EXTENT, CAUSE, AND TIMING OF MOOSE CALF MORTALITY IN WESTERN INTERIOR ALASKA

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ABSTRACT: We examined the causes and timing of moose *(Alces alces)* calf mortality during 1988-90 in 2 locations in western interior Alaska. Annual survival rates of all calves in 1988 (0.34, n = 42) and 1989 (0.29, n = 47) on the Nowitna National Wildlife Refuge (NWR) and in 1990 (0.25, n = 62) on the Koyukuk NWR were not significantly different. Survival rates of male and female calves were not significantly different during any year. Annual survival of single calves was significantly higher than that for twins in 1989 (0.56 vs. 0.20) and 1990 (0.37 vs. 0.21), but not in 1988. Black bears *(Ursus americanus)* killed 40% of all calves. Wolves *(Canis lupus)* killed 9% of the calves, unknown predators killed 8%, grizzly bears *(Ursus arctos)* killed 3%, and 5% died from other causes.

Previous studies in the boreal forest of North America have documented predation as the predominant source of mortality in moose calves. The principal predator has varied among areas (Ballard and Larsen 1987). Black bears were the principal predator on neonatal moose on the Kenai Peninsula (Franzmann *et al.* 1980, 1984); grizzly bears were the main predator in southcentral Alaska (Ballard *et al.* 1991), eastern interior Alaska (Boertje *et al.* 1987, Gasaway *et al.* 1990), and southern Yukon Territory (Larsen *et al.* 1989); and wolves were a major predator on calves in central interior Alaska (Gasaway *et al.* 1983). Most prior studies in Alaska (e.g., Franzmann 1980, Gasaway *et al.* 1990) determined only summer mortality.

Moose occur throughout the Nowitna NWR and Koyukuk NWR and are a priority species on the refuges. A 1980 population survey on the lower Nowitna River estimated 1,389 moose (341 moose/1,000 km², 90% CL = 1,016-1,763), and the 1986 survey estimated 878 moose (210 moose/1,000 km², 90% CL = 996-1,087), indicating a significant decline (t-test, 0.02 < *P* < 0.05) of 7.4% annually (D. A. Haggstrom, Alaska Department of Fish and Game (ADF&G), pers. comm.). Because predation may be the most important factor in structuring moose populations (Ballard and Larsen 1987), the Koyukuk-Nowitna NWR and the ADF&G initiated a cooperative study of moose calf mortality. The objective of this study was to determine extent, causes, and timing of mortality of moose calves from birth through 12 months of age. Subsequent to the Nowitna study in 1988 and 1989, we repeated the study in an area of the Koyukuk NWR that had an abundant and apparently increasing moose population to determine if differences existed in mortality sources and rates.

STUDY AREA AND METHODS

Our study was conducted in the northern portion (1,500 km²) of the Nowitna NWR along the Nowitna/Yukon River floodplain and in the central portion (650 km²) of the Koyukuk NWR on the Koyukuk River floodplain in western interior Alaska (Fig. 1). Both areas consist of a meandering river system with numerous lakes, meadows, and oxbows. The climate is continental, characterized by long, cold winters and short, warm summers (Selkregg 1976).

Dominant vegetation types include: alluvial mixed forest of white spruce *(Picea glauca)* and paper birch *(Betula papyrifera)*;
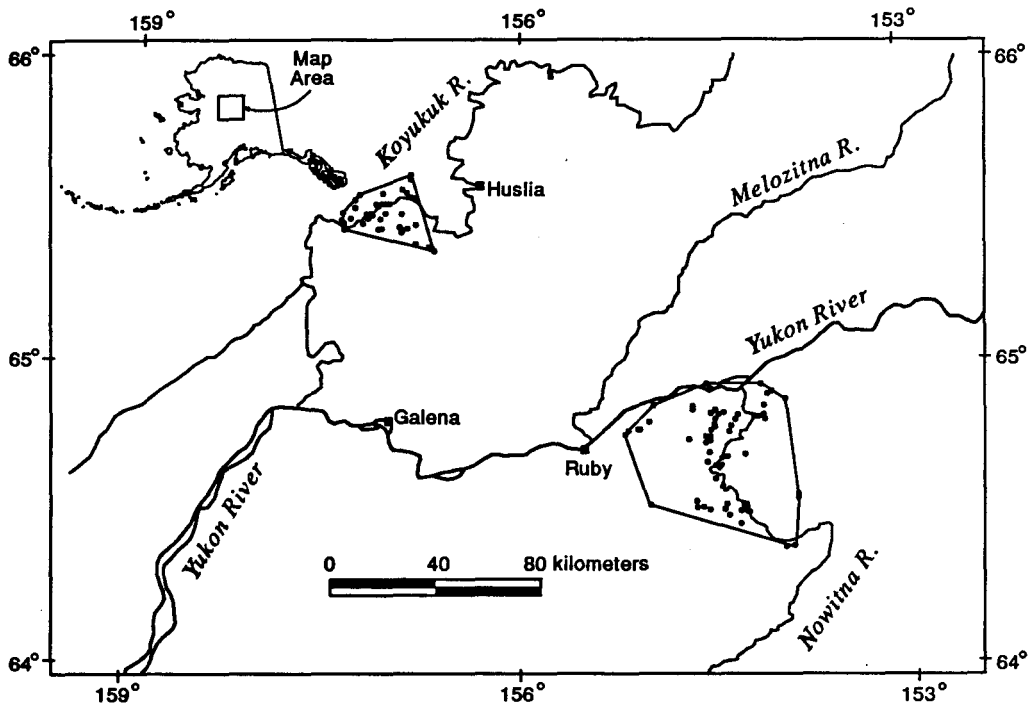
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Fig. 1. The study area in western Alaska showing capture sites of neonatal moose calves.

alluvial deciduous forest of balsam poplar (*Populus balsamifera*); alluvial broadleaf shrub of feltleaf willow (*Salix alaxensis*); lowland open needleleaf forest of black spruce (*P. mariana*); dwarf shrub-graminoid tussock peatland complex with sparse black spruce, larch (*Larix laricina*), resin birch (*B. glandulosa*), Eriophorum sp., and Sphagnum sp.; and old river meander channels that have silted in and vegetated with blue-joint grass (*Calamagrostis canadensis*), diamondleaf willow (*S. planifolia pulchra*), and Bebb willow (*S. bebbiana*).

To determine the onset of calving we flew daily over known calving areas in a Cessna 185 starting on 15 May. Neonatal moose calves were captured, sexed, and collared following methods described by Ballard *et al.* (1981), Franzmann *et al.* (1984), Boertje *et al.* (1987), and Larsen *et al.* (1989). We attempted to capture every calf that was located and did not select for or against single or twin calves. Expandable collars fitted with a MOD300 radio transmitter with mortality-mode (Telonics, Inc., Mesa, Ariz.) similar in design to those used elsewhere in interior Alaska (Boertje *et al.* 1987) were used. In 1988 the transmitters started to wear through the bandage material after 5 months, and 6 dropped off prematurely. All remaining radio-collared calves were immobilized with M-99 and fitted with new collars. The new collar design included a canvas transmitter pocket and Peg® brand self-adhering elastic bandage material which allowed us to eliminate the zig-zag stitching along the edges of the collar (Boertje *et al.* 1987). The self-adhering nature allowed us to increase the maximum circumference of the collar by installing accordion-pleats which released as calves grew.

Radio-collared calves were usually located daily with fixed-wing aircraft for the first 6 weeks of life. Calves were usually monitored on alternate days between the end of June and the end of July, then twice per week during August and September. From October until May calves were monitored 1-

2 times a month, typically by listening for mortality pulses while flying at 1,000-2,000 m. The transmitters had a mortality sensor with a 2-hour delay. Whenever possible all mortalities during the first 6 weeks were investigated within 24 hours of death using standard techniques (Ballard *et al.* 1979). Date of death was estimated as the midpoint between last date confirmed alive and date of confirmed death. All mortality sites were investigated on the ground.

The proportion of calves surviving over time for all years defined 3 survival intervals (21 May-1 Jun, 2 Jun-10 Jul, and 11 Jul-20 May). Daily survival rates within intervals were estimated using MICROMORT (Heisey and Fuller 1985), with daily survival rate assumed to be constant within intervals. Annual survival rates for all calves, males vs. females, and single vs. twin calves were also estimated using MICROMORT (Heisey and Fuller 1985). Calves with unknown fate, such as failed radio transmitters, were considered alive until the last day of radio contact and then dropped from the calculations.

MICROMORT calculates daily survival as the number of radio-days that animals survived in an interval divided by the total number of radio-days that animals were monitored (Heisey and Fuller 1985:669). Thus, the survival rate is a proportion of days alive. We compared daily survival rates among intervals each year with a multiple comparison procedure recommended by Zar (1984:400-402). Also, annual survival rates were compared among years using this method. Differences among annual survival rates were tested for males vs. females and single vs. twin calves each year using a 2-tailed Z-test for proportions (Zar 1984:395-396). For all tests, groups being compared were assumed to be independent.

Numbers of moose and sex-age composition were estimated using stratified random sampling (Gasaway *et al.* 1986) in a 4,026-km^2 area on the Nowitna NWR in 1980, 1986,

and 1990 and a 8,555-km^2 area on the Koyukuk NWR in 1987. On the Koyukuk NWR, annual trend surveys for age-sex composition and density following Gasaway *et al.* (1986) were conducted from 1981 to 1989 within a 219-km^2 area that was within the calf survival study site. Although no confidence estimates or sightability correction factors are available for these trend surveys, the same techniques and personnel were used each year.

RESULTS

One hundred sixty calves were captured during 21-30 May for all 3 years, with 92% captured 21-24 May. Thus, the algorithms used to calculate survival rates in MICROMORT should be suitable for our data because each year all calves were radio-marked essentially at the same time (Heisey and Fuller 1985, Pollack *et al.* 1989). All calves captured were less than 3 days old based on aging criteria in Ballard *et al.* (1979).

In 1988 we captured 46 calves on the Nowitna NWR. The sample included 17 single calves, 13 sets of twins, and 3 calves with unmarked siblings. During the capture period the twinning rate of all cows observed (n = 42), including cows with calves not captured, was 48%.

In 1989 we captured 49 calves on the Nowitna NWR with 13 single calves, 17 sets of twins, and 2 calves with siblings not captured. The twinning rate was 58% for 114 cows observed.

In 1990 we captured 65 calves on the Koyukuk NWR with 24 single calves, 20 sets of twins, and 1 calf with sibling not collared. Twinning rate was 44% for 45 cows.

In 1988 capture time averaged 5 min (range 60 sec-15 min). By 1989 and 1990 we had reduced mean capture time to 103 sec (range 15 sec-5 min, n = 114).

All midpoint interpolations of death for periods >3 days (n = 12) occurred after 15 August. Six mortalities of the 1988 cohort were from periods of 3-21 days (x = 12 days),

and 3 mortalities of the 1989 cohort were from periods of 16-33 days ($x = 26$ days). Two deaths from the 1990 cohort were the midpoint of 20-day periods. A third death (unknown cause) in 1990 was interpolated as the midpoint of the last visual on the calf (10 Oct) and the next time we saw its radio-collared sibling and mother without it (25 Feb). This last calf had a transmitter that gradually weakened in signal strength until it was not audible beyond 100 m.

Daily survival rates of the 3 intervals were significantly different ($P < 0.001$) in 1988 ($X^2 = 59.91$), in 1989 ($X^2 = 77.00$), and in 1990 ($X^2 = 116.47$). Multiple comparisons for each year indicated that daily survival rates increased with consecutive interval ($P < 0.05$) for all comparisons except between first and second intervals in 1989 ($0.05 < P < 0.10$). The proportion of calves surviving to the end of each interval varied among years (Table 1).

Annual calf survival rates averaged 29% over the 3 years and were not significantly different among years ($X^2 = 3.02$, $0.10 < P < 0.25$; Table 2). For 1988-90 combined, male survival was not different from female survival ($Z = 0$), but survival of single calves was different from that of twin calves ($Z = 3.22$, $P = 0.001$; Table 2). Survival rates of single calves (Table 2) were not different from twin calves in 1988 ($Z = 0.23$, $P = 0.818$), but survival of single calves was higher in 1989 ($Z = 3.02$, $P = 0.003$) and in 1990 ($Z = 2.37$, $P = 0.02$). An interaction between sex and calf status (single vs. twin) would confound the 2 previous analyses, but further dividing of sample sizes would have made survival esti-

mates substantially less precise.

Black bears accounted for at least 40% of the calf mortality over the 3 years (Table 3). We do not have estimates of bear numbers. However, our frequent overflights of the study area suggested that black bears were common and grizzly bears were rare. Of the 12 natural mortalities during winter, wolves were responsible for 8. We found 3 calves dead in lakes, and necropsy showed contusions and hemorrhaging, which indicated that a predator had attacked the calves. We presumed that the calves had taken refuge in the lake and either died of injuries or drowned.

The Nowitna NWR moose population in 1990 was 1,214 (309/1,000 km^2, 90% CL = 1,000-1,428), indicating an 8.5% average annual increase since 1986 (D. A. Haggstrom, ADF&G, pers. comm.). Although confidence limits around the estimates overlap, we assume that the increase meant that our calf mortality study was conducted during a population increase rather than a decrease as we had assumed at the onset.

The density of moose in the Koyukuk NWR study area as determined by trend surveys has increased from 1,600 moose/1,000 km^2 in 1981 to 3,700 moose/1,000 km^2 in 1989. A population estimate (Gasaway et al. 1986) in 1987 revealed 3,400 moose/1,000 km^2, confirming the trend survey data. No surveys were conducted in 1990.

DISCUSSION

This study was initiated to determine the extent and characteristics of calf mortality in

Table 1. Proportion of moose calves of known fate surviving to the end of 3 intervals during their first year of life on the Nowitna (1988 and 1989) and Koyukuk (1990) National Wildlife Refuges, Alaska.

	% Alive at End of Interval		
Interval	1988 (n = 42)	1989 (n = 47)	1990 (n = 62)
21 May - 1 Jun	78	72	68
2 Jun - 10 Jul	60	38	44
11 Jul - 20 May	38	30	38

Table 2. Annual survival estimates[a] for moose calves on the Nowitna (1988, 1989) and Koyukuk (1990) National Wildlife Refuges, Alaska.

	1988			1989			1990			All years		
	n	x	95% CL	n	x	95% CL	n	x	95% CL	n	x	95%CL
All calves	42	0.34	0.22-0.52	47	0.29	0.18-0.45	62	0.25	0.16-0.39	151	0.29	0.23-0.38
Males[b]	22	0.42	0.25-0.70	16	0.32	0.16-0.63	33	0.24	0.13-0.45	71	0.30	0.21-0.42
Females[b]	14	0.23	0.09-0.62	29	0.26	0.14-0.49	29	0.29	0.17-0.52	72	0.28	0.19-0.41
Singles	14	0.27	0.10-0.73	12	0.56	0.33-0.93	24	0.37	0.21-0.66	50	0.42	0.29-0.59
Twins	28	0.35	0.21-0.58	35	0.20	0.10-0.39	38	0.21	0.12-0.39	101	0.25	0.18-0.36

[a] Estimates derived from MICROMORT software (Heisey and Fuller 1985).
[b] Six calves in 1988 and 2 calves in 1989, sex not determined.

Table 3. Fate of moose calves monitored from birth to 1 year old (May-May) on the Nowitna National Wildlife Refuge in 1988 and 1989 and the Koyukuk National Wildlife Refuge, Alaska in 1990.

	1988		1989		1990		All years	
	n	%	n	%	n	%	n	%
Censored calves	0	0	8	17	9	15	14	9
Causes of mortality								
Black bear	14	33	20	42	26	42	60	40
Grizzly bear	1	2	1	2	3	5	5	3
Wolf	6	14	4	9	3	5	13	9
Unknown predator	2	5	5	11	5	8	12	8
Drowning	2	5	0	0	1	1	3	2
Unknown cause[a]	1	2	2	4	3	5	6	4
Surviving calves	16	38	7	15	11	18	34	23
Total	42	99	47	100	62	100	151	99

[a] In 1988 the probable cause was starvation (23 Mar). In 1989 the probable causes were disease (10 Aug) and starvation (8 Mar). In 1990, 2 sets of twins had 1 calf censored (3 Jun and 18 Dec), suggesting death, and 1 calf likely died of starvation (15 Apr).

an apparently declining moose population on the Nowitna NWR and was expanded to examine calf mortality in an increasing population on the Koyukuk NWR. Although population estimates were not sufficient to discern actual trends with confidence because of irregular timing, we suspect the Nowitna moose population was increasing during the mortality study.

Mean annual survival of moose calves in this study was similar to survival estimates for calves in southcentral Alaska (0.31 for males, 0.34 for females; Ballard et al. 1991). Survival of single calves in our study was significantly higher than for twin calves during 2 of 3 years, contrary to prior studies in Alaska

(Franzmann and Schwartz 1986, Boertje et al. 1987, Ballard et al. 1991) in which there was no significant difference.

Black bears caused about 35% of moose calf mortality on the Kenai Peninsula, Alaska (Franzmann et al. 1980, 1984) and were the principal predator in our study. In contrast, grizzly bears killed 43% of the radio-collared moose calves in the Nelchina and Susitna basins of southcentral Alaska (Ballard et al. 1981) and 52% of calves in eastcentral Alaska (Boertje et al. 1987). Other studies in interior Alaska indicated that wolf predation was the major source of calf mortality (Gasaway et al. 1983; D. G. Kelleyhouse, ADF&G, pers. comm.).

High calf mortality in the first 8 weeks of life was also evident in earlier studies (Fig. 2). On the Kenai Peninsula it was 57% and 51%, respectively. Boertje *et al.* (1987) reported 76%, Larsen *et al.* (1989) reported 60%, and Ballard *et al.* (1981) reported 52%. An exception was D.G. Kelleyhouse (pers. comm.) reporting only 33%. Because grizzly bears usually kill both twins at the same time (Boertje *et al.* 1987), the survival rate of calves in areas with grizzlies as the main predator is lower than in areas where black bears are the main predator (Fig. 2).

Although the principal predator may vary across regions, predation on moose calves in Alaska and adjacent Canada is consistently high. The reproductive strategy of highly synchronous calving coupled with high twinning rates and low adult mortality seem to compensate for high calf mortality. Our limited data on changes in moose density on the Koyukuk and Nowitna NWRs suggest that calf mortality alone is not limiting abundance of older moose.
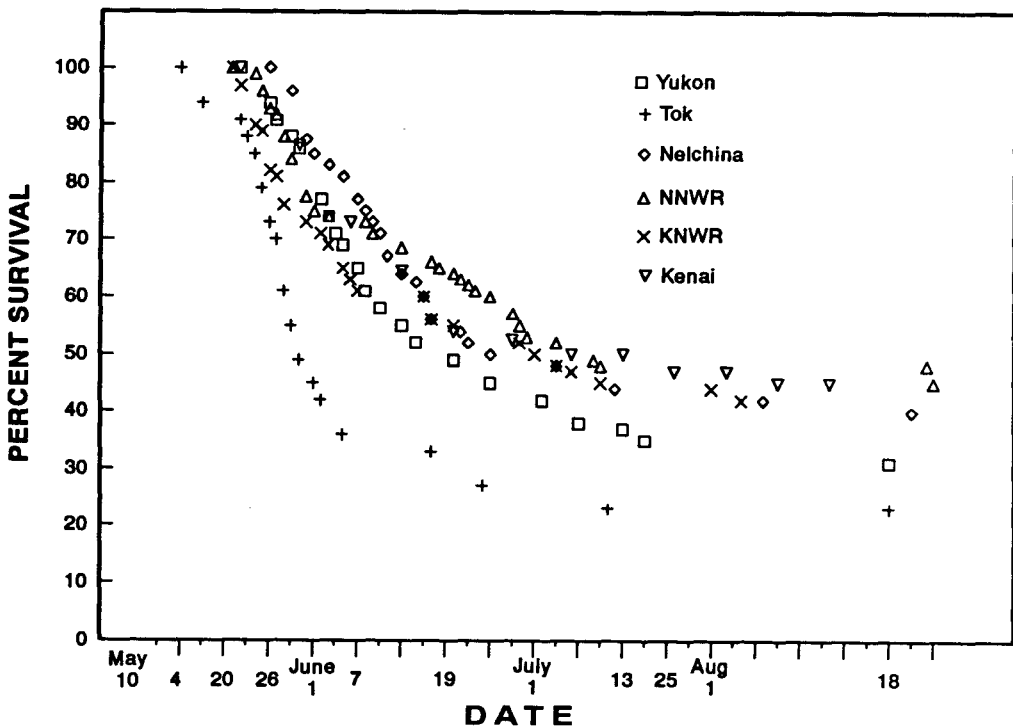
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MOOSE CALF SURVIVAL

Fig. 2. Moose calf survival during the first 100 days of life from 6 studies in Alaska and Canada. Yukon, *n* = 48 (Ballard *et al.* 1981); NNWR (Nowitna NWR), *n* - 95; KKNR (Koyukuk NWR), *n* = 65, and Kenai, *n* = 117 (Schwartz and Franzmann 1989).

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