

Forage diversity and nutrient supply of reindeer

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Abstract: This study describes the mineral and nitrogen concentrations of reindeer forage plants from the Elgå reindeer herding district of south-eastern Norway. The data are compared with results from 5 other areas in Norway. Emphasis is put on the importance of environmental diversity. Different plant species accumulate Ca, Mg, P, S, Na, K, Cl and K to a varying degree but reindeer can meet their nutritional requirements by eating different types of forage. Examples are sodium from aquatic herbs, sulphur and sodium from horsetails etc. Of further importance are variations in soil type, phenological development of plants in relation to differences in time for snowmelting, as well as different levels of nutrients in forage from different geographical areas.

Key words: reindeer, *Rangifer*, minerals, forage.

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Introduction

The staple diet of reindeer in winter forage consists of different species of lichens. These are high in energy but usually low in minerals and nitrogen. Important summer forage plants like grasses and birch and willow leaves also have low nutrient concentrations (Gaare and Skogland, 1975; Wielgolaski *et al.*, 1975; Warenberg, 1982; Staaland *et al.*, 1983; Staaland and Sæbø, 1987; Nieminen and Heiskari, 1989). It is, however, well known that the nutrient concentrations of plants vary with such factors as soil type, phenological development and with distance from the sea (Låg, 1963; Warenberg, 1982). Additionally, large interspecific variation occurs in nitrogen and mineral concentrations. A noted example is the very high concentrations of sodium found in aquatic plants (see e.g. Belovsky and Jordan, 1981, Fraser *et al.*, 1984).

Therefore even though some of the quantitatively most important forage species in the diet

of reindeer may be low in particular essential nutrients, the animals may be able to achieve a balanced diet by feeding on a mixture of plants in which some species are rich in minerals and others in nitrogen. The nutritional rôle of particular diet species may therefore be greater than might appear to be the case from their relative abundance in the animals' diet alone.

The present paper explores the variations in nutrient concentrations in potential forage plants in a reindeer herding district in south-eastern Norway. Results are compared to data from other districts in coastal and inland areas in Norway.

Material and methods

Sixty-six species of important reindeer forage plants were collected in the Elgå reindeer herding district in 1980–1982. Samples were collected in August and September 1980, through the growing season of 1981 (May 27, June 20, July

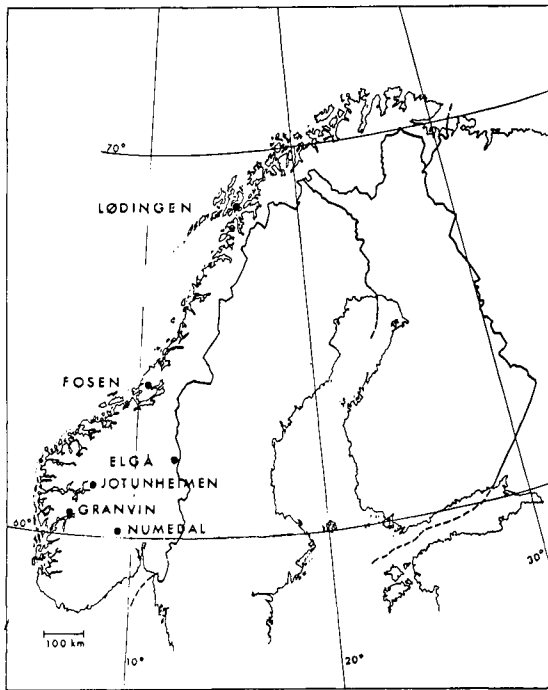


Fig. 1. Sampling locations in Norway.

15, August 6, September 3 and October 1), and in April and July 1982. For geographical comparison samples were also collected from 5 other areas in Norway (Fig. 1).

Study areas

The primary study area, Elgå reindeer herding district, is located in the south-eastern part of Norway on the border to Sweden. Within the area is the large lake Femund (662 m above sea level) (Fig. 1). Most of the area has poor washed-out soil deposits covering sandstones, quartzite and granite. Orthoceras limestones are found in a few small areas. The climate is continental with a short, warm summer and a long, cold winter. Yearly mean temperature is +0.6°C and yearly precipitation 545 mm. Most of the area is dominated by Scots pine (*Pinus sylvestris*) with a ground cover of lichens and heather. Part of the area is above treeline with an alpine vegetation type. A domestic reindeer herd of about 3000 animals graze the area all year round.

The plants sampled for comparison with Elgå were collected on 5 other localities in Norway; at Lødingen in the Lofoten area, within the reindeer herding district on the Fosen peninsula,

western Jotunheimen mountain range, the southern part of Hardangervidda mountain plateau in Veggli, Numedal and in the mountains close to Granvin in western Norway (Fig 1). Most of the samples were collected above treeline from areas with quartzitic, granitic or gneissic type bedrocks. The Lødingen, Fosen, and Granvin areas are close to the sea or fjord districts. Numedal and Jotunheimen like Elgå are inland landscapes.

Chemical analyses

All plants were kept frozen until analysis. Samples were dried at 105°C for determination of dry matter content and then dry ashed at 550°C. Sodium and potassium were determined by flame photometry and calcium and magnesium by atomic absorption spectroscopy (Perkin Elmer 306). Phosphorus was determined colorimetrically by means of the molybdovanadophosphoric acid method (Boltz and Howell, 1978). Chloride was determined colorimetrically from ash obtained in the presence of sodium carbonate and dissolved in nitric acid using $Hg(SCN)_2$ and Fe^{3+} as reagents. Sulphur was determined turbidimetrically by oxidizing S to SO_4^{2-} with $Mg(NO_3)_2$ and converting the SO_4^{2-} to $BaSO_4^{2-}$. Nitrogen was determined by the Kjeldahl method.

Results

Phenology

In most green vegetation there was a pronounced decrease in potassium, phosphorus and nitrogen concentrations through the growing season. A similar but less pronounced decrease was also observed for magnesium, but usually not for sodium, calcium, sulphur and chloride. These observations are exemplified for *Betula nana*, *Vaccinium myrtillus*, *Deschampsia flexuosa*, *Salix lapponum* (Fig. 2). In mosses and lichens there was little or no seasonal variation in the concentrations of any of the nutrients which we measured.

Regional variations

The seasonal variation in the nutrient concentrations in different species of plants make regional comparisons difficult unless sampling is carried out when the plants have reached the same phenological stage (Fig. 2). However nutrients that show less seasonal variations like sodium, calcium, sulphur and chloride can be

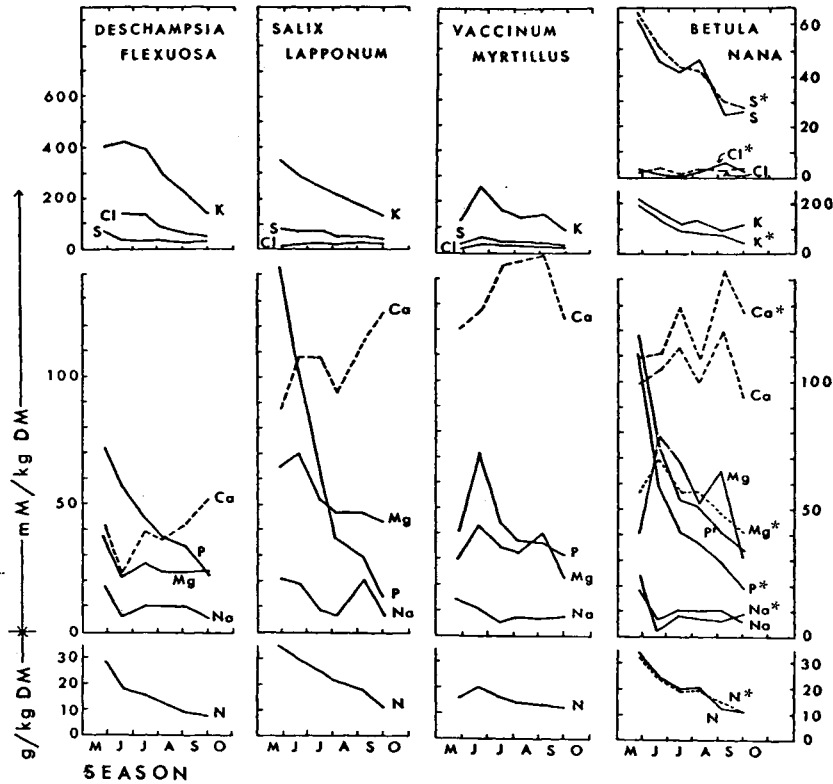


Fig. 2. Examples of seasonal variations in mineral and nitrogen concentrations of 4 forage plants from the Elgå reindeer herding district. *Betula nana* was collected from two different locations. The elements marked * are from a small location with orthoceras limestone whereas those unmarked are from an area with washed out soil deposits on sandstone and quartzite.

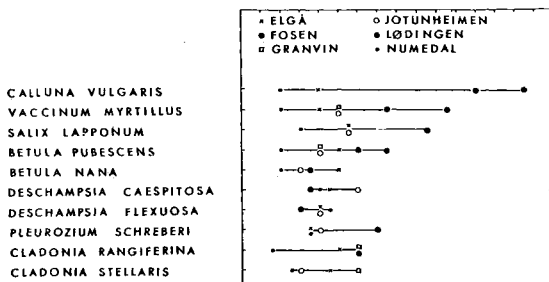


Fig. 3. Range of variation in sodium concentrations in forage plants from different geographical areas.

more easily compared. A sampling of *Betula nana* from two localities in Elgå, one from a small area with Orthoceras limestone and one from a sandstone area showed that the limestone area apparently caused an increase in calcium, phosphorus and possibly potassium (Fig. 2).

There was considerable geographical variation in concentration of sodium (Fig. 3). Lowest values (about 4 mM/kg DM) were found in samples from Numedal, whereas values from the

Elgå area were usually about twice this. We found particularly high values in plants from coastal regions: e.g. *Calluna vulgaris* from the Lødingen and Fosen areas.

Interspecific variation

The range of variation in mineral and nitrogen concentration in forage species from Elgå was large for all elements (Fig. 4). Sodium was low in lichens, some heather and tree leaves, but extremely high in aquatic plants like *Menyanthes*

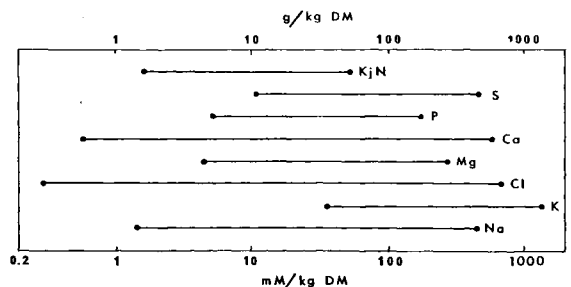


Fig. 4. Interspecific range of variations in mineral and nitrogen concentrations in reindeer forage from the Elgå herding district. Nitrogen is given in g/kg DM and minerals in mM/kg DM.

Table 1. Kjeldahl nitrogen (g/kg DM, \pm S.D.) in potential reindeer forage plants collected in different areas of Norway: E=Elgå, F=Fosen, G=Granvin, J=Jotunheimen, L=Lødingen; N=Numedal (see Fig. 1).

| Species | N- | P | Ca | Mg | S | Na | K | Cl |
|----------------------------------|---------|----------|-----------|----------|----------|----------|-----------|-----------|
| Mosses: | | | | | | | | |
| <i>Pleurozium schreberi</i> (E) | 7 | 31 | 75 | 28 | 32 | 7 | 81 | 5 |
| (n=3) | ± 1 | ± 4 | ± 30 | ± 5 | ± 0 | ± 3 | ± 32 | ± 2 |
| <i>Pleurozium schreberi</i> (F) | 9 | 29 | 96 | 63 | 33 | 14 | 81 | 10 |
| <i>Pleurozium schreberi</i> (J) | 9 | 35 | 68 | 31 | 28 | 8 | 92 | 9 |
| <i>Pleurozium schreberi</i> (N) | 10 | 31 | 68 | 30 | 34 | 7 | 103 | 3 |
| <i>Rhacomitrium</i> sp. (F) | 2 | 6 | 14 | 23 | 11 | 20 | 174 | 10 |
| <i>Rhacomitrium</i> sp. (L) | 4 | 6 | 16 | 24 | . | 9 | 14 | 4 |
| <i>Sphagnum papillosum</i> (E) | 17 | 91 | 125 | 94 | 41 | 30 | 293 | 138 |
| <i>Bryophyta</i> indet. (L) | 12 | 38 | 61 | 35 | . | 12 | 89 | 11 |
| Lichens: | | | | | | | | |
| <i>Alectoria</i> sp. (E) | 14 | 18 | 12 | 12 | 54 | 18 | 69 | 24 |
| <i>Cetraria delisei</i> (J) | 7 | 25 | 12 | 10 | 16 | 8 | 50 | 7 |
| <i>Cladonia stellaris</i> (E) | 4 | 12 | 12 | 8 | 13 | 9 | 22 | 2 |
| (n=3) | ± 1 | ± 1 | ± 5 | ± 3 | ± 2 | ± 5 | ± 8 | ± 2 |
| <i>Cladonia stellaris</i> (G) | 5 | 8 | 8 | 11 | 18 | 12 | 24 | 6 |
| <i>Cladonia stellaris</i> (J) | 7 | 22 | 25 | 13 | 19 | 6 | 39 | 5 |
| <i>Cladonia stellaris</i> (N) | 7 | 14 | 15 | 9 | 19 | 5 | 27 | 3 |
| <i>Cladonia arbuscula</i> (E) | 5 | 13 | 19 | 15 | 14 | 11 | 30 | 4 |
| <i>Cladonia arbuscula</i> (G) | 4 | 5 | 10 | 13 | 13 | 12 | 17 | 6 |
| <i>Cladonia mitis</i> (E) | 8 | 14 | 16 | 10 | 14 | 10 | 26 | 6 |
| <i>Cladonia mitis</i> (L) | 4 | 10 | 10 | 16 | 11 | 17 | 20 | 5 |
| <i>Cladonia nivalis</i> (E) | 5 | 12 | 33 | 11 | 16 | 14 | 36 | 7 |
| (n=4) | ± 2 | ± 3 | ± 8 | ± 2 | ± 6 | ± 6 | ± 4 | ± 3 |
| <i>Cladonia nivalis</i> (J) | 4 | 16 | 43 | 33 | 12 | 16 | 44 | 7 |
| <i>Cladonia rangiferina</i> (E) | 4 | 9 | 17 | 8 | 13 | 10 | 20 | 2 |
| <i>Cladonia rangiferina</i> (G) | 4 | 13 | 10 | 12 | 13 | 12 | 34 | 4 |
| <i>Cladonia rangiferina</i> (L) | 6 | 14 | 26 | 22 | 15 | 12 | 27 | 6 |
| <i>Cladonia rangiferina</i> (N) | 6 | 16 | 22 | 10 | 19 | 3 | 36 | 3 |
| <i>Cladonia</i> sp. (F) | 5 | 12 | 30 | 25 | 15 | 7 | 23 | 3 |
| <i>Nephroma arcticum</i> (E) | 22 | 42 | 20 | 18 | 32 | 16 | 201 | 19 |
| Club moss: | | | | | | | | |
| <i>Diphysium complanatum</i> (E) | 9 | 35 | 55 | 86 | . | 19 | 267 | 10 |
| Horsetail: | | | | | | | | |
| <i>Equisetum fluviatile</i> (E) | 20 | 66 | 381 | 137 | 286 | 40 | 646 | 298 |
| (n=7) | ± 8 | ± 34 | ± 152 | ± 28 | ± 76 | ± 18 | ± 251 | ± 94 |
| <i>Equisetum sylvaticum</i> (E) | 23 | 63 | 245 | 142 | 123 | 12 | 590 | 472 |
| (n=7) | ± 6 | ± 34 | ± 96 | ± 21 | ± 24 | ± 5 | ± 255 | ± 152 |
| <i>Equisetum sylvaticum</i> (F) | 25 | 73 | 239 | 159 | 178 | 19 | 903 | 647 |
| <i>Equisetum sylvaticum</i> (N) | 25 | 55 | 310 | 158 | 120 | 12 | 167 | 419 |
| Ferns: | | | | | | | | |
| <i>Blechnum spicant</i> (E) | 16 | 27 | 118 | 241 | . | 225 | 247 | 241 |

Mushrooms:

| | | | | | | | | |
|--------------------------------------|----|-----|----|----|---|----|-----|----|
| <i>Lactarius rufus</i> (E) | 38 | 167 | 5 | 30 | . | 13 | 740 | 5 |
| <i>Leccinum scabrum</i> (E) | 34 | 116 | 2 | 24 | . | 10 | 278 | 32 |
| <i>Leccinum testaceo scabrum</i> (E) | 30 | 123 | 1 | 21 | . | 6 | 552 | 45 |
| (n=3) | ±6 | ±34 | ±1 | ±4 | . | ±0 | ±65 | ±3 |
| <i>Russula paludosa</i> (E) | 32 | 146 | 1 | 30 | . | 20 | 805 | 94 |
| <i>Suillus variegatus</i> (E) | 23 | 123 | 1 | 25 | . | 8 | 543 | 53 |

Grasses and sedges:

| | | | | | | | | |
|-----------------------------------|----|-----|------|-----|-----|----|------|-----|
| <i>Carex bigelowii</i> (E) | 16 | 34 | 50 | 33 | 54 | 12 | 295 | 16 |
| (n=5) | ±6 | ±14 | ±9 | ±7 | ±10 | ±3 | ±127 | ±8 |
| <i>Carex bigelowii</i> (F) | 19 | 33 | 24 | 38 | . | 12 | 323 | 33 |
| <i>Carex bigelowii</i> (N) | 13 | 22 | 22 | 29 | 43 | 8 | 243 | 21 |
| <i>Carex canescens</i> (E) | 23 | 63 | 73 | 50 | 66 | 5 | 326 | 63 |
| (n=3) | ±7 | ±16 | ±2 | ±12 | ±7 | ±3 | ±45 | ±52 |
| <i>Carex nigra</i> (F) | 28 | 48 | 40 | 96 | 73 | 37 | 429 | 114 |
| | ±2 | ±3 | ±8 | ±2 | ±6 | ±6 | ±4 | ±3 |
| <i>Carex rostrata</i> (E) | 17 | 31 | 55 | 29 | 58 | 9 | 360 | 12 |
| (n=7) | ±5 | ±12 | ±15 | ±5 | ±14 | ±3 | ±86 | ±4 |
| <i>Carex rostrata</i> (F) | 20 | 58 | 50 | 48 | 69 | 7 | 454 | 15 |
| <i>Carex chordorrhiza</i> (F) | . | 41 | 55 | 48 | . | 9 | 367 | 6 |
| <i>Carex flava</i> (E) | . | 53 | 54 | 54 | . | 19 | 387 | . |
| <i>Carex lasiocarpa</i> (E) | 18 | 42 | 79 | 38 | . | 6 | 451 | 124 |
| <i>Carex limosa</i> (E) | . | 34 | 71 | 63 | . | 16 | 258 | 56 |
| <i>Carex magellanica</i> (E) | . | 74 | 52 | 68 | . | 14 | 407 | 415 |
| <i>Carex rotundata</i> (E) | . | 70 | 41 | 45 | . | 22 | 321 | 4 |
| <i>Deschampsia caespitosa</i> (E) | 19 | 64 | 64 | 53 | 55 | 9 | 454 | 200 |
| (n=7) | ±9 | ±23 | ±16 | ±24 | ±20 | ±4 | ±129 | ±93 |
| <i>Deschampsia caespitosa</i> (F) | 15 | 42 | 43 | 73 | 65 | 7 | 463 | 254 |
| <i>Deschampsia caespitosa</i> (J) | 31 | 68 | 55 | 65 | 99 | 12 | 552 | 110 |
| <i>Deschampsia caespitosa</i> (N) | 22 | 48 | 84 | 56 | 72 | 8 | 575 | 322 |
| <i>Deschampsia flexuosa</i> (E) | 14 | 39 | 40 | 25 | 37 | 8 | 273 | 78 |
| (n=10) | ±7 | ±17 | ±8 | ±5 | ±13 | ±5 | ±124 | ±49 |
| <i>Deschampsia flexuosa</i> (F) | 12 | 43 | 46 | 40 | 52 | 6 | 390 | 147 |
| <i>Deschampsia flexuosa</i> (J) | 24 | 71 | 32 | 48 | 56 | 8 | 388 | 113 |
| <i>Deschampsia flexuosa</i> (N) | 16 | 45 | 37 | 34 | 66 | 9 | 553 | 236 |
| <i>Eriophorum angustif.</i> (E) | 18 | 42 | ~ 38 | 36 | 58 | 16 | 299 | 55 |
| (n=7) | ±6 | ±25 | ±7 | ±8 | ±11 | ±9 | ±156 | ±25 |
| <i>Eriophorum angustif.</i> (F) | 19 | 34 | 34 | 41 | 53 | 36 | 203 | 42 |
| <i>Eriophorum angustif.</i> (L) | 14 | 33 | 25 | 32 | . | 9 | 184 | 21 |
| <i>Juncus trifidus</i> (E) | 20 | 38 | 38 | 24 | 55 | 15 | 303 | 102 |
| (n=6) | ±8 | ±14 | ±14 | ±3 | ±8 | ±7 | ±136 | ±22 |
| <i>Juncus trifidus</i> (J) | 25 | 72 | 32 | 34 | 63 | 13 | 303 | 84 |
| <i>Juncus trifidus</i> (N) | 17 | 30 | 34 | 22 | 50 | 9 | 264 | 72 |
| <i>Luzula pilosa</i> (E) | 13 | 61 | 75 | 110 | 30 | 17 | 837 | 197 |
| <i>Luzula pilosa</i> (L) | 16 | 73 | 94 | 110 | . | 11 | 466 | 357 |
| <i>Molinia caerulea</i> (E) | 25 | 44 | 33 | 40 | 83 | 7 | 317 | 91 |
| <i>Molinia caerulea</i> (F) | 26 | 51 | 34 | 43 | 76 | 6 | 332 | 94 |
| <i>Scirpus caespitosus</i> (E) | 16 | 30 | 48 | 33 | 66 | 10 | 267 | 61 |
| (n=7) | ±7 | ±18 | ±17 | ±3 | ±15 | ±5 | ±104 | ±27 |
| <i>Scirpus caespitosus</i> (F) | 20 | 35 | 40 | 46 | 50 | 6 | 284 | 97 |
| <i>Scirpus caespitosus</i> (N) | 18 | 28 | 61 | 28 | 56 | 11 | 350 | 78 |

Liliaceae:

| | | | | | | | | |
|----------------------------------|----|----|----|----|----|----|-----|-----|
| <i>Narthecium ossifragum</i> (F) | 28 | 41 | 85 | 79 | 73 | 37 | 611 | 473 |
|----------------------------------|----|----|----|----|----|----|-----|-----|

Aquatic graminids:

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| <i>Sparganium angustifo.</i> (E) | 33 | 93 | 265 | 91 | . | 106 | 746 | 174 |
|----------------------------------|----|----|-----|----|---|-----|-----|-----|

Herbs:

| | | | | | | | | |
|--------------------------------|----|----|-----|-----|---|---|-----|-----|
| <i>Angelica sylvestris</i> (E) | 32 | 87 | 435 | 153 | . | 5 | 948 | 295 |
|--------------------------------|----|----|-----|-----|---|---|-----|-----|

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|------------------------------|----|----|-----|-----|---|----|-----|-----|
| <i>Alchemilla alpina</i> (E) | 19 | 51 | 198 | 101 | . | 10 | 375 | 196 |
|------------------------------|----|----|-----|-----|---|----|-----|-----|

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|-----------------------------|----|----|-----|-----|---|----|------|-----|
| <i>Caltha palustris</i> (E) | 28 | 88 | 337 | 173 | . | 11 | 1118 | 362 |
|-----------------------------|----|----|-----|-----|---|----|------|-----|

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|----------------------------------|----|----|-----|-----|---|---|-----|-----|
| <i>Cirsium heterophyllum</i> (E) | 25 | 57 | 473 | 105 | . | 5 | 778 | 614 |
|----------------------------------|----|----|-----|-----|---|---|-----|-----|

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|---------------------------------|----|----|-----|-----|---|---|-----|-----|
| <i>Filipendula vulgaris</i> (E) | 26 | 69 | 147 | 193 | . | 5 | 415 | 127 |
|---------------------------------|----|----|-----|-----|---|---|-----|-----|

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|--------------------------------|----|----|-----|-----|---|---|-----|-----|
| <i>Geranium sylvaticum</i> (E) | 22 | 93 | 317 | 107 | . | 7 | 541 | 144 |
|--------------------------------|----|----|-----|-----|---|---|-----|-----|

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|---------------------------|----|----|-----|-----|---|---|------|-----|
| <i>Lactuca alpina</i> (F) | 24 | 60 | 267 | 310 | . | 8 | 1241 | 733 |
|---------------------------|----|----|-----|-----|---|---|------|-----|

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|-----------------------------|---|----|-----|----|---|----|-----|---|
| <i>Linnaea borealis</i> (E) | . | 56 | 215 | 90 | . | 10 | 406 | . |
|-----------------------------|---|----|-----|----|---|----|-----|---|

| | | | | | | | | |
|--------------------------------|----|----|-----|-----|----|----|-----|----|
| <i>Melampyrum pratense</i> (E) | 22 | 81 | 229 | 100 | 90 | 12 | 504 | 61 |
|--------------------------------|----|----|-----|-----|----|----|-----|----|

| | | | | | | | | |
|-------|----|-----|-----|-----|-----|----|-----|----|
| (n=4) | ±8 | ±26 | ±68 | ±14 | ±15 | ±3 | ±61 | ±9 |
|-------|----|-----|-----|-----|-----|----|-----|----|

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|--------------------------------|----|----|-----|-----|----|----|-----|----|
| <i>Melampyrum pratense</i> (F) | 18 | 92 | 258 | 178 | 65 | 31 | 630 | 73 |
|--------------------------------|----|----|-----|-----|----|----|-----|----|

| | | | | | | | | |
|--------------------------------|----|----|-----|-----|----|---|-----|----|
| <i>Melampyrum pratense</i> (J) | 25 | 96 | 156 | 118 | 86 | 7 | 508 | 78 |
|--------------------------------|----|----|-----|-----|----|---|-----|----|

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|--------------------------------|----|----|-----|-----|----|---|-----|----|
| <i>Melampyrum pratense</i> (N) | 14 | 62 | 148 | 140 | 66 | 8 | 475 | 42 |
|--------------------------------|----|----|-----|-----|----|---|-----|----|

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|-------------------|--|--|--|--|--|--|--|--|
| <i>Melampyrum</i> | | | | | | | | |
|-------------------|--|--|--|--|--|--|--|--|

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|-----------------------|----|----|-----|-----|---|---|-----|-----|
| <i>sylvaticum</i> (E) | 20 | 72 | 235 | 137 | . | 6 | 482 | 141 |
|-----------------------|----|----|-----|-----|---|---|-----|-----|

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|--------------------------|----|-----|-----|-----|----|----|-----|----|
| <i>Oxyria digyna</i> (J) | 35 | 112 | 439 | 134 | 72 | 11 | 487 | 59 |
|--------------------------|----|-----|-----|-----|----|----|-----|----|

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|----------------------------------|----|----|-----|----|----|----|-----|----|
| <i>Pedicularis lapponica</i> (J) | 24 | 86 | 109 | 66 | 73 | 17 | 473 | 17 |
|----------------------------------|----|----|-----|----|----|----|-----|----|

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|------------------------------------|---|-----|-----|-----|---|---|-----|----|
| <i>Pedicularis sceptrum-c.</i> (E) | . | 135 | 277 | 122 | . | 6 | 447 | 40 |
|------------------------------------|---|-----|-----|-----|---|---|-----|----|

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|--------------------------------|----|----|-----|-----|---|----|-----|-----|
| <i>Polygonum viviparum</i> (E) | 30 | 96 | 168 | 172 | . | 13 | 364 | 106 |
|--------------------------------|----|----|-----|-----|---|----|-----|-----|

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|------------------------------|----|----|-----|-----|---|---|-----|-----|
| <i>Potentilla erecta</i> (E) | 24 | 60 | 287 | 117 | . | 8 | 252 | 127 |
|------------------------------|----|----|-----|-----|---|---|-----|-----|

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|------------------------------|----|----|-----|-----|----|----|-----|-----|
| <i>Potentilla erecta</i> (F) | 17 | 50 | 151 | 222 | 60 | 41 | 362 | 139 |
|------------------------------|----|----|-----|-----|----|----|-----|-----|

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|---------------------------------|----|-----|-----|-----|---|---|-----|----|
| <i>Potentilla palustris</i> (E) | 27 | 100 | 254 | 159 | . | 8 | 509 | 78 |
|---------------------------------|----|-----|-----|-----|---|---|-----|----|

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|----------------------------|----|----|-----|-----|---|---|-----|-----|
| <i>Rubus saxatilis</i> (E) | 20 | 51 | 173 | 267 | . | 8 | 249 | 111 |
|----------------------------|----|----|-----|-----|---|---|-----|-----|

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|--------------------------|----|-----|-----|-----|----|----|-----|-----|
| <i>Rumex acetosa</i> (E) | 35 | 113 | 125 | 128 | 75 | 46 | 840 | 264 |
|--------------------------|----|-----|-----|-----|----|----|-----|-----|

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|-------|-----|-----|-----|-----|-----|----|------|------|
| (n=5) | ±10 | ±39 | ±18 | ±48 | ±12 | ±9 | ±149 | ±120 |
|-------|-----|-----|-----|-----|-----|----|------|------|

| | | | | | | | | |
|--------------------------|----|-----|----|-----|---|----|-----|-----|
| <i>Rumex acetosa</i> (L) | 49 | 170 | 81 | 126 | . | 37 | 694 | 193 |
|--------------------------|----|-----|----|-----|---|----|-----|-----|

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|-----------------------------|---|----|-----|-----|---|----|------|-----|
| <i>Saussurea alpina</i> (L) | . | 61 | 393 | 145 | . | 16 | 1072 | 672 |
|-----------------------------|---|----|-----|-----|---|----|------|-----|

| | | | | | | | | |
|-------------------------------|----|----|-----|-----|----|-----|-----|-----|
| <i>Solidago virgaurea</i> (F) | 23 | 61 | 137 | 226 | 71 | 215 | 931 | 286 |
|-------------------------------|----|----|-----|-----|----|-----|-----|-----|

Aquatic herbs:

| | | | | | | | | |
|----------------------------------|--|--|--|--|--|--|--|--|
| <i>Menyanthes trifoliata</i> (E) | | | | | | | | |
|----------------------------------|--|--|--|--|--|--|--|--|

| | | | | | | | | |
|---------|----|----|-----|----|-----|----|-----|----|
| leaves: | 19 | 57 | 244 | 60 | 138 | 81 | 532 | 11 |
|---------|----|----|-----|----|-----|----|-----|----|

| | | | | | | | | |
|-------|----|-----|------|-----|-----|-----|------|----|
| (n=7) | ±8 | ±39 | ±104 | ±16 | ±22 | ±33 | ±275 | ±6 |
|-------|----|-----|------|-----|-----|-----|------|----|

| | | | | | | | | |
|--------|----|----|-----|----|-----|----|-----|----|
| roots: | 11 | 26 | 131 | 30 | 128 | 96 | 295 | 15 |
|--------|----|----|-----|----|-----|----|-----|----|

| | | | | | | | | |
|-------|----|-----|-----|----|-----|-----|-----|----|
| (n=6) | ±2 | ±10 | ±15 | ±3 | ±17 | ±36 | ±76 | ±8 |
|-------|----|-----|-----|----|-----|-----|-----|----|

| | | | | | | | | |
|--------|----|----|-----|----|----|----|-----|---|
| stems: | 10 | 27 | 136 | 40 | 87 | 45 | 358 | 3 |
|--------|----|----|-----|----|----|----|-----|---|

| | | | | | | | | |
|-------|----|----|----|----|-----|-----|-----|----|
| (n=7) | ±2 | ±7 | ±9 | ±5 | ±10 | ±14 | ±71 | ±1 |
|-------|----|----|----|----|-----|-----|-----|----|

| | | | | | | | | |
|---------------------------|----|-----|-----|-----|----|----|------|-----|
| <i>Montia fontana</i> (E) | 31 | 115 | 104 | 164 | 84 | 47 | 1018 | 310 |
|---------------------------|----|-----|-----|-----|----|----|------|-----|

| | | | | | | | | |
|-------|----|-----|-----|-----|-----|-----|------|------|
| (n=5) | ±8 | ±27 | ±24 | ±34 | ±18 | ±26 | ±192 | ±108 |
|-------|----|-----|-----|-----|-----|-----|------|------|

| | | | | | | | | |
|-------------------------|--|--|--|--|--|--|--|--|
| <i>Nuphar lutea</i> (E) | | | | | | | | |
|-------------------------|--|--|--|--|--|--|--|--|

| | | | | | | | | |
|---------|----|----|-----|----|-----|-----|-----|-----|
| leaves: | 31 | 67 | 384 | 62 | 124 | 310 | 613 | 292 |
|---------|----|----|-----|----|-----|-----|-----|-----|

| | | | | | | | | |
|--------|----|----|-----|----|-----|-----|-----|-----|
| roots: | 15 | 31 | 128 | 34 | 124 | 232 | 312 | 248 |
|--------|----|----|-----|----|-----|-----|-----|-----|

| | | | | | | | | |
|--------|----|----|-----|----|-----|-----|-----|-----|
| stems: | 16 | 29 | 103 | 29 | 141 | 266 | 439 | 423 |
|--------|----|----|-----|----|-----|-----|-----|-----|

| | | | | | | | | |
|-------|----|----|-----|----|-----|------|------|------|
| (n=3) | ±2 | ±6 | ±36 | ±5 | ±48 | ±182 | ±421 | ±130 |
|-------|----|----|-----|----|-----|------|------|------|

Trees and shrubs:

| | | | | | | | | |
|-----------------------------|-----|-----|-----|-----|-----|----|-----|----|
| <i>Alnus incana</i> (E) | 32 | 84 | 232 | 76 | . | 3 | 255 | 14 |
| <i>Betula nana</i> (E) | 19 | 50 | 116 | 62 | 41 | 10 | 118 | 3 |
| (n=21) | ±7 | ±26 | ±20 | ±19 | ±14 | ±5 | ±44 | ±2 |
| <i>Betula nana</i> (F) | 19 | 40 | 109 | 98 | 45 | 7 | 133 | 11 |
| <i>Betula nana</i> (J) | 30 | 109 | 76 | 74 | 63 | 6 | 202 | 4 |
| <i>Betula nana</i> (N) | 20 | 34 | 104 | 79 | 40 | 4 | 158 | 1 |
| <i>Betula pubescens</i> (E) | 20 | 61 | 153 | 87 | 49 | 10 | 204 | 5 |
| (n=9) | ±10 | ±41 | ±29 | ±25 | ±19 | ±6 | ±67 | ±2 |
| <i>Betula pubescens</i> (F) | 25 | 63 | 124 | 138 | 51 | 12 | 187 | 17 |
| <i>Betula pubescens</i> (G) | 19 | 45 | 176 | 137 | 43 | 8 | 115 | 12 |
| <i>Betula pubescens</i> (J) | 46 | 149 | 174 | 132 | 90 | 8 | 373 | 9 |
| <i>Betula pubescens</i> (L) | 23 | 82 | 91 | 79 | 49 | 15 | 166 | 11 |
| <i>Betula pubescens</i> (N) | 18 | 34 | 178 | 114 | 40 | 4 | 202 | 4 |
| <i>Populus tremula</i> (E) | 27 | 82 | 371 | 50 | . | 4 | 310 | 23 |
| <i>Salix herbacea</i> (J) | 27 | 89 | 85 | 52 | 56 | 7 | 257 | 18 |
| <i>Salix lapponum</i> (E) | 19 | 51 | 106 | 51 | 60 | 11 | 211 | 21 |

trifoliata and *Nuphar lutea*. Potassium was lowest in lichens and usually highest in grasses, sedges and herbs. Chloride was low in most mosses, lichens, trees and shrubs as well as in heather, but generally high in grasses and sedges, and highest in horsetails and aquatic plants. Particularly high values were found in herbs like *Cirsium heterophyllum*, *Lactuca alpina* and *Saussurea alpina*. (Table 1). Calcium and magnesium were low in most mosses, lichens, grasses, sedges, mushrooms, trees, and shrubs. The best calcium and magnesium sources were generally herbs. The best sources of phosphorus were mushrooms, herbs including *Oxyria digyna*, *Pedicularis sp.*, *Rumex acetosa*, and trees including *Sorbus aucuparia* and *Salix sp.* Sulphur was exceptionally high in horsetails and in aquatic herbs. Nitrogen was very low in most lichens, except for *Nephroma arcticum*, and generally high in mushrooms, grasses and herbs including *Rumex acetosa* and in some trees, *Alnus incana*, *Sorbus aucuparia* and *Salix sp.*

Discussion

Comparison of mineral and nitrogen concentrations in different species of plants and between plants collected from different soil types or in different geographical regions is complicated by the fact that the nutrient content is strongly dependent on phenological development of any particular species (Fig. 2). This seasonal variation can easily overshadow regional variation and can exaggerate or mask differences unless plants

are not collected at exactly the same stage of development. These problems can only partly be overcome by collecting plants regularly through the growing season and comparing graphs. The graphs should preferably be zeroed at particular development points of the plant, e.g. sprouting. However, not all nutrients undergo the same seasonal variation. For instance sodium, chloride, sulphur and calcium seem to remain stable throughout the growing season in some species. Mosses and lichens exhibit little seasonal variation in any element (Table 1; Fig 2). Nitrogen, phosphorus and potassium are highest in early phenological stages of green forage. These stages are the best suppliers of these nutrients. Areas with large variation in snow cover and time of the melt therefore give good supply of these elements through a longer period of the summer grazing season.

High intake of potassium may interact with sodium and cause increased excretion of Na^+ and reduced body pools of this ion (Staal and Garmo, 1987). An increased demand for sodium can, however, be met by eating more sodium rich vegetation including aquatic herbs. As an example 1 kg DM of leaves of the waterlily, *Nuphar lutea*, contains as much sodium as 34 kg DM of the lichen *Cladonia stellaris* or as much as 39 kg DM of the wavy hair-grass *Deschampsia flexuosa*. The obligatory fecal loss of sodium feeding on lichens may equal or surpass the intake (Table 2). Likely the fecal loss is approximately the same by eating one kg of li-

Table 2. Hypotetical forage-fecal balance of nitrogen and minerals for a reindeer feeding on a pure diet of *Cladonia stellaris* from Elgå herding district. Fecal concentrations are from a feeding experiment with reindeer fed a pure lichen diet (White and Staaland 1984). Assumed digestibility of dry matter 75 %.

| Element | Nutrient content in 1 kg dry <i>C. stellaris</i> | Fecal concentrations per kg dry matter | «Balance» Food-fecal output |
|---------|--------------------------------------------------------|-------------------------------------------|-----------------------------------|
| Kj.N- | 4.0 g | 17.7 g | -0.43 g |
| Na | 9 mM | 68 mM | - 8 mM |
| K | 22 mM | 56 mM | + 8 mM |
| Ca | 12 mM | 160 mM | -28 mM |
| Mg | 8 mM | 59 mM | - 7 mM |
| S | 13 mM | 59 mM | + 3 mM |
| Cl | 2 mM | 1 mM | + 2 mM |
| P | 12 mM | 44 mM | + 1 mM |

chens or aquatics. The net sodium gain for a reindeer eating 1 kg waterlilies could therefore be as high as 300 mM.

It is well established that reindeer can be in a negative nitrogen and sodium balance through the winter (McEwan and Whitehead, 1970; Staaland *et al.*, 1982) and need to replenish their body pools in summer. Early green vegetation and plants including mushrooms, mountain sorrel (*Oxyria digyna*) and other herbs are important nitrogen sources. Aquatics and horsetails are important sodium sources.

Less is known about the requirements for other nutrients in reindeer. Plasma or bone concentrations of magnesium may decline through the winter (Bjarghov *et al.*, 1977; Staaland *et al.*, 1982; Staaland *et al.*, 1991). Horsetails and herbs are apparently potentially good sources of magnesium (Table 1). Similar evaluations can be made for other elements. Based on comparison of fecal nutrient concentrations from reindeer fed a pure lichen diet and nutrient content of the lichen *Cladonia stellaris* from Elgå, reindeer would apparently frequently experience a negative mineral and nitrogen balance unless supplementing their diet with other types of vegetation (Table 2). Reindeer frequently also feed on mineral rich plants like horsetail (*Equisetum* spp.) and buck-bean (*Menyanthes trifoliata*) and snow beds with plants in early stage of development are preferred grazing (Skjenneberg and Slagsvold, 1968).

Although the requirements for different nutrients in reindeer are poorly known, reindeer

pasture with a diversified vegetation, landscape, melt off time and geological formation would best ensure that the animals can meet their nutrient demands (Staaland *et al.*, 1986). The mineral content of lichens, which are an important part of the diet in winter can vary considerably regionally. For example, the lichens from the Elgå area have 2-3 times as much sodium as lichens of the same species in Numedal. The reason for such differences are not known but may depend on the distance from the sea and on prevailing wind direction. Since aquatic plants apparently accumulate important minerals like sodium, special attention should be paid to the occurrence of wet areas in pasture evaluations.

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