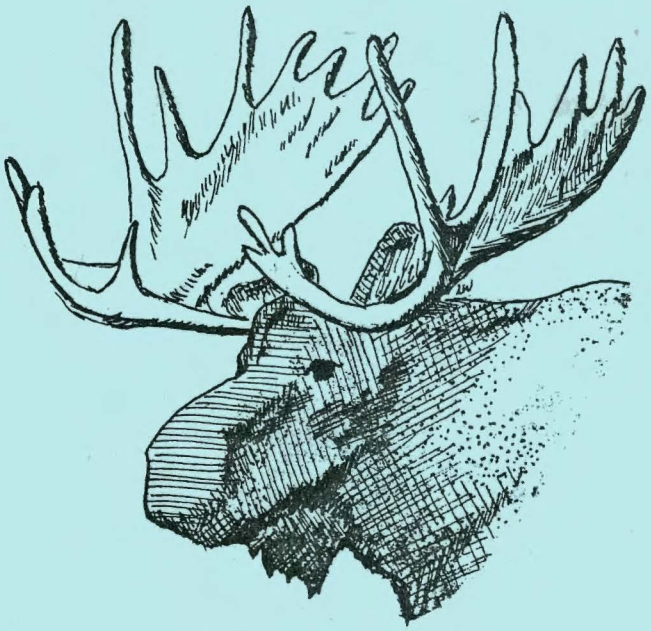
ALASKA DEPARTMENT OF FISH AND GAME
JUNEAU, ALASKA

MOOSE PRODUCTIVITY AND PHYSIOLOGY



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Final Report
Federal Aid in Wildlife Restoration
Projects W-17-9, W-17-10, W-17-11, W-21-1, and W-21-2
Job 1.21R

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FINAL REPORT (RESEARCH)

State: Alaska

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Project Nos.: W-17-9, W-17-10, W-17-11, W-21-1, W-21-2

Project Title: Big Game Investigations

Job No.: 1.21 R

Job Title: Moose Productivity and Physiology

Period Covered: July 1, 1976 through June 30, 1981

SUMMARY

A review of the literature on population assessment using physiologic parameters in ungulates provides the background for this report. This final report officially covers moose (Alces alces) productivity and physiology studies at the Moose Research Center (MRC) from July 1, 1976 to June 30, 1981, but physiologic data collected prior to that was combined with data from this period to produce the report and strengthen the sample size. Data were stored and retrieved via the standard SPSS program. Total moose sampled was 2,529. Blood was analyzed for up to 35 parameters, but emphasis was placed on blood parameters which reflected condition in moose: packed cell volume (PCV), hemoglobin (Hb), total serum protein (TSP), phosphorus (P), and calcium (Ca). Baseline values for each parameter analyzed were provided for calves, yearlings and 2-year-olds, and adults. Sex-influenced values were presented separately; all others were combined. Condition-related blood parameters for 18 different Alaskan moose populations were presented and were ranked based on these qualities. Blood values were particularly useful in identifying populations with the highest and lowest conditions. Ranking those not in the extreme was not valid because we were only comparing relative goodness in the populations. Morphometric data from these populations were also presented, and the applications of these data to population assessment were discussed. The status of hair element analysis was outlined. The hair element values that appeared to be related to condition classes of moose were discussed, and their application as supportive condition assessments outlined. Milk was analyzed from immediate postparturient cows. The data are useful for compounding milk substitutes for newborn calves. Milk data on a serial basis through lactation are lacking. An assessment of measurements taken from moose was made; those most useful for population assessment are total body length, chest girth, and head length. Other measurements may be dropped from routine procedure unless special needs exist. A new field collection and

data form for moose is proposed which incorporates findings of this report. The form has space to list the condition blood parameters, and we suggest that comparative population analysis of condition can be made using a calculator or minicomputer and alleviate the problems associated with central programming. A sort and listing is all that will be required, and comparisons can be made to data presented in this report. The value of long-term productivity studies of the MRC was illustrated by long-term trend data. The MRC populations have provided an insight to events occurring in moose populations on the Kenai Peninsula and have served as a model.

Long-term moose productivity studies must be supported with corresponding vegetative and habitat studies. The U.S. Fish and Wildlife Service cooperation and habitat studies should continue. Many findings from this study have been reported in the 21 publications produced since 1976, in 24 publications during the 1st phase of these studies (1969 to 1976), and in annual segment reports.

Key words: Alaska, moose, physiology, productivity.

CONTENTS

BACKGROUND

Methods to assess the status of wildlife populations have been primarily concerned with direct evaluation of the population's environment (habitat analysis and evaluation) and its vital statistics (sex and age ratios, natality, recruitment, mortality, and survival) (Schemnitz 1980). In the last decade, another method of assessment has evolved based upon the indicator animal concept in which the function or physiology of the animal is monitored to reflect the changes in its environment. Physiological monitoring is the last of the 3 major areas of adaptive response to be developed for wildlife population assessment. Morphological (form) and behavioral (activity) have been explored.

Direct measurements of habitat and vital statistics of a population will continue to be major methods of population assessment; nevertheless, methods that will refine our assessments need to be developed both within traditional and other procedures.

Slobodkin and Rapoport (1974) diagrammatically represented the adaptive events which follow a perturbation (disturbance) (Fig. 1). They demonstrated that the frequency, intensity, and periodicity of perturbations would dictate the animal and population response on a progressive continuum from a behavioral

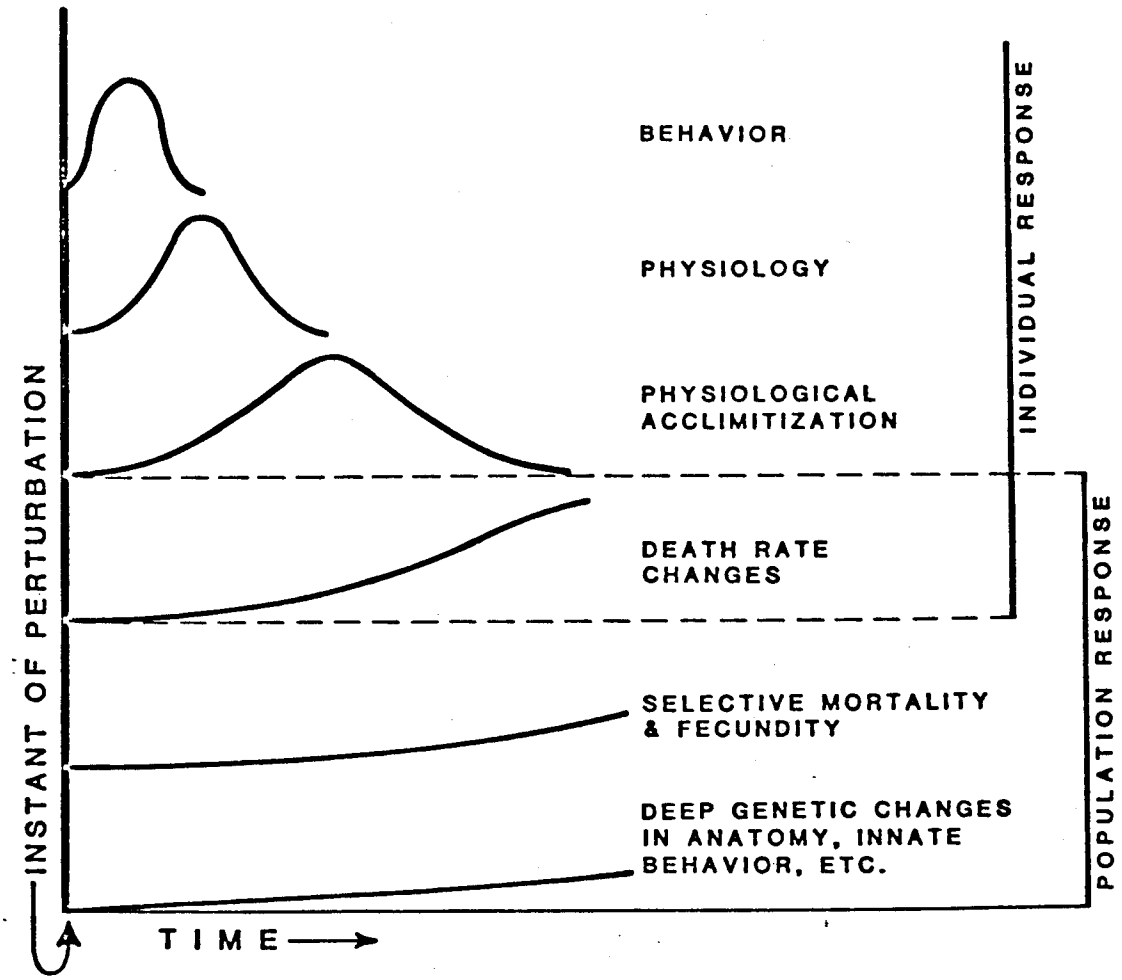


Fig. 1. A diagrammatic and simplified representation of the events that follow an environmental perturbation (from Slobodkin and Rapoport 1974).

adjustment to death. The progression would include short-term physiological adjustments, physiological acclimatization, death rate changes, selective mortality and fecundity, and finally deep genetic changes.

Seal (1977) indicated that inferences about the duration of perturbations in habitat condition can be made from changes in physiologic indicators that reflect different rates of response to environmental change. Seal (1977) stated these range from seconds (blood glucose, catecholamines, cortisol, and glucagon) to days (ketone bodies, nonesterified fatty acids, triiodothyronine, thyroxine, urea, blood amino acids) to weeks (serum proteins) to months (red blood cell size and hemoglobin). He concluded that by measurement of the appropriate substrates, metabolites, enzymes, hormones, blood chemistries, hematology, serum proteins, and their correlation with growth, reproduction, and survival, it is conceivably possible to assess the quantity and composition of the food supply available to an animal over time, the presence of disease, the impact of social factors, and the reproductive state.

The above conclusion infers a panacea for the wildlife manager and would indicate there should be a headlong rush into physiologic monitoring. The reasons we have not experienced this are several: (1) all procedures used have not been tested in species of concern; (2) basic physiologic norms have not been established for most species; (3) the physiologic tendency for homeostasis may mask some of the values; (4) controlled studies on captive animals are necessary to establish baseline values and how the species respond physiologically; (5) cost of developing base-line data may be great; (6) for some species, obtaining an adequate number of samples from a population may be impossible; and (7) the lack of trained persons to apply and interpret the system to wildlife populations.

Physiological monitoring to evaluate the health or condition of animals and populations is, nevertheless, a reality; increasing reports appear in the literature on new applications. An outline for field application of many of the methods to assess the health of a population are outlined in Appendix A.

Background information for this study necessitates an intensive review of blood studies on North American wild ruminants since this was our major physiological emphasis. The studies reviewed consisted of 2 general types: (1) blood studies from wild populations that evaluated blood changes to the environment and (2) blood studies which reported blood values and/or studied blood characteristics per se.

Blood studies of wild ruminants which included environmental assessment were chronologically as follows: Rosen and Bischoff (1952) were first to report on attempts to use blood analyses to evaluate condition. They sampled a black-tailed deer (Odocoileus hemionus columbianus) population that was near starvation and reported lowered red cell count, packed cell volume (PCV), and hemoglobin (Hb). Browman and Sears (1955) reported the possible

relationship between Hb and the physical condition of mule deer (Odocoileus hemionus) from Montana and between some blood cell values and the circumstances of death. They noted that blood values were similar to domestic livestock sampled under the same environmental conditions.

Kitts et al. (1956a) studied blood of Columbian black-tailed deer in relation to growth and caloric plane of nutrition. They reported differences of PCV and Hb between 2 age groups but no differences in sedimentation rate. High and low caloric intake were not reflected in PCV, Hb, or sedimentation rates. Bandy et al. (1957) using the same group of deer as Kitts et al. (1956a) found that the differences between high and low planes of nutrition influences only blood glucose and fibrinogen. No differences were noted for nonprotein nitrogen, total serum protein (TSP), albumin, and globulin.

Youatt et al. (1965) reported that blood composition of nursing white-tailed deer (Odocoileus virginianus) remains relatively stable during the 3-week postpartum period. They also reported major adjustments in serum protein components of fawns during this period. Albumin and beta-globulin increased steadily while alpha- and gamma-globulins decreased. Payne et al. (1967) suggested using electrophoresis as an aid in detecting pathological conditions in wild mammals. McEwan (1968) compared blood values between wild and captive barren-ground caribou (Rangifer tarandus) and noted higher (28%) blood urea nitrogen (BUN) levels in the captive caribou which were on a higher level of protein intake. Herin (1968) compared blood values from 39 Colorado elk (Cervis canadensis) to domestic animals and noted that clotting time was slower for elk, Hb was higher than the highest reported for domestics, blood glucose was much higher in elk which he attributed to stress of handling, and calcium (Ca), sodium (Na), PCV, and sedimentation rates were similar to domestic animals. Seal and Erickson (1969) sampled 146 white-tailed deer and reported sex and age differences for many blood values. They noted no protein changes characterizing pregnancy as reported for humans but reported protein polymorphisms. McEwan and Whitehead (1969) compared blood constituents of reindeer and caribou and noted that PCV, Hb, and red blood cells were lower in reindeer. Activity and excitement increased levels of PCV, Hb, and TSP, but these components decreased during estrus and progressively increased through pregnancy.

Anderson et al. (1970) sampled 177 mule deer and reported no hematological differences by sex. They reported no differences by year, age, sex, or season for PCV, Hb, and some white cell constituents (segmented and band neutrophils, lymphocytes, and basophils). Seasonal differences were detected in total leukocyte and monocyte counts which peaked during summer. Other potential influences such as circumstances of death, altitude, physical condition, reproduction, and weather were discussed as potential sources of variation. Murphy and Korschgen (1970) and Dommert et al. (1968) reported no effect on hematology and serum protein levels in white-tailed deer fed sublethal amounts of dieldrin at 9 months and 1 year after start of trial. Franzmann

and Thorne (1970) reported bighorn sheep (Ovis canadensis) blood values at capture, after handling, and after captivity and noted increased glucose and serum glutamic oxalacetic transaminase (SGOT) levels with stress and excitement. They reported an increase in BUN levels attributed to increased protein intake.

Franzmann (1971a) compared blood values from captive and wild bighorn sheep and concluded that the variables, wild and captive, in their total concept influenced physiologic values, not as entities in themselves, but as related to variables associated with them, such as stress from handling. Walton (1971) noted seasonal variation in PCV, Hb, and leukocyte components in white-tailed deer and suggested the leukocyte count was related to condition of deer. Yousef and Luick (1971) studied thyroxine secretion rate in reindeer and found no change related to season or sex but noted a marked decrease with age. Yousef et al. (1971) reported that adrenocortical activity in winter was increased over the summer in Alaskan reindeer. Franzmann (1971b) reported significant differences in bighorn sheep blood values between those on a diet of less than 5% protein and those with more than 15% protein. BUN on low-protein diets was 14.9 mg/dl and 36.9 mg/dl on high-protein diet. PCV was 43.4% and 49.2%, and Hb was 16.8 g/dl and 18.0 g/dl, respectively. The albumin/globulin ratio (A/G) was higher (1.37 vs. 0.95) on the poor than the good diet.

Franzmann (1972) concluded from analyses of blood from 220 bighorn sheep that glucose and rectal temperature reflected excitability, PCV reflected condition, and BUN reflected protein intake. Cholesterol was influenced by excitability, but not consistently. Other sources of variation were discussed. Follis (1972) reported differences between pregnant and nonpregnant elk of Hb, alkaline phosphotase (APT), BUN, and TSP. He also noted differences between captive and free-ranging elk for alkaline phosphotase, TSP, albumin, total lymphocytes, and glucose. Changes were noted over time (20 hours) for elk sampled every 4 hours for Ca, phosphorus (P), glucose, BUN, SGOT, and lactic dehydrogenase (LDH). Cholesterol, total bilirubin, APT, TSP, albumin, and uric acid showed no change over time. Seal et al. (1972a) reported hemodilution using phencyclidine (Sernylan, Bio-Ceutics Laboratories, Inc.) and promazine (Sparine, Wyeth Laboratories, Inc.) to immobilize white-tailed deer. They also noted physiological changes associated with capture stress without drugs. Their conclusion was that standardization of collection techniques was essential to make comparisons of blood parameters between animals and populations. Weber and Bliss (1972) compared wild and zoo resident Roosevelt elk (C. canadensis roosevelti) blood values and reported lower glucose and globulin levels in zoo animals, and higher albumin levels in zoo animals. Alkaline phosphotase was lower in older elk. Seal et al. (1972b) reported significant increases for Hb, PCV, erythrocyte count, cholesterol, TSP, albumin, P, and fibrinogen of pregnant white-tailed deer on a high plane of nutrition. They reported a decrease in serum thyroxine on deer on lower planes of nutrition, suggesting a state of hypothyroidism and decreased

metabolic rate that may allow further conservation of limited energy resources.

Presidente et al. (1973) physically restrained and immobilized white-tailed deer with etorphine (M99, Lemmon Co., Rockville, Md.) and xylazine (Rompun, Haver-Lockhart Co., Shawnee, Kans.); they noted approximately 39 min after injection significant decreases in erythrocyte count, PCV, and Hb levels. Blood gas analyses remained constant. Luick et al. (1973) studied seasonal variations in glucose metabolism in reindeer using radioisotope markers. Whitehead and McEwan (1973) studied seasonal variation of blood testosterone levels in reindeer and caribou and noted peaks associated with the rutting period in October. Woolf and Kradel (1973) monitored a disease syndrome in captive bighorn sheep, and as the disease progressed, noted leukocytosis, neutrophilia, lymphopenia, and eosinopenia. Anemia was progressive as characterized by decreasing PCV, Hb, mean cell volume (MCV), and mean cell hemoglobin (MCH). Serum albumin decreased and globulin increased, resulting in a progressively decreasing A/G ratio.

LeResche et al. (1974) reviewed the blood chemistry of moose (Alces alces) and other cervids with emphasis on nutritional assessment and concluded that blood analyses hold promise for evaluating the condition of wild cervids and the condition of their range. They indicated the potential for measuring ecological and behavioral relationships of individuals and populations by quantifying the metabolic status by continually improving technology.

Pedersen and Pedersen (1975) found no differences in sex and age for elk blood Ca, BUN, uric acid, cholesterol, TSP, bilirubin, and creatinine. Differences were noted between yearling and adult females for glucose and inorganic phosphorus and between yearling males and adult females for alkaline phosphotase. Coblentz (1975) reported seasonal changes in white-tailed deer blood cholesterol levels which he attributed to nutritional status.

Hartsook et al. (1975) sampled white-tailed deer during gestation and suckling for blood proteins and noted that TSP, albumin, and alpha-globulin tended to decrease during gestation, but beta-globulin increased. Gamma-globulin of does decreased significantly with gestation, but fetal TSP and albumin increased during gestation. Fawns not permitted to suckle had no blood gamma-globulin and those that suckled had high levels on day 1 which decreased exponentially to day 24. Bubenik et al. (1975) noted no seasonal influence on white-tailed deer blood cortisol levels, but noted a distinct annual rhythm for growth hormone (GH) with the peak in mid-April. Kirkpatrick et al. (1975) did controlled energy and protein intake studies on white-tailed deer and reported that BUN levels were significantly higher in fawns receiving high-protein diets. Conversely, fawns on high-energy diets had lower BUN levels. Skeen (1974) in related studies found that BUN levels in wild white-tailed deer correlated closely with crude protein content of both forages collected from the field gross rumen contents on a seasonal basis. Franzmann et

al. (1975b) reported on the positive relationship of handling stress and blood corticoid levels for Alaskan moose and with body (rectal) temperature.

Abler et al. (1976) related progestin levels to high and low levels of protein and energy and noted higher progestin levels were associated with high-energy diets, but no relationship was noted with high-protein diets. The conclusion was that deer on high-energy diets would experience higher incidence of ovulation and puberty. Franzmann et al. (1976) and Franzmann and LeResche (1978) reported results of blood studies from over 1,500 Alaskan moose using 22 blood chemistry and hematology parameters. Blood values were classified and sorted as to sex, age, month, and year sampled, age class, season-age class, reproductive status, rectal temperature class (excitability), location, and condition. Season was a source of variation at some point for every blood parameter; pregnancy was influenced by none. Sex was a source of variation only during the rutting period (October), and age influenced each blood parameter except P, glucose, alpha-globulin, and beta-globulin. P levels were significantly influenced by lactation. Rectal temperature (excitability) was a significant source of variations for glucose, LDH, albumin, and all globulin fractions. Locations influenced all values at some point except gamma-globulin. Condition improvement in adult moose significantly increased PCV, Hb, Ca, P, TSP, albumin, beta-globulin, and glucose values. However, excitability influenced albumin, beta-globulin, and glucose levels. It was therefore concluded that the most useful parameters to assess condition of moose were PCV, Hb, Ca, P, and TSP in that order. This study also demonstrated the value of population comparisons using the condition-rating parameters for adult moose in late winter or early spring.

Seal (1977) provided an assessment of the "state-of-the-art" in physiological monitoring of wildlife populations and concluded that physiological data should provide clues as to habitat differences not previously suspected and provide means for quantitative assessment of the nutritional status of the habitat with respect to the species using it.

Seal (1977) also described the need for controlled studies on animals to determine baseline data and determine the effects of measured change on the physiology of the animal. He noted that no single assay is adequate for assessment of condition. Franzmann and Bailey (1977a) reported serial samples from 11 moose over a 2 to 5-year period and noted seasonal change for individual animals generally reflected by lowered values of PCV, Hb, Ca, P, and TSP in late winter with higher levels in fall.

Seal et al. (1978b) compared 26 blood assays from 4 Minnesota white-tailed deer populations and reported the only sex differences were lower creatine phosphokinase (CPK) in males. Date of collection effects were reported for erythrocyte count, MCV, glucose, and nonesterified fatty acids (NEFA). Capture method affected glucose, acid base balance, and serum enzymes. Effects related to location on habitat differences were found for

erythrocyte count, MCV, mean corpuscular hemoglobin concentrations (MCHC), serum urea, cholesterol, LDH, thyroxine, and NEFA. They suggested that deer, whose assays indicated the poorest nutritional status, were from areas with older vegetation. Seal et al. (1978a) used 56 blood and plasma assays to test differences in feeding 2 levels each of protein and energy in white-tailed deer fawns for 10 weeks. The assays affected solely by protein content were Hb, MCHC, BUN, and ornithine. The assays affected solely by energy intake were: Ca, P, APT, SGPT, CPK, NEFA, cortisol, triidothyronine, insulin, isolencine, lencine, phenylalanine, histidine, theorine, and glycine. The assays affected by both protein and energy intakes were: erythrocytes, MCV, MCH, Na, Cl, and valine. Seal and Hoskinson (1978) reported on blood assays from 3 Idaho pronghorn antelope (Antilocapra americana) populations and noted capture effects in levels of serum enzymes and cortisol. Effects of nutrition were observed in assays of BUN, NEFA, triglycerides, and APT. Karns and Crichton (1978) reported on the effects of handling and physical restraints on blood parameters of woodland caribou (R. caribou) and noted significant changes in red blood cells, PCV, MCV, glucose, P, and Na with mean restraint times of 33 min. Keith et al. (1978) noted significant variation between a group of bison (Bison bison) fed high levels of nitrogen and one fed low levels in the following blood parameters: BUN, chloride, cholesterol, creatinine, eosinophils, glucose, Hb, LDH, leukocytes, PCV, K, globulin, SGOT, SGPT, and Na.

Bahnak et al. (1979) monitored 3 groups of white-tailed deer for 21 months by blood sampling at monthly intervals. One group was on a high-nutrition diet, 1 on a low-nutrition, and 1 group was semi-starved in winter and spring. BUN levels were the higher in the high-intake group, particularly during lactation. Amino acid nitrogen was greater in high-diet does, and TSP decreased in low-diet deer during lactation. When the winter-starved does were fasted, the BUN and ammino acid nitrogen levels became abnormally elevated signaling that protein catabolism was occurring. They noted that PCV exhibited a rhythmic pattern in both groups with peak values in winter and low values in summer. There was a significant difference between seasons. They also noted that the deer on a low-protein diet did not suffer the weight loss anticipated as noted for free-ranging deer in upper Michigan. Wesson et al. (1979a) studied the influence of chemical immobilization and physical restraint on white-tailed deer blood parameters and found PCV and TSP were highest with manually restrained deer. After chemical immobilization, PCV declined moderately. BUN was unaffected by these methods of restraint. Glucose levels were highest in deer using succinylcholine chloride (SCC) and were variable with other treatments. Wesson et al. (1979b) studied the influence of time of sampling after death on white-tailed deer blood values and reported that PCV and glucose values varied considerably on individual deer bled at collapse and 5 and 30 min after collapse. BUN, TSP, corticoids, progestins, and androgens did not vary appreciably. Wesson et al. (1979c) reported on steroid hormone levels in white-tailed deer blood as influenced by chemical immobilization and physical restraint. Barrett and Chalmers

(1979) sampled 253 free-ranging pronghorn fawns in Alberta and noted that significant variation of blood values were also correlated with physical and physiological characteristics and wind speed.

Franzmann et al. (1980) sampled neonatal moose calves and their mothers from 2 populations in Alaska and noted no differences among neonates. Neonatal cows were at a physiological low based on significant lower levels of PCV, Hb, and TSP than nonpostparturient cows. The cows were in poor condition based also upon physical characteristics. Moose neonate blood value aberrations closely resembled those reported for pronghorns (Barrett and Chalmers 1979). For calves, lower than expected levels were noted for PCV, Hb, TSP, and albumin. Mautz et al. (1980) studied short (10-60 min) and long-term (1-4 days) effects of chemically and physically restrained white-tailed deer with 11 blood parameters. The 3 drug treatments (Rompun, CI-744, M99) did not alter blood levels when samples were drawn immediately following immobilization, as compared with physical restraint. They concluded that any of the 4 treatments would result in comparable data. However, physical restraint does cause short-term effects as noted by others (Seal et al. 1972a). Long-term effects were limited to trends, showing increased levels of blood enzymes resulting from tissue damage. It was noted that Rompun use reflected less of a rise in blood enzymes than etorphine (M99, Lemmon Co., Sellersville, Pa.) or CI-744 (Parke-Davis Co., Detroit, Mich.). Gibson (1980) used Rompun to immobilize white-tailed deer and found no effects of the drug on Hb, PCV, or BUN in adult deer within 30 min after immobilization.

Warren et al. (1981) did a long-term controlled experiment testing the dietary and seasonal influences on nutritional indices of adult white-tailed deer. They concluded that their inability to detect significant nutritional influences on the physiological indices measured was likely prevented because of seasonal influences and sample variation. Nevertheless, important trends were noted such as significant seasonal variation of cholesterol regardless of feeding. Hb, PCV, and MCHC varied monthly, but MCHC was significantly lower in deer on restricted diet.

In addition to the studies outlined which related physiological blood values to the environment, many other studies were published which presented blood values per se. These data provided a beginning for some species and a stimulus to build upon. The studies by species were: white-tailed deer (Teeri et al. 1958; Wilber and Robinson 1958; Kitchen et al. 1964; Miller et al. 1965; Noyes et al. 1966; Johnson et al. 1968; Tumbleson et al. 1968a, 1968b, 1970; Anderson et al. 1972b, 1972b; White and Cook 1974; and Hoff and Trainer 1975); mule deer (Rowher and Lesperance 1970, Smith 1976); black-tailed deer (Cowan and Johnson 1962, Cowan and Bandy 1969); caribou and reindeer (Cameron and Luick 1972, Karns and Crighton 1976); elk (Knight 1969, Vaughn et al. 1973); moose (Houston 1969, Dieterich 1970); pronghorn antelope (Trout 1976); Rocky Mountain bighorn sheep (Woolf and Kradel 1970); Nelson desert bighorn sheep (Ovis

canadensis nelsoni) (McDonald et al. 1981); stone sheep (Ovis dalli stonei) (Franzmann 1971c); musk-ox (Ovibos moschatus) (Dietrich 1970); and bison (Marler 1975, Mehrer 1976).

These annotated and listed studies are not a complete background because we can gain much information from studies of domestic animals and from wild animals other than North American ungulates. The studies did provide us with a status of blood physiology work on wild North American ungulates, and several generalizations can be made regarding the "state-of-the-art." It is apparent that white-tailed deer studies dominate past efforts and will perhaps continue to do so. Controlled studies are lacking for all species except white-tailed deer. Controlled moose studies were not possible until a method was devised to maintain captive moose without maintaining them on browse, cut, hauled, and fed to them daily. A pelleted ration for maintaining moose free of browse was recently developed at the MRC (Schwartz et al. 1980).

Another observation from past studies is that there is an increasing tendency to quantify potential sources of variation. Many of the earlier studies and a few recent ones simply reported blood values obtained. As we begin to sort out the factors influencing blood parameters, the collections will become more meaningful.

Most past studies are difficult to compare with one another due to the variety of circumstances and the types of analyses done. Many studies concluded that standardization of technique was essential throughout the procedure from capture to data processing. This does not mean we cannot utilize the information, but we must adapt it to our circumstances. A great part of the diversity in reports is a result of differences in study design and objectives.

Baseline blood physiological data for most species are still lacking in spite of past efforts. The initial requirement for applying a physiological monitoring system to wildlife populations is to obtain baseline data from populations which can be quantified. This study began with that objective, and baseline data was obtained from the enclosed moose populations at the MRC (Figs. 2, 3, 4). We reported our findings on MRC productivity physiology studies in 1976 (Franzmann et al. 1976). The study was renewed to refine the data with additional sample size and to assess the applications in other populations in Alaska. This report covers those studies. Progress reports have been prepared on ongoing studies (Franzmann and Bailey 1977b; Franzmann and Schwartz 1978; Franzmann and Schwartz 1979a; Schwartz and Franzmann 1981; and Schwartz et al. 1981).

In addition to progress reports, some of the information from these studies has been published. Reports that were published prior to the 1976 Moose Productivity and Physiology Final Report are listed in that report. Twenty-one publications from these studies were produced since 1976 (Flynn et al. 1977; Franzmann and Flynn 1977b; Franzmann 1977a, 1977b; Franzmann and Bailey

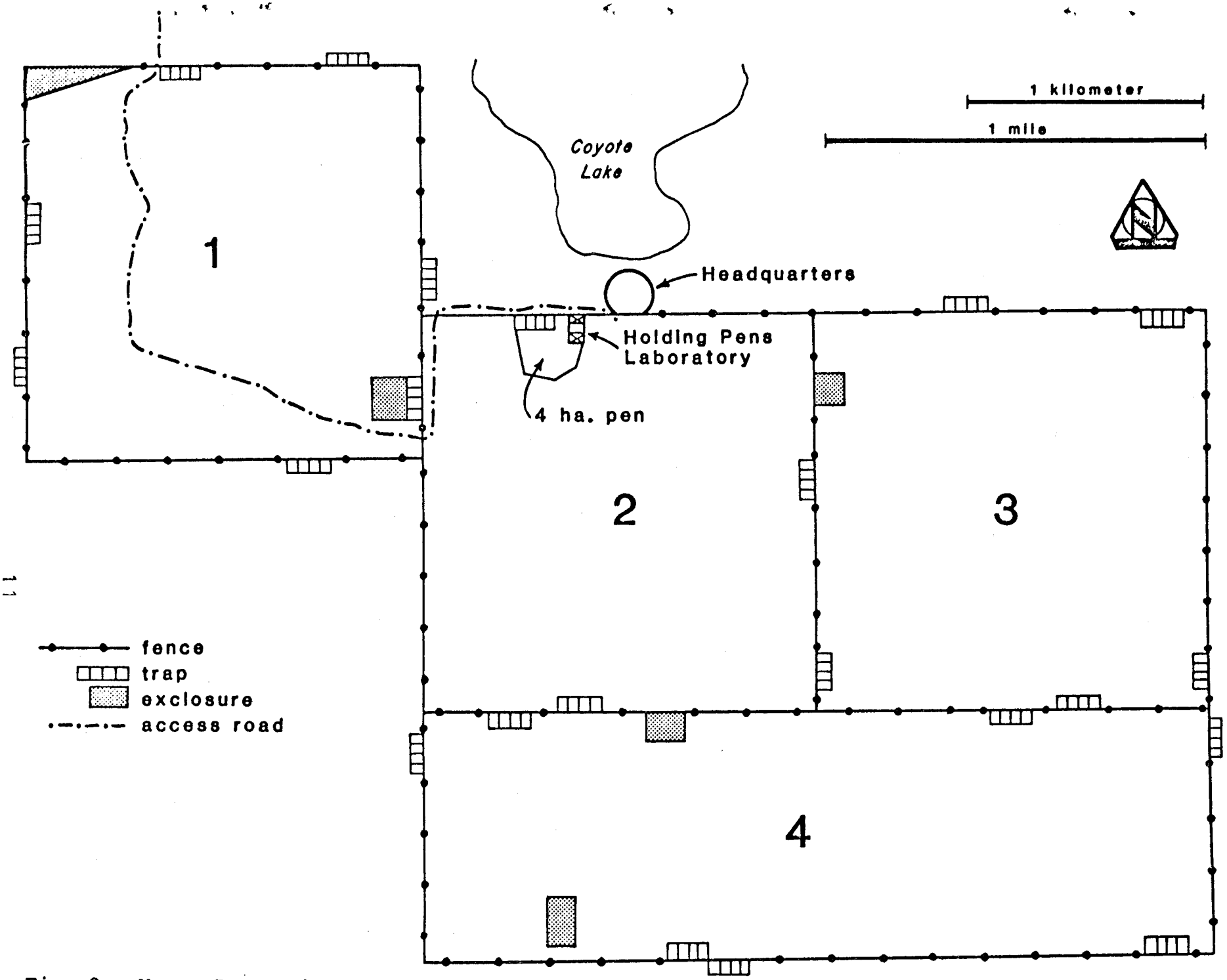


Fig. 2. Moose Research Center enclosures.

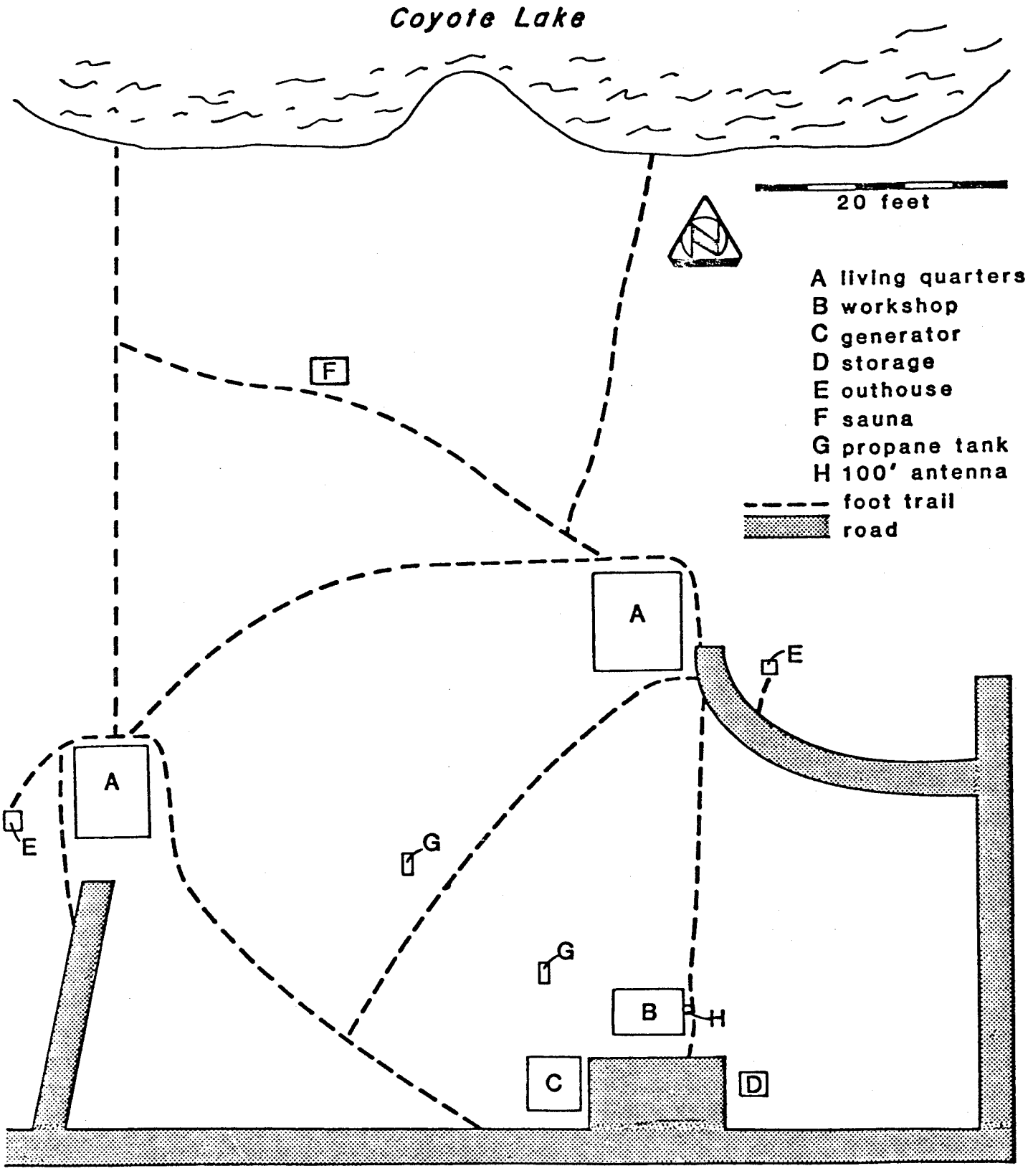
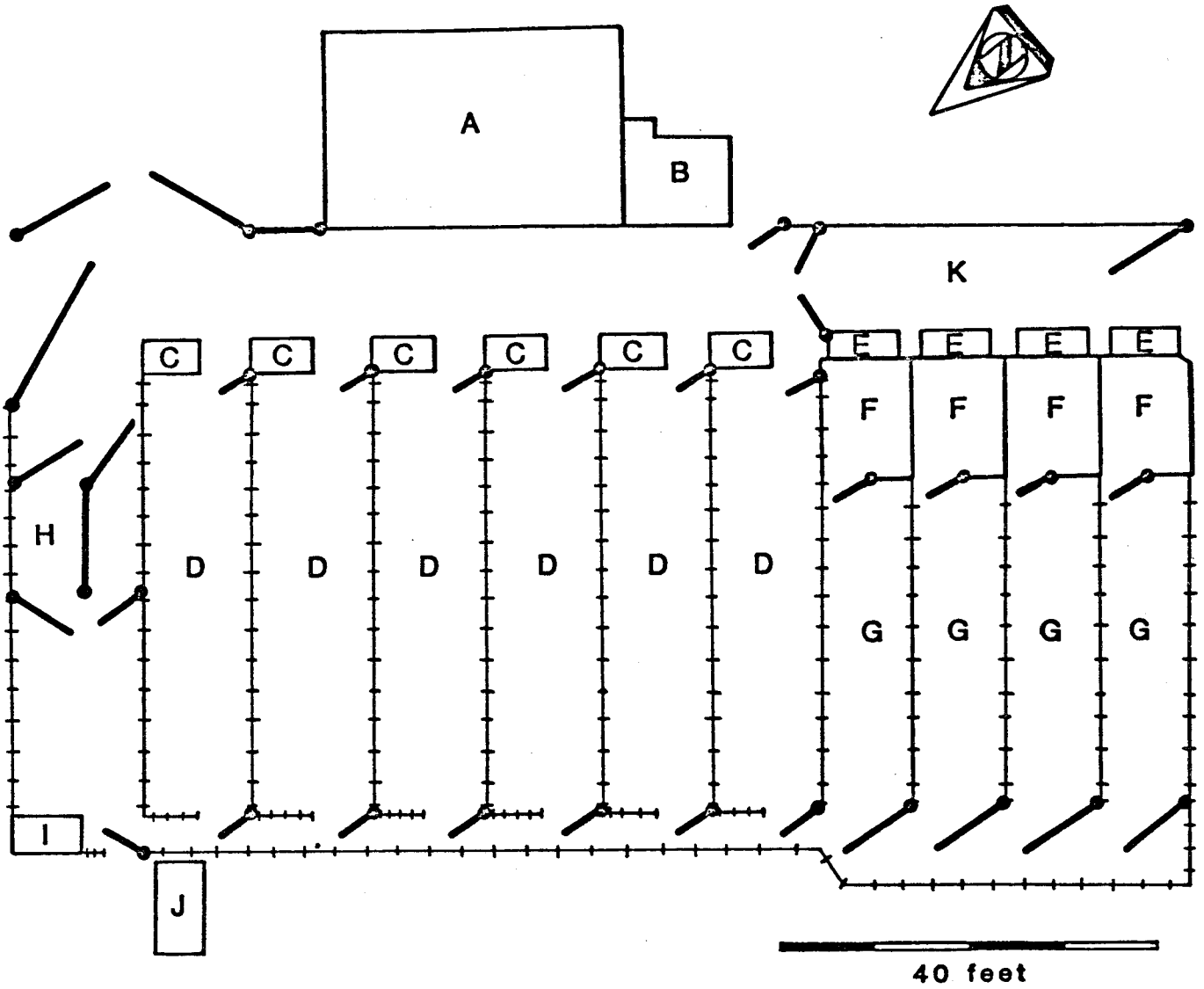


Fig. 3. Moose Research Center headquarters area.



A lab & feed storage
B respiratory chamber
C feed box (3' x 4')
D holding pen (10' x 50')
E feed box
F digestion cage
G holding pen (10' x 40')
H scale
I water tank
J self feeder
K covered work area

gate
fence

Fig. 4. Moose Research Center tame moose experimental area.

1977a; Flynn and Franzmann 1977; Franzmann and Flynn 1977a, 1977b; Franzmann et al. 1977; Oldemeyer et al. 1977; Franzmann and LeResche 1978; Franzmann 1978a, 1978b; Faro and Franzmann 1978; Franzmann 1980; Smith and Franzmann 1980; Doerr et al. 1980; Flynn et al. 1980; Franzmann 1981; and Franzmann et al. 1981).

Objectives of the moose productivity and physiology study included vegetation and browse studies which were accomplished via a cooperative agreement with the U.S. Fish and Wildlife Service. Drs. John Oldemeyer and Wayne Regelin were the cooperators who performed these studies at the MRC through their assignment from the Denver Wildlife Research Center. Most of their findings have been published (Oldemeyer et al. 1977; Oldemeyer and Regelin 1980a, 1980b, Oldemeyer 1981).

Moose productivity and physiology studies at the MRC since 1968 have provided material and data for 10 Pittman-Robertson (P-R) Progress Reports, 8 Denver Wildlife Research Center Reports, 2 P-R Final Reports, and 48 publications.

This report assesses the findings, many of which have been reported, and includes findings since 1976 which have not been reported. The continuing nature of these studies necessitates including information gathered since the initiation of moose productivity and physiology studies in 1968.

Background information was collected and reported for other aspects of this study, including: milk, hair, physiology, body condition, marrow fat, morphology, and productivity (Franzmann et al. 1976).

OBJECTIVES

To establish baselines 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 condition status of moose.

To apply the above criteria to various moose populations over the State.

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

To determine nutritional values and digestibilities of the more common moose forage species and to relate hair element monitoring to moose mineral metabolism.

To measure natality, mortality, and general condition of moose at the MRC.

The overall objective is to obtain a 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 physiology was an integral part of this objective.

PROCEDURES

Blood Chemistry and Hematology

Specific procedures for collecting, handling, and analyzing blood were outlined in another report (Franzmann et al. 1976). During this report period, blood data were reprogrammed to accommodate the SPSS (Statistical Package for the Social Sciences) program (Nie et al. 1975). A revised Game Biological Input Form was used to record data for keypunching (Fig. 5). The form revisions were made to accommodate most Alaskan game species and to correct or modify the original Game Biological Input Form (Franzmann et al. 1976). A key for numerical entry onto the form was developed (Fig. 6).

During this report period, samples were collected from moose at the MRC and from moose populations in the upper Susitna, Alaska Peninsula, Moose River Flats and Willow Lake (Kenai Peninsula), Yakutat, Thomas Bay (Petersburg), and Tanana Flats. Data from populations sampled prior to 1976 (Franzmann et al. 1976) were combined with the above data into the SPSS file.

Hair

Specific procedures for collecting, handling, and analyzing moose hair samples have been previously reported (Franzmann et al. 1975c, Franzmann et al. 1976). During this report period, samples were obtained from moose at the MRC and from moose populations in the upper Susitna, Alaska Peninsula, Moose River Flats and Willow Lake (Kenai Peninsula), Yakutat, Thomas Bay (Petersburg), Tanana Flats, from 3 areas in Sweden, and the 1969 Kenai burn and Slikok Lake areas.

Hair element data were processed with the SPSS program after combining with data obtained prior to 1976. All samples were analyzed at the Cleveland Clinic Foundation, Cleveland, Ohio.

Milk

Procedures for collecting, handling, and analyzing moose milk samples were reported (Franzmann et al. 1976). Samples for this report were collected from moose maintained at the MRC, from moose sampled in conjunction with the Kenai Peninsula Moose Calf Mortality Study (Franzmann and Schwartz 1979b), and from moose collected at least 96 hours after parturition. However, samples from the Kenai Peninsula Moose Calf Mortality Study were collected within 96 hours of parturition, most within 24 hours. These samples were analyzed by the Animal Husbandry Nutrition Laboratory, Michigan State University.

STATE OF ALASKA DEPARTMENT OF FISH AND GAME - GAME BIOLOGICAL INPUT FORM

SYSTEM NUMBER	SPECIE	IDENTIFICATION	DATE			UPDATE CODE
			MONTH	DAY	YEAR	1 - DELETE 2 - ADD 3 - REVISE
1 1 A						
01	04	06	11	13	15	17

CARD	SEX	DRUG	DOSE	DOWN TIME	LOCATION	REAR	AGE (MONTHS)	TOTAL LENGTH (CM)	HIND FOOT (CM)	SHOULDER HEIGHT (CM)	CHEST GIRTH (CM)	EAR (CM)	TAIL (CM)	NECK (CM)	WEIGHT BODY (KG)	WEIGHT CARCASS (KG)	WEIGHT HIDE (KG)
1																	
	18	19	20	21	22	24	28	29	32	35	38	41	44	46	48	50	54	58	60

CARD	GLUC.	CHOL.	TRI GLYCER	LDH	SGOT	SGPT	ALK. PHOS.	PHOS.	CA	IRON	CA/P RATIO	C/BUN RATIO	NA	K
2														
	18	19	22	25	28	31	34	37	40	43	46	49	52	55	58	59

CARD	CHLO-RIDE	CO2	BUN	CREAT	BILI	TP SMAC	ALB. SMAC	VRIC ACID	GLOB SMAC	BAL-ANCE	TP (ELEC)	ALB. (ELEC)	GLOB (ELEC)	ALPH 1	ALPH 2	BETA	GAMMA	A/G RATIO
3																		
	18	19	22	24	26	28	30	32	34	36	38	40	43	46	49	51	53	55	57	59

CARD	WBC	NEUT ROPH	LYMP HOCY	DIFF	HB (GM)	PCV	MCV %	MCHC %	MARROW % FAT	EXCIT	COND	HEART RATE	RESP. RATE	RECT TEMP	CLASS	AMB. TEMP	CLASS	AGE CL	SEASON AGE CLASS	PARA
4																				
	18	19	21	23	25	26	29	31	34	37	40	41	43	46	49	52	53	56	57	58	60

CARD	CA	MG	K	NA	ZN	CU	CD	CO	FE	PB	MN	CR	HG	MO
5														
	18	19	23	26	30	34	38	41	43	45	49	52	54	56	59	60

CARD	SE	AL	NI	AS	CESSIUM	RUMP FAT	FLANK FAT	BACK FAT	STERN FAT	LOIN SCAN.	RUMP SCAN.	ANTLER SPREAD	ANTLER BASE	BOONE CROCKET SCORE
6														
	18	19	21	23	25	28	32	34	36	38	40	44	48	51	54	57

CARD	SKULL LENGTH (CM)	SKULL WIDTH (CM)	V.L.C LGTH (CM)	L.L.C LGTH (CM)	TEAT WDTH (CM)	AGE WEAR MO.	COLOR NUMBER (PACK)	WRIST TO NAIL	WRIST TO PAD	SHOULDER TO NAIL	SHOULDER TO PAD	HOCK TO NAIL	HOCK TO PAD	PAD WIDTH	FOOT WIDTH
7															
	18	19	22	25	27	29	31	34	39	42	45	48	51	54	57	59	60

Fig. 5. Game Biological Input Form.

KEY TO GAME BIOLOGICAL INPUT FORM

CARD 1	1	2	3	4	5	6	7	8	9
SPECIES	moose	sheep	caribou	br.bear	wolf	bl.bear	goat	coyote	
IDENTIFICATION	number as assigned up to 5 digits								
DATE	date of sample								
SEX	female	male							unknown
DRUG	m-99	anect.	serny.	1+wyd.	2+wyd.	3+wyd.	violent	winter	unknown
DOSE (moose)	1cc or less	2cc	3cc	4cc	5cc	6cc	7cc	8cc or more	unknown
(wolf)									
(bear)	heli-copter	trap	snare	den					unknown
DOWN TIME (min.)	minutes from injection to immobilization								
LOCATION (4 digits) 1	trap	GMU	outside Alaska						
2, 3	trap#, pen#, or GMU#								
4	A	B	C or third digit of trap#						
REPRO STAT (moose)	preg.	not preg.	C/1calf	C/2calves	lact.	rut	oestrus	C/0calf	unknown
(bear)	breed. M or F	non-br. M or F	F/1cub	F/2cubs	F/3cubs	F/1 yrl	F/2yrl	F/ 3yrl	unknown
AGE (months)	moose birthdate= 23 May, wolf birthdate= 15 May, bear birthdate= 15 Feb								
MEASUREMENTS (cm)									
WEIGHTS (kg)									
CARD 2	blood values								
CARD 3	blood values (cont.)								

Fig. 6. Key to Game Biological Input Form.

KEY TO GAME BIOLOGICAL INPUT FORM (continued)

CARD 4 — 1 2 3 4 5 6 7 8 9

EXCITABILITY — Values from 1 through 5 as per Franzmann et al. 1976

CONDITION — Values from 1 through 10 as per Franzmann et al. 1976

HEART RATE — beats/minute

RESP. RATE — respirations/minute

RECTAL TEMP. — degrees Centigrade

CLASS (52) — rectal temperature class

AMBIANT TEMP. — degrees centigrade

CLASS (56) — ambiant temperature class except wolves (color class-- 1=gray, 2=black, 3=white)

AGE CLASS (57)

	0-12mo	13-24mo	25-36mo	37-96mo	97-144	145+ mo	unk.
(moose)							
(bear)	cub	yrl	2 yr	3yr+			

SEASON-AGE CLASS (58- 59)

(moose)

	1-12 mo	13-24 mo	25-36 mo	37-144	144+
Jun Jul Aug Sep Oct	1	4	7	10	13
Nov Dec Jan	2	5	8	11	14
Feb Mar Apr May	3	6	9	12	15

(bear)

	1-12 mo	13-24 mo	25-36 mo	37+
May	1	5	9	13
Jun Jul	2	6	10	14
Aug Sep Oct	3	7	11	15
Nov through Apr	4	8	12	16

Fig. 6. Continued.

KEY TO GAME BIOLOGICAL INPUT FORM (continued)

CARD 4 (cont.)

SEASON-AGE CLASS (58-59) (wolf)

	1-12 mo	13-24mo	25-36mo	37-48mo	49-60mo	61-72mo	73-84mo
Jun Jul Aug Sep	1	4	7	10	13	16	19
Oct Nov Dec Jan.	2	5	8	11	14	17	20
Feb Mar Apr May	3	6	9	12	15	18	21

PARA — coded for each species as needed for papasite identification

CARD 5 — hair element values

CARD 6 — hair element values (cont.)

fat measurements in cm

LOIN SCAN (bear) — first 2 digits = Upper Ant./Post. Canine (mm)
second 2 digits= Upper Labial/Lingual Canine (mm)

RUMP SCAN (bear) — First 2 digits -= Lower Ant./Post. Canine (mm)
second 2 digits = Lower Labial/Lingual Canine (mm)

ANTLER SPREAD & BASE — cm measyrements

BOONE CROCKET SCORE — points as outlined by Boone and Crocket Club

CARD 7 — Card primarily for wolf and bear All measurements in cm

COLOR NUMBER (PACK) — Kenai Peninsula Pack Code

Skilak - 01000
Big Indian - 02000
Bear Lake - 03000
Swanson R. - 04000
Killey R. - 05000
Mystery Cr.- 06000
Lone - 07000

Fig. 6. Continued.

Condition (Health) Evaluation

Appendix A (Health [condition] evaluation of wild animal populations: the indicator animal concept) which was prepared for the Workshop on Techniques in Wildlife Research and Management at Kanha Park, India, outlines the procedures used for condition evaluation of wildlife populations. The information for the paper was primarily generated from this study.

Morphometric Measurements and Body Weight

Specific procedures for obtaining measurement and weight information from moose have been outlined (Franzmann et al. 1978). Measurements and, when possible, weights were obtained from all moose handled. Morphometric data were processed with the SPSS program after combining with data obtained prior to 1976. Morphometric data prior to 1976 were analyzed using t-test, regression analysis, and analysis of various programs by Computer Services Division of the Alaska Department of Administration (Franzmann et al. 1978) and since 1976 using the SPSS (Nie et al. 1975).

Productivity of MRC Moose

Mortality and natality within the MRC enclosures were assessed by ground observations, periodical aerial observations, trapping (LeResche and Lynch 1973) and radiotelementry.

Moose within the MRC enclosures were moved from one enclosure to another or transferred outside the enclosures to ultimately obtain approximately the following numbers and distribution: 3 bulls and 3 cows in Pen 1; 1 bull and 2 cows in addition to tame moose being raised at MRC (Regelin et al. 1979) in Pen 2; 8 cows and no bulls (1978) until late in rut when 1 bull was introduced (1979) in Pen 3; no moose in Pen 4 (study effects on vegetation with removal of moose from the pen which has been overstocked for nearly 10 years).

Moose were moved utilizing an etorphine (M99, Lemmon Co., Sellersville, Pa.) and xylazine hydrochloride (Rompun, Haver-Lockhart, Shawnee, Kans.) mixture for initial immobilization of trapped animals (Gasaway et al. 1978) and retaining the immobilized state by subsequent doses of intravenous Rompun. Animals that could not be removed from one enclosure to another or to the outside by opening the fence were loaded by a winch-hoist or winch-tripod device (Arneson and Franzmann 1975) and placed on a trailer and moved to the appropriate place. Diprenorphine (M50-50, Lemmon Co., Sellersville, Pa.) was given intravenously to negate the effects of M99. Each animal was routinely processed when immobilized (Franzmann et al. 1976).

Browse Productivity, Utilization, and Quality

Procedures for determining in vitro dry-matter disappearance (IVDMD), fiber content, protein content, and concentration of 18 mineral elements were outlined by Oldemeyer et al. (1977). Methods for determining production and utilization of moose

browse were outlined by Oldemeyer (1981). Methods for estimating density of shrubs and saplings used by moose were presented by Oldemeyer and Regelin (1980).

FINDINGS AND DISCUSSION

Blood Chemistry and Hematology

Moose were sampled for a variety of purposes at the MRC as well as from other regions of Alaska (Table 1). Blood samples were taken from most moose, however, some animals had only morphology measurements or hair element values. Total moose numbers in the SPSS file were 2,472, plus an additional 57 adult females, from Game Management Unit (GMU) 9 that were inadvertently omitted for a total of 2,529. Franzmann et al. (1976) reported findings from 1,506 of these moose sampled from 1969 to 1976. Sorting of data from Table 2 and combining variable classes for this report will follow their outline. They also reported that Ca, P, glucose, TSP, albumin, beta-globulin, Hb, and PCV were the blood parameters that reflected condition change of moose, but that glucose, albumin, and beta-globulin were influenced by excitability. For condition comparisons between populations, we will only use those parameters not influenced by excitability (Ca, P, TSP, Hb, and PCV).

Differences in blood parameters related to sex were tested for adult moose from MRC populations (N = 704). For each adult season/age class, APT was significantly higher (P = .013) in males. During postrut (Nov, Dec, and Jan), the following values were significantly higher in females: Ca (P = 0.007), P (P = 0.006), Hb (P = 0.045) and PCV (P = 0.029). These values are all condition-related parameters and indicate better condition of postrut females than males. These were the only sex differences detected; for comparisons other than these, sexes were combined.

Our analyses included 2 methods to obtain TSP and albumin; one by blood chemistry analysis with an auto analyzer and the other by protein electrophoresis. The electrophoresis method is considered the most precise and preferred for a complete protein analysis. The Pearson correlation coefficient was used to test the relationships between the 2 methods for both TSP and albumin. The r value for TSP was 0.91 (N = 1,153) and for albumin 0.30 (N = 1,114). For condition assessment, we use only the TSP value from the entire electrophoretic analysis and thereby suggest that when the objective is to compare condition only, it is not necessary to order an electrophoretic analysis that will thereby lessen the cost/animal approximately >20.

Condition-related blood parameters of Ca, P, TSP, Hb, and PCV (Table 2) for adult moose were determined as outlined by Franzmann et al. (1976). Table 3 lists condition-related blood parameters which were also influenced by excitability (glucose, albumin, and beta-globulin) for adult moose.

Table 1. Sources of moose sampled in Alaska from June 1969 to July 1981.

Source	No. of moose
Inside Moose Research Center	428
Outside Moose Research Center	312
Game Management Unit 1	14
Game Management Unit 5	52
Game Management Unit 6	52
Game Management Unit 7	12
Game Management Unit 9	57
Game Management Unit 13	478
Game Management Unit 14	340
Game Management Unit 15	532
Game Management Unit 20	139
Game Management Unit 22	84
Origin unknown	29
Total	2,529

Table 2. Condition-related blood parameters from Alaskan moose by condition class.[a]

Condition class	Ca (mg/dl) $\bar{x}$	Ca (mg/dl) SD	P (mg/dl) $\bar{x}$	P (mg/dl) SD	TSP (g/dl) $\bar{x}$	TSP (g/dl) SD	Hb (g/dl) $\bar{x}$	Hb (g/dl) SD	PCV (%) $\bar{x}$	PCV (%) SD	MCHC (%) $\bar{x}$	MCHC (%) SD	Ca/P ratio $\bar{x}$
4	9.8	0.6(17)[b]	4.5	0.9(17)	7.2	0.9(17)	17.6	2.3(16)	44.0	4.8(15)	40.3	2.9(11)	2.18
5	10.1	0.9(96)	4.5	1.3(96)	7.2	0.8(95)	17.6	2.1(96)	43.9	5.3(90)	40.4	2.8(54)	2.24
6	10.4	0.8(270)	4.5	1.2(270)	7.4	0.6(270)	17.9	2.1(256)	46.4	6.4(226)	39.3	3.0(135)	2.31
7	10.5	0.7(276)	5.0	1.2(276)	7.5	0.8(276)	18.5	2.1(251)	49.3	5.9(219)	38.4	2.7(141)	2.10
8	10.5	0.7(125)	5.2	1.2(125)	7.6	0.6(125)	19.0	1.8(114)	50.6	6.4(102)	38.3	2.8(74)	2.02
9	10.6	0.8(12)	5.9	1.3(12)	7.8	0.5(12)	19.2	0.9(12)	52.0	4.8(10)	36.4	1.3(6)	1.80

[a] Condition class as per Franzmann et al. (1976).

[b] Sample size in parenthesis.

Table 3. Condition- and excitability-related blood parameters from Alaskan moose by condition class.[a]

Condition class	Glucose (mg/dl) $\bar{x}$	SD	N	Albumin (g/dl) $\bar{x}$	SD	N	Beta-globulin (g/dl) $\bar{x}$	SD	N
4	107	32	(17)	4.1	0.6	(17)	0.63	0.35	(17)
5	124	35	(96)	4.3	0.7	(95)	0.71	0.17	(95)
6	134	30	(270)	4.5	0.7	(271)	0.70	0.18	(271)
7	140	35	(276)	4.7	0.7	(280)	0.71	0.19	(280)
8	154	41	(125)	4.7	0.7	(127)	0.72	0.17	(127)
9	141	33	(12)	4.9	0.6	(14)	1.29	2.22	(14)

[a] Condition class and excitability class as per Franzmann et al. (1976).

Table 2 may be used as a reference to relate general condition of a sample from a population as per criteria outlined by Franzmann et al. (1976). Table 3 may also be used in this manner when it is determined that excitability is not a factor influencing the moose when sampled. It may also be used as an adjunct to values in Table 2.

Pearson correlation coefficients were used to rank the parameters that were most useful for condition evaluation. The rank in highest order of value was: PCV ($\underline{r}$ = 0.35), glucose ($\underline{r}$ = 0.25), Hb ($\underline{r}$ = 0.22), TSP ($\underline{r}$ = 0.22), P ($\underline{r}$ = 0.22), albumin ($\underline{r}$ = 0.21), Ca ($\underline{r}$ = 0.17), and beta-globulin ($\underline{r}$ = 0.11). Using this ranking and eliminating parameters influenced by excitability, the values rank in the following descending order: PCV, Hb, TSP, P, and Ca. Both PCV and Hb (ranking 1 and 2) were obtained from whole blood but each require a separate testing procedure. Therefore, a whole blood collection with a PCV determination would be the single test recommended, followed by a Hb determination. For additional support of condition evaluation based upon blood parameters, blood serum could be analyzed by automated blood chemistry equipment to obtain TSP, P, and Ca values. Glucose would also be obtained from this automated procedure, but excitability considerations would have to be made. Albumin and beta-globulin values that are useful would have to be obtained by protein electrophoresis and would thereby add considerable cost without substantial gain.

If automated blood chemistries were determined from a population, other values would be provided such as cholestrol, triglyceride, LDH, SGOT, SGPT, APT, BUN, creatanine, bilirubin, uric acid, and depending upon the laboratory, Fe, Na, K, CO_2, and electrolyte balance. For condition evaluation, these would not add to the assessment but may provide other information about the sampled population. For example, BUN is directly related to protein intake and may provide useful information regarding quality of forage. This is true until body catabolism occurs (body tissue protein is used when intake is inadequate) and must be considered in starving or near-starving animals. Some studies have related higher cholesterol to an increased plane of nutrition (Seal et al. 1972b, Coblentz 1975) and may be considered in nutritional assessments. Mean corpuscular hemoglobin concentration (MCHC) may be considered a condition-related blood parameter because it is a relationship between PCV and Hb (Table 2). The relationship is reversed in that higher MCHC levels are seen in lower condition ratings. We were not able to demonstrate that the Ca/P ratio followed an upward trend with improved conditions (Table 2). It appears that Ca is a better parameter for identifying the lower end of condition and P better on the high end. For this reason, the Ca/P ratios demonstrate a bell curve with condition. Other values may provide useful information regarding moose physiology under more specific sampling, particularly for serially sampling individuals over time.

Population condition assessment was our major goal, and efforts were devoted to sort out those values that would be most useful in field application. Possible applications of the other

parameters were outlined by Franzmann et al. (1976). Nieminen (1980) provided a review of hematological application to reindeer. Table 4 lists blood values for calves, and Table 5 lists blood values for yearlings and 2-year-olds by season with sex, location, and year combined. Table 6 lists blood values for adult moose by season with location and year combined, but with sex differences listed for postrut periods (Nov, Dec, Jan) and APT sex difference listed for all seasons. These tables provide a basic baseline set of blood values for all moose sorted by major sources of variation. Table 7 lists mean condition-related blood parameters by populations in Alaska during the critical late winter/spring season. Three populations were used as markers. The MRC population representing the lower scale due to its high density, summer confinement, and low productivity (Franzmann and Arneson 1975), the Copper River Delta (1974) moose population representing an expanding, highly productive population (McKnight 1975), and the GMU 15 (1977) sample which was from a group of postparturient cows in extremely poor condition (Franzmann and Schwartz 1979a). Much less was known about the other populations sampled, therefore, comparisons with populations of known status would provide a valuable comparative assessment.

As one may expect, the listing of population blood parameters (Table 7) does not provide a clear-cut and definite ranking. However, it does provide a good example of how these data must be interpreted and used. Homeostasis, or the ability of a system to maintain internal equilibrium, is the basis for maintenance of a normal or functional physiological system. The blood parameters we extracted from that system are a time-place record of the system. To deviate from the functional level requires conditions which may be considered exceptional. Therefore, we may often record degrees of "relative goodness" from a sample of animals. What we are interested in and what the blood parameters provide for us are the extremes, those populations on the perimeter of the ranges of physiological values. This system allows us to establish priorities regarding a population. For example, from a sampled population of which we have limited background data, we may use blood parameters to assist us in a status assessment of that population. The sample must be taken, however, during the critical late winter/early spring season when the physiological system is stressed the most. Blood data will not suffice as the only method of assessment but provides additional quantitative data to assist the manager in making a population assessment. This approach has been reported for several populations in Alaska: Alaska Peninsula (Faro and Franzmann 1978), Yakutat Forelands (Smith and Franzmann 1979), and Thomas Bay (Doerr et al. 1980). This report includes these data (Table 7).

One approach we may consider to establish priorities is to list the populations by rank from high to low for the condition-related blood parameters (Table 8). From this ranking, we may establish a relationship for the population of concern. The mean for all populations may be designated to determine a relative status to the mean. For example, the GMU 13 (1975) population ranks at or near the top for all parameters, as does the GMU 6

Table 4. Alaskan moose calf (0-12 months) blood values by season, 1969-1981.

Blood values		Summer/fall (Jun, Jul, Aug, Sep, Oct)			Early winter (Nov, Dec, Jan)			Late winter/early spring (Feb, Mar, Apr, May)			Combined seasons		
		$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Glucose	mg/dl	150.1	48.8	(50)	112.6	63.0	(41)	128.2	41.8	(175)	129.8	48.1	(266)
Cholesterol	mg/dl	107.8	13.8	(50)	74.9	20.5	(41)	85.2	24.8	(175)	87.8	24.7	(266)
Triglyceride	mg/dl	126.4	43.1	(14)				73.2	108.1	(143)	77.9	105.0	(157)
LDH	U/L	559.3	184.3	(49)	398.4	129.4	(41)	438.5	193.8	(174)	454.7	190.2	(264)
SGOT	U/L	137.0	49.5	(50)	228.7	64.7	(41)	103.7	107.3	(173)	129.4	103.0	(264)
SGPT	U/L	116.1	116.2	(14)				78.5	111.1	(128)	82.2	111.7	(142)
APT	U/L	334.6	248.1	(50)	74.0	65.8	(41)	316.1	302.1	(125)	282.3	282.7	(266)
P	mg/dl	7.7	1.9	(50)	5.5	2.4	(41)	6.9	2.1	(173)	6.9	2.2	(264)
Ca	mg/dl	10.8	1.1	(50)	9.0	2.2	(41)	10.8	1.4	(175)	10.5	1.6	(266)
Ca/P	ratio	1.49		(45)	1.96		(28)	1.66		(169)	1.66	0.45	(242)
Fe	mg/dl	431.1	235.9	(7)				149.8	131.9	(41)	190.9	178.8	(48)
Na	mEq/L	132.4	11.4	(14)				139.3	11.1	(150)	134.2	11.1	(164)
K	mEq/L	6.3	1.5	(13)				6.2	1.5	(150)	6.2	1.5	(163)
Cl	mEq/L	89.7	8.1	(14)				90.4	8.8	(149)	90.3	8.8	(163)
CO^2	mEq/L	10.1	6.1	(14)				16.8	6.6	(149)	16.2	6.8	(163)
BUN	mg/dl	15.9	5.8	(50)	10.9	9.7	(41)	10.4	9.0	(175)	11.5	8.9	(266)
Creatanine (c)	mg/dl	1.05	0.28	(14)				1.40	0.50	(150)	1.38	0.50	(164)
C/BUN	ratio	0.08	0.03	(14)				0.52	0.92	(147)	0.48	0.88	(161)
Bilirubin	mg/dl	0.59	0.26	(50)	0.37	0.17	(41)	0.38	0.36	(175)	0.42	0.33	(266)
Uric Acid	mg/dl	0.51	0.31	(48)	0.53	1.07	(41)	0.48	0.73	(175)	0.49	0.74	(262)
TSP (Chem)	g/dl	6.3	1.0	(50)	5.5	1.3	(41)	5.3	0.7	(175)	5.5	1.0	(266)
Albumin (Chem)	g/dl	1.9	1.3	(50)	0.9	0.4	(41)	3.0	0.8	(175)			

Table 4. Continued.

Blood values		Summer/fall (Jun, Jul, Aug, Sep, Oct)			Early winter (Nov, Dec, Jan)			Late winter/early spring (Feb, Mar, Apr, May)			Combined seasons		
		$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Globulin (Chem)	g/dl	1.7	1.1	(14)				2.0	0.7	(149)			
Balance		27.6	8.2	(14)				20.0	9.2	(146)			
TSP(Elec)	g/dl	6.4	1.0	(51)	5.5	1.4	(41)	5.3	0.8	(177)	5.6	1.0	(269)
Albumin (Elec)	g/dl	3.8	0.9	(51)	3.3	1.0	(41)	3.1	0.8	(177)	3.3	0.8	(177)
Globulin (Elec)	g/dl	2.6	0.6	(50)	2.3	0.7	(41)	2.2	0.8	(166)	2.3	0.8	(257)
Alpha 1 globulin	g/dl	0.36	0.13	(51)	0.28	0.13	(41)	0.39	0.24	(177)	0.37	0.21	(269)
Alpha 2 globulin	g/dl	0.53	0.16	(51)	0.50	0.25	(41)	0.49	0.22	(177)	0.50	0.21	(269)
Beta globulin	g/dl	0.81	0.21	(51)	0.59	0.39	(41)	0.59	0.41	(177)	0.63	0.39	(269)
Gamma globulin	g/dl	0.88	0.45	(51)	0.93	0.33	(41)	0.77	0.45	(177)	0.81	0.43	(269)
Albumin/globulin	ratio	1.84		(51)	1.52		(41)	1.71		(177)	1.71		(269)
Hb	g/dl	14.9	3.3	(49)	18.7	1.8	(23)	13.8	3.1	(171)	14.5	3.4	(243)
PCV	%	38.8	6.7	(47)	45.6	5.4	(19)	34.1	6.0	(170)	36.0	7.0	(236)
MCHC	%	36.3	2.9	(13)	41.4	3.7	(8)	36.5	4.1	(38)	37.1	4.2	(59)

Table 5. Blood values of Alaskan yearling and 2-year-old (13-36 months) moose by season, 1969-81.

Blood values		Summer/fall (Jun, Jul, Sep, Oct)			Early winter (Nov, Dec, Jan)			Late winter/early spring (Feb, Mar, Apr, May)			Combined seasons		
		$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Glucose	mg/dl	142.7	55.4	(100)	113.5	48.0	(43)	132.3	35.3	(132)	133.1	46.4	(275)
Cholesterol	mg/dl	86.7	18.5	(100)	73.2	17.5	(43)	75.8	13.8	(132)	79.4	17.1	(279)
Triglyceride	mg/dl	15.5	12.4	(15)				12.5	11.0	(41)	13.4	11.3	(57)
LDH	U/L	379.3	110.8	(100)	335.5	118.7	(43)	290.6	96.6	(132)	329.9	113.1	(275)
SGOT	U/L	138.4	51.4	(100)	183.9	55.8	(43)	138.7	70.2	(132)	145.6	63.7	(275)
SGPT	U/L	62.2	38.2	(14)				52.1	26.2	(38)	54.8	29.8	(52)
APT	U/L	108.7	79.2	(99)	41.9	17.5	(43)	60.8	51.7	(132)	75.1	65.3	(274)
P	mg/dl	5.5	1.4	(100)	5.8	1.9	(43)	5.1	1.5	(132)	5.4	1.5	(275)
Ca	mg/dl	10.6	0.9	(100)	9.3	1.7	(43)	10.2	1.2	(132)	10.2	1.3	(275)
Ca/P	ratio	2.10		(77)	1.70		(35)	2.28		(107)	2.12		(219)
Fe	mg/dl	128.7	28.6	(6)				134.0	44.1	(11)	132.1	38.5	(17)
Na	mEq/L	136.9	16.0	(15)				139.9	5.1	(42)	139.1	9.1	(58)
K	mEq/L	9.0	11.9	(15)				5.5	1.9	(42)	6.4	6.3	(58)
Cl	mEq/L	91.3	12.8	(15)				96.6	4.5	(42)	95.2	7.7	(58)
CO^2	mEq/L	21.2	7.0	(15)				17.5	7.1	(41)	18.6	7.1	(58)
BUN	mg/dl	20.7	13.2	(100)	9.5	7.4	(43)	8.7	10.1	(132)	13.2	12.3	(275)
Creatanine	mg/dl	2.71	0.89					2.55	0.39	(43)	2.59	0.56	(58)
C/BUN	ratio	0.32	0.24	(9)				0.88	0.64	(33)	0.75	0.62	(43)
Bilirubin	mg/dl	0.48	0.29	(100)	0.40	0.23	(43)	0.27	0.15	(132)	0.37	0.24	(275)
Uric Acid	mg/dl	0.60	1.03	(100)	0.36	0.19	(42)	0.33	0.23	(132)	0.44	0.66	(274)
TSP (Chem)	g/dl	7.3	0.7	(100)	6.2	1.4	(43)	6.5	0.7	(132)	6.8	1.0	(275)
Albumin (Chem)	g/dl	1.9	1.3	(98)	1.2	0.6	(43)	2.1	1.7	(132)	1.9	1.4	(273)

Table 5. Continued.

Blood values		Summer/fall (Jun, Jul, Aug, Sep, Oct)			Early winter (Nov, Dec, Jan)			Late winter/early spring (Feb, Mar, Apr, May)			Combined seasons		
		$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Globulin (Chem)	g/dl	3.1	1.0	(10)				2.5	1.3	(38)	2.6	1.1	(48)
Balance		19.0	6.7	(13)				18.9	8.9	(36)	18.9	8.3	(49)
TSP (Elec)	g/dl	7.3	0.7	(100)	6.4	1.4	(51)	6.5	0.7	(134)	6.8	0.9	(285)
Albumin	g/dl	4.2	0.7	(100)	3.9	1.1	(51)	4.0	0.7	(134)	4.1	0.8	(285)
Globulin	g/dl	3.1	0.7	(96)	2.5	0.7	(50)	2.5	0.7	(132)	2.7	0.8	(278)
Alpha 1 globulin	g/dl	0.33	0.16	(100)	0.27	0.1	(51)	0.33	0.14	(134)	0.32	0.14	(285)
Alpha 2 globulin	g/dl	0.65	0.18	(100)	0.50	0.23	(51)	0.48	0.17	(134)	0.54	0.20	(285)
Beta globulin	g/dl	0.77	0.18	(100)	0.60	0.19	(51)	0.60	0.23	(134)	0.66	0.22	(285)
Gamma globulin	g/dl	1.38	0.45	(100)	1.12	0.38	(51)	1.05	0.43	(134)			
Albumin/ globulin	ratio	1.46		(100)	1.65		(51)	1.87		(134)	1.69		(285)
Hb	g/dl	17.3	2.3	(71)	18.6	1.7	(31)	16.8	2.7	(82)	17.3	2.5	(184)
PCV	%	46.5	5.6	(47)	48.0	5.3	(21)	42.1	7.2	(82)	44.4	6.9	(150)
MCHC	%	38.3	3.4	(22)	40.7	3.7	(18)	40.1	4.3	(36)	39.7	4.0	(76)

Table 6. Alaskan adult moose (37+ months) blood values by season, 1969-1981.

Blood values		Summer/fall (Jun, Jul, Aug, Sep, Oct)			Early winter (Nov, Dec, Jan)			Late winter/early spring (Feb, Mar, Apr, May)			Combined seasons		
		x	SD	N	x	SD	N	x	SD	N	x	SD	N
Glucose	mg/dl	141.3	39.2	(491)	128.5	50.4	(186)	124.2	34.7	(487)	132.1	40.2	(1164)
Cholesterol	mg/dl	88.2	18.3	(492)	81.2	14.4	(186)	80.2	16.6	(487)	83.7	17.4	(1165)
Triglyceride	mg/dl	20.7	13.0	(40)	14.1	9.5	(7)	16.0	13.6	(163)	16.8	13.4	(210)
LDH	U/L	344.0	86.1	(492)	332.9	96.3	(185)	257.7	85.4	(487)	306.1	96.7	(1164)
SGOT	U/L	157.1	59.6	(492)	194.5	54.5	(185)	133.9	76.4	(486)	153.3	69.6	(1163)
SGPT	U/L	88.9	123.2	(40)	67.3	5.8	(3)	58.7	103.5	(117)	66.4	108.2	(160)
APT (female)	U/L	71.7	79.6	(370)	36.6	27.6	(162)	57.5	57.4	(438)	59.4	64.6	(970)
APT (male)	U/L	106.9	114.8	(120)	63.9	66.3	(24)	86.1	90.8	(47)	96.4	105.0	(191)
P (female)	mg/dl	5.1	1.2	(492)	5.2	1.9	(162)	4.6	1.3	(487)	4.9	1.4	(1165)
P (male)	mg/dl	Sex combined			3.9	0.1	(24)	Sex combined			Sex combined		
Ca (female)	mg/dl	10.5	0.9	(492)	10.0	1.4	(162)	10.4	0.9	(487)	10.4	1.0	(1165)
Ca (male)	mg/dl	Sex combined			9.8	0.6	(24)	Sex combined			Sex combined		
Ca/P (female)	ratio	2.06		(492)				2.26		(487)	2.12		(1165)
Ca/P (male)	ratio	Sex combined			2.51		(24)	Sex combined			Sex combined		
Fe	mg/dl	137.8	29.0	(35)	126.0	29.0	(3)	160.9	45.1	(47)	150.2	40.3	(85)
Na	mEq/L	139.1	5.2	(41)	138.9	3.9	(7)	137.4	6.5	(164)	137.8	6.2	(212)
K	mEq/L	5.9	1.5	(41)	5.0	0.8	(7)	5.2	1.4	(164)	5.3	1.4	(212)
Cl	mEq/L	96.9	4.4	(41)	97.6	4.1	(7)	96.0	5.5	(164)	96.2	5.3	(212)
CO^2	mEq/L	14.6	7.5	(41)	16.9	7.4	(7)	17.3	9.4	(162)	16.8	9.0	(210)
BUN	mg/dl	16.8	11.9	(492)	9.5	6.4	(186)	6.7	7.7	(485)	11.5	10.6	(1163)

Table 6. Continued.

Blood values		Summer/fall (Jun, Jul, Aug, Sep, Oct)			Early winter (Nov, Dec, Jan)			Late winter/early spring (Feb, Mar, Apr, May)			Combined seasons		
		$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Creatanine (c)	mg/dl	2.56	1.15	(41)	3.11	0.91	(7)	2.41	0.45	(164)	2.46	0.687	(212)
C/BUN	ratio	0.62		(35)	0.45		(7)	0.80		(131)	0.75		(173)
Bilirubin	mg/dl	0.51	0.29	(492)	0.53	0.30	(186)	0.33	0.21	(487)	0.44	0.27	(1165)
Uric Acid	mg/dl	0.36	0.21	(477)	0.31	0.22	(181)	0.30	0.23	(473)	0.33	0.22	(1131)
TSP (Chem)	g/dl	7.8	0.7	(492)	7.0	1.2	(185)	6.9	0.6	(487)	7.3	0.9	(1164)
Albumin (Chem)	g/dl	1.6	0.9	(487)	1.4	0.7	(185)	2.2	1.6	(486)	1.8	1.3	(1138)
Globulin (Chem)	g/dl	2.7	1.0	(12)				2.7	1.2	(142)	2.7	1.6	(154)
Balance		28.2	8.6	(37)	31.7	2.1	(3)	20.7	9.6	(117)	22.7	9.8	(157)
TSP (Elec)	g/dl	7.8	0.6	(494)	7.1	1.1	(186)	6.8	0.8	(503)	7.3	0.9	(1183)
Albumin (Elec)	g/dl	4.5	0.7	(494)	4.3	0.9	(186)	4.3	0.8	(409)	4.4	0.8	(1170)
Globulin (Elec)	g/dl	3.3	0.7	(489)	2.8	0.7	(182)	2.6	0.7	(484)	2.9	0.8	(1155)
Alpha 1 globulin	g/dl	0.36	0.15	(493)	0.31	0.13	(186)	0.36	0.41	(489)	0.35	0.28	(1168)
Alph 2 globulin	g/dl	0.62	0.18	(494)	0.52	0.18	(185)	0.51	0.35	(476)	0.56	0.27	(1155)
Beta globulin	g/dl	0.28	0.17	(494)	0.65	0.17	(185)	0.65	0.43	(490)	0.71	0.31	(1169)
Gamma globulin	g/dl	1.52	0.43	(494)	1.34	0.47	(186)	1.15	0.41	(490)	1.34	0.46	(1170)
A/G (Elec)	ratio	1.47		(494)	1.63		(186)	1.84		(490)	1.65		(1170)
Hb (female)	g/dl	18.3	2.4	(370)	19.3	1.3	(87)	12.3	2.6	(392)	18.0	2.5	(857)
Hb (male)	g/dl	Sex combined			18.7	1.5	(14)	Sex combined			Sex combined		
PCV (female)	%	49.7	6.0	(313)	51.4	4.8	(71)	43.5	6.9	(350)	46.9	7.1	(775)
PCV (male)	%	Sex combined			48.4	5.6	(9)	Sex combined			Sex combined		
MCHC	%	37.9	2.3	(202)	38.4	3.2	(74)	39.6	10.4	(213)	38.7	2.9	(489)

Table 7. Condition-related blood parameters for Alaskan moose populations during later winter/early spring season, 1969-1981.

Population	PCV %			Hb (g/dl)			TSP (g/dl)			P (mg/dl)			Ca (mg/dl)		
	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Moose Research Center (inside)	41.0	5.0	(37)[a]	16.8	2.1	(38)	6.9	0.6	(42)	4.3	1.6	(42)	9.8	1.3	(42)
Moose Research Center (outside)	41.8	5.2	(38)	16.5	1.9	(39)	6.8	0.6	(52)	3.8	1.1	(52)	10.0	0.7	(52)
GMU 1,[b] 1978	36.6	6.1	(14)	14.2	2.3	(14)	6.4	0.4	(14)	5.0	0.9	(14)	9.8	0.5	(14)
GMU 5, 1978	40.4	3.4	(36)	16.6	1.4	(36)	7.5	0.3	(35)	3.7	1.0	(35)	11.0	0.5	(35)
GMU 6, 1974	53.5	3.8	(32)	19.9	0.3	(32)	7.3	0.5	(30)	5.3	0.6	(30)	10.5	0.7	(30)
GMU 9, 1977	39.0	5.4	(56)	16.4	1.3	(54)	7.8	0.4	(57)	4.4	0.6	(57)	10.8	0.4	(57)
GMU 13. 1975	49.2	3.8	(55)	19.7	0.7	(55)	7.4	0.4	(53)	5.6	0.9	(53)	10.8	0.8	(53)
GMU 13, 1977							7.2	0.5	(29)	4.4	0.9	(29)	11.4	0.8	(29)
GMU 13, 1979	40.9	3.6	(10)	16.8	1.6	(10)	5.6	0.6	(12)	4.8	0.8	(12)	9.4	1.0	(12)
GMU 13, 1980	43.0	5.2	(23)	17.8	1.2	(23)	6.8	0.5	(27)	5.1	1.3	(27)	10.2	0.5	(27)
GMU 13, 1981	43.8	4.3	(9)	17.8	1.7	(9)	6.7	0.5	(7)	5.2	1.2	(7)	10.5	0.6	(7)
GMU 14, 1974	35.8	10.2	(21)	13.5	3.0	(20)	6.8	0.4	(30)	4.7	1.3	(30)	10.3	0.7	(30)
GMU 15, 1970							6.7	0.5	(24)	4.4	0.9	(24)	11.1	0.6	(24)
GMU 15, 1971							6.6	0.4	(40)	3.5	0.9	(40)	10.2	0.4	(40)
GMU 15, 1975	46.4	3.0	(25)	18.9	1.3	(25)	6.9	0.7	(24)	4.8	1.1	(24)	9.9	0.9	(24)
GMU 15, 1977	36.5	4.4	(12)	13.2	2.3	(12)	6.2	0.3	(13)	3.9	1.4	(13)	10.5	1.1	(13)
GMU 20, 1975							6.9	0.5	(12)	4.7	1.1	(19)	8.9	0.6	(12)
GMU 22, 1981	42.6	4.0	(25)	17.3	1.1	(25)	6.3	0.5	(25)	3.9	0.7	(25)	10.8	0.9	(26)
All pop. combined	43.5	6.9	(406)	17.3	2.6	(406)	6.9	0.6	(544)	4.6	1.3	(544)	10.4	1.0	(544)

[a] Sample size in parenthesis.
[b] GMU = Game Management Unit.

Table 8. Rank of Alaskan moose populations based on condition-related blood parameters.

Rank	PCV (%)	Hb (g/dl)	TSP (g/dl)	P (mg/dl)	Ca (mg/dl)
1	GMU 6[a] (1974)[b]	GMU 6 (1974)	GMU 13 (1975)	GMU 13 (1975)	GMU 13 (1977)
2	GMU 13 (1975)	GMU 13 (1975)	GMU 5 (1978)	GMU 6 (1974)	GMU 15 (1970)
3	GMU 15 (1975)	GMU 15 (1975)	GMU 13 (1975)	GMU 13 (1981)	GMU 5 (1978)
4	GMU 13 (1981)[c]	GMU 13 (1981)	GMU 6 (1974)	GMU 13 (1980)	GMU 13 (1975)
5	GMU 13 (1980)	GMU 13 (1980)	GMU 13 (1977)	GMU 1 (1978)	GMU 22 (1981)
6	GMU 22 (1981)	GMU 22 (1981)	GMU 15 (1975)	GMU 15 (1975)	GMU 9 (1977)
7	MRC (outside)	GMU 13 (1979)	MRC (inside)	GMU 13 (1979)	GMU 6 (1974)
8	MRC (inside)	MRC (inside)	GMU 20 (1975)	GMU 20 (1975)	GMU 13 (1981)
9	GMU 13 (1979)	GMU 5 (1978)	MRC (outside)	GMU 14 (1974)	GMU 15 (1977)
10	GMU 5 (1978)	MRC (outside)	GMU 13 (1980)	GMU 9 (1977)	GMU 14 (1974)
11	GMU 9 (1977)	GMU 9 (1977)	GMU 14 (1974)	GMU 15 (1970)	GMU 15 (1971)
12	GMU 1 (1978)	GMU 1 (1978)	GMU 13 (1981)	GMU 13 (1977)	GMU 13 (1980)
13	GMU 15 (1977)	GMU 14 (1974)	GMU 15 (1970)	MRC (inside)	MRC (outside)
14	GMU 14 (1974)	GMU 15 (1977)	GMU 15 (1971)	GMU 22 (1981)	GMU 15 (1975)
15			GMU 1 (1978)	GMU 15 (1977)	MRC (inside)
16			GMU 22 (1981)	MRC (outside)	GMU 1 (1978)
17			GMU 15 (1977)	GMU 5 (1978)	GMU 13 (1979)
18			GMU 13 (1978)	GMU 15 (1971)	GMU 20 (1975)

[a] GMU = Game Management Unit.
[b] Year sampled in parenthesis.
[c] Line represents combined populations' mean value.

(Copper River Delta) population. We may safely conclude that the GMU 13 (1975) population was in good condition based upon blood parameters. We reaffirm this because it ranks closely to the GMU 6 (1974) population which we know to be an expanding, highly productive population. The same conclusion may be drawn for several other populations ranked comparatively. Based on our background information about the MRC population sampled, the other end of the scale may be just as important; we may consider that those populations listed below the MRC as requiring additional assessment. Based upon blood values, the populations are poorly represented. Another marker population of value is the GMU 15 (1977) population which represented a population in extremely poor condition (Franzmann and Schwartz 1979b). Populations with values similar to this population may be considered to be in extremely poor condition, and a high priority may be placed upon determining the reasons for that status.

There are discrepancies in the ranking (Table 8). In general, the populations are in a relatively similar order for each parameter, especially those representing the best and poorest populations. However, a few populations are scattered throughout the ranking, particularly for P and Ca. This exemplifies the importance of using these parameters to identify the extremes and not to measure relative goodness. It also demonstrates that Ca and P are disproportionately weighed at either end of the scale (Table 3). For these data, we can readily see that PCV and Hb are the better parameters for condition assessment of moose.

There may be a tendency to use the ranking of populations to conclude "my population is better than yours"; however, in most instances this would be meaningless and untrue except perhaps when comparing high and low ends of the scale. It would be safe to say that the GMU 6 (1974), GMU 13 (1975), and GMU 15 (1975) populations were in better condition than the GMU 15 (1977), GMU 14 (1974), and GMU 1 (1978) populations. We cannot overemphasize that the data are limited to statements about the exceptional populations on either end of the scale and should be considered as supportive data for other population assessments, not as entities in themselves.

We are suggesting that a new data form for field collection of moose be used which will have space for listing the condition-related parameters (Fig. 7). When the analyses are completed, the results may be placed on the field cards. The maximum number of variables listed on the card would be 5 (PCV, Hb, TSP, P, and Ca), and some may select only PCV and Hb or PCV alone. This information can be readily analyzed with a calculator and provide the manager with a quick assessment of the population. The data only needs to be sorted and listed; then a population comparison may be made with data provided in this report. It will, we hope, put the tool in a useful form and allow a field biologist to assess the data in a reasonable time.

Studies on blood parameters (background section of this report) indicate the difficulties associated with comparisons of data where handling, collecting, and analyzing data are not

MOOSE TAGGING RECORD

Moose No. _____ Location _____

Sex _____ Date _____

Collar Color _____ Ear Tag No(s) & Color(s)

Number _____ LE _____

Metal Tag No. _____ RE _____

Year Born _____ W/Calf _____ Operators _____

Blood: Yes ___ No ___ Tooth: Yes ___ No ___ Hair: Yes __ No ___

Measurements: T.L. ____ H. L. ____ Girth ____ Neck ____ Weight _____

Excit. _____ Cond. _____ Antler Spread _____ Antler Base _____

Remarks: _____

_____

Pregnant: Yes ____ No ____

Fig. 7. Revised moose tagging record form.

(reverse side of card)

IMMOBILIZATION DATA

Time	Dart 1	Dart 2	Dart 3
Hit			
Ataxia			
Down			
Antagonist			
Up			
Dose			
Hit Location			

Blood Values: PCV _____ Hb _____ TSP _____ P _____ Ca _____

Remarks: _____

Fig. 7. Continued.

standardized. Every attempt should be made to maintain standard procedures. We have discarded using many variables that are affected by major influences, such as excitability. Unfortunately, many studies are not comparable due to the diversity of procedures used. All comparisons in this report between populations were from adults. We reported separately comparisons between Kenai Peninsula, Nelchina Basin, and Susitna Basin neonatal moose blood and measurement data (Franzmann et al. 1980). No significant differences were noted between the neonatal calves based on location. The study provided some baseline blood and measurement data for neonatal moose calves.

Hair

Results of initial hair element studies at the MRC were summarized (Franzmann et al. 1976). Results published since then are summarized by the following abstracts:

ALASKAN MOOSE HAIR ELEMENT VALUES AND VARIABILITY (Franzmann et al. 1977)

Hair from 1,250 moose (Alces alces gigas) collected from 12 regions in Alaska were analyzed by atomic absorption spectroscopy for 4 essential macroelements (Ca, K, Mg, and Na), 4 essential microelements (Cu, Fe, Mn, and Zn) and 2 nonessential microelements (Cd and Pb). Analysis of variance detected significant differences among monthly regional samples in 90 of 120 comparisons that may provide basis for identification and forensic application. Low essential mineral element hair values provided basis for delineating potential mineral deficient areas.

INDICATIONS OF COPPER DEFICIENCY IN A SUBPOPULATION OF ALASKA MOOSE (Flynn et al. 1977).

Three years of moose hair analyses indicated low copper status in a subpopulation of Alaskan moose (Alces alces gigas) 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 parameters. 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. Clinical signs of copper deficiency 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 deficiency by both mineral element analyses and photoelectron spectroscopy. Decreased copper and sulfur hoof content and an abnormal electron spectroscopy chemical analysis (ESCA) spectra indicated incomplete sulfur cross-linking in the hoof keratin. The decreased reproductive rates, actual 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

deficiency in moose from the Kenai Peninsula linked to decreased browse copper content.

FORENSIC MINERAL ANALYSIS IN MOOSE MANAGEMENT. (Flynn and Franzmann 1977)

Control of illegal harvesting of moose is costly and difficult even when the probable violators can be identified. Generally, the evidence collected is circumstantial in nature and provides little objective proof in a court of law. We have examined mineral element analysis of mammal hair as an objective link between kill site remains and carcasses found in the possession of suspects. Hair samples of only 100 mg are needed for analysis by atomic absorption spectroscopy for 8 elements: Ca, Cu, Fe, K, Mg, Na, Pb, and Zn. Pearson r coefficient of correlations were calculated comparing hair samples and critical values of r determined to describe the probability of such correlations. These elemental patterns in the hair "fingerprint" samples allow for good statistical comparison. Four cases involving illegally taken moose from the State of Alaska will be discussed to demonstrate the utilization of the results as objective evidence. Mineral element analyses may have even greater potential than just comparative analysis because such determinations can also pinpoint geographical site and month of harvest.

CONDITION ASSESSMENT OF ALASKAN MOOSE (Franzmann 1977a)

The ultimate measure of a population's condition is its reproductive success; however, in some instances, this information may not be available or easily obtained. Other methods to assess a population's condition may then be useful to game managers as sole or supplemental data. Condition assessments were made of Alaskan moose (Alces alces gigas) population using morphometric measurements (total length, chest girth, hind foot, and shoulder height), weight, antler growth, condition grading based on form and composition, and physiological parameters (blood and hair). Blood parameters which best reflected condition in Alaskan moose were calcium, phosphorus, total protein, hemoglobin, and packed cell volume. Hair mineral element determinations did not directly reflect condition of a population but were useful in identifying potential trace element deficiencies which may influence reproductive success. Application of these various condition assessments to different Alaskan moose populations resulted in similar population condition ranking.

SEASONAL CALCIUM FLUX IN MOOSE (Flynn et al. 1980).

Seasonal mobilization of calcium in relation to antler growth has focused on the site of new bone growth, but systematic changes have not been fully studied. Several theories on the role of various steroids in activating the transport of calcium to the site of growth have been postulated, but little attention has been paid to the impact on body stores of this essential element. We have analyzed hair calcium levels as an indicator of mineral

status and have noted seasonal changes in both males and females. Hair calcium levels in May and June samples were markedly elevated over the other 10 months in both males and females. To follow up on these observations, we monitored blood serum calcium and serum hydroxyproline as indicators of calcium flux. Serum calcium was significantly higher in June through October than in winter and spring. The flux of calcium as indicated by hydroxyproline was markedly higher in May through August than in a later winter sample in February. Although both males and females demonstrated this change, the magnitude of the male response was greater.

In addition to the above abstracts, hair element studies of moose at the MRC and in Alaska have provided new insight to mineral metabolism studies of moose and have given the wildlife manager and researcher an additional tool to improve the information base on moose populations. We continue to collect hair from moose populations over the State to build the baseline hair element values for moose. The ease of collecting, storing, and handling hair samples should stimulate wider use and application of the technique. Franzmann (1977b) provided a "popularized" explanation of the use of hair samples from moose for wildlife management.

Analyses of hair element values have been done through a cooperative arrangement with Dr. Arthur Flynn, who is now associated with The Cleveland Clinic Foundation research staff. There is a substantial backlog of hair samples in his possession which have not been analyzed due to other commitments. Dr. Flynn was doing the analyses on a cost basis and as he could work them in. Unfortunately, he has not been able to keep up in the last few years, and we do not have a significant amount of new data to add to that which has already been published. When the data are available, we will put it in the computer file.

Consideration has been given to have the analyses done at a commercial laboratory. The cost would be >30 for analysis of Cd, Hg, Pb, Ni, Mn, Cu, Co, Fe, Zn, Cr, K, Na, Li, Mg, Ca, and P by Albion Clinical Laboratories, Clearfield, Utah. In discussing this possibility with Dr. Flynn, he assured us that he would get the data to us and was interested in remaining a cooperator in our studies. We hope the arrangement continues to be productive, but in the future if extensive delays are experienced, we may again reassess the possibility of using commercial laboratories.

With the hair data in the SPSS program, we tested the hair parameters in the same manner as we handled the blood for selecting condition-related values. Hair element values which demonstrated a relationship to condition classes of moose were: Zn, Cu, Co, Fe, K, and Pb (Table 9). The relationships are interesting but require additional sampling, particularly of values from high- and low-condition classes before we begin thinking of applying the data. All the elements listed are essential except lead, which is a toxic element. The data show that moose in better condition have a greater uptake of these elements and that may be the most than can be made from it. There is no reason that the

Table 9. Mineral element levels (ppm) in Alaskan moose hair by moose condition class, 1974-1978.

Condition	Zinc			Copper			Cobalt			Iron			Potassium			Lead		
class	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
4	77	19	(14)	5.3	2.6	(14)	0.8	0.7	(14)	48	12	(14)	618	373	(14)	1.7	2.4	(14)
5	82	22	(79)	4.8	3.1	(79)	0.7	0.6	(79)	52	18	(79)	685	359	(79)	4.3	3.6	(79)
6	82	23	(215)	7.1	5.1	(215)	0.8	0.9	(215)	50	18	(215)	884	636	(215)	5.9	5.5	(215)
7	83	24	(235)	8.0	4.2	(235)	1.1	1.0	(235)	53	20	(235)	1079	740	(235)	6.4	5.2	(235)
8	84	24	(109)	10.6	4.4	(109)	1.2	1.0	(109)	55	23	(109)	1235	734	(109)	6.8	5.3	(109)
9	94	25	(12)	10.4	3.9	(12)	1.3	1.0	(12)	66	46	(12)	1157	1063	(12)	5.5	4.6	(12)

[a] Condition class as per Franzmann et al. (1976).

information could not be used as additional supportive data for assessment of condition of moose populations as long as statements are qualified.

Milk

Table 10 lists the means and standard deviations of postpartum gross composition of milk from Alaskan moose, nonpostpartum milk from Alaskan moose, and milk from other North American wild ruminants. The immediate postpartum moose milk, when compared to midlactation moose milk, has significantly higher ($P < 0.05$) levels of lipids, but ash, crude protein, lactose, and gross energy were significantly lower ($P < 0.05$). There was no difference in total solids; therefore, it appears the increase in lipids from postpartum moose milk was offset by decreases in other components of milk solids. Although significant differences were noted between postpartum and midlactation samples, the differences were not as great as we anticipated.

There are many factors which influence milk composition including: stage of lactation, climate, age, nutrition, and disease (Kirchgessner et al. 1967, Lauer et al. 1969, Cook et al. 1970b, Mueller and Sadleir 1977). In our postpartum sample, we have only accounted for the stage of lactation variable. Nevertheless, this is a major variable (Luick et al. 1974).

The known composition of postpartum moose milk is important in selecting or compounding a milk substitute formula for raising orphan or young moose calves. In most instances, one is confronted with raising calves that are only 1 or 2 days old, and until now, no data were available for postpartum moose milk. Mineral analyses were also done to provide postpartum baseline data (Table 11).

It is apparent that gross milk composition information from wild North American ruminants is lacking and that significant variability exists among species (Table 10). We confined our listing to North American ruminants because of their similar digestive systems and their breeding regimen which allows them to lactate during the season of high quantity and quality food intake. We would expect some similarity, but this is not the case. We can only speculate on the reasons with the paucity of data available. Many of the differences between species may relate more to sample size and stage of lactation than to real interspecies variability. Larger sample sizes from various stages of lactation are needed to establish baseline milk composition for North American wild ruminants. The composition of moose milk presented should serve as a basis for further comparisons with other moose and other species.

Condition (Health) Evaluation

Findings are presented in Appendix A (Health [Condition] evaluation of wild animal populations: the animal indicator concept) which was prepared for the Workshop on Techniques in Wildlife Research and Management at Kanha Park, India.

Table 10. Gross composition of milk from Alaskan moose and other North American ruminants.

Animal	Sample size	Total solids %	Lipids %	Ash %	Crude protein %	Lactose[a] %	Gross energy K cal/g	Specific gravity	pH	Reference source
Moose (postpartum)	17	23.18(16)[b]	8.33	1.46(16)	8.10	5.29(16)	0.946(16)	1.039	6.42	This work
		±6.07[c]	±2.82	±0.09	±3.45	±2.30	±0.407	0.007	±0.10	
Moose	20	25.54	5.83(8)	2.01(5)	10.32(17)	6.81(5)	1.42	1.038(3)	6.76	Franzmann et al. 1975c
		±6.11	±2.78	±0.26	±2.24	±2.54	±0.477	±0.014	±0.30	
Moose	2	24.85	7.20	1.60	14.35	1.70		1.055	6.35	Cook et al. 1970a
Mule deer	1	20.40	8.30	1.44						Hagen 1951
White-tailed deer	29	24.16	9.53							Youatt et al. 1965
Black-tailed deer	1	25.00	10.40	1.50	8.70	4.40				Kitt et al. 1956b
Caribou (colostrum)[d]	1	40.40	23.20	1.07	11.60	2.45			6.28	Hatcher et al. 1957
Caribou (postpartum)	1	31.80	16.90	1.20	9.70	2.50			6.55	Hatcher et al. 1957
Bighorn sheep	5	24.06	10.43	1.12	7.89	4.46		1.019	6.43	Chen et al. 1965
Dall sheep	9	10.32	1.09	8.20	3.81			1.041	6.57	Cook et al. 1970b
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
Musk-ox	2	21.50	11.00	1.80	5.30	3.60				Tener 1956
Musk-ox	5	27.10	10.90	1.20	11.90	2.10		1.023	5.40	Baker et al. 1970
Reindeer	100+[e]	33.30	18.00	1.50	10.70	2.80				Luick et al. 1974

[a] Lactose = % solids - % crude protein - % lipids - % ash.
[b] Sample size in parenthesis when different from group.
[c] Standard deviation.
[d] Caribou sampled was captive animal on artifical ration.
[e] Values represent a composite of reindeer in midlactation.

Table 11. Mineral composition of postparturient milk from Alaskan moose.

Element	Ca (%)[a]	P (%)	Na (%)	K (%)	Cu (ppm)	Fe (ppm)	Mg (ppm)	Mn (ppm)	Se (ppm)	Zn (ppm)
Mean	0.27	0.15	0.07	0.22	0.54	4.20	187.4	0.62	0.05	8.0
SD	0.03	0.02	0.04	0.02	0.23	1.32	34.6	0.26	0.02	1.8
Sample size	10	10	10	10	10	10	10	10	10	10

[a] Percentage of wet ash.

Information for the paper was primarily generated from this study.

Morphometric Measurements and Body Weight

Measurement data from over 1,200 moose were compiled, and their relationship with body weights from 500 moose were made (Franzmann et al. 1978). Seasonal weight patterns demonstrated increases from 21 to 55% from spring to late fall. Measurements, particularly total lengths, were better indicators of growth rate than were weights. Body measurements were significantly correlated with weight: total length $r = 0.94$; chest girth $r = 0.90$, shoulder height $r = 0.87$; and hind foot length $r = 0.81$ (Franzmann et al. 1978).

Haigh et al. (1980) compared linear measurements and weights of Alberta and Saskatchewan moose and found all measurements were correlated with weight. The highest correlation was girth 2x total length ($r = 0.91$). However, they pointed out that based upon ease and repeatability of measurement, head length was useful in predicting body weight.

An assessment of available moose measurement and measurement/weight data provided us with a set of recommended measurements for field use. Shoulder height, ear length, hind foot length, and tail length measurements are not useful for weight correlations. Measurements recommended are total length, chest girth, and head length. Body weight is also recommended but in most instances is difficult to obtain.

Table 12 lists female moose total body length, hind foot length, shoulder height, chest girth, and body weight by condition class. Condition classes were determined as outlined by Franzmann et al. (1976). All parameters reflect improved condition with larger measurements, but the hind foot length relationship is not significant between highest and lowest classes ($P < 0.05$) while the others are. Those measurements most highly correlated with body weight were the best condition indicators. Measurements and weights from various Alaskan moose populations (Table 13) allow a comparison with condition blood parameters (Table 7). There are missing data from populations for weight, shoulder height, and hind foot length measurements. Live weights for moose are rarely obtained; shoulder height data is not always taken due to position of immobilized moose (sternal recumbency); and hind foot length measurements were omitted from several populations. Fortunately, the 2 measurements most highly correlated with body weight were available from most populations: total body length and chest girth. We ranked the Alaskan populations from high to low based on these measurements (Table 14). The ranking was not similar to those for condition blood parameters (Table 7), or between total length and chest girth. Populations that ranked above average for both total length and chest girth were from GMU 6 (1974), GMU 9 (1977), and GMU 13 (1977). Only the GMU 6 (1974) population was consistently ranked high by blood parameter (Table 8). We must use measurements judiciously when assessing populations. Measurements may reflect long-term forces on the

Table 12. Measurements and weights of adult female Alaskan moose by condition class, 1969-1981.

Condition class	Total body length (cm) $\bar{x}$	SD	N	Hind foot length (cm) $\bar{x}$	SD	N	Shoulder length (cm) $\bar{x}$	SD	N	Chest girth (cm) $\bar{x}$	SD	N	Body weight (kg) $\bar{x}$	SD	N
4	279.1	13.7	(17)	79.6	1.8	(12)							259.8	29.6	(3)
5	285.9	12.3	(92)	79.5	2.5	(84)	178.0	9.6	(23)	182.8	13.8	(92)	323.3	38.7	(24)
6	288.5	14.3	(259)	80.3	3.3	(228)	178.4	13.4	(52)	187.2	16.4	(259)	370.1	46.2	(54)
7	289.2	16.6	(259)	80.2	3.1	(232)	179.3	24.6	(61)	193.9	37.4	(255)	399.5	43.4	(31)
8	300.3	18.0	(110)	80.2	2.8	(101)	187.2	6.2	(19)	198.5	21.5	(109)	460.1	71.3	(9)
9	296.7	13.5	(12)	81.3	3.1	(9)	189.3	7.6	(4)	202.3	20.7	(10)			

[a] Condition class as per Franzmann et al. (1976).

Table 13. Morphometric measurements and weights from adult female Alaskan moose populations during late winter/spring season, 1969-1981.

Population	Total length (cm)			Hind foot length (cm)			Shoulder height (cm)			Chest girth (cm)			Body weight (kg)		
	x	SD	N	x	SD	N	x	SD	N	x	SD	N	x	SD	N
Moose Research Center															
(inside)	283	21	(40)	79.3	3.3	(39)	175	18	(11)	183	16	(39)	365	43	(15)
Moose Research Center															
(outside)	286	11	(51)	79.4	2.6	(50)	174	16	(15)	183	13	(51)	359	56	(19)
GMU 1,[a] 1978	276	14	(4)	79.4	2.7	(7)				187	12	(7)			
GMU 5, 1978	288	11	(32)	81.3	2.8	(31)				202	11	(32)			
GMU 6, 1974	302	9	(25)	82.5	2.2	(20)				201	13	(30)			
GMU 9, 1977	302	7	(54)	80.8	1.8	(12)				201	12	(53)			
GMU 13, 1975	296	10	(53)	79.2	2.9	(32)				12	13	(50)			
GMU 13, 1977	292	16	(25)							197	13	(22)			
GMU 13, 1979	290	13	(12)	85.7	4.1	(11)				189	15	(12)			
GMU 13, 1980	315	116	(26)	80.3	4.1	(24)				218	110	(25)			
GMU 13, 1981	289	15	(8)	8.0	8.3	(7)				203	19	(7)			
GMU 15, 1970	285	20	(55)	79.1	6.6	(46)	166	21	(37)	173	15	(41)			
GMU 15, 1971	292	13	(45)	79.0	4.6	(39)	169	13	(27)	177	11	(39)			
GMU 15, 1975	286	11	(23)	80.0	2.6	(17)	173	4	(7)	181	14	(24)			
GMU 15, 1977	272	26	(13)							193	28	(12)			
GMU 20, 1971	276	15	(8)				180	11	(13)	182	11	(7)	354	50	(12)
GMU 22, 1981	290	19	(27)	88.2	3.5	(24)				201	13	(26)			
Combined	290	32	(504)	80.0	5.5	(389)	170	27	(83)	189	32	(430)			

[a] GMU = Game Management Unit.

Table 14. Rank of adult female Alaskan moose populations based on measurement parameters correlated with body weight.

Rank	Total length ($\underline{r}$ = 0.94)	Chest girth ($\underline{r}$ = 0.90)
1	GMU[a] 6 (1974)[b]	GMU 5 (1978)
		GMU 13 (1981)
2	GMU 9 (1977)	GMU 6 (1974)
3	GMU 13 (1975)	GMU 9 (1977)
4	GMU 13 (1977)	GMU 22 (1981)
5	GMU 15 (1971)[c]	GMU 13 (1977)
6	GMU 13 (1979)	GMU 15 (1977)[c]
7	GMU 22 (1981)	GMU 13 (1979)
8	GMU 13 (1981)	GMU 13 (1975)
9	GMU 5 (1978)	GMU 1 (1978)
10	GMU 15 (1975)	MRC (outside)
11	MRC (outside)	MRC (inside)
12	GMU 15 (1970)	GMU 20 (1971)
13	MRC (inside)	GMU 15 (1975)
14	GMU 20 (1977)	GMU 15 (1971)
15	GMU 1 (1978)	GMU 15 (1970)
16	GMU 15 (1977)	

[a] GMU = Game Management Unit.

[b] Year sampled in parenthesis.

[c] Line indicates mean for combined populations.

population, while blood parameters reflect short-term forces. Looking at both gives us additional insight into the population, but the same considerations stated for blood parameters must be made: use them to identify extremes, but not to measure relative goodness. In addition, the information should be used as supportive data for other population assessments, not as entities in themselves.

Productivity of MRC Moose

Annual progress reports have described histories of individual moose and listed moose mortalities at the MRC (Franzmann and Bailey 1977b; Franzmann and Schwartz 1978, 1979a; Schwartz and Franzmann 1981). Moose productivity at the MRC through June 1976 was summarized and discussed (Franzmann et al. 1976). Since 1976, additional objectives for utilization of MRC moose were established which altered productivity assessment as previously reported. Nevertheless, we must review MRC productivity data in light of new findings from calf mortality studies (Franzmann et al. 1979b, Franzmann et al. 1980). We (Franzmann et al. 1976) reported declining productivity of MRC moose which had occurred and which was largely attributed to the severe winters of the early 1970's. The long-term effects of plant succession following the 1947 Kenai Peninsula burn was also noted (Oldemeyer et al. 1977). The severe winters, high moose density, and reduced browse quality and quantity exhibited themselves through the MRC moose populations by lowered productivity measured by lowered pregnancy and natality. Moose at the MRC were also in poor condition (physiologically and morphometrically) (Franzmann et al. 1976). Overbrowsing by moose in the MRC enclosures was exemplified by low production and high utilization of birch (Betula papyrifera) and scarce density of aspen (Populus tremuloides) and willow (Salix spp.) (Appendix B). The MRC populations provided a model for populations on the Kenai Peninsula lowlands by accentuating the conditions which were occurring over the entire Peninsula.

Calf mortality studies on the Kenai Peninsula revealed an additional force which was depressing moose productivity in the 1947 burn on the Kenai Peninsula. Franzmann et al. (1980) reported that 27 of 47 (57%) moose calves radio-collared at birth died by midsummer; 23 of 47 moose calves were killed (49%) by predators, with black bears (Ursus americanus) accounting for 16 deaths (34%). Moose calves within the MRC enclosures were also subject to these mortality forces in that predators were not deterred by MRC fencing (4 radio-collared black bears denning within the MRC enclosures in winter 1981). Natality data reported previously (Franzmann et al. 1976) for MRC moose becomes suspect because most of the moose calf predation occurred within 2 weeks after birth, generally before sightings were made. We believe this must also be considered in any other moose populations where predation of neonatal calves may occur. We reported low mortality during summer for calves we located at the MRC, but in most instances, these sightings occurred after the peak of the neonatal predation period.

The cumulative negative forces exerted upon MRC moose productivity may also be measured by changes in density of moose over time in Pen 1 which was subject to minimum manipulation. In June 1972, 12 adults occupied Pen 1. The number of adults at the same season in 1973 was 9, 6 in 1974, 6 in 1975, 6 in 1977, 5 in 1978, 5 in 1979, and 5 in 1980. Many circumstances are involved which in any year may alter the specific individuals present, but the trend downward models the change in carrying capacity. This should not infer that the present density of 5 moose/2.6 km^2 is ideal. We can only speculate that the figure represents the maximum density sustainable. The carrying capacity was probably prevented from a continuing downward trend by mechanical rehabilitation of nearly one-third of Pen 1 in fall 1976. In addition, other than winter 1977-78, the winters from 1976 through 1980-81 have been characterized by relatively short periods of extremely cold weather and snow accumulations which did not exceed 28 cm at the MRC. It must be noted that moose occupying Pen 1 do not represent a healthy population as reflected by productivity and condition (Franzmann et al. 1976).

In 1977, we began trapping and turning Pen 4 moose outside in an effort to remove all Pen 4 moose. Vegetative recovery could then be studied in the enclosure where high densities of moose were artificially maintained over a period of 10 years. Our success was thwarted by successive break-ins through the fence. Efforts to repair and maintain the fence were initiated, and a 1-way gate was constructed in 1981 to allow passage of moose out of the pen. We have decreased the Pen 4 moose population again but have not completely removed all of the moose. Efforts will continue to remove all moose and to prevent further break-ins, so vegetative studies can begin.

By summer 1978, we trapped and removed all male moose from Pen 3, successfully. The objective was to reintroduce a mature male late in the breeding season to evaluate the effect of late conception on natality and calf viability. We were not successful in trapping a mature bull during late rut in fall 1978, but on 23 October 1979, we trapped a mature bull (male No. 5) in Pen 1 and introduced him into Pen 3. Flights over Pen 3 in spring 1980 during the normal calving period indicated no calves were produced, but not all female moose were sighted. On 1 July, a helicopter search of Pen 3 revealed that female No. 3 had a calf less than 3 days old. No other calves were sighted. On 14 July, another helicopter survey was made and again female No. 3 was sighted with a calf, but the other 4 cows had no calves.

Although the results from this pilot study were very preliminary in nature, several important things were learned. First, the potential does exist to test late breeding in moose within the MRC enclosures and it is possible to physically transport a drugged moose from 1 enclosure to another. Second, the sightability of moose in Pen 3 is very poor; routine Super Cub flights do not provide sufficient information to ascertain if and when cows gave birth. Third, and of significance, it appears

that late breeding does occur, with the subsequent parturition date delayed by a similar length of time.

From this pilot study, it is possible to develop several hypotheses to be tested in the next few years. By placing radio collars on all female moose in Pen 3, we can locate all individuals either on the ground or via aircraft. This should provide the necessary observation to determine calving dates and calf survival. The potential management implications from such studies are very important. If late breeding produces calves born later in the summer, it seems logical that these calves would be smaller at the end of the vegetative growing seasons. Small calves would have less chance of surviving a long, severe winter. Continued studies are requisite to determine the effects of late breeding on moose calf production and survival. Once these effects are understood, it will be necessary to determine if late breeding occurs in wild moose populations with low bull: cow ratios.

Male moose No. 5 was trapped and removed from Pen 3 during summer 1981; several Pen 3 females were radio-collared. We anticipated repeating the introduction study with an improved ability to monitor the Pen 3 moose. However, early in the rut during fall 1981, a mature male moose from Pen 4 broke into Pen 3 and we lost our attempt to repeat the study.

The condition of MRC fencing was illustrated by the delay of both Pen 3 and Pen 4 studies due to break-ins which occur because the wooden posts are rotting at ground level. We have attempted to maintain them with limited manpower but have obviously not been successful. The U.S. Fish and Wildlife Service in 1981 contracted for setting 1,500 new posts at the MRC. Their effort was most welcome and will be a start to upgrade the MRC fence lines. This contract will bring the Pen 1 fence line up to par and will do the same for the north ends of Pens 2 and 3.

We are hopeful that the entire fence line will be upgraded because in the near future each of the pens will be utilized for specific studies. The principal near-future use of the MRC enclosures are designated for testing the carrying capacity model which is being developed through other MRC studies (Franzmann and Schwartz 1979a, Schwartz and Franzmann 1981, Schwartz et al. 1981).

Browse Productivity, Utilization, and Quality

Long-term browse vegetation and habitat studies at the MRC were done by John L. Oldemeyer and Wayne Regelin, U.S. Fish and Wildlife Service, Denver Wildlife Research Center as cooperators with the Alaska Department of Fish and Game in MRC studies. Findings related to occurrence and nutritive quality of lowbush cranberry (Vaccinium vitis-idaea) were published (Oldemeyer and Seemel 1976). Oldemeyer et al. (1977) reported on the relationship of browse quality and the Kenai moose population.

Productivity and utilization of birch (Betula papyrifera) and its response to browsing were the subject of John Oldemeyer's Ph.D. dissertation (Oldemeyer 1981). Use of browse by moose and hares (Lepus americanus) at the MRC is discussed in a paper in review (Appendix B). Oldemeyer and Regelin (1980) compared methods for estimating density of shrubs and saplings in Alaska.

The impact of mechanical rehabilitation on moose browse production on the Kenai Peninsula was reported (Oldemeyer and Regelin 1980), and a further assessment of mechanical rehabilitation on moose browse is in preparation. Regelin et al. (1980) reported the effects of nitrogen fertilizer upon production of moose forage; Franzmann and Flynn (1977a) compared mineral contents of volcanic and tree ash as related to remineralization of soils.

RECOMMENDATIONS

1. Selected blood parameters may be used to make comparative assessments of condition of moose populations. The most useful parameters in order of value are: PCV, Hb, TSP, P, and Ca which are collected during late winter/early spring (Feb, Mar, Apr, May).

2. For condition assessment, a single whole blood sample will provide PCV and the Hb values.

3. Total serum protein (TSP) may be obtained from automated blood chemistry analysis, and protein electrophoresis would not be required. Automated blood chemistry analysis also provides P and Ca values which are not influenced by excitability.

4. Assessment of moose population condition with these parameters must be used judiciously, and emphasis should be placed on populations with levels at the extreme high or low. Measures of relative goodness of populations not at the high or low end are not warranted.

5. Supportive condition assessment may come from other blood chemistry values, hair element values, and measurements; however, they must be qualified as supportive.

6. A standard field form should be adapted to record condition-related parameters and measurements most useful for routine assessments. Fig. 5 represents a suggested revised collecting field form for moose.

7. Measurements that we recommend for routine collections are total body length (from dorsal border of planum nasale to tip of tail), chest girth (circumference of chest perpendicular to long axis and passing over the heart), and head length (from dorsal border of planum nasale to the occipital crest). Neck circumference

measurements may be taken for proper fit of radio collars, if in doubt, but this information and most collars have a liberal degree of adjustment.

8. Hair samples should be taken from moose populations when the sample is 15 or greater and particularly from populations which have not been sampled. Analysis of moose hair is presently backlogged, but we are anticipating getting back on schedule.

9. Milk collected serially from cow moose over time are needed to better understand changes in milk composition through lactation.

10. Productivity of MRC moose should continue to be monitored since long-term trends and vegetative changes are reflected in the population. The MRC moose productivity data have provided a model for populations on the Kenai Peninsula.

11. Browse and habitat studies should be reinstated by the U.S. Fish and Wildlife Service at the MRC to maintain the continuity in long-term browse and habitat studies which were initiated at the MRC nearly 15 years ago. These studies are also needed as supportive data for testing the carrying capacity model for moose which is being developed through another study at the MRC. The productive nature of the Alaska Department of Fish and Game and U.S. Fish and Wildlife Service cooperative studies should be maintained.

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APPENDIX A. HEALTH (CONDITION) EVALUATION OF WILD ANIMAL POPULATIONS: THE ANIMAL INDICATOR CONCEPT. Speech presented by Albert W. Franzmann at a workshop on techniques in Wildlife Research and Management, Kanha National Park, India, 4-20 January 1982.

I. INTRODUCTION

Webster defines health as the general condition of body and mind and condition as the state of being or health. It is apparent that the terms are somewhat similar. I prefer the term health because I prescribe to the broad definition of disease as outlined by Hippocrates. He defined disease as disharmony within the body, between the body and mind, and between man (or animals) and the environment. Disease is simply a departure from health.

It is extremely important that the broad concept of health and disease be used for wildlife populations, so we may begin to discard the 20th century trend to define disease as the result of the collision between a pathogenic agent and a susceptible individual (Dixon 1978). To date, wildlife disease interest has primarily concentrated on parasitological and infectious diseases, disease entities with specific and identifiable etiologies. The consequence has led to emphasis on cure and not prevention. Thereby, the focus was on individuals rather than populations and on clinical medicine rather than preventive medicine. Many veterinarians and wildlife disease specialists working on wildlife population problems have unfortunately not functioned under the broad definition of disease and have thereby not been effective in applying their training to wildlife populations. Individual animal orientation can be beneficial to the animal but may not relate to population health. The classic example in North America was the preoccupation of individuals working with bighorn sheep who identified lungworm (Protostrongylus stilesii) as the cause of mortality in several bighorn sheep die-offs. They correctly identified an etiological agent, and they could demonstrate definite lung pathology. But the investigations unfortunately ended there, and the basic problem was not addressed for a number of years. The basic problem was that these populations of bighorn sheep were forced to utilize submarginal range, were excluded from traditional wintering areas, were confined to small areas, were exposed to stress, and were limited from migrating. With the basic cause of the problem not thoroughly investigated, the solution to the problem was delayed, and political and funding emphasis was misdirected. Perhaps a solution was not possible, but earlier recognition of the basic problem would have been helpful.

This health evaluation section will be based upon the premise that animals in a population act as indicators of the status of their relationship with their environment. We will concentrate on physiological and morphometric methods

of extracting information from representative animals in a population, so we may effectively monitor and assess the health (condition) of the population. Most importantly, we will attempt to bridge the gap of individual health versus population health.

The use of the indicator concept to wild animal populations requires application of some procedures and techniques developed for clinical medicine. That is why we must stress the broad definition of health and its aberrations--disease. We will take clinical medicine to the field and apply it to populations by sampling its indicators.

The need for an animal indicator approach to assessment of populations is obvious. The complexity of forces, namely nutritional, behavioral, environmental, and genetic, acting upon a population have been assessed by secondary indicators such as habitat evaluation, food habits, and population characteristics. In many cases, certain aspects of these assessments are difficult or impossible to obtain, costly, time-consuming, and subject to misinterpretation. Theoretically, assessment of primary indicators obtained directly from animals representing a population would minimize many sources of variation and provide greater precision in our assessment. These primary indicators are physiological and morphometric measurements. Physiology is the study of function of living things. When we monitor function, we are monitoring the end result of an animal's ability to relate to its environment. We are monitoring the end product of the animal's behavioral, nutritional, environmental, and genetic forces. It is not a panacea for monitoring wildlife populations, but another way to gain information that has inherent problems as well, such as: 1) all procedures used have not been thoroughly tested, 2) basic physiological norms have not been established for most species, 3) the physiological tendency for homeostasis masks subtle changes, 4) cost of developing base-line data for a species is great, and 5) a representative sample of animals must be handled.

What is the status of physiological and morphometric monitoring of a population? It is a developing area of wildlife population study that is an adjunct to traditional methods of study. We should refer to it as wildlife health monitoring. It, like other disciplines of population studies, gains strength when combined with other studies to make the final population assessment for management decisions.

There are several approaches to wildlife health monitoring. A statistically representative sample from a population provides the ideal circumstance. That sample may be dead or live animals. However, in most instances, we do not have the luxury of a statistically representative sample. Nevertheless, we must extract all the information we can from whatever sample we have and place it in proper perspective.

II. METHODS

A. Examination of Live Animals

1. Introduction.

The opportunity to handle and examine live animals from a wild, free-ranging population affords an opportunity to gain special insight into the population. This opportunity may be frequent for some populations, but not possible for others, such as endangered species. It is important that when the opportunity arises we are prepared and equipped to extract as much information as possible. This section will outline methods to accomplish that goal.

In designing a study, one should consider the types of information possible to gather, as well as those necessary to meet the objectives. From this, a field form should evolve that will help organize field procedures. It may be as simple as a check list or encompass all examinations. Fig. 1 is an example of a form used for bear ecology studies in Alaska.

2. Restraint and handling.

This subject requires separate coverage. An excellent reference is Fowler (1978).

3. History (anemnesis).

Too often the most neglected part of an animal examination is the history. This is particularly true for wild populations and, in many instances, perhaps the most important part of the evaluation. The individual making the examination must know the ecology of the species involved or have someone who does assist in recording an adequate history. Without a background on the ecology of the species, it may be difficult to assess the events associated with the examination.

The history may be limited to the observations of the immediate surroundings of the animal, but an attempt should be made to obtain information beyond what is evident by questioning individuals familiar with circumstances not available to the observer. In some cases, excellent history is available on a population under study, but even in this case assuming circumstances may negate information that a thorough history would provide.

4. Description (signalment).

The field form must include the description, such as: date (including year), location, species, sex, age, color and markings, method of capture, and collectors. If drugs were used for capture, they should be identified and quantified. The animal is given an identification number corresponding to a tag, collar, or tattoo number.

5. General observations (distance).

Often the tendency is to immediately get the animal to be examined in hand, and obvious signs are overlooked. When possible, the animal should be observed from a distance before handling; its physical attitude, condition, confirmation, and temperament should be noted. Here again, it is important that the observer know the animals physical characteristics and behavior to focus on that which appears abnormal.

The physical attitude of the animal may be obtained by observing the animal in motion, lying, standing, drinking, and eating. The gait of the animal may be helpful; limping or uncoordination may be noted. The animal may exhibit stiffness, languid attitude, arched back, heavy breathing, partial paralysis, swellings and enlargements, and discharges from natural or artificial orifices.

The condition of the animal may be recognized by the rotundity and fullness of development of the body, the quality of hair, fur, or feathers, as well as its physical attitude. This assessment may be made in general terms by our initial observation, but criteria to quantify condition must follow.

The temperament of the animal may be helpful in our initial observations. The animal's temperament is the mental attitude it assumes toward impressions perceived through organs of sense. Unusual temperament or behavior may clue the observer to impairment of certain sense organs. Obviously, if the animal is blinded, we can perceive this via temperament of the animal.

It is generally useful to photograph the animal during this part of the examination for identification and descriptive purposes.

6. Physical examination (animal in hand).

When we have the animal in hand, the first objective should be to check its vital signs, state of

consciousness, evidence of external bleeding, color of mucosa, respiratory rate, heart rate, and body temperature. This is particularly true for handling wild animals because of the stress that may be imposed when captured.

Once we are satisfied that the animals vital signs are normal, we may proceed with the examination. From this point on, the examination procedure will vary with the objectives of the examination or study. Each major body system or area may be examined to include: skin and integument, lymph, head, neck and back, abdomen, thorax, extremities, respiratory system, circulatory system, reproductive system, nervous system, and digestive system. Our tools for examining the live animal are our senses and augmentation of them. We observe, smell, auscultate, and palpate. We may be aided by instruments such as opthalmascopes, stethoscopes, and endoscopes. Textbooks have been written on clinical and physical examinations of animals, and we will not detail this science first outlined by Malkmus (1901). Nevertheless, it is necessary to become familiar with the procedures that will provide the information relative to the objectives. With the animal in hand, no matter what the objective, there are certain types of information we should obtain which do not necessarily constitute a complete physical examination, but which may assist us in evaluating our indicator animal. These include:

a. Skin - color, moisture, elasticity, swelling, lacerations, ulcers, parasites (ticks, lice, fleas, mites). COLLECT PARASITES.

b. Hair - brittleness, lustre, length, alopecia (hair loss), color. COLLECT HAIR.

c. Lymph glands - swelling.

d. Eye - discharge, color of conjunctiva, clarity of cornea.

e. Pulse - rate.

f. Heart and Circulation - sounds, rate, swelling of extremities, ascites (abdominal filling). COLLECT BLOOD.

g. Respiration - rate rhythm, intensity, sounds (wheezing, rattling, blowing), cough, odor of expirum.

h. Nasal discharge - color, consistency, odor presence of air, blood.

i. Oral cavity - odor, teeth, gum color, condition, abrasions, foreign material. COLLECT TOOTH (aging).

j. Abdomen - bloat, rumination, impaction.

k. Evacuations - diarrhea, blood, mucous, frequency, form, color, composition. COLLECT FECES (food habits, parasites).

l. Food and Drink - appetite, deprived, depressed, mastication, thirst, vomiting.

m. Urination - frequency, difficulty, painful, quantity, color. COLLECT URINE.

n. Reproductive system - discharge, swelling, check for pregnancy.

o. Mammary gland - lactating, swelling, inflamation. COLLECT MILK.

p. Feet and hooves - puncture wounds, swelling, hoof growth abnormalities.

q. Skeletal system - fractures, enlargements, measurements.

r. Condition evaluation - (discussion follows).

s. Excitability evaluation - (discussion follows).

There are two subjective evaluations that should be done on each animal handled: condition and excitability. Condition evaluation criteria have been established for white-tailed deer (Odocoileus virginianus) (Robinson 1960) and moose (Franzmann et al. 1976) Both systems are based on a 1 to 10 score as follows for moose:

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) definitions of neck from shoulders, (B) upper foreleg (humerus musculature) distinct from chest, or (C) rib cage is prominent.

5) A state when two of the characteristics in Class 6 are evident.

4) A state when all three of the characteristics in Class 6 is evident.

3) A state 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. 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 circuis taures.

This outline may not be applicable to most other species. It will be necessary to modify the criteria based upon the characteristics of each species. Obviously, the criteria must be established by a person or persons familiar with the species.

Excitability evaluation should be made on the animal 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) (Franzmann and LeResche 1978).

Another assist in evaluating the individual and interpreting some blood values is a rectal temperature class. The following were established for moose (Franzmann and LeResche 1978) Class 1 - 38 C, Class 2 - 38 to 39 C, Class 3 - 39 to 40 C, Class 4 - 40 to 41 C, and Class 5 - C. Depending upon the species, these may have to be adjusted accordingly.

7. Measurements and weights.

An integral part of an examination should include body measurements and weight when possible. These parameters are useful in assessing conditions and comparing populations. Measurements taken for each species may vary; for example, in ungulates we generally measure total length (nose to tip of tail), chest girth, head length, hind foot length (point of hock to tip of hoof), height of shoulder, neck circumference, and horns or antlers if present. For Ursidae, Canidae, and Felidae, we generally measure total length (nose to tip of tail), tail length, skull length and width, chest girth, hind foot pad width and length, shoulder height, neck circumference, length of canine teeth (may measure anterior-posterior width at base and lingual-labial width at base), baculum length on males, and teat length and width on females. The important consideration is consistency of measurements within a species, so comparisons between populations can be made.

Weight is also a valuable parameter and should be obtained whenever possible. In ruminant animals, the "fill" of the animal may greatly influence weight, and, if known, the status of "fill" should be recorded. For example, if the animal was in a trap without food or drink for a number of hours, it obviously would not be full. For large mammals, various devices have been used to sling and weigh animals (Fowler 1978, Arneson and Franzmann 1975).

8. Tissue collection (live animal).

During the physical examination, we suggested collecting samples of blood, hair, milk, tooth, feces, urine, and ectoparasites. In this section, we will focus on these collections. Collections are not limited to these mentioned, but they constitute the more routine collections.

Blood from live animals is collected by vena puncture utilizing sterile needles (18-21 gauge) and sterile syringes or by using sterile evacuated containers (Vacutainer, Becton-Dickinson and Co., Rutherford, N.J.). The jugular vein is generally used for adult ungulates. The radial vein may be used on ungulate calves. The saphenous vein of the hind limb is preferred for black bear (Ursus americanus) and brown bear (Ursus arctos). The radial vein is preferred for most felids and canids.

A minimum of four vacutainer vials (15 ml) are filled with blood, one of which contains an anticoagulant (Heparin or EDTA). A vial with the anticoagulant sodium fluoride may be used to collect samples for blood glucose determination. The vials are identified and protected from freezing and extreme heat. A blood smear using microscope slides as described by Wobesser et al. (1980) should also be made at this time. The blood should be taken to a field laboratory or facility with electricity as soon as possible, preferably within 24 hours. The coagulated blood is centrifuged, and serum extracted and placed in 2 or 3 plastic serum vials and frozen. The uncoagulated blood is used to determine hemoglobin (Hb) and packed cell volume (PCV), or hematocrit. Hb may be determined using a colori meter such as a Hemoglobinmeter (American Optical Corp., Buffalo, N.Y.), and PCV values are obtained with a micro-hematocrit centrifuge (Triac, TM Clay-Adams Co., Parsippany, N.J.). Hb and PCV determinations should be done soon after blood collection in a field laboratory; if desired, uncoagulated blood should be rushed to a facility to determine blood and differential counts. In Alaska, we generally are not in reasonable proximity to a laboratory to do the blood and differential counts, but we are set up in the field laboratory to determine PCV and Hb.

When it is not possible to obtain sera for freezing, a special 17-mm diameter paper disc may be used to collect both whole blood and serum in the field (Karstad et al. 1957). This method is not preferred but may be used in lieu of obtaining no sample.

One of the frozen serum samples (3 ml minimum) is sent to a laboratory with auto-analyzing equipment to obtain the following blood chemistries: glucose (may use sodium fluoride tube for separate analysis), blood urea nitrogen (BUN), creatanine, sodium (Na^+), potassium (K^+), chloride (Cl^-), carbon dioxide (CO_2), uric acid, total bilirubin, calcium (Ca), phosphorus (P), alkaline phosphotase (APT), lactic dehydrogenase (LDH), glutamic oxalacetic transaminase (GOT), glutamic pyruvic transaminase (GPT), cholesterol, and triglycerides. The laboratory should also do protein electrophoresis to determine total protein (TSP), albumin, globulin, alpha 1 globulin, alpha 2 globulin, beta globulin, gamma globulin, and albumin/globulin ratio (A/G). Total protein albumin, globulin, and A/G determinations from electrophoresis are preferred to those obtained by

auto analyzers. For TSP only, results from auto analyzers are adequate.

The remainder of the serum sample may be divided as needed for various other tests. In Alaska, we monitor selected moose population every few years for potential exposure to some of the infectious diseases of domestic animals which may infect moose. We use serologic tests (FIAX Immunoflorescent Analyzer) for mucosal disease (bovine virus diarrhea), infectious bovine rhinotracheitis (IBR), brucellosis, salmonellosis, tuberculosis, anthrax, leptospirosis, theleriosis, toxoplasmosis, blue tongue, trypanasomiasis, and sarcocystosis. Some serum samples have been used to determine hormone levels (testosterone, progesterone, thyroid, corticosteroids), and brain peptides (beta-endorphin). Maintaining a serum bank is recommended and can be most useful when new techniques develop which allow additional analyses of serum which may not be possible or practical when collected.

Hair has been utilized to monitor mineral metabolism in domestic animals (Anke 1965, Brossard 1965, Halletal 1971, Hidiroglou and Spurr 1974, Miller et al. 1975, O'Mary et al. 1970, Van Koetsveld 1958), to monitor heavy metal toxicity in wild animals (Cumbie 1975, Huckabee et al. 1973, Raymond and Forbes 1975), and to study mineral metabolism in wild animals (Franzmann et al. 1975a, Flynn et al. 1975). A mineral copper deficiency was identified in moose based upon hair element values (Flynn and Franzmann 1974, Flynn et al. 1975, Flynn et al 1977).

Hair samples are obtained by plucking (not cutting) hair from an area on the animal where hair grows rapidly. For moose, hair is plucked from the shoulder hump and consists of a 4 to 6 cm bundle (2 gram minimum). The hair sample is identified, air dried, and stored in a plastic bag (Whirl-pac, Nasco, Inc., Modesto, Calif.). The hair sample may be kept indefinitely before analyzing.

Hair analysis is done using atomic absorption spectroscopy (Franzmann et al. 1977) and may include part or all of the following elements: Ca, Mg, P, K, Na, Cd, Cu, Fe, Pb, Mn, Zn, Hg, Ni, Co, Cr, Li, Se, Mo, and As.

Milk should be collected from lactating animals, identified, and frozen. Analyses for gross composition include: total solids, lipids, ash,

crude protein, lactose, gross energy, specific gravity, and pH. Analyses may be done on vitamins, minerals, enzymes, and hormones. Milk may also be used as a monitor for environmental contaminants such as antibiotics, pesticides, and radioisotopes. Establishing normal constituents of milk may be useful for compounding milk replacers for orphaned animals.

Depending upon the species sampled, a tooth may be extracted and sectioned to examine cementum annuli for age. Aging techniques for various animals are summarized by Larson and Taber (1980).

Fecal samples may be collected for parasitological examination and/or for food habits studies. References for preparation of slides and identification of parasites include Coles (1967), Davis and Anderson (1971), Davis et al. (1971), Dieterich (1981), Fyvie and Addison (1969), Sloss (1970), and Adrian (1981), but it is generally advantageous to have a trained parasitologist make the identifications. Food habits studies using fecal samples have been outlined by Korschgen (1981).

Collection and analysis of urine may provide supplementary data for our health evaluation. A minimum of 30 ml of urine should be collected as aseptically as possible and should be refrigerated as soon as possible. If refrigeration is not possible, toluene may be added to form a layer on top of the sample. Formalin may be used when urine cell sediments and costs must be maintained for identification at the rate of 1 drop of 40% formalin for each 15 ml of urine. Analysis of a fresh, clean sample is of course preferred and consists of a gross examination for color, transparency, odor, and specific gravity. Chemical analysis generally includes the following tests: ph, protein, retones, glucose, bile pigments, and Hb.

Analyses done on samples from wildlife populations are most often obtained through cooperative agreements with institutions having the facilities and expertise to assist us. It is not practical in most instances for wildlife agencies to develop sophisticated support laboratories. Collection should be made even though cooperative arrangements are not available because most material can be stored for future analyses.

In some instances while examining the live animal, we may have the opportunity and/or the objective of the study may dictate that other tissue collection be made. The most common would be cultures from wounds, discharges or areas where suspected infection may occur. Both aerobic and anaerobic culture collection systems are available (Culturette, Scientific Products, Division of American Hospital Supply Corp. Evanston, Ill.). Certain growths or tumors may be excised from the animal for histological examination and identification. Skin scrapings may be made to identify microscopic parasites in the skin such as demodective mange. Various less applicable procedures may be required such as tissue biopsy, bone marrow sample, collecting cerebrospinal fluid, semen collection, urine collection via catheters, vaginal smears, proctoscopic examination, measuring blood pressure, and radiographs. These procedures are described by Kirk and Bistner (1975).

9. Base-line (normal) values.

One basic application for obtaining the morphometric and physiologic values other than direct assessment is to establish base-line values for a species. We can utilize values from related species, particularly domestic, but we must be careful not to rely on these comparisons. As we develop our physiologic and morphometric information base for a species, we become more precise in using the animal as a monitor of its environment.

Establishing normal values depends upon many samples, and this may not be possible for some species. However, when possible, we must also consider the factors that influence these values and classify our samples accordingly. We may expect influences by season, sex, age, reproductive status, excitability, stress, nutrition, and location. The sources of variation may be the key to monitoring the species or may be factors that override our ability to do so.

To attain the point in time when we can apply these values, we must have good collections and well-organized data. Each value we obtain and each animal sampled builds our data base. To maintain it in an organized way, we should utilize computer technology. In Alaska, we have sufficient base-line data for moose that we can compare populations by season, age class, location, and sex to quantify differences in physiology and

morphometrics that relate to nutrition and condition (Franzmann et al. 1976, Franzmann 1977, Franzmann and LeResche 1978, Faro and Franzmann 1978, Smith and Franzmann 1979, Doerr et al. 1980) in addition to the present study. It may not be possible to achieve this for many species; nevertheless, the attempt should be made where feasible. A following section will outline the data processing used at the Moose Research Center.

B. Examination of Dead Animals

Procedures for handling and examining dead animals in the field go beyond a necropsy when we consider that the animal is an indicator animal and that we have accepted the broad concept disease and health. Circumstances as to examination technique will vary with the objectives of the examinations, the time of death, population history, logistics, and personnel involved. Nevertheless, the procedures may be considered under four general headings: (a) record circumstances relative to area, (b) record circumstances relative to animal, (c) necropsy, (d) physical condition, and (e) tissue collection.

1. Record circumstances relative to area.

When we enter the areas of the deceased animals, it is most important that we do not disturb the scene. This of course may not be as important if we are collecting the animal for population sampling and have shot the animal. But consider how important it may be if we are making an assessment of potential predation. We must assume that signs in the area may hold the clue to the cause of death.

It is generally advisable to photograph the area before proceeding. Record the positions of the animal or animals.

The area should be examined for track or spoor, bed, fecal droppings, hair, and blood. The condition of the terrain should be noted as well as habitat type. Evidence of physical phenomena that may have come and gone such as lightning strike marks on trees or recent high-water marks should be noted.

Once we are convinced that we have obtained all the signs in the area, we should proceed to the animal.

2. Record circumstances relative to the animal.

All the steps that were outlined for examination of the live animal are just as appropriate to the dead animal, and reference to those should be made at this time.

The only difference is we are dealing with a dead animal, and we may obtain more information and have more tissues to collect. Before the animal is handled, we must assume that whatever was the cause of death it is possible that the animal is a reservoir for human disease. Anyone handling the animal should wear acceptable protective gear, including coveralls, rubber apron, rubber gloves, and rubber boots.

After completing our examination of the area and animal, an assessment may be made as to the desirability of bringing a pathologist to the scene, taking the animal to a pathologist or diagnostic laboratory, or proceeding with a gross necropsy. The circumstances will dictate the choice. The ideal situation would be to have the representation of each specific area of expertise to assist in evaluation. This is not often possible but should be the goal. Transportation of the animal to a diagnostic laboratory would be preferred when possible.

3. Gross necropsy.

Procedures and equipment for necropsy techniques have been outlined for wild mammals and birds (Cowan 1963, Karstad 1969, Wobeser and Spraker 1980, Dau 1981, Fay et al. 1979). Several related considerations must be emphasized:

a. Seek professional help when possible (pathological).

b. Develop and follow a standard necropsy technique.

c. Consider that each animal has a disease transmittable to man (zoonotic diseases) and protect yourself accordingly.

d. Fresh specimens are most desirable.

e. Necropsy procedure should not be limited to infectious and parasitic disease identification. Having a indicator animal from a free-ranging population provides opportunity to assess reproductive status, nutritional status, food habitats, condition, and stress.

4. Tissue collection.

a. General considerations

The types of tissue examinations and tests is nearly unlimited, but certainly all are not warranted. Collections should be made on the basis of study objectives and on sight assessment, preferably with professional assistance in the field and laboratory. Some general rules on tissue collection are:

(1) Collect and deliver to laboratory the entire animal when possible.

(2) Collect extra specimens when in doubt.

(3) Refrigerate (4 C) samples for short-term preservation.

(4) Place specimens in leak-proof containers and clearly identify (collector, date, specimen, sex, and age).

(5) Perishable specimens should be delivered directly to the laboratory when possible. If not, shipping should be done in a manner to preserve a specimen.

(6) Avoid contamination and physical damage to specimens.

(7) Techniques for preservation of biological material are outlined by Wobeser et al. (1980, Table 32.1).

The following outline will provide a guide to tissues to collect for various types of examinations, but is not considered complete. Specialized examinations may require additional tissues or procedures for collecting and storing.

b. Histopathology.

Histology is essentially microscopic anatomy, and therefore histopathology would consist of the study of diseased tissue, essentially at the cellular level.

(1) Collect portion of gross lesions and adjacent normal tissue.

(2) For supportive diagnosis, also collect sections from major organs (liver, kidney, spleen, lung, heart, stomach, intestine, and brain).

(3) Ideal tissue sample size for quick fixation is 2.5 cm square and 1 cm thick.

(4) Fix tissue in 10% neutral buffered formalin.

c. Microbiology

Examinations for bacteria, viruses, and fungi are generally dependent upon isolating living organisms; therefore, prompt delivery to a laboratory is essential. When possible, the entire animal should be delivered.

(1) Sterile collection - avoid contamination.

(2) Refrigeration preferred.

(3) Specimen for bacteriological and fungal examination may be frozen, but freezing except at -40 C should be avoided for virus specimens.

(4) For rabies suspects, entire head of animal should be refrigerated and delivered to laboratory.

(5) Sterile swabs (Culturette, Scientific Production, Division of American Hospital Supply Corp., Evanston, Ill.) may be used to collect and transport samples of feces or body fluids for bacterial culture.

d. Toxicology

A good history should accompany samples for toxicological examination.

(1) Collect blood, liver, kidney, brain, fat, and digestive tract contents.

(2) Tissue may be refrigerated or frozen.

(3) Pluck hair from animal to determine heavy metal accumulation (Kopito et al. 1967).

e. Parasitology

(1) Ectoparasites preferred live for identification.

(2) Helminths should be relaxed in cold water or saline. Nematodes should be

fixed in hot 20% ethyl alcohol or 5% formalin. Cestodes and trematodes fixed in 10% formalin.

(3) Fecal sample collected for egg identification or for quantification (eggs/gram feces).

(4) Abomassum ligated and contents examined for abomassal parasite count (Eve and Kellogg 1977, Davidson et al. 1980).

(5) Protozoa may be identified from tissue, blood and feces; refrigeration is preferred. Smears of blood at collection site are helpful.

(6) Various tissues may be collected for specific parasites such as brain and carotial artery for Elaeophora schneideri in elk and moose; brain tissue for Pneumostrongylus tenuis in moose; muscle, liver, and lung for lanal tapeworms in herbivores; and muscles for Sarcocystis.

f. Reproductive status

The reproductive success of a population which is best measured by natality is often difficult to obtain from a free-ranging population. When sampling from the population, we may gain additional insight by examining the reproductive tract. Kirkpatrick (1980) outlined the physiological indices of reproduction.

(1) Collect female reproduction tract and fix in 10% formalin.

(2) Luteal glands, follicle counts, fetal counts, and placental scars are used in mammals.

(3) Spermatozoa in testes and epididymis indicate reproductive condition and ability in males (Kirkpatrick 1980).

(4) Examine mammary gland for presence of milk; collect milk.

(5) History of presence of young may assist in evaluation.

g. Age determination

From the carcass, several types of collections may be made for age determination and are outlined for various species by Larson and Taber (1980).

Become familiar with tissues that are best indicators for animal in question. Some examples of tissues used for aging are:

(1) Teeth
(2) Eye lens
(3) Baculum
(4) Longbones
(5) Feathers
(6) Reproductive tracts in birds
(7) External genitalia - measurements

h. Nutritional status

We have covered the collections and assessments of condition and nutritional status from live animals. These assessments may also be used on the dead animal. We may gain additional information regarding condition of the population from the dead animal. Nutritional indices to consider are:

(1) Fat indices

(a) Whole body fat

(i) Catabolic loss from key areas. The order of fat catabolism on a declining nutritional plane was described by Harris (1945) and Riney (1955) and follows this pattern: (1) subcutaneous fat over rump and saddle, (2) abdominal fat, (3) bone marrow.

(ii) Whole animal minced and fat extracted. Method primarily reserved for small mammals and birds but has been done on limited scale for deer and elk (W. Regelin, pers. commun.). This method preferred for intensive research studies on animal nutrition.

(b) Femur marrow fat. The most widely used method with techniques varying from visual rating to fat analysis. Kirkpatrick (1980) reviewed the many methods used.

When possible, a marrow fat analysis is most desirable because we have more comparative data than with other methods.

(c) Grading system for deer. Kistner et al. (1980) developed a technique based on the amount of carcass fat to evaluate physical condition of deer. Tissue from the following areas is graded from 0 to 15 on the amount of fat present: (1) heart base and coronary groove, (2) pericardium, (3) omentum, (4) perirenal (kidney) area, (5) tail-base and rump, and (6) brisket. Fat rating is applied to each site: (1) no visible fat = 0 points, (2) slight quantities of fat = 5 points, (3) moderate quantities of fat = 10 points, and (4) heavy quantities fat = 15 points. For musculature, 0 points are awarded if the carcass is bony, 5 points if partially full, and 10 points if the musculature is full. Each carcass will score within the range of 0-100 points. The criteria used could be adapted and applied to other species.

(d) Mandible marrow fat. A method gaining favor because the mandible is much easier and a more likely collection in many cases than the femur. The method was first described by Baker and Lueth (1966) and is outlined and updated by Kirkpatrick (1980). Use when femur not available, but preferably use both to obtain relationship.

(e) Kidney fat index. Riney (1955) described this method which has been widely used but not considered as reliable as marrow fat methods.

(f) Other fat indices. Kirkpatrick (1980) reviewed other fat indices that are less applicable for various reasons.

(2) Measurements and heights and measurement weight relationships.

(a) Total body weight. Preferred when possible, but comparisons must be done on seasonal basis.

(b) Measurement/weight relationships. Certain body measurements have been highly correlated with weight in cervids such as hind foot length (Bandy et al. 1956, McEwan and Wood 1966, Franzmann et al. 1978) and chest girth (Riney 1955, Bandy et al. 1956, Franzmann et al. 1978). Franzmann et al. (1978) reported highest correlation for chest girth measurements in moose (r = 0.94). Haigh et al. (1980) reported similar correlation for moose but suggested head length may be most practical measurement to utilize due to its consistency and good correlation coefficient (r = 0.88).

(c) Carcass weight. Eviscerated carcass weight (whole body weight minus all fat within the body cavity and all viscera except esophagus and trachea) was a good index of condition in female mule deer (Odocoileus hemionus) (Anderson et al. 1972).

(d) Fat weight-kidney fat index (Section 1,e).

(e) Skeletal development (measurements) may have phenotypic (environmental) as well as genotypic (hereditary) variability. Several skeletal measurements have been used such as brain volume (Bubenik et al. 1980) and metatarsal length (Peterson 1977) to relate to phenotypic variability and particularly status of nutrition during pregnancy.

(3) Blood. Outline same as for live animal (Section A, 8).

(4) Hair. Outline same as for live animal (Section A, 8).

(5) Gastorintestinal tract. Kirkpatrick (1980) reviewed various procedures to assess habitat from gastrointestinal

contents such as chemical composition of rumen contents, cell wall constituents, volatile fatty acids, lignin, digestible energy, and digestibility. Collections of material would follow those prescribed for method used.

Under the parasitology section, the abomassal parasite count was listed as an assessment method used to monitor conditions of white-tailed deer. The abomassum is ligated and removed and parasites counted (Eve and Kellogg 1977).

(6) Thymus gland. Ozoga and Verme (1978) reported the use of thymus gland weights as an indicator of nutritional status in white-tailed deer.

i. Stress status

Stress was defined by Selye (1973) as the cumulative response of an animal resulting from interaction with its environment via receptors. The definition alone implies the importance of this syndrome and of our need to understand it. Pathologic changes may occur in the body with overstimulation of receptors, and the response was described as the general adapter syndrome (GAS) (Selye 1946). He outlined three phases of the syndrome: alarm reaction, stage of resistance, and exhaustion phase. The exhaustion phase is of primary concern because this is the period in the GAS when derangement of the animal's adaptive mechanisms play a decisive role in the development of many diseases (Selye 1946).

Our ability to measure or assess stress in wild populations is somewhat limited, but we may utilize several means to assist us, from a subjective excitability classification to blood parameters measuring corticosteroid and beta-endorphin levels.

To assess state of stress from the dead animal, we may collect:

(1) Blood - analysis of corticosteriods and beta-endorphin

(2) Adrenal gland - weight of adrenal gland has been correlated with adrenal gland secretion of corticosteroids (Adams and

Hane 1972). Kirkpatrick (1980) reviewed the application of adrenal gland weights to stress.

j. Food Habits

Collection of gastrointestinal tract materials for food habit studies was reviewed by Korschgen (1980).

C. Data Processing

We have indicated under the outlines for examining live and dead animals that they may be applied to population sampling. Assimilating all information from a sampling scheme and applying it may be very cumbersome and in some instances nearly impossible. The methods that will be presented are those used at the Moose Research Center, Alaska for assimilating the biological data for population assessment.

1. Field forms. Forms for field should be simple, but inclusive. Fig. 1 is a form used for live bear captures; Fig. 2 is the form used for live moose captures. For assessment of moose calf mortality, we used the form in Fig. 3.

   Each person and project will develop a form that suits their purpose best. These are just presented as examples.

2. Biological Input Forms. Once we receive all information from the laboratories, we begin to enter it on our Game Biological Input Form (Fig. 4). Since all information is digitalized, we have coded information, so we may enter it as per our Key to Game Biological Input Form (Fig. 5). Once all the information is entered, the Game Biological Input Form is sent for key punching and then entered into the computer. We check and correct entries from a computer file dump and edit programs. The data is now stored and ready for analysis.

3. Computer analysis (SPSS Program). We have selected the program entitled Statistical Package for the Social Sciences (SPSS) for our analysis because of its versatility (Nie et al. 1975).

III. DISCUSSION

Some methods we may potentially incorporate to apply the indicator animal concept to assess population status of reproduction, nutrition, disease, and stress have been outlined. No guidelines were given on selections of assessments because the choice will be dictated by many forces

including: (1) funding, (2) personnel and training level, (3) support personnel and laboratories, (4) location, (5) social and political constraints, (6) status of populations, (7) technology available, (8) cultural and religious constraints, and (9) data processing capabilities.

Each person and/or project must decide what parameters will provide the best information and which can be measured, given the limitations any project must work under. The goal should be to be as inclusive as possible. The potential of involving interested persons from Outside institutions or laboratories to assist will often result in agreements whereby costs may be minimized.

Many procedures outlined will not be applicable to certain species until considerable base-line data is accumulated. Building base-line values should be considered as a study objective.

Information from our assessment may be limited to a single animal, and application to the population may be limited except in the case where a highly infectious disease may have been detected. However, most information regarding the population will come from accumulated data or representative sampling of the population.

Interpretation of findings from the indicator animal in many cases will require assistance from persons involved in the area of question. Our sampling has the potential of involving many specialities, such as clinical pathologists, biochemists, pathologists, histopathologists, biometricians, bacteriologists, mycologists, virologists, immunologists, parasitologists, toxicologists, nutritionists, population ecologists, and others. The point is that we must seek assistance and use a team approach for interpretations.

In some areas of interpretation, such as the use of blood chemistry and hematological values to assess status of free-ranging populations, we are in the learning process. Some values have proven useful in ruminants, such as BUN as an indicator of protein intake (Franzmann 1972), cholesterol as an index of nutritional condition (Coblentz 1975), alkaline phosphotase increase related to growth (Barrett and Chalmers 1979), corticosteroid levels as index of stress (Franzmann et al. 1975b), lowered thyroxine levels related to low-quality diet (Seal et al. 1972), and hematocrit and its relationship to condition (Franzmann and LeResche 1978).

There are other values that reflect change or differences between populations, but which are as yet not well understood due to lack of controlled studies. Kirkpartrick (1980) reviewed some of the problems associated with using blood characteristics as indicators of nutritional status, particularly stress of collection. To minimize some of the sources of variation, it is important to standardize procedure and to properly classify samples.

If we follow a standardized procedure, we begin to accumulate data on perhaps not just one population, but of several. We then have the capability of comparing populations if we have adequate samples. Comparing populations or even ranking them by one or more criteria will assist the manager in establishing priorities for the populations for which he is responsible. For example, if in a population comparison of blood parameters in spring, we note the values from one population that reflect general condition are significantly lower than another's and funding for studies are limited, we have established which population should receive first consideration for funding. Examples could be made for other criteria as well. Population health (condition) comparisons and ranking have been made using physiologic and morphometric data from moose in Alaska (Section II, A, 9).

Population comparison do not necessarily constitute the only workable product. As indicated earlier, information from a single animal or small sample may have a major consequence. As we accumulate information about a population, we begin to answer basic questions, but often it results in redirecting our efforts. These directions will be weighed with other factors and management decisions will follow. We can demonstrate this by outlining some choices and potential directions that management decisions may take based upon findings provided by our health assessment.

A. Infectious diseases

1. Determine source - epidemiology

2. Disposal of animals

3. Zoonotic disease - transmissible to humans; public health involvement.

4. Disease transmissible to domestic animals - agriculture involved.

5. Chronic disease - may be self-limiting.

6. Determine presence in adjacent populations

   a. collections - necropsy
   b. live animals - antibody titre

7. Quarantine

8. Population control

9. Overreaction - maintain a proper perspective; need input from diverse expertise

B. Noninfectious diseases

1. Nutritional origin

a. Malnutrition/starvation

(1) Cause - availability, quantity, and quality food
(2) Supplementation
(3) Population implication

b. Mineral deficiency

(1) Cause - availability, quantity, and quality of source
(2) Supplementation
(3) Population implications

2. Chemical or physical origin

a. Locate and eliminate source
b. Population implications

3. Stress origins

a. Identify stressor

(1) overpopulations
(2) harassment
(3) climate

b. Population implications

C. Parasitic disease

(1) Identify life cycle
(2) Control possibilities
(3) Population implications

The one single consideration common to all the above situations is the population implication. The single most important message from this entire outline is that when accumulating indicator data that one does not become enamored with the indicator itself and neglect to apply it to the population.

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APPENDIX B.

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BROWSE PRODUCTION AND ITS USE BY MOOSE AND SNOWSHOE HARES AT THE KENAI MOOSE RESEARCH CENTER

RH: Browse Production and Utilization on the Kenai · Oldemeyer

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Abstract:

A 4-year study was conducted at the Moose Research Center (MRC) on the Kenai National Wildlife Refuge, Alaska, to evaluate the effect of different densities of moose (Alces alces gigas) on paper birch (Betula papyrifera) production and utilization. Secondary objectives were to estimate production and utilization of aspen (Populus tremuloides) and willow (Salix spp.) and to evaluate the impact of snowshoe hares (Lepus americanus) on paper birch. The study was conducted in the 4-2.6 km^2 enclosures of the MRC where

different densities of moose were maintained in each enclosure. Densities ranged from 1,237 to 5,851 moose days per pen per winter period. Tagged birch saplings in 81 stands in the 4 enclosures and in 20 stands outside the fenced portion of the MRC were measured in fall to estimate production and in spring to estimate utilization. Paper birch produced an average of 102 kg/ha in the 4 enclosures whereas willow and aspen, together, produced only 3.7 kg/ha. During the first 3 years there was a significant difference in per plant production among the 5 important vegetative types. The stocking rate of moose began having an effect the third year and significant differences in mean plant production among enclosures occurred during the third and fourth years. Birch utilization ranged from 31.8 to 83.3% of current annual production. Pen 4, which contained very high moose populations, received heaviest utilization ranging from 61.8 to 83.3%. During the 4 years, snowshoe hares browsed a greater percentage of tagged plants than did moose. There was a dichotomy in forage use between hares and moose; 65% of the birches browsed by hares were less than 1.5 m tall and 62% of those browsed by moose were taller than 1.5 m. Height growth of birch was affected by browsing; plants browsed in a given year were shorter on the average the following growing season. Seventy percent of the willow and 58.7% of the aspen plants were browsed during winter. Low production, high utilization, and low density of aspen and willow point out their susceptibility to overbrowsing. It was concluded that habitat management is necessary to maintain healthy browse ranges.

Key words: moose, Alces alces gigas, Kenai Peninsula, paper birch, Betula papyrifera, snowshoe hares, Lepus americanus, pen study, willow, Salix spp., aspen, Populus tremuloides, browse production, browse utilization

I evaluated the effects of habitat use by moose (Alces alces gigas) at the Moose Research Center (MRC) on the Kenai National Wildlife Refuge, Alaska, from October 1971 through May 1975. The project complemented research on moose biology which has been reported by LeResche and Davis (1973), LeResche and Rausch (1974), Franzmann et al. (1975), Oldemeyer et al. (1977), Franzmann et al. (1978), Franzmann and LeResche (1978), and Oldemeyer and Franzmann (1981).

The primary objective of the present study was to evaluate the effect of different moose densities on production and utilization of paper birch (Betula papyrifera). Although aspen (Populus tremuloides) and willow (Salix spp.) occur at the MRC, paper birch was emphasized because it was the dominant forage species and LeResche and Davis (1973) found that it made up the bulk of the moose's year-round diet. Populations of snowshoe hare (Lepus americanus) were near a cycle high when the study began and were having an obvious effect on the vegetation. Therefore, the secondary objectives of the study were to estimate production of aspen and willow and their utilization by herbivores, and evaluate the impact of snowshoe hares on paper birch.

The MRC is located in the northern portion of the Kenai Lowlands on the western side of the Kenai Peninsula. Vegetation in the

lowlands consists of plants associated with the northern boreal forest where white spruce (Picea glauca) is the climax tree and seral communities contain paper birch and aspen mixed with white spruce. Black spruce (Picea mariana) occurs in wetter sites and disturbed sites. The MRC consists of 4 enclosures, each 2.59 km^2, within a 125,500 ha area that was burned in 1947. This fire had a beneficial effect on moose populations because it created seral ranges containing an abundance of browse species (Spencer and Hakala 1964).

Vegetation in the 4-2.59 km^2 pens at MRC was not disturbed since 1947 other than minimal clearing when the fences were built during 1968-1970. As a part of other studies the moose populations were managed to maintain 3 levels: a normal level comparable to outside the MRC (Pen 3); an unrestricted level allowed to fluctuate naturally (Pens 1 and 2); and a high level which severely over-used the vegetation (Pen 4). During the last 2 years of the study, production and utilization of browse outside the enclosures was evaluated. Stocking density of moose in the pens from 1971 to 1975 is shown in Table 1 (from Franzman and Arneson 1975).

P. D. Arneson, A. W. Franzmann, and R. E. LeResche of the Alaska Department of Fish and Game; J. B. Hakala, J. B. Monnie, and R. K. Seemel of the Kenai National Wildlife Refuge; and R. B. Finley, Denver Wildlife Research Center provided logistic support and guidance for the study. I thank S. Blackhall, T. Corr, R. Pietron, D. Porter, and T. Spraker for their capable field assistance. The manuscript was reviewed by C. P. Stone, National Park Service;

Table 1. Days of moose use (number of moose) in 4 pens at the Kenai Moose Research Center during winters (Oct 1 - May 1) 1971-74.

	Pen			
Winter	1	2	3	4
1971	3625 (17)	4183 (20)	2486 (12)	5851 (28)
1972	2515 (12)	2956 (14)	1484 (7)	4084 (19)
1973	1662 (8)	3015 (14)	1816 (9)	3910 (18)
1974	1237 (6)	2590 (12)	1600 (8)	3213 (15)

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The Moose Research Center is a cooperative research project between the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service.

METHODS

Twenty stands of vegetation, ranging from 0.18 to 1.25 ha, were randomly selected for study in each pen. A twenty-first stand was used in Pen 4. A stand was described for this study as being of 1 vegetative type and relatively uniform topography. Seven upland vegetative types occur in the MRC; however, only 5 were of importance as browse producing types (dense, medium, and thin birch-spruce regrowth; spruce-birch regrowth; and thin mature hardwoods). The number of stands sampled in each of the 5 vegetative types (Table 2) was determined by a combination of the size of the vegetative type in the pen and the relative importance of the type for producing moose forage (Oldemeyer 1981). Twenty stands were sampled outside the MRC; they were allocated proportionately to vegetative types of the 81 stands within the pens and were no closer than 400 m to any fenceline.

In each stand, I estimated density of woody plants using a sample of 25 randomly located 1 x 5 m quadrats. To study birch production and utilization, I randomly selected and tagged 24 individual birch saplings in each stand. Saplings more than 50 cm

Table 2. Size of vegetative types in the Kenai Moose Research Center and allocation of sampled stands among types.

Pen		Birch - Spruce Regrowth			Spruce- Birch Regrowth	Spruce Regrowth	Mature Hardwood		Pen Size	All Regrowth
		Dense	Med.	Thin			Dense	Thin		
1	Hectares	45.7	38.5	27.9	16.2	36.0	21.9	18.6	240	164.3
	No. stands sampled	10	6	2	2	0	0	0		
2	Hectares	28.7	32.4	33.2	14.2	42.9	43.3	68.8	271	151.4
	No. stands sampled	6	6	4	2	0	0	2		
3	Hectares	37.2	28.3	28.7	7.7	12.1	71.7	40.9	253	114
	No. stands sampled	8	5	4	0	0	0	3		
4	Hectares	9.3	40.9	33.2	17.4	20.6	47.8	70.4	260	121.4
	No. stands sampled	2	8	5	3	0	0	3		
Outside										
	No. stands sampled	6	6	4	2	0	0	2		

in height and less than 4.2 cm DBH were considered as available browse. Production and utilization were estimated in Pens 3 and 4 in 1971-75, Pen 2 in 1972-75, and Pen 4 and outside 1973-75.

Oldemeyer (in press) described in detail the procedure used to estimate birch production and utilization. Regression equations of the form: Production = $a + b_1$ (circumference) + b_2 (circumference)^2 + b_3 number of current annual growth (CAG) twigs were developed from clipped plant measurements and weights each fall and were used to estimate current annual growth production of each tagged sapling. Diameters of browsed twigs on the tagged saplings were measured each spring and regression equations of the form: Twig weight = $a + b_1$(twig diameter) + b_2(twig diameter)^2 were used to estimate how much current growth was removed by browsing from each tagged sapling. In addition to the spring measurements on each plant, I recorded whether the plant had been browsed by moose or snowshoe hares.

Willow and aspen saplings were sampled for production and utilization only during 1974-75 due to their scarcity. Of the 20 stands in each enclosure, the 2 with the greatest density of aspen or willow were selected for study. Twenty-four aspen or willows were selected and tagged in the same manner as birch except there was no minimum size restriction. Regression estimation of production did not work well because of the reduced vigor of the plants. Therefore, only CAG and height were used to describe production and "percent of plants browsed" was used to describe utilization of those tagged saplings.

RESULTS

Woody Plant Density

Most of the study stands were in the birch-spruce regrowth types (Table 2) because they produced the most browse (Oldemeyer 1981). Dense mature hardwoods made up a large proportion of MRC; however, so little browse is produced in this type that it was not given enough weight, compared with other types, to warrant establishment of study stands.

Fifty-four percent of the area of the MRC was regrowth vegetation (Table 2), the result of the 1947 fire. In regrowth stands black spruce and paper birch were the dominant species (Table 3). Of the browse species (paper birch, willow, and aspen), paper birch had a relative density of 90% in all vegetative types except thin mature hardwoods. Willow had a relative density in regrowth types of 7%. Aspen was most important in thin mature hardwood types where its relative density was 49% (Table 3).

Average birch density ranged from 3,813 plants/ha in the thin mature hardwood type to 24,983 plants/ha in the dense birch regrowth type. Birch density in dense birch regrowth types was somewhat higher than browse density at 1 of the highest browse producing areas on the KNWR studied by Oldemeyer and Regelin (1980) and was higher than regrowth stands in other parts of Alaska (Milke 1969; Wolff and Zasada 1979). However, Wolff (1980) estimated high black spruce densities of 20,512 plants/ha in spruce thickets in interior Alaska.

Table 3. Density (stems/ha) of woody plants in 101 stands at Kenai Moose Research Center.

Habitat Type	White Spruce	Black Spruce	Paper Sirch	Aspen	Willow	Total Browse Density
Dense birch-spruce regrowth						
Density ±	12,332.8	3,903.6	24,983.2	51.5	558.3	25,593.0
Std. Dev.	1,238.0	1,413.9	1,383.0	107.0	610.6	
Freq. of occurrence	66.4	40.6	86.5	2.2	14.5	
Medium birch-spruce regrowth						
Density ±	3,446.7	8,117.2	5,664.6	402.2	532.5	6,599.3
Std. Dev.	5,664.6	5,556.2	14,903.2	532.5	2,214.3	
Freq. of occurrence	31.3	74.7	76.9	12.0	19.1	
Thin birch-spruce regrowth						
Density ±	1,293.8	9,635.4	18,133.4	286.0	2,069.6	20,480.0
Std. Dev.	1,820.4	5,510.7	11,463.0	304.8	2,715.6	
Freq. of occurrence	22.3	72.4	83.3	9.7	23.1	
Spruce-birch regrowth						
Density ±	558.8	12,902.1	8,000.4	93.4	758.8	8,852.6
Std. Dev.	909.5	6,315.6	1,792.2	136.5	4,593.2	
Freq. of occurrence	12.7	90.9	78.3	4.2	9.9	
Thin mature hardwoods						
Density ±	1,139.9	1,678.4	3,813.4	3,876.6	184.1	7,874.1
Std. Dev.	1,719.4	1,719.4	3,607.4	2,677.1	188.4	
Freq. of occurrence	29.8	26.1	35.6	51.6	6.3	

Birch Production

Average birch production was compared among types and among pens for each of the 4 years by analysis of variance. Significant differences ($p \geq 0.95$) occurred each year (Table 4). During the first 2 years, these differences were among types, and the type means maintained the same relative order each year. Average birch production was greatest in spruce-birch regrowth stands (4.3 and 9.0 g/plant in 1971 and 1972, respectively) whereas thin mature hardwood stands produced only 1.4 and 1.7 g/plant, respectively.

By 1973 the different moose densities were having detectable influence on plant production (Table 4). Plant production in Pen 1 was highest at 6.1 g/plant while Pen 3 was lowest at 3.7 g/plant. During 1973 there was also a significant difference in plant production among types, with a ranking order similar to previous years. The order of production among pens was similar in 1973 except the average production per plant was lowest in Pen 4 rather than Pen 3.

Total birch production was greatest in Pens 1 and 2 (Table 5). The difference in production between Pens 3 and 4 increased each year for the 4-year period as did the difference between Pens 2 and 4 for 1972-74. Production varied annually due to precipitation and growing season, but the trend indicates that the heavy stocking rate of moose in Pen 4 reduced production.

Dense birch regrowth stands produced, on the average, as much as 223 kg/ha whereas thin mature hardwood stands produced only a maximum of 32.5 kg/ha. Much of the difference is undoubtedly due to

Table 4. Birch production (g) on a per plant basis by habitat types and years at the Kenai Moose Research Center. Sample sizes are in parentheses. Type means with the same letter were not significantly different.

Year	Pen	Habitat Type: Regrowth			
		Dense birch-spruce	Medium birch-spruce	Thin birch-spruce	Spruce birch
1971	3	3.5(192)	2.1(120)	3.2 (96)	-
	4	3.7 (72)	3.2(144)	2.5(120)	4.3 (96)
	Type Mean	3.5(264)[a]	2.7(264)[a]	2.9(216)[a]	4.3 (96)[a]
1972	2	6.4(120)	6.4(144)	4.9(120)	13.8 (48)
	3	5.3(192)	3.8(120)	5.2 (96)	-
	4	7.1 (72)	4.0(144)	4.8(120)	6.6 (96)
	Type Mean	6.1(384)[a,b]	4.8(408)[b]	5.1(336)[b]	9.0(144)[a]
1973	1	6.2(240)	8.8(120)	3.1 (72)	11.5 (48)
	2	5.5(120)	5.3(144)	5.7(120)	10.8 (48)
	3	4.5(192)	2.8(120)	4.7 (96)	-
	4	5.5 (72)	2.9(144)	4.4(120)	6.2 (96)
	5	4.3(120)	6.8(144)	3.1 (48)	6.6 (96)
	Type Mean	5.3(744)[a,b]	5.3(672)[a,b]	4.5(456)[b]	8.0(288)[a]
1974	1	9.1(240)	12.7(120)	4.2 (72)	15.2 (48)
	2	8.0(120)	7.6(144)	8.1(120)	15.0 (48)
	3	6.5(192)	3.9(120)	7.8 (96)	-
	4	7.5 (72)	5.4(144)	5.8(120)	6.2 (96)
	5	6.6(120)	8.2(144)	6.2 (48)	8.6 (96)
	Type Mean	7.7(744)[a,b]	7.5(672)[a,b]	6.6(456)[b]	10.0(288)[a]

Table 4. Continued.

Year	Pen	Habitat Type: Thin mature hardwoods	Habitat Type: Pen Average
1971	3	1.6 (72)	2.8(480)[a]
	4	1.2 (72)	3.0(504)[a]
	Type Mean	1.4(144)[a]	2.9(984)
1972	2	2.1 (48)	6.3(480)[a]
	3	2.1 (72)	4.4(480)[a]
	4	1.1 (72)	4.7(504)[a]
	Type Mean	1.7(192)[c]	5.2(1464)
1973	1	-	6.9(480)[a]
	2	1.4 (48)	5.6(480)[a,b]
	3	1.5 (72)	3.7(480)[b]
	4	0.8 (72)	3.9(504)[b]
	5	2.0 (72)	5.1(480)[a,b]
	Type Mean	1.4(264)[c]	5.0(2464)
1974	1	-	9.8(480)[a]
	2	2.6 (48)	8.0(480)[a,b]
	3	3.0 (72)	5.6(480)[b]
	4	1.5 (72)	5.4(504)[b]
	5	4.1 (72)	7.1(480)[a,b]
	Type Mean	2.8(264)[c]	7.2(2424)

Table 5. Birch production by habitat, pen, and year (kg/ha) at the Kenai Moose Research Center.

Year	Pen	Habitat Type					
		Regrowth					
		Dense birch-spruce	Medium birch-spruce	Thin birch-spruce	Spruce-birch	Thin mature hardwoods	Kg/pen
1971	3	172.7	91.0	82.8	-	6.0	11,619
	4	101.8	105.2	97.2	76.2	6.7	10,295
1972	2	131.0	136.2	63.0	93.5	11.1	12,357
	3	166.0	85.6	86.9	-	6.3	11,347
	4	97.2	71.9	109.0	77.4	4.3	9,115
1973	1	141.5	115.9	51.4	41.4	-	13,033
	2	127.8	139.5	64.3	77.8	8.1	11,867
	3	151.2	80.1	74.7	-	4.7	10,226
	4	86.3	52.4	100.8	64.0	3.9	7,681
	Outside	125.0	120.7	85.5	63.8	17.9	
1974	1	223.1	179.0	97.0	62.2	-	20,866
	2	186.5	190.0	101.1	104.4	14.1	17,318
	3	217.0	109.5	124.0	-	8.0	15,058
	4	116.5	100.5	159.4	74.1	7.3	12,292
	Outside	187.6	159.3	158.6	92.0	32.4	

birch density in those habitat types; however, birch production was consistently low on a per plant basis in the thin mature hardwoods type.

Aspen and Willow Production

Production of willow and aspen was considerably less than birch for both species in all pens and vegetation types (Table 6). Overall production estimates indicate paper birch produced an average of 102 kg/ha in the 4 pens whereas willow and aspen combined produced an estimated 3.7 kg/ha, or 3.5% of the total browse production in 1974. Production of willow and aspen was lower than ranges examined by Wolff (1978) and Milke (1969) where up to 204 kg/ha of willow was produced. Birch production was similar to production of mountain maple (Acer spicatum) and beaked hazel (Corylus cornuta), individually, on the Gaspe' Peninsula (Bedard et al. 1978). Total browse production at that study location included balsam fir (Abies balsamea) and exceeded 600 kg/ha on browsed range 8-years postlogging. On a 20-25 year-old clearcut in New Brunswick, Telfer (1972) reported deciduous browse production of 112 kg/ha, similar to MRC.

Birch Utilization

Birch utilization by both moose and snowshoe hares (Table 7), ranged from 31.8% to 83.3% of current annual production. Pen 3 had the lightest utilization except in 1973-74. During each year, Pen 4 had the heaviest utilization, ranging from 61.8% to 83.3% of the production.

Table 6. Summary of aspen and willow production and utilization during 1974-75.

Stand no.	Vegetative type[a]	No. CAG (X/SD) (g)	Fall height (X/SD) (cm)	Production (X/SD) (g)	Stand Production (kg/ha)	Fall plants browsed (%)	Spring plants browsed (%)
Aspen							
1-29	TBR	2.1/1.6	36.8/20.5	0.4/0.82	0	50.0	56.2
1-24	DBR	1.5/0.9	30.4/14.8	0.9/1.27	0.07	42.0	58.3
2-26	TMH	2.5/2.4	38.0/14.6	1.1/1.42	8.21	62.5	75.0
2-40	TMH	2.5/2.9	32.5/18.9	0.4/0.40	0.43	60.4	91.7
3-18	TMH	2.7/2.0	48.8/34.8	0.6/0.80	1.44	31.2	31.2
3-24	TMH	4.4/2.9	60.1/21.9	0.7/0.50	2.99	4.2	33.3
4-19	TMH	1.7/1.2	32.6/12.2	0.5/0.40	2.10	37.5	50.0
4-36	TMH	2.3/1.5	31.7/12.0	0.3/0.21	0.59	56.3	62.5
5-06	TMH	1.9/1.7	33.1/12.9	0.9/0.70	5.95	35.4	62.5
5-15	TMH	1.8/1.0	40.5/15.1	0.7/0.60	4.32	27.1	56.3
Willow							
1-26	DBR	6.8/9.9	90.7/40.5	1.94/2.0	3.10	68.8	81.3
1-42	DBR	4.2/3.9	82.9/45.7	1.10/1.23	0.66	58.3	66.7
2-08	TBR	10.1/17.0	74.6/30.1	0.78/1.14	0.94	58.3	58.3
2-21	DBR	4.7/4.8	77.6/33.6	1.2/0.94	0.72	56.3	77.1
3-10	DBR	5.0/2.7	62.1/18.0	1.8/3.60	0.74	25.0	85.4
3-13	TBR	5.2/4.6	77.0/34.2	1.0/1.43	0.60	45.6	68.8

Table 6. Continued.

Stand no.	Vegetative type	No. CAG (X/SD) (g)	Fall height (X/SD) (cm)	Production (X/SD) (g)	Stand production (kg/ha)	Fall plants browsed (%)	Spring plants browsed (%)
4-27	MBR	4.6/6.6	52.8/21.3	0.51/1.00	0.51	79.2	83.3
4-31	TBR	4.2/3.6	48.8/17.3	0.60/0.30	0.48	56.3	56.3
5-02	TBR	9.4/15.5	61.8/23.6	1.3/1.70	1.82	42.0	62.5
5-11	DBR	6.3/7.8	67.5/23.8	0.83/1.02	.50	60.4	60.4

a/ TBR - thin birch-spruce regrowth
DBR - dense birch-spruce regrowth
TMH - thin mature hardwoods
MBR - medium birch-spruce regrowth

Table 7. Utilization of birch at the Kenai Moose Research Center by moose and snowshoe hares. Utilization is expressed as percent of production, percent of CAGs, and percent of plants browsed.

	Pen 1			Pen 2			Pen 3		
Year	Pro-duction	CAG	Plants	Pro-duction	CAG	Plants	Pro-duction	CAG	Plants
1971		-			-		31.8	31.1	64.4
1972		-		58.2	60.6	81.7	55.4	58.8	77.9
1973	46.2	43.7	66.3	75.5	73.0	91.3	72.8	71.7	89.0
1974	43.2	43.3	67.1	51.8	54.0	77.1	39.6	40.6	60.0

Table 7. Continued.

Year	Pen 4			Outside		
	Pro-duction	CAG	Plants	Pro-duction	CAG	Plants
1971	61.8	62.9	87.1		-	
1972	75.2	79.0	94.4		-	
1973	83.3	83.2	94.4	65.1	63.6	87.3
1974	62.1	63.6	81.7	44.6	47.7	75.4

Percent of plants and percent of CAG twigs browsed were high (Table 7). Up to 94.4% of the plants and 83.2% of the CAG twigs in Pen 4 were browsed. Oldemeyer (in press) showed a high correlation among the three measures of utilization which allows use of one measure to predict either of the other 2.

Of the five habitat types, average percent of birch production browsed was lowest in the thin mature hardwood type (50.9%). This was probably due to a combination of low density of food in that type, the short height of plants which made them unavailable for part of the winter, and the availability of an alternate food, aspen. Average utilization in the dense birch regrowth types over the 4 years was 62.1%, the highest of all habitat types.

Birch plants were subdivided into those browsed only by moose, those browsed only by snowshoe hares, and those browsed by both (Table 8). Hares browsed a greater percentage of plants than did moose in most years, pens, and types. Of those plants browsed only by moose, percent of current annual production browsed ranged from a low of 47.0% outside the MRC during 1974-75 to a high of 76.2% in Pen 4 during 1973-74. During each year, utilization was highest in Pen 4. Percent of all plants browsed by moose ranged from a low of 25.0% in Pen 3 in 1974-75 to a high of 56.0% outside during 1973-74, and was consistantly highest in Pen 4 and outside.

Considering the plants browsed only by moose, utilization was higher than reported in most other studies. Telfer (1972) reported that moose and deer browsed a maximum of 10.3% of available browse in a 2-year old clearcut in New Brunswick. Wolff (1978) found that

Table 8. Utilization of plants browsed by moose or hares by year and pen.

Year	Pen	Percent browsed by moose				Percent browsed by hares			
		Current annual production	CAG twigs	Plants by only moose	Plants by moose and hares	Current annual production	CAG twigs	Plants by only hares	Plants by moose and hares
1972	2	51.3	52.5	12.9	36.3	79.8	81.2	45.4	68.8
	3	57.4	61.7	18.8	34.1	81.2	84.6	42.1	59.2
	4	67.2	71.0	20.0	50.8	87.2	88.9	43.6	78.1
1973	1	53.0	47.9	32.5	39.8	88.7	87.6	26.4	33.8
	2	70.2	65.0	25.8	41.0	90.6	88.8	50.6	67.9
	3	68.3	62.2	14.4	33.8	89.2	88.5	55.2	74.6
	4	76.2	79.0	14.3	42.3	92.2	90.7	52.2	80.2
	Outside	63.1	59.0	32.1	56.7	85.1	84.0	30.6	55.2
1974	1	58.4	55.4	15.0	26.5	68.2	69.0	40.6	52.1
	2	54.9	58.5	19.6	39.0	75.6	77.6	38.1	57.5
	3	54.6	51.3	16.0	25.0	72.6	74.3	35.0	44.0
	4	64.5	66.2	28.0	53.4	82.6	83.2	28.4	53.8
	Outside	47.0	49.8	30.4	46.7	70.4	73.0	28.8	45.0

10.2% of the 52.5 kg/ha of willow produced in a recent burn in interior Alaska was browsed. A similar degree of browsing was reported by Bedard et al. (1978), and Peek et al. (1976) observed only 7-36% of birch twigs browsed in Minnesota.

However, Bergerud and Manuel (1968) in Newfoundland and Wolff and Zasada (1979) in Alaska reported heavy browsing intensity by moose. In interior Alaska 67-77% of the plants were browsed and up to 79% of available forage (containing more than CAG) was browsed. In that study, where birch, aspen, willow, and alder were present in one site, 22% of the birch, 79% of the willow, 44% of the aspen, and 4% of the alder was browsed. In Newfoundland, moose browsed 51-81% of the stems in areas 4-13 years after logging. Under browsing intensities of this magnitude, average height of birch was only about 30 cm and mortality due to excessive browsing had occurred.

Snowshoe hare browsing was greatest (89.6% of production) during 1973-74, the year I considered to be the peak of the population cycle. Utilization among types was similar except for the spruce-birch type in which utilization was considerably lower than the others. Browsing intensity of the plants browsed only by hares was greater than on the plants browsed only by moose (Table 8).

Lower levels of hare browsing were observed by Telfer (1972) in New Brunswick where snowshoe hares browsed up to 4.9% of the available forage in a 15-18 year-old cutover. Pease et al. (1979) determined that in about half of the woody stems sampled, over 50% of the terminal or the lateral twigs had been clipped off by snowshoe hares. They considered this level of use to be heavy to severe browsing.

Birch Response to Browsing

I evaluated plant response to different browsing intensities using differences in production and height (Figs. 1 and 2). A production ratio was calculated for each of 11 utilization categories (0% to 100% in 10% increments) by summing the production estimates of the plants in a given utilization category and dividing that sum by the summed production of those same plants the previous year. The ratio behaved erratically each of the 3 years (Fig. 1). In 1972 the ratio peaked at 30% and 70%. In 1973 the ratio immediately dropped below the level of the 0% browsed plants and continued this drop to the point that the 1973 plants only produced about 65% as much forage at the 100% utilization level as they did in 1972. In 1974 the ratio behaved as I had originally hypothesized with a peak at 30% utilization followed by a drop to below the 0% ratio that continued to the 100% level.

A height ratio using fall height measurements (Fig. 2) was calculated in a similar manner as the production ratio. In 1972 and 1973, the ratio immediately fell to a level below the 0% browsed plant ratio. In 1974 the ratio peaked at 10%, gradually dropped, and went below the ratio of the 0% browsed plants when utilization was at the 50% level.

The response in birch production contrasts to what Aldous (1952) observed for birch in the Great Lakes region and to what others (Garrison 1953; Ferguson and Basile 1966; Willard and McKell 1978; and Wolff 1978) have observed for saplings and shrubs. The Kenai Lowlands are at a western extreme of the boreal forest and the range

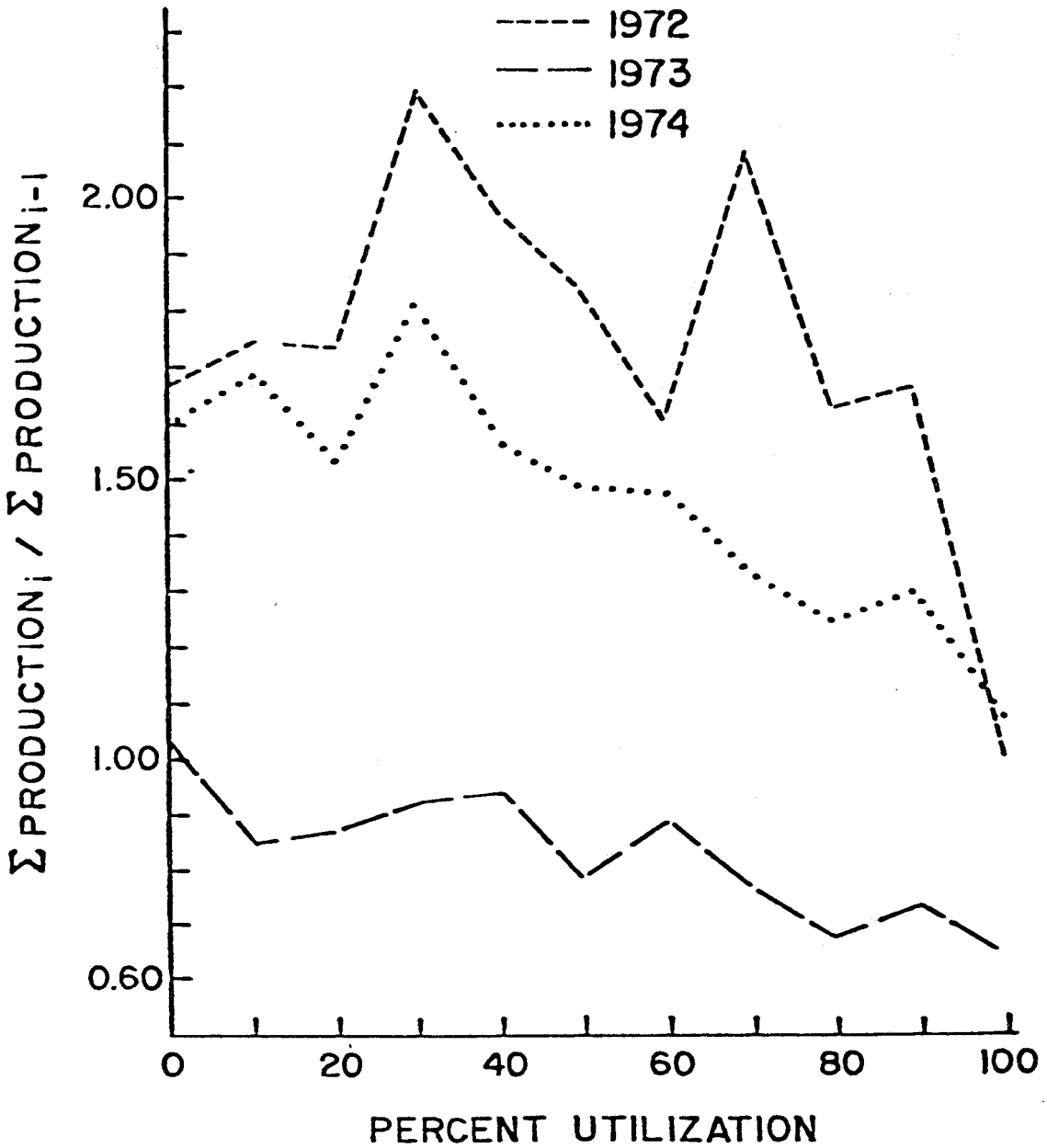

Fig. 1. Response of production to different intensities of browsing (from Oldemeyer 1981).

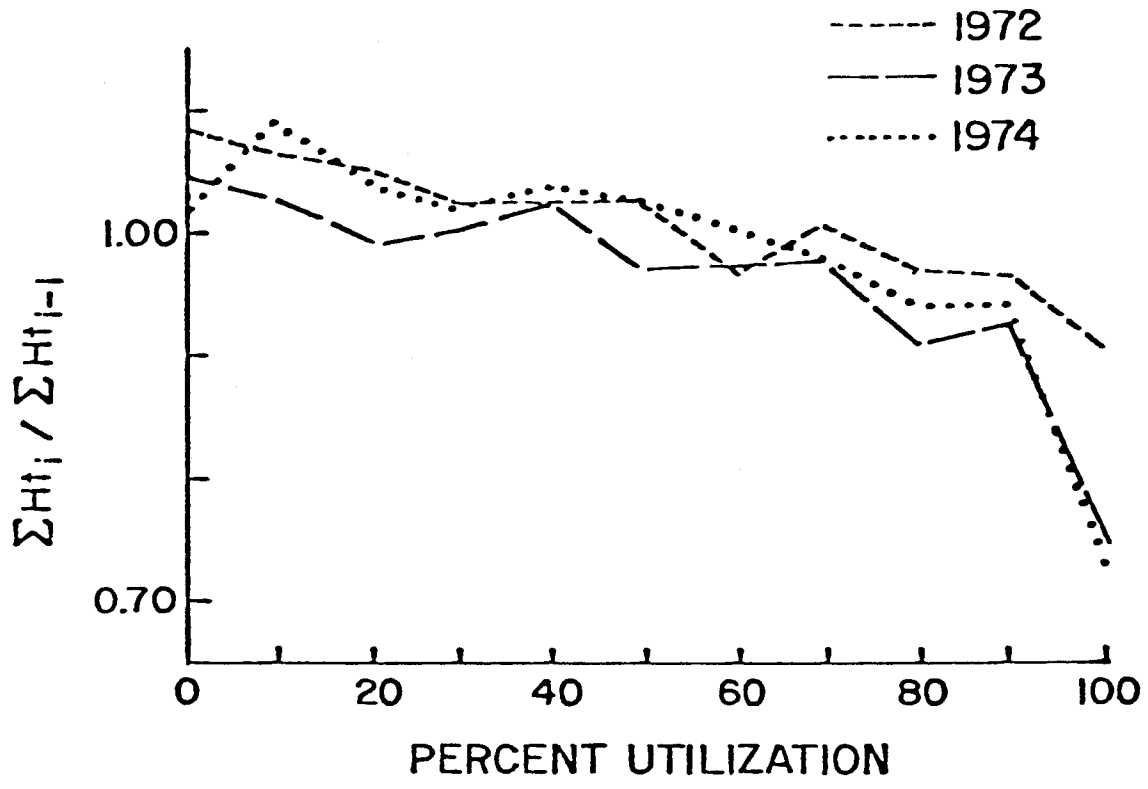

Fig. 2. Response in height growth of birch to different intensities of browsing (from Oldemeyer 1981).

of paper birch in Alaska, and this growing location may affect the response of birch to browsing. During 1973, when May-September precipitation was lowest and when degree days were highest of the 4 years of the study, the response curves show no stimulation effect of browsing (Figs. 1 and 2). A slight stimulation in production at low utilization levels was observed when weather was warmer and wetter in 1972 and 1974. Near Aldous' (1952) study sites in the Great Lakes region, both temperature and precipitation are normally greater than on the Kenai Lowlands, perhaps inducing the response reported by Aldous.

Broken Stems of Birch

Telfer and Cairns (1978) described stem breakage by moose in Canada where they found that moose broke stems up to 3.5 cm DBH. I found larger stems broken and set the maximum size limit for browse as 4.2 cm DBH. As a result some tagged plants exceeded 4 m in height. In many other studies, 2.5 m is considered an upper limit for moose browse; my data indicate that 2.5 m is not a realistic maximum height for moose browse studies.

Stem breakage was not great; in Pen 4 breakage averaged only 0.4% of the marked plants per year, whereas in Pen 1 an average of 2.1% were broken each year. Height of broken plants in 1974 ranged from 1.7 to 5.0 m and averaged 2.4 m. Plants of this height averaged over 15 g of forage production but made up only 5% of the browse population (Fig. 3). None of the marked plants which were broken died.

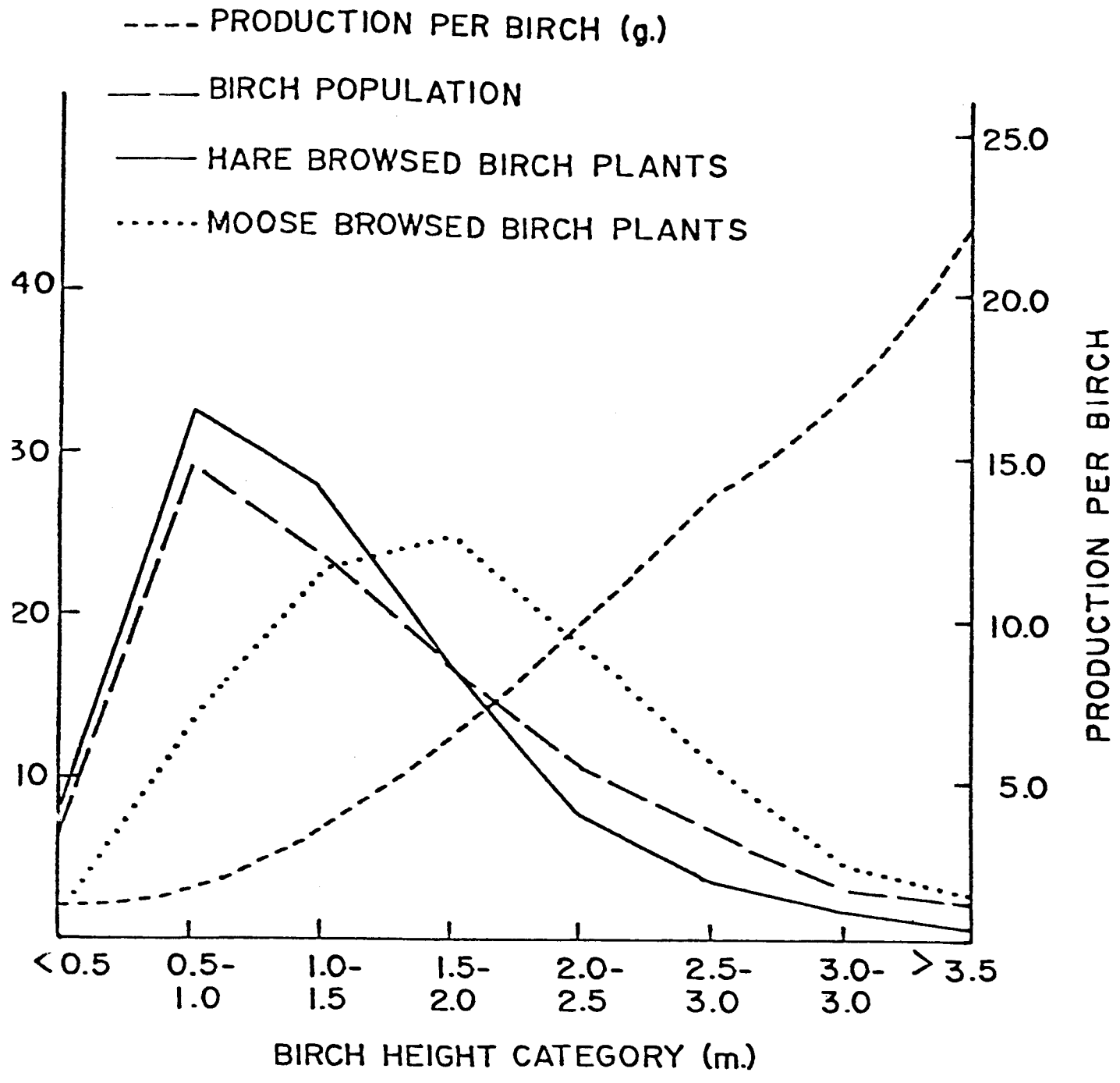

Fig. 3. Birch heights as related to production, browsing by moose and hares, and the normal birch population at the Kenai Moose Research Center and outside study sites.

Birch Mortality

Hare browsing caused birch mortality in 9% of the 2424 tagged plants during winter 1973-74. Clipping the stem below the lowest external bud was generally the cause of mortality. This high mortality followed the peak in the hare population cycle at MRC. The previous fall, 5% of the tagged plant population was replaced because of mortality.

Although no mortality was attributed to moose in this study, an early KNWR Annual Report (1965, p 46a) graphs the mortality of tagged browse plants over a 12 year period. At the end of 12 years, 75% of the willow, 65% of the aspen, and 44% of the birch plants had died. This mortality was attributed to heavy browsing by moose.

Aspen and Willow Utilization

Browsing levels of willow and aspen were high (Table 6). Fall production surveys revealed an average of 40.7% of the aspen plants in the 10 study stands had been browsed. By spring, utilization had increased to 57.8%. Willow utilization was higher than aspen both in the fall and spring surveys; 55.0% and 70.0%, respectively, of the willow plants were browsed.

In regrowth stands, willow and aspen were generally found growing between 2 or more close-growing spruces, protected from moose. Height distribution and production of these species are indicative of intense browsing. In lightly browsed stands both species would have been considerably more productive. Peek et al. (1976), for example, estimated utilization levels of 11-48% of leaders browsed on willow and aspen and believed that this

utilization was not excessive with respect to plant vigor and production.

Allocation of Birch to Browsers

A record of which animal browsed each twig was not kept; thus only a range of use by species can be made. Fig. 3 shows that production increased with height and that over 65% of the plants browsed by hares were less than 1.5 m tall. These plants averaged less than 3.5 g production each. On the other hand, 62% of the birch plants browsed by moose were over 1.5 m tall. Those plants averaged at least 6.4 g production. Whereas hares browsed the shorter plants, they also browsed birch proportionately to its occurrence in the population.

The plants browsed by only moose were larger than those browsed by only hares. Using Table 9 and the moose density of each pen, I calculated the kilograms of birch browsed by moose in each pen. For those plants browsed only by moose this value ranged from 0.18 kg/moose day in Pen 4 to 1.94 kg/moose day in Pen 1. This represents a minimum consumption since it is made up of only birch CAG of the plants browsed only by moose. Ignoring the plants browsed by only hare and assuming (incorrectly) that moose consumed all the forage browsed on the remaining browsed plants, then the maximum daily consumption could have ranged from 1.2 to 3.8 kg/day of birch. LeResche and Davis (1973) estimated that moose consumed 1.3 kg/day of forage during the winter of 1970-71 on normal ranges in the MRC. Almost 15% of that was mountain cranberry (Vaccinium vitis-idaea). Birch made up 77% of the diet and a significant but undetermined portion was older growth twigs.

Table 9. Utilization of birch browsed by only moose, only hares, and both moose and hares at the Kenai Moose Research Center.

	Pen 1			Pen 2			Pen 3		
	Moose	Hare	Moose & hare	Moose	Hare	Moose & hare	Moose	Hare	Moose & hare
1972									
g/plant				11.0	3.5	10.8	5.2	2.8	7.7
g browsed/ plant				5.5	2.1	6.0	2.6	1.7	4.1
% Util.				49.7	59.5	55.8	49.6	60.3	53.9
1973									
g/plant	9.4	1.7	9.3	10.5	2.0	8.7	5.7	1.9	7.3
g browsed/ plant	4.5	1.4	7.0	7.2	1.6	6.0	3.3	0.9	4.8
% Util.	48.4	80.3	74.9	68.8	82.3	68.6	58.0	47.4	64.8
1974									
g/plant	14.0	6.2	17.7	11.4	5.1	13.4	7.6	3.8	10.7
g browsed/ plant	7.3	2.8	9.0	6.1	3.0	7.4	4.1	2.0	5.4
% Util.	52.0	44.9	50.6	53.5	58.6	54.9	54.0	52.5	50.2

Table 9. Continued.

	Pen 4			Outside		
	Moose	Hare	Moose & hare	Moose	Hare	Moose & hare
1972						
g/plant	2.6	2.9	8.9			
g browsed/ plant	1.7	2.2	6.4			
% Util.	65.4	77.7	72.3			
1973						
g/plant	3.9	1.7	7.4	6.8	1.8	6.9
g browsed/ plant	3.2	0.9	6.3	3.9	0.9	4.9
% Util.	8.2	53.6	85.6	56.6	47.3	70.7
1974						
g/plant	4.8	3.3	9.8	8.0	4.5	13.0
g browsed/ plant	3.3	2.9	8.3	3.5	2.4	7.4
% Util.	68.7	87.2	84.3	43.3	53.0	56.8

Two studies (Conroy et al. 1979; Wolff 1980) have shown that hares are closely associated with habitats containing a high density of cover. The combined density of all woody plants at the MRC (Table 3) approaches the density of preferred winter habitat (Type III) near Fairbanks (Wolff 1980). He estimated total shrub density exceeded 21,000 plants/ha. In the MRC, the only vegetative type with plant densities not approaching 20,000/ha was the thin mature hardwoods type. Assuming all vegetative types with fewer than 20,000 plants/ha were not preferred winter habitats for snowshoe hare, then about 43% of the MRC area was preferred winter habitat for hares.

DISCUSSION

Spencer and Chatelain (1953) described the preburn forests in one section of the 1947 burn as black spruce forest with scattered aspen. After the fire, abundant aspen root-sprouting occurred. Five years after the burn, unbrowsed aspen reached a height of nearly 3 m. By this time increased number of black spruce, paper birch, willow, and aspen seedlings occurred throughout the burn. Spencer and Chatelain's description is probably for an area to the southeast of the MRC where aspen is the dominant hardwood, however their description of the successional pattern is similar to what probably occurred at the MRC (Viereck 1973). LeResche et al. (1974) described the 1947 burn as one of the "most productive large areas of moose habitat known to them." They attributed this productivity to the combination of high forage production, generally mild winters, abundant alternative food (mountain cranberry), edge effect, and adjoining upland ranges.

Oldemeyer

My study occurred 25 years after the fire at a time when over 4 moose/km^2 wintered in the vicinity of MRC. The browse population was certain to be affected by moose populations of this size. Bergerud and Manuel (1968) showed that height growth of birch was severely retarded with high moose populations. Spencer and Chatelain (1953) thought aspen had low browsing resistance on the Kenai and that overuse would cause lowered productivity of willow. I found many more dead than live aspen and willow plants during the density surveys of my study. The high use of those two species is probably the reason for their short heights and low production and density.

At the time of my study (when there was only a single important browse species), the moose stocking rate had little effect on birch production except in Pen 4. In that pen the difference in production, compared with Pen 3, increased from 1971 through 1974 (Table 5). Height decreased slightly in Pen 4 from 121 to 113 cm/plant over the 4-year period whereas it increased slightly in Pen 3 from 133 to 135 cm/plant. I believe the slight height increase, which occurred in all pens except Pen 4, was due to the stimulating effect of moderate moose browsing as shown in Fig. 2.

Peek et al. (1976) and others have shown that both aspen and willow are preferred over birch as forage by moose. However, W.L. Regelin and I have unpublished data showing equal use of all 3 species on a 15 year-old mechanically disturbed area well-stocked with each. This study has shown that light browsing controls height growth, but not necessarily production, of birch. If willow and

aspen are less tolerant of browsing than birch, and my density surveys indicate that they are, then a basis for maintaining high forage production may be made by keeping the moose population at a level which does not overbrowse aspen and willow on a broad-scale basis.

This approach is probably not practical. A wildlife population with a good food supply will increase; thus hunting regulations must be geared to respond to reproductive success to avoid overbrowsing. However, severe winters cause greater concentration of moose and a greater browsing pressure on the shrub populations than would be observed in normal winters. If the moose population is managed to avoid overbrowsing critical areas, then the browse populations of areas receiving use in normal winters may grow out of reach. Thus, it is difficult to manage wild populations to achieve the desired effect on the vegetation. In addition, snowshoe hare populations rise and fall with little control by man. Their populations often crash because they have devastated their food supply. When shrubs such as willows are an important part of that food supply, high hare densities influence moose and habitat management.

Because of these uncontrollable influences, managing a moose population is more than creating innovative hunting seasons. If management is devoted to developing and maintaining a healthy moose population, then an active habitat management program is required. The benefits of such a program are an abundant food supply for moose, reduction in habitat deterioration, and an increase in habitat diversity for all species of wildlife.

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