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ALASKA DEPARTMENT OF FISH AND GAME
JUNEAU, ALASKA

MOOSE PRODUCTIVITY AND PHYSIOLOGY

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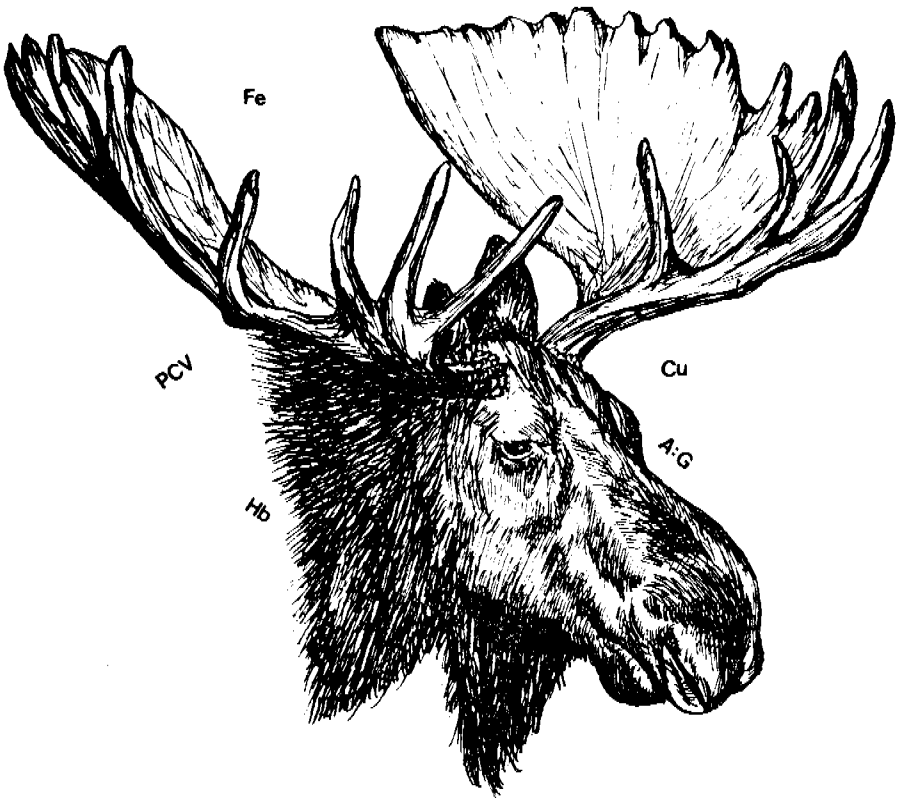

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Final Report
Federal Aid in Wildlife Restoration
Projects W-17-2, W-17-3, W-17-4, W-17-5, W-17-6 and W-17-7
Job 1.1R

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FINAL REPORT

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SUMMARY

Previously reported studies concerning establishment of base line physiologic values for moose milk (chemistry and minerals), hair (macro and trace elements), heart and respiratory rates, body temperature, excitability stress classification, condition evaluation, marrow fat determination and morphometric measurements are summarized. Establishing base line blood chemistry and hematology values for moose was an important part of this study. Fifteen-hundred and six serum and 1,235 whole blood samples were obtained from Alaskan moose from various regions and populations. Collections at the Kenai Moose Research Center (MRC) provided 687 serum and 646 whole blood samples. Blood sera were analyzed for Ca, P, glucose, BUN, uric acid, cholesterol, bilirubin, alkaline phosphatase LDH, SGOT, TP, albumin, globulin, alpha 1 globulin, alpha 2 globulin, beta globulin, and gamma globulin. Hemoglobin and PCV values were obtained from whole blood. Blood samples were classified as to sex, age, month and year sampled, age class, season-age class, reproductive status, rectal temperature class (excitability), location and condition. Base line data for applicable classifications were determined. Season classification was a source of significant variation at some point for every blood parameter while pregnancy was the only classification influencing none ($P < 0.01$). Sex was a source of variations only during rutting period (October), and age significantly influenced each blood parameter except P, glucose and alpha and beta globulins. Phosphorus, uric acid, and cholestrol levels were significantly influenced by lactation. Rectal temperature class was a significant source of variation for glucose, bilirubin, LDH, albumin, and all globulin fractions. All adult blood parameters were at some point influenced by location except for gamma globulin. Condition improvement in adult moose significantly increased Ca, P, glucose, TP, albumin, beta globulin, Hb and PCV values. Condition rating, based upon the premise that animal form and compositon are largely dictated by the interactions of the complexes of climate and nutrition, was used to compare populations classified to eliminate most major sources of variation.

Blood parameters most useful in condition evaluation in order of value were PCV, Hb, Ca, and P. Glucose, albumin, and beta globulin also increased with improved condition, but were additionally influenced by excitability. Adult moose from five populations sampled during late winter were condition ranked based upon condition-influenced parameters and a realistic ranking was provided based upon inclusion of a known highly productive population (Copper River Delta) and a poor producing population (MRC). Using condition-influenced parameters we considered adult moose with the following blood levels or greater to be in an average or better condition; PCV - 50 percent, Hb - 18.6 percent, Ca - 10.4 mg/100 ml, P - 5.2 mg/100 ml, TP - 7.5 g/100 ml, albumin - 4.5 g/100 ml, beta globulin 0.7 g/100 ml and glucose 140 g/100 ml. Utilization of these condition-influenced parameters, as outlined, may provide game managers with quantitative evidence to supplement population information in formulating management decisions. Classified, base line, moose blood data reported may provide comparative and background information for other physiologic studies of moose. Productivity of moose at the MRC was monitored throughout this study and these data are summarized. Browse production, utilization, quality and digestibility study findings were reported in U. S. Fish and Wildlife Service Annual Reports and journal publications and are not included in this report.

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BACKGROUND

Past assessments of habitat carrying capacity utilized for moose (*Alces alces*) management were secondary indicators summarizing the manifestations of nutritional, behavioral, environmental and genetic forces acting upon a population. These assessments (food habits, range productivity and utilization, and estimates of population size and trend) have not proven adequate in situations where intensive management of moose populations was necessary. They indicated trends and the need was for analysis of individual primary factors rather than collective manifestations. Quantitative assessments from physiologic (function) information from the animal using a particular environment and physiologically reacting to it provide a more specific means to assess population status. There is a need for more intensive, imaginative and flexible management, and correspondingly, we need more sophisticated indicators to monitor wildlife populations. Productivity and physiology studies at the Kenai Moose Research Center (MRC) over the past 7 years have been based upon application of this concept and, in general, concerned with determining how moose affect vegetation and how vegetation affects moose. Results of these studies have been presented in six Project Progress Reports (LeResche 1970, LeResche and Davis 1971, LeResche et al. 1973, Franzmann and Arneson 1973, Franzmann and Arneson 1974b, and Franzmann and Arneson 1975), and 24 publications (LeResche and Davis 1973, Flynn and Franzmann 1974a, 1974b, Flynn et al. 1974, Franzmann et al. 1974, LeResche et al. 1974b, Oldemeyer 1974a, 1974b, Arneson and Franzmann 1975, Flynn et al. 1975a, 1975b, 1975c, Franzmann et al. 1975a, 1975b, 1975c, 1975d, Oldemeyer 1975, Flynn et al. 1976, Franzmann and Arneson 1976, Franzmann et al. 1976a, 1976b, Oldemeyer 1976, Oldemeyer and Seemel 1976, Oldemeyer et al. 1976). This Final Report summarizes findings reported in greater detail in the reports and publications listed.

Blood Chemistry and Hematology

The use of hematologic and blood chemistry values to monitor a population requires that base line values be established for the species in question. LeResche et al. (1974b) outlined the procedure for establishing nutrition-blood parameter correlations in moose as: (a) determining boundary conditions, or those characteristics of an individual animal that must be known before blood values may be interpreted; (b) establishing normal values within these boundary conditions using standardized handling and collecting procedures and (c) determining the nature and magnitude of changes in blood values resulting from known changes in food intake, nutrition or related parameters. The same criteria may be used for assessment of influences on blood and other physiologic parameters by factors other than nutrition.

Boundary conditions recognized for cervids in a state of good health and nutrition include; species, sex, age, season, reproductive status, handling method and fasting (LeResche et al. 1974b). In bighorn sheep (*Ovis canadensis canadensis*) sources of variation in blood values reported were; condition, excitability, habitat (Franzmann 1972), protein intake (Franzmann 1971b), handling (Franzmann and Thorne 1970) and pathologic conditions (Woolf and Kradel 1973 and Woolf et al. 1973).

Marler (1975) recognized age sources of variation in American bison (*Bison bison*). Sources of variation or boundary conditions for other wild North American ruminants have not been reported; however, hematologic and physiologic studies in nonruminants indicate similar sources of variation (Sealander 1964, Hock 1966, Seal et al. 1967, Dieterich 1970, Adams and Strahler 1972, Heidt and Hargroves 1974, Doyle et al. 1975 and Seal et al. 1975).

Hematologic and blood chemistry interpretations in human and veterinary medicine have progressed to clinical application due to the tremendous amount of base line data accumulated under identifiable and classifiable boundary conditions. In addition, the sources of variation confounding wild animal sampling can generally be avoided in human and domestic animal application.

When dealing with wild animals, it is very important to minimize sources of variation by standardizing procedures from capture of animals to tabulation of laboratory assays (Franzmann 1971a and LeResche et al. 1974b). Standardization of procedures was not always possible, however, and it was therefore necessary to identify and quantify identifiable alterations in procedure. To these collecting sources of variation were added those attributed to age, sex, season and other unalterable factors necessitating large sample sizes.

The problems and promise associated with application of hematology and blood chemistry values to moose management were an early consideration in the research program outline for the MRC. An effort was made at the MRC to establish base line hematologic and blood chemistry values for Alaskan moose with emphasis on classification of identifiable sources of variation and standardization of procedure.

Milk

Limited data have been collected in characterizing the constituents of moose milk. Gross composition, fatty acid content and mineral levels (Ca, Fe, K, Mg, Na and P) have been reported for only three moose (Cook et al. 1970b). Composition of milk from various other North American wild ruminants has been reported: white-tailed deer (*Odocoileus virginianus*) (Silver 1961, and Youatt et al. 1965), mule and black-tailed deer (*Odocoileus hemionus*) (Hagen 1951, and Kitts et al. 1956), barren-ground caribou (*Rangifer tarandus*) (Hatcher et al. 1967), muskoxen (*Ovibos moschatus*) (Tener 1956, Tener 1965, and Baker et al. 1970), bighorn sheep (Chen et al. 1965, and Forrester and Senger 1965), Dall sheep (*Ovis dalli*) (Cook et al. 1970a), and mountain goats (*Oreamnos americanus*) (Lauer et al. 1969).

One aspect of studies at the MRC was to monitor moose mineral metabolism. Tissue from moose (hair) as well as forage, soil and water were analyzed. Selected milk parameters in relation to hair elemental values corresponding to lactation were additionally analyzed.

Hair

Hair mineral element analysis has been increasingly utilized in animal research, primarily due to improved laboratory capability and the desirability of hair as a relatively stable physiologic parameter. Hopps (1974) reviewed the biological basis for using hair for trace element analysis. Researchers in human medicine have been analyzing hair to monitor exposure to toxic elements (Chattopadhyay and Jervis, 1974, Forshufvud et al. 1961, Habercam et al. 1974, Hammer et al. 1971, Klevay 1973, Kopito et al. 1967, Locheretz 1971, Petering et al. 1973, Smith et al. 1962, Strain et al. 1964, Weiss et al. 1972 and Yamaguchi et al. 1971) and to monitor mineral metabolism (Anke and Schneider 1962, Anke and Schneider 1966, Baumslag et al. 1974, Bradfield et al. 1969, Hambridge and Baum 1972, Hambridge et al. 1972, Klevay 1970a, Klevay 1970b, Klevay 1974, McBean et al. 1971, Petering et al. 1971, Reinhold et al. 1966, Schroeder and Nason 1969, Strain et al. 1966 and Strain et al. 1972).

First reports of mineral element analysis of domestic animal hair were published by Van Koetsveld (1958). A variety of reports relative to monitoring mineral elements via hair element analysis in domestic animals have followed (Anke 1965, 1973, Anke and Jeroch 1966, Brossard 1965, Hall et al. 1971, Hartmans 1965, 1972, Hidiroglou and Spurr 1974, Miller et al. 1965, Nogues and Lamand 1972, O'Mary 1970). Monitoring toxic elements in domestic animals was reported by Dorn et al. (1974).

Berg et al. (1966) utilized feathers from Swedish birds to monitor environmental mercury over a 100-year period. Mercury and lead hair values from small mammals and rodents have been published as well (Cumbie 1975, Huckabee et al. 1973 and Raymond and Forbes 1975).

Researchers at the Kenai Moose Research Center (MRC), Alaska, utilized hair element analysis as a means to monitor mineral metabolism and reported monthly and seasonal variations in moose hair values (Flynn and Franzmann 1974a, Franzmann et al. 1974 and Franzmann et al. 1975a). The application of moose hair and hoof mineral analyses to monitor copper deficiency was similarly reported (Flynn and Franzmann 1974b). This paper reports the findings of moose hair element values of 4 essential macro-elements (Ca, Mg, K and Na), 4 essential micro-elements (Cu, Fe, Mn and Zn), and 2 nonessential micro-elements (Cd and Pb) from various regions in Alaska from May 1972 through April 1975.

This hair element monitoring study was initiated to evaluate potential regional geochemical variations in Alaska and to elucidate potential mineral deficiencies in specific regions. The potential of geochemical variability in moose hair for forensic application was also considered. A final objective was to obtain a quantity of samples from various regions throughout the year to assist in establishing base line data on hair element values for moose.

Excitability Stress, Heart and Respiratory Rates and Body Temperature

Severe aberrations in blood values may result from the animal's acute physiological state when blood is collected. These are related to recent food intake and to handling stress. The former variables are uncontrollable in wild animals, and the latter are "controllable" only to the extent they can be quantified in all animals handled. Such quantification is crude because individuals differ in response to drugs, traps and handling. It is clear that many results depend upon whether the animal was shot, drugged or manually restrained. These variables are at least known. More importantly, the marked effects of restraint 24 hours previous to blood collections suggest that not only can short-term serial studies be seriously compromised, but that it is possible that levels in immediately obtained samples from wild animals may reflect the previous several days' activities.

A system to classify individual excitability states, based on heart rate, respiratory rate and rectal temperature, was developed for bighorn sheep (Franzmann 1972). Each individual was classified into one of five classes of excitability (not excited, slightly excited, moderately excited and highly excited). It was concluded that classes of excitability could be established and would aid in interpreting blood values.

Evaluating, and subsequently classifying, stress states in animals may also be approached through analyses of intracellular enzymes such as LDH, SGOT and CPK, which escape into the circulatory system when cells are injured (Coles 1967). Tissue breakdown and subsequent release of these enzymes has been examined in pathologic conditions in domestic animals (Blinko and Dye 1958, Whanger et al. 1969). The influence of handling excitability on SGOT values in bighorn sheep was demonstrated, but no correlation with degree of excitability was noted (Franzmann and Thorne 1970). Another potentially useful index of handling is a combination of CPK and LDH levels which show a different time course of elevation and decline after handling and tissue damage (Seal et at. 1972).

Immobilizing drugs have potentially contradictory effects on blood values. Many of these drugs calm the individuals being handled, decreasing excitability and stress. In addition, however, drugs may have other more discrete physiological affects due to their pharmacologic action (cf: Table 4, Harthoorn 1965, Fujita 1970). These must be experimentally determined for each species studied.

Since obtaining blood from sufficiently large samples of wild animals is difficult by any means, standardization of procedures is often extremely difficult. Nevertheless, it is extremely important to standardize methods as much as possible, and to realize that some measured values may be more plastic under stress (e.g. LDH, CPK, SGOT, glucose) than others (e.g. BUN, uric acid, cholesterol, proteins). With these relationships in mind, it is possible to use the more plastic assays as stress indicators, while examining nutritional status using those values little affected by handling. In any event, it should be recognized at the outset that even well-documented "norms" for a wildlife population are not strictly comparable to resting normals for human or domestic

species. Instead, the "normal" values are resting normals modified by the variable stress of the standardized animal handling procedure. For this reason, blood studies of wildlife are concerned with trends, and often require large sample sizes in order to document differences between populations.

Heart rate, respiratory rate and body temperature information from a species is basic to assessment of excitability state. Base line information regarding these parameters is needed for more accurate assessment.

Condition

Ledger (1968) outlined the premise that form and composition are largely dictated by the interaction of the complexes of climate and nutrition. Condition is relative and is simply the state in which an animal is at a particular time. To make condition a usuable term it must be quantified. To best accomplish a meaningful quantifiable condition state it should be related to form and composition of the animal.

Once a procedure for standardizing condition evaluation is developed, various physiologic parameters that reflect condition change should be investigated. This provides the manager with quantifiable physiologic values useful for population condition comparison and evaluation. Robinson (1960) established condition evaluation criteria for white-tailed deer based on form, composition and movement.

Marrow Fat

Femur marrow fat content, as determined by alcohol-ether extraction, has been correlated with condition in white-tailed deer (Cheatum 1949). Color and consistency of marrow was used by Riney (1955) to estimate marrow fat content in red deer (*Cervus elaphus*). Bischoff (1954) indicated marrow characteristics have limitations in assessing condition of black-tailed deer and consistency of marrow was the only adequate measure of its condition. Greer (1968) reported a compression method as an index of fat content in elk (*Cervus canadensis*) femur marrows. Neiland (1970) reported the dry-weight method for determining fat in barren-ground caribou femurs and Verme and Holland (1973) utilized a reagent-dry assay of marrow fat in white-tailed deer.

Marrow fat indices utilizing color and consistency as a basis for evaluation have subjective error potential. Extraction procedures are relatively accurate but time consuming. All methods may be subject to variation based upon handling of femurs prior to analysis. For example, femur marrows frozen for extended periods of time may have 5 to 10 percent higher fat content than a fresh sample (Greer 1968).

With consistency in collection, handling and procedure, each method has validity for comparative purposes. The Alaska Department of Fish and Game has utilized Neiland's dry-weight method for several years.

Sampling was done on the Kenai Peninsula, Alaska, to identify the level of marrow fat associated with the variety of known and suspected mortality factors experienced during biological collections.

Morphometric Measurements and Body Weight

Measurements of body weight and morphometry are potentially valuable techniques in wild animal studies primarily because most data are easy to obtain and values are not subject to acute stress-related changes. Although not acutely variable, whole body weight is subject to certain variation because of changes in rumen volume (Ledger 1968), genetic characteristics (Tanner et al. 1970) and normal seasonal variability (Verme 1970). Varying proportions of body constituents (eg: fat, muscle, water) (Short et al. 1969, Tanner et al. 1970, Seltzer et al. 1970) by season, nutrition, and other environmental influences further complicate live animal measurements. Growth patterns and body measurements, especially when used in conjunction with body weight (Klein 1968, Wood and Cowan 1968, Verme 1963, 1970) minimize some of these problems if valid base line values are available.

Productivity at MRC

The ultimate response of a population to its environment is its reproductive success or failure. This is the population's response to all forces acting upon it. Populations within the MRC enclosures were regularly monitored for natality, mortality, pregnancy and recruitment.

OBJECTIVES

To establish base lines by sex, age, season, reproductive status, area, drug used, excitability and condition for blood, hair and milk parameters in moose, and to evaluate their usefulness as indicators of nutritional and general status in moose.

To establish excitability stress classifications for moose based upon appropriate and selected physiologic parameters mentioned above.

To estimate browse production and utilization and to quantitatively and qualitatively estimate consumption of all plant materials by moose.

To determine nutritional values and digestibilities of the more common moose forage species.

To measure natality, mortality and general condition of moose at the Kenai Moose Research Center.

The overall objective was to obtain more thorough and specific knowledge of how moose affect vegetation and how vegetation affects moose. The application of the indicator species concept to moose by gaining knowledge specific to moose function (physiology) was an integral part of this objective.

PROCEDURES

Blood Chemistry and Hematology

Sampling Areas

Most of the blood samples used in this study came from collections at the MRC; however, samples were also obtained during hunts and in conjunction with movement and population identity tagging studies. Sources of moose blood samples collected and analyzed for this study are listed in Table 1.

The MRC (Fig. 1) encompasses four 259 ha (2.59 km^2) enclosures located in the area of the 1947 burn, 45 km northeast of Soldotna, Alaska. These enclosures contain representative vegetation of both burned (regenerative: predominately Alaska paper birch [*Betula papyrifera*], white spruce [*Picea glauca*], black spruce [*P. mariana*]) and remnant (mixed birch-spruce-aspen [*Populus tremuloides*]) stands. Twenty-two fence-line traps (LeResche and Lynch 1973) were strategically located (13 within and 9 outside the enclosures) to facilitate capture, handling and sampling of moose. During this study moose populations within the four MRC enclosures naturally and artifically fluctuated between 48 and 75 animals. Moose sampled included those from inside the enclosures and free-ranging moose from outside the enclosures.

Moose were sampled from the Fort Richardson late season hunts near Anchorage in January 1973 and 1974. This area is an important winter concentration area for moose and also supports a year-round resident population. The remaining blood samples were obtained during hunts on the Kenai Peninsula in 1969 and 1970.

Eight moose tagging operations on the Kenai Peninsula from 1970 through 1975 provided the opportunity to obtain blood samples (Table 1). Additionally, samples were obtained during moose tagging at the Copper River Delta, the Nelchina Basin, Fort Richardson and Elmendorf Air Force Base. LeResche et al. (1974a) reviewed habitats and distribution of moose in Alaska and Bishop and Rausch (1974) reviewed moose populations in Alaska. Both reviews provide excellent background information relative to Alaskan moose.

Field Phase

Capture methods varied depending upon location. At the MRC moose were trapped and subsequently immobilized (Franzmann and Arneson 1974a). Immobilization from a helicopter was used in tagging operations and occasionally at the MRC. Collections were made in conjunction with monitored hunts and scientific collections. Handling procedures were adjusted for each individual animal to minimize struggle and stress.

Field data applicable to this study, obtained and recorded when possible from each moose sampled, were: identification number, sex, location, reproductive status, age, measurements, weight, excitability, general condition and rectal temperature.

Table 1. Sources of moose blood collected from June 1969 to July 1975.

SOURCE	SERUM	WHOLE BLOOD
Trapping at Kenai Moose Research Center		
Pen 1	108	103
Pen 2	151	142
Pen 3	62	59
Pen 4	113	106
Outside Pens	253	236
Total Kenai Moose Research Center	687	646
Hunts		
GMU[1] 15(B) Kenai Peninsula (1969)	13	6
GMU 15(C) Kenai Peninsula (1969)	32	26
GMU 14(A) Fort Richardson (1969)	39	26
GMU 14(B) Fort Richardson (1969)	14	6
GMU 15(A) Kenai Peninsula (1970)	28	0
GMU 7 Kenai Peninsula (1970)	7	2
GMU 14(C) Fort Richardson (1973)	44	44
GMU 14(C) Fort Richardson (1974)	47	47
Total Hunts	224	157
Tagging		
GMU 15(A) Bott Lake (1970)	38	23
GMU 15(A) Moose River Flats (1970)	61	0
GMU 15(B) Skilak-Tustamena Bench (1971)	3	0
GMU 15(A) Moose River Flats (1971)	60	0
GMU 15(A) Mystery Creek Bench (1972)	60	60
GMU 15(B) Caribou Hills (1973)	61	61
GMU 6 Copper River (1974)	44	44
GMU 15(C) Bald Mountain (1974)	56	56
GMU 13 Alphabet Hills (1974)	64	64
GMU 15(C) Fox River Flats (1975)	31	31
GMU 13 Tulsona Burn (1973)	62	62
GMU 14(C) Fort Richardson (1975)	21	21
Total Tagging	561	422
Miscellaneous Collections	34	10
TOTAL	1506	1235

1. GMU - Alaska Department of Fish and Game, Game Management Units

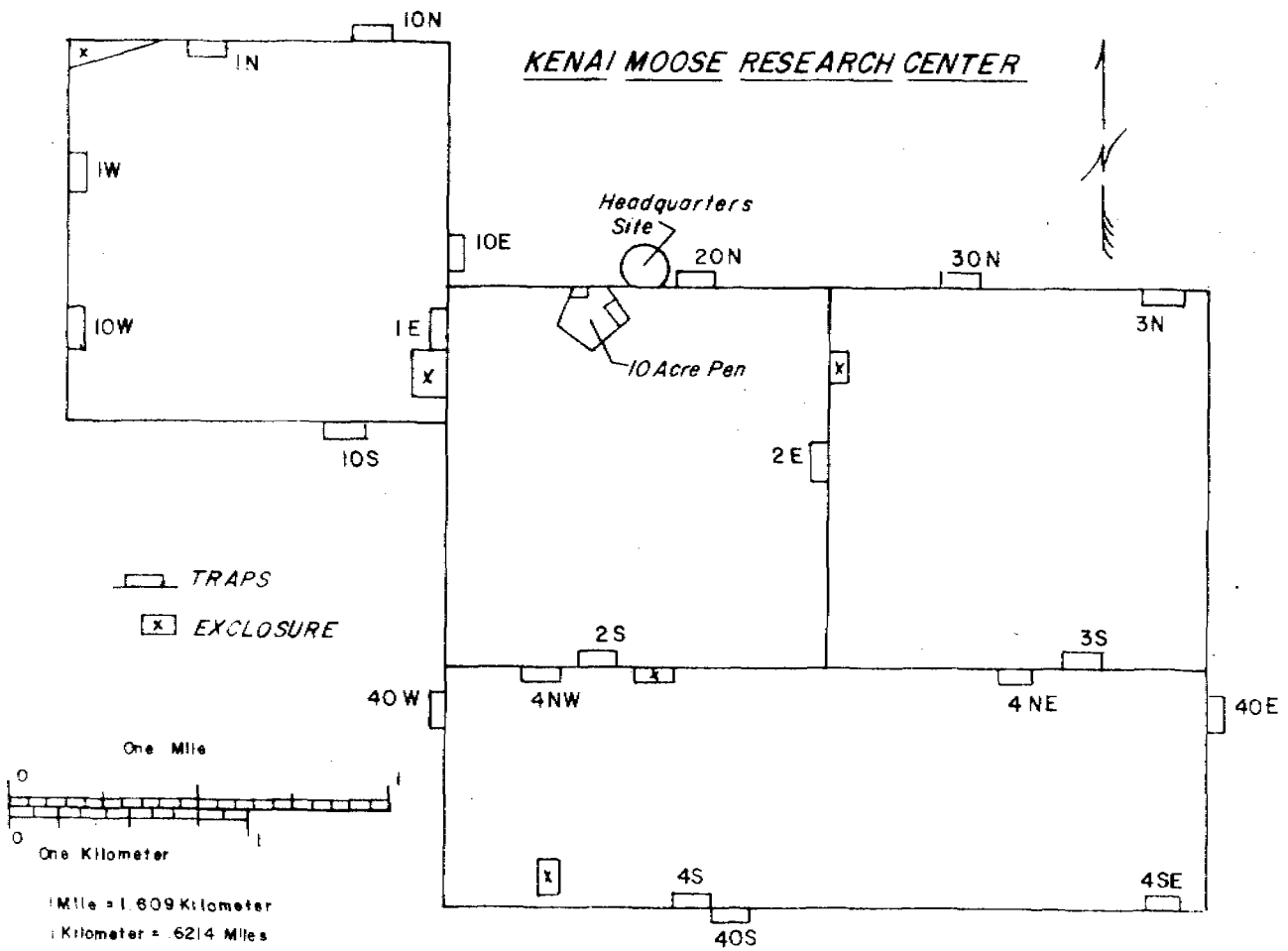


Figure 1. Map of Kenai Moose Research Center

Reproductive status was established by observation when possible (cow with or without calves, estrus, rut), and by rectal palpatation of cows from December through June. Age was determined from tooth section cementum layers (Sergeant and Pimlott 1959).

Blood samples were obtained for this study from July 23, 1969 to March 1975. Blood was collected from live animals by jugular vein puncture utilizing sterile evacuated containers. One 15 ml vial contained heparin to provide an uncoagulated whole blood sample. Three other plain 15 ml vials were filled to provide sera. Blood specimens were identified and protected from freezing and extreme heat.

Laboratory Phase

Soon after sampling, blood was taken to MRC headquarters or to a temporary field laboratory where initial laboratory tests were performed. From the uncoagulated whole blood sample a hemoglobin determination was made utilizing a Hb-Meter (American Optical Corp., Buffalo, NY) and packed cell volume (PCV) values were established with a micro-hematocrit centrifuge (Readacrit - Clay Adams Co., Parsippany, NJ).

Blood serum was obtained by centrifuging samples at 34,000 RPM for approximately 5 minutes and pipetting serum into 3 separate vials and freezing. One sample was sent to Alaska Medical Laboratories, Anchorage, for blood chemistry analysis (Technichon Autoanalyzer SMA-12) and protein electrophoresis for these parameters; calcium (Ca), phosphorus (P), glucose, blood urea nitrogen (BUN), uric acid, cholesterol, bilirubin, alkaline phosphatase, lactic dehydrogenase (LDH), serum glutamic oxalacetic transaminase (SGOT), total protein (TP), albumin, globulin, alpha 1 globulin, alpha 2 globulin, beta globulin and gamma globulin. Calcium/phosphorus ratios (CA:P) and albumin/globulin ratios (A:G) were computed from these data. One sample was utilized for steroid and other biochemical analyses and the third vial was retained for future analyses.

Analysis of Data Phase

Both field and laboratory data were recorded and sent to the Computer Services Division of the Alaska Department of Administration, Anchorage, where they were stored and programmed for retrieval. Data were sorted by the computer based upon sex, month sampled, age class, season-age class, reproductive status, rectal temperature class, location and condition. Means, standard deviations, and sample sizes were provided in sort outputs for the various combinations to provide input for t-test programs with paired samples and an analysis of variance with unequal sample size program. All differences referred to hereafter were at 0.01 level of significance unless otherwise indicated. Calcium/phosphorus and albumin/globulin ratios were not included in statistical tests for differences, but were listed to demonstrate trends.

Milk

Twenty-one trapped and immobilized lactating moose were "milked" to obtain a minimum 5 ml sample. Posterior pituitary extract (10 U.S.P. units) was administered intravenously to some moose to stimulate

milk let-down and facilitate "milking." Milk samples were frozen in vials until analyzed.

Milk samples were analyzed by the Animal Husbandry Nutrition Laboratory, Michigan State University, for specific gravity, pH, percent solids, gross energy (Kcal/g), percent crude protein, percent lipids and percent ash. AOAC procedures were utilized except as modified and described by Ullrey et al. (1966). None of the samples were collected during the first 96 hours of lactation.

Milk samples for mineral analysis, obtained primarily in June and July during 1971, 1972 and 1973, were digested at room temperature with 24 percent tetramethyl ammonium hydroxide, using a 1:4 dilution (v/v). Milk samples were analyzed by the Department of Surgery, Cleveland Metropolitan General Hospital, Case Western Reserve University School of Medicine, Cleveland, Ohio on a semi-automated Perkin-Elmer Model 503 spectrometer adapted for automated dilution with a Hamilton Precision Dispenser. Samples were analyzed by flame (Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Na, Pb, and Zn), electrically heated graphite furnace (Al, Mo, Mn, and Ni), a flame volatilization method (As and Se) and a flameless volatilization technique (Hg). Twelve milk samples were not analyzed for Cd, Hg, Pb and Se.

Hair

Hair samples were obtained by plucking hair from the shoulder hump of moose (Franzmann et al. 1975a). Samples were stored and shipped in plastic containers and analyzed by Department of Surgery, Cleveland Metropolitan General Hospital, Case Western Reserve University School of Medicine, Cleveland, Ohio on a semi-automated Perkin-Elmer Model 503 Spectrometer adapted for automated dilution with a Hamilton Precision Dispenser. Prior to analysis, hair samples were washed twice with diethyl ether to remove surface particulate matter without leaching elements from the hair structure. A 200 mg sample of hair was digested in 10.0 ml of 24 percent methanolic tetramethyl ammonium hydroxide for 2 hours at 55° C (Gross and Parkinson 1974). Moose hair samples were obtained during tagging and movement studies, from hunter kills and from regular collections at the MRC. Fig. 2 depicts areas of collection. Forty-three percent of the samples were from the MRC.

Samples were designated by area of collection, month sampled, sex and age (when known). Analysis of variance was used to test for difference among area samples on a monthly basis. Scheffe's S value test was utilized to determine where difference occurred among monthly samples with significant ANOVA ($P = 0.10$).

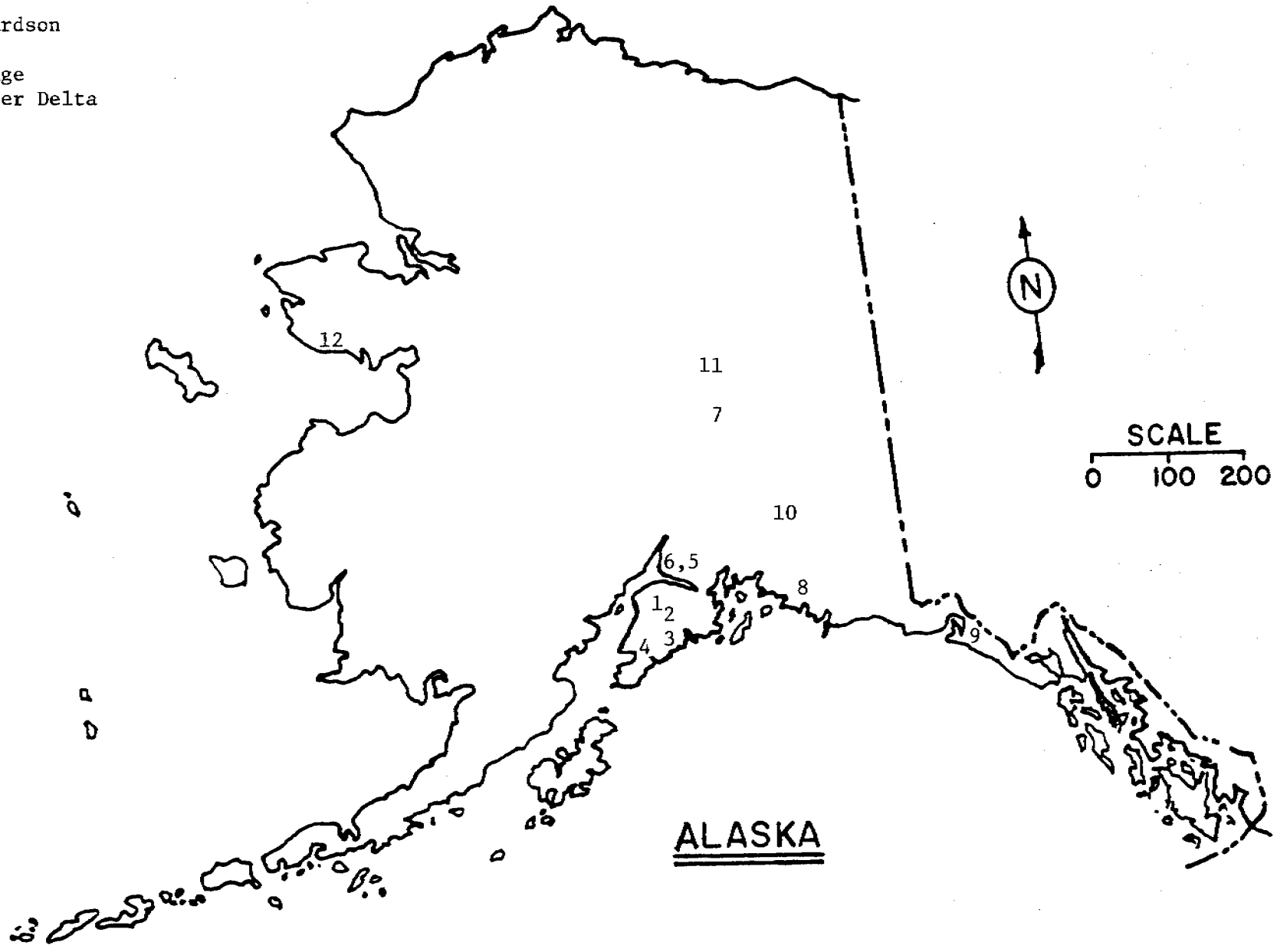
Excitability Stress Evaluation, Heart and Respiratory Rates and Body Temperature

Classification of individual excitability was based upon activity prior to and during handling on a 1 to 5 scale (1 - none, 2 - slight, 3 - moderate, 4 - excited and 5 - highly excited).

Rectal temperature was obtained with a 5-inch mercury bulb thermometer. Rectal temperture classes were established as follows: Class 1 was

1. Kenai Moose Research Center (MRC)
2. Benchland
3. Caribou Hills
4. Homer
5. Fort Richardson
6. Elmendorf
7. Alaska Range
8. Copper river Delta
9. Southeast
10. Glennallen
11. Fairbanks
12. Nome

Figure 2. Alaska map dipicting regional origin of moose hair samples.



moose with rectal temperature below 38° C; correspondingly, Class 2 was 38 to 39° C, Class 3 was 39 to 40° C, Class 4 was 40 to 41° C and Class 5 was all moose above 41° C.

Heart and respiratory rates were obtained utilizing a stethoscope and rates/minute were established.

Condition

Evaluation of condition was made and graded (1 to 10) on the basis of the following criteria (adapted to moose from Robinson 1960):

10. A prime, fat moose with thick, firm rump fat by sight. Well fleshed over back and loin. Shoulders are round and full.

9. A choice, fat moose with evidence of rump fat by feel. Fleshed over back and loin. Shoulders are round and full.

8. A good, fat moose with slight evidence of rump fat by feel. Bony structures of back and loin not prominent. Shoulders well fleshed.

7. An "average" moose with no evidence of rump fat, but well fleshed. Bony structures of back and loin evident by feel. Shoulders with some angularity.

6. A moderately fleshed moose beginning to demonstrate one of the following conditions: (A) definition of neck from shoulders; (B) upper foreleg (humerus and musculature) distinct from chest; or (C) rib cage is prominent.

5. A condition in which two of the characteristics listed in Class 6 are evident.

4. A condition in which all three of the characteristics listed in Class 6 are evident.

3. A condition in which the hide fits loosely about neck and shoulders. Head is carried at a lower profile. Walking and running postures appear normal.

2. Signs of malnutrition are obvious. The outline of the scapula is evident. Head and neck low and extended. The moose walks normally but trots and paces with difficulty, and cannot canter.

1. A point of no return. A generalized appearance of weakness. The moose walks with difficulty and can no longer trot, pace or canter.

0. A dead moose, from malnutrition and/or accompanying circumstances.

Marrow Fat

During the winter months, many adult and calf femurs were collected from road kills, winter kills and miscellaneous mortalities both at the

MRC and many other points on the Kenai Peninsula by biologists from the Soldotna Office, Alaska Department of Fish and Game. With these samples, comparisons between areas were made and the general condition of the Kenai moose herd assessed. In all cases, femurs were frozen and processed in the Anchorage Department of Fish and Game laboratory by the technique described by Neiland (1970). Times from death of the moose to femur collection and from femur collection to processing varied considerably. Femurs were collected as soon after the death of the moose as possible, but some may have remained frozen for up to 60 days before processing.

Morphometic Measurements and Body Weight

Measurements were obtained for total length, hind foot, height at shoulder, heart girth, ear length, tail length, antler spread and antler base. Weights were obtained by utilizing a weighing device consisting of a winch mounted on the front of a pickup truck with a bracket holding two legs of a tripod (Arneson and Franzmann 1975).

Productivity and Mortality at MRC

Mortality and natality within the pens were assessed by ground observations, periodic aerial observations (including intensive spring and fall helicopter surveys), trapping, and radiotelemetry. Rectal examination of females after January 1 was utilized for pregnancy determination.

FINDINGS

Blood Chemistry and Hematology

Collections at the MRC provided 687 serum and 646 whole blood samples, monitored hunts provided 224 serum and 157 whole blood samples, tagging operations provided 561 serum and 422 whole blood samples while miscellaneous collections provided an additional 34 serum and 10 whole blood samples. A total of 1,506 serum and 1,235 whole blood samples was collected.

It was evident from review of computer sort output that differences in blood values between classifications were influenced more by certain variables than others. The month/sex/age sort indicated that yearly age classes could be combined as: calves (0-12 mo.), yearlings and two-year-olds (13-36 mo.) and adults (37 mo.+). Further examination of this sort indicated that sexes could be combined for each month and age group, except for adult moose during October. The month/sex/age sort also provided the basis for combining months into four season classifications: (1) summer/fall (June, July, August, September), (2) rut (October), (3) early winter (November, December, January) and (4) late winter/spring (February, March, April, May). Adult MRC moose blood parameters were tested between years by season (except rut) and no differences were detected.

Testing sex differences by season provided the basis for separating October from other months in a season. October female values were significantly higher for P, glucose, cholesterol, albumin and PCV with

male values higher in uric acid, globulin, alpha 1 globulin, alpha 2 globulin and gamma globulin (Table 2). During early winter, alkaline phosphatase values were significantly higher in males in age group 37 to 60 months. In late winter/spring, alkaline phosphatase levels were also significantly higher in males than females of ages 49-60 months. These were the only sex differences detected for these two seasons. When October was originally included in the summer/fall season we detected sex differences by season for eight parameters. Removing October from the summer/fall classification resulted in no sex differences.

The rutting period for moose in Southcentral Alaska extends from mid-September to mid-November and we anticipated adult sex differences during September and November. Table 2 lists blood values by sex for September, October and November. No differences by sex were detected during September, but alkaline phosphatase values were significantly higher for adult males during November, and total protein and albumin values were lower for adult males.

Tables 3, 4 and 5 list blood values for moose by three age groups and three seasons with sexes combined. Sixty-nine of 126 blood value comparisons revealed significant differences between summer/fall and both early and late winter seasons among the three age groups. No differences between early winter and late winter/spring calf values were detected, but these seasonal yearling/two-year-old comparisons revealed significantly high P and SGOT and lower alkaline phosphatase and alpha 1 globulin levels in early winter (Tables 3 and 4). In addition, for adult moose P, bilirubin, LDH, SGOT and gamma globulin values were significantly higher and alkaline phosphatase and albumin values lower in early winter than late winter/spring (Table 5).

Age class differences by season, based upon values listed in Tables 3, 4 and 5, are listed in Table 6. Only P, glucose and alpha and beta globulins had no significant age class source of variation.

Blood values from 232 pregnant and 188 nonpregnant adult female moose were compared from January through May (Table 7). No significant differences were detected by month for any of the blood parameters; however, the May sample of only nine pregnant and four nonpregnant females may not have been adequate to test that critical month.

Lactating moose, represented by a cow with calf or calves, and lactating reproductive status classifications were compared to cows with no calf or calves during the summer/fall season (Table 8). The mean level of P was significantly higher in nonlactating moose, and BUN, uric acid and cholesterol means were significantly higher in lactating moose.

Excitability evaluation, based upon rectal temperature class, permitted assessment of this influcence on blood values. Table 9 summarizes differences based upon rectal temperature classes of adult female moose. No significant differences in blood values were detected between rectal temperature classes 4 and 5. Significant increases were noted between blood glucose levels with increase in rectal temperatures class. Bilirubin and LDH values reflected similar increases between at least six rectal temperature class comparisons. The ranges in these values from class 1 to class 5 were 118.6 to 171.7 mg/100 ml for glucose, 0.43 to 0.68 mg/100 ml for bilirubin and 278.0 to 382.3 mU/100 ml for LDH

Table 2. Blood value comparisons by sex in adult moose during September, October and November.

		September						October						November					
		Female			Male			Female			Male			Female			Male		
		n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD
Calcium	mg/100ml	39	10.57	0.90	15	10.52	0.66	142	10.24	0.64	56	10.14	0.58	67	10.36	0.48	18	10.07	0.48
Phosphorus	mg/100ml	39	4.88	1.11	15	5.63	0.94	142	5.49	1.22*	56	4.98	0.91	67	5.03	1.54	18	5.09	1.54
Glucose	mg/100ml	39	149.1	34.5	15	156.2	29.1	142	157.8	38.9*	56	130.2	27.3	67	153.8	34.7	18	142.1	33.2
BUN	mU/100ml	39	22.8	8.8	15	21.0	6.5	142	7.4	6.0	56	9.3	5.6	67	7.0	4.7	18	8.7	5.1
Uric acid	mg/100ml	39	0.39	0.16	15	0.47	0.21	142	0.15	0.17*	56	0.33	0.19	67	0.25	0.11	18	0.29	0.10
Cholesterol	mg/100ml	39	104.6	14.4	15	109.5	15.1	142	91.3	12.8*	56	7.38	14.1	67	82.6	10.2	18	75.9	13.6
Bilirubin	mg/100ml	39	0.53	0.17	15	0.51	0.15	142	0.41	0.18	56	0.54	0.44	67	0.54	0.21	18	0.57	0.16
Alkaline phosphatase	mg/100ml	39	100.0	114.9	15	127.4	42.6	142	49.6	53.4	56	32.1	22.9	67	34.8	19.9*	18	50.7	23.1
LDH	mU/100ml	39	408.7	130.6	15	465.2	110.2	142	338.3	57.0	56	361.4	74.8	67	331.8	51.2	18	370.1	72.9
SGOT	mU/100ml	39	174.7	36.7	15	177.4	37.6	142	169.9	45.6	56	162.1	44.6	67	187.4	44.8	18	182.5	38.6
Calcium/Phosphorus	ratio	39	2.19		15	1.87		142	1.87		56	2.04		67	2.06		18	1.94	
Total protein	g/100ml	40	7.89	0.61	15	7.57	0.66	147	7.70	0.48	56	7.63	0.71	72	7.68	0.52*	19	7.05	0.35
Albumin	g/100ml	40	4.72	0.62	15	4.61	0.60	147	4.69	0.62*	56	4.15	0.72	72	4.94	0.57*	19	4.42	0.57
Globulin	g/100ml	40	3.17	0.58	15	2.96	0.66	147	3.01	0.71*	56	3.49	0.85	72	2.74	0.66	19	2.63	0.46
Alpha 1 globulin	g/100ml	40	0.35	0.11	15	0.31	0.07	147	0.34	0.14*	56	0.41	0.19	72	0.30	0.10	19	0.29	0.09
Alpha 2 globulin	g/100ml	40	0.61	0.14	15	0.60	0.20	147	0.56	0.15*	56	0.69	0.20	72	0.47	0.16	19	0.49	0.14
Beta globulin	g/100ml	40	0.82	0.15	15	0.80	0.18	147	0.75	0.16	56	0.71	o.15	72	0.69	0.18	19	0.68	0.21
Gamma globulin	g/100ml	40	1.39	0.34	15	1.25	0.40	147	1.36	0.41*	56	1.68	0.51	72	1.28	0.39	19	1.17	0.33
Albumin/Globulin	ratio	40	1.49		15	1.56		147	1.56		56	1.19		72	1.80		19	1.68	
Hemoglobin	g/100ml	39	18.7	1.3	11	18.2	1.6	118	19.5	2.2	43	19.2	2.3	71	19.5	1.1	18	18.8	1.7
PCV	%	28	5.08	4.2	11	47.2	6.1	112	52.1	3.4*	39	50.2	3.7	61	51.6	4.7	11	50.2	4.3

1. * indicates significant difference by sex for same month ($P < 0.01$).

Table 3. Moose calf (0 - 12 mo.) blood values by season.

Blood Values		Summer/Fall (Jun,Jul,Aug,Sep,Oct)			Early Winter (Nov,Dec,Jan)			Late Winter/Spring (Feb,Mar,Apr,May)		
		n	$\bar{x}$	SD	n	$\bar{x}$	SD	N	$\bar{x}$	SD
Calcium	mg/100 ml	38	10.56[a,b]	0.94	46	9.21	2.15	9	9.40	1.58
Phosphorus	mg/100 ml	38	6.78[a,b]	1.20	46	5.54	2.32	9	5.50	1.44
Glucose	mg/100 ml	38	157.7[a,b]	30.6	46	115.5[b]	69.2	9	96.8	50.2
BUN	mU/100 ml	38	15.3[b]	6.3	46	13.2[b]	16.5	9	24.9	8.9
Uric acid	mg/100 ml	38	0.42	0.23	46	0.73	1.63	9	0.43	0.17
Cholesterol	mg/100 ml	38	107.7[a,b]	15.1	46	79.8	29.6	9	76.4	12.9
Bilirubin	mg/100 ml	38	0.52[a]	0.20	46	0.37	0.22	9	0.48	0.23
Alkaline phosphatase	mg/100 ml	38	189.2[a]	86.1	46	74.6	62.6	9	127.6	90.0
LDH	mU/100 ml	38	490.8[a]	144.4	46	396.4	135.9	9	416.4	111.2
SGOT	mU/100 ml	38	161.0[a,b]	35.7	46	230.5	67.4	9	221.1	58.8
Calcium/Phosphorus	ratio	38	1.56		46	1.66		9	1.71	
Total protein	g/100 ml	39	6.79[a]	0.73	46	5.62	1.34	9	6.36	0.70
Albumin	g/100 ml	39	4.19[a]	0.64	46	3.18	0.95	9	3.76	0.50
Globulin	g/100 ml	39	2.60	0.59	46	2.44	0.77	9	2.59	0.31
Alpha 1 globulin	g/100 ml	39	0.34	0.10	46	0.32	0.14	9	0.33	0.19
Alpha 2 globulin	g/100 ml	39	0.55	0.14	46	0.53	0.25	9	0.62	0.14
Beta globulin	g/100 ml	39	0.74[b]	0.14	46	0.59	0.37	9	0.53	0.09
Gamma globulin	g/100 ml	39	0.97	0.39	46	1.00	0.36	9	1.09	0.15
Albumin/Globulin	ratio	39	1.61		46	1.30		9	1.45	
Hemoglobin	g/100 ml	35	17.1	1.9	27	17.5	3.2	3	17.1	1.7
PCV	%	32	42.8	3.8	24	42.9	7.6	3	41.7	5.5

a. Significantly different than early winter ($P < 0.01$)
b. Significantly different than late winter/spring ($P < 0.01$)

Table 4. Moose yearling and two-year old (13 - 36 mo.) blood values by season.

Blood Values		Summer/Fall (Jun,Jul,Aug,Sep,Oct)			Early Winter (Nov,Dec,Jan)			Late Winter/Spring (Feb,Mar,Apr,May)		
		n	$\bar{x}$	SD	n	$\bar{x}$	SD	N	$\bar{x}$	SD
Calcium	mg/100 ml	76	10.47[a,b]	0.82	45	9.51	1.86	87	9.97	1.26
Phosphorus	mg/100 ml	76	5.68[b]	1.32	45	5.85[c]	1.89	87	4.86	1.23
Glucose	mg/100 ml	76	150.1[a,b]	53.1	45	99.7[c]	34.9	87	130.7	36.2
BUN	mU/100 ml	76	18.4[a,b]	12.1	45	9.0	3.1	87	12.3	12.2
Uric acid	mg/100 ml	76	0.59	0.95	45	0.37	0.19	87	0.37	0.25
Cholesterol	mg/100 ml	76	87.8[a,b]	16.3	45	75.0	17.9	87	77.3	11.3
Bilirubin	mg/100 ml	76	0.46	0.23	45	0.35	0.22	87	0.40	0.27
Alkaline phosphatase	mg/100 ml	76	95.3[a]	68.6	45	44.9[c]	5.3	87	71.5	56.0
LDH	mU/100 ml	76	382.9[b]	112.6	45	347.4	138.2	87	310.9	84.4
SGOT	mU/100 ml	76	150.9[a]	48.8	45	200.0[c]	61.1	87	159.2	56.6
Calcium/Phosphorus	ratio	76	1.84		41	1.69		87	2.05	
Total protein	g/100 ml	80	7.37[a,b]	0.64	49	6.15	1.23	88	6.54	0.62
Albumin	g/100 ml	80	4.33[a,b]	0.60	49	3.44	0.81	88	3.72	0.54
Globulin	g/100 ml	80	3.04[b]	0.66	49	2.71	0.77	88	2.82	0.41
Alpha 1 globulin	g/100 ml	80	0.31[b]	0.14	49	0.32[c]	0.15	88	0.39	0.13
Alpha 2 globulin	g/100 ml	80	0.62[a,b]	0.18	49	0.53	0.22	88	0.54	0.18
Beta globulin	g/100 ml	80	0.76[a,b]	0.19	49	0.63	0.19	88	0.63	0.16
Gamma globulin	g/100 ml	80	1.80[a,b]	0.42	49	1.23	0.39	88	1.26	0.34
Albumin/Globulin	ratio	80	1.42		49	1.27		88	1.32	
Hemoglobin	g/100 ml	54	18.0	2.6	26	16.5	3.0	53	17.3	2.1
PCV	%	34	50.1[a,b]	3.8	19	41.1	8.9	49	44.3	6.1

a. Significantly different than early winter ($P < 0.01$)
b. & c. Significantly different than late winter/spring ($P < 0.01$)

Table 5. Moose adult (37 mo. +) blood values by season.

Blood Values		Summer/Fall (Jun,Jul,Aug,Sep.)			Early Winter (Nov,Dec,Jan)			Late Winter/Spring (Feb,Mar,Apr,May)		
		n	$\bar{x}$	SD	n	$\bar{x}$	SD	N	$\bar{x}$	SD
Calcium	mg/100 ml	286	10.48[a]	0.76	170	10.09[c]	1.21	273	10.38	0.76
Phosphorus	mg/100 ml	286	5.22[b]	1.24	170	5.14[c]	1.72	273	4.53	1.24
Glucose	mg/100 ml	286	142.4[a,b]	39.0	170	117.3	43.2	273	119.8	29.3
BUN	mU/100 ml	286	15.0[a,b]	11.0	170	11.4	7.6	273	9.3	9.5
Uric acid	mg/100 ml	286	0.35	0.20	170	0.34	0.21	273	0.29	0.24
Cholesterol	mg/100 ml	286	88.0[a]	17.4	170	82.1	13.3	273	85.8	22.6
Bilirubin	mg/100 ml	286	0.50	0.26	170	0.53[c]	0.27	273	0.46	0.23
Alkaline phosphatase	mg/100 ml	286	58.4[b]	73.7	170	50.8[c]	44.0	273	72.5	64.4
LDH	mU/100 ml	286	345.0[b]	80.5	170	341.2[c]	109.1	273	271.2	78.7
SGOT	mU/100 ml	286	166.6[a,b]	50.0	170	213.2[c]	54.1	273	151.5	50.4
Calcium/Phosphorus	ratio	286	2.01		129	2.03		273	2.29	
Total protein	g/100 ml	286	7.77[a,b]	0.57	169	6.86	0.88	277	7.01	0.61
Albumin	g/100 ml	286	4.55[a,b]	0.68	169	3.85[c]	0.73	277	4.12	0.68
Globulin	g/100 ml	286	3.22[a,b]	0.72	169	3.01	0.73	277	2.89	0.64
Alpha 1 globulin	g/100 ml	286	0.35[b]	0.14	169	0.37	0.15	277	0.40	0.23
Alpha 2 globulin	g/100 ml	286	0.60[b]	0.17	169	0.57	0.18	277	0.56	0.25
Beta globulin	g/100 ml	286	0.76[a,b]	0.15	169	0.66	0.16	277	0.69	0.27
Gamma globulin	g/100 ml	286	1.51[b]	0.42	169	1.41[c]	0.44	277	1.24	.40
Albumin/Globulin	ratio	286	1.41		169	1.28		277	1.43	
Hemoglobin	g/100	235	18.8[a,b]	2.0	116	17.5	2.5	187	18.2	1.8
PCV	%	178	51.4[a,b]	4.7	100	44.7	6.4	184	45.6	5.7

a. Significantly different than early winter ($P < 0.01$)
b. & c. Significantly different than late winter/spring ($P < 0.01$)

Table 6. Age group differences by season (P = 0.01)[1]

Blood Values		Summer/Fall		Early Winter		Late Winter/Spring	
		Calves	Yrlg/twoyearold	Calves	Yrlg/two-yearold	Calves	Yrlg/twoyearold
Calcium	mg/100ml	AB		b		b	
Phosphorus	mg/100ml						
Glucose	mg/100ml						
BUN	mU/100ml					AB	
Uric acid	mg/100ml		D				
Cholesterol	mg/100ml	AB					
Bilirubin	mg/100ml			b	d		
Alkaline phosphatase	mg/100ml	AB	D	AB		a	D
LDH	mU/100ml	AB	D			AB	D
SGOT	mU/100ml					AB	
Total protein	g/100ml	ab	d	b	d	a	d
Albumin	g/100ml	b		b	d		
Globulin	g/100ml	ab		ab			
Alpha 1 globulin	g/100ml						
Alpha 2 globulin	g/100ml						
Beta globulin	g/100ml						
Gamma globulin	g/100ml	ab	D	ab			
Hemoglobin	g/100ml	b					
PCV	%	ab					

1. Values for these age classes are in Table 3, 4 and 5.
A Calves significantly higher than yearly/two-year old.
B Calves significantly higher than adults.
D Yearling/two-year-old significantly higher than adults.
a Calves significantly lower than two-year-olds.
b Calves significantly lower than adults.
d Yearling/two-year-old significantly lower than adults.

Table 7. Blood values means from pregnant and nonpregnant moose by month sampled.[1]

Blood Values		January				February				March				April				May			
		Pregnant		Nonpregnant		Pregnant		Nonpregnant		Pregnant		Nonpregnant		Pregnant		Nonpregnant		Pregnant		Nonpregnant	
		n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Calcium	mg/100ml	36	8.59	18	8.73	50	10.44	22	10.44	91	10.57	14	10.82	46	10.18	13	10.32	9	10.24	4	7.97
Phosphorus	mg/100ml	36	4.86	18	5.86	50	5.17	22	5.64	91	5.12	14	5.21	46	4.25	13	4.86	9	4.52	4	4.28
Glucose	mg/100ml	36	96.8	18	103.2	50	115.3	22	126.9	91	127.7	14	133.9	46	102.9	13	109.2	9	116.3	4	152.0
BUN	mU/100ml	36	8.7	18	8.7	50	9.0	22	11.0	91	5.9	14	6.7	46	5.5	13	4.2	9	7.8	4	12.5
Uric Acid	mg/100ml	36	0.21	18	0.29	50	0.29	22	0.29	91	0.18	14	0.13	46	0.27	13	0.27	9	0.41	4	0.40
Cholesterol	mg/100ml	36	69.6	18	74.7	50	83.6	22	86.8	91	87.2	14	87.3	46	83.4	13	80.4	9	97.8	4	84.3
Bilirubin	mg/100ml	36	0.45	18	0.47	50	0.45	22	0.43	91	0.39	14	0.41	46	0.42	13	0.32	9	0.38	4	0.45
Alkaline phosphatase	mg/100ml	36	36.8	18	44.0	50	52.6	22	70.3	91	46.7	14	51.6	46	60.9	13	38.5	9	62.9	4	35.0
LDH	mU/100ml	36	317.8	18	307.7	50	352.8	22	373.1	91	247.6	14	241.1	46	278.5	13	290.2	9	309.3	4	327.5
SGOT	mU/100ml	36	191.5	18	200.3	50	228.4	22	234.9	91	155.1	14	157.4	46	163.7	13	180.8	9	143.0	4	163.0
Calcium/Phosphorus	ratio	29	1.85	18	1.71	50	2.17	22	2.00	91	2.19	14	2.23	46	2.78	13	2.21	3	3.32	4	2.63
Total Protein	g/100ml	35	5.89	18	5.53	50	6.95	22	6.69	93	7.28	14	7.28	47	6.92	13	6.55	9	6.96	4	6.49
Albumin	g/100ml	35	3.42	18	3.11	50	3.76	22	3.59	93	4.69	14	4.69	47	4.14	13	3.82	9	4.01	4	3.72
Globulin	g/100ml	35	2.47	18	2.42	50	3.19	22	3.10	93	2.59	14	2.69	47	2.78	13	2.73	9	2.95	4	2.77
Alpha 1 Globulin	g/100ml	35	0.32	18	0.26	50	0.43	22	0.40	93	0.32	14	0.39	47	0.33	13	0.38	9	0.34	4	0.33
Alpha 2 Globulin	g/100ml	35	0.46	18	0.51	50	0.59	22	0.60	93	0.48	14	0.50	47	0.53	13	0.45	9	0.59	4	0.51
Beta Globulin	g/100ml	35	0.56	18	0.57	50	0.76	22	0.70	93	0.64	14	0.70	47	0.60	13	0.61	9	0.57	4	0.75
Gamma Globulin	g/100ml	35	1.13	18	1.08	50	1.41	22	1.40	93	1.15	14	1.10	47	1.32	13	1.27	9	1.46	4	1.18
Albumin/Globulin	ratio	35	1.44	18	1.30	49	1.30	22	1.27	93	1.96	14	1.98	47	1.59	13	1.50	9	1.39	4	1.39
Hemoglobin	g/100ml	16	19.3	7	18.2	40	16.2	20	14.5	90	19.2	13	18.9	39	17.4	12	16.2	1	19.5	2	17.9
PCV	%	16	49.0	7	46.6	40	42.3	21	38.9	90	49.1	13	47.8	39	42.9	12	40.5	1	49.0	1	47.0

1. No significant differences ($P > 0.01$) were detected between pregnant and nonpregnant moose by month.

Table 8. Blood values from lactating and nonlactating adult female moose during summer/fall season.

Blood Values		Lactating			Nonlactating		
		n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.
Calcium	mg/100ml	115	10.62	0.73	161	10.40	0.91
Phosphorus	mg/100ml	115	4.92	1.22*[1]	161	5.41	1.18
Glucose	mg/100ml	115	139.4	39.2	161	143.5	38.1
BUN	mU/100ml	115	19.2	7.3	161	16.6	6.1
Uric Acid	mg/100ml	115	0.36	0.18*	161	0.15	0.14
Cholesterol	mg/100ml	115	96.2	14.2 *	161	91.6	11.6
Bilirubin	mg/100ml	115	0.55	0.13	161	0.52	0.23
Alkaline phosphatase	mg/100ml	115	61.9	63.3	161	76.4	72.0
LDH	mU/100ml	115	370.1	82.6	161	348.8	80.0
SGOT	mU/100ml	115	169.6	54.1	161	165.7	45.7
Calcium/Phosphorus	ratio	104	2.20		161	1.92	
Total Protein	g/100ml	117	7.73	0.56	161	7.78	0.55
Albumin	g/100ml	117	4.56	0.64	161	4.50	0.62
Globulin	g/100ml	117	3.17	0.59	161	3.28	0.69
Alpha 1 Globulin	g/100ml	117	0.36	0.13	161	0.39	0.13
Alpha 2 Globulin	g/100ml	117	0.60	0.16	161	0.60	0.16
Beta Globulin	g/100ml	117	0.77	0.15	161	0.79	0.15
Gamma Globulin	g/100ml	117	1.44	0.38	161	1.50	0.29
Albumin/Globulin	ratio	117	1.53		161	1.37	
Hemoglobin	g/100ml	98	18.6	1.8	150	18.2	2.2
PCV	%	84	50.0	4.1	111	51.6	4.1

1. * Indicates value means significantly different ($P < 0.01$).

Table 9. Adult female moose (37 mo. +) blood value differences for rectal temperature class comparisons.

Blood Values[1]		1/2	1/3	1/4	1/5	2/3	2/4	2/5	3/4	3/5	4/5
Glucose	mg/100ml	+[2]	+	+	+	+	+	+	+	+	
Bilirubin	mg/100ml			+	+	+	+	+		+	
LDH	mU/100ml		+	+	+	+	+	+		+	
Albumin	g/100ml			+	+						
Globulin	g/100ml	+	+	+	+						
Alpha 1 Globulin	g/100ml			+	+					+	
Alpha 2 Globulin	g/100ml		+	+	+						
Beta Globulin	g/100ml		+	+	+						
Gamma Globulin	g/100ml			+	+						

1. Blood parameters not listed had not significant differences between comparisons ($P < 0.01$).
2. + indicates value increased with increase in rectal temperature class.

(Table 10). The differences detected in protein fractions were associated with comparisons always including rectal temperature class 1.

Blood parameters by condition classes 4, 5, 6, 7 and 8 were compared between adult moose. Condition classes 1, 2, 3, 9 and 10 were not considered due to inadequate sample sizes. No significant differences in blood values were noted between condition classes 4 and 5 (Table 11). For all other comparisons, glucose and PCV values were significantly higher as condition class improved. Total protein reflected significantly higher values in better condition classes in all comparisons except class 4 with 6 and class 7 with 8. Calcium, P, albumin, beta globulin and Hb had significantly different values in four or more condition class comparisons. All values increased with improved condition class. Glucose and PCV values consistently reflected condition class differences. The range in blood values from condition class 4 to condition class 8 for values reflecting significant differences between comparison were; 9.94 to 10.51 mg/100 ml for Ca, 4.51 to 5.47 mg/100 ml for P, 103.6 to 156.1 mg/100 ml for glucose, 7.01 to 7.66 g/100 ml for total protein, 4.10 to 4.58 g/100 ml for albumin, 0.57 to 0.74 g/100 ml for beta globulin, 17.4 to 18.9 g/100 ml for Hb and 43.1 to 51.9 percent for PCV (Table 12).

Location classifications were compared on a seasonal basis considering MRC (animals enclosed), outside MRC (those trappped in outside MRC traps), Kenai Peninsula (all others sampled on the Kenai) and Alaska (all others from Alaska). The summer/fall season included samples from the MRC and outside MRC only. No significant differences were detected between these samples. The October (rut) sample came from several locations, but due to the rutting influence on blood parameters, differences between locations were not tested.

Comparisons during early winter and late winter/spring between MRC and outside MRC samples (Table 13) revealed no significant differences except for 1 of 40 comparisons where total protein in early winter was higher in the outside MRC sample than the MRC sample. Eighty-two of 191 (43 percent) of other location blood value comparisons revealed significant differences (Table 13).

Blood parameter sources of variation tested in our study (sex, season, age, pregnancy, lactation, rectal temperature, condition and location) and their significant influence on blood parameters are summarized in Table 14. Season source of variation influenced, at some point, every blood parameter while pregnancy influenced none.

Condition related blood parameters (Table 11) were compared from specific moose populations during the critical late winter/spring season. The Copper River Delta moose population was an expanding, productive population (McKnight 1975) and the MRC population was a high-density, confined, low productive population (Franzmann and Arneson 1975). The Copper River Delta sample was collected in March and we thereby selected the March MRC sample for comparison; however, the sample size was extremely

Table 10. Blood values for parameters influenced by adult female rectal temperature class (sample size in parenthesis).

Blood Values		Rectal Temperature Class				
		1	2	3	4	5
Glucose	mg/100ml	118.6(30)	132.0(243)	142.1(228)	152.1(75)	171.7(29)
Bilirubin	mg/100ml	0.43(30)	0.47(243)	0.54(228)	0.59(75)	0.68(29)
LDH	mU/100ml	278.0(30)	314.0(243)	335.7(228)	353.6(75)	382.3(29)
Albumin	g/100ml	4.72(31)	4.51(249)	4.51(240)	4.36(77)	4.27(29)
Globulin	g/100ml	2.52(31)	3.00(249)	2.99(240)	3.08(77)	3.24(29)
Alpha 1 globulin	g/100ml	0.28(31)	0.37(249)	0.34(240)	0.37(77)	0.41(29)
Alpha 2 globulin	g/100ml	0.46(31)	0.57(249)	0.57(240)	0.56(77)	0.61(29)
Beta globulin	g/100ml	0.61(31)	0.73(249)	0.73(240)	0.74(77)	0.79(29)
Gamma globulin	g/100ml	1.18(31)	1.40(249)	1.36(240)	1.40(77)	1.44(29)

Table 11. Adult moose (37 mo. +) blood value differences for condition class comparisons.

Blood Values[1]		Class Comparisons[2] (P< 0.01)									
		4/5	4/6	4/7	4/8	5/6	5/7	5/8	6/7	6/8	7/8
Calcium	mg/100ml				+[3]	+	+	+		+	
Phosphorus	mg/100ml			+	+		+	+	+	+	
Glucose	mg/100ml		+	+	+	+	+	+	+	+	+
Total Protein	g/100ml			+	+	+	+	+	+	+	
Albumin	g/100ml				+	+	+	+			
Beta Globulin	g/100ml			+	+		+	+			
Hemoglobin	g/100ml				+		+	+		+	
PCV	%		+	+	+	+	+	+	+	+	+

1. Blood parameters not listed, had no sigfnificant differences betweeen comparisons (P<0.01).
2. Sample size; Class 4=20, Class 5=100, Class 6=276, Class 7=292, Class 8=122.
3. + indicates value increased with increase in condition class.

Table 12. Blood values for parameters influenced by adult moose condition class (sample size in parenthesis).

		Condition Class					
Blood values		4	5	6	7	8	9
Calcium	mg/100ml	10.03(20)	9.94(100)	10.31(276)	10.41(292)	10.51(122)	10.57(10)
Phosphorus	mg/100ml	4.51(20)	4.52(100)	4.71(276)	5.26(292)	5.47(122)	5.90(10)
Glucose	mg/100ml	103.6(20)	121.5(100)	133.5(276)	142.2(292)	156.1(122)	145.7(10)
Calcium/Phosphorus	ratio	2.22(20)	2.20(100)	2.19(276)	1.98(292)	1.92(122)	1.92(10)
Total protein	g/100ml	7.01(20)	7.00(104)	7.36(282)	7.52(300)	7.66(124)	7.80(12)
Albumin	g/100ml	4.10(20)	4.13(104)	4.35(282)	4.50(300)	4.58(124)	4.80(12)
Beta globulin	g/100ml	0.57(20)	0.63(104)	0.71(282)	0.73(300)	0.74(124)	1.43(12)
Hemoglobin	g/100ml	17.4(20)	17.7(101)	18.2(276)	18.6(289)	18.9(116)	19.5(10)
PCV	%	43.1(19)	44.3(89)	47.2(237)	49.6(242)	51.9(97)	54.0(8)

Table 13. Comparison of adult moose blood value differences between locations by season (n=20 to 122).

Blood Values		MRC[1]/OMRC[2]			MRC/Kenai			MRC/Alaska			OMRC/Kenai			OMRC/Alaska			Kenai/Alaska		
		Early Winter	Late Winter	Winter-Spring	Early Winter	Late Winter	Winter-Spring	Early Winter	Late Winter	Winter-Spring	Early Winter	Late Winter	Winter-Spring	Early Winter	Late Winter	Winter-Spring	Early Winter	Late Winter	Winter-Spring
Calcium	mg/100ml							+[3]						+			+		
Phosphorus	mg/100ml				-[4]			-	-		-			-	-				-
Glucose	mg/100ml				-	-		+					+	+			+		
BUN	mg/100ml				+	+		+	+		+		+	+	+				
Uric acid	mg/100ml													-	+		+		+
Cholesterol	mg/100ml													+					+
Bilirubin	mg/100ml				+	+		+	+		+		+	+	+				+
Alkaline phosphatase	mg/100ml													-					+
LDH	mU/100ml					+			+				+						-
SGOT	mU/100ml				-	+			+		-		+					+	-
Total Protein	g/100ml	-			-			+						+				+	-
Albumin	g/100ml				-			+			-			+				+	
Globulin	g/100ml										+			+					
Alpha 1 Globu.	g/100ml				+						+		+						
Alpha 2 Globu.	g/100ml										+								
Beta Globulin	g/100ml													+				+	
Gamma Globulin	g/100ml																		
Hemoglobin	g/100ml				-	-		No	-		-		-	No				No	
PCV	%				-	-		Data	-		-			Data	-			Data	

1 MRC Kenai Moose Research Center
2 OMRC Outside traps at Kenai Moose Research Center
3 + indicates numerator in comparison is significantly larger (P 0.01)
4 - indicates denominator in comparison is significantly larger (P 0.01)

Table 14. Sources of blood parameter variation tested and their significant influence on blood values.

Blood Values	Source of Variation							
	Sex[1]	Season	Age	Pregnancy	Lactation	Rectal Temperature	Condition	Location
Calcium		+	+				+	+
Phosphorus	+[2]	+			+		+	+
Glucose	+	+				+	+	+
BUN		+	+					+
Uric acid	+	+	+		+			+
Cholesterol	+	+	+		+			+
Bilirubin		+	+			+		+
Alkaline phosphatase		+	+					+
LDH		+	+			+		+
SGOT		+	+					+
Total protein	+	+	+				+	
Albumin	+	+	+			+	+	+
Globulin	+	+	+			+		+
Alpha 1 globulin	+	+				+		+
Alpha 2 globulin	+	+				+		+
Beta globulin		+				+	+	+
Gamma globulin	+	+	+			+		
Hemoglobin		+	+				+	+
PCV	+	+	+			+	+	+

1. Sex influence during rut period only.
2. + indicates significant change ($P > 0.01$).

small (n=6), so we added February and April MRC data for further comparison. Other populations included in the comparisons were; GMU 15C (April), GMU 14C (February) and GMU 13 (March). All collections were from adult moose.

Table 15 lists Ca, P, glucose, TP, beta globulin, Hb and PCV means, standard deviations and sample sizes for these moose population condition comparisons. Fifty-five of 80 possible comparisons were significantly different.

We arrayed comparisons, totaled the significantly higher differences between each comparison and credited that population with the tally. The condition ranking based upon equal weight from each potentially influencing blood parameter from highest to lowest with significantly higher difference tally in parenthesis was: GMU 13(21), Copper River Delta (20), GMU 14C (7), GMU 15C (6) and MRC (1).

Table 16 ranks the populations based upon each of the blood parameters. Four GMU 13 and four Copper River Delta individual parameters ranked highest. The MRC sample was lowest for five values.

Blood Parameter Characteristics

Blood parameters have a common characteristic in that the values of the various blood constituents are maintained at functional levels, if at all possible, by physiologic forces. A natural state of homeostasis is the rule rather than the exception. Practitioners of human and animal medicine have utilized this characteristic to identify pathological states in an individual by associating alterations in certain blood levels with disease in certain organs or systems. Clinical pathology is a branch of medicine that originated with this concept. Our blood studies of moose are an attempt to utilize this concept on a population rather than an individual basis. We recognized that in a sampling procedure individual variation may influence our results and this was reflected by high standard deviations of certain values. This factor made it necessary for us to obtain many samples from moose under a variety of conditions. Classification of the sample as to sex, age, month sampled, season-age class, reproductive status, excitability, condition and location correspondingly necessitated large sample sizes. Certain hematologic values were obtained but not utilized in this study since classification of some samples resulted in inadequate sample sizes.

The following outlines the physiologic highlights and pertinent findings of each blood parameter studied. Detailed physiological and biochemical background is available in several texts (Coles 1967, Kaneko and Cornelius 1970, Schalm et al. 1975 and Swenson 1970a).

Calcium (Ca)

Overall, the moose serum Ca mean was 10.34$\pm$ 1.17 mg/100 ml (n=1506). Blood Ca differences detected between seasons among the three moose age groups (Tables 3, 4 and 5), between age groups by season (Table 6), between adult moose condition classes (Table 12) and between locations

Table 15. Condition related blood parameters from moose population sampled during February, March, and April. (sample size in parenthesis).

Blood Values		Copper River Delta (Mar)		MRC (Feb.,Mar.,Apr)		GMU 13 (Apr)		GMU 15C (Apr)		GMU 14C (Feb)	
Calcium	mg/100ml	10.38	0.74(44)	9.81	0.64(39)	10.91	0.86(58)	9.61	0.98(29)	10.33	0.81(18)
Phosphorus	mg/100ml	5.50	0.69(44)	3.90	1.09(39)	5.63	0.99(59)	4.72	1.08(29)	4.74	1.51(18)
Glucose	mg/100ml	147.0	37.5(44)	116.2	26.1(39)	127.8	20.2(59)	91.3	16.2(29)	109.9	16.3(18)
Total protein	g/100ml[45]	7.07	0.57(45)	6.60	0.44(39)	7.43	0.40(61)	6.70	0.83(30)	7.20	0.54(18)
Albumin	g/100ml	3.82	0.39(45)	3.76	0.46(39)	5.21	0.39(61)	4.21	0.51(30)	4.80	0.41(18)
Beta globulin	g/100ml	0.72	0.09(45)	0.58	0.10(39)	0.60	0.11(61)	0.55	0.12(30)	0.60	0.07(18)
WBC											
Hemoglobin	g/100ml	19.8	0.5(46)	15.9	2.2(39)	19.7	0.7(60)	18.7	1.5(29)	15.4	1.2(17)
PCV	%	53.2	4.2(46)	39.9	4.6(39)	49.2	3.7(60)	45.9	3.9(29)	43.4	2.8(19)

Table 16. Rank of moose population condition based upon individual blood parameters and combined parameters.

Rank	INDIVIDUAL BLOOD PARAMETERS								Combined Parameters
	Ca	P	Glucose[1]	TP	Albumin[1]	Beta Globulin[1]	Hb	PCV	
1	GMU 13	GMU 13	Copper River	GMU 13	GMU 13	Copper River	Copper River	Copper River	GMU 13
2	Copper River	Copper River	GMU 13	GMU 14C	GMU 14C	GMU 13	GMU 13	GMU 13	Copper River
3	GMU 14C	GMU 14C	MRC	Copper River	GMU 15C	GMU 14C	GMU 15C	GMU 15C	GMU 14C
4	GMU 15C	GMU 15C	GMU 14C	GMU 15C	Copper River	MRC	MRC	GMU 14C	GMU 15C
5	MRC	MRC	GMU 15C	MRC	MRC	GMU 15C	GMU 14C	MRC	MRC

1. Glucose, albumin, and beta globulin were influenced by excitability and are of lesser value in evaluating condition.

(Table 13) were a reflection of the changing balance between absorption, withdrawal or deposition in the bone, and excretion via urine or feces. Ultimately the Ca contained in the diet will determine the amount of Ca absorbed from the gastrointestinal tract. In most species blood Ca levels tend to rise or fall with the dietary Ca level (Simeson 1970). This likely explains the significantly higher calf calcium values during the summer/fall season (Table 7).

There are many intrinsic factors affecting absorption such as: increased demand (pregnancy and lactation) which increases absorption; presence of oxalates, phytates, nucleic acids and chelating agents in the intestinal tract which decrease absorption; decreases in absorption with increased age; and the Ca:P of the diet which influences absorption in such a manner that high levels of one element decrease absorption of the other (Simeson 1970).

Simeson (1970) indicated that apart from dietary intake of Ca, vitamin D is a most important factor in regulating absorption of Ca. It also has a direct effect on bone mineralization. This may partly explain why the blood Ca level was lowest in the early winter season than in both summer/fall and late winter/spring groups. The early winter season includes November, December and January which constitute the months of least daylight hours in Alaska. Vitamin D is known as the "sunshine" vitamin.

More than 99 percent of total body Ca is in bone, and mobilization of this Ca is regulated by the parathyroid hormone and thyrocalcitonin. Secretion of the parathyroid hormone is affected by the blood Ca level itself. Parathyroid excretion releases Ca, whereas thyrocalcitonin depresses release. Excretion of Ca is via feces (undigested Ca and Ca from small intestine secretions), urine and from mammary secretions in lactating animals (Simeson 1970).

Cardielhac (1971) stated that about one-half the serum Ca is bound to protein, mostly albumin. Blood values increasing with improving condition (Table 12) perhaps reflect this relationship in that Ca and albumin have similar differences between condition class comparisons.

Calcium has potential as an indicator of condition for moose; however, due to vast bone stores and potential immobilization of these stores Ca by itself should not be the only criterion. Calcium values of 10.40 mg/100 ml and above may be considered desirable levels for moose in relation to condition (Table 12). This value is very close to the overall Ca mean of 10.34 mg/100 ml.

Calcium metabolism is obviously complex, therefore the mechanism by which our comparative Ca levels were altered can only be a matter of conjecture. The differences noted were significant, however, and we may expect moose blood Ca alterations with season, age, condition and location.

Inorganic Phosphorus (P)

The overall moose serum inorganic P mean was 5.30$\pm$ 1.64 mg(100m) (n=1506). Blood P differences, as detected between seasons (Tables 3, 4,

and 5), lactating and nonlactating moose (Table 8), adult moose condition classes (Table 12) and locations (Table 13), were, as with Ca, a reflection of the changing balance between absorption, withdrawal and deposition in bone, and excretion. The mechanism by which these changes occur is, in general, similar to that of Ca. In spite of the similarity of metabolic influences on these two elements and their usual, balanced relationship (Ca:P ratio of 2:1), an inverse relationship occurs when an excess of either is present, which tends to depress levels of the other. No such phenomenon on a population sampling basis was noted for moose, probably because no excess abundance of either element was present in their diet.

Inorganic P levels decreased from summer/fall through late winter/spring among all age groups. These did not resemble the Ca increase in late winter/spring. For Ca levels, this was postulated as a response to daylight periods and increased availability of vitamin D. Phosphorus metabolism also corresponds to vitamin D but to a lesser extent, perhaps explaining the difference.

Calcium and P levels increased with improved condition. Condition classes were not classified by season but the higher condition classes did correspond to forage availability and thus, we would expect increased availability of both elements during more favorable seasons. Phosphorus levels above 5.25 mg/100 ml may be considered desirable levels for moose, relative to condition (Table 12). This value, as with Ca, is very close to the overall P mean of 5.30 mg/100 ml.

Lactating moose had a significantly lower P mean than nonlactating moose, but no difference in Ca levels. This may indicate that P availability, absorption, and metabolism are more critical in lactating moose than those for Ca. One might expect differences in age groups on this basis; however, no age group differences were detected (Table 6).

Moose at the MRC and outside the MRC were lower in P than in all other areas compared except late winter/spring Kenai locations (Table 13). Additionally, regional population comparisons in late winter reflected lower P values for the MRC population (Table 15).

Phosphorus values alone, like those for Ca, may not be indicative of conditions of moose in an area, but in stressful situations, such as lactation, blood levels did reflect potential metabolic stress.

Glucose

The overall moose blood glucose mean was 129.1 $\pm$ 46.9 mg/100 ml (n=1505). Blood glucose levels dropped significantly from summer/fall through late winter/spring seasons for each moose age group (Table 3, 4, and 5). Glucose is the "fuel" for cells and in ruminants only small amounts of dietary glucose are absorbed. The main source of dietary glucose is absorbed volatile fatty acids (VFA) produced in the rumen from dietary carbohydrates, including cellulose and pentosans. Proprionic acid, a VFA, is subject to glucogenesis and is the major source of glucose and liver glycogen in ruminants (Bergman 1970). Although dietary

intake has a definite influence on blood levels, rates of glucogenesis and mobilization of liver glycogen stores may be influenced by other factors.

LeResche et al. (1974b) reported glucose elevations in pregnant versus nonpregnant moose and had difficulty explaining this phenomenon. Our data indicate no significant difference (Table 7), however for each month tested the nonpregnant moose had slightly higher blood glucose levels. Larger sample size and monthly separation of pregnant and nonpregnant moose may account for differences between the studies.

As body temperature, an indicator of excitability, increased blood glucose levels increased significantly between rectal temperature classes (Table 9). This association was previously reported for bighorn sheep (Franzmann 1972). Corticosteroid hormone levels increased with increased excitability in moose (Franzmann et al. 1975c). The glucocorticoid portion of this hormone accounts, in part, for the increase in blood glucose levels associated with increased excitability.

Blood glucose level increases with improved condition classes of adult moose (Table 11) are most likely associated with improved intake of carbohydrates in the diet and maximization of hepatic output of glucose.

Although blood glucose location differences were evident (Table 13) no general trend was apparent except for the lower glucose levels in the Alaska sample when compared to MRC, outside MRC and Kenai samples. No basis for location differences can be established. Excitability and condition influences on glucose levels appear to dominate other criteria, and the location differences are likely related to these influences. No age group differences were detected (Table 6).

The excitability factor appears to dominate most of the sources of variation associated with moose blood glucose levels. Glucose would perhaps be a good indicator of condition were it not for the excitability influence. In general, moose blood glucose levels above 140 mg/100 ml were detected in the "average" moose condition class 7 or better (Table 13).

Blood Urea Nitrogen (BUN)

The overall moose BUN mean was 12.5 $\pm$ 11.3 mg/100 ml (n=1506). Significant BUN differences in the classified sample were detected only among season/age group and location classifications. Moose calf BUN means between summer/fall and early winter were not significantly different, however, the late winter/spring mean was significantly higher than that for summer/fall and early winter (Table 13). Moose yearling/two-year-old and adult BUN summer/fall means were significantly higher than early winter and late winter/spring means (Tables 4 and 5).

Blood urea nitrogen levels reflect dietary protein intake and absorption and we would expect decreases related to lowered quality intake with seasons. Increased BUN noted during late winter/spring in

calves does not likely reflect intake, but rather catabolism of body tissue protein (Coles 1967). This phenomenon may confound interpretation of BUN values if other factors, generally observable, are not considered.

Relatively high standard deviations were noted for BUN values in nearly all classifications. BUN values have more application in serially monitoring an animal or group of animals on similar habitat. Nevertheless, lowered BUN values were detected as moose entered critical protein intake seasons and catabolism in calves was detected (Table 6). Most of the calves sampled during the late winter/spring season were in very poor condition and most did not survive the winter. High calf mortality at the MRC was experienced for all winters except one during this study.

No BUN location differences were detected between MRC and outside MRC or between Kenai and Alaska samples (Table 13). All comparisons of MRC and outside MRC samples with Kenai or Alaska samples resulted in significantly higher BUN values for the MRC or outside MRC samples. We believe protein catabolism was a major factor in these differences since condition of both MRC and outside MRC moose, as reflected by PCV values, was lower in all similar comparisons except between outside MRC and Kenai samples in late winter/early spring (Table 13).

BUN values reflect protein intake up to the point where protein catabolism provides substantial physiologic requirements. When sampling from a population this point is difficult to define and makes BUN values difficult to evaluate when not combined with other information regarding the population. When serially sampling individuals the catabolism point could be identified and useful application regarding protein intake and catabolism could be made.

Uric Acid

The overall moose serum uric acid mean was 0.41 ± 0.47 mg/100 ml (n=1505). Lactating moose had significantly higher serum uric acid mean than nonlactating moose (Table 8) and some location differences were detected (Table 13).

Uric acid is a product of purine metabolism and may increase as a result of increased tissue protein turnover, decreased renal excretion due to acidosis or increased gluconeogenesis. Lactating moose may experience all three mechanisms due to increased demands.

Increased uric acid levels in poor condition moose, particularly calves in late winter/spring were not evident. There was a slight increase in calves during early winter, but not a significant increase. In man, the major end product of purine metabolism is solely uric acid. All domestic animals are capable of converting uric acid to allantoin in the liver (Osbaldiston 1971). This factor accounts for the small quantities of uric acid in blood streams and urine of these animals. On the basis of small quantities of uric acid in blood serum we suspect this species is also capable of converting uric acid to allantoin. This characteristic may impede detection of tissue protein turnover using uric acid levels unless it is a turnover of great magnitude. No pattern for age group (Table 6) or location (Table 13) was noted for uric acid differences.

We do not consider uric acid analyses a useful tool for moose population evaluation due to small quantities present in serum and a lack of pattern in differences. For studies of individual or small groups of moose, serially sampled, it may prove useful in monitoring tissue protein turnover and gluconeogenesis.

Cholesterol

The overall moose serum cholesterol mean was 85.3 ± 18.3 mg/100 ml (n=1506). Cholesterol means of calves and yearling/two-year-old moose were significantly higher in summer/fall than early winter or late winter/spring (Tables 3 and 4). In adults the summer/fall mean was significantly higher than early winter only (Table 5). These results, in general, reflect improved summer dietary intake of saturated fatty acid. Calf cholesterol levels in summer/fall were significantly higher than for yearling/two-year-old and adult moose (Table 6). The influence of milk in calves' diet was likely responsible for these differences. Correspondingly, cholesterol levels were significantly higher in lactating than nonlactating moose. Cholesterol levels were not significantly influenced by rectal temperature (Table 9) or condition classes (Table 11) in adult moose, but some location differences were noted (Table 13).

Low saturated fatty acid diets and starvation will result in decreased cholesterol levels, probably due to altered quantities of fat ingested (Coles 1967). This was most noticeable in moose calf and yearling/two-year-old age groups as winter progressed. Both age groups, and particularly calves, were more vulnerable to starvation in this study than were adults. One might expect serum cholesterol levels to increase with improved condition class, however, this was not detected in adult moose. Condition classes of calves and yearling/two-year-old moose may reflect this with adequate sample size.

Cholesterol reflected seasonal intake and location differences in moose as was reported by LeResche et al. (1974b). As a single criterion for monitoring moose function it has some value, but should be utilized with other factors for better interpretation.

Bilirubin

The overall total bilirubin mean was 0.46 ± 0.26 mg/100 ml (n=1503). Bilirubin is the chief bile pigment found in serum and it is derived from hemoglobin. Significant elevations of total bilirubin are generally associated with hemolytic crisis (Coles 1967). Seasonal bilirubin differences were detected in calves, with significantly higher values in summer/fall than early winter (Table 3), and in adults with higher values in early winter than late winter/spring (Table 5). In early winter alkalum phosplotum values were significantly lower in calves and yearling/two-year-olds than in adults (Table 6). We have no explanation for these differences.

Rectal temperature class comparisons (Table 8) detected differences, with bilirubin values increasing with increased temperature class. This was caused by the breakdown of hemoglobin and release of bilirubin associated with excitability, the major influence in rectal class temperature differences.

One consistency in bilirubin value levels was detected in location comparisons. Significantly higher bilirubin values were detected for all MRC and outside MRC comparisons with Kenai and Alaska samples (Table 13). A difference, other than location, in obtaining these samples was that MRC and outside MRC individuals were captured by trapping and immobilization and Kenai and Alaska individuals were captured by helicopter immobilization. The trapped animals may have experienced more Hb breakdown releasing bilirubin due to time in trap versus stress over a shorter period of time with helicopter captures. The lower Hb levels detected in trapped samples (Table 13) support this premise in part.

Bilirubin was not considered a useful parameter for moose population evaluation. For studies of individuals or small groups of moose serially sampled it may have application, particularly in evaluating hemoglobin breakdown.

Alkaline Phosphatase

The overall moose serum alkaline phosphatase mean was 71.8 $\pm$ 74.7mg/100 ml (n=1503). Alkaline phosphatase analysis has been called an "empirical" test since the reason for elevated values is not well understood. Osteoblasts, the cells that participate in bone ossification, contain alkaline phosphatase levels higher than other cells and some have theorized that alkaline phosphatase may have an important role in bone calcification (Wasserman 1970). In moose calves and yearling/two-year-olds alkaline phosphatase levels were significantly higher in the summer/fall season than early winter (Tables 3 and 4). In yearling/two-year-olds alkaline phosphatase levels were also higher in late winter/spring than early winter. In adults alkaline phosphatase levels were significantly higher in late winter/spring than in either early winter or summer/fall (Table 5).

Adult male values were also significantly higher than those for adult females during November (Table 2). Alkaline phosphatase levels in young animals (calves and yearling/two-year-olds) were significantly higher during the summer/fall season during their periods of rapid growth. This is likely related to the active bone calcification period in which alkaline phosphatase may play an important role. The seasonal variability associated with alkaline phosphatase values in adults may have a similar relationship to bone calcification, however, the pattern of differences is not consistent in our results and cannot be explained.

Comparisons between age groups within seasons indicated calf alkaline phosphatase levels during summer/fall and late winter/spring seasons were significantly higher than for yearling/two-year-olds and adults and yearling/two-year-old values were also higher than those of adults (Table 6). These relationships are also likely related to active bone calcification periods in these younger animals.

Alkaline phosphatase variations in adult moose related to pregnancy, lactation, rectal temperature and condition were not detected, but the outside MRC mean was significantly lower than the Alaskan mean during early winter and the Kenai mean was significantly lower than the Alaska mean during late winter/spring (Table 6).

It appears that alkaline phosphatase levels reflect change, with higher values associated primarily with periods of active calcification in young moose. The high standard deviation of all grouped alkaline phosphatase values precludes any useful comparisons between populations.

Lactic Dehydrogenase (LDH)

The overall moose serum LDH mean was 337.2 $\pm$ 113.7 mg/100 ml (n=1504). LDH is a serum enzyme found in high concentrations in various tissues. Elevations in serum LDH have been detected in malignancies, intoxications and various infections. These elevations are associated with tissue breakdown and subsequent release of LDH into the blood serum (Coles 1967). Rectal temperature class comparisons (Table 8) detected significantly increasing LDH values with increasing temperature class. Tissue breakdown associated with excitability and increased rectal temperature accounts for this phenomenon.

Season, age and location differences (Tables 3, 4, 5, 6 and 13) were likely related to tissue release of LDH associated with capture related excitability and stress and with generalized tissue breakdown during winter periods of negative energy balance.

Serum Glutamic Oxalacetic Transaminase (SGOT)

The overall moose serum SGOT mean was 172.7 $\pm$ 57.6 mg/100 ml (n=1504). As with LDH, increased SGOT levels are associated with cell necrosis of many different tissues (Coles 1967), however, our results indicated that SGOT levels were less specific than LDH levels in relation to rectal temperature or excitability influences. No significant differences were detected between rectal temperature classes for SGOT values. Season, age and SGOT location differences (Tables 3, 4, 5, 6, and 13) were, as with LDH, likely related to tissue release of SGOT associated with capture related excitability and stress and with generalized tissue breakdown during winter periods of negative energy balance in most moose. Neither LDH or SGOT were adequately specific for utilization as measures of degree of excitability as proposed by LeResche et al. (1974b).

Calcium/Phosphorus Ratio (Ca:P)

The overall Ca:P mean was 2.16 $\pm$ 0.70 (n=1032). Calcium/phosphorus ratios were listed to demonstrate trends and then variance from the traditional 2:1 relationship. With increasing age, Ca:P increased and the ratios for adults during all seasons was 2:1 or greater while for calves and yearling/two-year-olds it was less than 2:1 except for yearling/two-year-olds in late winter/spring (Tables 3,4 and 5).

A definite trend of increased Ca:P was noted for pregnant and nonpregnant moose from January through May. Pregnant moose Ca:P rose from 1.85 to 3.32 while nonpregnant moose Ca:P rose from 1.71 to 2.63 (Table 7). The shift, in both instances, was previously related to lowering P levels associated with nutrition through seasons, perhaps more than pregnancy. In both cases, it reflects the more critical aspects related to P metabolism and in particular to the pregnant female. The lactating moose Ca:P ratio was also higher than for non-lactating moose and here also the P level was primarily responsibile for the shift (Table 8).

Condition class Ca:P comparisons reflected a decreasing ratio with improved condition, from 2.22 for condition class 4 to 1.92 for condition classes 8 and 9 (Table 12). This was related more to increasing P than change in Ca levels.

Application of Ca:P provides an adjunct to interpretation of Ca and P physiologic data.

Total Protein (TP)

The overall moose serum total protein mean was 7.14 $\pm$ 0.95 g/100 ml (n=1409). Total protein was significantly higher in adult females than adult male moose during post-rut November (Table 2). All age groups had higher TP values in summer/fall than other seasons (Tables 3, 4, and 5). Calf TP levels were significantly lower than yearling/two-year-old levels during summer/fall and late winter/spring seasons and they were lower than adults in summer/fall and early winter. Yearling/two-year-old TP levels were significantly lower than those of adults during all seasons (Table 6). Condition classes reflected significantly higher TP values as condition improved (Table 11).

Plasma proteins may be utilized as an estimation of the nutritive state of the animal. The nutritive state is dependent upon proper dietary intake and is also a reflection of protein metabolism within the animal (Coles 1967). Proteins are present in the plasma and all living cells, with nearly 80 percent of the body's protein stores in striated muscles, skeltons and skin. Structural proteins are among the last components to be "consumed" by starving animals. Thus, the body tends to conserve its proteins (Schalm et al. 1975).

The concentration of protein in the plasma, at any time, is a function of the hormonal balance, nutritional status, water balance and other factors affecting the state of health (Schalm et al. 1975).

The differences detected in our moose samples are indicative of the changes expected with age, season, condition and location criteria. We did not detect significant differences in pregnancy, lactation, or rectal temperatures sources of variation. Based upon moose condition class criteria, and the ability for TP to reflect the nutritive state of the animal, we believe it to be a useful tool to monitor moose populations (Table 16). Total protein values of 7.5 g/100 ml or greater would indicate a good nutritive state in an adult moose (Table 12). Immature moose in a good nutritive state would have, in general, lower total protein values equivalent to summer/fall mean values (calves-6.79 g/100 ml and yearling/two-year-olds-7.37 g/100 ml) (Tables 3 and 4).

Albumin

The overall moose serum albumin mean was 4.17 $\pm$ 0.82 g/100 ml (n=1409). Albumin is the major quantitative component of TP. Total protein and albumin values are closely related in that an alteration in TP is most often associated with an alteration in albumin. A decrease in albumin may result from deficient protein intake, deficient synthesis of albumin, excessive protein breakdown or loss of albumin (Coles 1967).

Albumin values in our sample reflected relationships to sources of variation similar to TP except albumin differences were additionally detected in rectal temperature comparisons. In rectal temperature class comparisons, albumin was significantly higher in classes 4 and 5 than in class 1 comparisons.

The close relationship between albumin and TP gives us an additional useful monitoring parameter. Adult moose albumin levels of 4.5 g/100 ml or greater should be considered values representing animals in good nutritional states (Table 12). As with TP, calf and yearling/two-year-old albumin levels in animals in a good nutritional state would be lower and would resemble summer/fall mean values (calves-4.19 g/100 ml and yearling/two-year-olds-4.33 g/100 ml).

Globulin and Globulin Fractions

The overall moose serum total globulin mean was 2.99 $\pm$ 0.73 g/100 ml (n=1409) while the corresponding globulin fraction means were; alpha 1 globulin-0.35 $\pm$ 0.21, alpha 2 globulin-0.58 $\pm$ 0.25, beta globulin-0.70 $\pm$ 0.29 and gamma globulin-1.37 $\pm$ 0.43(n=1409). These parameters will be considered together due to their relatively close relationship.

Electrophoretic determinations of serum protein detect bands or zones of proteins, and with the exception of albumin, these bands or zones are made up of a group of individual proteins with many and varied functions. Schalm et al. (1975) listed 22 individual proteins within the globulin zones. In general, each has a separate function. We will not relate our findings to individual functions, but will demonstrate when these proteins are influenced by sources of variation of concern to us regarding moose populations.

During rut (October) adult male moose globulin and globulin fractions were all significantly higher than females' except beta globulin (no difference) (Table 2). Increased demands upon male moose during this period would result in higher levels of these proteins that are, in part, associated with transport of hormones, lipids and fat soluble vitamins.

Seasonal variation was detected in calf beta globulin fraction only, with the summer/fall level significantly higher than late winter/spring level (Table 3). Yearling/two-year-old levels of globulin and all fractions were significantly higher in summer/fall than late winter/spring except alpha 1 globulin which was significantly lower. In addition, alpha 2, beta and gamma globulins were significantly higher in summer/fall than early winter (Table 4). The drop in levels because of increased severity of seasons is understandable, however, the increase in alpha 1 globulin in late winter/spring is difficult to explain. Adult moose seasonal relationships were similar to those of yearling/two-year-olds with levels of all globulins decreasing, through increased severity of seasons except alpha 1 globulin (Table 5). One possible explanation for the alpha 1 globulin increase may be related to the alpha-1-acid glycoprotein part of the band which has an unknown function. Schalm et al. (1975) indicated it increases in inflammatory, degenerative and neoplastic disease. Late winter stress may produce degenerative syndromes stimulating increase in this protein.

Age group source of variation was detected with globulin, and gamma globulin levels were significantly lower in calves than yearling/two-year-olds and adults during summer/fall and early winter. Gamma globulin levels were higher in yearling/two-year-olds than adults during summer/fall (Table 6). Gamma gloublins are primarily associated with antibodies and lower levels in calves would be expected, except during the colostrum intake period, since their antibody producing mechanisms are still developing. The higher levels in yearling/two-year-olds during summer/fall are likely related to their attainment of full antibody production capability which is responding to multiple antibody challenges.

Globulin and all its fractions demonstrated significant increases when class 1 rectal temperature class was compared to most higher rectal temperature classes (Table 9). We believe this influence resulted from an ambient temperature and nutritional state relationship since moose in poor condition, generally in late winter, had low rectal temperatures. In addition, comparisons in other rectal temperature classes did not reflect this trend.

Beta globulin was the only globulin component that significantly increased with increased condition class (Table 11). The range was 0.57 g/100 ml for condition class 4 to 1.43 g/100 ml for condition class 9 (Table 12). Beta globulin levels above 0.73 g/100 ml may be considered a desirable level for moose based upon the condition class 7 level (Table 12).

Location sources of variation reflected alterations in globulin and all its fractions except gamma globulin (Tables 13 and 14).

Albumin/Globulin Ratio (A:G)

The overall A:G mean was 1.50 $\pm$ 0.54 (n=1409). Albumin/globulin ratios were listed to demonstrate trends. The A:G was 1.19 in adult males and 1.56 for adult females during October (rut) (Table 2). Although total protein values between the adult males and females were not significantly different all other protein fractions except beta globulin were. The shift was a lowered albumin and an increased globulin which of course, is reflected in the ratio. Following rut (November) the A:G for adult males was up to 1.68.

Each moose age group had lower A:G during early winter than either summer/fall or late winter/spring (Tables 3, 4 and 5). Calves during summer/fall had higher A:G than either yearling/two-year-olds or adults. This was due to lowered globulin, primarily gamma globulin.

The value of A:G in evaluating blood protein data was that it provided a means to screen aberrant protein fraction relationships. Its application should be for screening only since A:G ratios can be variously derived.

Hemoglobin (Hb)

The overall moose blood hemoglobin mean was 17.9 $\pm$ 2.8 g/100 ml (n=983). Hemoglobin is a complex, iron-containing, conjugated protein composed of a pigment and a protein. The pigment is reduced heme and the protein is globin (Dukes 1947). Its primary function is oxygen

transport. Hemoglobin levels in adult moose were significantly higher in summer/fall than either early winter or late winter/spring seasons (Table 5). No seasonal differences were noted for calves or yearling/two-year-olds, however, calf values were significantly lower than those for adults in summer/fall (Table 3).

Hemoglobin levels increased with improved condition class (Table 12) and significant differences were detected for some class comparisons (Table 11). Condition class 7 Hb value was 18.6 g/100 ml and this may be considered the level above which the general condition of moose is satisfactory. Rosen and Bischoff (1952) noted possible relationships between Hb levels and relative physical condition of mule deer.

Outside MRC and MRC Hb values were significantly lower in all available comparisons with Kenai and Alaska values, except the outside MRC and Alaska comparison during late winter/spring (Table 13).

Swenson (1970b) stated that excitement may increase not only Hb concentration, but also PCV and erythrocyte numbers per unit of volume due to the release of catecholamines (epinepherine and norepinepherine). We were unable to detect an excitability influence on Hb levels utilizing the rectal temperature class data (Table 10). The Hb values for each class were; class 1-17.9 g/100 ml (n=31), class 2-18.6 g/100 ml (n=232), Class 3-18.5 g/100 ml (n=226), Class 4-18.5 g/100 ml (n=71) and Class 5-17.8 g/100 ml (n=29). The excitability influence on free-ranging moose physiologic parameters was considered in our study design and we were able to detect values that were significantly influenced by excitability (Table 9), however, Hb was not added. It is our belief that in the moose capturing process, whether trapping or helicopter immobilization, the influence of catecholamines may be similar in all moose handled. Therefore we could not detect its influence with Hb values. In addition, the moose Hb overall mean (17.9 g/100 ml) is higher than listed by Swenson (1970b) for most mammals (between 13 and 15 g/100 ml). Catecholamines may be responsible for maintaining these high moose Hb means.

Packed Cell Volume (PCV)

The overall moose blood PCV mean was 47.0 $\pm$ 7.7 percent (n=864). Centrifuging whole blood under standardized conditions produces: (1) a mass of erythrocytes at the bottom which is referred to as packed cell volume (PCV), (2) a white or gray layer of leukocytes and thrombocytes immediately above the PCV mass (buffy coat) and (3) the blood plasma or serum. Separated blood is termed hematocrit. Coles (1967:74) stated, "Use of the hematocrit tube for determinination of the percentage of blood that is composed of erythrocytes is one of the most valuable techniques in the clinical laboratory."

Packed cell volumes of adult bull moose during October (rut) were significantly lower than those from adult females (Table 2). Yearling/two-year-olds and adult moose had significantly higher PCV values in summer/fall than in early winter and late winter/spring (Tables 4 and 5). Calf values decreased slightly from summer/fall through late winter/spring

but not significantly (Table 3). Calf values in summer/fall were significantly lower than those for yearling/two-year-olds and adult moose (Table 6).

Packed cell volume values increased significantly with improved condition for all comparisons except class 4 with 5 (Table 11). This relationship makes PCV a valuable parameter for evaluating moose condition. The PCV value for condition class 7 was 49.6 percent (Table 12) and from this we may establish that moose PCV values of 50 percent or more generally indicate good to excellent moose condition.

Location comparisons detected significantly lower PCV values in MRC and outside MRC samples in all comparisons made with Kenai and Alaska samples except for outside MRC and Kenai comparison in late winter/spring (Table 13).

DISCUSSION

For the parameters tested we have presented base line moose blood chemistry and hematology data classified by sex, age, season, pregnancy, lactation, excitability, condition and location. Some classifications were more important sources of variation than others. Consistent differences provided a basis for physiologically monitoring moose populations through some blood parameters.

Identifying some major sources of variation in blood parameters permitted us to compare moose populations. Variation due to condition was of particular importance in that some parameters tested (Ca, P, Glucose, TP, albumin, beta globulin, Hb and PCV) positively reflected improved condition of moose.

Our criteria for rating condition were based upon the premise that animal form and composition are largely dictated by the interactions of the complexes of climate and nutrition (Ledger 1968). Demonstrated variations due to season, age and sex (during rut) necessitated comparing moose within these classifications. Because pregnancy and lactation had no significant influence on blood parameters their consideration was obviated. Excitability was a source of variation for some condition parameters (glucose, albumin, and beta globulin) and this somewhat lessens their applicability in condition comparisons. Our comparisons of adult moose from five populations during the late winter season, using parameters influenced by condition (Table 16), provided a condition ranking of these populations which we consider realistic based upon the high productivity of one of these populations (Copper River Delta) and the low productivity of another (MRC). Calcium, P, TP, Hb, and PCV blood parameters can be utilized to provide condition comparisons between adult segments of moose populations in late winter without concern for excitability status. Late winter comparisons were used since they reflect the critical season for moose. Packed cell volume appears to be the most useful parameter because it reflected differences between all condition class comparisons, except Class 4 with Class 5 (Table 11), and was not influenced by excitability.

Using the condition influenced parameters detected in this study and extrapolated from Table 12, we may consider adult moose with the following blood levels or greater to be in an average or better condition;

PCV - 50 percent, Hb - 18.6 percent, Ca - 10.4 mg/100 ml, P - 5.2 mg/100 ml, TP - 7.5 g/100 ml, albumin - 4.5 g/100 ml, beta globulin - 0.7 g/100 ml, and glucose 140 g/100 ml.

Although no between year differences by season were detected among adult MRC moose blood values, the possiblity that this source of variation may influence parameters when comparing populations must be considered. Ideally, condition of populations should be compared the same year and same month; however, this may not always be possible and it is not necessarily critical since the condition evaluation reflects climatic as well as nutritional influences. We must be aware of climatic influence and not concentrate solely on nutritional influences. If differences between years at MRC were tested on a monthly basis, it is likely that differences may be detected, however, with combined months into seasons this influence was negated.

Moose blood parameters used for other physiologic comparisons must consider the influence of excitability upon certain parameters, particularly glucose, bilirubin and LDH. Conversely, these parameters may be applied to grossly assess the excitability state of a moose population during collection. Serum corticoid levels may, however, better reflect handling stress in moose (Franzmann et al. 1975c).

Blood urea nitrogen, cholesterol, bilirubin, alkaline phosphatase, uric acid and SGOT determinations may provide useful information regarding moose physiology under more specific sampling, particularly for serially sampling individuals over a period of time. Nevertheless, for population condition assessment they were not useful in this study. The base line blood data from this study may provide useful comparative information for researchers utilizing some or all of these parameters in moose physiological studies. Application of these data may also have comparative value in studies of other ruminant species.

Base line data provided by season-age classes, lactating and pregnant moose must be considered on the basis that the samples were obtained from different locations, regardless of the fact that nearly one-half the samples were from the MRC. This diversity of sampling did not remove the location source of variation, but it did produce a better representation from Alaskan moose.

A benefit derived from blood sampling, not necessarily outlined in our goals, was the potential screening of a population or populations for aberrant values that may lead to the need for more intensive research in some areas. For example, the low P levels from MRC and outside MRC moose indicate further investigation is necessary thereby assisting us in establishing priorities for future research.

Management Implications

Quantitative condition assessment of moose populations provides a means for game managers to determine priorities for more intensive investigation. In Alaska, moose are widely distributed and in many instances little is known regarding the status of certain populations. Other populations have been intensively studied, however, and are monitored

regularly (McKnight 1975). Blood sampling from well understood populations provides a comparative standard to which comparisons with populations of unknown quality may be made.

Certain prerequisites must be met to accomplish comparative moose population condition assessments using blood parameters. Standardized collection of samples is necessary. Adult moose should be sampled in late winter and preferably during the same month and year. However, on the basis of background information from populations sampled during late winter and considered in excellent condition (Copper River Delta) and in poor condition (MRC), between year comparisons during any part of the late winter season (February, March, April, May) can be accomplished for Alaskan moose populations. If no known populations have been sampled in a state or region, base line information should be obtained. It may be possible to obtain an assessment using low base line MRC samples and high base line Copper River Delta samples from other parts of Northern Hemisphere moose ranges until such information is available. With differing subspecies and habitats of moose these sources of variation should be weighed in considering potential differences in the blood profiles.

Standardized laboratory procedures should be followed in analyzing blood parameters. Preferably the same laboratory and equipment should be used. Cost of collecting an adequate sample must be evaluated. In many cases samples can be collected in conjunction with other projects and costs will be minimal. Collecting samples in late winter generally obviates use of hunter-kill samples and a special effort must be made to obtain samples.

Four approaches to analysis may be considered: (1) use of PCV as a sole comparative parameter, (2) use of PCV and Hb, (3) use of PCV, Hb, Ca, P and TP and (4) use of PCV, Hb, Ca, P, TP, glucose, albumin, and beta globulin. Packed cell volume was considered the best single parameter for condition assessment. A single, whole blood sample is all that would be required and it is possible to obtain this from bleeding an immobilized moose or obtaining it from a killed moose before the blood clots. Required laboratory equipment consists of standard microhematocrit tubes and a microhematocrit. Field laboratory facilities with power would suffice. If Hb were desired in addition to PCV, the same blood sample could be used and a hemoglobin meter would be required. The samples should be analyzed within 12 hours and the sample in both above instances must be protected from freezing or excessive heat. For the third approach (PCV, Hb, Ca, P and TP) it would be necessary to prepare a serum sample, in addition to the whole blood sample. In this case, a standard centrifuge would be required to spin-down the sample to obtain serum. The serum sample could be frozen and stored prior to shipment to a laboratory for standard blood chemistry analysis.

The last approach (PCV, Hb, Ca, P, TP, glucose, albumin, and beta globulin) requires the same field equipment as the former, but laboratory protein electrophoresis would be required in addition to the blood chemistry analysis to obtain albumin and beta globulin values. The additional analyses provided by the fourth option do not provide sufficient additional information to justify them, in our estimation.

Data obtained from these comparisons provide additional quantitative evidence regarding a population, but should not be used alone in a final population assessment. We believe they can be a useful additional tool in making game management decisions.

Milk

Results of this study were published and are summarized by the following abstracts:

COMPOSITION OF MILK FROM ALASKAN MOOSE IN RELATION TO OTHER NORTH AMERICAN WILD RUMINANTS (Franzmann et al. 1975b).

Table 17 lists the mean and standard deviation for the MRC moose milk components analyzed and mean values reported for some other North American ruminants. The standard deviation of our samples was relatively high for all components except percent ash, specific gravity and pH. Environmental factors which contribute to variance in values would potentially be climate, date of calving, stage of lactation and diet, as well as age, general condition of the animal and the length of the dry period (Kirchgessner et al. 1967). The genetic influence on composition may differ between animals of the same species as well as between species (Kirchgessner et al. 1967). Variability in collecting, handling and storage of samples would also potentially influence results.

Percent lipid variability in our sample may reflect the differences in stage of lactation when samples were collected (Chen et al. 1965 and Kirchgessner et al. 1967). We collected samples during June, July and August during five lactation seasons (1970 through 1974). Differences in seasons, although not generally apparent, may have influenced all values. The variability in total solids would be influenced by lipid variability. Since quality of food intake was unknown, its influence on milk composition variability was unknown. Nevertheless, this influence, particularly on percent lipids and crude protein, must be considered (Kirchgessner et al. 1967).

It is apparent that difficulties arise when interpretation of variability within species milk values is attempted, and comparisons between species add another dimension. Published data from North American wild ruminants (Table 17) illustrate this, but most important they illustrate the paucity of information available.

The variability between species which have similar digestive systems and which have evolved to lactate during the season of high quantity and quality food intake, may relate more to sample size, stage of lactation, and analytical procedures than to real inter-species variability. A comparison of species differences with the small sample sizes available would not be valid; however, the need for more base line milk composition data has been demonstrated. With an increased sample size, more meaningful base line milk compostion data would be available to enhance interpretation of differences observed.

Table 17. Gross composition of milk from Alaskan moose and other North American ruminnats.

Animal	Sample Size	Total Solids %	Lipids %	Ash %	Crude Protein % Nx6.38	Lactose[1] %	Gross Energy Kcal/g	Specific Gravity	pH	Reference Taken From
Moose	20	24.54 ±6.11	5.83(8)[2] ±2.78	2.01(5) ±0.26	10.32(17) ±2.24	6.81(5) ±2.54	1.42 ±0.477	1.038(3) ±0.014	6.76 ±0.03	This work
Moose	2	24.85	7.20	1.60	14.35	1.70	-	1.055	6.35	Cook etal(1970b)
Mule Deer	1	20.40	8.30	1.44	-	-	-	-	-	Hagen (1951)
White-tailed Deer	4	25.24	10.38	1.61	10.28	2.70	-	-	-	Silver(1961)
White-tailed Deer	29	24.16	9.53	-	-	-	-	-	-	Youatt etal(1965)
Black-tailed Deer	1	25.00	10.40	1.50	8.70	4.40	-	-	-	Kitts etal (1956)
Bighorn Sheep	5	24.06	10.43	1.12	7.89	4.46	-	1.019	6.43	Chen et al (1965)
Dall Sheep	9	27.55	10.32	1.09	8.20	3.81	-	1.041	6.57	Cook et al (1970a)
Muskox	2	21.50	11.00	1.80	5.30	3.60	-	-	-	Tener (1956)
Muskox	5	27.10	10.90	1.20	11.90	2.10	-	1.023	5.40	Baker etal (1970)
Caribou	1	31.80	16.90	1.20	9.70	2.50	-	-	6.55	Hatcher etal(1967)
Caribou	1	40.40	23.20	1.07	11.60	2.45	-	-	6.28	Hatcher etal(1967)
Mountain Goat	1	21.20	5.74	1.18	11.40	2.80	-	1.055	-	Lauer et al (1969)
Mountain Goat	1	38.70	17.70	1.43	18.00	-	-	-	-	Lauer et al (1969)

1. Lactose = % Solids - % Crude protein - % Lipids - % Ash
2. Sample size in parentheses when different from group.

MOOSE MILK AND HAIR ELEMENT LEVELS AND RELATIONSHIPS (Franzmann et al. 1976)

Milk was collected from 21 Alaskan moose at the MRC and analyzed by atomic absorption spectroscopy for Al, As, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Se, and Zn. Hair samples were collected from 100 moose at the MRC to correspond with the lactation period and serve as a metabolic indicator of mineral elements stored in tissue. Published analyses of bovine milk were compared to moose milk; Al, Fe, Se and Zn were higher in moose milk by factors of 1.6 to 290. Elements potentially influenced by nutrition and those determined genetically were also considered. Elements in moose milk and hair values were compared, since mineral element levels in hair potentially reflect the availability and intake of these elements. Calcium and Mg were the only values in hair lower than the values in milk (factors of 4.2 and 1.5, respectively). Moose, as well as domestic cattle, apparently are subjected to lactation stress by the genetically determined levels of Ca and Mg in milk.

Hair

Thirty-one monthly moose hair samples (n = 541) were obtained from the MRC for four essential macro-elements (Ca, K, Mg and Na), four essential micro-elements (Cu, Fe, Mn, and Zn), and two nonessential micro-elements (Cd and Pb). Values for these elements were also obtained from 11 different regions in Alaska (Fig. 2) from 21 monthly samplings (n = 709). Tables 18 through 27 list means, standard deviations and sample sizes, and depict statistical difference among monthly classifications for different regions and designated Alaska Department of Fish and Game Game Management Units (GMU).

There was no significant difference ($P > 0.10$) between male and female samples for each element. Age variable was not tested due to high proportion of unknown ages in total sample. Samples from every region except MRC were from adult moose. At MRC less than three percent of the sample represented calves. Differences between and/or among samples were detected for seasonal, yearly, and regional mean element comparisons (Tables 18 through 27).

Seasonal variability from the same area during the same year was demonstrated by the MRC samples (Tables 18 through 27). Element values, in general, peaked during late summer and early fall and dropped to their lowest levels during late winter. This situation was reported previously for those data represented by the May 1972 through April 1973 MRC samples (Franzmann et al. 1975a). Samples from the MRC since that time continue to reflect seasonal variability.

Monthly samples from the MRC reflected hair element variability between years. For 10 months of the year, when more than one yearly MRC sample was available (except March and April), 61 of 100 monthly groups were significantly different ($P < 0.10$) between and among years. Nine of ten monthly samples for each element were from three different years, the other (May) was between 2 years. In 4 of 90 monthly samples representing 3 collection years, all 3 years were significantly different (Mg in October, Zn in February and July, and Pb in September, Tables 18 through 27).

Regional variability was noted when samples from the same month and year were compared (Tables 18 - 27): January 1973 - Calcium, Cu and Cd means were significantly different ($P \leq 0.10$) between Fort Richardson and MRC samples. The Fort Richardson Cu mean was greater than the MRC Cu mean by a factor of 2.7 and, correspondingly, the Cd mean was greater by a factor of 23.5. January 1975 - Magnesium, Na, Cu and Pb means were significantly different between MRC and Nome samples. Nome Cu mean was greater than the MRC Cu mean by a factor of 3.8 and, conversely, the MRC Pb mean was greater by a factor of 11.2. February 1974 - Magnesium, Na, Cu, Mn, Zn and Pb means were significantly different between MRC and Fort Richardson samples. Fort Richardson Mg mean was greater than MRC Mg mean by a factor of 2.4. Correspondingly, Cu was greater by a factor of 5.8 and Pb by a factor of 52.0. February 1975 - Calcium, Mg, Cu, Mn and Zn means were significantly different between MRC and Elmendorf samples. Elmendorf Cu mean was greater than MRC Cu mean by a factor of 3.1 and, correspondingly, the Mn mean was greater by a factor of 9.5. March 1975 - Calcium, Na, Mn, Zn, Cd and Pb means were significantly different between Glennallen and Fairbanks samples. Calcium and Mn means from Glennallen were greater than Fairbanks means by factors of 2.0 and 3.3, respectively. April 1975 - Calcium, Cu and Zn means were significantly different between Glennallen and Homer samples. The Glennallen Ca mean was greater by a factor of 3.1. August 1974 - Calcium, Cu, Mn, Zn and Pb differences among MRC, Copper River Delta, and Nome sample means were noted. The Copper River Delta means for these elements were greater than those for either MRC or Nome and were greater by factors of 1.9 and 2.0 for Ca and 3.0 and 2.8 for Mn than MRC and Nome, respectively. Nome Cu mean was 2.3 times greater and the Copper River Delta 3.4 times greater than the MRC Cu mean. September 1973 - Calcium, Mg, Zn, Cd and Pb means were all different between MRC and Southeast Alaska samples by factors of 1.7 or more. Southeast Alaska Cu and Zn means were greater by factors of 2.1 and 1.7, respectively, and MRC means were greater by factors of 2.3 for Mg, 2.7 for Cd and 4.2 for Pb. September 1974 -Significant differences among Ca, Mg, K, Na, Cu, Mn, Zn, and Pb means were detected among MRC, Copper River Delta and Nome samples. Copper River Delta Ca mean was greater than MRC mean by a factor of 2.7 and greater than Nome mean by a factor of 1.9 as was the Cu mean by factors of 2.3 and 1.9, respectively. Nome Mn was less than MRC by a factor of 3.1 and less than Copper River Delta by a factor of 3.5. October 1972 -Magnesium and Mn means were significantly different between MRC and Benchland samples. Benchland Mn mean was greater than MRC mean by a factor of 2.3. October 1973 - Calcium, Mg, K, Fe, Mn and Pb differences among MRC, Alaska Range and Caribou Hills samples were detected. Caribou Hills Ca mean was greater than both MRC and Alaska Range samples by a factor of 1.8. Alaska Range Mn mean was 2.6 times greater and the Caribou Hills mean 2.8 times greater than the MRC Mn mean. October 1974 -Significant differences among Ca, Mg, K, Na, Cu and Fe means were detected among MRC, Nome and Glennallen samples. Glennallen Mg mean was greater by factors of 2.1 and 1.7 than MRC and Nome samples, respectively. November 1974 - Calcium, Mg, K, Na, Fe, Mn, Zn, Cd and Pb differences among MRC, Glennallen and Homer samples were detected. MRC Ca mean was 2.6 times higher than Glennallen Ca mean and 2.3 times higher than Homer Ca mean. Similarly, MRC Mn mean was 5.1 and 5.8 times the Glennallen and Homer means, respectively, and MRC Pb mean was 8.0 and 6.1 times those for these respective areas.

Table 18. Moose hair mean monthly calcium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					335.0±67.7 (11)a	284.7±108.1 (19)a	313.3±107.0 (19)a	699.7±208.8 (13)a	515.5±125.5 (12)a	227.8±66.4 (10)a	196.4±38.0 (16)a	220.9±31.8 (17)a
MRC(GMU 15A)1973	196.0±38.1 (21)b[3]	295.6±68.0 (23)ab	241.8±42.2 (23)b	249.3±46.1 (29)b		216.2±262.5 (22)a	297.6±206.7 (22)a	361.1±158.1 (16)b	283.0±126.1 (20)b	134.8±48.4 (21)b	194.2±85.8 (10)a	225.1±71.0 (15)a
MRC(GMU 15A)1974	203.4±50.6 (17)b	280.2±45.7 (18)bc			226.7±74.3 (10)b	258.5±87.3 (19)a	514.3±398.2 (22)b	382.9±255.3 (14)b	207.8±119.2 (26)b	93.9±48.8 (26)b	195.2±38.1 (11)a	222.2±67.2 (17)a
MRC(GMU15A)1975	234.9±78.8 (10)ab	208.7±27.5 (12)d										
Benchland (GMU15A & 15B)										225.2±71.3 (58-1972)a		
Fort Richardson (GMU 14C)	280.4±100.3 (44-1973)a	289.9±58.5 (50-1974)bc										
Alaska Range (GMU 20A)										129.6±37.6 (21-1973)b		
Caribou Hills (GMU 15B)										238.8±42.0 (67-1973)a		
Southeast Alaska (GMU 5)									602.2±205.9 (13-1973)a			
Copper River Delta (GMU 6)			132.1±63.2 (50-1974)c					712.5±71.1 (12-1974)a	569.6±108.1 (27-1974)a			
Nome (GMU 22)	167.6±55.7 (26-1975)b							347.9±252.6 (5-1974)b	293.4±209.3 (37-1974)b	241.0±164.1 (21-1974)a		
Glennallen (GMU 13)			321.7±51.3 (64-1975)a	591.9±127.7 (10-1975)a						167.6±107.0 (68-1974)c	75.1±37.9 (20-1974)b	
Homer (GMU 15C)				192.0±41.1 (31-1975)b							84.7±60.7 (60-1974)b	
Fairbanks (GMU 20B)			159.2±16.3 (5-1975)c									
Elmendorf (GMU 14C)		337.7±84.2 (20-1975)a										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P > 0.10$) for within month comparisons.

Table 19. Moose hair mean monthly magnesium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2]15A)1972					38.3±6.0 (11)a	29.4±12.8 (19)a	31.9±16.8 (19)a	107.5±40.5 (13)a	149.5±61.6 (12)a	92.0±17.8 (10)ad	80.8±19.8 (16)a	64.2±12.2 (17)a
MRC(GMU15A)1973	55.4±10.7 (21)ac[3]	51.1±12.7 (23)a	49.1±18.8 (23)a	45.5±12.4 (29)a		36.4±30.0 (22)a	57.9±52.4 (22)a	191.8±65.2 (16)b	166.2±45.8 (20)a	152.4±32.1 (21)b	50.0±21.5 (10)bc	40.9±16.4 (15)b
MRC(GMU 15A)1974	32.0±16.0 (17)b	31.4±5.7 (16)b			33.8±6.2 (10)a	41.6±23.2 (19)a	82.6±56.3 (22)a	94.0±62.0 (14)a	102.6±33.5 (26)b	45.6±14.3 (26)c	72.1±10.3 (11)ab	65.8±15.2 (17)a
MRC(GMU 15A)1975	67.4±15.4 (10)c	50.6±9.0 (12)a										
Benchland (GMU 15A & 15B)										120.5±45.1 (58-1972)b		
Fort Richardson (GMU 14C)	76.8±22.0 (44-1973)c	75.2±17.1 (50-1974)c										
Alaska Range (GMU 20A)										102.5±34.3 (21-1973)d		
Caribou Hills (GMU 15B)										122.6±39.3 (67-1973)d		
Southeast Alaska (GMU 5)									72.0±24.6 (13-1973)b			
Copper River Delta (GMU 6)			64.0±3.6 (50-1974)b					122.4±20.1 (12-1974)a	132.3±17.9 (27-1974)c			
Nome (GMU 22)	44.9±14.4 (26-1975)ab							114.3±58.9 (5-1974)a	72.1±47.7 (37-1974)b	56.5±42.5 (21-1974)c		
Glennallen (GMU 13)			68.4±9.4 (64-1975)b	72.6±8.0 (10-1975)b						93.9±25.7 (68-1974)ad	35.1±20.5 (20-1974)c	
Homer (GMU 15C)				67.0±10.8 (31-1975)b							38.6±26.4 (60-1974)c	
Fairbanks (GMU 20B)			62.1±8.2 (5-1975)b									
Elmendorf (GMU 14C)		77.6±12.6 (20-1975)c										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P > 0.10$) for within month comparisons.

Table 20. Moose hair mean monthly potassium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					257.5±71.0 (11)a	756.1±485.8 (19)a	1056.4±409.0 (19)a	916.8±498.4 (13)a	1579.1±947.2 (12)ac	1943.6±693.3 (10)a	1032.2±569.4 (16)ab	467.8±203.2 (17)a
MRC (GMU 15A) 1973	326.9±66.1 (21)a[3]	379.4±134.6 (23)a	429.4±124.0 (23)a	435.0±112.7 (29)a		1001.1±535.7 (22)a	964.8±511.4 (22)a	1669.9±611.8 (16)b	1653.1±343.4 (20)a	1125.2±144.7 (21)a	1479.6±579.9 (10)b	863.3±444.4 (15)a
MRC (GMU 15A) 1974	497.1±163.2 (17)b	473.0±90.2 (18)a			697.1±373.4 (10)b	898.1±407.2 (19)a	1215.1±532.5 (22)a	1161.0±593.0 (14)ab	1046.0±607.2 (26)bc	1800.2±1066.7 (26)a	950.9±233.6 (11)ab	537.7±148.7 (17)a
MRC (GMU 15A) 1975	502.6±126.6 (10)bc	454.6±124.4 (12)a										
Benchland (GMU 15A & 15B)										2090.4±781.5 (58-1972)a		
Fort Richardson (GMU 14C)	406.2±239.0 (44-1973)ab	445.9±144.9 (50-1974)a										
Alaska Range (GMU 20A)										854.9±324.0 (21-1973)b		
Caribou Hills (GMU 15B)										1972.1±443.2 (67-1973)a		
Southeast Alaska (GMU 5)									1367.1±953.9 (13-1973)ac			
Copper River Delta (GMU 6)			501.2±172.5 (50-1974)a					784.5±250.4 (12-1974)a	906.6±266.9 (27-1974)bc			
Nome (GMU 22)	653.8±144.5 (26-1975)c							1285.7±326.1 (5-1974)ab	1185.9±592.3 (37-1974)ac	1101.9±631.0 (21-1974)a		
Glennallen (GMU 13)			633.8±77.5 (64-1975)b	552.5±41.1 (10-1975)a						868.2±554.5 (68-1974)b	571.1±246.3 (20-1974)a	
Nozer (GMU 15C)				558.3±71.8 (31-1975)a							1034.8±602.9 (60-1974)b	
Fairbanks (GMU 20B)			743.6±107.7 (5-1975)b									
Elmendorf (GMU 14C)		471.8±90.0 (20-1975)a										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P > 0.10$) for within month comparisons.

Table 21. Moose hair mean monthly sodium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2]15A)1972					633.5±113.3 (11)a	460.4±141.7 (19)a	618.0±185.8 (19)a	448.2±148.2 (13)a	714.2±140.7 (12)a	1073.2±279.4 (10)ab	1191.6±292.7 (16)a	1277.1±285.0 (17)a
MRC (GMU 15A)1973	1174.9±384.3 (21)a[3]	870.0±185.3 (23)a	787.2±149.8 (23)a	644.7±146.0 (29)a		670.1±308.4 (22)a	791.9±161.4 (22)a	1037.2±170.9 (16)b	1025.4±230.7 (20)b	1125.2±144.7 (21)ab	1964.3±569.5 (10)b	1088.6±233.5 (15)a
MRC (GMU 15A)1974	1250.9±441.2 (17)a	914.8±391.8 (18)a			687.6±170.3 (10)a	771.6±250.0 (19)a	606.9±181.1 (22)a	556.8±183.8 (14)a	674.7±191.1 (26)a	1181.3±253.1 (26)ab	1250.1±176.4 (11)a	1206.1±189.8 (17)a
MRC (GMU 15A)1975	1131.7±322.3 (10)a	738.6±109.1 (12)a										
Benchland (GMU 15A & 15B)										1235.4±328.5 (58-1972)ab		
Fort Richardson (GMU 14C)	1189.5±503.1 (44-1973)a	1257.3±452.0 (50-1974)b										
Alaska Range (GMU 20A)										1374.6±381.4 (21-1973)a		
Caribou Hills (GMU 15B)										1258.1±296.9 (67-1973)ab		
Southeast Alaska (GMU 5)									1438.1±328.2 (13-1973)b			
Copper River Delta (GMU 6)			894.7±182.2 (50-1974)a					600.9±123.8 (12-1974)a	859.2±137.8 (27-1974)b			
Nome (GMU 22)	705.8±106.1 (26-1975)b							652.6±260.1 (5-1974)a	897.9±267.7 (37-1974)b	902.1±360.7 (21-1974)b		
Glennallen (GMU 13)			816.1±71.2 (64-1975)a	702.8±78.4 (10-1975)a						601.9±210.8 (68-1974)c	758.4±238.2 (20-1974)c	
Homer (GMU 15C)				703.1±100.3 (31-1975)a							935.3±331.3 (60-1974)c	
Fairbanks (GMU 20B)			489.8±137.7 (5-1975)b									
Elmendorf (GMU 14C)		939.1±221.5 (20-1975)a										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P \geq 0.10$) for within month comparisons.

Table 22. Moose hair mean monthly copper values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2]15A)1972					3.4±1.4 (11)a	3.4±1.3 (19)a	3.5±1.9 (19)a	4.8±1.8 (13)a	13.3±3.3 (12)a	14.0±2.8 (10) a	12.2±6.6 (16)a	1.5±1.0 (17) a
MRC(GMU 15A)1973	2.6±1.2 (21)a	4.8±3.6 (23)a	7.5±3.8 (23)a	7.8±4.0 (29)a		7.0±3.7 (22)b	8.0±3.2 (22)b	11.2±2.4 (16)b	12.3±3.7 (20)a	10.6±3.6 (21)bc	1.7±0.6 (10)c	1.5±0.4 (15) a
MRC(GMU 15A)1974	1.4±0.3 (17)a	1.3±0.3 (18)a			2.0±0.7 (10)b	2.1±0.7 (19)a	6.0±3.0 (22)c	5.2±2.9 (14)a	10.4±2.3 (26)a	8.7±1.3 (26)c	11.8±2.6 (11)ab	3.7±2.2 (17) b
MRC(GMU 15A)1975	2.4±0.9 (10)a	2.7±1.2 (12)a										
Benchland (GMU 15A & 15B)										14.7±5.0 (58-1972)a		
Fort Richardson (GMU 14C)	7.1±2.5 (44-1973)b	7.5±2.6 (50-1974)b										
Alaska Range (GMU 20A)										13.0±3.5 (21-1973)ab		
Caribou Hills (GMU 15B)										11.5±3.1 (67-1973)b		
Southeast Alaska (GMU 5)									10.2±1.9 (13-1973)a			
Copper River Delta (GMU 6)			10.0±2.8 (50-1974)b					17.7±3.8 (12-1974)c	24.2±4.2 (27-1974)b			
Nome (GMU 22)	9.2±1.6 (26-1975)c							14.5±10.1 (5-1974)bc	12.5±6.3 (37-1974)a	11.7±4.0 (21-1974)b		
Glennallen (GMU 13)			7.8±2.5 (64-1975)a	4.6±1.1 (10-1975)b						11.7±2.4 (68-1974)b	9.0±1.6 (20-1974)b	
Homer (GMU 15C)				7.0±2.1 (31-1975)a							9.2±1.6 (60-1974)b	
Fairbanks (GMU 20B)			6.0±1.4 (5-1975)a									
Elmendorf (GMU 14C)		8.5±2.1 (20-1975)b										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P > 0.10$) for within month comparisons.

Table 23. Moose hair mean monthly iron values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2]15A)1972					33.4±12.1 (11)a	52.9±19.4 (19)a	50.5±16.7 (19)a	35.2±9.9 (13)a	41.9±14.9 (12)ad	47.9±17.4 (10)a	42.1±12.3 (16)ac	51.9±18.8 (17)a
MRC (GMU 15A)1973	59.0±23.6 (21)a[3]	55.5±19.5 (23)a	64.1±18.2 (23)ab	67.7±20.7 (29)a		32.9±33.8 (22)a	55.4±75.4 (22)a	51.2±15.9 (16)bc	62.7±3.4 (20)bc	67.0±4.6 (21)b	31.4±8.4 (10)a	36.9±7.2 (15)a
MRC (GMU 15A)1974	48.8±21.1 (17)a	48.2±15.9 (18)a			65.8±16.4 (10)b	68.1±29.0 (19)a	39.3±9.0 (22)a	35.2±6.6 (14)ac	51.3±18.1 (26)bd	59.5±10.8 (26)a	48.9±8.6 (11)ac	52.0±10.0 (17)a
MRC (GMU 15A)1975	50.9±8.1 (10)a	52.2±7.7 (12)a										
Beachland (GMU 15A & 15B)										51.4±14.6 (58-1972)a		
Fort Richardson (GMU 14C)	55.8±14.4 (44-1973)a	53.1±16.8 (50-1974)a										
Alaska Range (GMU 20A)										68.0±7.0 (21-1973)b		
Caribou Hills (GMU 15B)										55.8±13.6 (67-1973)a		
Southeast Alaska (GMU 5)									69.2±34.7 (13-1973)c			
Copper River Delta (GMU 6)			28.4±9.8 (50-1974)d					48.9±13.6 (12-1974)abc	51.7±6.5 (27-1974)bd			
Nome (GMU 22)	44.4±9.8 (26-1975)a							51.9±14.4 (5-1974)c	49.4±12.4 (37-1974)ad	49.0±8.1 (21-1974)a		
Glennallen (GMU 13)			52.8±5.9 (64-1975)c	50.1±5.7 (10-1975)a						74.2±41.5 (68-1974)b	62.8±11.8 (20-1974)b	
Homer (GMU 15C)				51.2±12.9 (31-1975)a							50.1±9.4 (60-1974)c	
Fairbanks (GMU 20B)			63.6±10.7 (5-1975)ac									
Elmendorf (GMU 14C)		46.9±10.6 (20-1975)a										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P > 0.10$) for within month comparisons.

Table 24. Moose hair mean monthly manganese values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2]15A)1972					3.6±1.8 (11)a	0.8±1.4 (19)a	0.1±0.2 (19)a	0.2±0.4 (13)a	2.2±1.4 (12)a	5.1±3.0 (10)a	5.2±3.4 (16)a	6.5±4.8 (17)a
MRC (GMU 15A)1973	1.6±2.0 (21)a[3]	0.7±1.2 (23)a	1.8±1.2 (23)a	1.7±1.6 (29)a		0.1±0.4 (22)b	0.4±0.6 (22)a	1.3±0.4 (16)b	0.9±0.4 (20)a	3.9±3.6 (21)a	2.8±1.3 (10)b	2.8±1.1 (15)a
MRC (GMU 15A)1974	1.7±1.3 (17)a	2.3±1.3 (18)b			1.5±1.0 (10)b	2.4±0.8 (19)c	1.4±0.7 (22)a	1.2±0.6 (14)b	3.7±1.2 (26)b	1.6±0.6 (26)b	4.6±1.9 (11)ab	4.8±1.7 (17)a
MRC (GMU 15A)1975	2.2±1.2 (10)a	0.2±0.2 (12)a										
Bonchland (GMU 15A & 15B)										11.6±8.4 (58-1972)c		
Fort Richardson (GMU 14C)	1.6±2.1 (44-1973)a	1.2±1.5 (50-1974)ac										
Alaska Range (GMU 20A)										10.3±4.3 (21-1973)c		
Caribou Hills (GMU 15B)										11.0±8.6 (67-1973)c		
Southeast Alaska (GMU 5)									0.9±0.4 (13-1973)a			
Copper River Delta (GMU 6)			0.6±0.3 (50-1974)b					3.6±1.3 (12-1974)c	4.2±0.8 (27-1974)b			
Nome (GMU 22)	0.5±0.3 (26-1975)a							1.3±0.2 (5-1974)ab	1.2±0.9 (37-1974)a	1.2±0.8 (21-1974)b		
Glennallen (GMU 13)			2.0±0.8 (64-1975)a	1.2±0.3 (10-1975)a						2.7±1.1 (68-1974)b	0.9±0.7 (20-1974) c	
Homer (GMU 15C)				1.3±0.5 (31-1975)a							0.8±0.4 (60-1974) c	
Fairbanks (GMU 20B)			0.6±0.2 (5-1975)b									
Elmendorf (GMU 14C)		1.9±1.3 (20-1975)bc										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P > 0.10$) for within month comparisons.

Table 25. Moose hair mean monthly zinc values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2] 15A)1972					65.5±9.6 (11)a	49.6±8.7 (19)a	45.3±14.5 (19)a	54.9±13.5 (13)a	78.4±12.9 (12)a	86.3±32.4 (10)a	71.6±8.0 (16)a	63.1±4.9 (17)a
MRC(GMU 15A)1973	66.7±6.0 (21)ab	81.0±13.2 (23)a	74.3±24.1 (23)a	74.0±21.2 (29)a		82.8±21.5 (22)b	75.4±15.4 (22)b	67.1±7.1 (16)a	68.1±5.9 (20)a	63.0±6.4 (21)b	103.3±27.0 (10)b	102.6±16.9 (15)b
MRC(GMU 15A)1974	95.9±3.5 (17)c	96.3±11.3 (18)b			95.5±8.8 (10)b	79.8±20.3 (19)b	93.8±21.0 (22)c	94.6±19.3 (14)b	97.8±12.2 (26)b	92.7±6.6 (26)a	68.2±9.4 (11)a	57.1±7.7 (17)a
MRC(GMU 15A)1975	59.0±11.4 (10)ab	54.6±12.0 (12)ce										
Benchland (GMU 15A & 15B)										89.1±26.5 (58-1972)a		
Fort Richardson (GMU 14C),	65.2±9.2 (44-1973)ab	61.6±9.1 (50-1974)de										
Alaska Range (GMU 20A)										60.1±6.6 (21-1973)b		
Caribou Hills (GMU 15B)										69.5±14.2 (67-1973)b		
Southeast Alaska (GMU 5)									112.9±14.6 (13-1973)c			
Copper River Delta (GMU 6)			102.0±16.1 (50-1974)b					135.6±10.5 (12-1974)c	133.9±11.6 27-1974)d			
Nome (GMU 22)	71.7±11.4 (26-1965)b							99.8±6.0 (5-1974)b	106.7±16.0 37-1974)bc	104.9±24.6 (21-1974)a		
Glennallen (GMU 13)			109.7±19.0 (64-1975)b	57.7±10.0 (10-1975)b						105.5±13.5 (68-1974)a	95.2±15.2 (20-1974)b	
Homer (GMU 15C)				74.6±8.2 (31-1975)a							91.1±8.6 (60-1974)b	
Fairbanks (GMU 20B)			65.6±1.8 (5-1975)a									
Elmendorf (GMU 14C)		61.7±6.5 (20-1975)d										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different (P>0.10) for within month comparisons.

Table 26. Moose hair mean monthly cadmium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2] 15A)1972					0.28±0.23 (11)a	0.32±0.31 (19)a	0.26±0.20 (19)a	0.50±0.61 (13)a	1.35±1.30 (12)a	1.71±1.61 (10)abc	0.75±1.09 (16)a	0.34±0.31 (17)a
MRC (GMU 15A)1973	0.02±0.07 (21)a[3]	0.88±1.89 (23)a	0.18±0.26 (23)a	0.15±0.32 (29)a		0.35±1.42 (22)a	0.32±0.31 (22)a	0.88±0.35 (16)a	1.42±1.80 (20)a	1.38±0.46 (21)abc	0.39±0.26 (10)a	0.96±0.26 (15)b
MRC (GMU 15A)1974	0.59±0.23 (17)b	0.64±0.14 (18)a			0.65±0.22 (10)b	0.81±0.29 (19)a	2.27±0.64 (22)b	2.34±0.73 (14)b	2.30±0.81 (26)a	1.93±1.13 (26)b	0.82±0.28 (11)ac	0.23±0.30 (17)a
MRC (GMU 15A)1975	0.12±0.14 (10)ac	0.62±0.26 (12)a										
Benchland (GMU 15A & 15B)										1.50±1.46 (58-1972)abc		
Fort Richardson (GMU 14C)	0.47±0.34 (44-1973)bd	0.42±0.36 (50-1974)a										
Alaska Range (GMU 20A)										1.20±0.80 (21-1973)abc		
Caribou Hills (GMU 15B)										1.16±1.22 (67-1973)c		
Southeast Alaska (GMU 5)									0.52±0.21 (13-1973)b			
Copper River Delta (GMU 6)			0.48±0.20 (50-1974)b					1.73±0.63 (12-1974)b	4.17±1.81 (27-1974)c			
Nome (GMU 22)	0.32±0.29 (26-1975)cd							1.88±1.01 (5-1974)b	1.93±1.27 (37-1974)a	1.71±0.67 (21-1974)abc		
Glennallen (GMU 13)			0.58±0.23 (64-1975)c	0.79±0.31 (10-1975)a						1.93±0.82 (68-1974)b	2.14±0.86 (20-1974)b	
Homer (GMU 15C)				0.56±0.16 (31-1975)a							1.51±1.07 (60-1974)c	
Fairbanks (GMU 20B)			0.84±0.30 (5-1975)d									
Elmendorf (GMU 14C)		0.38±0.24 (20-1975)a										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P \geq 0.10$) for within month comparisons.

Table 27. Moose hair mean monthly lead values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2] 15A)1972					5.6±1.8 (11)a	5.1±2.5 (19)a	8.8±3.7 (19)a	7.2±3.2 (13)ad	9.1±3.9 (12)a	12.3±6.3 (10)a	13.8±9.9 (26)a	10.7±5.3 (17)a
MRC (GMU 15A)1973	4.0±2.7 (21)a[3]	5.5±2.5 (23)a	5.4±2.7 (23)a	5.6±3.3 (29)a		5.5±5.0 (22)a	12.2±7.2 (22)a	17.6±1.1 (16)b	15.7±7.7 (20)b	11.5±3.4 (21)a	0.4±0.9 (10)b	0.9±2.1 (15)b
MRC (GMU 15A)1974	0.0±0.0 (17)b	0.1±0.2 (18)b			1.4±0.5 (10)b	3.9±2.4 (19)a	4.0±1.7 (22)a	5.2±2.4 (14)a	4.1±1.4 (26)d	2.5±2.3 (26)b	10.4±3.3 (11)a	10.0±2.2 (17)a
MRC (GMU 15A)1975)	5.6±3.0 (10)a	5.7±2.0 (12)a										
Benchland (GMU 15A & 15B)										12.3±5.9 (58-1972)a		
Fort Richardson (GMU 14C)	5.1±7.1 (44-1973)a	5.2±3.8 (50-1974)a										
Alaska Range (GMU 20A)										14.8±5.8 (21-1973)c		
Caribou Hills (GMU 15B)										10.2±5.0 (67-1973)a		
Southeast Alaska (GMU 5)									3.7±2.1 (13-1973)d			
Copper River Delta (GMU 6)			4.3±3.3 (50-1974)a					12.8±5.4 (12-1974)bc	13.5±4.3 (27-1974)c			
Nome (GMU 22)	0.5±0.7 (26-1975)b							7.6±3.8 (5-1974)acd	2.6±2.7 (37-1974)d	1.5±6.4 (21-1974)b 4.1±2.7 (68-1974)b	1.3±1.3 (25-1974)b	
Glennallen (GMU 13)			7.4±2.1 (64-1975)b	1.1±0.6 (10-1975)b							1.7±1.3 (60-1974)b	
Homer (GMU 15C)				0.3±0.4 (31-1975)b								
Fairbanks (GMU 20B)			3.6±0.4 (5-1975)a									
Elmendorf (GMU 14C)		3.9±1.9 (20-1975)a										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. Any means followed by a common letter are not significantly different ($P \geq 0.10$) for within month comparisons.

There was considerable variation between samples as reflected by large standard deviations of overall element means. Sex was not a factor in this variability and the age variable was not tested. Nearly all samples were from adult moose and age among adults was not a major source of variation. Considerable variation was attributed to seasonal influence. This factor was anticipated prior to analyzing these data and for that reason regional sampling was compared on a monthly basis.

Between year, monthly hair element variability for an area was not anticipated, however, much of this variability occurred during periods of rapid uptake of elments. At peak and low seasonal periods for each element the between year variability was less. This variation likely reflected the dynamics of hair element uptake based upon differences in vegetative growth between years (Guha and Mitchell 1966). It also may reflect geochemical diversity in an area (Thornton and Alloway 1974). These factors must be considered when application of these data is made.

Regional variation was anticipated (Franzmann et al. 1975a) and these data substantiated that premise. Critical aspects of regional variation may be applied to identification of hair samples by region of origin. Screening regions for potential element deficiencies via hair element analysis is an additional application. Both applications require substantial regional and seasonal (monthly) moose hair element base line values. This study provides data toward that goal (Tables 18 through 27).

Presently, we must rely upon information from domestic animal research base line hair values to evaluate potential deficiency syndromes since feeding trial information on moose is not available. Normal and minimal values have been established for some elements for domestic cattle hair (Anke 1965, 1973; Anke and Jeroch 1966). Moose hair element levels below reported minimal values in domestic cattle do not necessarily imply deficiencies since moose do not experience optimum intake of most nutrients throughout the year. We may, however, suspect potential deficiency syndromes when moose hair element levels do not attain minimal domestic levels during seasonal peaks. We have utilized the year-round monthly MRC samplings to determine the periods of peak hair levels for each element.

Moose hair element values can be applied only as a screening procedure to suggest element deficiencies in an area. Further investigation of element tissue levels in moose and definition of deficiency signs in the animal must follow the screening by hair element analysis. This procedure was initiated following findings of low hair Cu values in some Kenai Peninsula moose. Further investigation of tissue Cu levels, metabolically associated elements and clinical findings identified Cu deficiency in some Kenai Peninsula moose (Flynn and Franzmann 1974b).

Franzmann et al. (1975d) reviewed major symptoms associated with essential mineral element deficiencies in domestic and laboratory animals

and outlined potential problems in moose management and land use planning that may relate to mineral deficiencies. They suggested that positive population reproductive response may depend upon availability of some essential trace elements.

Low limits of normal cattle hair element levels for Ca (300 ppm), Mg (100 ppm), K (350 ppm), Na (175 ppm), Fe (40 ppm) and Zn (75 ppm) have been established.[3] The level determined for Mn in cattle hair was 7 ppm[2] and for Cu 8.5 ppm[2]. With seasonal peaks established by MRC sampling, we found 5 of 8 essential moose hair element means attained the cattle hair minima levels for all regions sampled during peak months.

Magnesium mean from Southeast Alaska in 1973 was 72.0 ppm in September. This was the only Southeast Alaska sample and it is very likely that sampling during the months immediately preceding or following this sample may provide peak values that approach 100 ppm. This finding, however, should encourage additional research into moose Mg metabolism in that region.

Alaska Range and Caribou Hills October 1973 Zn means were 60.1 and 69.5, respectively. There were no samples available from these areas in months immediately preceding or following these samples, but these data should encourage additional sampling and investigations of moose Zn metabolism in these regions.

This screening of areas for detection of potential deficiency syndromes can only be considered an aid in identifying areas where mineral metabolism research should have highest priority. This screening procedure does not alleviate the possibility of deficiencies in an area where peak hair element levels attain those considered minimum for cattle. Moose hair Cu means at MRC were over these minima, yet Cu deficiency has been identified in Kenai Peninsula moose. Moose hair Cu level normal may range higher than cattle norms.

As previously mentioned cattle hair data were used as a comparative base because no comparative data existed from wild ruminants. Ecologists can become much more knowledgeable in animal biology if they avail themselves of the vast amount of information available about domestic animals. As we obtain more information about wild species, we can depend more upon basic data derived from them. Unfortunately, for many areas of wildlife research we must revert to domestic animal data for reference points.

The potential for use of identification of hair samples by regional source based on element analysis differences is confounded by demonstrated between year and seasonal variability of MRC samples. Comparisons must be made the same year and month. Results of these comparisons provided many significant differences between and among elements from various

regions of Alaska. More important, however, were the differences measured by factors of two or more represented by 35 element comparisons. The ranges of many of these comparisons did not overlap and differences were measured by factors up to 52.

Outlining these hair element differences between regions implies a potential for utilizing hair element analysis for identification purposes but does not define it. These data represent nine Alaska Game Management Units. With staggered seasons and special hunts the ability to identify hair on the basis of region of origin would enhance enforcement of harvest regulations. We believe this can be accomplished with additional base line data throughout the year from regions and Game Management Units of concern.

Additional information regarding hair element analysis results from this study is summarized in the following abstracts of published papers:

DETERMINATION OF PAST TRACE ELEMENT UPTAKE IN A WILD ANIMAL BY LONGITUDINAL ANALYSIS OF THE HAIR SHAFT. (Flynn et al. 1974).

The ability of hair to act as a recording filament of past metabolic changes in mineral elements has been inferred. Hair is illustrated by numerous isotope studies. But, whether the storage of stable elements in the keratin structure of the hair is sufficiently maintained so that the hair strand can reflect past nutritional states has not been proven. We examined the hair shafts of Alaskan moose as an animal model, monthly from June 1972 to April 1973 for the trace elements copper and lead. The environmental importance of one and the essentiality of the other were the reasons for their selection and determination by atomic absorption spectroscopy.

Hair from 275 moose was plucked from the mane of the animal so as to include the follicle. The growth rate of moose hair was tentatively set at 0.8-1.0 cm per month by serial samples from two tame moose at the Kenai Moose Research Center. The first 2.0 cm of hair was used in the monthly sample, reflecting the mineral uptake of the previous two months. The hair was washed, digested and analyzed for copper and lead. Monthly results were compared with data from sequentially analyzed hair shafts from April 1973 and November 1972. Two subsamples were separated from these two hair samples: one subsample was cut into three 2.0-cm pieces including the follicle, and the other subsample had the initial 1.0 cm of hair with follicle discarded and the remainder cut into three 2.0-cm pieces. This arrangement allowed the two subsamples of each sample to be compared with the previous six monthly results, with an overlap in the November data. The results from the sequential hair analyses were then statistically correlated with the monthly data using Pearson r coefficients of correlation and tested for significance.

Table 1. Trace element correlation coefficients of hair shaft analysis.

	Copper	Lead
Mean r for both sexes	+0.666	+0.904
Probability	p 0.005	p 0.001

The range in moose hair copper was < 0.05 to 16.9 µg/g and in moose hair lead was 1.1 to 16.4 µg/g. The wide variance in the levels is due, in part, to the seasonal variations in available trace elements in the browse material. The Pearson r coefficients are given in Table 1.

The significant correlations for the trace elements copper and lead give support to the concept that hair can act as a recording filament of trace element history. Kopito et al. (1967) suggested this idea in studies on hair-lead changes in relation to recent versus past lead ingestion. Several factors must be considered that may change with the element, namely their relative quantity, water solubility and keratin binding. The use of hair shaft analysis appears to have the capability of reflecting past absorption of copper and lead and perhaps other elements. This simple technique may be of use in monitoring environmental and pathological changes in animal populations due to prior insults.

MINERALS AND MOOSE (Franzmann et al. 1975d).

The essential macro- and micro-elements are reviewed and the potential influence deficiencies of these nutrients may have on moose is discussed. The complexity of mineral metabolism is recognized, but the advent of equipment for efficient analysis has opened an area of study needed to better understand mineral metabolism and utilization in wildlife populations. Land use planning and management, fire suppression and prescribed burning, forestry practices and vegetative rehabilitation and fertilization all may influence mineral availability and utilization. Our present state of knowledge does not specifically guide the manager, but awareness of the potential alteration of mineral availability, in general, may influence decisions regarding these practices. The need for additional mineral research to supplement our management decisions is stressed for all wildlife species. Criteria for determining essentiality of an element are included as are some symptoms and signs associated with deficiencies of the essential macro- and micro-elements.

LEVELS OF SOME MINERAL ELEMENTS IN ALASKAN MOOSE HAIR. (Franzmann et al. 1975a).

Hair samples from 317 Alaskan moose were analyzed for 10 elements by atomic absorption spectroscopy between May 1972 and May 1973. Results demonstrated seasonal variation associated with general moose condition. Peak levels occurred in the fall and the low levels occurred during late winter and early spring. Some element levels were below lower limits of "normal values" for domestic animals over extended periods of time. Moose from different geographical locations demonstrated significant differences with certain elements, which suggested geochemical or range differences. Significant differences in magnesium, copper and manganese, were noted between winter-killed calves and live moose from the same area.

SEQUENTIAL HAIR SHAFT ANALYSIS AS AN INDICATOR OF PRIOR MINERALIZATION IN THE ALASKAN MOOSE (Flynn et al. 1975a).

Longitudinal analysis of moose hair shafts for 10 mineral elements (cadmium calcium, copper, iron, lead, magnesium, manganese, potassium,

sodium and zinc) demonstrated the ability of hair mineral status to reflect prior mineralization. A significant mean correlation of monthly results with sequentially derived data was noted for all elements with the exception of zinc. Absorption of zinc onto the hair shaft may be involved in elevated zinc levels for the sectioned hair samples. Sex influences in hair mineralization were noted, so that in females seven elements had significant correlations between the two sampling techniques (Ca, Cd, Fe, K, Mg, Na, Pb), whereas in males six elements had significant correlations (Ca, Cu, K, Mg, Mn, Pb). Thus, the uptake and retention of many mineral elements in moose hair are consistent enough to allow sequential analysis to describe prior mineralization.

MANIFESTATION OF COPPER DEFICIENCY IN A NONRESTRICTED WILD ANIMAL-THE ALASKAN MOOSE (Flynn and Franzmann 1974b).

Copper deficiency was determined in a population of Alaskan moose by sequential hair analysis over a 12-month period. Three hundred and sixteen hair samples from moose on the Kenai Peninsula of Southcentral Alaska were analyzed for 10 mineral elements. Only during three months of late summer and early autumn were Cu levels determined to be within normal range when compared with domestic ruminant normal values. The seasonal elevation of hair Cu from animals on the Kenai Peninsula strongly relates to increased browse Cu values.

Manifestation of elemental deficiencies in a population of nonrestricted wild animals is difficult where predation is evident. Several examples of Cu deficiency interference with the keratinization process were observed and samples were obtained to positively relate the defects with Cu deficiency. Cadmium, copper, iron, molybdenum, sulfur and zinc were analyzed by atomic absorption and X-ray fluorescence in hair and hoof material from normal and abnormal animals. Copper deficiency is known to interfere with the establishment of a proper matrix in the formation of "hard" keratin. The structural weakness in the keratin arises from condensation reactions following the oxidative deamination of amino groups allowing the creation of the strengthening disulfide bonds. Copper and S levels were significantly decreased in the moose with abnormal keratinization of the hoof, whereas the limiting factors of Cu activity (Cd, Fe, Mo and Zn) were all in normal ranges. Normal levels of these four elements were also noted in the browse samples. Copper deficiency appears to be the only elemental defect in the faulty keratin synthesis of the moose hoof.

MOLYBDENUM-SULFUR INTERACTION IN THE UTILIZATION OF MARGINAL DIETARY COPPER IN ALASKAN MOOSE (Flynn et al. 1975b).

Manifestations of copper deficiency have been observed in a large subpopulation of Alaskan moose from one area on the Kenai Peninsula. Other subpopulations from six divergent areas of the state have not shown similar growth abnormalities or measured copper deficits. Further investigations into copper levels in eight species of browse materials demonstrated relatively low, yet normal, copper levels and substantially normal molybdenum and

sulfur values. The question was then raised that perhaps the interactive effects of normal molybdenum and sulfur were inducing the copper faults.

The determination of molybdenum-sulfur interactive influences on copper values were made utilizing hair mineral levels of moose from seven different sampling sites in Alaska. A comparison was made using a hair molybdenum X sulfur factor with hair copper levels. Hair Mo X S was significantly elevated in the hair samples derived from the affected area of the Kenai Peninsula, using a one-way analysis of variance ($P < 0.05$). A Spearman r rank correlation between the Mo X S factor and copper was also significant with an $r = -0.55$ ($N = 70$, $P < 0.01$). These data indicate that relatively normal molybdenum and sulfur in browse material and hair may be involved in manifestations of copper deficiency.

SEASONAL RHYTHM OF CADMIUM AND LEAD IN MOOSE (Flynn et al. 1975c).

Moose hair cadmium and lead levels indicate seasonal rhythms in the biological cycles of toxic elements. Different pathways in bioconcentration are noted between the two elements. The animal levels appear to relate to an enrichment of browse plants with the production of new growth for the element lead. Cadmium values in the moose, though, do not follow the same pattern. Plant levels remain low for cadmium and so do not directly relate to animal concentrations. The source and movement of cadmium and lead from soil and water through vegetation into the moose provide some basis for defining the site of bioconcentration of heavy metals in wild ruminant nutrition.

MOOSE MILK AND HAIR ELEMENT LEVELS AND RELATIONSHIPS (Franzmann et al. 1976).

Abstract of this paper appears in Milk section of this report.

INDICATIONS OF COPPER DEFICIENCY IN A SUBPOPULATION OF ALASKAN MOOSE (Flynn et al. 1976).

Three years of moose hair analyses indicated low copper status in a subpopulation of moose from the Kenai Peninsula of Southcentral Alaska. To confirm these findings and to determine if these animals had a copper deficiency, further studies were conducted that involved both animal and plant measurements. Ceruloplasmin and blood copper levels were markedly lower than domestic ruminant norms and demonstrated seasonal peaking. Browse plants were marginally sufficient in copper content with an overall mean of 5.72 ppm, which was reflected in low rumen liquor copper content. Clinical signs of copper deficit were noted in the Kenai Peninsula moose subpopulation: 1) a faulty hoof keratinization, and 2) a decrease in reproductive rates. Faulty keratinization was linked with copper deficits by both mineral element analyses and photoelectron spectroscopy. Decreased copper and sulfur hoof content and an abnormal ESCA spectra indicated incomplete sulfur cross-linking in the hoof keratin. The decreased reproductive rates (from pregnancy counts), may be correlated with poorer nutritive quality of browse in the region of this subpopulation of moose. All data supported the initial hair copper findings and indicated a copper deficit in the moose from the Kenai Peninsula linked to decreased browse copper content.

Excitability Stress, Heart and Respiratory Rates and Body Temperatures

Results of this aspect of our studies are partially covered in the Findings section relative to blood chemistry and hematology. Results relative to corticosteroid evaluation of excitability stress are summarized by the following abstract:

SERUM CORTICOID LEVELS RELATIVE TO HANDLING STRESS IN ALASKAN MOOSE (Franzmann et al. 1975c).

Blood serum 11-hydroxycorticosteroids were compared to visual evaluation of handling stress in moose at the MRC. Moose were evaluated for handling excitability before and during handling when trapped, and were graded on a scale from 1 (not excited) to 5 (highly excited). There were significant differences in corticosteroid levels ($a = 0.1$) between each class comparison, except between classes 4 and 5, suggesting that this analysis provided a means to classify and compare other blood chemistry values from similarly stressed moose. Other factors may influence the 11-hydroxycorticosteroid levels, but handling stress had an overwhelming influence. Other methods to evaluate handling stress, such as body temperature, should also be considered but when not feasible this method may be utilized.

Condition

Results of this aspect of our studies are covered in the Findings section relative to blood chemistry and hematology.

Marrow Fat

Results of this aspect of our studies are summarized by the following abstract:

ALASKAN MOOSE FEMUR MARROW FAT CONTENT IN RELATION TO MORTALITY FACTORS (Franzmann and Arneson 1976).

Femur marrow fat content from 181 moose was analyzed by the dry-weight method. Samples were classified as adults or calves, cause of death and month sampled. Marrow fat values from adults killed by wolves (*Canis lupus*) or by various accidental means (road-kill, shot and drug) did not differ significantly from each other, but both were significantly higher than other mortality classifications. Marrow fat values from wolf-killed calves were not significantly different from those of calves dying accidentally, however, they were significantly higher than those of suspected winter-killed calves. Only 3 of 97 marrow fat values from suspected winter-kills were above 10 percent. Wolves were not selective for moose with marrow fat values below 10 percent, but instead took both cows and calves with marrow fat means not significantly different from unnatural mortalities. The effect of severity of winter on fat values is discussed. Femur marrow fat values provide a method for comparing mortality factors and a means of identifying winter-killed or starved moose.

Morphometric Measurements and Body Weight

Data on this aspect of our studies are being assembled for publication. From this study and information obtained from studies by Robert A. Rausch we have weights of 539 moose, total length measurements of 1,475, hind foot measurements of 1,434, height at shoulder measurements of 666, heart girth measurements of 1,454, ear measurements of 1,267, tail measurements of 86, antler spread measurements of 176 and antler base measurements of 177.

Productivity

Annual progress reports have described histories of individual moose and listed moose mortalities at the MRC. Tables 28 and 29 update these accounts to June 30, 1976. The complexity of data in Table 30 which summarizes productivity and survival of moose calves at the MRC from 1968 to 1975 must be qualified in the following manner. For adult male and females: (1) the table includes only those individuals inside pens during breeding season (Sept-Oct) and following calving season, (2) the table excludes all individuals breaking into or introduced into pens after a breeding season, and females entering or introduced into pens before a breeding season but dying before or during the following calving season, and Raquel and (3) these data assume age of sexual maturity at 1+ years or second autumn after birth. For calves the table excludes calves born to females that were introduced into pens after the breeding season (assumed calves conceived outside pens) and that died during calving (almost always an introduced female). Calf:cow ratios (at birth and survival) were based on number of females present during breeding season prior to calving; therefore, we assumed no adult female mortality occurred after calving for that year's calves. Calf survival was based on the assumption that calves survived the summer if present at about 1 September, and calves survived winter if present around 1 April.

Several observations regarding MRC productivity were made based upon extrapolations from Table 29. Moose in Pen 4 were maintained at artifically high densities and mean summer calf survival (83.3 percent) was lower than other Pens (Pens 1 and 3 - 100 percent, Pen 2 - 92.9 percent). In general, these mean summer calf survival rates are relatively high when compared to other populations, but this reflects percentage of calves born. Calves:100 females born at the MRC were: Pen 1 - 55:100, Pen 2 - 54:100, Pen 3 - 33:100 and Pen 4 - 34:100. As of September 1 the calves:100 females remained nearly the same since very few calf mortalities occurred during summers.

Mean calf survival as of April 1 (Pen 1 - 26:100 females, Pen 2 - 10:100 females, Pen 3 - 12:100 females, and Pen 4 - 12:100 females) reflect the high winter calf mortalities of winters 1970-71, 1971-72, and 1973-74. Poor winter calf survival was experienced over the entire Kenai Peninsula during those winters.

Pregnancy rates during 1973, 1974 and 1975 were on the average lower (59.5 percent, n = 37) than reported from other Alaskan populations (86 to 100 percent) (Rausch and Bratlie 1965, Rausch 1971, Franzmann and Arneson 1974b, 1975). No twins were born to moose after 1970 but Raquel,

Table 28. Histories of individual moose in Kenai Moose Research Center enclosures, July 1, 1972 through June 30, 1973

Moose No.	Sex	Age (years)	PEN 1 Significant Observations			No. Times Observed	No. Times Captured
			Date	Event	Circumstances		
35	M	8	June 16, 1976	Last seen	Helicopter Survey	5	0
43	M	9	June 7, 1976	Last seen	Observed	8	0
58	M	6	June 11, 1976	Last seen	Helicopter Survey	6	0
R70-8	F	8	June 9, 1976	With calf, condition 6 replaced ear tags	Trapped	9	1
			June 11, 1976	Last seen, without calf	Helicopter Survey		
69	F	7	June 9, 1976	Without calf, condition 6, wt. 65016 replaced ear tags	Trapped	17	1
125	F	10	June 11, 1976	With calf	Helicopter Survey	5	0
U/C	?	1	June 11, 1976	1975 calf of R70-8 or 69	Helicopter Survey	1	0
U/C	?	1	June 11, 1976	1975 calf of R70-8 or 69	Helicopter Survey	1	0
1	F	12	June 16, 1976	With calf	Helicopter Survey	10	0
3	F	14	March 9, 1975	Last seen, not seen on			
			June 19, 1975 to June 16, 1976	4 consecutive helicopter surveys Assumed dead		0	0
670	F	6	June 1, 1976	Seen with calf, separated from calf by fence	Observed	11	0
			June 11, 1976	Last seen without calf	Helicopter Survey		
36	M	9	June 11, 1976	Last seen	Helicopter Survey	9	0

Table 28. (cont.) Histories of individual moose in Kenai Moose Research Center enclosures, July 1, 1972 through June 30, 1973

Moose No.	Sex	Age (years)	PEN 1 Significant Observations			No. Times Observed	No. Times Captured
			Date	Event	Circumstances		
73	M	7	June 16, 1976	Last seen	Helicopter Survey	11	0
79	F	8	March 5, 1976	Died after installing internal brotelemetry transmitter in conjunction with drug dosage	Trapped	21	1
120	F	5	June 11, 1976	With calf	Helicopter Survey	9	0
U/C	F	1	June 16, 1976	Last seen alone 1975 calf of #1 or #79	Helicopter Survey	1	0
Raquel	F	7	June 3, 1976	With 2 male calves, 2-3 days old	Observed	Tame	1
Rastus	M	1+	Feb. 24, 1976	Installed temp.transmitter	Trapped	Tame	1
			Feb. 26, 1976	Found dead	Observed		
Olive	F	1+	May 20, 1975	Calf of Raquel: 28 lb. (hours old)	Observed	Tame	1
			Feb. 25, 1976	Installed internal temperature transmitter	Trapped		
27	F	10	Jan. 14, 1976	Last seen	Helicopter Survey	7	0
2870	F	6	June 16, 1976	Last seen: no calf seen	Helicopter Survey	5	0

Table 28. (cont.) Histories of individual moose in Kenai Moose Research Center enclosures, July 1, 1972 through June 30, 1973

Moose No.	Sex	Age (years)	PEN 1 Significant Observations			No. Times Observed	No. Times Captur
			Date	Event	Circumstance		
39	F	11	June 19, 1975	Last seen	Observed	2	0
72	F	6	June 15,1976	Last seen, no calf seen	Helicopter Survey	10	0
75	F	7	Jan. 14, 1976	Last seen	Helicopter Survey	4	0
80	M	7	June 22, 1976	Last seen	Observed	5	0
U/C	F	?	June 16, 1976	With calf and U/C yearling	Helicopter Survey	3	0
U/C	?	1	June 16, 1976	With U/C adult female 1975 calf of #2870 or #72 or U/C ♀	Helicopter Survey	1	0
7	M	7	June 10, 1976	Wt. 720 lb. Antler 89cm retagged	Trapped	3	1
			June 11, 1976	Last observed	Helicopter Survey		
36	F	10	June 19, 1975	Found dead	Helicopter Survey	2	0
37	F	7	June 11, 1976	Last observed, no calf	Helicopter Survey	7	0
57	F	6	June 11, 1976	Last observed with calf	Helicopter Survey	5	
59	M	8	June 19, 1975	Last observed. Not seen on 3 subsequent helicopter surveys, possibly dead	Helicopter Survey	3	0
71	F	7	June 25, 1975	With calf	Observed		
			June 16, 1976	Last seen, no calf	Helicopter Survey	10	0

Table 28. (cont.) Histories of individual moose in Kenai Moose Research Center enclosures, July 1, 1972 through June 30, 1973

PEN 1

Moose No.	Sex	Age (years)	Significant Observations Date	Event	Circumstances	No. Times Observed	No. Times Captur
81	F	7	June 19, 1975	Seen with calf	Helicopter Survey	7	0
			June 11, 1975	Seen with yearling	Helicopter Survey		
			June 17, 1975	Seen with yearling	Observed		
84	F	8	June 3, 1975	Found dead	Observed	0	0
100	M	7	June 8, 1976	Antler: 57cm, retagged condition 5	Trapped	4	1
			June 16,1976	Last seen	Helicopter Survey		
102	F	5	June 24, 1975	Found dead	Observed	0	0
103	F	6	June 16, 1976	Last seen; no calf		5	0
105	F	10	June 8, 1976	No calf- retagged	Trapped	5	1
111	F	5	May 2, 1975	Last seen (Not seen on 4 successive surveys, assumed dead)	Helicopter Survey	1	0
115	F	12	June 23, 1975	Found dead	Observed	0	0
124	F	7	June 10, 1976	No calf, Wt. 600 lbs, condition 5, retagged	Trapped	5	
U/C	?	1	June 11, 1976	With female #81	Helicopter Survey	2	0
			June 23, 1976	With female #81	Observed		

Table 29. Mortalities within Kenai Moose Research Center enclosures May 1, 1975 through June 30, 1976

Pen No.	Moose No.	Sex	Age	Month	Year	Cause
2	3	F	14	Never	Found	Unknown
2	Rastus	M	1+	February	1976	Stress related to surgery and implantation of radio.
2	79	F	8	March	1976	Stress related to surgery and implantation of radio in conjunction with drug dosage
U/C	?	?	Calf of #1 #79	Never	Found	Assumed dead
3	U/C	?	Calf of #72	Never	Found	Assumed dead
3	U/C	?	Calf of #2870	Never	Found	Assumed dead
4	36	F	10	June	1975	Winter
4	84	F	8	June	1975	Winter
4	102	F	5	June	1975	Winter
4	111	F	5	Never	Found	Assumed dead
4	115	F	11	June	1975	Winter
4	U/C		Calf #71	Never	Found	Assumed dead
4	U/C		Calf #105	Never	Found	Assumed dead

Table 30. Productivity and survival of moose calves at the MRC.

PEN	YEAR	BREEDING SEASON Males in pen	Females in pen	Sex Ratio 88/100 ♀♀	Calves born	Calves/ 100 ♀♀	as of ± SEPT 1 Summer calves/100 ♀♀	Survival #	% born	as of ± APR 1 Winter calves/100 ♀♀	Survival #	% born	Preg. Rate #	% preg
1	1968	0	5	0:100	5	-	-	5	100%	-	3	60%	--	--
	1969	1	6	17:100	0	No male 0:100	--	--	--	--	--	--	--	--
	1970	2	6	33:100	4	67:100	67:100	4	100%	67:100	4	100%	--	--
	1971	2	7	29:100	5	83:100	83:100	5	100%	0:100	0	0%	--	--
	1972	3	7	43:100	1	14:100	14:100	1	100%	0:100	0	0%	--	--
	1973	3	3	100:100	4	57:100	57:100	4	100%	20:100[3]	1/2	50%[2]	4	100%
	1974	3	3	100:100	1	33:100	33:100	1	100%	0:100	0	0%	1	0%
	1975	3	3	100:100	2	67:100	67:100	2	100%	67:100	2	100%	--	--
	1976	3	3	100:100	2	67:100	-		-	-		-	--	--
	Average			N=8	N=8	N=7	N=6	N=7		N=6	N=7			
				65:100	3.0[1]	55:100[1]	54:100		100%	26:100		44.3%		
2	1968	0	10		0				--			--		
	1969	1	8	13:100	4	40:100	20:100	2	50%	20:100	2	50%	--	--
	1970	2	8	25:100	2	25:100	25:100	2	100%	25:100	2	100%	--	--
	1971	3	7	43:100	8	100:100	100:100	8	100%	0:100	0	0%	--	--
	1972	5	5	100:100	3	43:100	43:100	3	100%	0:100	0	0%	--	--
	1973	2	7	29:100	1	20:100	20:100	1	100%	0:100	0	0%	4	50%
	1974	2	4	50:100	4	57:100	57:100	4	100%	0:100	0	0%	--	--
	1975	2	3	67:100	2	50:100	50:100	2	100%	25:100	1	50%	2	100%
	1976	2	3	67:100	3	100:100	-		-	-		-	--	--
	Average			N=8	N=9	N=8	N=7	N=7		N=7	N=7			
				49:100	3.0	54:100	45:100		92.9%	10:100		28.6%		

Table 30. (cont.) Productivity and survival of moose calves at the MRC.

PEN	YEAR	BREEDING SEASON Males in pen	Females in pen	Sex Ratio 88/100 ♀♀	Calves born	Calves/ 100 ♂♂	as of ± SEPT 1 Summer calves/100 ♀♀	Survival #	% born	as of ± APR 1 Winter calves/100 ♀♀	Survival #	% born	Preg. Rate #	% preg
3	1969	1	6	17:100	3	-	-	3	100%	-	2	67%	--	--
	1970	1	5	20:100	2	33:100	33:100	2	100%	33:100	2	100%	--	--
	1971	1	6	17:100	3	60:100	60:100	3	100%	0:100	0	0%	--	--
	1972	1	6	17:100	0	0:100	0:100	--	--	0:100	--	--	--	--
	1973	1	6	17:100	2	33:100	33:100	2	100%	17:100	1	50%	4	75%
	1974	1	5	20:100	2	33:100	33:100	2	100%	0:100	0	0%	2	50%
	1975	1	4	25:100	2	40:100	40:100	2	100%	20:100	1	50%	--	--
	1976	1	-	-	-	-	-		-	-		-	--	--
	Average			N=7	N=7	N=6	N=6	N=6		N=6	N=6			
				19:100	2.0	33:100	33:100		100%	12:100		44.5%		
4	1969	1	9	11:100	7	?	?	7	100%	?	4	57%	--	--
	1970	1	8	13:100	5	56:100	56:100	5	100%	56:100	5	100%	--	--
	1971	3	6	50:100	6	75:100	75:100	6	100%	0:100	0	0%	--	--
	1972	2	9	22:100	0	0:100	0:100	--	--	0:100	--	--	--	--
	1973	3	10	30:100	2	22:100	22:100	2	100%	0:100	0	0%	10	50%
	1974	3	7	43:100	3	30:100	20:100	2	67%	0:100	0	0%	7	57%
	1975	3	7	43:100	3	43:100	16:100	1	33%	16:100	1	33%	3	67%
	1976	3	7	43:100	1	14:100	-		-	-		-		
	Average			N=8	N=8	N=7	N=6	N=6		N=6	N=6			
				32:100	3.4	34:100	32:100		83.3%	12:100		31.7%		

1 Excludes 1969 calving season because no females were bred previous breeding season (in 1968)
2 Excludes two calves which escaped from pen
3 Excludes two calves which escaped from pen and their mothers
4 Excludes 1968

our tame moose which receives supplemental feeding, twinned in 1975 and 1976. The pregnancy rate sample size from the MRC was small, but it represented a high proportion of the population, particularly during 1973.

High winter calf mortality, particularly during greater than average snow fall on the Kenai Peninsula, and reduced productivity at the MRC were udoubtedly influenced to some extent by enclosing the moose. Nevertheless, similar mortality and lowered productivity were noted for moose populations outside the enclosures (Franzmann and Arneson 1973, 1974b and 1975). The MRC provided a model to detect mortality and productivity problems associated with the Kenai Peninsula moose populations earlier, particularly those associated with the lowland 1947 burn habitat.

The decline of moose populations on the Kenai Peninsula since the early 1970's was primarily associated with a succession of severe winters. However, as with most ungulate population declines, other factors such as plant succession leading to decreased quality of forage, overuse and decline of primary browse species, predation, hunting and poaching additively combined as depressive forces on the population. LeResche et al. (1973) summarized some major factors contributing to establishing high moose densities on the northern Kenai Peninsula lowlands.

In addition to the observations of LeResche et al. (1973) the declining productivity of moose within the enclosures demonstrated not only the loss of calves during severe winters but lowered pregnancy and natality rates. Lowered availability of browse in sufficient variety and quality must be strongly considered as a causative factor since birch productivity remained greater than birch utilization even in high density pens (J. Oldemeyer, Pers. Comm.). Over time much of the nonbrowse forage was unavailable during critical winter months and willow was totally extirpated by moose use within the enclosures. Moose have responded by lowered productivity. In early succession on the Kenai lowlands we believe the abundance of willow played an important part in positive moose population response. Exclosures at the MRC contain a good proportion of willow but there is presently nearly none within the enclosures and very little in the northern Kenai lowlands.

Hair sampling of moose in the Kenai lowlands indicated low Cu, Mg, and Mn levels (Franzmann et al. 1975a) and further studies indicated that a Cu deficiency syndrome occurs in this subpopulation of moose (Flynn et al. 1976). These essential trace elements are associated with various reproductive processes and may be a part of the finite mechanism by which reproductive success was curtailed. Without diversity of forage plants for moose and with advanced birch succession, the nutritional quality of browse including major nutrients, essential macro-elements, and essential micro-elements has apparently declined to the point of affecting moose productivity.

This process has been accentuated within the MRC enclosures; however, signs in the adjacent outside population indicate a similar trend (lowered pregnancy rates, stage of birch succession, comparable blood profiles of MRC with outside MRC moose, and paucity of willow). Lowered moose numbers, utilization of the 1969 burn, and mechanical rehabilitation in the area will perhaps alleviate the extreme signs detected in the MRC population for the northern Kenai lowlands moose.

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