CAUSES OF BLACK BEAR CUB MORTALITY

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Abstract: From 1982 to 1985, 23 Arizona black bear (*Ursus americanus*) cubs were equipped with motion-sensitive, breakaway radiocollars while in winter dens. Eleven (48%) of these cubs died, but cause of death was determined in only 8 cases because of collar loss. Fifty percent of these deaths were the result of cannibalism by other bears. Other causes of mortality included other predation, disease, and hunting. The majority of cub deaths occurred within 60 days of den emergence; only 1 cub dying of natural causes lived beyond the end of the May–June breeding season. Seven of 13 individual litters (54%) containing radio-collared cubs experienced mortality, and in 6 of those cases (86%), the total litter died. In this population, hunter-caused mortality appeared to be additive rather than compensatory.

Int. Conf. Bear Res. and Manage. 7:75–82

Black bear mortality caused by humans is well documented (Jonkel and Cowan 1971, Lindzey et al. 1976, McCaffrey et al. 1976), as are deaths caused by food shortages (Jonkel and Cowan 1971, Rogers 1976, Carlock et al. 1983) and habitat loss (Cowan 1972). Natural mortality from cannibalism, predation, and disease, however, are not well understood. Limited information on cannibalism, predation, and health problems of adult and subadult animals has been collected, but data on causes of cub mortality are virtually nonexistant (Rogers 1983). This information is lacking because most data on natural mortality in any age class have been collected from radio-instrumented animals, and cubs are normally too small to radio-collar with standard telemetry equipment. Therefore, when cubs die, observers cannot locate their carcasses to diagnose cause of death.

In 1981 a motion-sensitive radiotransmitter was developed that was light enough to be carried by a 1.5 to 2-month-old cub. From 1982 to 1985, I placed these collars on black bear cubs in northern Arizona and intensively radio-tracked them until they lost their collars or died. I then located the carcasses of dead cubs and determined the cause of death.

I am grateful to Becky Benda, Bill Carrel, Cheryl Gast, Cheryl Mollohan, and Jim Wegge, of the Ariz. Game and Fish Dep., and student interns Michelle Brown, Deanna Doan, Lori Ginn, and Brian Wakeling for their assistance in radio-instrumenting and radio-tracking cubs. Their many hours of effort and frustration are appreciated. I would also like to thank the Univ. of Ariz. Pathology Lab. for help in determining pathological conditions and laboratory assistance. This project was conducted under Fed. Aid in Wildl. Restor. Proj. W-78-R, Ariz. Game and Fish Dep.

STUDY AREA AND POPULATION

The 465-km^2 study area straddles the Mogollon Rim in north-central Arizona and encompasses portions of the Coconino, Apache-Sitgraves, and Tonto national forests (Mollohan, this volume). Topography above the Rim consists of flat wide ridges separated by deeply cut canyons; the area below the Rim is steep and rugged. The primary vegetative communities consist of the Rocky Mountain Conifer Forest and the Great Basin Conifer Woodland (Brown and Lowe 1974) with ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and white fir (*Abies concolor*) being the dominant species. Primary land uses are logging, cattle grazing, and recreation; many hunters use the area from September-December. Important wildlife species in the area include bear, elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and turkey (*Meleagris gallopavo*). Predatores include mountain lions (*Felis concolor*), bobcats (*Felis rufus*), and coyotes (*Canis latrans*). For a more detailed description of the study area see Mollohan (1985).

Data collected in a companion project of the study area indicated a bear density of 1/16.8 km^2, with a mean age of 4.8 $\pm$ 3.1 (SD) years. Annual hunting seasons were approximately 90 days in length and began about 1 September. All types of hunting techniques were allowed, except baits, and any sex or age bear could be taken; 24% $\pm$ 9 (SD) of the population was taken annually. Population growth appeared to be related more to cub survival than to the birth rate. Females produced cubs at rates close to their potential, but of 43 cubs born from 1980 to 1985, only 60% survived their 1st year of life (LeCount, unpubl. data).

METHODS

Each fall, radio-instrumented adult females were radio-tracked to their winter dens. The following March each den was visited to determine the presence of cubs. If cubs were found, the female was immobilized with Sernylan (phencyclidine hydrochloride) and the cubs were removed from the den. Each cub was weighed, measured, marked, and radio-collared. Cub weights averaged 2.4 ± 1.4 (SD) kg.

Radio-collars consisted of 2 layers of dacron-butyl-rubber material, which partially encased a whip antenna, and were lined with a piece of foam rubber to allow for neck growth (Fig. 1). Each collar carried a S2B5 radio transmitter (Telonics, Inc., Mesa, Ariz.), powered by a 1/2 AA lithium cell battery capable of producing power for 20 months. A motion-sensitive (mortality) mode in each transmitter increased the pulse rate from approximately 30 beats per minute (BPM) to 70 BPM if the collar did not move for 4 hours. Collar weights averaged 109 grams. Collars were attached to cubs by lacing the end of the collar material together with amber walled surgical tubing (Fig. 1). Heat and ultraviolet light deteriorated this tubing through time, causing the collar to break away. Mean time from instrumentation to collar breakaway was 145 days but ranged 87–215 days.

Following radio-instrumentation each cub was returned to its maternal den. Weekly aerial radio checks were made of all radio-collars in each family group until den emergence was noted. Upon den emergence,

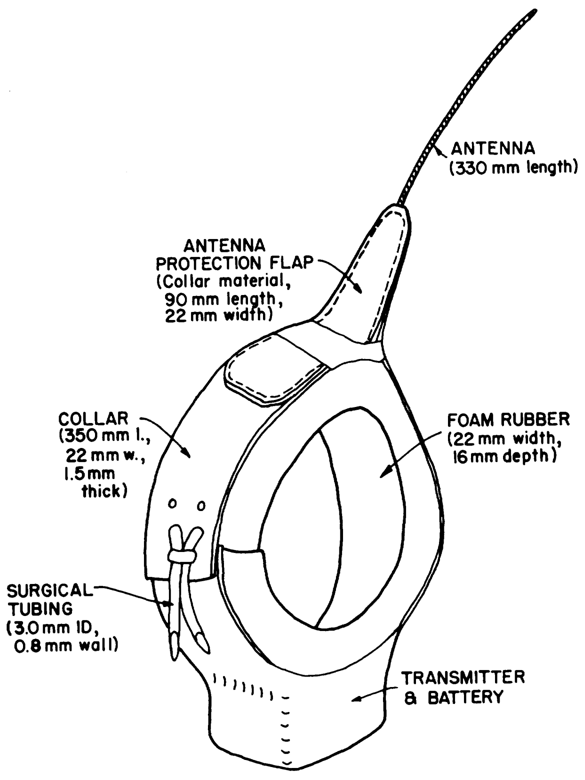

Fig. 1. Breakaway black bear cub collar with surgical tubing fastener.

daily ground radio-tracking, supplemented by weekly aerial radio-tracking flights, began. Ground observers did not attempt to precisely locate each cub during their daily checks. Instead, to avoid disturbing the family group, observers only approached close enough to hear if the radio transmitter was in the active or mortality mode. Precise locations of each member of all family groups were made during the weekly aerial radio-tracking flights.

Upon hearing a cub collar in the mortality mode, we checked the mother's radio signal to see if she was in the immediate vicinity. If not, we immediately located the site of the collar. If the female was nearby, we avoided disturbing her by approaching only after she moved out of the vicinity. Using this technique, all mortalities except 1 were investigated within 24 hours after death occurred.

As each collar was located, evidence of mortality was noted. Field sign near the site, such as tracks, scats, blood, or hair, were recorded, along with any tooth marks or blood on the collar. Any portions of carcasses found were examined for wounds and indications of general health. Whole carcasses were collected, placed in ice, and immediately transported to the University of Arizona Pathology Laboratory for analysis. If the collar had broken away, and no evidence of mortality could be found, we checked the mother's den the following winter to see if the cub had survived after losing its collar. In this way, survival of all cubs through the 1st year of life could be recorded.

RESULTS AND DISCUSSION

From 1981 to 1985, we radio-collared 23 (14 males, 9 females) of 43 cubs born in the study area. Eleven (6 males, 5 females) of the 23 (48%) died during their 1st year of life (Table 1). Mortality rates between collared and noncollared cubs did not differ ($P > 0.05$), and weights of cubs dying from natural causes were not lighter than those surviving ($P > 0.05$).

Cause of Death

We determined cause of death of 8 (6 males, 2 females) of the 11 dead radio-collared cubs (Table 1). The remaining 3 died after losing their collars, preventing location of carcasses in 2 cases and confirmation of cause of death in the 3rd. Of the 8 confirmed deaths, 7 were caused by cannibalism, predation by other animals, or disease. Only 1 was human-caused, and none were attributed to poor nutrition.

Cannibalism was the major cause of death, accounting for 50% of all deaths (Table 1). The 4 cubs killed and cannibalized by other bears died in 3 separate incidents. In the 1st case, an adult male was directly implicated. On 6 April 1983, following a light snowfall, an adult female emerged from her den with 2 cubs (1 male, 1 female). Tracks indicated the family group climbed down a small cliff from the den and traveled approximately 200 m before encountering an adult male. The male killed both cubs, completely consumed 1, and ate all but a small piece of skin and 1 hind foot of the other. Following the attack the mother left the area and 24 hours later was located 2.1 km south of the den site. This rapid and long movement away from the site of a cub's death was typical for females that had cubs killed by bears or other predators.

In the 2nd incident, a female with 2 male cubs was located on 28 May 1984 in an area the family group had been using for several weeks. The following day the female and 1 cub had moved 2.4 km to the south. The other cub's transmitter was heard in the mortality mode at the previous day's location. Subsequent investigation revealed the cub had been killed by a bite on the neck, the skin had been inverted, and the carcass consumed in a fashion typical of a bear (LeCount 1986). Size of the remaining pieces of the carcass and analyses of bone marrow in the remaining leg bones indicated the cub had grown normally and was in good condition at the time of death. A check for other radio-instrumented bears in the area revealed that an adult male was within 300 m of the site of death. Because this male was so close to the site, I suspect he may have killed the cub, although I could not confirm this by finding tracks at the site.

The 3rd case of cannibalism occurred on 19 July 1982. Four days earlier, loggers disturbed a female and her 2 cubs (1 male, 1 female) in an area that the family group had been using since emerging from their den in late April. The following day the family group had moved approximately 1 km west. During the next 2 days none of the 3 bears could be located, but on 21 July the male cub's radio signal was heard in the mortality mode 2.0 km south of the previous location. Investigation revealed the inverted skin, head, and legs of a cub killed and eaten by another bear. The cub had been bitten over the back just behind the shoulders; the size of maggots found in the carcass indicated that the cub had been dead for approximately 2 days. The size and condition of the remaining pieces of the carcass indicated the cub had grown normally and was in good condition at the time of death. No tracks or other evidence indicating the size or sex of the bear killing the cub could be found. The female and her other cub were located 3 weeks later 8.0 km south of where the male cub had been killed.

Table 1. Causes of death for black bear cubs in northern Arizona, 1982–85.

	N	%
Total cubs radio-collared	23	
Cubs lost	11	48.0
Cause of death		
Unknown	3	27.0
Determined	8	73.0
Bears	4	50.0
Mountain lions	1	12.5
Bobcats	1	12.5
Heart disease	1	12.5
Hunting	1	12.5

The female cub in this litter survived until fall, when she was shot by a hunter. This was the only cub to be killed by a human during the study (Table 1). The killing of her brother by another bear, however, may have been indirectly caused by humans. Following disturbance by loggers this family group moved out of the maternity area they had been using for over 2 months. Within 4 days of this disturbance, the cub was killed by another bear. A similar situation was also observed during this study when an adult female accompanied by her feamle yearling suddenly moved out of an area she had been using for approximately 1 month after den emergence. The reason she moved was not known, but 3 days following the move another bear killed and ate the yearling. Track size near the carcass indicated the death had been caused by an adult female or subadult male.

Killing of cubs by adult male and female black bears has been hypothesized (Lindzey and Meslow 1977, LeCount 1982, Stringham 1987) and has been observed in the wild on at least 4 occasions (Rogers 1983). Biologically, both sexes could benefit through prudent cannibalism. By killing genetically unrelated cubs, an adult male could eliminate another male's offspring and at the same time create a potential breeding partner for dissemination of his genes. Studies of the movements of black bears have shown that each adult female's home range overlaps that of several adult males, and adult male home ranges overlap (Lindzey and Meslow 1977, Rogers 1977, Alt et al. 1980, LeCount 1980, Reynolds and Beecham 1980, Hugie 1982, Young and Ruff 1982, Carlock et al. 1983). Therefore, during each breeding season, several males may compete for breeding privileges with each female, and a female may breed with more than 1 male (Rogers 1977). If a male finds a female with unrelated cubs and kills them, the female will be available to the male for breeding within 48 hours of losing the nursing stimulus (LeCount 1983). How males know which cubs to kill is not known, but it seems reasonable to assume they do know because it would be biologically defeating for a male to kill his own offspring. This assumption is supported in other studies of large mammals such as lions (*Panthera leo*) and langurs (*Presbytis* sp.), where males also kill young (Sugiyama 1967, Eisenberg et al. 1972, Schaller 1972, Bertram 1975).

Females would benefit from killing other female's cubs because this would increase the habitat resources available for her offspring. Adult females' home ranges normally do not overlap as much as males, but do overlap to some degree (Lindzey and Meslow 1977, Rogers 1977, LeCount 1980, Reynolds and Beecham 1980, Young and Ruff 1982, Carlock et al. 1983), and habitat components in these overlap areas must be shared with other females and their offspring. Because females allow their young to remain in their home ranges 2–4 years after birth (Rogers 1977), the elimination of nonkin allows these offspring increased use of food, water, and cover in these overlap areas.

Predation of bear cubs by animals other than bears is considered to be rare (Graber 1982, Rogers 1983). The only 2 documented cases involve eagles (*Aquila* sp.) (Nelson 1957) and wolves (*Canis lupus*) (Rogers and Mech 1981). In this study 2 additional species, mountain lion and bobcat, were found to prey on cubs, and losses due to predation by animals other than bears made up 25% of all deaths (Table 1).

The cub killed by a mountain lion was 1 of a 2-cub litter (1 male, 1 female) instrumented in March 1984. The female cub pulled her collar off in the den several days after being collared. The male was still wearing his collar on 14 April, when the family group emerged from the den. Upon emergence, the mother and her cubs remained near the den site for the next 6 days. On 20 April, the male cub's collar was heard in the mortality mode near the den site, and the female had moved 2.5 km to the northeast. Investigation revealed the collar lying in a daybed approximately 350 m from the den. The surgical tubing had been broken, and the collar had been chewed by a large carnivore. No evidence of the cub was found, but investigation of the site revealed a fresh lion scat approximately 10 m from the collar. Scat analyses revealed cub hair and claws. It appeared the lion had killed the cub, eaten the entire carcass, and remained bedded in the area until after the scat was passed. Such behavior is not unusual for mountain lions (Hornocker 1970). Cub claws and hair have also been reported in a mountain lion scat collected in May in northeastern Arizona (N. Dodd, pers. commun.) and in the stomach of a lion killed in May in southern Arizona (D. Lee, pers. commun.).

The bobcat kill was similar to the lion kill except the carcass was located. In March 1985 2 cubs (1 male, 1 female) were instrumented. The female cub pulled its collar off before leaving the den with the family group on 14 April. On 16 April a mortality signal was heard from the male cub's collar near the den site, and its mother was located 1.5 km to the east. Investigation revealed an intact cub carcass completely covered with sticks and pine needles in a fashion typical of mountain lion and bobcat kills (Roy and Dorrance 1976). The carcass was removed and submitted for necropsy. The cub appeared to be in excellent condition. Death had been caused by a bite over the head, which fractured the skull. Puncture wounds made by canine teeth were also found on the thorax and throat, and lacerations from claws occurred around the eyes and nose. Measurements of diameter and distance between these canine holes matched those of a bobcat.

Black bear females are considered to be attentive to their offspring and good mothers; however, they rely on putting their cubs in trees for protection (Herrero 1972). When cubs are very young and on the ground, they appear to be vulnerable to feline predation. Bobcats and mountain lions hunt by stalking their prey. When close, they suddenly spring and kill. With an animal the size of a bear cub, this may take only 1 bite, as evidenced by a bobcat fracturing a cub's skull. With this killing behavior it would be difficult for a female bear to defend her young; even if she detected the attack, the cub would probably be killed before she could chase the cat away. The cat could then return to feed on its prey after the mother bear moved out of the area.

A variety of health problems have been reported for black bears, but no 1 disease has been reported to be particularly important, and apparently disease does not limit bear populations (Rogers 1983). The fact that only 1 disease-related death was found in this study appears to substantiate these findings. On 23 March 1982, a 2.3 kg male cub was radio-collared. In late April this cub emerged from the den with its mother and brother. The family group remained within 0.7 km of the den site for the next 6 weeks, and on 16 June a mortality signal was detected. The female was approximately 0.4 km west of the cub's location but over a ridge, so the site could be approached without disturbing her. Investigation revealed an intact cub carcass lying along a game trail. The cub appeared to be in very poor condition and had not gained weight since being instrumented. No external wounds were observed on the carcass. Subsequent necropsy confirmed the lack of wounds, the poorly nourished condition, and detected no disease-producing organisms. The heart appeared fairly normal, but a narrowing of the aortic valve caused the left ventricle to become hypertrophied, leaving only a slitlike space for the right ventricle. The condition (subaortic stenosis) is congenital, and in the pathologist's opinion, explained the poor growth and condition of the cub and its subsequent death.

Time of Mortality

Without radio-instrumented cubs, the only method for determining when cubs die has been by observation. In Minnesota, where it was hypothesized that most cubs were dying from poor nutrition, the majority of losses occurred by late summer; cubs living until fall survived their entire 1st year of life (Rogers 1977). In Pennsylvania, cubs were normally lost between April and July, and 63% (5 of 8) of females who lost entire litters did so before the end of the June–July breeding season (Alt 1982). In central Arizona cubs disappeared from family groups 71–128 days after departure from the den, and 3 of 5 females lost cubs before the end of the breeding season (LeCount 1984).

In this study, with the exception of the hunter-killed cub, natural mortality occurred 1–86 days after cubs left their dens (Table 2). Only 1 cub died from natural causes after the May–June breeding season. This rapid loss appears to be a result of the type of mortality occurring.

Six of 8 cubs dying during this study were killed by bears and other predators. If bears, especially males, are going to kill cubs it is advantageous for them to do so before the end of the breeding season, because the death of cubs causes the female to come into estrus and be available for breeding. Other predators would also find cubs newly emerged from the den easier to kill. A cub's defense against real or perceived danger is to climb a tree (Herrero 1972); however, even with tree-climbing ability, newly emerged cubs undoubtedly are not as aware of danger, or are as quick to respond to it, as older cubs. Therefore, a cub's greatest vulnerability to predation would be the 1st few days following den emergence.

Table 2. Life span after den emergence for 8 black bear cubs dying in northern Arizona, 1982–85.

Bear no.	Sex	Type of death	Life span (days)
141	M	Bear kill	1
142	F	Bear kill	1
167	M	Bear kill	37
137	M	Bear kill	86
168	M	Mountain lion kill	6
177	M	Bobcat kill	1
136	M	Heart disease	57
135	F	Hunter kill	189

Sibling Mortality

The number of cubs dying per litter appears to depend on the factors causing death. In Minnesota, where berry crop failures were thought to contribute to cub starvation, Rogers (1977) noted partial loss of litters. In Pennsylvania, 73% of females losing cubs lost all their offspring, and in central Arizona, 80%. Cause of cub death in these 2 areas was not verified, but in both areas nutrition was not thought to be a major problem (Alt 1982, LeCount 1984).

In northern Arizona, inadequate nutrition did not appear to be a problem (Mollohan 1985), and all cub mortality appeared to be related to factors other than starvation. In this situation most females lost entire litters. The 23 radio-collared cubs in this study were members of 13 litters. One or more cubs in 7 of these litters (54%) died, and in 6 cases (86%) the total litter was lost (Table 3). However, only 1 case of complete litter loss involved a 1-cub litter (Table 3). This was a female cub that pulled its collar off outside the den approximately 2 days before death. The manner in which the carcass had been eaten suggested predation or cannibalism, but the exact cause of death could not be confirmed. The other 5 litters were all 2-cub litters. In 2 of the 5, the cause of death of both cubs was documented. In 1, both cubs were killed at

Table 3. Mortality rates within 13 litters of black bear cubs in northern Arizona, 1982–85

	N	%
Total litters	13	
2-cub litters	11	85
1-cub litters	2	15
Litters experiencing deaths	7	54
2-cub litters	6	55
1-cub litters	1	50
Litters experiencing total cub loss	6	86
2-cub litters	5	45
1-cub litters	1	50

the same time by another bear, and in the 2nd, 1 cub was killed by a bear and the other shot by a hunter. In the remaining 3 cases, 1 cub of each litter was killed by a mountain lion or bobcat or died from heart disease, but the time and cause of death of the sibling could not be determined because it was either not radio-collared or had pulled its collar off before death. All that was known about these individuals was that they were not observed with their mothers in a den the following winter. In the 1 case of partial litter loss the dead cub was killed by another bear.

In areas where nutrition appears adequate, it is not known why cubs of multiple-cub litters often die after their sibling dies, but this phenomenon could affect cub recruitment into a population. Tait (1980) described cub abandonment as a reproductive strategy for brown bears (*U. arctos*). He demonstrated theoretically that in some populations, mother bears with 1 cub were likely to produce 2 or 3 cubs in their next litter; it was, therefore, to their advantage to abandon the 1 cub, come into estrus, breed, and produce another litter of cubs the following year. With this reproductive strategy, a female could produce a significantly greater number of offspring during her lifetime. Failure to raise a single remaining cub of a 2-cub litter following the death of 1 cub could produce similar results if the cub died before the end of the breeding season.

In this study, of 5 females that lost entire 2-cub litters, 4 lost both their cubs before the end of the breeding season—1 simultaneously and 3 at different times. One of these females could not produce cubs until 1986, so the results of her loss are not known. Of the remaining 3, all produced another litter of 2 cubs the following year, and 2 of the 3 successfully raised their next litter. Therefore, instead of 3 females raising a total of 2 cubs during a 2-year breeding cycle, these individuals added 4 cubs to the population; and more importantly, 2 of them doubled their number of surviving offspring. Obviously the 3 individuals described here are too small a sample to determine if such a reproductive strategy really operates within some bear populations, but these observations lend support to the hypothesis that raising 1 sibling is not reproductively advantageous when nutrition is not limiting reproduction.

CONCLUSION

Black bear cub production appears to be density-independent and is a function of habitat quality and the number of females in the population, with most females producing cubs at near-maximum potential (Rogers 1977, Beecham 1980). Therefore, wildlife managers cannot expect increased cub production to compensate for heavy harvest of subadults and adults. Cub survival also appears to be limited by habitat quality in some areas (Rogers 1976), but in others, such as my northern Arizona study area, social regulation may also be important. Therefore, managers should also consider the effect of heavy hunting on the social structure of the population when setting seasons and bag limits. Increased cub survival may not result from increased harvest.

Adult male black bears do not help feed or defend their young (Jonkel and Cowan 1971). They may, however, indirectly protect their offspring by reducing immigration of new males into an area. Rogers (1977), in his kinship theory, hypothesized that resident males would normally not kill cubs because they typically use the same area year after year and share these areas with their offspring. Therefore, the chances are high that if a resident male killed a cub he would be killing his own offspring. Immigrating males, however, would not run such a risk. For them, killing cubs would eliminate a competing male's young and increase their own chances for mating by causing a female to become receptive for breeding. Thus, as the number of resident males are reduced, the killing of young by immigrating males may increase. Such a phenomenon has been reported in lion and langur populations (Sugiyama 1967, Eisenberg et al. 1972, Schaller 1972, Bertram 1975).

Subjecting bear populations to heavy hunting pressure may also increase cub mortality by reducing the number of adult males. Adult males are normally the 1st bears killed by hunters (Bunnell and Tait 1981).

These males are then replaced by immigrating males (Kemp 1976, Young and Ruff 1982), which could benefit from killing cubs. This appears to be what has occurred in northern Arizona.

The studied population was very heavily exploited: 24% of the animals were shot annually. The mean age of males in the area was 4.2 years, compared with a mean age of 6.2 years for males in a lightly hunted population in central Arizona (LeCount, unpubl. data). Cub survival under the northern Arizona hunting regime averaged only 58%. Predation by other animals and natural deaths accounted for 38% of this loss, but cannibalism caused 50%. The age of bears killing cubs could not be determined, but since few older age animals remained in the population, younger age males were suspected. Therefore, in areas where most cub deaths are not nutritionally- or hunter-related, wildlife managers might not observe increased cub survival rates as compensation for heavy hunting. In fact, heavy hunting may indirectly increase the cub mortality rate by decreasing the number of resident males, thus making hunting mortality additive rather than compensatory.

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