ALASKA DEPARTMENT OF FISH AND GAME

JUNEAU, ALASKA

STATE OF ALASKA
Jay S. Hammond, Governor

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Ronald O. Skoog, Commissioner

DIVISION ON GAME
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Steven R. Peterson, Research Chief

NELCHINA YEARLING MOOSE MORTALITY STUDY

by
Warren B. Ballard
Craig L. Gardner
and
Sterling D. Miller

Volume II

Federal Aid in Wildlife Restoration
Projects W-21-1 and W-21-2, Job 1.27R
with Additional Support from the Alaska
Power Authority

(May 1982)

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ERRATA

This report was erroneously titled Progress Report; it is instead the Final Report for Job 1.27R. The correct period covered is July 1, 1978 to June 30, 1981.

FINAL

JOB ~~PROGRESS~~ REPORT (RESEARCH)

State: Alaska

Cooperators: Warren B. Ballard, Craig L. Gardner, Sterling Miller, John Westlund, and Dennis McAllister.

Project No: W-17-11 & W-21-1 Project Title: Big Game Investigations

Job No.: 1.27R Job Title: Nelchina Yearling Moose Mortality Study

Period Covered: March 1, 1980 to June 30, 1981.

SUMMARY

Causes and rates of calf (< 6 months), short yearling (7 to 12 months), and yearling (13 to 24 months) moose mortality were studied in Game Management Unit 13 from late March 1979 through June 1981. As of 1 July 1981, the status of 64 moose captured as short yearlings in 1979 was as follows: 22 had lost their radio collars due to poor collar design; the status of 8 others was unknown, 17 died, and 17 were alive. Annual mortality rates for the 1978 cohort were 76-80% the 1st year and 5% the 2nd year.

An additional 34 calves were captured and radio-collared in November 1979 to assess 1st year survival following removal of 48 brown bears from the study area. From capture to 1 June 1980, 6% of the moose died. No other mortality of radio-collared calves was observed. Second year mortality was 4%, and was attributed to unknown causes. The low rate of mortality prior to 1981 was attributed to a mild winter and low predator densities.

During fall 1980, both a standard moose sex-age composition survey and an intensive quadrat sampling technique were used in the bear transplant area to both compare sex-age data acquired from the 2 methods and to obtain estimates of moose density. Results of the comparisons are briefly described.

Census and composition data collected in 1980 were used to adjust sex-age composition data collected in fall 1979. Based upon this readjustment it was calculated that the fall 1979 calf:cow ratio following the brown bear transplant was 73:100. Corrected 1979 composition data were used to calculate mortality from birth to 1 November 1979 following the bear transplant. Calves that died from all mortality factors in 1979 was estimated at 9%. In comparison, studies conducted in 1977 and 1978 revealed that mortality during the same time period was 55%; 80% of which was attributable to predation by brown bears. Approximate rates of 1st year moose mortality under varying rates of wolf and bear predation and winter kill are presented and discussed. This analysis suggested that the largest increases in 1st year survival occurred when brown bear densities were temporarily reduced. It was tentatively concluded that the moose population was not being limited by deteriorating range conditions and that predation, primarily by brown bears, was preventing the moose population from increasing.

Key Words: moose, calf mortality, yearling mortality, bear predation, wolf predation

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BACKGROUND

Studies of wolf (Canis lupus) food habits in the Nelchina and Susitna River Basins of southcentral Alaska (Game Management Unit 13) from 1975 through 1980 suggested that from January through July each year, wolves were preying upon calf and yearling moose disproportionately to their presence in the moose population (Ballard et al. 1981). Consequently, this study was initiated to determine the importance of wolf predation to yearling moose survival. First year results of this study were reported by Ballard and Gardner (1980).

During the 2nd year of study, additional calf moose were captured and radio-collared to assess the causes and extent of yearling moose mortality in an area of reduced brown bear (Ursus arctos) density. Background for this portion of the study was provided by Ballard et al. (1980,1981).

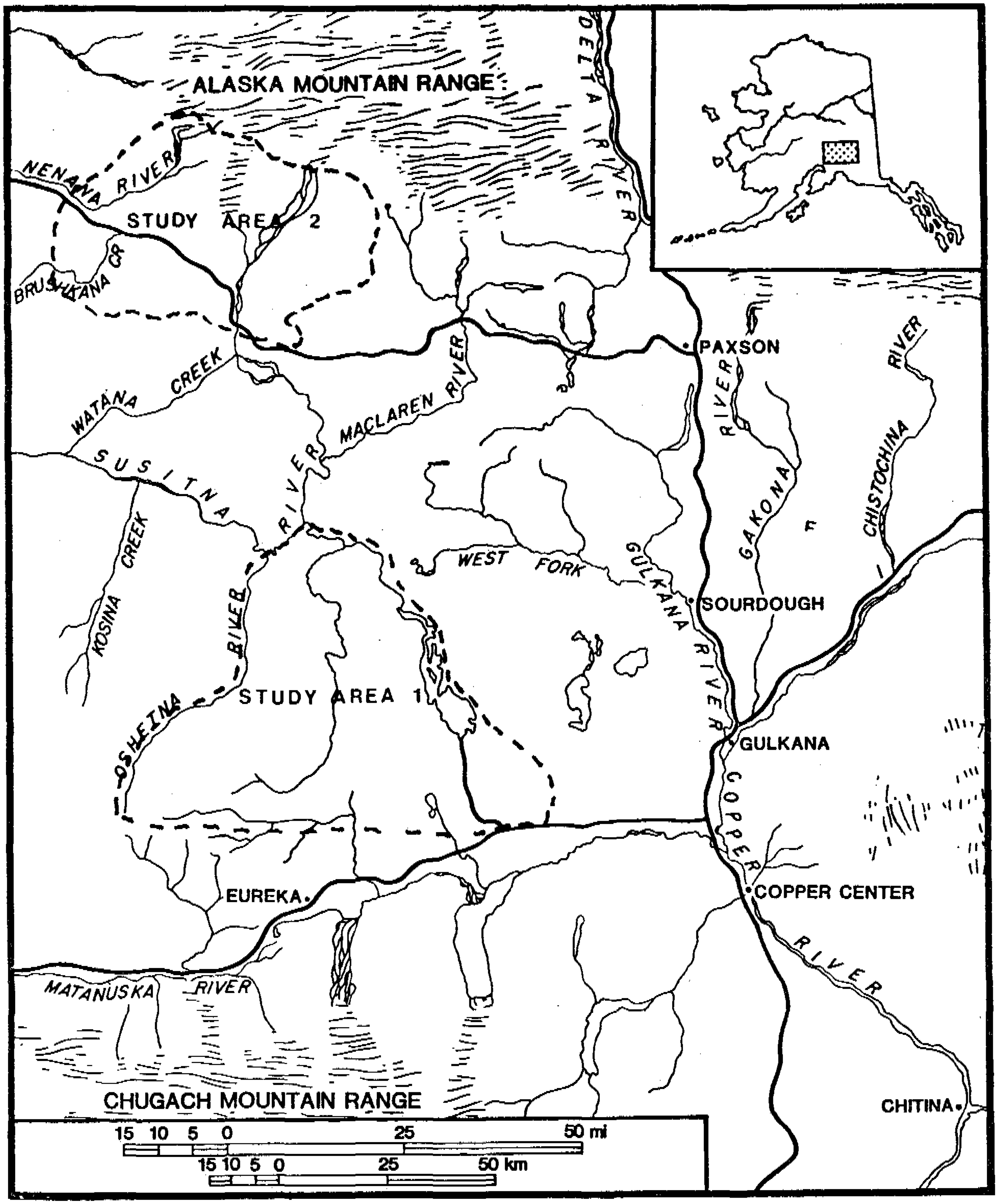
OBJECTIVES

To determine the extent and causes of yearling moose mortality in the Nelchina and Susitna River Basins of southcentral Alaska.

PROCEDURES

Yearling moose mortality was studied in 2 areas of GMU 13 (Fig. 1). Short yearling moose (7 to 12 months) were captured in Area 1 during March and April 1979, while calf moose (≤6 months) were captured in Area 2 during late November 1979. An additional 17 short yearlings were captured in March 1981 as part of the Susitna Dam Studies but this group will be discussed in the final report. Information on topography, weather, geology, and vegetation of this area has been presented elsewhere (Skoog 1968, Ballard and Taylor 1980, Ballard 1981).

Fig. 1. Location of study area in southcentral Alaska where causes of short yearling moose mortality were studied from March 1979 through June 1981.



Capture, processing, and radio-monitoring methods were described by Ballard and Gardner (1980) and Ballard et al. (1979). Procedures used on moose captured in the bear removal area in November 1979 were identical to those used earlier with the following exceptions: (1) 5 cc (1 mg/ml) of M-99 (D-M Pharmacuticals, Inc. Rockville, MD) was used to immobilize calves, (2) radio collars were constructed of butyl rubber with 2-3 inches of foam rubber lining the inner circumference to permit growth: (3) no blood samples were taken.

Annual mortality rates were calculated by multiplying percent survival estimates from different sampling periods within a year by one another and then subtracting from 100%.

RESULTS AND DISCUSSION

Capture related statistics including morphometric and blood parameters for short yearling moose captured in March-April 1979 were presented in Ballard and Gardner (1980) and will not be repeated here. Table 1 summarizes these statistics for Area 2 calves captured in November 1979.

During this reporting period a paper comparing bone marrow fat between long bones and mandibles for moose and caribou (Rangifer tarandus) was presented at the 17th North American Moose Conference and Workshop (Appendix A).

1978 Cohort

The status on 1 June 1981 of 64 short yearlings captured in Area 1 during 1979 is given in Table 2. As reported earlier, a large number (n=22, 34%) of the radio collars fell off due to problems with collar design (Ballard and Gardner 1980). Of the remaining radio-collared short yearlings, 17 were alive on 1 June 1981, and the status of 8 was unknown because of either dispersal or radio failure. Of the 34 known status moose, 17 (50%) had died. Causes of death for these were: 10 winter-killed (59%), 3 brown bear predation (18%), 2 hunter kills (12%), 1 unidentified predation (6%), and 1 tagging mortality (6%).

Table 3 summarizes the rates and causes of annual calf and yearling moose mortality for Area 1 from March 1979 through June 1981. Moose which either had lost their collars or whose status as of 1 June was unknown were excluded from calculations for the preceding year. Natural causes, primarily winter-kill (77% of mortality), accounted for 30% mortality of the short yearlings from late March to 1 June 1979. Results of calf mortality studies during 1977 and 1978 indicated that 45% of the moose calves survived to 1 November (Ballard et al. 1981). Based upon this survival rate and that of short yearlings (70%), for every 100 calves produced in 1978, a minimum of 69 died. However, this figure is conservative because it excludes the period between 1 November to late March during which time some moose doubtless

Table 1. Location, ages, physical measurements, incisor status and other statistics associated with capturing and collaring 34 calf moose in Game Management Unit 13 from 27 November through 30 November 1979.

Accession #	Date	Collaring Location	Sex	Age (Months)	Measurements (cm) Total Length	Hind Foot	Neck Circum.	Chest Girth	Drug Dosage (cc)	Induction Time
120375	11/29/79	Between Windy and Valdez Creek	M	5	215	67	69	156	5	--
120376	11/29/79	Windy Creek	M	5	210	67	65	148	5	--
120377	11/29/79	Windy Creek	F	5	207	65	65	136	5	--
120378	11/29/79	Windy Creek	F	5	212	66	67	162	5	--
120379	11/29/79	Between Windy and Valdez Creek	M	5	---	--	--	---	5	7
120380	11/29/81	Valdez Creek	F	5	206	69	60	142	5	--
120381	11/29/81	Middle Fork of Susitna River	M	5	---	--	--	---	5	--
120382	11/29/81	Middle Fork Susitna River	M	5	---	--	--	---	5	9
120383	11/29/79	Valdez Creek	F	5	213	72	67	173	5	9
120384	11/29/79	Valdez Creek	F	5	218	70	62	152	5	--
120385	11/29/79	Valdez Creek	M	5	212	73	64	157	5	--
120386	11/29/79	Gracious House	F	5	202	67	66	152	5	--
120387	11/29/79	Susitna Lodge	F	5	222	68	65	157	5	9
120388	11/27/79	Windy Creek	M	5	205	72	70	163	5	9

Table 1. (cont'd)

Accession #	Date	Collaring Location	Sex	Age (Months)	Measurements (cm) Total Length	Hind Foot	Neck Circum.	Chest Girth	Drug Dosage (cc)	Induction Time
120389	11/27/79	Between Windy and Valdez Creek	F	5	205	70	67	150	5	7
120390	11/27/79	Between Windy and Valdez Creek	F	5	202	--	68	---	5	--
120391	11/27/79	Between Windy and Valdez Creek	M	5	214	72	70	163	5	15
120392	11/27/79	Between Valdez and Windy Creek	M	5	190	--	67	155	5	--
120393	11/27/79	Between Windy and Valdez Creek	M	5	210	--	--	---	5	--
120394	11/27/79	Between Windy and Valdez Creek	F	5	205	--	--	---	5	--
120395	11/27/79	Between Windy and Valdez Creek	M	5	200	--	79	---	5	--
120396	11/30/79	West Fork Susitna River	M	5	197	63	66	144	5	3
120397	11/30/79	West Fork Susitna River	F	5	199	67	61	140	5	11
120398	11/30/79	Mdl Fork Susitna River	M	5	200	68	68	162	5	12
120399	11/30/79	Mdl Fork Susitna River	M	5	202	65	70	158	5	12
120400	11/30/79	West Fork Susitna River	M	5	211	67	62	148	5 1/	24
120401	11/30/79	West Fork Susitna River	M	5	214	66	68	142	5	10
120402	11/30/79	Mdl Fork Susitna River	M	5	201	--	66	134	5	8
120403	11/30/79	Mdl Fork Susitna River	F	5	207	65	67	150	5	9
120404	11/30/79	Mdl Fork Susitna River	F	5	213	65	61	142	5 1/	19
120405	11/30/79	Mdl Fork Susitna River	F	5	192	66	62	139	5	11
120406	11/30/79	West Fork Susitna River	F	5	211	69	61	154	5	6
120407	11/30/79	West Fork Susitna River	F	5	198	67	67	148	5	9
120408	11/30/79	West Fork Susitna River	M	5	204	67	64	148	6	12

1/ Was darted twice.

Table 2. Summary of the status by date of 64 radio-collared short yearling moose from March 1979 to 1 June 1981 in the Nelchina Basin of Southcentral Alaska.

I.D. #	Sex	Radio #	Surviving to 6/1/81	Slipped Collar	Lost Radio Contact	Bear Predation	Winter Kill	Hunting Mortality	Tagging Mortality	Unk. I.D. Pred.
120255	F	3600		6/7/79						
120227	M	3617		4/5/79						
120229	M	3586			7/2/79					
120231	M	3602				5/29/79				
120233	F	3589		7/9/79						
120235	M	3603		5/31/79						
120236	F	3606		4/8/79						
120237	F	3619		4/30/79						
120239	F	3611					4/11/79			
120241	M	3582						9/79		
120244	F	3581		4/5/79						
120249	M	3594	X							
120250	M	3616		4/30/79						
120252	F	3610		5/22/79						
120253	F	3583		5/79						
120254	M	3604		4/5/79						
120255	F	3592		4/8/79						
120256	F	3620		4/5/79						
120257	M	3607			6/23/79					
120258	F	3599					4/5/79			
120259	F	3585			4/5/79					
120260	F	3561		4/5/79						
120261	M	3629			10/7/80					
120262	F	3621		10/7/80						
120263	F	3584		4/14/79						
120264	F	3588	X							
120265	M	3601			1/80					
120266	M	3597		4/5/79						
120267	F	3618		4/8/79						
120268	M	3596			3/08/80					
120269	M	3590	X							
120270	M	3593					4/6/79			

Table 2 (cont'd)

I.D. #	Sex	Radio #	Surviving to 6/1/81	Slipped Collar	Lost Radio Contact	Bear Predation	Winter Kill	Hunting Mortality	Tagging Mortality	Unk. I.D. Pred.
120271	M	3613			8/7/80					
120273	F	3612					4/14/79			
120275	F	3615		4/10/79						
120276	F	3622		4/12/79						
120277	M	3623				5/2/79				
120278	M	3598					4/20/79			
120279	F	3614		4/6/79						
120280	M	3608		4/30/79						
120281	M	3605					4/27/79			
120284	M	3587					4/27/79			
120285	M	3595					4/27/79			
120287	M	3582					5/2/79			
120288	F	3620							4/20/79	
120290	F	3599	X							
120291	F	3618	X							
120292	M	3507					5/18/79			
120293	F	3604	X							
120294	M	3615	X							
120295	M	3591				8/4/79				
120296	F	3587								5/18/79
120297	F	3595	X							
120298	F	3612	X							
120299	F	3592	X							
120300	F	3598	X							
120301	M	3622	X							
120302	F	3611	X							
120303	F	3605	X							
120304	M	3617						9/12/79		
120305	F	3606			3/18/81					
120306	F	3620	X							
120307	F	3593	X							
120308	F	3581	X							

Table 3. Rates and causes of annual mortality (March 1979 to June 1981) of moose captured as short yearlings in late winter 1979 in GMU13 of southcentral Alaska.

	Dates					
	3/79 - 6/1/79 1/		6/2/79 - 6/1/80		6/2/80 - 6/1/81	
	No.	%	No.	%	No.	%
Sample Size	43	100	24	100	17	100
Causes of mortality						
Natural						
Winter Kill	10	23	0	0	0	0
Bear Predation	2	5	1	4	0	0
Unknown Predation	1	2	0	0	0	0
Subtotal	13	30	1	4	0	0
Hunting	0	0	2	8	0	0
Total	13	30	3	13	0	0
No. Surviving	30	70	21	87	17	100

1/ Does not include period from birth up to March 1979.

died during 1978-79 (the 2nd most severe winter on record in terms of total snowfall and to wolf predation). During winter 1978-79, 7 of 17 (41%) short yearlings of radio-collared cows perished (Ballard and Taylor 1980). Thus, a more accurate estimate of 1st year mortality during a severe winter was 73%; however, even this estimate may be low because 16 of 33 of the radio-collared adults occupied an area of low wolf density (Ballard and Taylor 1978). Correspondingly, many of the short yearling losses were probably attributable to winter-kill. During winters 1978-79 and 1979-80, it was estimated that 2 wolf packs had preyed upon 9 to 24% of the short yearlings during late winter (Ballard et al. 1981). During this study, no losses of radio-collared yearlings were attributable to wolf predation even though wolf studies indicated short yearlings were being killed. We do not know if the lack of wolf predation on the radio-collared yearlings from March through June was representative, or if sample size, or other unknown factors, precluded its identification. Thus, including losses due to winter wolf predation we estimate that 1st year mortality during this year with a severe winter ranged from 79 to 84% based upon the following assumptions: 55% newborn moose calf mortality attributable primarily to bear predation; 30 to 41% winter and spring mortality of surviving members of this cohort primarily from starvation and bear predation; and a maximum of 24% mortality due to wolf predation (total mortality estimated by multiplying individual survival rates, and subtracting from 100%, therefore, summing the individual rates will exceed 100%).

Yearling mortality of the 1978 cohort was 14%, however, hunting losses accounted for 2/3 of this mortality. Therefore, 2nd year natural mortality was estimated at 5% which was similar to the 6% adult mortality estimated by Ballard and Taylor (1980) for adult moose. No mortality was observed for 2-year-old moose.

Rates and causes of mortality for the 1978 bull cohort from late March through May 1979 are summarized in Table 4. Mortality during this time period was estimated at 43%, while yearling (2nd year of life) losses, including hunting mortality, were 38%. Excluding hunting, natural mortality from 2 June 1979 to 1 June 1980 was 17%. No mortality was observed among 2-year-olds, which suggests that new hunting regulations based upon antler restriction (legal bulls must have an antler spread of 36 or more) are protecting this cohort from hunting mortality. Winter kill (n = 7) and bear predation (n = 3) were the causes of natural mortality. Rate of natural mortality for males of the 1978 cohort during the 1st and 2nd years of life was significantly greater ($P \leq 0.05$) than for females. Based upon blood parameters used by Franzmann and LeResche (1978) to assess the physical condition of adult moose, male short yearlings were in poorer physical condition at the time of capture than were females (Ballard and Gardner 1980).

Table 4. Rates and causes of annual mortality of bull moose captured as short yearlings in late winter 1979 in southcentral Alaska (GMU13).

	Dates					
	3/79 - 6/1/79 1/		6/2/79 - 6/1/80		6/2/80 - 6/1/81	
	No.	%	No.	%	No.	%
Sample Size	21	100	8	100	3	100
Causes of mortality						
Natural						
Winter Kill	7	33	0	0	0	0
Bear Predation	2	10	1	13	0	0
Subtotal	9	43	1	13	0	0
Hunting	0	0	2	25	0	0
Total	9	43	3	38	0	0
No. Surviving	12	57	5	62	3	100

1/ Does not include period from birth up to March 1979.

1979 Cohort

The status of 34 moose calves studied in Area 2 from November 1979 through June 1981 is summarized in Table 5. Twenty-seven moose were known to be alive as of 1 June 1981. Two died from winter-related causes in March 1980 while 2 others died of unknown causes, and 1 slipped its collar during winter 1980-81. Radio contact with 4 moose (3 in 1980, 1 in 1981) was lost due to either radio failure or dispersal.

Table 6 summarizes rates and causes of annual mortality to 1 June 1981 for moose captured as calves in November 1979. Excluding early neonatal losses (pre-November), 1st year (11/79-6/1/80) mortality due to winter-related causes was 6%, significantly less ($P \leq 0.05$) than that suffered by the 1978 cohort during the severe winter of 1978-79. This significantly lower mortality rate can be attributed to milder snow conditions during winter 1979-80 and perhaps to reduced bear predation. High survival was also confirmed during a spring composition survey flown on May 23, 1980 (Table 7). Because bull moose cannot be accurately identified from aircraft during spring, we assumed the spring sex ratio of adults was identical to the fall 1979 bull:cow ratio (18 males:100females). Subtracting adult bulls (n=14) from the total numbers of adults counted (n=93) yielded an estimate of 58 short yearlings:100 cows (includes cows $\leq$ 2 yr olds). This estimate was comparable with the fall ratio of 58 calves:100 cows ($\geq$ 2 yrs old) which indicates survival was quite high.

Second year survival of the 1979 cohort during winter 1980-81 was similar to that experienced by the 1978 cohort during 1979-80; 96% survival in 1980-81 for the 1979 cohort versus 95% (excluding hunting) survival in 1979-80 for the 1978 cohort.

Evaluation of Brown Bear Transplant

Routine moose sex and age composition counts were conducted in Moose Count Area 3 during early November 1980. Immediately following the composition count, the area was censused using quadrat sampling techniques developed by Gasaway (1978), Gasaway et al. (1979), and Gasaway and Dubois (unpubl. report). Comparison of the resulting sex and age composition data, in addition to the fall population estimate, is summarized in Table 8. Similar to comparisons made elsewhere in Alaska, calf:100 cow ratios provided by quadrat sampling methods were considerably higher than those provided from standard composition counts (Gasaway pers. commun.) This discrepancy is related to survey intensity and a higher probability of observing large groups of moose which proportionately contain fewer calves.

We used the relationship between the 1980 moose composition counts and the quadrat sampling to recompute ratios obtained in 1979 following the transplanting of 48 brown bears (Ballard et al. 1980; Miller and Ballard 1983). Based upon the 1979 calf: cow ratio of 52:100 estimated from a composition count, the estimated ratio, had the area been censused, would have been 73 calves:100 cows, while the bull:cow ratio would have been 15:100.

Table 5. Summary of the status by date of 64 radio-collared short yearling moose from March 1979 to 1 June 1981 in the Nelchina Basin by southcentral Alaska.

I.D. #	Sex	Radio #	Surviving to 6/1/81	Slipped Collar	Lost Radio Contact	Bear Predation	Winter Kill	Hunting Mortality	Tagging Mortality	Unk. I.D. Pred.
120375	M	5712	X							
120376	M	5517			12/2/80					
120377	F	5199			3/19/81 1/					
120378	F	5190	X							
120379	M	5185	X							
120380	F	5181	X							
120381	M	5197	X							
120382	M	5182	X							
120383	F	5186			7/18/80					
120384	F	5175	X							
120385	M	5196			3/27/80					
120386	F	5171	X							
120387	F	5195	X							
120388	M	5180	X							
120389	F	5176	X							
120390	F	5192	X							
120391	M	5193	X							
120392	M	5174	X							
120393	M	5191	X							
120394	F	5194	X							
120395	M	5200	X							
120396	M	5184	X							
120397	F	5179	X							
120398	M	3992	X							
120399	M	3597								12/6/80
120400	M	5183	X							
120401	M	5178					3/6/80			
120402	M	5198	X							
120403	F	3623	X							
120404	F	3602	X							
120405	F	3614					3/6/80			
120406	F	5187		3/19/81						
120407	F	5173	X							
120408	M	5188	X							

1/ Radio-failure confirmed present with radio-collared twin.

Table 6. Rates and causes of annual mortality of moose captured as calves in November 1979 southcentral Alaska (GMU13).

	Dates			
	11/2/79 - 6/1/80 1/		6/2/80 - 6/1/81	
	No.	%	No.	%
Causes of mortality	33	100	28	100
Natural Mortality				
Winter kill	2	6	0	0
Bear predation	0	0	0	0
Unknown predation	0	0	0	0
Unknown causes	0	0	1	4
Subtotal	2	6	1	4
Hunting	0	0	0	0
Total	2	6	1	4
No. surviving	31	94	27	96

1/ Does not include period from birth to November 1979.

Table 7. Summary of spring moose composition survey conducted in Moose Count Area 3 on 23 May 1980 in the upper Susitna River Basin of southcentral Alaska.

# Adults without short yearlings	# Females with 1 short yearling	# Females with 2 short yearlings	Lone yearlings	Total # short yearlings
58	30	5	6	46

Adults = 93

Short Yearlings = 46

% Short Yearlings = 36%

Count time: 250 minutes

Table 8. Comparison of moose sex-age composition data collected from standard moose surveys to that obtained from quadrat sampling techniques used in Moose Count Area 3 during November 1980 in the upper Susitna River Basin.

	Date	Tot. bulls per 100 cows	Sm. Bulls per 100 cows	Sm. bulls per 100 lg. bulls	Sm. bulls % in Herd	Calves per 100 cows $\geq$ 2 yrs.	Calves per 100 cows	Incidence of twins per 100 cows w/calf	Calf % in herd	Animals per hour	Total sample	Count time (hr.)	Area Sampled (mi^2)	Minutes/ (mi^2)
Composition count	11/1-2	36.7	21.8	146.4	11.9	40.1	31.4	16.3	17.2	37.0	344	9.3	273.5	2.0
Census	11/2-4	29.9	20.1	203.9	11.6	55.0	43.9	13.9	25.3	27.8	459	16.5	247.5	4.0
Stratification	11/1	--	--	--	--	--	--	--	--	89.9	187	2.15	273.5	.5

	$\bar{x}$ moose/group	% of observed moose comprised of singles	% of observed moose comprised of pairs	% of observed moose comprised of groups of 3	% of observed moose comprised of groups of 4 or more
Composition count	2.7	9.6	29.9	8.3	52.2
Census	2.6	7.6	34.4	20.9	37.0
Stratification	2.7	7.5	32.1	17.6	42.8

Population Estimate = 473 = $\mp$ 38 (90% CI = 435 - 510).
(uncorrected for observability)

Similarly, the calf percentage of the herd would have been 45%. We estimated calf survival in Moose Count Area 3 following the bear transplant by applying these ratios to a hypothetical moose population of 1,000. According to our projections, this hypothetical population, in early November, would have been comprised of 450 calves, 83 bulls, 60 yearlings cows (assumed to be sexually immature) and 407 cows. Assuming a pregnancy rate of 90% (Ballard and Taylor 1980), 366 cows should have produced calves in 1979. Twinning rates were calculated based upon 89 newborn moose calves captured in Count Area 3 from 1977 through 1979, yielding a twinning rate of 35% or a gross production of 135 calves/100 cows (Ballard et al. 1980). Therefore, 494 calves should have been produced. Since 450 calves, theoretically, were alive by 1 November, after the period when most neonatal losses occur (Ballard et al. 1981), an estimated 44 calves died following a reduction in bear density of approximately 60% (Ballard et al. 1980). This provides an estimate of 9% calf mortality from birth to 1 November in 1979. Similar to the above analysis, we applied the relationship between the 1980 composition count and census data to the 1977 and 1978 composition counts which were conducted prior to the reduction in bear density. The resulting estimated mortality rates were 60 and 55% for 1977 and 1978, respectively. These latter estimates were similar to those observed for radio-collared moose calves.

Calf mortality studies conducted in GMU 13 during 1977 and 1978 prior to bear removal suggested that 55% of the newborn moose calves died between birth and 1 November of each year (Ballard et al. 1981). During 1979, after bears had been removed, the radio-collared calf data continued to indicate that about half of the calves were being killed by bears. We discounted these data for this analysis because of the following: 1) relatively small sample size (27 in 1979 versus 120 in 1977 and 1978); 2) the smaller sample of calves was concentrated in a relatively small area which made calves vulnerable to a relatively small number of bears (Ballard et al. 1980); and 3) comparisons of fall calf:cow ratios with other unmanipulated moose count areas suggested that there had been a significant improvement in calf survival. Based upon the estimated mortality rate derived from the 1979 composition count the temporary reduction in brown bear density may have reduced calf mortality from 55 to 9%, an 84% decrease in total mortality.

Mortality of calves and short yearlings in Count Area 3 during winter 1979-80 was estimated at 6%. Therefore, during the year of the bear reduction program, 1st year mortality of the 1979 cohort due to early neonatal losses and winter kill totaled an estimated 14%. No losses were attributable to wolf predation; however, if wolves had preyed upon 24% of the calves (the maximum estimate of wolf predation) and short yearlings from 1 November through early spring 1979, the 1st year mortality rate would have been 36%.

Table 9 summarizes approximate rates by cause of 1st year moose mortality for the Nelchina and upper Susitna River Basins as determined from several studies conducted from 1975 through 1981. Based upon these estimates, 1st year moose mortality varied from 23 to 84% depending upon the magnitude of bear predation, wolf predation, and winter severity. These figures do not consider winter-kill and wolf predation as compensatory mortality factors, nor do they consider variations in moose density. Nevertheless, they provide a general estimate of the extent of mortality from the 3 major mortality factors. This analysis suggests that the largest increases in survival occurred when brown bear densities were temporarily reduced to the level attained during the bear transplant.

According to this simple model, with high bear predation and severe winters, a reduction in wolf pack size from 7-8 to 2 wolves only resulted in a 7% decrease in mortality. A similar difference also occurred with the same conditions, but during mild winters. However, the difference between high and low wolf pre dation with high bear predation levels during severe versus mild winters was 22%.

During years of low bear predation, such as that following the bear transplant (Ballard et al. 1980), a difference in high and low wolf predation during severe winters would result in an estimated difference of 14% mortality, while during mild winters the projected difference was 13% (Table 9). With low predation by both bears and wolves during a mild winter, 1st year mortality was at its lowest level (23%).

The high survival of calf and yearling moose in Area 2 could be attributed to reduced brown bear predation as a result of the transplant (Ballard et al. 1980) and the mild winter of 1979-80. The high survival rates documented in this study suggest that at least on a short-term basis, the study area's moose population was not being limited by deteriorating range conditions and that predation, primarily by brown bears, was preventing the moose population from increasing.

RECOMMENDATIONS

1. Continue to monitor survival of moose captured in 1979 and 1981.

2. Initiate a long-term study to develop a satisfactory brown bear harvest strategy which would reduce bear predation and allow the moose population to increase while maintaining a viable bear population.

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Table 9. Estimates of 1st year moose mortality by cause and time period for the Nelchina and Susitna River Basins of Southcentral Alaska.

% Mortality birth - 1 Nov. (level of bear predation)	% Mortality from winter kill-1 Nov. - 1 June (winter severity)	% Mortality from wolf predation-1 Nov. - 1 June (predation level)	Total calculated first year mortality 7/
High 1/ .55	Severe 3/ .41	High 5/ .24	.84
		Low 6/ .09	.77
	Mild 4/ .06	High 5/ .24	.68
		Low 6/ .09	.62
Low 2/ .09	Severe 3/ .41	High 5/ .24	.68
		Low 6/ .09	.54
	Mild 4/ .06	High 5/ .24	.36
		Low 6/ .09	.23

1/ Mortality rate estimated from calf mortality studies (Ballard et al. 1981) and includes 20% of total mortality which was not attributable to brown bear predation.

2/ Based upon estimated calf production and survival following a 58% reduction (transplant) in brown bear density (see text, this report).

3/ Determined from observations of short yearling losses of radio-collared adult moose during 1978-79 (Ballard and Taylor 1980).

4/ Determined from observations of radio-collared calf moose during 1979-80.

5/ Extrapolated from predation rates for 2 wolf packs numbering 7-8 wolves studies during winter 1979-80 (Ballard et al. 1981). Percentage of calves preyed upon was determined by estimating the total pack area moose population by estimating % of moose observed according to survey (from Gasaway and Dubois, unpub rept.).

6/ Extrapolated from predation rate for 1 wolf pack numbering 2 wolves studied during winter 1978-79 (ballard et al. 1981). Percent calves preyed upon estimated same as that described for #5.

7/ Assumes no compensatory mortality. Annual mortality was estimated by determining percent survival from birth to 1 November and from 1 November to 1 June. The estimates were then multiplied and the sum subtracted from 100%.

and Game), and William Martin (U. S. Fish and Wildlife Service) participated in the tagging operations.

Special appreciation is extended to Mr. Alfred Lee, Lee's Air Taxi Service, not only for donating flying time, but also for helping pick up the radio collars which slipped off moose. Many of the projects successes could be attributed to the interest and effort given by Mr. Lee.

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Karl Schneider, Steve Peterson and Karen Wiley reviewed this report and made a number of suggestions for improvement. SuzAnne Miller advised us on statistical procedures.

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APPENDIX A.

Copy of paper presented at 17th North American Moose Conference and Workshop held in Thunder Bay, Ontario (April 21-23, 1981).

USE OF MANDIBLE VERSUS LONGBONE TO EVALUATE PERCENT MARROW FAT IN MOOSE AND CARIBOU

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Abstract: During winters 1977 through 1980 the mandible and a longbone were collected from moose (*Alces alces*) and caribou (*Rangifer tarandus*) kills found while conducting a wolf (*Canis lupus*) moose relationship study in southcentral Alaska. Percent marrow fat for the paired samples was correlated, suggesting that mandibles could be used in lieu of longbones for marrow fat analyses. Results of the study were compared with those obtained for Ontario moose and were combined for analysis. Percent fat for the paired bones was correlated for both calf and adult moose; however, the slopes and intercepts for the two age classes were different, suggesting differences in fat mobilization by age class.

Marrow fat of longbones has been widely used as an index of physical condition in North America ungulates. Prior to 1970 procedures for determining marrow fat content consisted of either crude visual estimates based upon marrow color and consistency, or extraction procedures which were relatively expensive and time consuming. Development of Neiland's (1970) dry weight for determining percent marrow fat in caribou allowed marrow fat content to be quantified with relative ease and low cost per sample.

Since 1970, Neiland's (1970) method of determining marrow fat content has been widely used on a number of ungulate species for assessing physical status. This type of information is of particular interest to students of predator-prey relationships because it allows inferences to be drawn about the physical condition of prey selected by predators. For comparison, samples from nonpredator killed ungulates are needed to determine condition of predator kills relative to the condition of other members of the population.

The most widely used bone for determining percent marrow fat of ungulates has been the femur (Cheatum 1949), although other longbones have been widely used also (Peterson 1977). Percent fat in the mandibular cavity has also received some attention as an indicator of physical condition (Baker and Lueth 1966, Purol et al. 1977, and Snider 1980).

While conducting a wolf-moose relationships study in Game Management Unit 13 of southcentral Alaska, we attempted to collect longbones from moose and caribou dead from all sources of mortality. Although we strove for collection of femurs, we often had to settle for metatarsals or metacarpals, and in many other cases no bone was collected at all. Reasons for this varied depending upon both the cause of mortality and the time available for specimen collection. On both predator- and winter-killed ungulates, which were only partially consumed, the flesh was frozen and extraction of the femur was time consuming and expensive, particularly when kills were visited via helicopter. On heavily consumed predator kills, the ends of longbones had often been chewed and the marrow either eaten or exposed to the air rendering the sample useless. In these latter cases, no specimens were collected. On several predator kills the only remaining intact bones suitable for marrow analysis were the mandibles. Similar types of problems occurred with collection of road-kill samples. Because of these problems and the presence of mandibles at many heavily consumed predator kills, it appeared desirable to determine if a relationship existed between percent marrow fat estimated from longbones compared to that estimated from mandibles. Since mandibles are relatively easy to extract and are often collected routinely for aging purposes, establishment of a fat relationship between the two bones would result in a considerably larger sample size of condition data. The purpose of this paper is to compare the percent marrow fat of mandibles to that of longbones for moose and caribou killed primarily by predators from 1977 through 1980.

STUDY AREA

The study was conducted in Game Management Unit 13 of southcentral Alaska. Detailed descriptions of vegetation, topography, weather patterns, etc., have been provided by Skoog (1968), Rausch (1969), Bishop and Rausch (1974) and Ballard (1982).

METHODS

During winters 1977 through 1980, 58 paired mandible and longbone samples were obtained from moose and caribou kills. Moose samples were comprised of 21 calves and 24 adults of both sexes, while the 13 caribou samples were adults of both sexes. Ages of moose were determined by incisor eruption and cementum annuli counts according to methods described by Sergeant and Pimlott (1959). Caribou were aged on the basis of tooth wear described by Skoog (1968).

Samples were collected on an opportunistic basis but most kills were detected while making flights to monitor radio-collared wolf packs. Causes of death for the paired samples were as follows: for calf moose--8 wolf kills, 7 winter kills and 6 road or accidental kills; for adult moose--15 wolf kills, 8 road or accidental kills, and 1 from unknown causes; and for adult caribou--12 wolf kills and 1 from unknown causes.

Procedures for determining percent fat of longbones were identical to those of Neiland (1970). Mandible marrow was extracted by cutting a 10 cm longitudinal section of bone from the labial side of the mandible beginning at the 2nd or 3rd premolar. The section was cut with a bone saw and the resulting bone dust was scraped from the marrow with a spatula. Later, we simplified this process by ventrally splitting the left or right ramus with a chisel and then extracting the entire section of marrow with a spatula. This modified procedure also eliminated the need for scraping off bone dust fragments. The remainder of the procedure was identical to that for the longbone, described by Neiland (1970).

RESULTS AND DISCUSSION

Paired samples for both calf and adult moose were compared with standard least squares regression techniques (Snedecor and Cochran 1973). The best fit was by linear regression (Fig. 1, r=.92, $P \leq 0.05$); however, the data appeared clumped according to age class (calf versus adult). Analysis of covariance for calf and adult moose indicated that the variances were significantly different (F=4.11, $P<0.001$) and, thus, comparison of slope and intercept between the two age classes was not possible. We subjected each age class to polynomial regression techniques and determined that the percent marrow fat relationship for adult moose could be expressed as a 3rd order polynomial. The relationship was also significantly related linearly and, thus, we chose it for adults because it allowed additional statistical tests to be performed.

Figs. 2 and 3 depict the relationship between percent fat for longbones and mandibles for calf and adult moose separately. Percent marrow fat in the 2 bones was significantly correlated for both age classes (calves r=0.88, $P \leq 0.05$; adults r=0.78 $P \leq 0.05$) suggesting that longbone fat could be estimated from mandible fat for each age class. However, there was considerably more variation in the relationship for calves (mean square [ms]=127.8) than for adults (ms=26.7). This may have been the result of sample size since all of the adult moose were above 65% fat which would have placed them in a relatively high condition class based upon criteria established by Greer (1968) and Franzmann and Arneson (1976).

Snider (1980) compared percent marrow fat for femurs and mandibles for 29 moose from Ontario. He, like us, concluded that the 2 variables were significantly correlated. He combined calf - moose (n=6) with adults (n=22) and determined that the percent fat relationship between the 2 bones was best expressed as a 3rd degree orthogonal polynomial (Fig. 4) where Y= mandible fat and X= femur fat. His data were subject to an orthogonal regression. For comparison, we subjected Snider's data to the same analyses performed on Nelchina Basin moose and determined that his data also exhibited a significant linear relationship (r=.87, $P \leq 0.05$ [Fig. 5]). In contrast to Nelchina data, however, the variances between age classes were equal (F=.87, $P>0.05$) and there were no significant differences between slopes (F=.87, $P \geq 0.05$) or intercepts (F=.32, $P \geq 0.05$). Reasons for the differences in

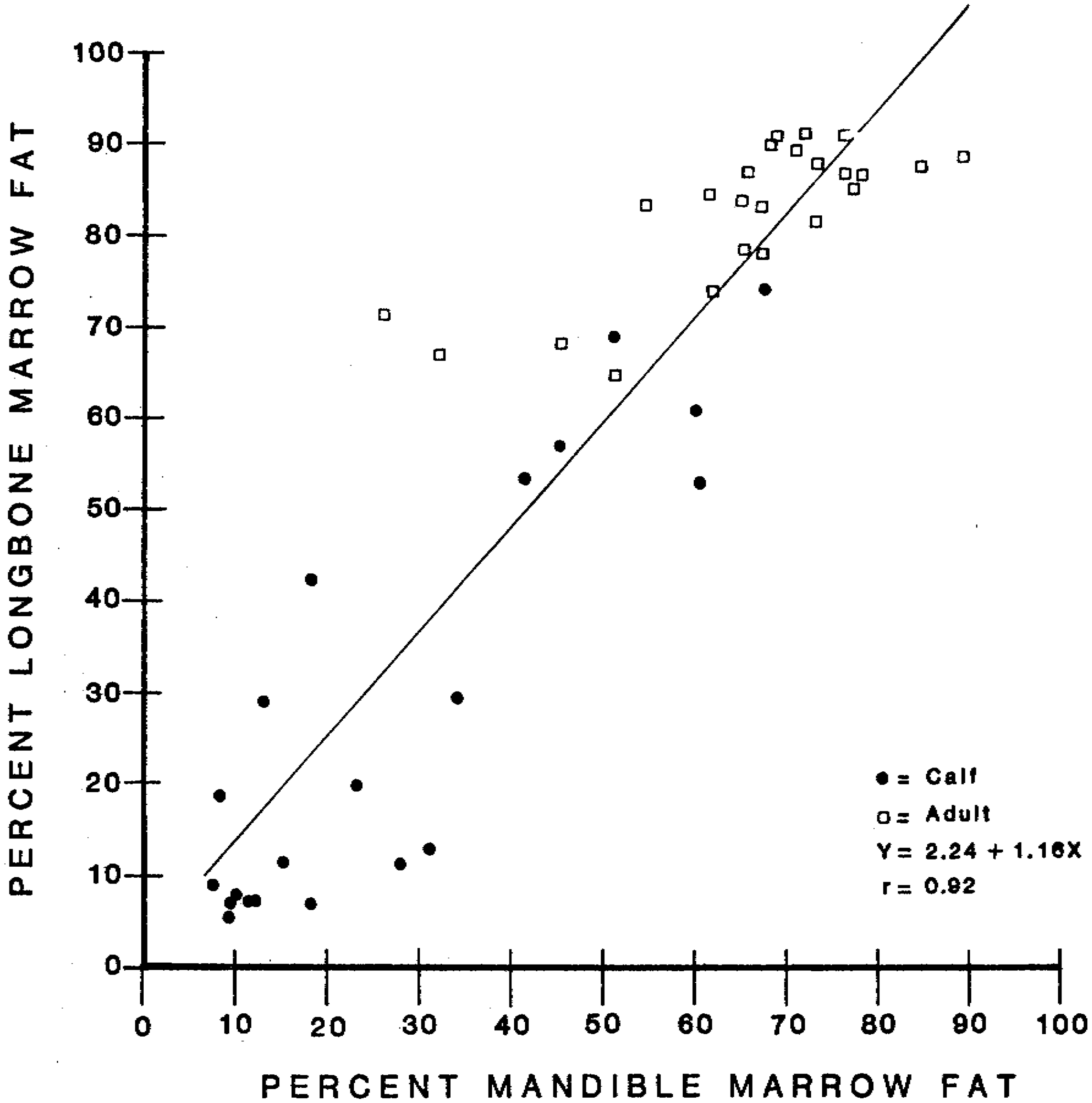

Figure 1. Relationship between percent marrow fat for mandibles and longbones from calf and adult moose in the Nelchina Basin, Alaska.

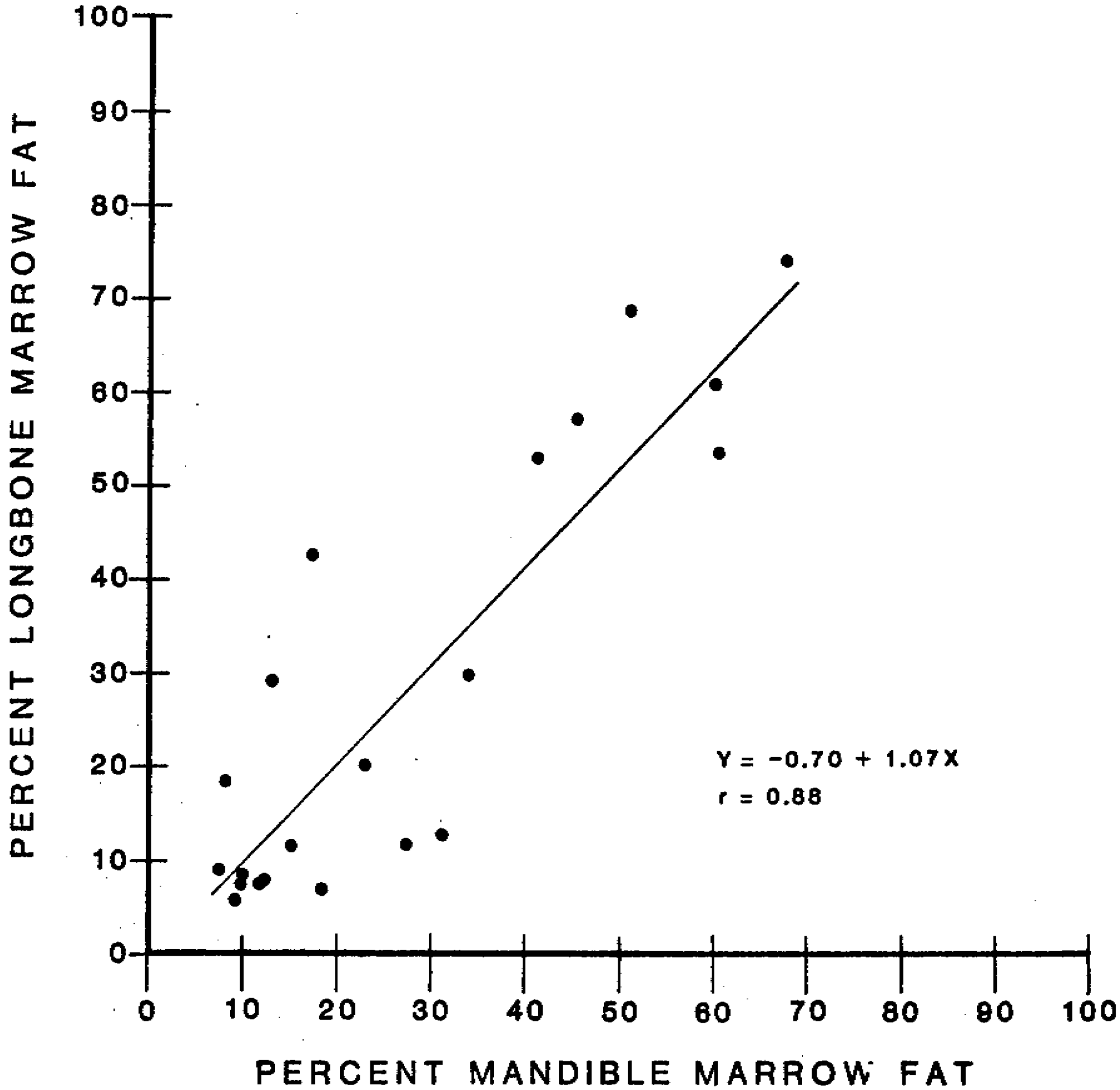

Figure 2. Relationship between percent marrow fat of mandibles and longbones for calf moose in the Nelchina Basin, Alaska.

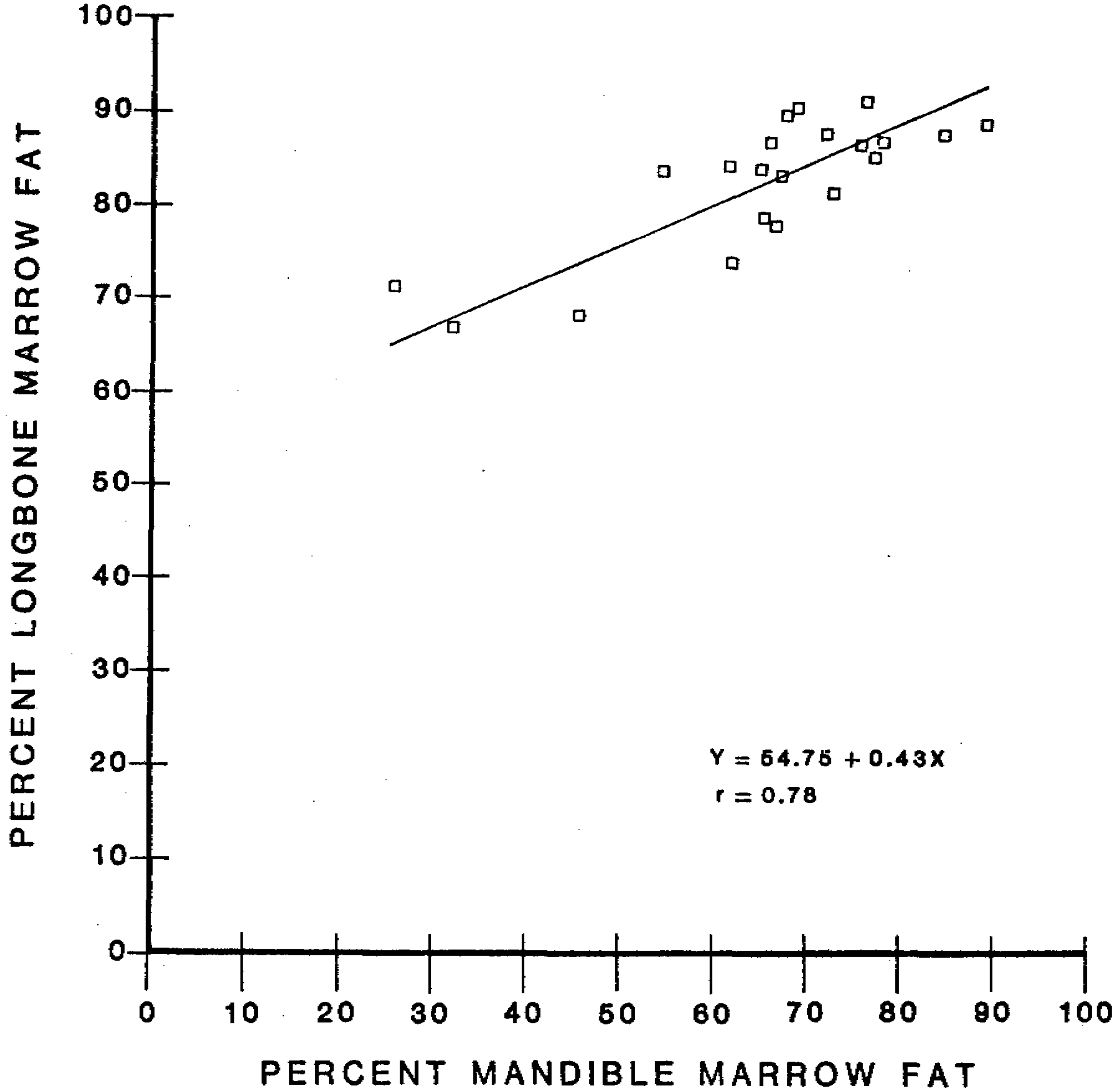

Figure 3. Relationship between percent marrow fat of mandibles and longbones for adult moose in the Nelchina Basin, Alaska.

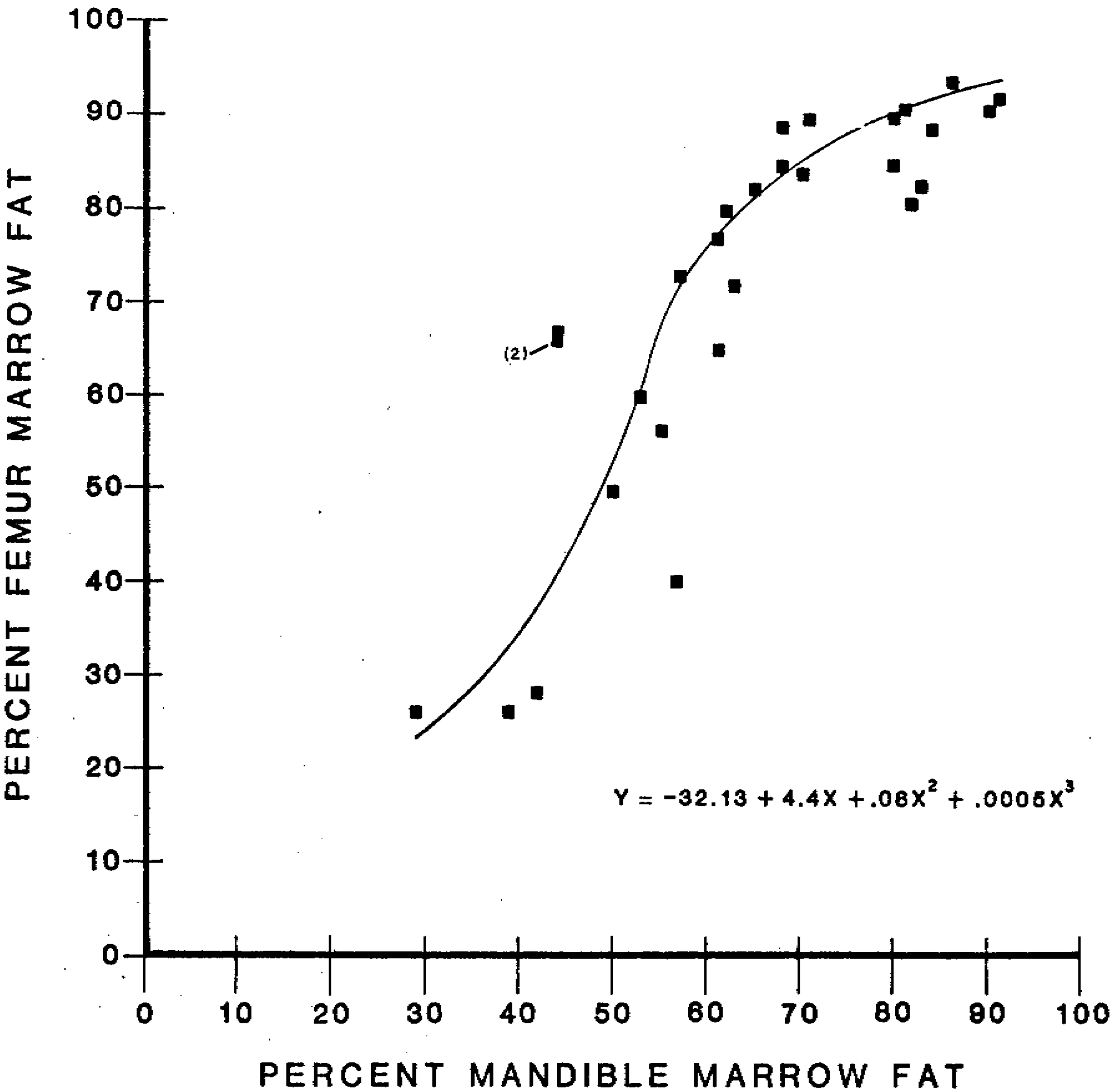

Figure 4. Relationship between percent marrow fat of mandibles and femurs for calf and adult moose in Ontario (from Snider 1980).

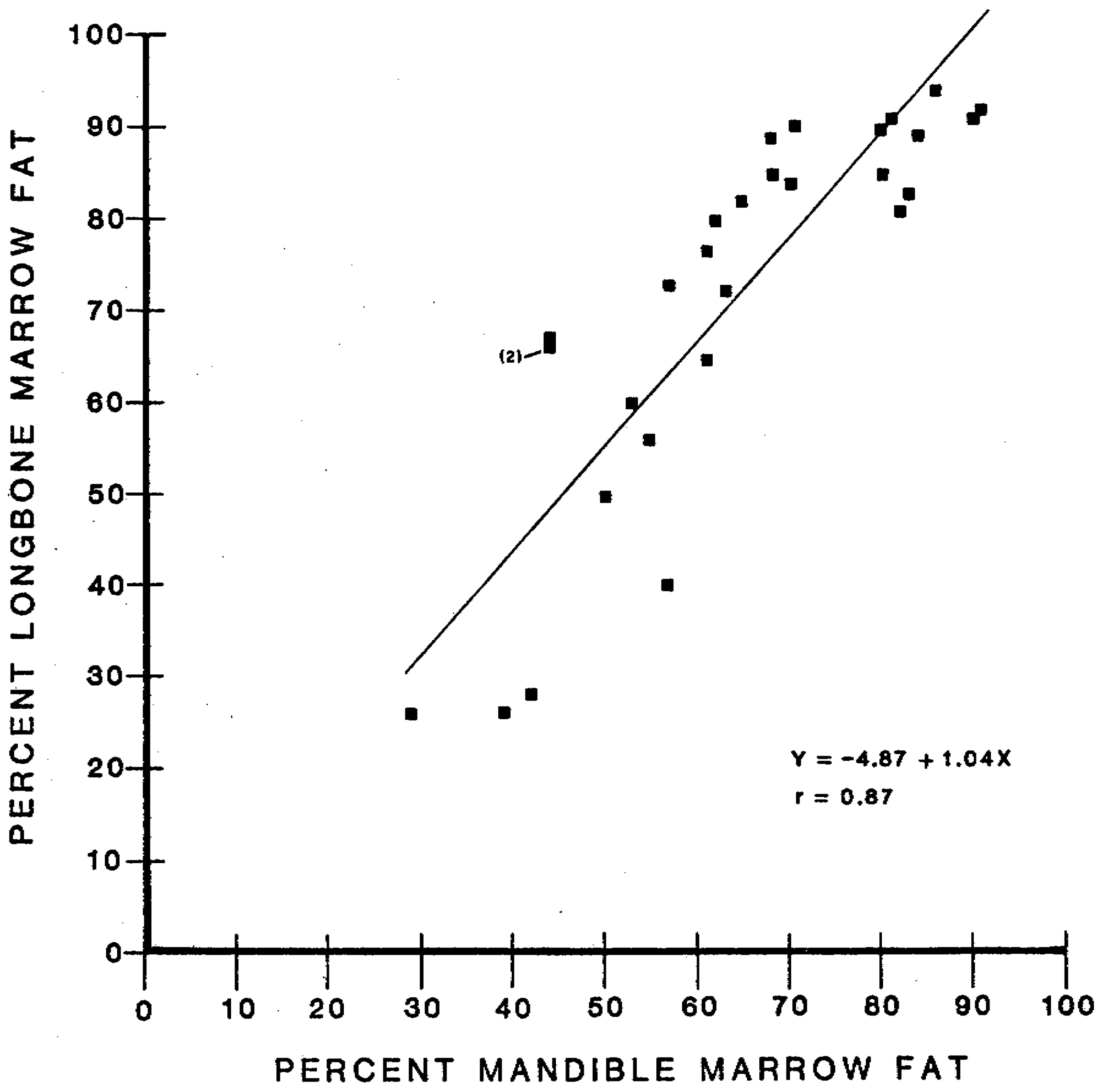

Figure 5. Relationship between percent marrow fat of mandibles and longbones for calf and adult moose in Ontario (from Snider 1980).

homogeneity of variances between the 2 studies are unknown but could have been related to a combination of both studies, or differences in fat deposition and mobilization between the study moose popu lations.

Because of small sample sizes in each of the studies, and because samples in the Nelchina study were collected primarily during winter for predator kills while those in Ontario were collected primarily in October or June mainly from road-killed moose, we combined samples in an effort to better describe the relationship between longbone and mandible fat (Table 1). The analysis assumed that there were no differences in fat mobilization between the 2 populations. Variances between calf and adult moose in these clumped data were not significantly different ($F=1.12$, $P \geq 0.05$) which allowed additional comparisons to be made. Both the slope and intercept for calf and adult moose were significantly different ($P \leq 0.05$) suggesting that fat mobilization in the 2 bones was different for the 2 age classes. The relationship between longbone and mandible marrow fat for each age class was best de scribed by linear regression (Figs. 6 and 7). However, because only 3 adult moose had longbone fat values less than 60%, the relationship between the 2 bones at lower fat levels warrants further investigation.

Similar to samples from Nelchina adult moose, bone marrow fat from mandibles and longbones of adult caribou were also significantly correlated (Fig. 8, $r=.90$, $P \leq 0.05$) suggesting that mandibles might be useful for estimating longbone fat in caribou. However, because sample sizes were extremely small and no samples of caribou in poor condition were collected, this relationship should be viewed with caution. Also, since no calf caribou were examined it is unknown whether a correlation exists in this age class as well.

Peterson (in press) recently compared marrow fat levels between several longbones of individual moose and determined that fat mobilization appeared to have proceeded more quickly in proximal than in distal longbones. If correct, this may partially explain some of the variability between longbones (femurs, metatarsals, and metacarpals) and mandibles found in this study. Even with this variation, however, mandibles appear useful for determining the percent marrow fat in longbones and consequently appear useful as an indicator of condition. Although results of this study suggest a positive relationship exists between marrow fat mobilization in mandibles and longbones, we suggest that biologists collect paired samples from ungulate kills in other populations to determine if relationships are similar. If this relationship is confirmed, then biologists should consider using the mandible in lieu of longbones for marrow fat analyses. Use of mandibles will allow biologists to greatly increase sample sizes for marrow fat analysis with minimal effort at relatively small additional costs.

Table 1. Analysis of covariance of percent marrow fat estimated from mandibles and longbones of calf and adult moose from southcentral Alaska and Ontario. 1/

Source	d.f.	M.S.
Within		
Calves	25	123.37
Adults	58	105.08
	83	110.59
Pooled Within	84	121.69
Differences Between Slopes	1	1042.99
Within and Between	85	361.68
Between Adjusted Means	1	20521.31

Significance Tests

(1) Heterscedasticity

$F = 1.17$ $F_{(25,58)}$ @ 0.25 $F = 1.23$

Therefore accept Ho: $c = a$

(2) Difference in Slopes

$F = 9.43$ $F_{(1,83)}$ @ 0.005 $F = 8.30$

Therefore reject Ho: $B = 1$

(3) Difference Between Intercepts

$F = 169_{(1,84)}$ @ 0.001 $F = 11.8$

Therefore reject Ho: $C = A$

1/ Ontario data from Snider (1980).

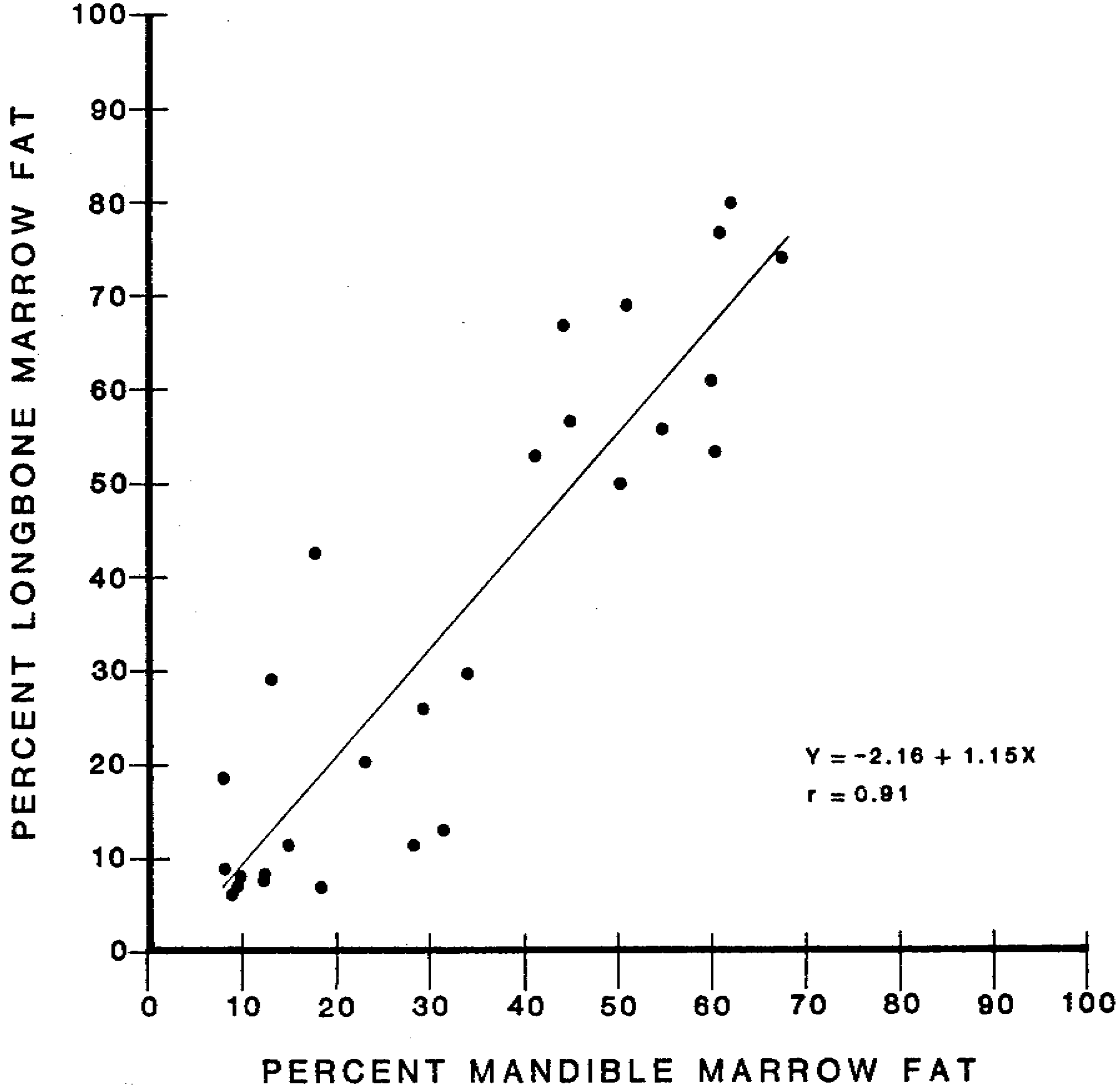

Figure 6. Relationship between percent marrow fat of mandibles and longbones for calf moose in Ontario (from Snider 1980) and the Nelchina Basin, Alaska.

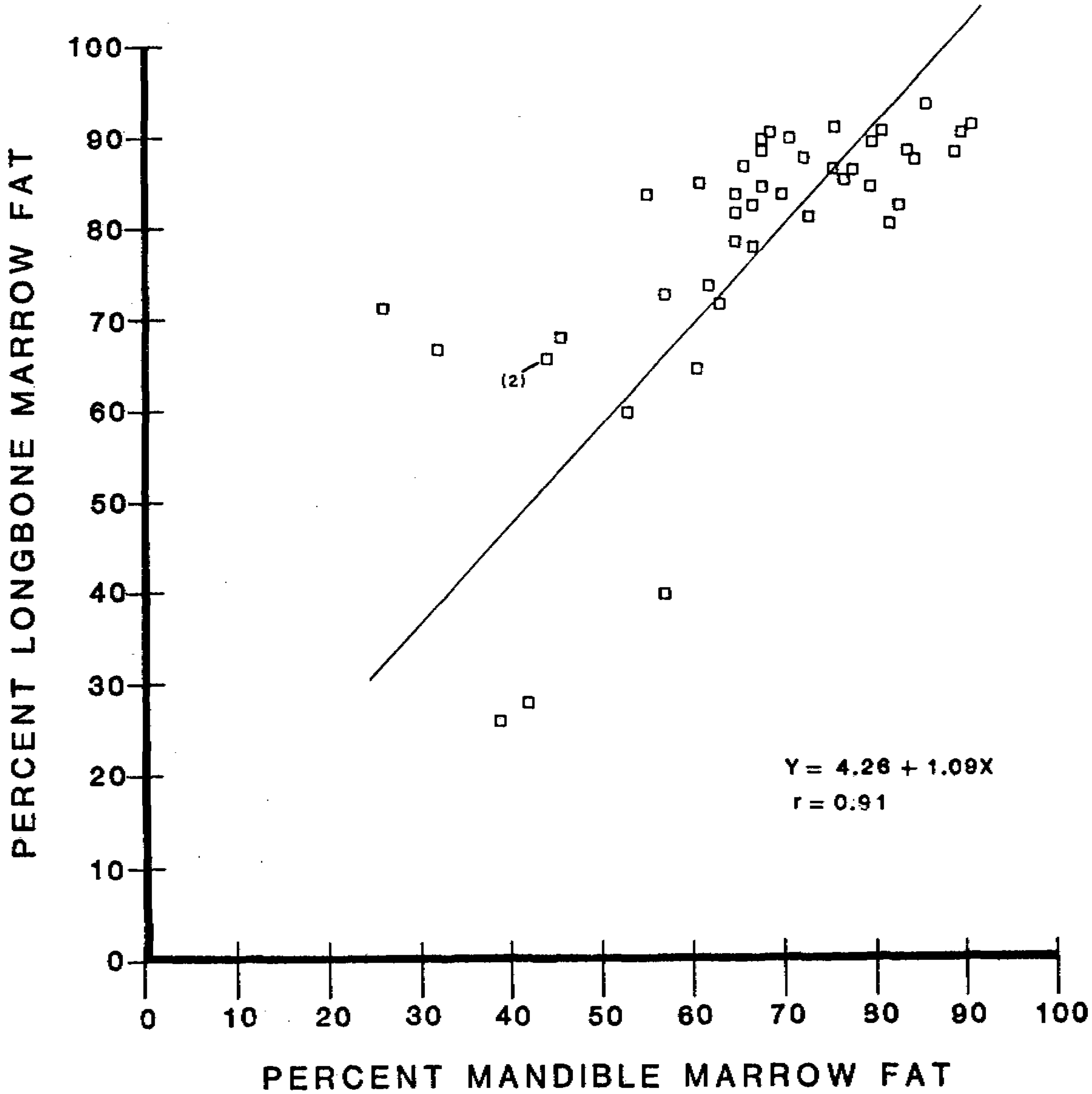

Figure 7. Relationship between percent marrow fat of mandibles and longbones for adult moose in Ontario (from Snider 1980) and the Nelchina Basin, Alaska.

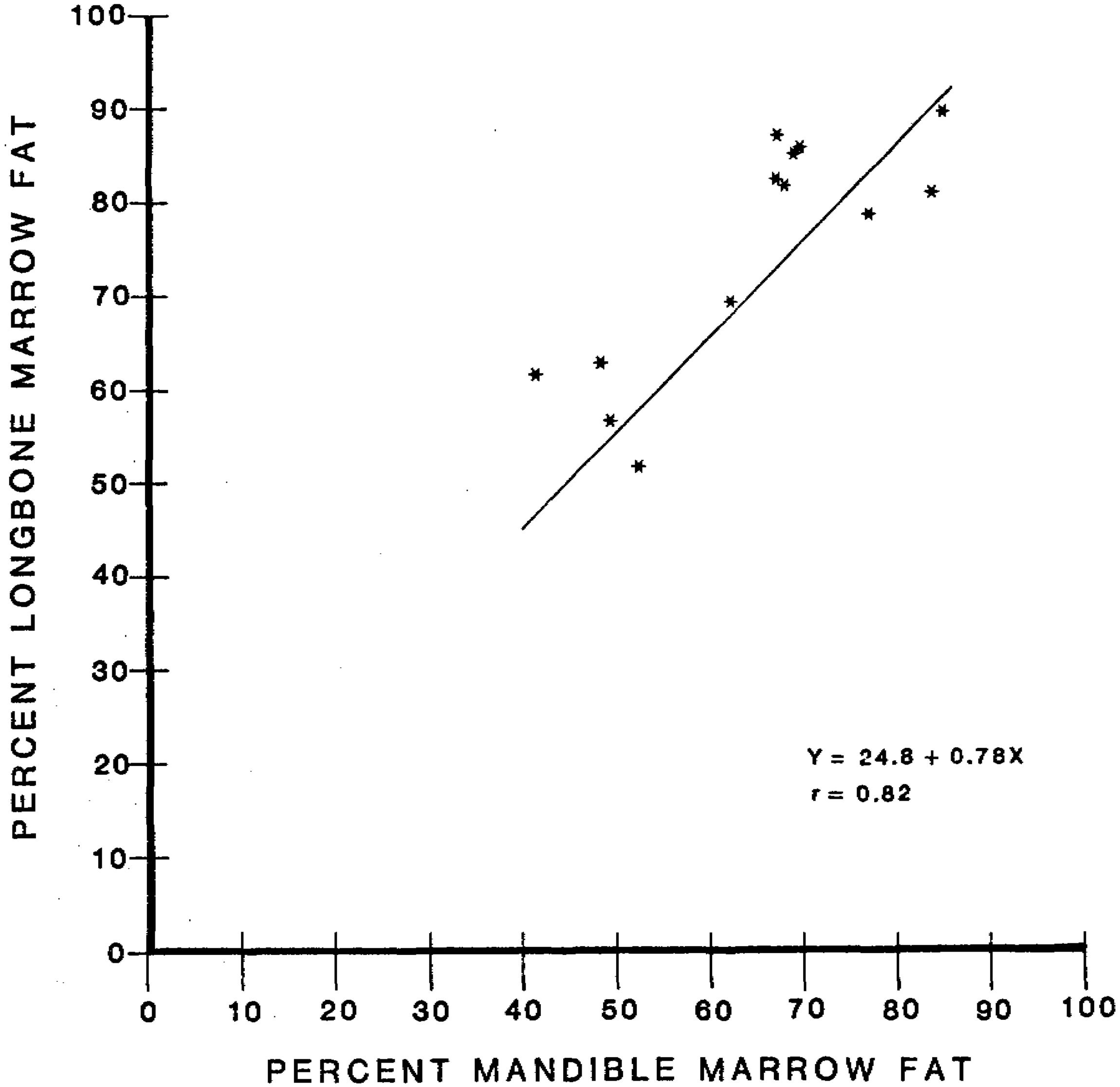

Figure 8. Relationship between percent marrow fat of mandibles and longbones for adult caribou in the Nelchina Basin, Alaska.

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