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Moose Research Center Reports

Evaluation and Testing of Techniques for Moose Management – Study 1.39
Estimation of Body Composition in Moose – Study 1.42

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PROGRESS REPORT (RESEARCH)

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Project No.: W-23-5 Project Title: Wildlife Research and Management

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SUMMARY

We report on continued studies of female reproduction, compensatory growth of first- versus second-estrus calves, and moose genetics. New studies during this report period concerned monitoring condition of moose fed hay versus those fed a balanced ration, and a test of palatability of different flavorings in a formulated moose ration. We conducted these studies in response to supplemental feeding of starving moose in winter. Eleven cows bred during their first estrus had a mean (SD) gestation length of 231.3 (3.9) days. Mean gestation length over the duration of the study (5 years) was 230.6 (5.0) days. Six first-estrus calves born in 1991 exhibited mean growth rates of 1.07 (0.16) kg/day from birth-late summer, 0.40 (0.17) kg/day from late summer-early winter, and 0.80 (0.12) kg/day from birth-late winter. Means for the same periods for 3 second-estrus calves were 0.96 (0.07) kg/day, 0.52 (0.18) kg/day, and 0.76 (0.04) kg/day, respectively. Considering data from all years of the study (4) mean weights of first estrus calves at birth, late summer, and early winter were 15.0 (2.1), 175 (16.1), and 218 (37.0) kg, respectively. Mean growth rates for these calves between birth-late summer, between late summer-early winter, and between birth-early winter were 1.16 (0.27), 0.47 (0.15), and 0.85 (0.26) kg/day, respectively. Equivalent means for second-estrus calves were 14.3 (1.4), 137 (18.2), and 176 (17.3) kg, and 1.13 (0.15), 0.56 (0.13), and 0.91 (0.10) kg/day, respectively. Comparisons (t-test) of means between first- and second-estrus calves indicated that there were no significant differences between birth weights ($P = 0.30$), and rates of growth between birth-late summer ($P = 0.78$), late summer-early winter ($P = 0.11$), and birth-early winter ($P = 0.50$). There were significant differences between late summer weights ($P < 0.0001$) and early winter weights ($P = 0.002$). These data substantiate our hypothesis that second-estrus calves do not exhibit compensatory growth before entering their first winter, thus entering that winter at a lower body weight and are more susceptible to winter mortality.

Mean weight loss for adult moose feeding on hay was 44 kg over the 11 weeks of the study. The mean gain for adults feeding on the balanced ration was 36.3 kg. Seven of

8 calves gained weight, with those feeding on hay gaining a mean of 4.25 kg, and those feeding on the balanced ration gaining a mean of 28.5 kg. Condition of moose as determined by analysis of urine indicated that those feeding on hay were consuming less nutritious food than those feeding on the ration but none of the moose were in poor condition. We hypothesize this was because all moose were in good condition upon entering the study. Of the seven new flavors tested for palatability in our formulated ration, one exceeded the palatability of our ration. Moose consumed feed containing the new flavor in significantly greater quantities compared with the other six test flavors.

Key Words: *Alces alces*, compensatory growth, estrus length, formulated ration, feed flavorings, gestation, genetics, hay, moose, palatability, reproduction, snow-urine, urine, weight, winter feeding.

TABLE OF CONTENTS

BACKGROUND

The Moose Research Center (MRC), with known numbers of confined animals and facilities to handle them, provides unique conditions for developing and testing techniques applicable to moose management. This study has been continuously active since 1969 when the MRC became functional. Three Federal Aid final reports covering the period from 1968 through 30 June 1986 have been published (Franzmann et al. 1974, Franzmann and Schwartz 1982, Franzmann et al. 1987), in addition to more than 30 journal publications (see Schwartz 1987). These publications covered evaluation and testing

drugs, trapping methods, aerial and pellet-count censuses, telemetry, biotelemetry, rumen sampling, marking and collaring, weighing, fertilization of browse, electronic tissue measuring, raising moose calves, developing a moose ration, developing feeding trial and digestion crates, developing a respiration chamber, radioisotope digestion markers, and a carrying capacity model.

The need to obtain information for better assessment of "optimum" bull:cow ratios in Alaska moose populations hinges on a thorough understanding of the estrous cycle. This entails the length of estrus, the receptive period during estrus, the time periods between estruses, and the number of estrous periods during the breeding season. Markgren (1969) identified the time between estruses at 25-30 days, but the other needed data have been speculative. At the MRC we conducted late-breeding experiments and demonstrated that calves are subsequently born late (Schwartz et al. 1986). The consequences of altered or nonoptimum breeding during the rut has been attributed to low bull:cow ratios, but with no clear supporting evidence. The issue needs systematic research to help resolve the matter. Past research at the MRC documented the length of estrus in moose (Schwartz 1987). During the past 4 years we looked at the effects of first and second estrus breeding on growth and development of calves, and also measured gestation length (Schwartz et al 1988, Hundertmark et al. 1989, 1990, 1992). During this report period we continued the breeding studies.

During the severe 1989-90 winter there was a public outcry to supplementally feed starving moose on the Kenai Peninsula and in the Matanuska-Susitna Valley. The typical feed offered to moose by well-meaning members of the public was locally-grown grass hay, which we believed to be nutritionally inadequate for moose in poor condition. Members of the public who attempted to feed commercially-available moose feed (MRC ration) reported mixed success, with many individuals reporting that moose would not eat it, even though it was a nutritionally complete and balanced ration (Schwartz et al. 1985). Conversely, anecdotal accounts from the public and some ADF&G staff indicated that moose readily ate hay and actually exhibited outward signs of nutritional recovery.

We decided to do 2 experiments to respond to this situation. First, we measured nutritional status of moose fed a hay diet vs. the MRC diet. Second, we tested the palatability of the basic MRC ration with added flavor enhancers designed for livestock feeds to determine if a more suitable formulation could be derived for use as an emergency food.

This report contains information collected from 1 July 1991 through 30 June 1992. Active jobs include: reproduction studies (Job 5), and miscellaneous techniques (Job 7).

OBJECTIVES

Test and evaluate techniques that are potentially useful for management of moose.

Investigate the basic parameters of moose reproduction. (Job 5).

Test miscellaneous techniques. (Job 7).

METHODS

Job 5. Reproduction Studies

Eleven cows were bred by 1 of 2 bulls on their first estrus. All animals were semi-tame and maintained at the MRC. Animals were held in either a 4-ha or a 3-ha enclosure during the study and fed a pelleted ration (Schwartz et al. 1985). All animals were observed daily beginning in the last week of September and continuing through October. Dates of breeding (determined by a cow being mounted by the bull) were noted for each female. Following breeding each female was observed when suspected to be cycling into another estrus (19-26 days post first estrus) to determine if they recycled (indicating they were not pregnant) or exhibited no signs of a subsequent estrus (indicating they were pregnant).

During the calving season, each cow was checked several times daily to record time and date of calving. Calves were weighed the day of birth using a spring scale (Salter No. 235, London, England), ear tagged, and fitted with a calf mortality transmitter (Telonics Inc., Mesa Arizona). When the calves were approximately 2 weeks old they were released with their cow into Pen 1, which contained regrowth vegetation from the 1947 burn and recently crushed vegetation from our crushing program in 1977 and 1986-87. We checked radio signals from each calf periodically during the summer. We measured growth and development as weight gain/day from time of birth to fall. Values in parentheses following means are standard deviations (SD).

Job 7. Miscellaneous Projects

Evaluation of hay as an emergency winter food: We conducted trials to determine intake, weight change, and nitrogen balance as measured by snow-urine analysis for treatment (hay) and control (MRC ration) groups. Each group consisted of 8 moose: 4 adult females and 4 female calves in the control group, and 4 adult female and 4 male calves in the treatment group. The trials began on 17 January and continued through 6 April (11 weeks). Control moose were housed in a 4 ha enclosure and offered feed ad libitum in a bulk feeder. Treatment moose were housed in a 3 ha enclosure and locally-grown grass hay was offered ad libitum by spreading it on the ground in several locations in the enclosure. Moose were housed in individual pens for 2 periods (Weeks 4 and 9) at which

time daily intakes were measured. Intake during these periods was expressed on a dry matter basis, with feed samples being dried at 100°C for 24-48h.

Urine was collected approximately biweekly by either maneuvering a container attached to a pole into the urine stream during urination (most samples) or collecting freshly deposited urine in snow. Samples collected during 3 arbitrarily-defined periods: 1 (Weeks 1-2), 2 (Weeks 4-7) and 3 (Week 11) were submitted for analysis for urinary urea nitrogen (U), phosphorus (P), cortisol (C) and creatinine (Cr). Nutritional status of moose was evaluated by expressing U and P as ratios to Cr (DelGiudice et al. 1989). Cortisol:Cr ratios were used to assess physiological stress levels which can be elevated during nutritional deprivation (Saltz and White 1991). Ratios were $\log_e$-transformed before being subjected to ANOVA with period (1-3) and trial (hay vs. MRC) as categorical variables.

Evaluation of flavor additives in a formulated moose ration: During summer 1991, 8 moose were used in a trial to determine preferences for 8 different flavorings of MRC ration. Each animal was offered all 8 feeds ad libitum for a 24-hr. period, with the different feeds being placed in separate compartments in a feed bunk. Assignment of animals to pens and feeds to compartments was randomized with a Latin Squares design. Each animal was offered 9 kg (fresh weight) of each flavored feed, and in certain cases some animals were supplemented with 5 additional kg of certain flavors to assure that they had an adequate supply. Refused food was collected and weighed. Differences between fresh weights of feed offered and feed refused were considered feed consumed. Rank transformations of amount consumed (response variable) were subjected to ANOVA for Latin Squares (Conover and Iman 1981, Hora and Conover 1984, Akritas 1990) with animals and feed placement being blocking variables.

Analysis of genetic diversity: We collected samples of liver, heart, kidney and striated muscle from hunter-killed moose in Subunits 15A and 21D in September 1991, and froze them for storage.

RESULTS AND DISCUSSION

Job 5. Reproduction Studies

All 11 cows were bred during 25 September through 9 October (Table 1). Nine cows gave birth to 8 female and 5 male calves during 21-28 May; of the 3 that did not give birth 1 aborted, 1 probably aborted, and the third either aborted or failed to conceive and was not observed in a subsequent estrus. Mean gestation length was 231.3 (3.9) days. When combined with historic data from the MRC (Schwartz et al. 1988, Hundertmark et al. 1989, 1990, 1992) we estimated a gestation length of 230.6 (5.0) days (n=29).

Of the 6 first-estrus and 3 second-estrus calves born at the MRC in 1991, weights at birth, late summer and early winter, and corresponding rates of growth were similar to those

reported previously (Hundertmark et al. 1989, 1990, 1992) (Table 2). When we considered data for all years (Table 2) there were no significant differences between birth weight (t = 1.08, d.f. = 19.4, P = 0.30), and rates of growth between birth-late summer (t = -0.28, d.f. = 18.0, P = 0.78), late summer-early winter (t = -1.66, d.f. = 23.6, P = 0.11), and birth-early winter (t = -0.69, d.f. = 14.9, P = 0.50). There were significant differences between late summer weight (t = 5.75, d.f. = 26.0, $P < 0.0001$) and early winter weight (t = 3.77, d.f. = 16.5, P = 0.002). These data substantiate our hypothesis that second-estrus calves do not exhibit compensatory growth before entering their first winter, thus entering that winter at a lower body weight and are more susceptible to winter mortality.

Job 7. Miscellaneous Projects

Evaluation of hay as an emergency winter food: Moose used in the hay feeding trial took 10 days to become accustomed to a hay food source. This was probably because MRC moose were accustomed to being fed the MRC ration and would eat very little natural food even when no pelleted ration was available. Once they accepted the hay they ate it readily. Adults eating hay lost weight (mean loss = 44 kg) while those eating MRC ration gained weight (mean gain = 36.3 kg) (Table 3). Two adults (1 MRC, 1 hay) were removed from this analysis because of actual or suspected abortions, which altered their weight considerably. Seven of the 8 calves in the trial gained weight. Mean weight gain for calves feeding on hay was 4.25 kg, and mean weight gain for calves feeding on MRC ration was 28.5 kg.

Mean U:Cr ratios differed ($F_{1,37}$ = 9.71, P = 0.004) between moose feeding on hay ($\bar{X}$ = 2.96, SE = 0.50) and on MRC ration ($\bar{X}$ = 5.48, SE = 0.46) but not among periods ($F_{2,37}$ = 0.033, P = 0.90), which indicated that nitrogen intake differed between hay and MRC moose but nitrogen balance of moose in both trials did not change over the course of the experiment. One observation was deleted from analysis because of anomalous ratios (Fig. 1). Phosphorus:Cr ratios did not differ between trials ($F_{1,37}$ = 0.65, P = 0.42) but differed among periods ($F_{2,37}$ = 3.08, P = 0.06), declining over time (Fig. 2). This decline probably was a function of the decreased intake observed in moose during this season (Schwartz et al. 1984). Although dry-matter intake data are not yet analyzed, feed records for moose fed MRC ration indicated a mean fresh weight consumption of 54.7 kg/day (for 8 moose) from 17 January-9 February, 39.7 kg/day from 17 February-15 March, and 34.7 kg/day from 23 March-6 April. Moose feeding on hay were sampled (Period 1) within 1 week of being weaned from MRC ration, which would account for the similar P:Cr ratios between the trials for Period 1. As moose continued to feed on hay their P:Cr ratios declined and remained noticeably lower than those of moose fed the formulated ration for the remainder of the study. Cortisol:Cr ratios did not differ between moose in the 2 trials ($F_{1,37}$ = 0.05, P = 0.82) or among periods ($F_{2,37}$ = 1.73, P = 0.19), and mean C:Cr ratios were similar to those observed in unstressed mule deer (*Odocoileus hemionus hemionus*) (Saltz and White 1991).

Based on changes in weight and urine chemistries we concluded that moose feeding on hay were in poorer condition after 11 weeks than moose feeding on MRC ration, but were still relatively healthy. Although differences in weight dynamics between the 2 groups were obvious, the magnitudes of the differences were less than expected. The 3 adults feeding on hay (not including the cow that aborted) lost 8-10% of their body weight over the course of the trial, which is in no way a serious weight loss. This lack of a significant decrease in condition can be attributed to the excellent condition of all animals entering the trials, as all animals had been fed MRC ration ad libitum before January. In this respect, we believe that our experiment did not reflect conditions which wild moose would experience in a severe winter before being supplementally fed. Evidence from the severe winter of 1989-90 on the Kenai Peninsula indicated that calves were in negative energy balance in late autumn, and winter-related mortality was widespread by January 1990. Cows, particularly those with nursing calves, rely on autumn and early winter ranges to accrue fat for the winter, gaining weight through December (Schwartz et al. 1987). Early, deep snows would inhibit this critical fat deposition, thus accelerating nutritional decline.

Evaluation of flavor additives in a formulated moose ration: Amounts of feed consumed differed among the 8 types offered ($F = 2.57$, $P = 0.027$), but was not affected by animal ($F = 0.97$, $P = 0.47$) or location ($F = 0.95$, $P = 0.48$). The mean rank for flavor 6 differed from those of flavors 2-5 and 7 (Table 4). Flavor 8 (control) was not included in the multiple comparison because we wanted to evaluate new flavors only. However, it is interesting to note that flavor 8 ranked second in amount consumed, indicating that only 1 flavor tested met or exceeded taste preference for the standard MRC ration.

Analysis of genetic diversity: Tissue samples collected this report period have not been submitted for analysis.

We submitted six manuscripts for publication in professional journals (Appendix A-F). One of these (Appendix C) was an invited review paper for a workshop on moose reproduction at the 28th North American Moose Conference and Workshop. The remaining manuscripts are the result of research conducted at the MRC.

RECOMMENDATIONS

We plan to continue to evaluate new drugs and related products as they become available for use. We will continue to evaluate hay as an emergency winter food using nutritionally-stressed animals instead of animals in peak condition, which will more closely approximate natural conditions under which moose would be fed hay. We will investigate the genetic composition of other moose populations in Alaska in order to describe the range of variation present in the state.

ACKNOWLEDGEMENTS

We thank Earl Becker for providing the experimental design and data analysis for evaluating flavor additives, and Eric Rolph for performing dry-matter determinations and data entry for the hay feeding trials.

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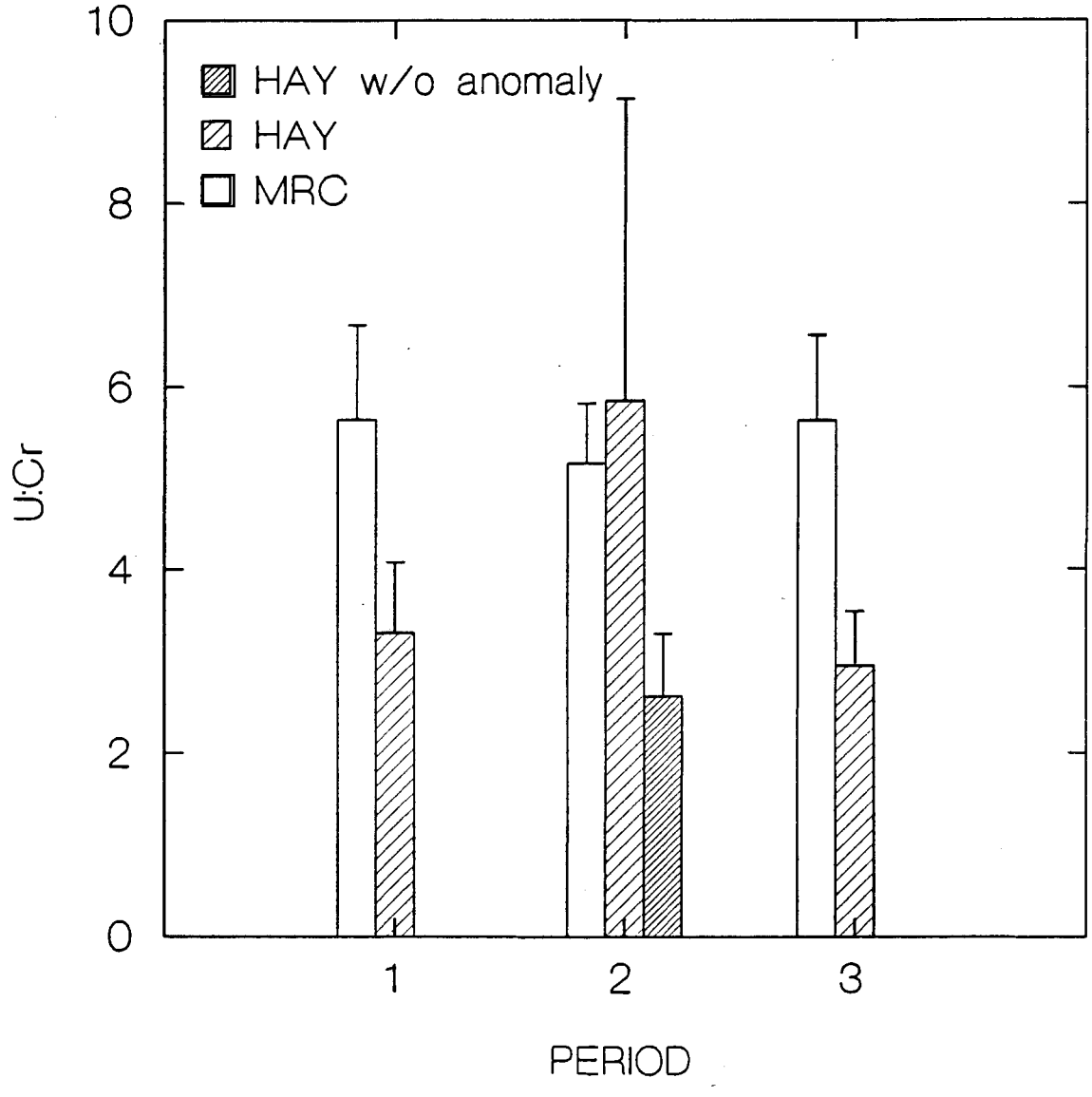

Fig. 1. Mean U:Cr ratios of moose on 2 different diets, for each of 3 periods (see text) during an 11-week feeding study. Error bars represent 1 SE. The mean ratio for moose feeding on hay during period 2 is presented with and without an anomalous datum.

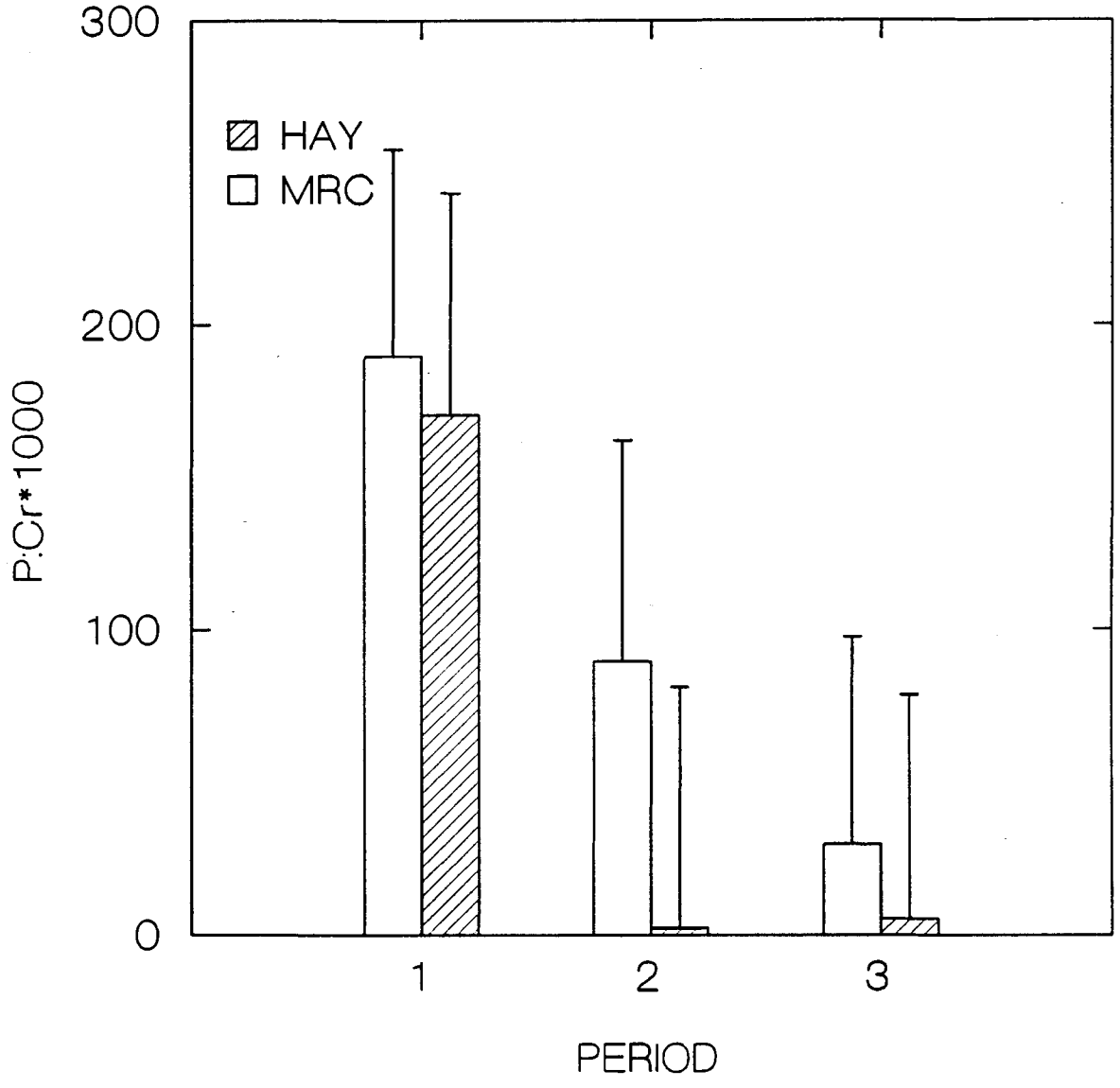

Fig. 2. Mean P:Cr*1000 ratios of moose on 2 different diets, for each of 3 periods (see text) during an 11-week feeding study. Error bars represent 1 SE.

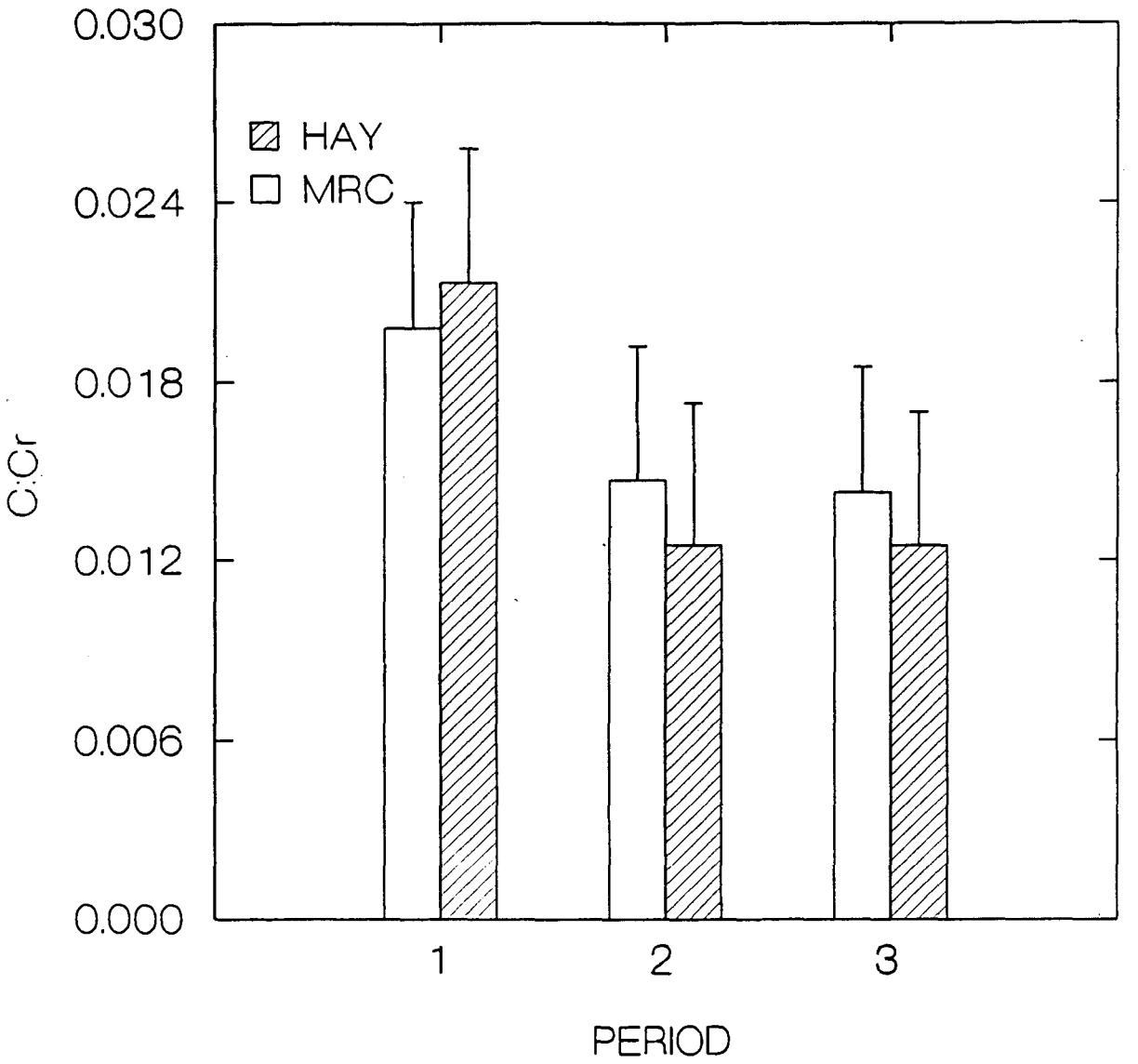

Fig. 3. Mean C:Cr ratios of moose on 2 different diets, for each of 3 periods (see text) during an 11-week feeding study. Error bars represent 1 SE.

Table 1. Reproductive observations of 11 captive female moose at the Kenai Moose Research Center from September to October 1991, and subsequent parturition data from May 1992.

Moose	Date of Estrus	Type of Data[a]	Date of Parturition	Length of Gestation (days)	Calf or Calves	
					Sex	Wt(Kgs)
Trixie	6 Oct	N	--[c]			
Betsy	25 Sept	O	25 May	240	F	11.4
					F	10.0
Zumu	29 Sept	O	--[d]			
Lara	9 Sept	N	21 May	230	F	16.4
					M	16.8
Sinuk	4 Oct	O	--[c]			
Sony	5 Oct	N	21 May	229	M	18.2
Deshka	5 Oct	N	24 May	232	F	13.2
					M	12.7
Satorene	6 Oct	O	24 May	231	F	16.8
Tarac	6 Oct	N	24 May	231	M	16.8
Lily	7 Oct	O	21 May	227	M	17.7
					F	16.8
Luna	7 Oct	O	28 May	234	F	15.5
Vicki	9 Oct	N	24 May	228	F	15.5

[a] O = Observed breeding, N = not observed, estrus assumed based on vaginal discharge, rumpled rump hair (from being mounted) and other circumstantial evidence.
[b] Time between first observed mounting of each estrus period.
[c] Aborted.
[d] Failed conception or abortion.

Table 2. Birth weights and selected subsequent weights of moose calves born at the Moose Research Center in 1991, and their corresponding rates of increase. Means are reported with SD in parentheses.

Animal name	Birth Weight (kg)	Birth Date	Late summer Weight (kg)	Late summer Date	Early winter Weight (kg)	Early winter Date	Rate of increase (kg/d): Birth - late summer	Late summer - early winter	Birth- early winter
First estrus calves									
Pechora	12.3	3 Jun	164	8 Oct	204	17 Jan	1.19	0.40	0.84
Los	18.6	22 May	186	8 Oct	227	17 Jan	1.20	0.41	0.87
Allye	13.2	25 May	150	11 Oct	159	17 Jan	0.98	0.09	0.62
Mario	13.6	25 May	176	11 Oct	232	17 Jan	1.19	0.58	0.93
Wassilli	16.8	1 Jun	177	27 Oct	207	17 Jan	1.08	0.37	0.83
Jammers	25.9[a]	22 May	143	13 Oct	193	17 Jan	0.81	0.53	0.70
Mean (1991)	14.9 (2.7)		166 (16.8)		219 (55.7)		1.07 (0.16)	0.40 (0.17)	0.80 (0.12)
Mean 1988-91	15.0[b](2.1)		175[c](16.1)		218[c](37.0)		1.16[c](0.27)	0.47[c](0.15)	0.85[c](0.26)
Second estrus calves									
Rachel	11.8	15 Jun	130	14 Oct	185	17 Jan	0.98	0.59	0.80
Soccer	13.9	15 Jun	137	14 Oct	166	17 Jan	1.02	0.31	0.71
Liz	15.9	22 Jun	117	14 Oct	178	17 Dec	0.89	0.65	0.78
Mean (1991)	13.9 (2.1)		128 (10.1)		176 (9.6)		0.96 (0.07)	0.52 (0.18)	0.76 (0.04)
Mean 1988-91	14.3[d](1.4)		137[e](18.2)		176[e](17.3)		1.13[e](0.15)	0.56[e](0.13)	0.91[e](0.10)

[a] First recorded weight for this calf, which was born 22 May 1991. This weight not used in calculation of mean birth weight.
[b] n = 12
[c] n = 13
[d] n = 13
[e] n = 15

Table 3. Weekly weights (kg) of moose fed either MRC ration or hay.

Treatment/	Week												
Animal	0	1	2	3	4	5	6	7	8	9	10	11	Gain/loss
MRC Ration													
Trixie	453	440	447	459	457	412	408	413	413	411	402	383	-70[a]
Lily	547	556	570	579	587	584	594	593	588	593	594	590	44
Deshka	475	492	503	508	508	505	506	504	499	503	506	507	32
Lara	451	468	479	485	487	488	489	486	488	496	496	485	33
Pechora	204	215	224	227	220	227	235	234	235	239	241	240	36
Liz	178	190	198	200	186	195	203	206	204	206	209	210	32
Allye	159	172	176	173	167	165	168	177	167	174	169	167	8
Rachel	155	169	178	182	183	183	193	189	192	196	195	197	38
Hay													
Deneki	406	391	392	389	383	380	372	380	375	372	359	354	-42
Zumu	517	505	497	503	477	486	485	481	474	473	466	456	-51
Sony	476	465	459	460	441	446	453	448	442	436	441	430	-39
Sinuk	459	447	445	441	427	436	432	420	407	396	386	382	-64[b]
Los	227	224	238	237	230	239	242	239	237	233	230	229	-4
Mario	232	225	233	237	236	243	240	238	239	245	238	239	7
Wassilli	207	202	218	217	212	226	226	222	217	215	207	211	3
Soccer	166	169	178	178	172	176	178	180	178	182	170	173	11

[a] This animal aborted a fetus during Week 5.
[b] This animal may have aborted a fetus during Week 7.

Table 4. Mean ranks of feed flavorings used in a test of flavor preference by moose. Higher mean ranks indicate a greater amount of feed was consumed.

Number	Mean Rank	Flavor	Manufacturer
1	38.69[a]	Apple	Crest Flavor Co.
2	34.75[a]	Carmel	Far-Mor
3	34.31[a]	Anise-molasses	Crest Flavor Co.
4	29.88[a]	Dairy Krave	Feed Flavors, Inc.
5	22.94[a]	Horse	Crest Flavor Co.
6	43.75[b]	Milkey Whay	Crest Flavor Co.
7	14.56[a]	Mineral	Crest Flavor Co.
8	41.13	Basic MRC (control)	Don Chemical

[a,b] Means with different superscripts are significantly different ($P < 0.05$); the mean for the control ration was not included in the comparison.

APPENDIX A.
REPRODUCTION IN MOOSE

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Abstract: The literature contains discrepancies in statistics describing the most basic parameters of moose (*Alces alces*) reproduction. Here we summarize reproductive data collected at the Moose Research Center, a facility of the Alaska Department of Fish and Game. We quantify the estrous cycle, estrous length, gestation length, and discuss sex ratio, litter size, fetal development, and birth mass of calves. Observations were made on a captive herd of moose and from a wild population on the Kenai Peninsula, Alaska. Estrous behavior in cows was signaled by an increased attentiveness by the bull. Estrous females did not display increased activity as noted for white-tailed deer (*Odocoileus viriginianus*). The estrous cycle ranged from 22-28 days ($\underline{X}$= 24.4 days) and the length did not increase with each successive cycle. The cycle of primiparous females was significantly shorter ($\underline{P}$ = 0.05) than multiparous females. Length of gestation averaged 231 days (SD = 5.4 days) and was not significantly different ($\underline{P}$ > 0.05) (1) between primiparous and multiparous females, (2) litters of one or two calves, (3) among 5 years of study, or (4) between cows bred their first or second overt estrus. Breeding occurred between 28 September and 12 October, and did not vary among years. Primiparous yearling at the MRC produced significantly ($\underline{P}$ = 0.005) fewer calves (1.07/cow) than primiparous 2-year-olds (1.60/cow). There was a significant ($\underline{P}$ = 0.0015) relationship between calf production in primiparous females and their body mass at time of breeding. Multiparous females at the MRC produced 1.59 calves/female, but no relationship was detected between body weight and calf production. Calf production per cow in the wild population was 0.22, 1.27, and 0.14 for yearlings, cows aged 2-15, and >16, respectively. The mean ovulation rate in the wild population were 1, 1.5, and 2.0 eggs per female aged 1, 2-15, and >16, respectively. Ova loss was 0, 9.3, and 100 percent for females aged 1, 2-15, and >16, respectively. Sex ratio of calves was not different from the expected ratio of 1:1. Data showed no empirical relationships among maternal age, maternal mass, or prior breeding parity and variation in sex ratio of offspring. Single calves (16.2 kg) weighed significantly ($\underline{P}$ = 0.001) more at birth than twin calves (13.5 kg), but within single or twin litters, males did not weigh more than females. We did not detect a significant difference ($\underline{P}$ > 0.05) in mass of calves born to: (1) primiparous vs. multiparous females, (2) male and female twins, and (3) mass of twin litters that were both male, both female, or mixed sexes. Findings are discussed in relationship to other cervid species and current theory. Fetal growth curves are presented for mass, total length, hind foot, and forehead-rump measurements. A von Bertalanffy equation provided the best fit for mass ($\underline{R}^2$ = 0.964) and hind foot length ($\underline{R}^2$ = 0.973), whereas linear fits conformed best to total length ($\underline{R}^2$ = 0.985) and forehead-rump ($\underline{R}^2$ = 0.984)

measurements. By using the hind foot length age relationship, we determined that 9.1%, and 0.6% of the fetuses examined were conceived during the second and third estrus, respectively. We accurately predicted 17 of 18 known second estrous births using these relationships.

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APPENDIX B.

MONITORING REPRODUCTION IN MOOSE USING URINARY AND FECAL STEROID METABOLITES

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Abstract: Radioimmunoassay (RIA) of urinary pregnanediol-3a-glucuronide (PdG), estrogen conjugates, and fecal progesterone and estradiol were used to assess estrous cycles and pregnancy in captive and semi free-ranging moose (*Alces alces*). Estrous cycles and pregnancy (n=3) were tracked using urinary PdG and estrogen conjugates. Urinary PdG identified distinct reproductive cycles that began during October and estrus behavior coincided with nadirs in PdG excretion. Although PdG increased up to 5-fold over cycling levels during pregnancy, hormone concentrations were quite variable making pregnancy diagnosis equivocal using this method. Estrogen conjugates were not useful for monitoring estrous cyclicity; however, during the final month of gestation urinary estrogen conjugat levels increased from <5 ng/mg Creatinine (Cr) to >50 ng/mg Cr making this a useful method for definitive pregnancy detection during late pregnancy. In an attempt to establish a simplified test for pregnancy, fecal estradiol and progesterone were evaluated in feces (1-6 samples/individual) collected over a two year interval from 16 moose of various age, gender and physiological (pregnant vs. nonpregnant) classifications. Using fecal progesterone, "blinded" technicians correctly identified pregnancy status in 22/26 cases with 3 false positive diagnoses; fecal estradiol proved less effective (15/26) for accurately diagnosing pregnancy. These methods provide the potential to monitor reproductive activity in both captive and free-living moose.

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APPENDIX C.

REPRODUCTIVE BIOLOGY OF NORTH AMERICAN MOOSE

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Abstract: An understanding of the reproductive biology of moose (*Alces alces*) facilitates wise management. Moose are polyestrous cervids with relatively high ovulation rates in adult females. Puberty varies among populations, but no calves are sexually active. In populations on good range or below carrying capacity, yearling ovulation and pregnancy occurs. The estrous cycle averages 24 days and ranges from 22-28 days. If not bred, moose have up to 6 recurrent estrous cycles. The period of heat when a female will accept the male is short, lasting from 1-36 hours. Gestation length ranges from 216-240 days with a mean of 230 days. Gestation length is not different for single vs. twin litters. Pregnancy rates in adult moose are remarkably constant averaging about 84%. Twinning rates vary with range quality and may be a good indicator of carrying capacity. Bull moose reach puberty as yearlings. Increasing levels of testosterone initiate antler growth. High levels of testosterone activate Leydig cells which begin spermatogenesis. By fall, bull moose are ready for the breeding season with hardened antlers and fully developed sperm. Breeding season is relatively short, with >85% of all pregnancies occurring in <10 days. Peak rut occurs in late-September and early-October. Rutting season is relatively constant across North America. Out of season births are rare, but have been reported as late as August. Declining levels of testosterone following the rut are responsible for antler drop in bulls, which occurs from early-December through March. Large bulls tent to shed their antlers earlier than young bulls.

Alces Vol. 28(1992)pp.##-##

APPENDIX D.

AN EVALUATION OF SELECTIVE BULL MOOSE HARVEST ON THE KENAI PENINSULA, ALASKA

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Abstract: Intense harvest of bull moose (*Alces alces*) on the Kenai Peninsula in the late 1970's and early 1980's resulted in a low proportion of bulls in the population. Ratios at that time varied from 5 to 12 bulls/100 cows in heavily hunted areas with easy access. Concern for the population's health, stability, and future hunting opportunity coupled with a public desire to increase viewing opportunities of bull moose prompted the Alaska Board of Game to institute a selective harvest system (SHS) for bull moose in 1987. Under the new regulation only males with a spike or forked antler (yearlings) or bulls with antlers >50 inches in spread or with three brow tines on one antler were legal to harvest. Here we compare population and harvest statistics for 5 years prior to SHS with the first 5 years of SHS. SHS resulted in a significant ($P < 0.05$) decline in both the total bull harvest (636 vs. 443 moose) and the number of hunters (3602 vs. 2605). Hunter success did not change (18 vs 17%). Population modeling closely predicted harvest changes with implementation of SHS following both normal and severe winters. Based on harvest statistics, we calculated that under SHS approximately 34, 79, 47, and 19% of yearling, 2-3, 4-5, and ≥ 6 old, respectively, were protected from harvest.. Reported illegal harvest averaged 6.7% of the legal kill during the 5 years of SHS. Most moose killed illegally were mistaken for larger moose. The bull:cow ratio increased from 16 to 29 bulls/100 cows 3 years after SHS was implemented. As the number of bulls in the population increased, we did not detect a change in calf/cow ratios, pregnancy rates, or sex ratio among calves. SHS appeared to be a viable alternative to a general bull moose season. It allowed for unlimited hunter participation, even following a severe winter when hunting seasons were severely restricted or closed in adjacent areas. SHS provided an alternative to more restrictive seasons or permit hunts. Management implications are discussed.

Alces Vol. 28(1992)pp.#-#

APPENDIX E.

GENETIC DIVERSITY OF MOOSE FROM THE KENAI PENINSULA, ALASKA

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Abstract: Six of 20 loci from liver and muscle tissue from Kenai Peninsula moose (Alces alces gigas) were polymorphic. Average heterozygosity was 7.7%, which represents an unprecedented level of genetic diversity for moose. This level of diversity was not expected because empirical evidence from other moose populations, as well as theoretical considerations, indicated that moose exhibited low levels of heterozygosity. We propose that moose populations with low diversity reside in areas that were glaciated during the last Ice Age and that the recolonization process reduced heterozygosity, while high-diversity populations reside in areas in the proximity of glacial refugia.

Alces Vol. 28 (1992) pp. 000-000

APPENDIX F.

URINARY CHEMISTRY PROFILES OF SUPPLEMENTALLY-FED MOOSE

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Abstract: We describe urine chemistry profiles for 4 healthy male moose (Alces alces) being fed an ad libitum or moderately restricted high protein-high energy diet, and for 1 male being fed the same diet ad libitum but recovering from severe undernutrition. Urea (U), phosphorus (P), potassium (K), calcium (Ca), and sodium (Na) were expressed as ratios to creatinine (Cr) to account for differences in urine concentrations and to facilitate analysis of urine deposited in snow (snow-urine). Urea:Cr ratios did not differ among animals or over time, although the nitrogen balance of the undernourished moose likely differed from those of the other animals. Profiles of K:Cr, Ca:Cr, and Na:Cr allowed us to differentiate between the undernourished and healthy moose, and Na:Cr differed among animals being fed ad libitum and those on restricted diets. The profiles from the 4 healthy moose can be considered as a baseline for this species. Analysis of urine deposited in snow can be a useful indicator of population condition in moose, but a clear understanding of the physiological processes indicated by these profiles and their inherent limitations is essential to proper implementation.

Alces Vol. 28 (1992) pp. 000-000

Estimation of Body Composition in Moose (Study 1.42)

by
Kris J. Hundertmark
Charles C. Schwartz
David C. Johnson

PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperator: Kenai National Wildlife Refuge, Soldotna, Alaska

Project No.: W-23-5 Project Title: Wildlife Research and Management

Study. No.: 1.42 Job Title: Estimation of body composition in moose

Period Covered: 1 July 1991-30 June 1992

SUMMARY

We evaluated techniques for estimating body composition in moose under field conditions. We estimated body water via bioelectrical impedance analysis (BIA) for 8 moose, and via urea dilution for 7 of those individuals. We slaughtered these animals and analyzed tissue samples for protein, water, fat and ash content. The peroneus muscle group was also dissected from 7 of these individuals and submitted to the same analyses. Chemically-determined ingesta-free body (IFB) fat estimates ranged from 1.07-19.08% on a fresh weight basis, and IFB water ranged from 73.4-58.1%. Peroneus fat was a poor predictor of IFB fat. Empty body water space (EBWS) determined by urea dilution approximated IFB water, but was not a precise estimator. Serum urea nitrogen tests offered by commercial veterinary laboratories were not precise enough to be useful for this technique. Percentage fat in the shaved skin, skinless empty carcass, and empty viscera declined linearly with % IFB fat, indicating that the fat in these body components was used simultaneously, contradicting the long-held belief of a sequence of fat mobilization in moose.

Chemically-determined fat and water content of the IFB were related significantly to a number of factors, including BIA parameters, live weight, total length and packed cell volume. Although our sample size was small we believe the results are promising and warrant further research. We best predicted live weights (LW) of moose by a linear model incorporating total length, heart girth, and condition class score.

Key Words: *Alces alces*, BIA, bioelectrical impedance analysis, body composition, body fat, body water, moose, urea dilution, weight.

TABLE OF CONTENTS

BACKGROUND

Body condition was identified as a critical variable within the moose carrying capacity model (Hubbert 1987, Schwartz et al. 1988a, 1988b) and body fat is a major factor in the moose submodel. Body fat must be accurately measured in moose. A proposal was prepared to test methods of estimating body composition of moose (Schwartz et al. 1988c), focusing primarily on measurement of urea space (Preston and Kock 1973), as an *in vivo* technique, and measurement of composition of the peroneus muscle group (peroneus tertius, extensor digitorum longus, and extensor digiti III proprius, Huot and Goodreault 1985), on dead animals.

Over the last decade a body composition estimation technique known as bioelectrical impedance analysis (BIA) has been demonstrated to be a precise and unbiased predictor of human body composition (Lukaski 1987) and is being investigated for potential use in animal applications (Hall et al. 1989, Jenkins et al. 1988, Swantek et al. 1991). This technique works on the principle of measuring the impedance (resistance to alternating current) of hydrated body tissues to an alternating current of known frequency. Nyboer et al. (1943) demonstrated that

$$V = rL^2/Z$$

where V = body water volume, r = volume resistivity and is constant for a given conductor, L = conductor length, and Z = impedance. Impedance is computed by $(R_s^2 + Xc^2)0.5$ where R_s = resistance and Xc = reactance, but as Xc is small in relation to R_s the equation can be reduced to $Z = R_s$; however, as R_s and Xc are both easily measured we decided to use Z as an estimator. We tested this technique as a potential indicator of moose body composition.

Implicit in estimating body composition by the aforementioned techniques is an accurate measurement of body weight. Obtaining weights of free-ranging moose is difficult as moose are often too heavy to be lifted and weighed by helicopter. Franzmann et al. (1978) and Haigh et al. (1980) reported high correlations between certain body measurements and body weight of moose; however, body measurements are not sensitive to changes in the fat depots of moose. Franzmann et al. (1976) developed a subjective 11-point scale to assess condition class (CC) of moose based on physical appearance that may, when combined with body length, predict body weight more precisely.

OBJECTIVES

Determine the relationship between urea space measurements, impedance measurements, chemically determined composition of the peroneus muscle group, and chemically determined body composition in moose.

Determine if moose body weight can be predicted accurately from measurement of body length and heart girth, and appraisal of physical appearance.

Determine if these techniques have potential to estimate moose body composition in field applications.

METHODS

Job 1. Acquire and maintain experimental animals

We obtained animals for the experiment from the pool of surplus animals at the Kenai Moose Research Center (MRC) herd, which included 2 adult females, 3 yearling bulls, and 3 bulls aged 2.5 years. These animals were held captive at the MRC and fed a controlled ration (Schwartz et al. 1985). We killed the first of the adult cows in March 1991 when it became apparent that she would not recover from a chronic illness. The second cow was included in the study in May 1991 under similar circumstances. The remaining animals were healthy and were killed at a rate of 1 per 2-wk interval beginning in September.

Job 2. Determine the body water content of experimental animals via urea dilution

We weighed experimental animals before immobilization whenever possible and immobilized them with either xylazine hydrochloride and/or carfentanil by means of hand-injection or darting. We inserted a polyethylene catheter into the jugular vein and drew blood samples into a heparinized and a non-heparinized vacutainer. A solution containing 20% urea in physiological saline was administered through the catheter at a rate of 66 ml/100 kg live weight (130 mg/kg). Non-heparinized blood samples were drawn at 10, 15, 20, 30, 40, 50, 60, 75 and 90 min post-infusion (time 0 was defined as the midpoint of the duration of the infusion, which took approximately 2 min to complete). We centrifuged the non-heparinized blood samples at the MRC immediately after collection, and stored serum frozen until it was analyzed by an independent veterinary pathology lab for serum urea nitrogen (SUN). Whole blood sampled before urea administration was analyzed for packed cell volume (PCV) and hemoglobin (Hb) (Franzmann et al. 1987) at the MRC.

Empty body water space (EBWS, the volume of water in the body not including ingesta) was calculated as:

$$EBWS = D(S_e\text{-}S_b)^{-1}\text{-}V_d$$

where D = dose of urea nitrogen (UN) administered (weight UN = weight urea * 0.4667); S_e = equilibrium-specific concentration of SUN, S_b = background SUN naturally occurring in the animal (from the sample taken at t = 0); and V_d = the volume of urea solution infused. As V_d is negligible in comparison to EBWS the equation can be reduced to

$$EBWS = D(S_e\text{-}S_b)^{-1}.$$

We estimated Se by a least squares model:

$$S_0 = S_t(e^{-kt})^{-1}$$

where S_0 = the extrapolated specific concentration of SUN, which approximates S_e; and S_t = SUN at time t, provided t occurs after equilibration (Holleman et al. 1982). As urea does not infuse significantly into the rumen space over the duration of our sampling (Bartle and Preston 1986) we will confine ourselves to analysis of the relationship between ingesta-free body (IFB) water (which we define as chemically determined water content) and EBWS.

Job 3. Determine the body water content of experimental animals via BIA

A plethysmograph (Model BIA-101, RJL Systems, Inc. Detroit, MI) was used to estimate impedance of moose. The animals were allowed to assume a sternally-recumbent position after immobilization. Any variation in positioning of animals was corrected so that all animals were tested in similar positions. Electrodes were constructed from trocars removed from 18ga spinal needles and were bent to an angle of 90° 13mm from the tip. A "source" electrode was inserted subdermally at the carpal joint on the foreleg and at the joint between the metatarsus and the hoof on the hind leg on the side of the body most exposed while the moose was

sternally-recumbent. A "detector" electrode was placed 7.5 cm proximal to each source electrode. The tips of the electrodes were oriented distally. Electrodes were connected to the plethysmograph via alligator clips on the end of 10-ft. cables. Resistance and Xc were recorded as well as total body length (TL) and heart girth (HG). Electrodes were removed and re-inserted, and R_s and Xc measured, a minimum of 3 times per animal to ascertain variation associated with electrode placement.

Job 4. Determine body composition of experimental animals

We killed the animals within 24 hours after final urea dilution and obtained BIA measurements. We eviscerated and skinned the animals, leaving as much fat as possible on the carcass. The empty carcasses were bisected along the spinal column, with half the carcass frozen for analysis. The peroneus muscle group was dissected from the carcass half that was not used in the analysis and were frozen. We emptied the digestive tract and weighed the ingesta and viscera separately. The entire viscera and samples of the ingesta and shaved hide were frozen. We cut the frozen side of the carcass and the visceral mass into 51- and 25-mm slices, respectively, on a commercial band saw. We collected the sawdust that collected at the base of the blade for each component, which we thoroughly mixed, refroze, and shipped along with ingesta, hide, and peroneus samples to the Wildlife Habitat Laboratory at Washington State University to determine crude fat, crude protein, ash, and water content (Huot and Picard 1988). The amount of crude fat in the samples was determined by methanol-chloroform extraction; crude protein content was determined by the Kjeldahl procedure (AOAC 1975); ash content was determined by burning in a muffle furnace at 550°C for 2 h; and percent organic dry matter (1-moisture content) was determined by drying samples in a 100°C oven for 12-16 h and subtracting ash content. Three replicates of each sample were analyzed. Peroneus and hide samples were freeze-dried and ground in a Wiley mill before being subject to chemical analysis.

Job 5. Determine if body weight of moose can be predicted accurately from total body length and visual appraisal

Moose at the MRC that were immobilized and weighed during this report period were subject to visual appraisal of CC. Total body length (TL), HG and CC were used in a multiple regression analysis to predict live weight (LW).

Job 6. Examine the relationship between urea space, impedance values, peroneus fat, and body composition estimates

Empty body water space estimates, peroneus composition, and BIA values (TL^2/Z and Z) were compared to body composition estimates by simple linear and/or stepwise multiple regression with LW and TL as additional predictors. Swantek et al. (1991) demonstrated that R_s and/or Xc (and by extension their product Z) were occasionally better predictors of IFB fat and water than the traditional parameter TL^2/Z. Packed cell volume (PCV) was also used as a predictor because it served as an index of dehydration, which accompanies malnutrition and would have an effect on BIA measurements (Brodie et al. 1991). We constrained the stepwise regression procedure

to minimize multicollinearity by instructing the software not to enter predictors that were highly correlated with predictors already in the model (Wilkinson 1990). Adjusted coefficients of multiple determination (R_a^2) were reported for multiple regressions rather than raw R^2 values because, unlike R^2, R_a^2 is not influenced by the number of independent variables in the model (Neter and Wassermân 1974:229).

RESULTS AND DISCUSSION

Job 2. Body water content of experimental animals via urea dilution

We estimated empty body water space for 7 moose. Estimates generated by the regression method approximated IFB water, but showed considerable variation (Fig. 1). We performed regressions with SUN estimates collected after 25 min post-infusion and after 30 min post-infusion. As we collected these data after the probable equilibration time of urea in moose (20-25 min, Hundertmark et al. 1992) they should have yielded identical estimates of EBWS for any given animal (Holleman et al. 1982) but they did not. We believe this is a function of the precision of SUN estimates from commercial laboratories, which are expressed to the nearest mg/dl. As post-equilibration estimates of SUN differ from background SUN by only 10-20 mg/dl any error in SUN estimates would result in biased EBWS estimates. To illustrate, we calculated EBWS for Brooks using a post-equilibration difference of 11 mg/dl instead of the 10 mg/dl calculated from the laboratory results. This difference of 1 mg/dl changed our estimate of urea space by 29l (10%). Such potential for significant error greatly diminishes the utility of this technique. More precise estimates of SUN are possible, but are not routinely available from commercial laboratories.

Job 3. Body water content of experimental animals via BIA

Mean R_s estimates varied between 235-581 ohms and Xc estimates varied between 14-42 ohms (Table 1). Within-animal variation was low for both parameters (CV $\leq$ 3.3%) with the exception of Xc for Oly (CV = 14.7%). This was the result of 1 Xc estimate of 52 ohms being far greater than the remaining 4 (37, 37, 41, and 43 ohms). Without this anomaly the CV for her Xc estimates (7.6%), although still relatively great, was much closer to those of the other animals. Our plethysmograph was found to be malfunctioning (bad batteries) shortly after Oly and Angel were sampled, which may have led to the great amount of variation noted here and the extremely high R_s estimate for Angel.

Job 4. Body composition of experimental animals

The range of body fat present in the subjects ranged from 1-17% of total composition and 1-19% of the IFB (Table 2), which represented what we believe is the normal range of condition for moose. The percentage of water in the IFB ranged from 58-73%, but we believe this range is wider than normal. Brooks (58.1% IFB water) was killed in early September when the weather was hot and windy which led to drying of the tissues, particularly viscera, during processing.

At the other extreme Angel (73% IFB water) probably was high because we washed her viscera with water to remove ingesta, and we probably did not dry the ingesta long enough to remove extraneous water. Angel was the last subject for which we used this method. Percentage fat in the peroneus muscle group of 7 moose ranged from 0.25-2.4%.

We observed linear relationships between IFB fat, visceral fat, empty carcass (skinned and eviscerated) fat and shaved skin fat expressed as percentages of weight (Fig. 2). This illustrated that mobile fat depots (with the probable exception of marrow fat which we did not measure in this study) were used simultaneously and that the sequence of fat mobilization described by Harris (1945) referred only to the sequence of disappearance of these depots based on visual appraisal, which depended on their original size. When weight of depot fat was expressed as a percentage of the weight of IFB fat we computed means (SE) of 72% (2.6), 25% (2.6), and 2% (0.6) for carcass, viscera, and skin, respectively. When fat depot percentages (independent variables) were regressed against % IFB fat (dependent variable) we concluded that the slopes of the regression lines were not significantly different from 0 (Table 3), which indicated that the amount of fat in each depot (expressed as a percentage of total fat) did not change across the range of body condition represented in our sample. If this relationship holds with additional sampling it would have a profound effect as a management tool, as a skin sample could be taken from dead moose from which % IFB fat could be estimated. Least squares estimation of % IFB fat (Y) using % shaved skin fat (X) as the independent variable resulted in the following predictive equation (regression through the origin) and regression parameters: $Y = 8.59(X)$, $R^2 = 0.93$, SEE = 2.25, $\underline{F} = 141.44$, $\underline{P} < 0.0001$.

Job 5. Body weight of moose as predicted from total body length and visual appraisal

Of the 8 animals used in this study, we assigned 5 a CC score at the time of death. We added these data along with weights and measurements to the data from 11 animals reported last year (Hundertmark et al. 1992). Of the various linear regression models applied to the data, the model using TL, HG and $1/CC^2$ offered the most precision (Table 4). Predicting LW using TL and HG actually yielded a lesser R_a^2 than TL alone but this can be attributed to the smaller sample size used in the former model as HG was not measured for 3 animals.

There were some notable differences between our results and those reported elsewhere for weight-length relationships (Franzmann et al. 1978, Haigh et al. 1980). The correlation (r) between TL and LW for our data was 0.84, which was not as high as that reported by Franzmann et al. (1978) (0.94) but was higher than that reported by Haigh et al. (1980) (0.71). These differences may be attributable to the considerably greater sample size reported by Franzmann et al. (1978) and the fact that Haigh et al. (1980) measured weight by suspending moose from a helicopter and recording weight only to the nearest 5 kg. Haigh et al. (1980) also subtracted a subjective estimate of antler weight from LW of males, which would increase the variation of the estimate. The regression equations presented in these publications for predicting LW as a function of TL differ from that reported here (Fig. 3). A major difference between our study and theirs is that we have no data from animals less than 1.5 years old. Also, Haigh et al. studied a smaller subspecies (*A. a. andersoni*) than that studied by Franzmann et al. (1978) and this study

(*A. a. gigas*). The relative positions of the regression lines (Fig. 3) indicated that representatives of *A. a. andersoni* are shorter than representatives of *A. a. gigas* of the same weight. We can only speculate that as our sample size increases the value of our parameters will approach those of Franzmann et al. (1978).

Job 6. Relationship between urea space, impedance values, peroneus fat, and body composition estimates.

Percent peroneus fat was significantly related to percent IFB fat when both parameters were expressed as natural logarithms but the relatively high standard error of the estimate makes this parameter a poor predictor of body fat (ln(% IFB fat) = 1.80 + 0.83 * ln(% peroneus fat), R_2 = 0.48, P = 0.02, SEE = 0.65). Hout and Goodreault (1985) reported a high correlation between peroneus fat and total body fat (r = 0.92) for caribou (*Rangifer tarandus*) and they observed a much wider range of peroneus fat (approximately 0.5-4.5%) than we did, yet we had a wider range of body fat estimates. The relationship they described between these 2 parameters fit our data reasonably well with the exception of 2 observations (Fig. 4).

When all animals were included in the analysis, impedance parameters (either TL^2/Z or Z) were included in the stepwise regression model for IFB fat (kg and %) and IFB water (%) but not for IFB water (kg) (Table 5). Live weight was included in all 4 models and was the first predictor entered, which indicated that variation in LW accounted for the greatest proportion of variation in the dependent variable. Similar results were reported for caribou and reindeer (Gerhart et al. 1992). This should not be interpreted as meaning that BIA was an insignificant variable. We expected LW would be an important predictor of weight of IFB water and fat, but LW would be insensitive to differences in IFB water and fat among animals of similar weights. We believe the inclusion of LW in the models for percentage IFB water and fat was a function of the animals we used in the study. Of the 8 animals, LW for 6 ranged between 290-392 kg, and within such a narrow range of weights we would expect greater percentages of IFB fat and lesser percentages of IFB water to result in greater LW. As our sample size increases we expect LW to have less predictive power for percentages of IFB water and fat.

As discussed previously, BIA measured the volume of water in the body. The exclusion of BIA parameters from the model for IFB water (kg) would indicate that the technique failed; however, we computed separate models with Angel removed from the analysis because of our suspicions that the plethysmograph was not working correctly when we sampled her. As a result, Z was included in the model and the SEE decreased considerably (Table 5).

Estimating body composition components for all animals without using LW as an independent variable (see Job 6) resulted in PCV entering into all models and TL entering into all models with the exception of IFB water (%). Removing Angel from the analysis improved predictive power (greater R_a^2 and lesser SEE) of models estimating IFB water (kg and %) but decreased predictive power for IFB fat (kg and %) (Table 5), and a BIA parameter was included in 3 of the models.

We realize that our sample sizes are extremely small for this type of analysis, and that regression parameters could change significantly with the addition of more animals. We present these data as preliminary, and caution against drawing conclusions from the information presented here. Indeed, Gerhart et al. (1992) concluded that BIA was inferior to traditional body composition indices in estimation of body composition in caribou and reindeer. However, we believe our data indicate that further research is warranted.

RECOMMENDATIONS

We plan to continue the study, focusing our efforts on BIA rather than urea dilution. If we cannot locate a laboratory that can determine SUN levels more precisely, we will discontinue that portion of the study. Historic records of moose measurements from the MRC will be analyzed for relationships to predict weight.

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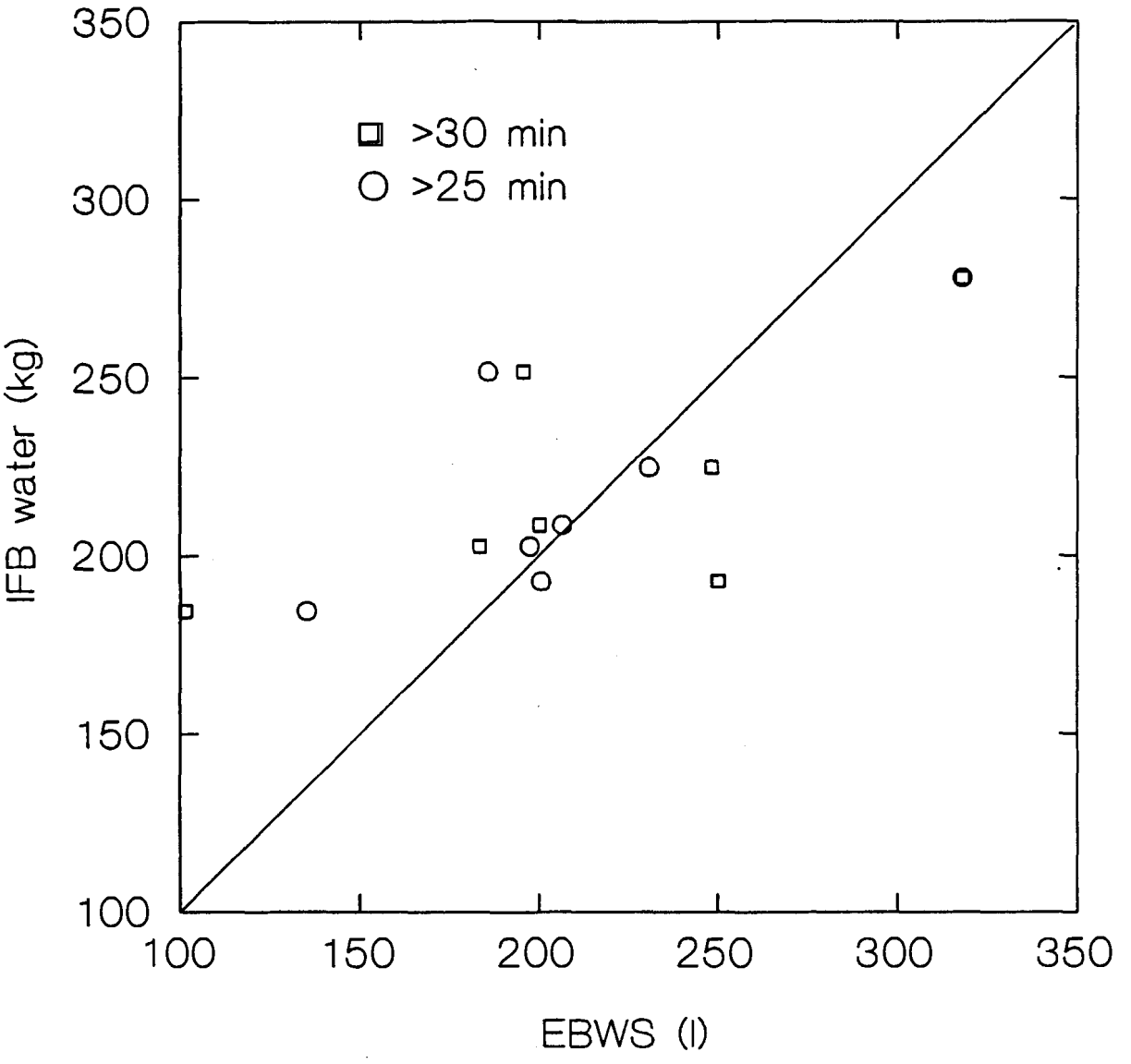


Fig. 1. The relationship between EBWS and IFB water using SUN estimates collected after 25 min and 30 min post infusion. Line of unity is indicated.

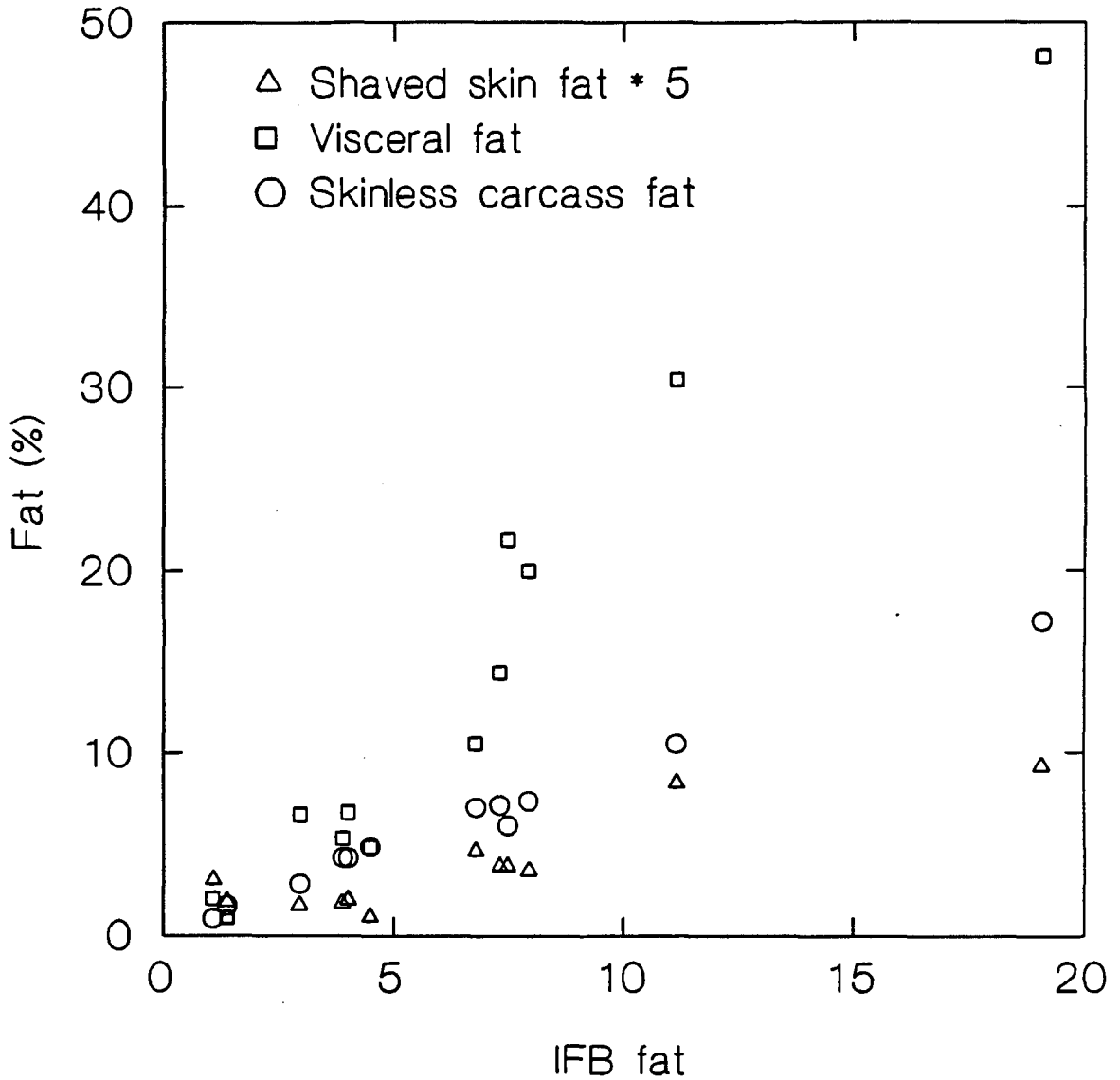


Fig. 2. The relationship between percent IFB fat and percent fat in the shaved skin, skinless carcass and viscera components.

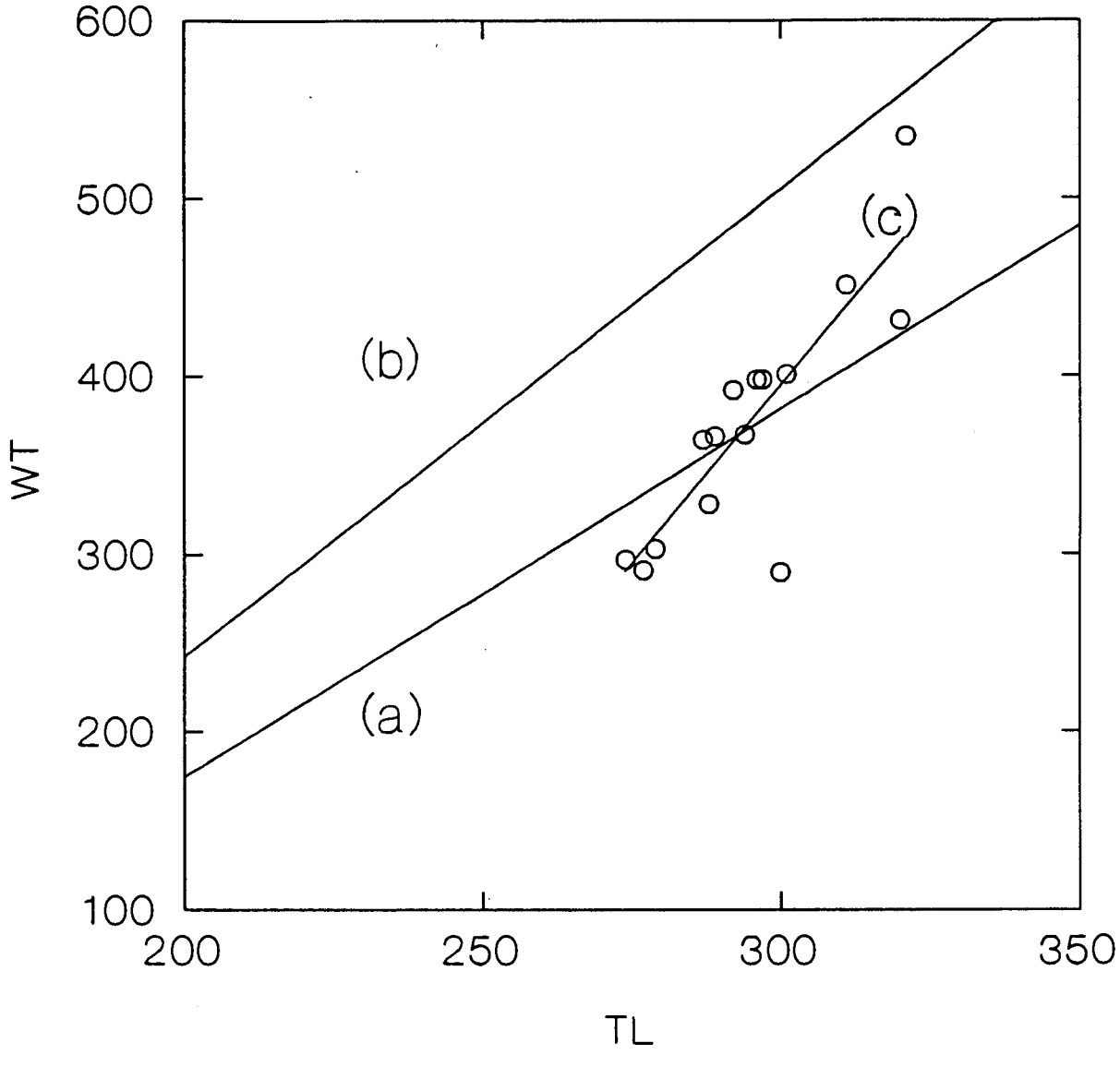


Fig. 3. The relationship between LW and TL. Lines were calculated from predictive equations from (a) Franzmann et al. (1978), (b) Haigh et al. (1984), and (c) this study.

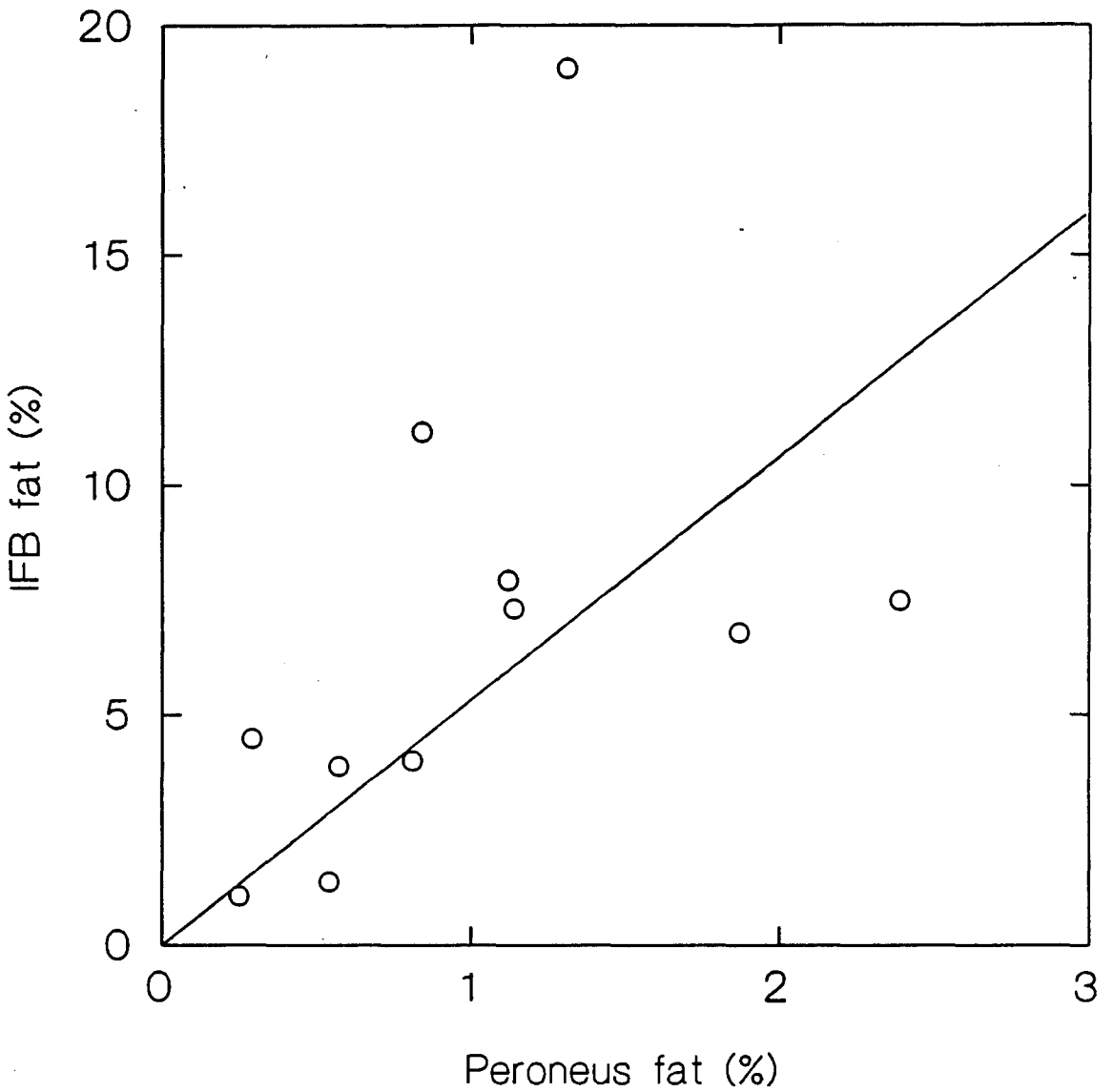


Fig. 4. The relationship between peroneus fat and IFB fat. The line was calculated from the relationship between these 2 parameters in caribou (Huot and Goodreault (1985).

Table 1. Mean (SEE) values of resistance (R) and reactance (Xc) and associated estimates of variation for moose used in the body composition study.

		R			Xc		
Animal	N	Mean	SEE	CV	Mean	SEE	CV
Angel	5	235.6	3.5	3.3	14.0	0.0	0.0
Brooks	3	302.0	1.2	0.7	21.0	0.0	0.0
Oly	5	581.6	8.2	3.2	42.0	2.8	14.7
Luke	3	363.0	0.6	0.3	30.7	0.3	0.3
Hydro	3	365.3	6.1	2.9	29.3	0.3	2.0
Sol	4	317.0	1.1	0.7	30.0	0.7	4.7
Stripes	3	411.7	2.3	1.0	30.0	0.6	3.3
Kobuk	3	365.3	7.1	3.3	34.3	0.3	1.7

Table 2. Composition of the ingesta-free body for 8 moose, Moose Research Center.

Animal	LW	Water (kg)	Protein (kg)	Fat (kg)	Ash (kg)	Water (%)	Protein (%)	Fat (%)	Ash (%)
Oly	340	192.86	59.93	3.02	19.37	68.15	21.18	1.07	6.84
Stripes	309	177.37	55.61	11.78	14.3	67.44	21.15	4.48	5.47
Kobuk	344	208.71	60.47	12.22	16.48	68.38	19.81	4.00	5.40
Hydro	364	202.69	66.29	25.46	16.84	63.18	20.66	7.94	5.25
Sol	392	224.79	73.37	25.07	18.89	65.54	21.39	7.31	5.51
Angel	290	184.52	53.59	7.43	13.19	73.40	21.32	2.96	5.25
Brooks	535	278.06	94.73	91.30	24.54	58.10	19.79	19.08	5.13
Luke	415	251.72	84.90	44.96	24.33	62.51	21.08	11.17	6.04

Table 3. Regression (Y = a + bX) parameters for percentage of IFB fat contained in each of 3 depots (Y) and percentage IFB fat (X) for 12 moose.

	Regression parameters		
Y	a	b	$\underline{Y}$
Carcass	74.8[a]	-0.37[b]	72.4
Viscera	22.2[a]	0.52[b]	25.6
Skin	3.35[a]	-0.19[b]	2.1

[a] $\underline{P} > 0.01$, t-test.
[b] $\underline{P} < 0.10$, t-test.

Table 4. Regression equations, coefficients of determination (R^2), standard errors of the estimate (SEE), and error degrees of freedom (DF) for prediction of moose live weight (LW) from total length (TL), heart girth (HG), and condition class (CC), Moose Research Center, 1991-92, $\underline{N}$ = 16.

Regression equation	R_a^2	SEE	DF
LW = 4.00(TL)-805	0.68[a]	37.0	14
= 3.21(TL)+0.35(HG)-646	0.57[a]	35.7	10[b]
= 3.23(TL)+17.0(CC)-685	0.90[a]	20.9	13
= 4.03(TL)-136.3(1/CC)-785	0.89[a]	22.0	13
= 4.16(TL)-118.0(1/CC2)-842	0.88[a]	22.9	13
= 2.81(TL)+0.33(HG)+14.8(CC)-610	0.86[a]	20.9	9[b]
= 3.26(TL)+0.70(HG)-127.7(1/CC)-695	0.92[a]	15.4	9[b]
= 3.33(TL)+0.84(HG)-114.3(1/CC2)-759	0.93[a]	14.8	9[b]

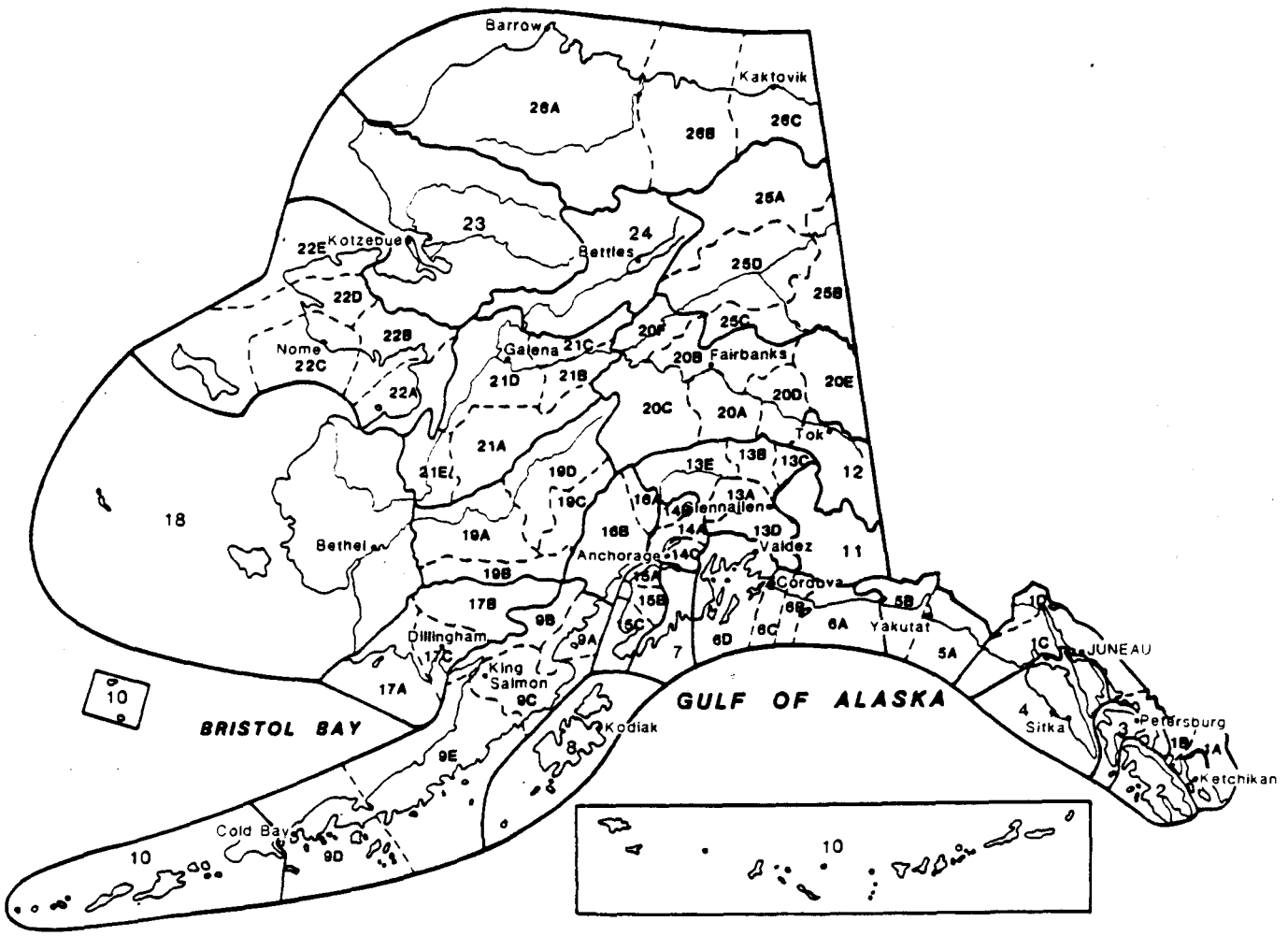
[a] $\underline{P}<0.01$
[b] Heart girth measurements were not available for 3 animals.

Table 5. Estimates of ingesta-free body composition components using total body length (TL), live weight (LW), packed cell volume (PCV) and bioimpedence analysis (BIA) parameters (impedance {Z}, TL^2/Z), fit by stepwise regression, and associated regression parameters.

Regression equation	df+	Error R^2_a	SEE	P[a]
<u>All animals, all parameters</u>:				
IFB* water (kg) = 53.36 + 0.43(LW)	6	0.90	10.77	0.0002
IFB water (%) = 84.17 + 0.02(TL2/Z) - 0.06(LW)	5	0.85	1.82	0.0041
IFB fat (kg) = -83.75 - 0.05(Z) + 0.35(LW)	5	0.93	7.39	0.0005
IFB fat (%) = -12.83 - 0.01(Z) + 0.07(LW)	5	0.92	1.67	0.0009
<u>Angel removed, all parameters</u>:				
IFB water (kg) = -294.57 -0.09(Z) + 1.87(TL)	4	0.98	4.82	0.0002
IFB water (%) = 82.47 - 0.05(LW)	5	0.80	1.67	0.0040
IFB fat (kg) = -153.28 + 0.66(PCV) + 0.41(LW)	3	0.98	4.13	0.0010
IFB fat (%) = -30.88 + 0.26(PCV) + 0.08(LW)	3	0.98	0.96	0.0017
<u>All animals, LW removed as a predictor</u>:				
IFB water (kg) = -408.97 + 1.86(TL) + 2.33(PCV)	4	0.78	15.51	0.0199
IFB water (%) = 80.94 - 0.47(PCV)	5	0.30	4.11	0.1132
IFB fat (kg) = -578.35 + 1.86(TL) + 1.68(PCV)	4	0.83	12.66	0.0132
IFB fat (%) = -109.83 + 0.35(TL) + 0.42(PCV)	4	0.86	2.27	0.0087
<u>Angel removed, LW removed as a predictor</u>:				
IFB water (kg) = -294.57 + 1.87(TL) - 0.09(Z)	4	0.98	4.82	0.0002
IFB water (%) = 122.71 - 0.20(TL)	5	0.70	2.07	0.0123
IFB fat (kg) = -67.88 + 0.42(TL2/Z)	5	0.77	13.85	0.0048
IFB fat (%) = -12.00 + 0.09(TL2/Z)	5	0.84	2.39	0.0025

[a] Significance level of F statistic from regression ANOVA.
* IFB = ingest-free body
+ df = degrees of freedom

Alaska's Game Management Units



WILDLIFE RESTORATION

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