontario fitted with radiotransmitters and released between May 24 and August 16, with 36 of the releases occurring prior to July 1. Twenty-seven were indigenous to the area, whereas 22 were transplants. Of the 49, the fate of 14 orphans was unknown, 14 survived to hibernation (with 10 surviving

>16 months of age), 7 died of starvation, 5 were killed by bears, 2 by lynx (*Lynx lynx*), 3 by unknown predators, 2 by vehicles, 1 when its den collapsed during snowmelt, and 1 was shot by a farmer when it tried to enter the back porch of a farmhouse. Kolenosky (Ontario Ministry of Natural Resources, personal communication, 2002) suspected that many orphaned cubs that died from starvation did not know when to switch to food sources that became available after they were orphaned. Cubs that fed on insects before they were orphaned continued to feed on insects even after it would have been more beneficial to feed on berries or mast.

In Minnesota, Lynn Rogers "put radiocollars on 14 cubs that were orphaned in late summer or fall. Of these, 2 were soon shot, 2 were killed by trains, 1 died of unknown causes, 1 was killed by predators, 1 probably died of starvation, and 7 survived past 17 months of age" (A. Willock, Canadians for Bears, Winnipeg, Manitoba, Canada, personal communication, 2002). Olfenbuttel, Bridges, and Vaughan (Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, unpublished data, 2002) reported that a wild female bear abandoned 5 cubs (2 natural, 3 fostered) after being released from temporary captivity in mid-May, 2000. Four cubs were recovered, whereas the fifth died of unknown causes. The 4 remaining cubs were released on 18 June. Two of the cubs survived and were still being monitored as of 2002. The fate of the third cub is unknown (collar lost), whereas the fourth cub died of unknown causes. Erickson (1959) reported black bear cubs as early as 5.5 months and as small as 18 pounds were self-sufficient in Michigan. Elowe and Dodge (1989) reported that in Massachusetts, all 4 cubs from 2 litters that were separated from their mothers in mid-June survived on their own. Lindzey and Meslow (1980) used 50% as an average estimate for the annual survivorship of cubs orphaned during the year in Oregon.

Manitoba's reproductive data suggests that females with cubs tend to be harvested in late May or June. Cubs at this stage have an increased chance of survival compared to cubs orphaned during April or early May.

Bias in data collection

Males are more vulnerable to hunting than females (Bunnell and Tate 1985), resulting in harvests biased toward males (Gilbert et al. 1978). Factors that may contribute to higher mortality rates for males include hunter selectivity against females with cubs, gender differences in vulnerability (baiting attracts males), dissimilarity in size of home ranges (male home ranges are 1.5–11.3 times larger than female home ranges), and hunter–prey strategies (hunting over bait versus stalking) (Bunnell and Tate 1985). The availability of natural bear foods in the spring does not seem to affect female representation in a harvest as reported in the fall. In Minnesota, Noyce and Garshelis (1997) showed a higher percent of females (48%, range = 39.9–58.9%) in fall harvests when fall food supplies decreased and when hunting pressure increased. In Manitoba, the proportion of females in the spring harvest remained constant under constant hunting pressure.

Because it is illegal in Manitoba to harvest a female accompanied by cubs, the harvest sample of females is likely biased in favor of solitary females. These would include females that did not give birth as well as females that had lost their litter. Family groups are relatively sedentary upon den emergence (Rogers 1987) and are less vulnerable to hunters during the spring hunt (Kolenosky and Strathearn unpublished report 1987). Females with cubs are less mobile (Rogers 1987) and tend to avoid males and areas of disturbance, including concentrated feeding areas such as baiting stations, where their cubs could be in jeopardy. If females do happen upon a bait site, our data indicate that hunters select against females accompanied by cubs. In Ontario, Kolenosky and Strathearn (unpublished report 1987) reported that females with cubs used 26% of their home ranges from den emergence to 15 July. Of 197 females tagged between 1977 and 1981, 40 were shot (20%) during spring hunts and 8 were nursing (Kolenosky and Strathearn unpublished report 1987).

No adjustment for non-response bias was used. Non-resident hunters (approximately 74% of the kill and 54% of licenses) were sampled at >90%. We consider that their kill is known with certainty. Even if resident hunters exhibited a serious non-response bias (which is not suggested by any other information source), the total kill would only be overestimated by approximately 4%. We do not consider this possibility serious enough to justify the cost and time of multiple mailings to measure non-response effects.

As the spring hunting debate drew increased attention, especially after Ontario closed its spring season in 1999, we believe hunters in Manitoba became increasingly sensitive to the issue by being more diligent in selecting bears without cubs. Conversely, it could be argued that hunters have selected against submitting samples from females with cubs. We have no way of knowing which holds true. Because the percent of samples submitted by hunters remained constant, there was no appreciable difference in the representation of females in questionnaire data and tooth sample submissions, and the combined data values were similar to the actual values for each year of the study, indicates that hunters had not changed their habits in selecting against submitting samples from females with cubs.

Confounding factors

We recommend that a tooth be read in conjunction with examining a reproductive tract. A tooth aged separately from its corresponding reproductive tract could present conflicting reproductive histories. Several examples from our data illustrate this. In one spring sample, the tooth showed an even layering of cementum (no paired annuli) and a non-reduced outside layer for the date of kill. The reproductive tract showed one new scar, thickened uterine walls, and ovaries with 3 mature follicles. The tooth suggested this female had never lactated, while the reproductive tract clearly showed that the female had given birth. The combined information suggested that this female lost its cub in the den or after den emergence but before mating season, as suggested by the amount of new cementum deposition and the presence of mature follicles. In a sample from the fall, the tooth showed paired annuli at 15 and another at 17 years of age, and much summer deposition at 18. The reproductive tract revealed 2 distinct sets of scars, one new and one old, and no corpora lutea. The tooth suggests this female had a surviving litter at 15 and 17 but had not lactated at 18. The reproductive tract showed this female had a litter at both 17 and 18. The combined tooth and tract data suggests that this female had a litter as a 17-year old but lost it late because of the reduced layer of new cement. It had another litter as an 18-year old but lost that litter early because of the large amount of new cementum. For this reason, we chose to use the term "prolonged lactation" to describe the appearance of paired annuli because not all paired annuli necessarily indicate surviving litters.

Conclusions and management implications

The model estimated that 41 black bear cubs were orphaned as a result of females killed during a spring hunting season. The values used in the model for natural cub mortality were obtained from the literature. The lower end of the reported range was used to ensure we did not underestimate the number of cubs that were potentially orphaned.

The spring hunting season is a valuable wildlife management tool. It can be used to reduce or maintain black bear populations at or below biological or cultural carrying capacity, thereby reducing or maintaining problem bear incidents at tolerable levels in a cost-effective manner. The spring hunt provides a hunting season when there are few other hunting opportunities, distributes hunting pressure over a greater period, gives hunters the advantage of short and sparse vegetation (which increases detectability of cubs with female bears), selects against nursing females because they are less mobile and tend to avoid areas of disturbance, supports the rural economy and the tourism industry, offers hunters the opportunity to harvest an animal when its coat is prime and the meat less fat and more palatable, reduces the number of bears before the problem bear season rather than after it (in nuisance situations, females accompanied with cubs are not exempt from management kills or from persons defending their property or personal safety), and is biologically sustainable.

The analysis of reproductive data from Manitoba is consistent with the reported reproductive biology for black bears. Reproductive tracts and teeth can be reliable indicators for age of prolonged lactation, litter size, and frequency of multi-cub litters, and may in the future be used to determine whether a female has lost its litter before being harvested by the presence of antral follicles >2 mm. By implementing a data collection program that includes the collection of reproductive tracts and tooth samples from females, managers can apply this model to estimate the number of cubs that may have been orphaned during a spring hunting season. The information we present contradicts allegations that hundreds of cubs were being orphaned during the spring hunting season in Manitoba. Reproductive information can be used to assist wildlife managers in the decision-making process to ensure effective and sustainable bear management programs.

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