

BROWN AND BLACK BEAR PREDATION ON MOOSE IN SOUTHCENTRAL ALASKA

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ABSTRACT: Causes of moose (*Alces alces*) calf mortality were studied during 1984 in an area where brown bear (*Ursus arctos*), black bear (*Ursus americanus*), and gray wolf (*Canis lupus*) populations were sympatric. Predation by brown bears was the greatest cause of mortality. Brown bears averaged 1 calf and 1 adult moose kill/11.7 and 43.7 bear-days, respectively, during late May-late June, while black bears averaged 1 calf moose kill/40 bear-days during the same period. No adult moose were killed by black bears. There were no statistically significant differences ($P > 0.05$) in predation rates among sexes, ages, or family classes of either brown or black bears. Predation rates were highly variable among individual bears.

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Predation by brown and black bears has recently been identified as an important cause of ungulate mortality in many areas of North America (Schlegel 1976, Franzmann *et al.* 1980, Ballard *et al.* 1981). This is particularly true for moose (Ballard and Larsen 1987, Ballard and Miller 1990). Franzmann *et al.* (1980) determined that black bears were responsible for 59% of calf moose mortalities on the Kenai Peninsula, Alaska. Ballard *et al.* (1981) determined that brown bears in southcentral Alaska were responsible for 79% of calf moose mortalities and were an important predator of adult moose. In both studies, the most numerous of the two bear species was responsible for most of the calf moose mortality. Based on these and subsequent studies, we hypothesized that the most numerous predator species would account for the greatest proportion of calf moose mortality.

Other than the estimate provided by Ballard *et al.* (1981) based on 1 year's data and Boertje *et al.* (1988), no estimates of rates of predation by either brown or black bears on ungulates exist in the literature. This paper reports on causes of moose calf mortality and rates of predation on moose during late spring and summer in areas where brown and black bears occur sympatrically in southcentral Alaska.

STUDY AREA

Brown bear predation rates studies and moose calf mortality studies were conducted in 4 areas and black bear studies in 1 area of the upper and middle Susitna River basins of southcentral Alaska. The 1984 calf moose mortality study was conducted in a 1,325 km² area where brown bear, black bear, and wolves were sympatric. Boundaries, vegetation, topography, and weather have been previously described (Ballard *et al.* 1981, Miller 1985). The areas contained the following densities of predators: wolf-2.8/1,000 km², brown bear-28/1,000 km², and black bear-90/1,000 km² (Miller *et al.* 1987, Ballard *et al.* 1987; unpubl. data). Caribou (*Rangifer tarandus*) were available in low numbers as alternate prey but only 1 kill was observed during the study. Of the 1,325 km² area where bear densities were studied, 532 km² (40%) was classified as black bear habitat. All moose calves were captured within or close to the black bear habitat. Although the average black bear density within the classified black bear habitat was estimated at 90/1,000 km², actual density was probably less in terms of distribution of radio-collared moose calves. Black bear densities were greater in forested habitats along the river where relatively few calves were captured in comparison to forest edges where most calves

were captured. Regardless, black bear density was at least 2 times higher than density of brown bears.

METHODS

Equipment and procedures used to determine causes of moose calf mortality in 1984 have been described by Ballard *et al.* (1979, 1981). Only calves that bonded with the cow following capture were included in calculations. Densities of brown and black bears were estimated using mark-recapture methods described by Miller *et al.* (1987). Wolf densities were determined by methods described by Ballard *et al.* (1987).

During late May and June of 1978, 1981, and 1984, an attempt was made to observe radio-collared brown and black bears once daily (usually twice daily during first 2 weeks of 1978 and 1984) from fixed-wing aircraft to determine if they had killed a calf or adult moose. Data used for calculation of predation rates in 1978 (Ballard *et al.* 1981) were included in these analyses. Black bear predation rates were studied only in 1981 and 1984. Black bear were rare or absent in the 1977 and 1978 moose calf study areas.

During 1984, the same bears monitored during spring were tracked daily between 23 July and 1 August to examine summer predation rates. Individual radio-collared bears observed on ungulate carcasses were assumed to have made the kill unless the carcass exhibited characteristics typical of other causes of death (Stephenson and Johnson 1973, Ballard *et al.* 1979) or other bears or gray wolves were observed. When more than 1 predator was present, the kill was counted as a partial kill by each predator unless the individual or species which had made the kill could be determined. Although calf kills were not examined in situ, examinations of radio-collared calf moose carcasses revealed predation by brown bears was responsible for 65 to 79% of the deaths (Ballard *et al.* 1981; this study).

Starvation mortalities of adult moose could have been misidentified from aircraft and kills could have been made by other predators. To the degree this applied, data on cause of death of adult moose are biased in that they overestimate actual kill rates. All wolf packs were monitored on the same flights made for bears and over half of the individuals within those packs were radio-collared. Wolf kills of adult moose were known, which removed wolf predation as an important source of bias (Ballard *et al.* 1987, unpubl. data). Although ungulates thought to have died from causes other than bear predation were excluded from predation rate calculations, we could not state with 100% certainty that some kills were not scavenged. Bears were considered present on a kill only if they were observed on the carcass or located in close proximity (<1 km).

Ages of radio-collared bears were estimated by tooth cementum annuli similar to methods described by Mundy and Fuller (1964). Bears were considered sexually mature if >5 years old (Ballard *et al.* 1982). Only offspring <1.0 years-old are termed "cubs".

Predation rate (i.e., moose killed/bear-day) is defined as the number of days between new kills. Predation rates were calculated separately for calf and adult moose because of differences in length of time bears remained with carcasses. Because bears can kill and consume a calf moose in <25 minutes and generally remain on calf moose kills less than the time between two daily flights (approximately 12 hours), daily flights would underestimate the number of calf moose kills. Bears were not located or observed during each flight due to inclement weather, overstory vegetation, or loss of radio contact. Predation rates on calf moose were calculated by summing the number of days each bear was observed divided by the total number of calf kills and expressed as 1 kill/no. of bear-days. These rates are considered to be minimum estimates of predation on calf moose.

Fuller and Keith (1980) demonstrated that

wolf predation rates were overestimated when based on numbers of observation days separated by periods of no contact. This was because wolves remained on kills >1 day, so the probability of detecting a kill based on sporadic monitoring was greater than the actual predation rate. This problem was also true for adult moose killed by bears, and preliminary results reported by Ballard *et al.* (1981) overestimated the predation rates on adult moose. To reduce this bias, this analysis included only days and adult moose kills that were preceded by 1 day of observation when no kill had been made. When daily monitoring was interrupted for intervals >1 day, the first day when observations were resumed and any kills observed on that day were excluded from the analysis. When bears were radio-located but not visually observed for 1 day between visuals, that single day was included in calculations for adult moose because a kill would have been confirmed the following day when visually observed. Days in which bears were located but not observed >1 day between visual observations were excluded.

Differences in rates of bear predation among years, sexes, ages, and family classes were tested by Student's *t*-test (Cochran 1977). Unless stated otherwise differences were not considered significantly different if $P > 0.05$.

RESULTS AND DISCUSSION

Causes of Calf Moose Mortality

Between 25 May and 1 June 1984, 46 moose calves ranging in age from 1-10 days were captured and radio-collared. Only 17% of the radio-collared calves survived from birth to early November. Brown bears killed 52% (N = 24) of the calves, while black bears and wolves killed 9 (N = 4) and 7% (N = 3) of the calves, respectively. Other natural mortality factors such as drowning and coyote (*Canis latrans*) predation accounted for approximately 18% (N = 7) of the mortalities. Mortality from all causes was 83%.

Most moose calf mortality occurs during the 6 weeks following birth (Ballard *et al.* 1981). Predation accounted for 86% of all mortalities in 1977, 1978, and 1984, with brown bears accounting for 63% of all mortalities in 1984 and 79% of all mortalities in 1977 and 1978. The calves studied in 1977 and 1978 were collared in areas where black bears were rare or absent. Thus, despite being less dense than black bears in 1984, brown bears were the most important cause of calf moose mortality. Black bears were the second most important cause of mortality, followed by wolf predation.

Based on this study, we conclude that the causes of calf moose mortality were not directly proportional to the relative densities of the three predator species. Brown bears appear to prey on moose calves more frequently than do black bears or wolves. Where brown bears are substantially less dense than black bears, such as on the Kenai Peninsula, Alaska (Franzmann *et al.* 1980), black bears can be frequent predators on calf moose or other ungulates. Elsewhere, wolves can be significant predators on moose calves (Gasaway *et al.* 1983) but their importance relative to varying levels of bear predation warrants further investigation.

Brown Bear Predation Rates

Forty-four adult radio-collared brown bears were monitored from fixed-wing aircraft either once or twice daily during late May-late June 1978, 1981, and 1984. They were visually observed on 921 (82%) of 1,121 relocations. The 44 bears were observed on 64.5 calf moose kills during 756 bear-days of monitoring and 13 adult moose kills during 590 bear-days of monitoring. Because some carcasses were buried or in a position that could not be adequately examined from fixed-wing aircraft, moose age or ungulate species of an additional 20 kills could not be identified. Overall, adult brown bears preyed on calf and adult moose at rates of 1 kill/11.7 and 43.7 bear-days, respectively.

Male brown bears preyed on calf and adult moose during late May-late June at rates of 1 kill/13.6 and 1 kill/45.3 bear-days, respectively (Table 1). Large differences existed in average predation rates by male bears among study years, sexes and age classes, but these differences were not significant, apparently due to large variability in predation rates among individual bears. Predation rates by individual male bears ranged from 0 kills to 1 kill/5.7 bear-days (Fig. 1), and on adult moose from 0 kills (18 bear-days) to 1 kill/4.0 bear-days (4 bear-days).

We recorded greater predation rates on calf and adult moose by female brown bears (Table 2) than male bears, but these differences were not significant. Females accompanied by offspring >1 year-old also appeared to have greater predation rates on calf moose than single females, but again these differences were not significant. Similar to males, lack of significant differences among all ages and family classes appeared to be due to large variability among individual bears (Fig. 1). Predation rates of individual females with offspring >1 year old ranged from 1 calf moose/3.8-21 bear-days, and on adult moose from 0 kills (23 bear-days) to 1/24 bear-days. Predation rates of single female bears ranged from 0 calf or adult moose kills (0/26 bear-

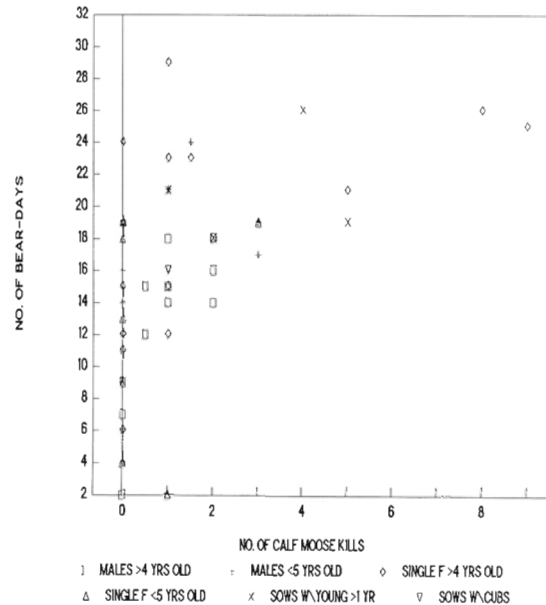


Fig. 1 Number of calf moose kills per number of bear-days monitored for individual adult radio-collared brown bears during late May-late June 1978, 1981 and 1984 in southcentral Alaska.

days) to 1/2.8 and 1/9 bear-days, respectively (Fig. 1). Twenty unidentified kills added as either calf or adult moose did not change the outcome of the statistical comparisons for either male or female bears.

Sample sizes of females with cubs were small for comparisons with other family groups

Table 1. Numbers and rates of calf and adult moose killed by radio-collared male brown bears (>2 yrs age) from approximately 24 May through 30 June 1978, 1981, and 1984 in southcentral Alaska.

Age (yrs)	Family status	Year monitored	No. bears	Calf moose*			Adult moose*		
				No. killed ^b	No. bear-days monitored	Bear-days/kill (SE)	No. killed ^b	No. bear-days monitored	Bear-days/kill (SE)
≥5	Alone	1978	6	3.5	52	14.9 (5.9)	1.5	29	19.3 (14.0)
		1981	1	0	9	0 (0.0)	0	2	0 (0.0)
		1984	5	6.5	76	11.7 (2.5)	0	59	0 (0.0)
		Subtotal	12	10.0	137	13.7 (2.8)	1.5	90	60.0 (46.4)
<5	Alone	1978	5	4.5	75	16.7 (9.8)	2.5	58	23.2 (6.5)
		1984	2	4.0	40	10.0 (5.5)	0	33	0 (0.0)
		Subtotal	7	8.5	115	13.5 (7.7)	2.5	91	36.4 (16.4)
		Total males	19	18.5	252	13.6 (2.7)	4.0	181	45.4 (5.4)

*Prey totals do not include 9 unidentified ungulates which could be either calf or adult moose.

^bKills counted as half kill if more than 1 predator was present.

Table 2. Numbers and rates of calf and adult moose killed by radio-collared female brown bears (>2 yrs age) from approximately 24 May through 30 June 1978, 1981, and 1984 in southcentral Alaska.

Age (yrs)	Family status	Year monitored	No. bears	Calf moose ^a				Adult moose ^a			
				No. killed ^b	No. bear-days monitored	Bear-days/kill (SE)	No. killed ^b	No. bear-days monitored	Bear-days/kill (SE)		
≥5	W/cubs	1978	1	1.0	16	16.0	(0.0)	0	10	0	(0.0)
		Subtotal	1	1.0	16	16.0	(0.0)	0	10	0	(0.0)
≥5	W/yrls. or 2-yr olds	1978	3	8.0	58	7.3	(3.4)	1.0	46	46.0	(43.7)
		1984	2	6.0	52	8.7	(2.9)	1.0	47	47.0	(46.0)
		Subtotal	5	14.0	110	7.9	(4.7)	2.0	93	46.5	(27.0)
≥5	Alone	1978	6	16.5	107	6.5	(2.8)	3.5	90	25.7	(11.0)
		1981	4	0	43	0	(0.0)	0	25	0	(0.0)
		1984	7	10.5	148	14.1	(9.0)	3.0	129	43.0	(26.4)
		Subtotal	17	27.0	298	11.0	(4.3)	6.5	244	37.5	(13.9)
<5	Alone	1978	3	1.0	30	30.0	(42.9)	1.0	24	24.0	(30.0)
		1981	3	3.0	50	16.7	(15.6)	0	38	0	(0.0)
		Subtotal	6	4.0	80	20.0	(14.9)	1.0	62	62.0	(66.6)
		Totals	29	46.0	504	11.0	(3.1)	9.5	409	43.1	(13.0)

^aPrey totals do not include following = 2 moose of unidentified age and 9 unidentified unglates of which 2 were possible kills, all of which could either be calf or adult moose.

^bKills counted as half kills if more than 1 predator was present.

in these studies. However, they appeared to have the lowest predation rate of any of the sex or family groups based on total numbers of visual sightings and numbers of kills observed over an 8-year period (Miller 1987). Because moose parturition occurs at relatively low elevations and females with cubs occupy relatively high elevations for 3-8 week periods after emergence from dens, the two groups are geographically separated.

During late July and early August 1984, 9 of 16 brown bears monitored during spring, plus 8 additional adults, not monitored during that period, were located daily to estimate summer predation rates. Based on numbers of kills observed and bear-days monitored in spring, these 17 bears would have been expected to kill 5 calves and 1.2 adult moose during 52 bear-days of monitoring in mid-summer, if we assume equal prey availability between the two periods. Only 1 moose kill of unidentified age was observed, but the bears were only visually sighted on 44% (71 of 161) of the relocations. Regardless, these data are

consistent with the chronology of radio-collared calf mortalities we recorded previously (Ballard *et al.* 1981): predation by brown bears on calf moose appears to decline substantially after mid-July of each year. Predation rates on adult moose probably also decline after spring-early summer. Boertje *et al.* (1988) reported a decline in predation rates by brown bears from spring to summer.

The length of time brown bears remained at kill sites was highly variable. The minimum period individual bears remained at calf moose kills ranged from 0.4-38.6 hours (N = 9 kills, X = 13.2 hrs., SE = 3.8). The latter average estimate was biased in favor of bears which remained on kills for >12-hour periods. When we made two flights per day, we found that bears remained on 88% of the calf moose kills (N = 32 kills) less than 12 hours. On a daily basis brown bears remained on calf kills an average of 1.1 days (N = 48 kills, SE = 0.06).

Minimum length of time brown bears remained on adult kills averaged 66 hours (N = 12 kills, SE = 12.5 hours, range 7.9-141.2

hours). On a daily basis these bears remained on adult moose kills a minimum of 1-7 days, averaging 2.8 days ($N = 18$ kills, $SE = 0.49$ days). Reasons for the relatively short time spent at adult moose carcasses are unknown, but some of the kills were probably usurped by other bears. Because bears remain on adult moose kills >1 day, predation rates based on periodic relocation of radioed bears would tend to overestimate predation rates (Fuller and Keith 1980). Consequently, brown bear predation rates reported by Ballard *et al.* (1981) based on observation days, overestimated the kill rates of adult moose. Large variation among individual bears prevents development of a correction factor for periodic relocation as proposed by Fuller and Keith (1980) for wolves.

Moose calves are born, and most mortalities occur, from mid-May through mid-July. Adult brown bears killed an average of 5.3 moose calves and 1.4 adult moose during this 60-day period. Estimated predation rates on calf moose were lower than those reported by Boertje *et al.* (1988) during late spring-early summer for interior Alaska, (1 calf moose kill/8.6 bear-days). However, predation rates on adult moose during late spring were similar between the two studies. Autumn moose densities were about 90% lower in interior Alaska than the estimates developed in this study. Also, the Boertje *et al.* spring study extended to 10 June, a period in our study when about half of the calf moose mortality had occurred. We recalculated our calf predation rates to correspond with their earlier time period, but the adjusted rates (1 kill/12.2 days) remained lower than their reported rate.

Black Bear Predation Rates

Radio-collared black bears (7 males, 5 single females, and 5 females with young) were monitored once or twice daily in conjunction with brown bears in late May-late June 1981 and 1984 to determine predation rates. During this period black bears were observed on 79% (452 of 573) of the

relocations. Sample sizes were too small to test for differences in predation rates among ages or family classes. None of the radio-collared bears were observed on fresh carcasses of adult moose. Male black bears were monitored for 151 bear-days and were observed on 6 calf moose carcasses for an average predation rate of 1 kill/25.2 bear-days ($SE = 12.7$). Females with cubs were monitored 92 bear-days and 0 kills observed; single females were observed on 3 calf moose kills during 120 bear-days ($X = 1$ calf moose/40 bear-days, $SE = 16.5$). There were no significant differences in rates of predation on calf moose between male (1 kill/25 bear-days) and female (1 kill/70 bear-days, $SE = 35.4$) black bears. Similar to brown bears, individual black bears exhibited highly variable predation rates, ranging from 0 kills (0/20-29 bear-days) for most bears (53%) to 1 calf moose kill/5.7 bear-days (3 in 17 bear-days). Overall predation rates by adult black bears on calf moose averaged 1/40 bear days.

Thirteen of 17 black bears monitored in spring 1984 plus 3 others not monitored in the spring were relocated several days in late July and early August to determine summer predation rates on moose. Observability of radio-collared bears averaged 71% (59 of 83 relocations). No kills of either calf or adult moose were observed during 59 and 38 bear-days, respectively. Similar to brown bears, a much lower number of kills (2.3 calves and 0 adult moose) was expected during this time period based on number of kills and days monitored in spring. Rates of predation on calf moose by black bears appeared to decline after mid-July in part due to fewer calves being available as prey. During either season, black bears appear to kill few, if any, adult moose.

Black bears were observed remaining with calf moose carcasses an average of 16.8 hours ($N = 4$ kills, $SE = 1.5$ hours). Similar to brown bears this estimate was biased in favor of bears which remained with kills for relatively

long periods. On a daily basis they remained on calf moose kills an average of 1.3 days ($N = 8$ kills, $SE = 0.16$ hours). When we monitored black bears twice daily we found the bears remained on 71% of the calf moose kills ($N = 7$ kills) less than 12 hours.

SUMMARY AND CONCLUSIONS

In a sympatric black and brown bear population where black bears were more numerous than brown bears, brown bears were the largest cause of moose calf mortality. Predation rates by brown bears on calf and adult moose during late spring-early summer averaged 1 kill/11.7 and 1 kill/43.7 bear-days, respectively. Black bears did not prey on adult moose, and their rates of predation on calf moose were substantially less (1 kill/40 bear-days) than those of brown bears. Large variability in kill rates of individual bears of both species was responsible for not detecting significant differences in predation rates by sex, age, or family class. This variability suggests that efforts by managers to increase ungulate survival rates by reducing particular classes of bear (based on sex, age, or family status) is a very imprecise tool for obtaining those objectives. Classes based on family status would be especially imprecise as the same adults would be in different classes in different years.

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