USE OF PHYSICAL AND PHYSIOLOGICAL INDICES FOR MONITORING MOOSE POPULATION STATUS - A REVIEW

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ABSTRACT: We briefly review several common physical and physiological indices used by wildlife biologists in North America for monitoring the status of moose (*Alces alces*). These include estimating general physical condition, taking morphological measurements, and using blood, body and marrow fat, urine, feces, hair, teeth, bone, and antlers for assessing relative condition. All methods have limitations and no single method should be relied upon. Rather, they should complement other procedures for monitoring the physical and phsiological status of moose populations.

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Scientific wildlife management requires that biologists continually monitor the status of populations to determine allowable harvests and determine magnitude and severity of limiting factors. Under optimal conditions, management requires collection of data concerning sex-age structure, density, natality, mortality, recruitment, survival, and habitat quantity and quality for each herd or management unit. In addition to the above parameters, biologists frequently seek additional data to describe the relative health of each population. Qualitative or quantitative measurements may provide additional insights to the status of the population. Physical and physiological parameters of individual animals, serving as indicators, are used for monitoring nutritional status of the populations (Franzmann 1985). This paper is not an exhaustive review of the methods available, but focuses on the methods most widely used in North America. Extensive reviews on this topic exist (Franzmann 1985, Franzmann *et al.* 1987, Huot 1988), and we have relied heavily on them in the preparation of this paper.

LIVE ANIMALS

Management programs frequently include research programs which involve live capture of moose. Often, an accompanying objective is determining the relative health of the individuals captured during the program. Live-capture provides biologists with a unique opportunity to gather data sets not otherwise attainable and every effort should be made to collect as much information as possible from this effort.

General Condition

Once a moose is immobilized an attempt should made to qualitatively assess the status of the individual. In Alaska, a subjective evaluation procedure (Franzmann 1977) has been used to evaluate condition of individual moose (Table 1). Although the system is subjective, it has proved useful for comparing relative goodness among moose populations from several different areas within Alaska. The primary advantages of this method are that it is easy to train personnel, no special equipment is required, the cost is low, and it is easy to use. All capture programs should either use this system or something similar to it.

Body Measurements

Measurements that are useful to apply to moose condition assessment are those that demonstrate some relationship to total body weight or mass. In order of their ability to predict weight, the best measurements are

Table 1. Condition evaluation criteria used to assess general condition of moose in Alaska (from Franzmann 1977)

Score	Description
10	A prime fat moose with thick, firm rump fat by sight. Well fleshed over back and loin.
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.
7	An "average moose" with no evidence of rump fat, but well fleshed. Bony structures of back and loin evident by feel. Shoulders with some angularity.
6	A moderately fleshed moose beginning to demonstrate one of the following conditions: (a) definition of neck and shoulders, (b) upper foreleg 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 are evident.
3	A state in which the hide fits loosely about the neck and shoulders, head is carried at a lower profile. Walking or running postures appear normal.
2	Signs of malnutrition are obvious. Outline of 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/starvation.

total body length, chest girth, shoulder height, and hind foot length (Franzmann *et al.* 1978).

Methods for obtaining measurements must be standardized so comparisons can be made. We suggest the following which were used to obtain data from over 1300 moose (Franzmann *et al.* 1978).

Total body length is measured across the top midline of moose beginning at the hairless triangle on the nose and following along the body to the tip of the tail. The moose should be lying in sternal recumbancy and the head upright, but not extended. Chest girth is the circumference of the body just posterior to the forelimbs and up to the highest point of the shoulder hump. This measurement is the the one most often lacking comparability because many of the measurements were taken around the chest perpendicular to the top line posterior to the hump and behind the forelimbs.

The problem with this method is that the perpendicular point is difficult to establish.

Shoulder height is measured from the bottom of the hoof, as if it were in a standing position, and then a straight line to the top of the shoulder. The hind foot length is obtained by measuring from the point of the hock to the tip of the hoof. The tip of the hoof determination may be problematic due to the different degrees of hoof wear. The point of the hock may also be difficult to establish. Because of these problems, this measurement has the least value. Total body length is the measurement generally relied upon. When combined with the condition index (Table 1) it is useful in estimating body weight (Hundertmark *et al.* 1992).

Blood

An array of blood parameters have been widely used in Alaska for assessing health of individuals and for comparing populations (Franzmann and Schwartz 1983). Some of the parameters are greatly influenced by one or more of the following: sex, age, season, habitat, excitability, stress, pregnancy, estrus, rut, drugs, protein and energy intake (Franzmann and LeResche 1978, Franzmann 1985). Consequently, some are of little value for assessing condition. However, several blood parameters are extremely useful. These include packed cell volume (PCV), % hemoglobin (Hb), calcium, phosphorous, and total protein (Franzmann *et al.* 1987).

Blood is usually collected in several 10 to 15 ml vacutainers (Becton-Dickinson and Co., Rutherford, N.J.), one of which contains an anticoagulant (heparin or EDTA). Uncoagulated samples are used to determine PCV and Hb as soon as possible following collection. PCV is the volume of red blood cells as a percentage of total volume of blood obtained by centrifuging a column of whole blood. Hb is the oxygen-carrying red pigment of red blood corpuscles (Coles 1967). PCV's can be determined at a field station with a micro-hematocrit centrifuge (Triac^R, Clay-Adams Co., Parsippany, NJ) while Hb can be determined with a portable Hemoglobinometer^R (American Optical Co., Buffalo, NY). Both instruments are relatively cheap and well worth the investment for long-term moose population studies. Whole blood samples are spun in a standard centrifuge after which the serum is extracted and frozen for laboratory analyses. Serum can also be separated by letting samples sit for >24 hrs in a cool area, but hemolysis (ruptured red blood cells) is more likely to occur which interferes with some of the blood analyses. Therefore, this procedure should only be used when immediate centrifugation is not possible.

Frozen serum can be stored indefinitely and used for a variety of serological, immunological, and microbiological tests. Complete blood profiles can be obtained from a number of commercial laboratories and are quite useful for evaluating moose condition. If only one parameter can be measured, PCV is the most useful for evaluating moose condition (Franzmann et al. 1976). In a number of field situations we have been able to correlate low PCV and Hb values with our visual examinations of moose. For example, moose which have recently experienced severe injury usually exhibit low PCV and Hb values in relation to healthy moose from the population. Even if a biologist has no specific objectives in mind, blood should always be collected since the serum can be banked and saved for future analyses. Franzmann (1985) pointed out that serological technology is changing rapidly and new developments may shed light on age-old questions. A moose blood bank could provide samples for future analyses to answer unknown questions.

Body Fat

Measurements of fat reserves have been used in a large number of studies to assess condition. Indices of body fat are obtained from condition assessments like those described above and by actual measurements in the field. Direct measurements have included needle probes of rump fat (Dauphine 1976), tritiated water (Schwartz *et al.* 1988), urea dilution (Hundertmark *et al.* 1990), and more recently by bioelectrical impedance (Hundertmark *et al.* 1992). However, most of these measurements are impractical for large-scale use in the field. The latter method may have potential for use in the field but further testing and refinement is necessary. Ultrasonic fat deposition measurements were tested at the Moose Research Center, Alaska, but the early equipment used proved difficult to apply (Franzmann and Schwartz 1978). However, recent advances in ultrasonic equipment shows promise in measuring thickness of fat deposits in moose (Stephenson *et al.* 1993).

Feces

A recent publication by Monfort *et al.* (1993) reports on the potential use of fecal estradiol and progesterone for identifying estrous and pregnancy in moose. These authors correctly identified pregnancy status in 22 of 26 moose. This method holds promise for being able to assess pregnancy rates without immobiliziation.

Hair

Analysis of moose hair for a variety of elements was used to access mineral uptake in moose (Flynn *et al.* 1974, 1975, 1977; Franzmann *et al.* 1975, 1977; Stewart and Flynn 1978). Hair is analyzed by atomic absorption analysis which can measure all macro- and micro-elements. Flynn *et al.* (1975) indicated that hair is a stable and useful indicator of mineral uptake as it reflects past uptake, is easy to collect, and storage will not alter results of future analyses. The method was used to identify copper deficiency in an Alaskan moose population (Flynn *et al.* 1977).

Pregnancy Assessment

The proportions of pregnant yearling and adult females within a population are data that many biologists desire for monitoring the status of a moose population. Pregnancy rates of immobilized moose may be determined by rectal palpation (Haigh *et al.* 1982). This method has been used routinely on domestic livestock, and when performed by trained and experienced personnel, is safe and provides accurate data on pregnancy rates. Blood serum (Rehbinder *et al.* 1981, Seip 1992), urine and feces (Monfort *et al.* 1993) have recently been used to assess pregnancy rates. These techniques may replace rectal palpation in most instances after further refinement and testing.

Boer (1992) reviewed pregnancy rates from 12 North American moose populations according to their relationship to habitat carrying capacity (KCC). He found that pregnancy rates were similar among populations, averaging 84%. Based on these findings, biologists may not need to determine pregnancy rates since they appear to vary little. However, given the uncertain nature of assessments of carrying capacity (based upon subjective evaluations by the individual investigators), biologists are encouraged to continue collecting this information to insure that their populations, in fact, are similar to the apparent norm.

Teeth

Biologists frequently desire information on the age structure of the population. Alaskan biologists have historically pulled incisor teeth from moose for age assessment with no apparent adverse effects on the individual. Incisor teeth (either I_1 or I_2) are usually aged by cross or longitudinally sectioning and counting annuli which correspond to annual growth (Sergeant and Pimlott 1959). Moose teeth can be easily ground and read by the individual investigator or sent off to a commercial laboratory.

The method provides biologists with an estimate of the age of each individual which then can be used to construct life tables and to examine parameters including: the relationship of age to conception, natality, senescence, movements, and migration. Sample size is a major consideration when deciding to pull teeth from moose. If a small number of moose are to be immobilized, it may be impractical to obtain information on age structure. The need for precise ageing must also be evaluated.

Recently, some biologists have questioned the wisdom of pulling teeth from moose, particularly incisors. The principle concern being that extaction of teeth may handicap a moose's ability to feed in future years. Although there has been no reported adverse affects from pulling teeth, there have been no studies designed to evaluate this concern. This practice deserves further investigation and consideration.

Urine

DelGuidice *et al.* (1989) reported that several compounds in white-tailed deer (*Odocoileus virginianus*) urine were useful for assessing condition status. DelGuidice *et al.* (1991) used this method to assess the condition of moose on Isle Royale, Michigan and concluded that creatanine ratios were a useful measure of physiological status. This method was tested on moose at the Moose Research Center, Alaska, by Hundertmark *et al.* (1992) who found that potassium: creatanine, calcium:creatanine, and sodium: creatanine ratios were useful for identifying moose in healthy versus poor condition. However, the method was not fool proof and they stressed that the limitations of the method need to be fully understood before this technique is used.

DEAD MOOSE

It is important to assess the status of dead animals for cause of death and for information regarding their condition at death. Frequently, these will be hunter kills from check stations or carcasses found in the field. When examining non-hunter killed carcasses it is extremely important that the biologist take detailed notes concerning the circumstances of death. Franzmann and Schwartz (1983) described an examination protocol which should be followed. It is summarized as follows: record a description of the area and the animal, perform a necropsy, determine the physical condition, and collect appropriate samples. The following focuses on the utility of collecting certain types of samples and making observations from dead moose.

General Condition

Attempt to place the animal in a condition class, if possible. If little of the carcass remains and condition assessment is not possible, then collect whatever useful specimens are present. It may be possible to weigh various parts from hunter-killed animals. Because there is considerable variation in weights and measurements, the qualitative notes concerning body condition may be more important than the quantitative data.

Antlers

Antler measurements and their shapes can provide useful data on relative condition of males within a population and between populations. Although factors such as genetic composition can affect antler growth and shape (Harmel *et al.* 1989), there does appear to be a relationship between habitat quality and antler growth. Antlers have been reported to be more directly affected by forage quality than body size (Cowan and Long 1962) and dietary energy and protein restrictions decrease antler volume, beam diameter, main beam length, and number of points in white-tailed deer (Ullrey 1982). Alaskan moose in high quality habitats have developed larger antlers at earlier ages than moose in poor quality habitats (Gasaway 1975, Franzmann 1985).

Bubenik and Pond (1992) reported use of

cast antlers of red deer (*Cervus elaphus*) for measuring condition. In red deer, concave antler stumps (base of cast antler) are indicative of senescence while convex antler stumps are indicative of healthy individuals. This method deserves consideration and testing for moose.

Bones

Bone size and joint surface condition may be used for assessment of the condition of moose. Peterson *et al.* (1981) compared skeletal morphology and pathology of moose from three areas and established base-line data for determining trends in population quality and physical condition. Bone mineral density can be measured using a computerized tomography (CT) scanner (Hindelang *et al.* 1992). There is promise in utilizing bone pathology and composition in assessing condition status and this approach deserves continued research.

Teeth

Constructing life tables from teeth collected from dead moose can be valuable in assessment of the age structure of the population. It does not directly relate to physical condition, but a skewed age structure may be indirectly involved. In some populations obtaining an estimate of age structure by tooth wear and eruption may be adequate. However, in a highly managed trophy hunt for males, ageing by tooth sectioning is important.

Blood

With proper planning and education programs it may be possible to have hunters acquire usable blood samples from moose. This requires that hunters understand the type of specimen required and how it should be collected. The quality of hunter collected specimens will vary greatly, and some samples may be useless. However, hunter collected blood samples have potential to provide information not otherwise available. Such samples are particularly useful for serological tests for diseases and parasites. Rarely, will biologists be able to collect blood samples from moose killed by natural causes.

Body Fat

Measures of fat content have been widely used for assessing physical condition of ungulates (Kirkpatrick 1980). Rump fat is usually mobilized first, followed by subcutaneous, visceral, and marrow fat (Harris 1945). Measurements of these fat deposits from hunter-killed moose can be obtained at check stations and spot field checks. Measurements of fat deposits during the fall hunting seasons have limited value since moose then have maximum levels of fat (Franzmann and Arneson 1976, Ballard *et al.* 1987). Few hunts are held after December, which is often the period of greatest concern.

Marrow fat has been used as an indicator of moose condition for both hunter and predator killed moose. The femur bone has traditionally been the bone of choice for collection, but other longbones including mandibles have equal value (Snider 1980, Ballard *et al.* 1981). Mandibles are particularly useful because hunters are often required, or asked, to turn in lower jaws when reporting their kill. Also, they frequently are the only body part remaining of heavily consumed, predator-killed animals (Snider 1980, Ballard *et al.* 1981).

Caution is required when evaluating bone marrow fat. Marrow fat may indicate if an animal is near death, but not that it is necessarily healthy (Mech and DelGuidice 1985, Ballard et al. 1987). Some have suggested that when moose femur marrow fat levels are <10 for calves or <20% for adult moose, the animals are in extremely poor condition, probably near death (Bischoff 1954, Franzmann and Arneson 1976, Kistner *et al.* 1980). However, Mech *et al.* (1993) suggest that the above levels may be conservative and could provide erroneous conclusions. They believe that animals with fat levels ≤70 to 87% are in a declining state of health from loss of body fat and muscle depletion, and that such animals could be in marginal condition.

Hair

As described for live animals, trace elements found within hair are stable and such analyses can be performed from hair collected from both dead and live moose.

Reproductive Tracts

Collection of reproductive tracts from dead moose can provide useful information concerning twinning rates, fetus sizes, in utero productivity, and past reproductive history. Hunters can also be instructed to collect reproductive tracts, but training on procedure is necessary. Crichton (1992) reported good success in obtaining hunter-killed reproductive tracts. Recently, Schwartz and Hundertmark (1993) determined that the relationship between hind foot length of fetuses and gestation period was a reliable indicator of the estrous cycle in which the calf was conceived. This method has tremendous potential for providing biologists good data concerning timing of conception which is of concern in moose populations with relatively low bull:cow ratios (Ballard *et al.* 1991).

CONCLUSIONS

A large number of methods exist for evaluating the condition of both live and dead moose. We have described the most commonly used physical and physiological methods currently used in North America. However, all of the methods have limitations. None of the methods should be relied upon solely. Alternatively, each should be considered as one of many tools available. As many tools as possible should be used depending upon objectives, personnel, budgetary, ethical, and political considerations. We must be fully aware that many of the physical and physiological parameters are subject to a great variety of sources of variation and we must identify these. In many cases, a large database may be required to serve as baseline values for detecting abnormalities. Lastly, although the methods we describe are useful and helpful there is still no substitute for obtaining accurate and precise estimates of sex-age composition, density, fecundity, recruitment, and survival.

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