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MONITORING STATUS (CONDITION, NUTRITION, HEALTH) OF MOOSE VIA BLOOD

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Studies of moose (*Alces alces*) blood parameters and their relationship to population status the past 10 years have focused upon identifying sources of variation (boundary conditions) and building baseline values within those boundary conditions. Studies quantifying changes in blood values relative to environmental changes were limited and assessment of resilience of moose to perturbation using blood were lacking. Blood parameters that best reflect condition of moose were identified (packed cell volume, hemoglobin, total serum protein, phosphorus, calcium). Their application was useful in population comparisons and for identifying populations that are at physiologic high or low extremes. Condition related baseline blood values were presented from selected Alaskan moose marker populations. Future needs for research are based around controlled studies using captive/tame moose. Potential for future application of blood parameters to research and management will grow with technological advances.

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Introduction

Moose (*Alces alces*) managers use 3 general methods to determine the status of a population; habitat evaluation, population statistics and direct animal assessments. Direct animal assessments consist of measures of morphology (form), behavior (activity), and physiology (function). The basis for direct animal assessments of the status of a population is the indicator animal concept (Franzmann 1971). This concept simply recognizes that since the animal is a product of its environment (Platt et al. 1964) we should utilize the animal to monitor changes in the environment.

Other papers in this symposium will review morphology and behavior. This review will cover blood as a physiologic monitor of moose in North America during the last decade following the review by LeResche et al. (1974). Blood, "the juice of life" is an ideal material because it serves as a transport medium to supply each cell in an animal all the nutrient requirements and to take from those cells the waste products of metabolism. Advances in recent years in animal capture (Tomkiewicz 1982) and laboratory procedure (Kaneko 1980) have enhanced our ability to sample live animals from free-ranging populations. Some additional physiological assessments may be obtained from dead animals (Franzmann

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1984). Marrow fat has been widely used to assess condition in moose (Franzmann and Arneson 1976, Fong 1981, Ballard et al. 1981, Peterson et al. 1982). Some other physiologic parameters (milk, urine) have been collected and analyzed but not used to assess population status (Franzmann et al. 1975a, Franzmann et al. 1976a, 1976b). Hair, however, was demonstrated to be useful for monitoring mineral metabolism in moose (Franzmann et al. 1974) and will be reviewed in this symposium.

The title of this review uses the terms status, condition, nutrition, and health as population criteria monitored. Each term has been used to describe similar or the same circumstances, but there are differences. Status covers all possibilities, as may condition; however, condition is generally associated with morphometric status. Health connotates freedom from disease, and this may apply to our considerations herein when we utilize the broad definition of disease (disharmony within the body, between the body and mind and between animals and the environment). Nutrition is perhaps most often used since this reflects nutrient dynamics between the animal and its environment.

Methods

Requirements needed to use blood parameters to assess the status of a population include: (1) determining boundary conditions (sources of variation), (2) establishing baseline values within boundary conditions, (3) quantifying changes in blood values relative to environmental changes, and (4) assessment of the resilience of a population (measure of its ability to withstand further perturbations) (LeResche et al. 1974, Hanks 1981, Franzmann 1984). Using blood parameters to monitor moose status has progressed through stage 2, and to some extent into stage 3. Assements of resilience are lacking.

Procedures for collecting, handling, and analyzing blood have been outlined (Franzmann et al. 1976b). These procedures may vary, but the greater the procedural variation between sampled populations the poorer the potential becomes for valid comparisons and evaluation. Standardization is essential to eliminate sources of variation other than those we wish to identify.

Results

Sources of Variation (Boundary Conditions)

The first criteria required for applying blood parameters to moose biology is to identify sources of variation. This is essential in both the laboratory and field phases. In methods, we identified the importance of standardized technique in collecting, handling and storing samples. Variation has been identified for certain parameters associated with: hemolysis (ruptured red blood cells), caused by trauma during venipuncture, rough handling of specimen, delayed storage before separation, water contamination, and freezing (Mia and Koger 1976); fresh versus frozen serum (Hunter and Madin 1978); method of analysis for same parameter, reagent used, equipment performance (Mia and Koger 1976); and of sampling after death (when applicable) (Wesson et al. 1979). The list is not necessarily limited to these problems, but the message is clear; standardization of procedure is essential.

In the field phase of these studies, we

Table 1. Condition related blood parameters from Alaskan moose populations used as markers for comparisons.

Blood parameters	Moose populations								
	Cooper River[a]			Moose Research Center[b]			Moose River[c]		
	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Packed cell volume (%)	53.5	3.8	32	41.0	5.0	37	36.5	4.4	12
Hemoglobin (g/dl)	19.9	0.3	32	16.8	2.1	38	13.2	2.3	12
Total serum protein (g/dl)	7.3	0.5	30	6.9	0.6	42	6.2	0.3	13
Phosphorus (mg/dl)	5.3	0.6	30	4.3	1.6	42	3.9	1.4	13
Calcium (mg/dl)	10.5	0.7	30	9.8	1.3	42	10.5[d]	1.1	13

[a] Expanding, highly productive population.
[b] Confined, high density population.
[c] Group of post-partum cows in extremely poor condition.
[d] Blood calcium rise may be related to onset of lactation.

are confronted with other sources of variation. Some we must eliminate or minimize, and others we want to identify. Sources of variation tested and identified for moose at the Moose Research Center (MRC) on 19 blood parameters included; sex, season, age, location, rectal temperature (excitability), lactation, and condition. Pregnancy had no influence on any parameters (Franzmann et al. 1976) The most important source of variation identified was condition. Pearson correlation coefficients were used to rank the parameters that were most useful for condition evaluation. The rank in highest order of value was: packed cell volume (PCV) (r=0.35); glucose (r=0.25); hemoglobin (Hb) (r=0.22); total serum protein (TSP) (r=0.22); phosphorus (P) (r=0.22); albumin (r=0.21); calcium (Ca) (r=0.17), and betaglobulin (r=0.11) (Table 1). Using this ranking and eliminating parameters influenced by excitability (glucose, albumin, beta globulin; Franzmann and LeResche 1978), the parameters rank in the following descending order: PCV, Hb, TSP, P, and Ca.

Franzmann et al. (1975b) identified that serum corticoid levels in moose were influenced by handling stress. Blood urea nitrogen (BUN) levels changed significantly with seasons and the greatest influence upon that change was attributed to protein intake (Franzmann and Schwartz 1983). Crete et al. (1982) attributed BUN changes in moose to protein intake. They also suggested parasitism as a source of variation based upon albumin differences in 2 populations of moose they sampled which also had a differential parasite load. Malnutrition was suggested as a source of variation for post-parturient moose cows (Franzmann et al. 1980), but controlled studies are needed to confirm this. Sources of variation identified for other herbivores which have not been tested in moose include: habitat, sample time postcapture, growth/weight, climate, captive versus

wild, malnutrition, drug, physical restraint, estrus, gestation, marrow or body fat, disease, and starvation (Franzman 1984). All have been suggested for moose, but not tested. However, it is logical to assume that these sources of variation will influence certain blood parameters in moose. The application of these parameters is based upon what parameters are influenced and by which source of variation.

Baseline Values Within Source of Variation

Baseline values for 30 blood parameters based upon sampling over 2 500 moose in Alaska were published based upon the boundary conditions of sex, age, and season (Franzmann and Schwartz 1983). These data provide a set of baseline blood values for Alaskan moose sorted by major sources of variation. Published data on moose from other areas of North America are lacking.

Quantifying Changes in Blood Values

The third criterion (quantifying changes in blood values relative to environmental changes) is difficult to attain because it requires maintaining captive animals for controlled studies or serially sampling from free-ranging animals. The only exception may be studies where animals are captured and handled under highly standardized procedures and quantification of the animals' status is done based upon pre-determined criteria. For moose there is a lack of substantial quantified data. Eleven moose were serially sampled at the MRC from 1972 to 1975, but on an irregular basis. The data quantified seasonal changes in blood parameters, but also identified the problem of individual animal variation (Franzmann and Bailey 1977). Other studies at the MRC made efforts to standardize procedure and quantify status (Franzmann et al. 1975 b, Franzmann and LeResche 1978, Franzmann et al. 1980), but precision in quantification was difficult. These studies identified the extremes and to quantify the changes within those ranges, highly controlled studies are needed. The only wild species where controlled studies for blood value quantification have been done in North America were white-tailed deer (*Odocoileus virginianus*) (Robbins et al. 1974, Kirkpatrick et al. 1975, Seal et al. 1978, Bahnak et al. 1979, Warren et al. 1982), bighorn sheep (*Ovis canadensis*) (Franzmann 1971), elk (*Cervus elaphus*) (Mould and Robbins 1981) and bison (*Bison bison*) (Hawley and Peden 1982).

Assessment of Resilience

There are no data measuring blood parameters to determine resilience of an animal to further perturbations for moose. Very little data are available from other wild species (Franzmann 1984). Animals must be maintained in controlled circumstances and stressed by the various criteria to be tested (starvation, harassment, hyperthermia, hypothermia, disease, etc.). There is much work to be done in this area.

Application of Blood Parameters to Moose Management

Information presently available allows limited but useful application of blood data to moose management. Identifying the parameters (PCV, Hb, TSP, P, Ca) that reflected condition in moose proved useful when applied to sampling and com-

paring adult moose populations during the same season, preferably late winter/early spring. Three populations in Alaska from which we had good background data on condition and status were used as markers and condition related blood parameters from them are listed in Table 1. 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 Moose River (1977) sample which was from a group of post-parturient cows in extremely poor condition (Franzmann and Schwartz 1979).

Fifteen other populations were sampled in Alaska during late winter/spring and were compared with our known marker populations (Franzmann and Schwartz 1983). As one may expect, the listing of population blood parameters did not provide a clearcut and definite ranking. However, it did provide a good example of how these data may be interpreted and used. Homeostasis, or the ability of a system to maintain internal equilibrium, is the basis for maintenance of a normal and functional physiologic system. The blood parameters 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 or extreme. Therefore, we may often record degrees of "relative goodness" from samples representing a population or populations. Of considerable interest to us and what the blood data provides were the identification of extremes; those populations on the perimeter of the ranges of blood values. Applying this allowed us to establish priorities from populations of which we had limited background data. 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 and decision. This approach was used to evaluate specific populations in Alaska where assessments were needed: Alaska Peninsula (Faro and Franzmann 1978), Yakutat forelands (Smith and Franzmann 1979), and Thomas Bay (Doerr et al. 1980). We also used the condition parameters to rank 18 moose populations in Alaska (Franzmann and Schwartz 1983).

There were discrepancies in the ranking. In general, the populations were in a relatively similar order for each parameter, especially those representing the best and poorest populations. However, a few populations were scattered throughout the ranking, particularly for P and Ca (Franzmann and Schwartz 1983). 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. From these data, we can readily see that PCV and Hb were the best 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. We cannot overemphasize that the data are limited to statements about the exceptional populations at either end of the scale and should be considered as supportive data for other population assessments, not as entities in themselves.

Discussions and Conclusions

Blood parameters provide an additional tool for the manager to assess population status of moose when properly applied. We have the capability of detecting populations on the extremes (excellent and poor), but have difficulty in detecting relative goodness within populations. We suggest that blood samples be collected whenever we have the opportunity to handle fre-eranging moose populations. If the resulting values are not applied to status assessment, they can at least be used to provide additional baseline data. Building good sets of baseline data requires time because the strength and value of the data increases with numbers. Standardization during capture, collecting, handling and analysis (laboratory and statistical) is essential and cannot be overemphasized.

Establishing a frozen blood serum bank from duplicate samples should become a routine for researchers and managers. Our moose serum bank has been utilized for serological survey for selected microbial pathogens (Zarnke 1982), for applying new laboratory technology (Beta-endorphine analysis, Franzmann et al. 1981) and for supplying other research requests. In time the serum bank becomes potentially more valuable because we may not be able to resample from the population and it also provides a time/space record for future comparisons.

We need controlled studies where nutrient intake can be quantified and animals not stressed by capture can be serially sampled and blood parameters measured. The use of remote-controlled blood collecting systems that function in extreme cold would be useful. Controlled studies are needed to monitor blood parameters on moose whose intake declines to the malnutrition/starvation level. We also must be able to assess the resilience of moose to perturbations using blood and other physiological monitors under controlled conditions.

We are in the infant stage with blood studies of moose. The future is wide-open and the challenge fascinating. Technological advances from capture to data processing will continue and each advancement will provide more opportunities to better use the "juice of life" for status assessment of moose.

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