MINERALS AND MOOSE

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

The concept that wild animals do not suffer from mineral deficiencies since most elements are widespread in their environment may be false. Similar consideration may be given to the statement "--it is doubtful whether deficiencies of trace elements are a matter for serious consideration for any class of livestock" (Abrams 1968).

The problem with these statements, we believe, concerns degree of deficiency. Classic symptomatology associated with deficiencies created artificially in a laboratory are not likely experienced in wild populations. It is also unlikely that we will observe "barnyard" type deficiencies in free-ranging animals. What are the effects of subtle deficiencies that do not exemplify themselves with known signs, but may affect the well being of the animal or animals and possibly interfere with reproductive success or calf viability?

To help understand the role of minerals, let us begin by reviewing the essential mineral elements. These have been classified as macro-elements and micro or trace-elements. The classification difference corresponds to concentration in tissues, with the trace elements generally expressed in concentrations of parts per million (ppm) and macro-elements in percent. The classic definition of a trace element is any element that exists in concentration equal to or less than Fe in the body, with iron being the first of the trace-elements. The essential macro-elements are calcium (Ca), chlorine (Cl), potassium (K), magnesium (Mg), sodium (Na), phosphorus (P) and sulphur (S) and they have long been known to be required (Church 1971). The essential micro-elements are iodine (I), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), cobalt (Co), molybdenum (Mo), selenium (Se) chromium (Cr), tin (Sn), vanadium (V), fluorine (F), silicon (Si) and nickel (Ni) (Underwood 1971, and Schwarz 1974). Schwarz (1974) indicated 20 additional elements should be considered and investigated as possibly essential.

There is some variability in standards for determining essentiality of an element. The standards originally set by Cotzias (1967) are by far the most restrictive, but perhaps the best. Some standards used are listed in Appendix I.

To elucidate the physiology of these elements and the symptomatology associated with their deficiencies would require a symposium in itself. We will only generalize and state that they all have been established as essential to normal function and their deficiencies are associated with malfunction in basic physiological systems. Some symptoms associated with deficiencies of these elements are listed in Appendix II. In addition, all essential elements, have recognized toxic levels and associated pathology. The field of mineral metabolism is so complex and interrelated with itself and with other systems, primarily neural and hormonal, that no element can be considered alone. Two classic examples of this are the detrimental effect of high molybdenum intake on copper metabolism (Underwood 1971), and the shift of the Ca: P ratio influenced primarily by phosphorus levels. There are other examples of these types of interractions between minerals which confound our understanding of mineral metabolism.

Research in mineral metabolism has progressed rapidly in recent years with the advent of technological equipment for analysis; however, much needs to be done. The extremes are identifiable, such as the effects of toxic levels of these elements and conversely the effects of extreme deficiencies. The difficult areas to assess are the continuum between the extremes and the requirements for the animal in question.

We know that the tissue and plant concentrations of these elements are dynamic. Research at the Kenai Moose Research Center (MRC) has demonstrated this through seasonal sampling of moose hair and plants that moose browse (Franzmann et al. 1974). Botkin et al. (1973) discussed the dynamics of Na associated with the Isle Royale moose. Kubota (1974) reviewed the complexity of mineral cycling influenced by rock and soil parent materials, soil development, weathering and variation in species of plants. He demonstrated the variation in concentration of the elements in selected plants in Alaska, Minnesota and Wisconsin and postulated that the adaptability of moose to its habitat may reflect its ability to utilize mineral elements from different feed plants. Morrison (1974) demonstrated variation in mineral content of leaves of young balsam fir within each tree. The importance of moisture and the complexity of mineral cycling was reviewed by Wilkinson and Lowry (1973) and they stressed that life is essentially aqueous, and the behavior of an element and the compounds in which it functions are critical to reactivity, distribution, and transport in the ecosystem.

The problems associated with plant mineral absorption were reviewed by Loneragan (1973). Butler and Jones (1973) discussed the complexity of mineral interactions and plant and animal mineral requirement.

So what can a wildlife manager do and why should he add the burden of this potential problem to the many he already has?

First of all he or she need not be concerned with the specifics of mineral element metabolism, but should be aware of the possibility of deficiencies. More specifically, the manager should be concerned with the possible consequences that land use and management practices may have regarding mineral utilization of the animal in question. Our present state of knowledge will not specifically guide the manager, but awareness of the potential alteration of mineral availability, in general, may influence management and land use decisions.

Some examples that illustrate this are:

1. Land-Use Planning and Management

Moose may assimilate and store a majority of their mineral requirements within the short span of summer. The bulk of their mineral requirements are obtained from primary plant species, but they may require additional supplemental sources such as licks. On the Kenai Peninsula and elsewhere (Krefting 1974) a minor source of total food intake comes from submerged vegetation; however, results from Kubota (1974) and Oldemeyer et al. (1975) show these plants to be high in mineral content. Jordan et al. (1973) indicated that aquatic macrophytes had 500 times more Na than found in terrestial vegetation. Land use planning and management decisions should consider these potentially important mineral sources (licks and submerged vegetation) and not exclude access and use by moose.

It is important that moose not be excluded from areas of traditional use by highways, campgrounds or land development. It may be these excluded areas that provide the minerals, among other nutrients, that balance the moose's intake.

For most moose populations these considerations may not be valid, due to the extent, diversity and/or remoteness of their habitat, but they should be made when changes in land use or management are contemplated.

2. Fire Suppression and Prescribed Burning.

Viereck (1973) indicated that whatever the actual cause, there does seem to be a release of nutrients and a fertilizing effect of fire on the organic soils in Alaska. Unfortunately, little is known regarding the uptake of micro-elements following fire, but the increase in macro-elements has been noted (Lutz 1956, and Scotter 1971). Ascherin (1973) observed a "favorable" decrease in the Ca:P ratio after a burn. He determined that shrubs in the control had a higher than recommended ratio and burning reduced the ratio to a more acceptable level. Perhaps more important is the demonstrated population response to fire, such as by moose on the Kenai Peninsula, Alaska (Spencer and Hakala 1964), and in Minnesota (Peek 1974).

Changes in soil and plant composition and quality following fire are influenced by many variables such as parent material, moisture, plant composition prior to fire, intensity of fire, and climatic events following fire. Nevertheless, the generalization can be made that browse quality and palatability improve and moose populations respond. Mineral content, including trace minerals, must be considered a positive factor in these events.

3. Forestry Practices

The alteration of mineral cycling in forestry practices is influenced by many factors; however, parent material and subsequent weathering basically determine mineral availability in the forest. The mineral content of hardwood litter usually is higher than that of conifer litter and bark usually contains 3 to 10 times as high a concentration of minerals as wood (Kramer and Kozlowski 1960). Removal of overstory permits revegetation in an area and browsing animals respond to the increase in available vegetative biomass; however, with harvest, appreciable amounts of nutrients are removed (Smith 1966). The long term effects that removal of the forest overstory has on mineral cycling and subsequent availability to animals is difficult to establish, but the ecosystem can remain productive only if the nutrients withdrawn are balanced by an inflow of replacements (Smith 1966).

4. Vegetative Rehabilitation and Fertilization.

The variation among plants in their ability to assimilate mineral elements may be cause for consideration in selection of areas for vegetative rehabilitation or chemical fertilization of moose browse. These practices are not widespread at present, but their application in relation to mineral metabolism will increase as more intensive management practices are stimulated by new information on moose mineral requirements and mineral status of the area.

It would not be wise to invest great sums of money on mechanical or chemical rehabilitation in areas where vegetative response may favor plants that poorly assimilate certain mineral elements. We could, instead, divert our activity to an area that would stimulate plants that have the ability to assimilate desirable elements.

In all the above examples, we are not inferring that the decision rests with mineral cycling alone. We but have utilized the mineral viewpoint to stress that it is an additional factor to be considered.

Much research is required to assess the various effects our management plans have on mineral cycling, and even more is required to assess the often subtle effects mineral deficiencies may have on a population. The advent of atomic absorption spectroscopy permits intensive mineral element investigations. Perhaps the lack of definitive information regarding wildlife mineral metabolism and the general lack of information on the mineral aspect of forage quality for wildlife, stems from our previous inability to study minerals on a practical level. Research projects at the MRC have incorporated mineral research into present and future studies, and we suggest that those planning research projects consider adding to the sparse information available relative to minerals and moose by incorporating this into their studies, when feasible. The need for mineral metabolism information is certainly not intrinsic to moose and these studies on other species should also be encouraged.

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APPENDIX I. Proposed sets of criteria required to fulfill the require ments of essentiality of mineral elements.

1. Criteria listed by Hopkins (1974) and Nielsen (1974).

   a. Chemically suitable for biological function.

   b. Ubiquitous on the geosphere.

   c. Generally present in all plants and animals.

   d. Relatively low toxicity.

   e. Mammalian homeostatic mechanisms are implied by serum levels.

   f. Low intake demonstrates impaired physiologic functions.

2. Criteria listed by Cotzias (1967).

   a. Present in all healthy tissues of all living things.

   b. Concentration from one animal to the next is fairly constant.

   c. Withdrawal from the body induces reproducibly the same structural and physiological abnormalities regardless of the species studied.

d. Addition either prevents or reverses these abnormalities.

e. Abnormalities induced by deficiency are always accompanied by pertinent, specific biochemical changes.

f. Biochemical changes can be prevented or cured when the deficiency is prevented or cured.

3. Criteria listed by Schwarz (1974).

a. Experiment should produce highly significant responses.

b. It should be reproducible at will, and in a series of tests over a lengthly period of time.

c. A dose-response curve should be established and the minimum effective dose level of the element should be determined.

d. Several compounds of the same element should be tested and compared in potency.

e. The effect should be physiological, i.e., it must be obtained using amounts which are normally present in food and tissues.

APPENDIX II. An outline of some recognized mineral deficiency symptoms and signs.

1. Macro-elements

Calcium (Church 1971)

a. Skeletal disorders (osteomalacia, osteodystrophy, and ricketts).

b. Anorexia and weight loss.

c. Lowered milk production.

d. Tetany and muscular dysfunction.

Chlorine (Hays and Swenson 1970)

a. Principal anion in body fluids.

b. Alkalosis.

Potassium (Church 1971)

a. Anorexia and weight loss.

b. Listlessness and weakness.

c. Pica (depraved appetite).

d. Impaired response to disturbance.

e. General stiffness.

f. Kidney degeneration.

g. Histologic change in muscles.

Magnesium (Church 1971)

a. Opisthotonus - retracted head - muscle tremors - convulsions.

b. Ataxia.

c. Hypersensitivity.

d. Increased heat production and fall in energy retention due to tonic muscular activity.

e. Reduced appetite.

f. Rumen flora changes and reduced digestibility.

g. Anemia and jaundice.

h. Impaired blood clotting.

i. Liver damage and reduced serum albumin and alpha and gamma globulins.

j. Serum enzyme changes.

Sodium (Church 1971)

a. Pica.

b. Decrease body weight.

c. Anorexia.

d. Listlessness.

e. Harsh skin.

f. Tetany - collapse and death.

Phosphorus (Church 1971)

a. Anorexia and weight loss.

b. Pica.

c. Listless and dull.

d. Osteomalacia and ricketts.

e. Impaired fertility in females.

Sulphur (Church 1971)

a. Anorexia and weight loss.

b. Emaciation.

c. Pica.

d. Hair and wool growth impaired.

e. Excessive lacrimation and profuse salivation.

f. Dullness and weakness.

g. Heart, liver, skeletal muscle and spleenic histologic changes.

h. Reduced digestibility.

2. Micro or trace-elements.

Iodine (Underwood 1971)

a. Thyroid deficiency (enlarged thyroid - goiter).

b. Lowered metabolic rate.

c. Birth of hairless, weak or dead young - cretinism.

d. Reduced reproductivity (suppressed estrus in females and reduced libido in males).

e. Relatively non-toxic.

Iron (Underwood 1971)

a. Anemia.

b. Anorexia and weight loss.

c. Listlessness.

d. Gastritis.

e. Relatively non-toxic.

Copper (Underwood 1971)

a. Anemia (iron transfer related).

b. Severe diarrhea.

c. Depigmentation of hair and defective keratinization of wool and hooves.

d. Ataxia and paralysis.

e. Fibrosis of cardiac muscles and heart failure.

f. Bone deformities (osteoporosis).

g. Reduced fertility and impaired reproductive performance.

h. Toxic symptoms recognized.

<u>Zinc</u> (Underwood 1971)

a. Skin irritability, inflammation and parakeratosis.

b. Difficult conception.

c. Abnormal estrus and cystic degeneration of ovary.

d. Retained placenta.

e. Excessive salivation.

f. Impaired digestibility by reduction of volatile fatty acids.

g. Cessation of spermatogenesis.

h. Growth retardation.

i. Anorexia.

j. Impaired wound healing.

k. Relatively non-toxic.

Manganese (Underwood 1971)

a. Impaired estrus and conception.

b. Enlarged joints and stiffness - skeletal abnormalities.

c. Weakness and impaired growth.

d. Pica.

e. Liver degenerative changes.

f. Ataxia of new-born.

g. Relatively non-toxic.

<u>Chromium</u> (Underwood 1971)

a. Impaired growth and longevity.

b. Disturbances in glucose, lipid and protein metabolism.

c. Eye disorder - corneal opacity.

d. Toxic symptoms recognized.

<u>Cobalt</u> (Underwood 1971)

a. Listlessness and emaciation.

b. Anemia.

c. Anorexia.

d. Depressed synthesis of B_{12} in rumen.

e. Relatively non-toxic.

<u>Molybdenum</u> (Underwood 1971)

a. Closely related to Cu and S. High levels depress Cu and S.

b. Renal calculi.

c. Relatively non-toxic, but high levels depress other elements.

Selenium (Underwood 1971)

a. Nutritional muscular dystrophy.

b. Impaired fertility.

c. Persistent diarrhea.

d. Depressed growth rate.

e. Associated with diseases responding to Vitamin E therapy.

f. Toxic symptons recognized.

Vanadium (Hopkins 1974)

a. Reduced body and feather growth.

b. Impaired reproduction and survival of young.

c. Altered RBC levels and iron metabolism.

d. Impaired hard tissue metabolism.

e. Altered blood lipid levels.

f. Toxic symptoms recognized.

<u>Fluorine</u> (Messer et al. 1974)

a. Retarded growth rate.

b. Infertility.

c. Anemia.

d. Toxic symptoms demonstrated.

<u>Silicon</u> (Schwarz 1974)

a. Postulated as structural element in metabolism.

b. Growth stimulating effect in rats.

c. Relatively non-toxic.

Nickel (Nielsen 1974)

a. Suboptimal reproductive performance.

b. Reduced oxidative ability in liver.

c. Toxic symptom recognized.

Tin (Schwarz 1974)

a. No definite signs recognized, but it has been demonstrated to have a growth stimulant effect.

b. Relatively non-toxic.

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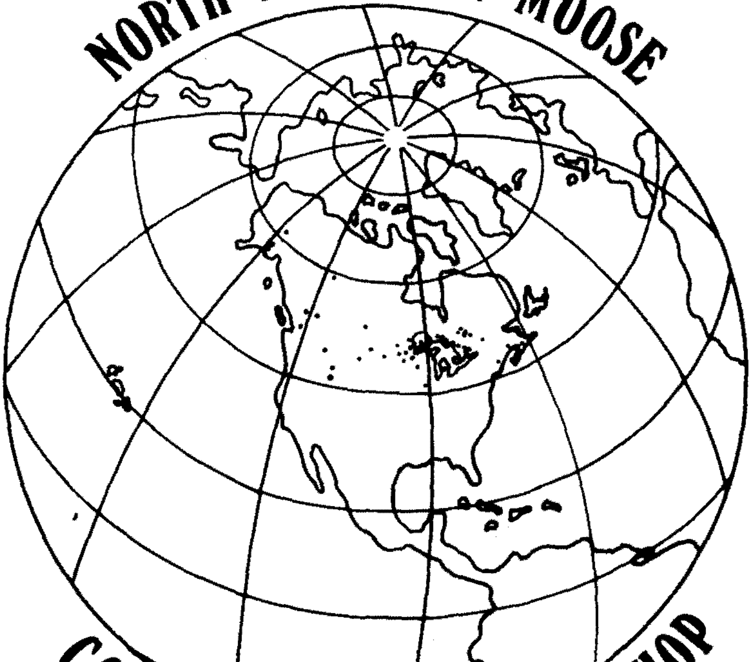

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