EFFECTS OF WINTERS ON PHYSICAL CONDITION OF MOOSE IN SOUTH-CENTRAL ALASKA

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ABSTRACT: We compared several blood parameters and morphometric measurements of adult female and newborn calf moose (*Alces alces*) during late winter and early summer in relation to winter severity during 1977 through 1985 in south-central Alaska. We examined packed cell volume, percent hemoglobin, calcium, phosphorus, beta globulin, albumin, total protein and glucose. Late-winter adult female moose blood parameters following a severe winter were significantly ($\underline{P}$ <0.05) lower than those following mild winters reflecting reduced condition following a severe winter. However, there were no differences ($\underline{P}$ >0.05) in blood and morphometric measurements of calf moose born following moderate winters in relation to those following a severe winter suggesting that neonates were not affected by the nutritional status of adults following one severe winter.

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Franzmann (1985) established baseline values for assessing moose condition during spring, following mild or average winter conditions. He used the "animal indicator concept" to reflect the nutritional status of moose populations. Comparisons of different populations following similar mild winter conditions allowed moose populations to be subjectively rated by nutritional status. Franzmann *et al.* (1976, 1987) and Franzmann (1985) suggested that biologists could use these criteria to rate moose condition within a population by comparing blood and morphometric measurements over a series of years following average or mild winters, as long as comparative measurements were conducted during similar time periods. However, Franzmann (1985:252) also concluded that the greatest limitation of most parameters is the inability to differentiate relative goodness. Extreme differences were easy to quantify but less dramatic differences were more difficult to assess.

Because condition evaluation based on blood parameters reflects climatic and nutritional (i.e., browse quality and quantity) influences (Franzmann and LeResch 1978), differences in winter severity should be reflected in blood values. We hypothesized that following a relatively severe winter, blood values from adult cow moose captured during late spring would be significantly lower than blood values following relatively mild winters. To test this we compared several adult moose blood parameters (packed cell volume [PCV], percent hemoglobin [HB], calcium [CA], phosphorus [P], glucose [G], total protein [TP], albumin [AB], and beta globulin [BG]) following mild and relatively severe winters during 1977-1985 in south-central Alaska.

Mech *et al.* (1987), Messier (1991) and

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McRoberts *et al.* (1995) debated the effects of severe winter weather on adult and calf ungulates. Mech *et al.* (1987) hypothesized that deep snow would adversely effect calf survival by restricting adult females from obtaining adequate food during the gestation period. They concluded that following three consecutive harsh winters there was a cumulative effect on neonates and successive cohorts. Cow moose who were restricted in movements by deep snow would tend to produce less viable calves. Franzmann *et al.* (1980) also provided baseline blood parameters and morphometric measurements for neonate Alaskan moose from the Kenai Peninsula and Unit 13 during 1977-1979. However, there was no indication as to what constituted a neonate in average or better condition. Therefore, we examined whether blood and morphometric values following a severe winter in 1979 were significantly different from values obtained following mild or average winter conditions during 1977, 1978, and 1984. We hypothesized that newborn calf moose born following severe winter conditions would be smaller in size, have lower birth weights, and lower blood level values than calves born following mild or average winters.

HISTORY AND DESCRIPTION OF STUDY AREA

The study was conducted in Game Management Unit 13 (GMU 13) in south-central Alaska. Vegetation, elevational use, and winter severities of the area were described by Skoog (1968); Bishop and Rausch (1974); Ballard and Taylor (1980); Ballard *et al.* (1982, 1987, 1991). During the 1940s and 1950s the moose population increased in response to favorable range conditions, low number of predators, and relatively low human harvests. The moose population apparently peaked in 1963 and then began declining in response to severe winters (Ballard *et al.* 1991). Wolf (*Canis lupus*) and moose numbers appeared to be inversely correlated leading to a wolf population control program during 1948-53 (Rausch 1967, 1969). When wolf control terminated in 1953 the wolf population increased and peaked in 1965; wolf predation was suspected to have contributed to a moose population decline (Bishop and Rausch 1974). The history of this moose population has been described by Bishop and Rausch (1974) and Ballard *et al.* (1991).

A series of studies were initiated in 1976 to determine the cause of the moose population decline. These studies involved investigation of wolf predation (Ballard *et al.* 1987), bear (*Ursus arctos* and *U. americanus*) predation (Ballard and Miller 1990; Ballard *et al.* 1990), and moose productivity and survival (Ballard *et al.* 1991). Initially there was concern that perhaps moose in Unit 13 were in relatively poor condition and that they may have been predisposed by other mortality factors besides predation. Preliminary investigation of moose condition based upon blood and morphometric measurements (total length, neck circumference, heart girth, and hind foot length) suggested that moose in Unit 13 were in relatively good condition following mild winter conditions compared to several other Alaskan moose populations (Ballard and Taylor1980). After the initial studies, biologists continued to collect blood and morphometric measurements on moose in Unit 13 in subsequent years during which the moose population increased at annual rates ranging from 1.02 to 1.23 (Ballard *et al.* 1991).

METHODS

We collected blood from adult females during March or April 1977-1985, and both blood and morphometric (i.e., chest girth, neck circumference, hindfoot length, and body weight) from neonates during late May and early June 1977-1984, from several study areas in the northern half of GMU 13 (Ballard *et al.* 1991). Blood parameters measured included packed cell volume, percent hemoglobin, calcium, phosphorous, glucose, total protein, albumin, and beta globulin.

Adult moose were captured in March or April each year by helicopter darting using several different types of drug combinations (Ballard and Tobey 1981, Franzmann *et al.* 1984). Newborn moose calves were captured on foot during late May and early June (Ballard *et al.* 1979). Blood collections were performed as outlined by Franzmann *et al.* (1974), Franzmann and Arneson (1973), and Franzmann and LeResche (1978).

Winter severity was assessed using the winter severity index (WSI) developed by Ballard *et al.* (1991). The index was based on U. S. Soil Conservation Service (SCS) snow -survey data collected during 1963-64 to 1985-86. Four snow sites near areas where moose were captured were used to develop the index. The WSI was composed of the average 3-month cumulative snow depths. The WSI was based on two assumptions: (1) the amount of snow cover during mid to late winter (January-April) was more important in terms of moose mortality than early winter snow depths; and (2) snow depths were the most important factor causing malnourishment in moose. There were three categories of winter identifiable using the WSI: (1) severe winters (WSI 28.0), (2) mild winters (WSI 18.0), and (3) moderate winters (WSI = 18 - 27.9).

Statistical Tests

Tests for equality were carried out between years for all blood and morphometric parameters. Differences among average values were tested by t-tests and Kolmogorov-Smirnov tests (Zar, 1984). Comparisons between WSIs and blood and morphometric data were analyzedwith Spearman's rank correlations (Conover 1971).

RESULTS AND DISCUSSION

There were no significant correlations ($P > 0.05$) between the 8 measured blood parameters for adult moose and average winter conditions (severe 1979 winter excluded) as indicated by the WSIs (Table 1). This suggested that there was no difference in the physical condition of cows following mild or moderately severe winters.

However, blood parameters obtained following the severe winter of 1979 (WSI = 28.3), were significantly lower ($P < 0.05$) for 22 of 32 blood comparisons made with those obtained following mild winter conditions (Tables 1 and 2). Also, 5 of 7 comparisons were significantly lower ($P < 0.05$) when 1979 was compared with the mildest winter (i.e., 1981) according to the WSI. Therefore, the blood parameters we measured appear useful for identifying severe winters and support our hypothesis that blood parameters would be significantly lower following a severe winter than following mild winters.

Blood parameters following winter 1977 were significantly higher ($P < 0.05$) than those obtained in other years for 26 of 32 comparisons (Table 2). Winter conditions during this year were moderate (WSI = 26.8) in comparison to other years and moose densities were the lowest during the study period (Ballard *et al.* 1991). Although we could detect no overall correlations among mild winter years there did appear to be a declining trend in adult female condition especially when 1977 values were compared with 1985 values. The latter values were lower than 1977 values for 6 of 8 comparisons (Table 1).

Of the 12 blood and morphometric values examined for neonatal calf moose (Table 3), the values following the severe winter of 1978-79 were not significantly different for 18 of 25 comparisons with years following mild or moderate winter conditions (Table 4). For 5 of 7 comparisons that were significantly different ($P < 0.05$), 1979 values were higher than those occurring following mild

Table 1. Average blood values of adult female moose captured during late winter and early spring in relation to winter severity indices (see text) in southcentral Alaska, 1977-1985.

		Blood Parameters																							
		PCV (%)			Hb (g/dL)			Ca (mg/dL)			P (mg/dL)			Glucose (md/dL)			TP (g/dL)			Albumin (g/dL)			Beta Globulin (g/dL)		
Year	WSI[a]	x̄	SD	N	x̄	SD	N	x̄	SD	N	x̄	SD	N	x̄	SD	N	x̄	SD	N	x̄	SD	N	x̄	SD	N
1977	26.8	50.2	3.5	51	18.8	1.4	25	11.2	0.8	49	4.5	1.0	49	152.4	26.6	49	7.1	0.6	54	4.9	0.6	54	0.9	0.4	54
1979	28.3	41.0	3.4	15	17.2	1.5	15	9.5	1.0	16	5.0	0.8	16	111.2	22.4	15	5.6	0.6	16	4.0	0.4	16	0.3	0.1	16
1980	25.8	42.8	5.1	25	17.7	1.3	25	10.2	0.5	26	5.1	1.3	26	129.5	21.5	26	6.9	0.5	26	4.8	0.3	26	0.5	0.3	26
1981	19.0	44.2	4.3	10	17.8	1.8	11	10.5	0.6	9	5.2	1.0	9	134.2	24.6	9	6.6	0.4	10	4.7	0.3	10	0.4	0.1	10
1985	23.5	45.9	5.4	19	16.6	1.9	19	10.5	0.8	19	5.3	0.8	17	114.5	14.0	19	7.2	0.9	19	4.2	0.4	19	0.5	0.1	19

[a] Winter severity index.

Table 2. P-values for comparisons of average annual blood parameters for cow moose captured in late winter and early spring in southcentral Alaska, 1977-1985.

Parameter	Year	1979	1980	1981	1985
PCV	1977	<0.001	<0.001	<0.001	<0.001
	1979		0.233	0.050	0.004
	1980			0.449	0.050
	1981				0.383
Hb	1977	<0.002	<0.010	<0.050	<0.001
	1979		0.264	0.390	0.342
	1980			0.901	0.029
	1981				0.116
Ca	1977	<0.001	<0.001	<0.020	<0.002
	1979		<0.001	0.023	0.003
	1980			0.175	<0.050
	1981				0.849
P	1977	>0.050	<0.050	>0.050	<0.010
	1979		>0.100	0.515	0.241
	1980			0.844	>0.200
	1981				0.815
G	1977	<0.001	<0.001	>0.050	<0.001
	1979		0.013	0.028	0.599
	1980			0.591	<0.005
	1981				0.012
TP	1977	<0.001	>0.050	<0.020	>0.050
	1979		<0.001	<0.001	<0.001
	1980			0.122	>0.010
	1981				<0.005
AB	1977	<0.001	>0.050	>0.050	<0.001
	1979		<0.001	0.001	0.254
	1980			0.179	<0.001
	1981				0.009
BG	1977	<0.001	<0.001	<0.001	<0.001
	1979		<0.001	0.007	<0.001
	1980			>0.200	0.999
	1981				0.026

or moderate winters (Table 4). The two exceptions involved chest girth measurements that were significantly greater (P <0.05) in 1979 than in 1977 and beta-globulins that were significantly lower than 1977 values. The difference in girth measurements is difficult to explain because body weights were not significantly different (P > 0.05) and this difference may have been due to measurement error. Franzmann and LeResche (1978) indicated that beta-globulin was the only globulin component that significantly increased with increased condition class, however, because this parameter is influenced by excitability it may be a misleading indicator of condition. These comparisons suggest that although the adult female moose were in relatively poor condition as a result of the severe winter of 1978-79, their lowered physical condition did not result in the production of calves in poorer physical condition as indicated by blood and morphometric values. Therefore we failed to accept our research hypothesis that newborn calves were smaller and had lower blood parameters than those born following mild winter conditions.

McRoberts *et al.* (1995) believed that the cumulative results of three severe winters would result in adult females that were in relatively poor condition and that these females would produce calves that would also be in relatively poor condition. Mech *et al.* 91987:623) stated that the inverse effect of the previous winter's snow on offspring viability the following summer was an accepted tenet of ungulate ecology. In this study, measurements were not made on the cumulative effects of severe winters on either adults or neonates. Instead, neonate blood and morphometric measurements were compared following three mild or moderately severe winters and one severe winter, and no differences were found in the average values. Following one severe winter there did not appear to be any adverse effects on the condition of neonates even though adult females did ex-

Table 3. Average blood and morphometric measurements of neonate moose captured in late spring and early summer within southcentral Alaska, 1977-1984.

Year	1977			1978			1979			1984		
WSI[a]	26.8			21.3			28.3			22.2		
	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
PCV (%)	21.3	16.9	22	17.3	14.6	27	17.2	15.0	14			
Hb (g/dL)	16.9	10.9	19	16.1	8.3	25	15.9	8.1	12			
Ca (mg/dL)	11.3	2.3	22	11.1	0.5	19	11.5	0.9	12			
P (mg/dL)	6.99	1.8	19	7.9	1.6	19	9.9	1.7	12			
Glucose (mg/dL)	146	31.5	19	131	37.2	20	141	29.5	12			
TP (g/dL)	4.9	1.3	22	5.0	0.5	19	5.1	0.4	12			
Albumin (g/dL)	2.6	0.8	22	2.2	0.4	19	2.7	0.2	12			
Beta Globulin (g/dL)	1.0	0.3	22	0.7	0.2	19	0.7	0.1	12			
Body Weight (kg)	17.6	3.9	29	18.1	3.7	29	19.8	3.6	15	17.5	3.2	19
Chest girth (cm)	58.1	5.8	27	59.4	5.0	27	70.4	35.7	14			
Neck Circum. (cm)	28.2	3.0	27	29.0	2.5	27	28.0	3.2	10			
Hind Foot Len. (cm)	43.8	4.2	29	45.0	2.0	25	48.5	11.6	15			

[a] Winter severity index.

hibit lower blood values that were indicative of nutritional stress following a severe winter. Neonates were not affected by the condition of adult females over one severe winter, based upon the parameters measured in this study.

Schwartz and Franzmann (1989) suggested that moose forage created by wildfire declines both in quantity and quality after approximately 25 years. There have been no significant improvements in moose habitat due to wildfire for at least 35 years and moose populations increased during the study at annual finite rates of increase ranging from 1.02 to 1.23 through at least 1985 (Ballard *et al.* 1982, 1991). Perhaps the quantity and quality of fire-created moose habitat in GMU 13 had already begun to decline prior to initiation of moose studies in 1977. Slight changes in habitat quality and quantity would probably not be detected with the parameters we measured because of large variations among individual moose and their subpopulations, and because blood parameters are only useful for determining large differences in condition (Franzmann 1985). However, gross trends in declining blood parameters may lend support to the hypothesis that moose condition in GMU 13 is slowly declining due to declines in forage quality or quantity and increasing moose densities.

Lastly, it should be noted that the use of the WSI developed by Ballard *et al.* (1991) may only crudely reflect winter severity conditions in the study area because it was based solely on snow depths. Other factors such as snow crust, snow pack density, temperature, and wind affect winter severity and these parameters were not measured in this study. Clearly, further refinement of winter severity indices is necessary to separate the effects of severe winter conditions from habitat condi-

Table 4. P-values for comparison of average annual blood and morphometric measurements for neonate moose calves in southcentral Alaska, 1977-1984.

Parameter	Year-	1978	1979	Parameter	Year-	1978	1979
PCV	1977	0.373	0.465	Hb	1977	0.785	0.787
	1978		0.993		1978		0.944
Ca	1977	<0.001	<0.050	P	1977	0.103	<0.001
	1978		<0.050		1978		0.003
G	1977	0.165	0.627	TP	1977	>0.05	>0.2
	1978		0.430		1978		>0.2
AB	1977	<0.001	>0.05	BG	1977	<0.001	<0.001
	1978		<0.001		1978		0.096
Weight[a/]	1977	0.622	0.069	Chest	1977	0.370	<0.005
	1978		0.138		1978		>0.200
Neck	1977	0.258	0.870	Hind Foot	1977	>0.500	>0.050
	1978		0.299		1978		>0.200

[a/] 1977 vs. 1984 = *P* 0.931.

tions during mild or moderate conditions.

SUMMARY

Our data suggest that blood values for adult female moose following severe winters are generally lower than those following average or mild winter conditions. Although adult female moose reflected nutritional stress due to severe winter conditions as reflected by increased snow depths, these stresses were not reflected in blood values, morphometric measurements, or weights of newborn calves following a severe winter.

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