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.

Rangifer, 13 (3): 169—177

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

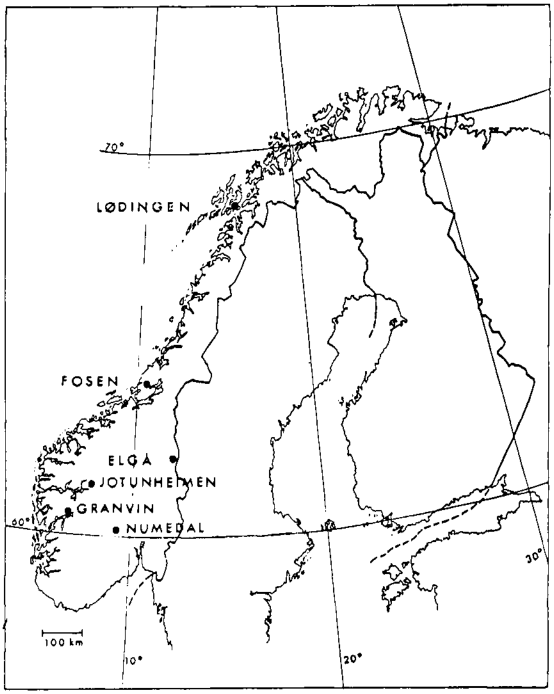

Fig. 1. Sampling locations in Norway.

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 cholride. These observations are exemplified for *Betula nana, Vaccinum 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

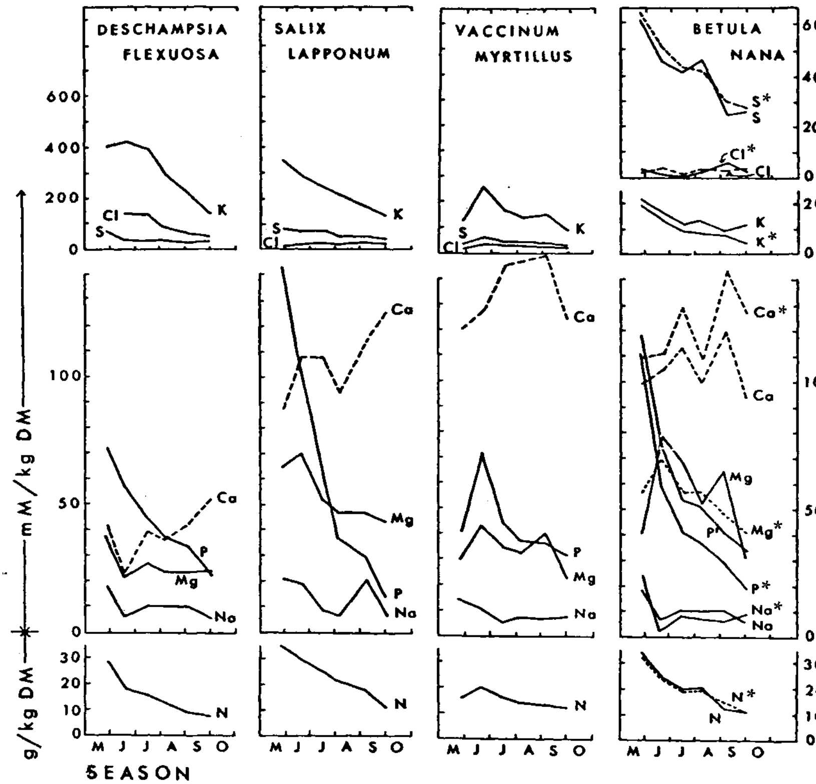

Fig. 2. Examples of seasonal variations in mineral and nitrogen concentrations of 4 forage plants from the Elgå reindeer herding district. *Betula nana* was collected from two different locations. The elements marked * are from a small location with orthoceras limestone whereas those unmarked are from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

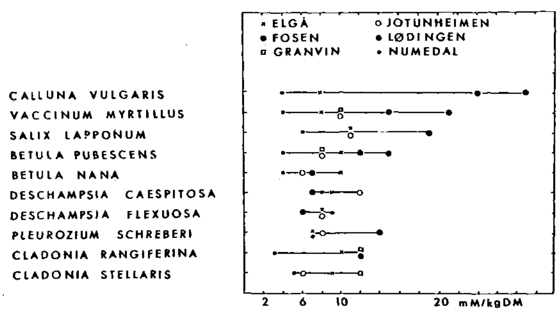

Fig. 3. Range of variation in sodium concentrations in forage plants from different geographical areas.

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*

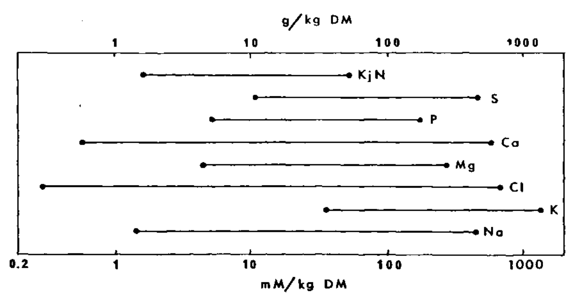

Fig. 4. Interspecific range of variations in mineral and nitrogen concentrations in reindeer forage from the Elgå herding district. Nitrogen is given in g/kg DM and minerals in mM/kg DM.

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

Mushrooms:								
Lactarius rufus (E)	38	167	5	30	.	13	740	5
Leccinum scabrum (E)	34	116	2	24	.	10	278	32
Leccinum testaceo scabrum (E)	30	123	1	21	.	6	552	45
(n=3)	±6	±34	±1	±4	.	±0	±65	±3
Russula paludosa (E)	32	146	1	30	.	20	805	94
Suillus variegatus (E)	23	123	1	25	.	8	543	53
Grasses and sedges:								
Carex bigelowii (E)	16	34	50	33	54	12	295	16
(n=5)	±6	±14	±9	±7	±10	±3	±127	±8
Carex bigelowii (F)	19	33	24	38	.	12	323	33
Carex bigelowii (N)	13	22	22	29	43	8	243	21
Carex canescens (E)	23	63	73	50	66	5	326	63
(n=3)	±7	±16	±2	±12	±7	±3	±45	±52
Carex nigra (F)	28	48	40	96	73	37	429	114
	±2	±3	±8	±2	±6	±6	±4	±3
Carex rostrata (E)	17	31	55	29	58	9	360	12
(n=7)	±5	±12	±15	±5	±14	±3	±86	±4
Carex rostrata (F)	20	58	50	48	69	7	454	15
Carex chordorrhiza (F)	.	41	55	48	.	9	367	6
Carex flava (E)	.	53	54	54	.	19	387	.
Carex lasiocarpa (E)	18	42	79	38	.	6	451	124
Carex limosa (E)	.	34	71	63	.	16	258	56
Carex magellanica (E)	.	74	52	68	.	14	407	415
Carex rotundata (E)	.	70	41	45	.	22	321	4
Deschampsia caespitosa (E)	19	64	64	53	55	9	454	200
(n=7)	±9	±23	±16	±24	±20	±4	±129	±93
Deschampsia caespitosa (F)	15	42	43	73	65	7	463	254
Deschampsia caespitosa (J)	31	68	55	65	99	12	552	110
Deschampsia caespitosa (N)	22	48	84	56	72	8	575	322
Deschampsia flexuosa (E)	14	39	40	25	37	8	273	78
(n=10)	±7	±17	±8	±5	±13	±5	±124	±49
Deschampsia flexuosa (F)	12	43	46	40	52	6	390	147
Deschampsia flexuosa (J)	24	71	32	48	56	8	388	113
Deschampsia flexuosa (N)	16	45	37	34	66	9	553	236
Eriophorum angustif. (E)	18	42	38	36	58	16	299	55
(n=7)	±6	±25	±7	±8	±11	±9	±156	±25
Eriophorum angustif. (F)	19	34	34	41	53	36	203	42
Eriophorum angustif. (L)	14	33	25	32	.	9	184	21
Juncus trifidus (E)	20	38	38	24	55	15	303	102
(n=6)	±8	±14	±14	±3	±8	±7	±136	±22
Juncus trifidus (J)	25	72	32	34	63	13	303	84
Juncus trifidus (N)	17	30	34	22	50	9	264	72
Luzula pilosa (E)	13	61	75	110	30	17	837	197
Luzula pilosa (L)	16	73	94	110	.	11	466	357
Molinia caerulea (E)	25	44	33	40	83	7	317	91
Molinia caerulea (F)	26	51	34	43	76	6	332	94
Scirpus caespitosus (E)	16	30	48	33	66	10	267	61
(n=7)	±7	±18	±17	±3	±15	±5	±104	±27
Scirpus caespitosus (F)	20	35	40	46	50	6	284	97
Scirpus caespitosus (N)	18	28	61	28	56	11	350	78

Liliaceae:								
Narthecium ossifragum (F)	28	41	85	79	73	37	611	473
Aquatic graminids:								
Sparganium angustifo. (E)	33	93	265	91	.	106	746	174
Herbs:								
Angelica sylvestris (E)	32	87	435	153	.	5	948	295
Alchemilla alpina (E)	19	51	198	101	.	10	375	196
Caltha palustris (E)	28	88	337	173	.	11	1118	362
Cirsium heterophyllum (E)	25	57	473	105	.	5	778	614
Filipendula vulgaris (E)	26	69	147	193	.	5	415	127
Geranium sylvaticum (E)	22	93	317	107	.	7	541	144
Lactuca alpina (F)	24	60	267	310	.	8	1241	733
Linnaea borealis (E)	.	56	215	90	.	10	406	.
Melampyrum pratense (E)	22	81	229	100	90	12	504	61
(n=4)	±8	±26	±68	±14	±15	±3	±61	±9
Melampyrum pratense (F)	18	92	258	178	65	31	630	73
Melampyrum pratense (J)	25	96	156	118	86	7	508	78
Melampyrum pratense (N)	14	62	148	140	66	8	475	42
Melampyrum sylvaticum (E)	20	72	235	137	.	6	482	141
Oxyria digyna (J)	35	112	439	134	72	11	487	59
Pedicularis lapponica (J)	24	86	109	66	73	17	473	17
Pedicularis sceptrum-c. (E)	.	135	277	122	.	6	447	40
Polygonum viviparum (E)	30	96	168	172	.	13	364	106
Potentilla erecta (E)	24	60	287	117	.	8	252	127
Potentilla erecta (F)	17	50	151	222	60	41	362	139
Potentilla palustris (E)	27	100	254	159	.	8	509	78
Rubus saxatilis (E)	20	51	173	267	.	8	249	111
Rumex acetosa (E)	35	113	125	128	75	46	840	264
(n=5)	±10	±39	±18	±48	±12	±9	±149	±120
Rumex acetosa (L)	49	170	81	126	.	37	694	193
Saussurea alpina (L)	.	61	393	145	.	16	1072	672
Solidago virgaurea (F)	23	61	137	226	71	215	931	286
Aquatic herbs:								
Menyanthes trifoliata (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
Montia fontana (E)	31	115	104	164	84	47	1018	310
(n=5)	±8	±27	±24	±34	±18	±26	±192	±108
Nuphar lutea (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:								
Alnus incana (E)	32	84	232	76	.	3	255	14
Betula nana (E)	19	50	116	62	41	10	118	3
(n=21)	±7	±26	±20	±19	±14	±5	±44	±2
Betula nana (F)	19	40	109	98	45	7	133	11
Betula nana (J)	30	109	76	74	63	6	202	4
Betula nana (N)	20	34	104	79	40	4	158	1
Betula pubescens (E)	20	61	153	87	49	10	204	5
(n=9)	±10	±41	±29	±25	±19	±6	±67	±2
Betula pubescens (F)	25	63	124	138	51	12	187	17
Betula pubescens (G)	19	45	176	137	43	8	115	12
Betula pubescens (J)	46	149	174	132	90	8	373	9
Betula pubescens (L)	23	82	91	79	49	15	166	11
Betula pubescens (N)	18	34	178	114	40	4	202	4
Populus tremula (E)	27	82	371	50	.	4	310	23
Salix herbacea (J)	27	89	85	52	56	7	257	18
Salix lapponum (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, liehens, 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., Rumes 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 variaton 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 (Staaland 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 *C. stellaris*	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 sorell (*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 (*Menyantes 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 diversed 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.

Acknowledgements

This study was supported by the Reindeer Husbandry Research Committee (RFU).

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Manuscript accepted 21 September, 1993