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# Selenium Concentrations in Forages of a Northern Herbivore

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ABSTRACT. The importance of adequate selenium in diets of native wild herbivores can only be inferred from data for beef cattle where minimum dietary concentrations range from 50 to 100 ppb. Concern about possible selenium deficiencies in wild herbivores is based on a few reports of symptoms in wildlife, a paucity of data on selenium in their forages, and the idea that excessive atmospheric sulfur may increase the incidence of selenium deficiencies in herbivores. Concentrations of selenium in sedges, *Carex* spp., and reedgrasses, *Calamagrostis* spp., the main food plants of bison, *Bison bison*, in northwestern Canada, varied from 9 to 800 ppb in samples collected at three lowland locations. However, approximately three-quarters of all the samples of plant species consumed by bison were dietarily deficient by the beef cattle standard.

Key words: *Carex, Calamagrostis*, bison, selenium concentration

RÉSUMÉ. L'importance d'un quantité adéquate de sélénium dans les régimes des herbivores sauvages locaux ne peut être inférée que d'après les données portant sur le bétail bovin, dans lequel les concentrations minimales varient entre 50 et 100 ppb. La question d'insuffisance possible en sélénium chez les herbivores sauvages fut levée par rapport à quelques études des symptômes d'animaux sauvages, à la pénurie de données sur le sélénium dans leur régime et à la hypothèse selon laquelle un excès de souffre dans l'atmosphère pourrait augmenter l'incidence d'insuffisance en sélénium chez les herbivores. Les concentrations de sélénium dans les laîches (*Carex* spp.) et les gourbets (*Calamagrostis* spp.), les plantes alimentaires principales du bison (*Bison bison*) dans le nord-ouest du Canada, variaient entre 9 et 800 ppb dans les échantillons recueillis à trois sites en terres basses. Cependant, environ les trois quarts de tous les échantillons des espèces de plantes consommées par le bison furent trouvées insuffisants au niveau alimentaire en comparaison avec la norme pour le bétail bovin.

Mots clés: *Carex, Calamagrostis*, bison, concentration de sélénium

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## INTRODUCTION

A small amount of selenium (Se) is essential in the diet of warm-blooded vertebrates. Selenium forms part of the enzyme glutathione peroxidase (GSH-Px) and has other important metabolic functions (Welsh and Soares, 1976; Stadtman, 1977; Harr, 1978). Hoekstra (1974) explained the role of Se and the biochemistry of GSH-Px in the prevention of such Se deficiency diseases as white muscle disease, exudative diathesis, and weak calf syndrome. The recommended minimum dietary concentrations of Se for beef cattle are 50-100 ppb (Prior *et al.*, 1982) and may apply also to wild herbivores such as bison.

During the last decade, several surveys of agricultural soils and cultivated forages in the boreal forest region of Canada found that a high proportion of forage samples was dietarily deficient in Se by the livestock standard (Levesque, 1974a,b,c; Gupta and Winter, 1975; Redshaw *et al.*, 1978; Winter and Gupta, 1979; Westra, 1982). Similarly, a large proportion of forage samples in the northern U.S.A. was deficient (Kubota *et al.*, 1967). Based on these data, it is conceivable that there may be a general Se deficiency in forages fed upon by wild herbivores in the North American boreal forest region. However, if this is true, why are Se deficiency diseases not more frequently reported for wild herbivores?

Hebert and Cowan (1971), Fleming *et al.* (1977), and Stoszek *et al.* (1978) have reported symptoms of either Se or vitamin E deficiencies in free-roaming mountain goats, woodchucks, and antelope respectively, although the causes of the symptoms were not confirmed. Symptoms have also been reported or demonstrated in other captive herbivores (Sauer and Zook, 1972; Brady *et al.*, 1978; Kurkela, 1980). However, conclusive evidence that native free-ranging herbivores may suffer from Se deficiencies in suspected low Se areas is lacking except in the case of some Oregon voles (Pond *et al.*, 1982; Whitfield, 1978).

Selenium deficiency diseases of wild herbivores in suspected low Se areas may not be reported because carcasses of dead herbivores sufficiently fresh for the diagnosis of Se deficiency symptoms would be difficult to find, and if found, the tissues may be decayed or may have been consumed by other animals. On the other hand, Se deficiency diseases may not occur in wild herbivores for the following reasons. The Se content of cultivated forages may not be representative of uncultivated plant species that are growing on soils with low Se content or availability. Wild herbivores normally may encounter uncultivated forage plants with moderate to high concentrations of Se, thus obtaining sufficient dietary Se. And finally, it is possible that "native" wild herbivores have adapted through evolution to diets low in Se in comparison to the standards set for livestock.

Because the preceding hypotheses have not been supported by empirical data, the question remains: how frequently and under what conditions do wild herbivores suffer from Se deficiencies? The need to answer this question has been given impetus by the idea that increased atmospheric sulfur from the combustion of fossil fuels (acid rain) may decrease the concentration of Se in vegetation over large areas of North America (Frost and Ingvoldstad, 1975). Hurd-Karrer (1935, 1937),

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Davies and Watkinson (1966), and Gissel-Nielsen (1973) have shown Se reductions in several crops to be associated with excessive elemental S and $SO_4$ in soils.

Gissel-Nielsen (1973) reported a reduction in Se concentrations in barley and red clover from soil $SO_4$ fertilization. Soils were fertilized to 12.5 and 125 ppm of sulfur. Fertilization with $SO_4$ markedly reduced the Se concentration in clover at all soil selenite concentrations, even those low enough to cause initial clover Se concentrations of less than 50 ppb. However, despite these results and other preliminary experiments (Shaw and Cocks, 1982), much research is needed to establish whether $SO_2$ or acid rain $SO_4$ will lead to lower Se concentration in vegetation and subsequently to an increased incidence of Se deficiencies in wild herbivores.

The purpose of this report is to present data on Se concentrations in several wild species of plants collected from three river lowland habitats within the boreal forest region of western Canada and to relate these data to the question of Se deficiency diseases in bison. The three locations represent areas of existing bison populations, of recently released wood bison (*Bison bison athabascae*), and of a proposed release site for wood bison (Reynolds *et al.*, 1982a).

## METHODS

Range quality and quantity were determined by systematic plot sampling of vegetation along transects located in lowland sites of the Slave River, Northwest Territories (Reynolds *et al.*, 1978), the Liard-South Nahanni rivers, N.W.T. (Reynolds *et al.*, 1980), and the Hay-Zama lakes area, Alberta (Reynolds *et al.*, 1982b). The Se data reported were derived from vegetation samples composed from several plots in the different wet meadow habitats where bison presently graze and where reintroduced wood bison would be likely to graze. Se data from a few plant samples in drier sites are also reported. Se analyses were performed by the Soil and Feed Testing Laboratory of Alberta Agriculture in accordance with standard fluorometric procedures (Levesque and Vendette, 1971). Average concentrations of Se for sedges, grasses, forbs, and other non-forbs were compared by t-tests ($P \leq 0.05$) for different wet meadow habitats. Transformation of raw data to the log scale was used to reduce variances. Fourteen, ten, and eleven plant species were analyzed from the Slave River lowlands, Nahanni River lowland habitats, and the Hay-Zama lakes area respectively.

## RESULTS AND DISCUSSION

Concentrations of Se in plant tissues were so variable that no comparisons between sedges, grasses, forbs, and other non-forbs were statistically significant (Tables 1, 2, 3). The coefficient of variation for duplicate determinations (Table 1) was 10%, indicating that analytical precision was good. Variability shown for the concentration of Se in plant tissues was probably due to differences between sites, between species and plant parts, and between sampling dates. The twigs of *Salix* spp. were significantly lower in Se than the leaves on a log scale ($P \leq 0.05$; Table 1). At Camp Meadow five of six species increased in Se concentrations from March to June, while at Stan's Meadow seven of nine decreased in Se concentrations during the same period (Table 1). Large variability in plant concentrations of Se within a single habitat has been reported before by Joblin and Pritchard (1981), where the concentration of Se in perennial ryegrass varied abruptly and irregularly across a pasture by as much as sevenfold.

Bison feed primarily in wet meadows and tend to select plant species not quite proportionally to their seasonal availability (Reynolds *et al.*, 1978). The major species are sedges (*Carex* spp.) and reedgrasses (*Calamagrostis* spp.) (Tables 1, 2, 3), and together they can form up to 87% of the plant biomass in sedge and wet meadows (Reynolds *et al.*, 1978, 1982b). Bison will sometimes feed on willows (*Salix* spp.), yellow avens (*Geum aleppicum*), slender wheat grass (*Agropyron trachycaulum*), wire rush (*Juncus balticus*), and horsetails (*Equisetum* spp.) (Reynolds *et al.*, 1978). When considering only the above plant species as food items of bison, and the recom-

TABLE 1. Concentration (ppb) of selenium in tissues of 14 plants from two wet meadow habitats in the Slave River lowlands, Northwest Territories, in 1975

| Species | Camp Meadow | | | | Stan's Meadow | | | |
|---|---|---|---|---|---|---|---|---|
| | March | | June | | March | | June | |
| *Carex atherodes* | 20[1] | 21[1] | 38 | 41 | 76 | 81 | 32 | 35 |
| *Carex rostrata* | — | — | 14 | 15 | 10 | 11 | 21 | 23 |
| *Carex aquatilis* | — | — | 12 | 13 | — | — | 45 | 49 |
| *Scolochloa festucacea* | 10 | 10 | 34 | 37 | 34 | 36 | 8 | 9 |
| *Beckmannia syzigachne* | 16 | 17 | 5 | 5 | 332 | 351 | 16 | 17 |
| *Calamagrostis* spp. | 14 | 15 | 20 | 22 | 44 | 47 | 37 | 40 |
| *Agropyron trachycaulum* | — | — | 1600 | 1748 | 438 | 462 | 273 | 295 |
| *Hordeum jubatum* | — | — | 1560 | 1683 | — | — | — | — |
| *Poa* spp. | — | — | 450 | 483 | — | — | — | — |
| *Glyceria* spp. | — | — | 19 | 20 | 136 | 144 | 18 | 20 |
| *Juncus balticus* | — | — | 670 | 724 | 310 | 311 | 520 | 563 |
| *Geum aleppicum* | 6 | 6 | 172 | 189 | 9 | 10 | 5 | 5 |
| *Rumex maritimus* | 10 | 11 | 21 | 23 | — | — | 20 | 22 |
| *Salix* spp. (leaves) | — | — | 41 | 45 | — | — | 420 | 462 |
| *Salix* spp. (twigs) | — | — | 22 | 24 | — | — | 175 | 189 |

[1]Duplicate determinations.

TABLE 2. Concentration (ppb) of selenium in tissues of 10 plants in Nahanni River lowland habitats in late June 1979

| Species | Habitat and site number[1] | Se |
|---|---|---|
| *Carex atherodes* | wet sedge meadow (3) | 250 |
| *Carex atherodes* | wet sedge meadow (5) | 640 |
| *Carex atherodes* | wet sedge meadow (5) | 400 |
| *Carex rostrata* | wet sedge meadow (5) | 635 |
| *Carex rostrata* | wet sedge meadow (3) | 37 |
| *Carex rostrata* | wet sedge meadow (5) | 220 |
| *Carex aquatilis* | shrub meadow (1) | 64 |
| *Carex aquatilis* | wet shrub bog (7) | 67 |
| *Carex aquatilis* | wet shrub bog (7) | 64 |
| *Calamagrostis canadensis* | wet sedge meadow (5) | 800 |
| *Calamagrostis canadensis* | wet sedge meadow (3) | 40 |
| *Equisetum arvense* | wet sedge meadow (5) | 670 |
| *Equisetum pratense* | wet sedge meadow (5) | 3875 |
| *Equisetum pratense* | aspen spruce forest (4) | 83 |
| *Equisetum pratense* | spruce forest (2) | 524 |
| *Equisetum palustre* | shrub meadow (1) | 79 |
| *Myrica gale* (leaves) | wet shrub bog (7) | 23 |
| *Salix* spp. (leaves) | shrub meadow (1) | 39 |
| *Betula* sp. (leaves) | shrub meadow (1) | 34 |

[1]Reynolds *et al.* (1980:Fig. 3).

TABLE 3. Concentration (ppb) of selenium in tissues of 11 plants in sedge meadow and wet sedge-grass meadow of the Hay-Zama lakes area of northwestern Alberta in August 1981

| Species | Sedge meadow Site E[1] | Wet sedge-grass meadow, Site H[1] |
|---|---|---|
| *Carex atherodes* | 30 | — |
| *Carex atherodes* (tops) | 60 | — |
| (midstems) | 25 | — |
| (stem bottoms) | 32 | — |
| *Carex aquatilis* | 9 10[2] | — |
| *Carex aquatilis* (tops) | 20 | — |
| (midstems) | 9 | — |
| (stem bottoms) | 10 | — |
| *Carex* sp. | — | 38 |
| *Eleocharis* sp. (a) | — | 39 |
| *Eleocharis* sp. (b) | — | 147 |
| *Scolochloa festucacea* | 19 | — |
| *Calamagrostis inexpansa* | — | 48 |
| *Beckmannia syzigachne* | — | 25 |
| *Typha latifolia* | — | 31 |
| *Alisma* sp. | — | 85 |
| *Bidens cernua* | — | 34 |

[1]Reynolds *et al.* (1982b:Fig. 3).
[2]Duplicate samples.

mended level of 100 ppb Se for beef cattle, 18 of 25 plant samples from the Slave River lowlands (Table 1), 8 of 17 samples from the Nahanni River lowlands (Table 2), and all of the samples from the Hay-Zama lakes region (Table 3) were dietarily deficient in Se. Three-quarters of all the samples of plants known as food items for bison were deficient by the beef-cattle standard.

However, species such as slender wheatgrass, wire rush, horsetail, yellow avens, willow, and sedges sometimes have concentrations of Se above 100 ppb (Tables 1, 2). A steady diet of plants with 3900 ppb (horsetail — Table 2) would be just subtoxic (Harr, 1978) but improbable, because such high concentrations are not common among the samples analyzed. Because bison move frequently between meadows while grazing they are likely to consume daily some plants with concentrations of Se above 100 ppb. Moreover, Reynolds *et al.* (1982a) reported bison to have relatively greater digestive capabilities than those of beef cattle. If this digestive superiority applies to Se, the overall diet of bison may be adequate to prevent Se deficiency diseases.

The concentrations of Se reported here for several plant species growing in the same locations were quite variable. This suggests that considerable variability of Se concentration in diets of wide-ranging herbivores may be expected, even in areas where their main food items may be Se-deficient. This should be confirmed by studies conducted on ranges of other herbivores such as antelope and mountain goats, for which symptoms of Se and vitamin E deficiencies have been reported previously.

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