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Impact of forest fertilizers on winter pastures of semi-domesticated reindeer

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Abstract: The effects of forest fertilizers on *Calluna vulgaris, Vaccinium vitis-idaea, Cladina arbusculua, Cladina rangiferina* and *Cladina stellaris* were studied during an eleven-year experimental period in Västerbotten, Sweden. The study site was situated in the boreal region and was part of a 130 years old *Pinus sylvestris* stand. The forest type is mainly the dry dwarf-shrub type.

Thirty-two demarcated plots (20 m x 20 m) were grouped into eight blocks, each containing four plots. In 1979 and 1985 fertilizations with ammonium nitrate equiavalent to 150 kg N ha^{-1}, with ammonium nitrate equiavalent to 250 kg N ha^{-1} and with urea equiavalent to 150 kg N ha^{-1} were carried out.

Field sampling wad done in late July 1979, 1980, 1982, 1984, 1985, 1986, 1988 and 1990. Main parameters studied were coverage, height and standing crop.

Effects were visible already after one growing season. All treatments had a positive effect on the growth of *C. vulgaris* and *V. vitis-idaea.* Doses around or over 150 kg N ha^{-1}, gave a clearly negative effect (range 23 % - 73 %) on the standing crop of *Cladina spp.* for a period of time exceeding eleven years compared to the control standing crop.

Key words: Fertilization, winter pastures, *Cladina arbuscula* (Wallr.) Hale & Culb., *Cladina rangiferina* (L.) Nyl., *Cladina stellaris* (Opiz) Brodo, *Cladina Spp., Vaccinium vitis-idaea* (L.), *Calluna vulgaris* (L.) Hull, *Rangifer tarandus tarandus* (L.), Sweden.

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Introduction

Abundance and availability of winter forage are among the most important controlling mechanisms in limiting reindeer populations unless supplementary feeding is widely practiced (Kojola & Helle, 1993).

Lichen-dominated plant communities of the northern but also the middle boreal forest region (Sjörs, 1987) form the most important winter range areas. Lichens, dwarf-shrubs and wintergreen graminoids are a primary source of winter food. Species like *Cladina arbuscula* (Wallr.) Hale & Culb./*Mitis* (Sandst.) Hale & Culb., *C. Rangiferina* (L.) Nyl., *C. stellaris* (Opis) Brodo, *Deschampsia flexuosa* (L.) Trin., *Eriophorum vaginatum* L., *Vaccinium myrtillus* L., *V. vitis-idaea* L., *Empetrum hermaphroditum* (Hagerup) and *Calluna vulgaris* (L.) Hull. are major forage plants (Skuncke, 1958; Gaare & Skogland, 1975; Eriksson *et al.*, 1981; Helle,

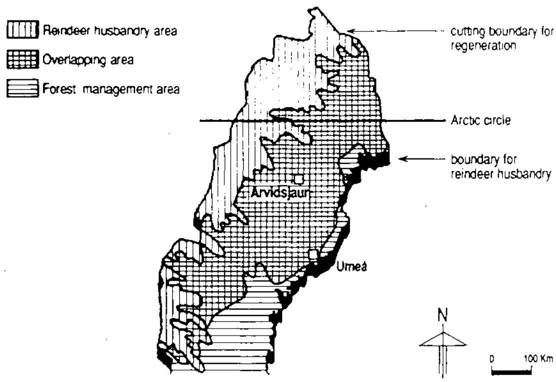

Fig. 1. Areas of interest to forestry and to reindeer husbandry in northern Sweden (Mattsson, 1981).

1981; Warenberg, 1982; Nieminen *et al.*, 1989).

Most of the winter range, about 90 000 km^2, lies in areas where logging is the major industry (Mattsson, 1981)(Fig. 1). Even though current forest management methods are considered by reindeer herders to be detrimental to reindeer pastures (Lantbruksstyrelsen, 1984) only few evaluations have been carried out in Sweden. However, Arnström (1975) studied the effects of clear-felling on reindeer pastures, and Eriksson *et al.* (1987) analyzed the influence of timber production on lichens for reindeer grazing. Andersson (1984) compared the occurrence and quantity of tree lichens between a *Picea abies* (L.) Karst., *Pinus sylvestris* (L.) and a *P. contorta* (Doug.) stand. Eriksson and Raunistola (1990) studied the impact of soil scarification on pastures, and Kardell and Eriksson (1992) studied effects of the introduction of *P. contorta* on reindeer pastures. Retrospective field studies in Sweden of the effects of forest fertilization on reindeer lichen biomass were first carried out by Andersson *et al.* (1974).

The annual acreage of treated areas has varied greatly with trade conditions during the past decade. A high figure was reached in 1986 when 56 000 ha of middle-aged to mature conifer stands were treated by large-scale forestry companies within the three northernmost counties in Sweden where most reindeer husbandry is located, whereas in 1988 only 26 000 ha were treated as compared with 36 000 ha in 1990 (Statistical Yearbook of Forestry, 1992).

Investigations have shown that the two most commonly used fertilizers, ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$), if properly handled and spread, have only negligible toxic effects on reindeer (Nordkvist & Erne, 1983). Åhman and Åhman (1984) found that fertilization with ammonium nitrate or urea caused a nitrate accumulation in forage plants, which was clearly below the toxic level for reindeer. They also showed that forest fertilization with ammonium nitrate as well as with urea increases the standing crop of some phanerogams of importans to reindeer, e.g. *Deschampsia flexuosa*. On the other hand, forest fertilization with ammonium nitrate markedly reduces pasture utilization during the first winter after treatment. Fertilization with urea has an even greater negative effect, that persists for at least two winters (Eriksson, 1980, 1984).

In 1975 a long-term project started, the aim being investigations into effects of forest fertilization on reindeer and on reindeer forage plants. The project was conduced in co-operation with the National Forest Enterprises of Sweden, the Institute for Forest Improvement, the Swedish University of Agricultural Sciences (Reindeer section), and the National Veterinary Institute. This paper examines the effects of fertiliziation on important reindeer forage plannt species/groups during an eleven-year experimental period.

Study area

The study site is situated 20 km WNW of Bjurholm, county of Västerbotten (64°00′N, 18°50′E), 235 m a.s.l. Mean annual precipitation is 560–807 mm, of which about 35 % falls as snow (Atlas över Sverige, 1953). The growing season (< + 6° C) lasts 131–139 days (Perttu & Huzar, 1976). The temperature sum for the study area is 903° C, with a threshold value of +5° C (Odin *et al.*, 1983). The soil is an iron podsol with an average thickness of the humus layer being about 3 cm. The soil type is sandy/gravely moraine.

The study site is situated in the boreal region (Sjörs, 1986) and is part of *Pinus sylvestris* (Scots pine) stand. The forest type is mainly the dry dwarf-shrub type (Arnborg, 1990). The field- and bottomlayers consist mainly of *Calluna vulgaris, Vaccinium vitis-idaea* and *Cladina spp.* Other lichens such as *Cetraria ericetorum* Opiz., *C. islandica* (L.) Ach., *Cladonia uncialis* (L.) Wigg., *Cladonia spp., Stereocaulon spp.* occur. Among mosses, *Pleurozium schreberi, Polytrichum spp.* and *Dicranum spp.* dominate. Graminids and herbs are rare.

Photo 1. Forest fertilizers are usually spread from helicopters. Photo L. Öster.

Stand age at the start of the study was 130 days. The density and the basal area amounted to 491 stems and 11.3 m^2 per hectare, respectively. Mean stem diameter at breast height was 17.5 and mean height was about 14 m. From an economical point of view, this stand should not have been fertilized, since the yield even after treatment would be too low. It was, however, chosen because the lichen carpet in the initial stage was prominent and thus, effects of fertilization would be easy to observe. The study site belongs to an area which, in winter time (December to March) is grazed mainly by reindeer owned by members of Vilhelmina norra Saami community.

Total deposition by long distance air transport of NH^{4+} -N and NO^{3-} -N in the study area was about 4–5 kg nitrogen ha^{-1} $year^{-1}$ (Lövblad 1991 in Bråkenhielm, 1991).

Material and methods

The study was based on 32 demarcated plots (20 m x 20 m), all within one fence to keep ungulates out. After visual examination the plots were grouped into eight blocks (BI - BVIII), each containing four plots. The four plots in the same block were chosen in such a way that they were as comparable as possible.

Fertilization

In 1979 and 1985 fertilization with ammonium nitrate (NH_4NO_3), containing 34.5 % (N), and with urea ($CO(NH_2)_2$), containing 46.0 % (N), was carried out in the blocks according to the following scheme:

1. 435 kg amminium nitrate ha^{-1}, being equivalent to the presently used standard dose in forestry of 150 kg N ha^{-1}, the treatment being called AN 150.

2. 725 kg ammonium nitrate ha^{-1}, equivalent to 250 kg N ha^{-1}, the treatment being called AN 250.

3. 326 urea ha^{-1}, equivalent to 150 kg N ha^{-1}, the treatment being called Urea 150.

4. No fertilization (control).

In 1985, when the plots were refertilized, boron (B), 1 kg ha^{-1} was added to treatments 1 and 2, thus following current practice in forestry. The fertilizer was distributed by hand as evenly as possible over the gross plot.

Field sampling

For experimental and sampling purposes, a net plot, size 15 m x 15 m, was used. The number of sampled quadrats was decided after experiences from an unpublished study of standing crop in a stand of the same kind (Eriksson O. unpublished data).

Field samplings were made at the end of July 1979, 1980, 1982, 1984, 1985, 1986, 1988 and 1990. The quadrats were randomly chosen at the first sampling and later randomly with previously treated quadrats excluded. Excluded were also quadrats housing boulders, tree stems etc.

Cover and height estimations

During each field sampling twenty 0.5 m x 0.5 m quadrats per plot (in total 640 quadrats) were scrutinized as to access cover and mean height for each plant species or species group. Cover was estimated in per cent so that the field- and bottomlayers together with litter and bare soil reached 100 %. The species were analyzed as single species or lumped together in species groups as follows:

Species/species group	Cover	Height	Standing crop
Calluna vulgaris	x	x	x
Vaccinium vitis-idaea	x	x	x
Cladina arbuscula	x	x	-
Cladina rangiferina	x	x	-
Cladina stellaris	x	x	-
Cladina spp. (*)	-	-	x

* including some *Cladonia* spp.

During 1979–1985 a fixed set of quadrats was analyzed in blocks BV - BVIII, but in blocks BI–BIV new quadrats were chosen at random and sampled on each occasion except in 1985 (for explanation see below). During 1986–1990 the quadrats were permanent in blocks BI - BIV and in blocks BV - BVIII new plots were selected. Because of the lack of resources in 1985, coverage and height estimations were made only in half of the blocks, namely in blocks BV - BVIII.

Estimation of standing crop

At each field sampling, a total of 320 destructive samples size 500 cm^2 were taken for standing crop estimation in half of the blocks. The samples were cut in the centre of the quadrats used for cover and height estimation; during 1979–1984 in blocks BI–BIV and in 1985 - 1990 in blocks BV - BVIII.

For standing crop assessments, the *Cladina* species were lumped together since the separation of small air dried lichen fragments into species was considered too laborious and unreliable. The samples were sorted into species or species groups, dried (24 hours at 85° C) and weighed (+– 0.1 g).

Weather during the fertilizing period

In 1979, the fertilization was immediately followed by a heavy rainfall. In 1985, there was dry, fair, weather during and after refertilization. After a few days there were some light rainshowers.

Statistical analyzes

The effects of treatments were tested with analysis of variance (ANOVA), with the GLM procedure, and Duncan's multiple range test. The confidence level between treatments and controls was set to 95 %. The development of vegetation in the control plots from 1979 to 1990 was tested with Duncan's multiple range test.

Nomenclature follows Lid (1985) for vascular plants, Hallingbäck and Holmåsen (1985) for mosses and Moberg and Holmåsen (1982) for lichens.

Results

Basic comparability of study plots

The ground vegetation within the investigation area is relatively homogeneous. There were no significant differences between plots at the start in 1979 in species cover or in cover of *Cladina* species lumped together (Figs. 2, 4, 6, 7, 8).

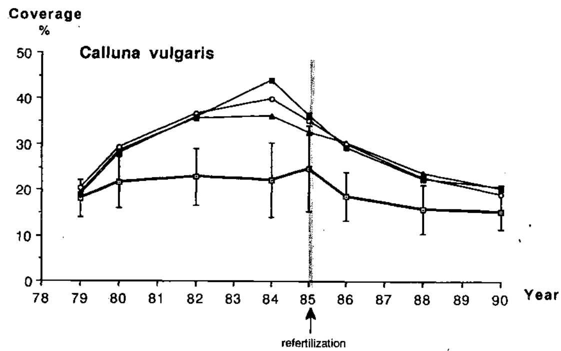

Fig. 2. The impact of forest fertilizers upon the cover of *Calluna vulgaris* during 1979–1990. (□ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

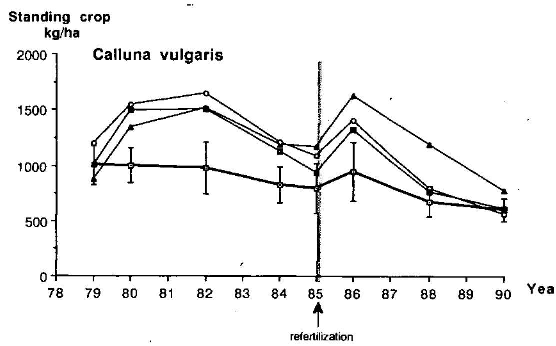

Fig. 3. The impact of forest fertilizers upon the standing crop of *Calluna vulgaris* during 1979–1990. (□ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

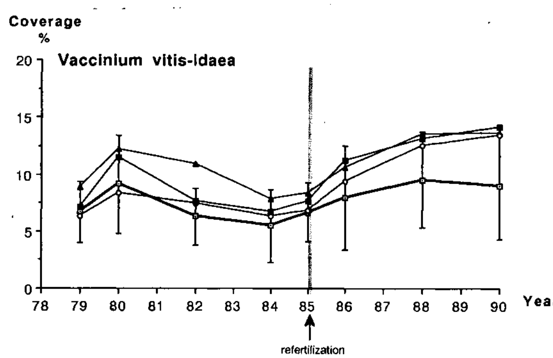

Fig. 4. The impact of forest fertilizers upon the cover of *Vaccinium vitis-idaea* during 1979–1990. (□ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

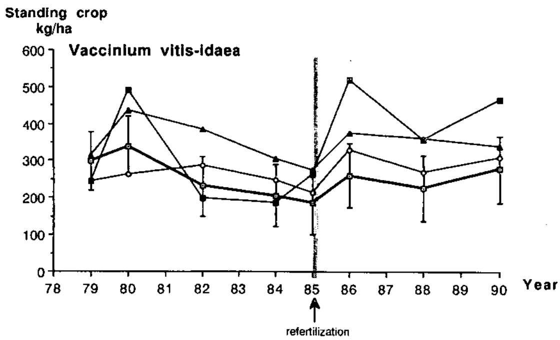

Fig. 5. The impact of forest fertilizers upon the standing crop of *Vaccinium vitis-idaea* during 1979–1990. (☐ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

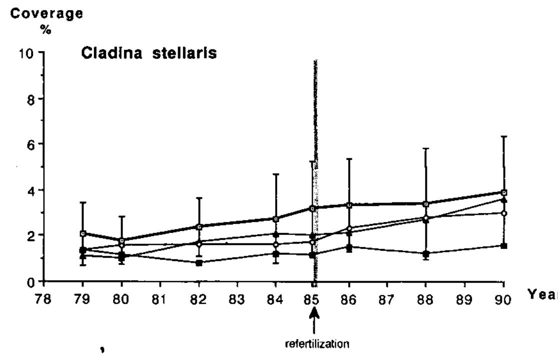

Fig. 8. The impact of forest fertilizers upon the cover of *Cladina stellaris* during 1979–1990. (☐ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

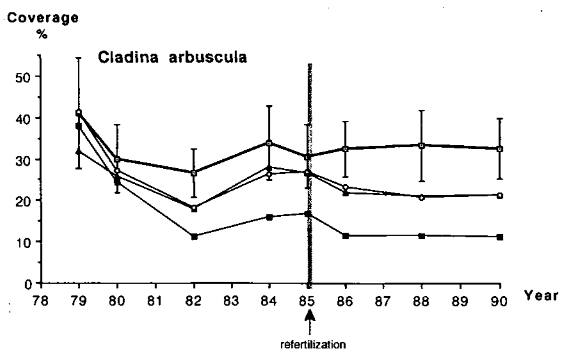

Fig. 6. The impact of forest fertilizers upon the cover of *Cladina arbuscula* during 1979–1990. (☐ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

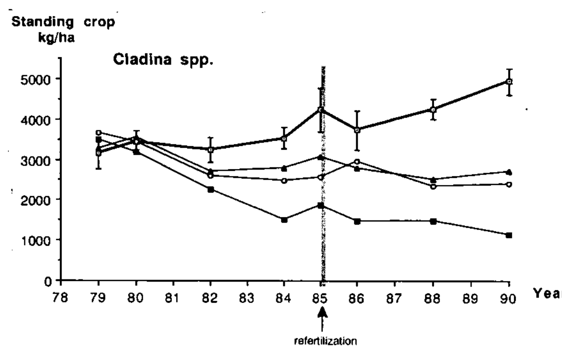

Fig. 9. The impact of forest fertilizers upon the standing crop of *Cladina spp.* during 1979–1990. (☐ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

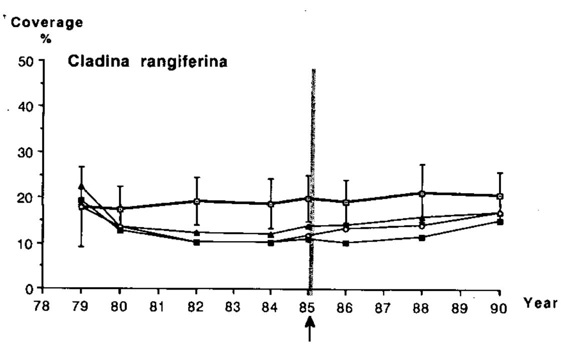

Fig. 7. The impact of forest fertilizers upon the cover of *Cladina rangiferina* during 1979–1990. (☐ = Control plots, ▲ = AN 150 plots, ○ = AN 250 plots, ■ = Urea 150 plots, I = confidence level between controls and treatments (95 %)).

Height and stading crop of some species did however differ between plots inspite of meticulous preparations. The standing crop of *Vaccinium vitis-idaea* was about 18 % lower in the AN 250 plots as well as in the Urea 150 plots as compared with the control plots (Fig. 5). In the AN 250 plots, the standing crop of *Calluna vulgaris* was about 18 % higher and that of *Cladina spp.* about 16 % higher than in the control plots (Figs. 3, 9).

During the study period there was no species turnover of important reindeer forage plants or plant groups in the area. The dynamics instead involved changes between already existing species or species groups.

Table 1. Mean cover, mean standing crop and mean height of *Calluna vulgaris* in the control plots and test of significant differences (Duncan's multiple range test). Years with the same letter are not significantly different.

Year	Cover	Standing crop	Height
	% Duncan's test	kg/ha Duncan's test	cm Duncan's test
1979	18 – B C	1011 A –	17 – B C –
1980	22 A B –	1000 A –	15 – – C D
1982	23 A B –	970 A –	14 – – – D
1984	22 A B –	823 A B	15 – – – D
1985	25 A – –	793 A B	15 – – C D
1986	19 – B C	945 A –	17 – B – –
1988	16 – – C	673 A B	17 – B – –
1990	15 – – C	590 – B	23 A – – –

Development in control plots

In the untreated plots, the coverage of *Calluna vulgaris* increased during the first six years but then decreased to a lower value than at the start of the investigation (Fig. 2). The cover in 1988–1990 was significantly lower than in 1980–1985 (Table 1). During the same period, the standing crop diminished from 1011 kg ha^{-1} to 596 kg ha^{-1} in 1990 (Fig. 3). The standing crop that year was significantly lower than during the three first sampling years (Table 1). The plant height first decreased to the lowest level three years after the start and then increased to 23 cm in 1990. The changes were statistically significant (Table 1).

Cover and standing crop of *Vaccinium vitis-idaea* fluctuated over time (Figs. 4, 5) with high values in 1980 and at the end of the investigation period, i.e. eight to ten years between peaks. The standing crop reached its first peak value of 339 kg ha^{-1} in 1980 and in 1990 its second peak with 277 kg ha^{-1}. Cover was highest in 1980 and 1988, 9 % in both years. The lowest cover was measured in 1984, 5 %, and the lowest standing crop in 1985, 185 kg ha^{-1}, respectively, both significantly different from the peak value in 1980 (Table 2). The average height of the plants increased significantly during the study period from 10 cm to 14 cm (Table 2).

The summed cover of all reindeer lichens did not change significantly during the investigation in spite of a rather high variation between sampling years. The cover of *C. arbuscula* was rather stable, around 26–34 %, except in 1979 when the cover amounted to 41 % (Fig. 6, Table 3). Changes in the cover of *C. rangiferina* and *C. stellaris* were insignificant (Figs. 7, 8; Tables 4, 5).

The standing crop of reindeer lichens increased significantly during the study period from 2152 kg ha^{-1} to 4935 kg^{-1} (Fig. 9; Table

Table 2. Mean cover, mean standing crop and mean height of *Vaccinium vitis-idaea* in the control plots and test of significant differences (Duncan's multiple range test). Years with the same letter are not significantly different.

Year	Cover	Standing crop	Height
	% Duncan's test	kg/ha Duncan's test	cm Duncan's test
1979	7 – B C D	299 A B	10 – – C –
1980	9 A B – –	339 A –	9 – – – D
1982	6 – – C D	230 A B	8 – – – D
1984	5 – – – D	205 – B	9 – – – D
1985	7 – B C D	185 – B	9 – – – D
1986	8 A B C D	260 A B	11 – B – –
1988	9 A – – –	225 A B	12 – B – –
1990	9 A B C –	277 A B	14 A – – –

Table 3. Mean cover, mean standing crop and mean height of *Cladina arbuscula* in the control plots and test of significant differences (Duncan's multiple range test). Years with the same letter are not significantly different.

Year	Cover		Height	
	%	Duncan's test	cm	Duncan's test
1979	41	A —	7	— — C — — —
1980	30	— B	5	— — — — — E F
1982	26	— B	5	— — — — — — F
1984	34	A B	6	— — — D E —
1985	31	— B	6	— — C D — —
1986	33	— B	8	— B — — — —
1988	33	— B	8	— B — — — —
1990	33	— B	9	A — — — — —

Table 4. Mean cover and mean and mean height of *Cladina rangiferina* in the control plots and test of significant differences (Duncan' s multiple range test). Years with the same letter are not significantly different.

Year	Cover		Height	
	%	Duncan' s test	cm	Duncan' s test
1979	18	A	8	— B C — — —
1980	17	A	6	— — — — — E F
1982	19	A	6	— — — — — — F
1984	19	A	7	— — — D E —
1985	20	A	7	— — C D — —
1986	19	A	8	— B — — — —
1988	21	A	8	— B — — — —
1990	21	A	9	A — — — — —

Table 5. Mean cover crop and mean height of *Cladina stellaris* in the control plots and test of significant differences (Duncan' s multiple range test). Years with the same letter are not significantly different.

Year	Cover		Height	
	%	Duncan' s test	cm	Duncan' s test
1979	2	A B	9	— B —
1980	2	— B	8	— — C
1982	2	A B	7	— — C
1984	3	A B	7	— — C
1985	3	A B	8	— — C
1986	3	A B	9	A B —
1988	3	A B	10	A B —
1990	4	A —	11	A — —

Table 6. Mean standing crop of *Cladina spp.* in the control plots and test of significant differences (Duncan' s multiple range test). Years with the same letter are not significantly different.

Year	Standing crop	
	kg/ha	Duncan' s test
1979	3152	— — C
1980	3433	— — C
1982	3235	— — C
1984	3527	— B C
1985	4231	A B —
1986	3729	— B C
1988	4247	A B —
1990	4935	A — —

6). In this standing crop figure also som *Cladonia* species were included, mostly *Cladonia uncialis,* whose cover increased from 0.1 % at the start of the study to 2.5 % in 1990. The height of the lichens increased only slightly, but significantly (Tables 3, 4, 5).

Effects of the fertilization

Effects were visible already after one growing season. All fertilization treatments had a positive effect on the growth of *Calluna vulgaris* and *Vaccinium vitis-idaea*, but a negative one on the *Cladonia* species.

Calluna vulgaris

All treatments gave the same pattern on the cover of *Calluna vulgaris,* with an increase already in the year after the first fertilization and a peak value five years after the first treatment, but no obvious effect of the second one (Fig. 2). The effect on cover lasted to the last year of the experiment except with the AN 250 alternative. The highest cover of *C. Vulgaris* during the whole experiment was achieved with the Urea 150 treatment in 1984 (Fig. 2).

Standing crop reached peak values with all treatments three years after the first fertilization and decreased later on. Still five or six years after the start of the experiment it was higher than in the control plots (Fig. 3). After refertilization in 1985 a new peak value occurred, which was obtained in all treatments already one year after the refertilization. During this second peak, the standing crop was higher than the first one within the AN 150 plots. At the end of the investigation the standing crop of all treatments had decreased to the same level as in controls except in the AN 150 plots. In AN 250 and Urea 150 plots, the standing crop decreased to same level as in the control plots already in 1988.

Vaccinium vitis-idaea

Few significant changes of the cover of *Vaccinium vitis-idaea* were observed. Only in AN 150 plots in 1982 and in the AN 150 and Urea 150 plots at the end of the investigation were significantly higher cover figures obtained (Fig. 4). The pattern of cover changes in the three treatments was, however, similar, with an initial peak one year after the first fertilization and then a decrease. After the second fertilization a new increase of the cover occurred, which still prevailed when then investigation was finished. However, the same pattern was found in the control plots (Fig. 4).

At the start of the experiment the average standing crop of *V. vitis-idaea* was significantly lower in the plots treated with AN 250 and with Urea 150 than the control plots (Fig. 5). Consequently, the effects of these two treatments were difficult to analyze. However, the standing crop increased one year after the fertilization in all treatments and peak values were found one to three years afterwards (Fig. 5). Second peaks were observed in the year after refertilization. Significant differences were measured in all years with the AN 150 treatment and in most of the years with the Urea 150 treatment, but none with AN 250. Similar to case the cover, the standing crop had the same general pattern as found in the control plots (Fig. 5).

Cladina spp.

The three *Cladina* species, *Cladina arbuscula*, *Cladina rangiferina* and *Cladina stellaris*, had a summed cover ranging between 55 % and 61 % at the beginning of the study period.

The cover of *C. arbuscula* in plots treated with AN differed significantly from the control plots in 1982, three years after the first fertilization and the again after refertilization (Fig. 6). In plots treated with Urea 150, the cover had decreased significantly in 1982 and all following years, an effect that could still be measured in all treatments in 1990, eleven years after the start of the experiment.

Also *C. rangiferina* reacted negatively (Fig. 7). Three years after the start the cover was significantly lower in the treated plots than in the control plots. The differences continued for nine years in plots treated with AN 150 and eleven years in those treated with AN 250. The effect of the Urea 150 treatment on *C. rangiferina* lasted throughout the study period.

The treatments with AN 150 and AN 250 did not change the cover of *C. stellaris* significantly (Fig. 8). The treatment with Urea 150 caused significant changes in cover only in 1982, three years after the first fertilization.

The cover of the three *Cladina* species together diminished to between 27 and 41 % at the end of the study period, depending on the treatment. The Urea 150 treatment diminished the cover of reindeer lichens more than the nitrate treatments. The lowest cover was mesured three years after the first fertilization compared to the control cover (22 %). The refertilization did not cause a further decrease in any of the treatments.

Treatments with the three different fertilizers all gave a diminishing trend on the standing crop of *Cladina spp.* during the study period (Fig. 9). During the first years the drop was steeper than later on, but the standing crop diminishing continuously during the investigation period. The decrease in standing crop was most obvious in the Urea 150 plots.

The fertilization effects on plant height

The treatments did not lead to significant changes in the height of *V. vitis-idaea*, but *C. vulgaris* grew significantly higher in fertilized plots than in the control plots. The Urea 150 treatment caused the largest effect over time. The height of *C. arbuscula* and *C. rangiferina* diminished significantly in Urea plots but did not show clear changes in the nitrate plots. The fertilization did not change the height of *C. stellaris* at all.

Discussion

In boreal forest ecosystmens lack of available nitrogen limits the growth of shrubs and trees (Albrektson *et al.*, 1977). The increase in *Calluna vulgaris* cover is probably an effect of increased shoot length and branching. *C. vulgaris* is a species with low requirements and it reacted with an increase in standing crop to all treatments. According to Kellner and Mårshagen

(1981), that kind of effect on the cover of *C. vulgaris* has been reported from other studies on sites where grasses and herbs occur with low cover and frequency.

Watt (1947, 1955) has shown that in the heath communities the life cycle of *C. vulgaris* can be grouped into pioneer, building, mature and degeneration phases. The standing crop of *C. vulgaris* is greatest in the early mature phase and decreases throughout the life cycle (Gimingham, 1960, 1977). *C. vulgaris* in the study area was not in a pioneer phase. The study area had not suffered from forest fire or any other obvious disturbance for many years. On the other hand, the amount of dead branches and other features of degeneration were not considered to be exceptional at the start of the experiment. The diminishing of the standing crop in the control plots may partly be explained as a transition from the mature to the degeneration phase.

The effect of nitrogen fertilizers on the cover of *Vaccinium vitis-idaea* seems to be quite indifferent even though the standing crop increased in plots treated with AN 150. The total cover of *V. vitis-idaea* was, however, rather small and the significant differences between treatment plots at the start make it difficult to draw convincing conclusions. Measurement of the cover of a low-covering species is difficult and causes higher uncertainty in results. This together with the presence or absence of other species, also affects the occurrence of *V. vitis-idaea.* Persson (1981) found that *V. vitis-idaea* increased after fertilization with ammonium nitrate in a young Scots pine stand. Chester and McGraw (1983) have shown that addition of nitrogen increased the shoot population of *V. vitis-idaea,* because the probability of shoot branching increased. In contrast, Gerhardt and Kellner (1986) reported that nitrogen supply led to reduction of the cover of *V. vitis-idaea,* whereas Kellner and Mårshagen (1991), who studied the influence of irrigation and liquid fertilization on the ground vegetation in a mature Scots pine stand, found that the cover of *V. vitis-idaea* was quite unaffected by the treatment.

The increase of reindeer lichens in the control plots is mainly explained by the fact that the fence had prevented reindeer grazing since 1979. Furthermore, the lichen carpet is still in the podetium renovation phase as described by Andreyev (1977). In this phase the growth of lichens is higher than the decomposition of the dead (lower) part of the lichen thalli. The large biomass makes it reasonable to believe, however, that the end of the renovation phase is approaching.

The treatments resulted in a continuous diminishing of the reindeer lichen standing crop and the cover decreased in all treatments. Persson (1981), Faltynowics (1986) and Kellner and Mårshagen (1991) also observed decreses in the cover of lichens after nitrogen fertilization, reporting that toxic effects of fertilizers and decreases in the amount of light through shading and competition are some of the most important factors for this decrease in the lichen standing crop.

Changes in soil pH and incresed litter production are also factors that may affect lichens. In the urea plots, it could be seen that the urea treatment had a clear lethal effect on the *Cladina* species after the first fertilization in 1979.

The drastic changes after the first fertilization may depend on the weather conditions. The heavy rainfall after the treatment dissolved the solid nitrate and urea granulates and thus made the total amount of added nitrogen available to plants within a fairly short period of time. After refertilization this process took longer and about 1-3 weeks had passed before the granulates could no longer be seen. Urea can cause injuries to vegetation depending on the weather conditions during and directly after treatment. Warm and dry weather after fertilization with incorrectly granulated urea has been observed to cause injuries to the bottom layer (Nohrstedt, 1988).

Lichens have no root-organs and nutrients dissolved in water are absorbed when the thalli come into contact with moisture such as rainfall, surface runoff, or atmospheric humidity (Hale, 1967; Kershaw, 1985). Lichens accumulate nutrients both intra- and extracellularly. According to Kershaw (1985), the nutrient requirements of lichens are little known and there is no knowledge of the kinds of nitrogen compounds that are important for them (Hale, 1967). It is, however, clear that there are differences between species. Scott *et al.* (1989) showed that nitrate from simulated acid rain may have a positive effect on the growth of *Cladina* species and that it is species-specific. On the other hand, it is also known that forest fertilization with ammonium nitrate and urea has a negative effect on nitrogen-fixing lichens (Hällbom & Bergman, 1979; Nohrstedt *et al.*, 1988).

The fertilization with nitrogen is more injurious to the fungal part in lichens than to the algal and disturbs the balance between the algal and fungal components (Kauppi, 1980; Holopainen & Kärenlampi, 1985). Scott *et al.* (1989) showed that low pH after long-term spraying with rain wate of *Cladina rangiferina* and *Cladina stellaris* resulted in diminished cover, reduced photosynthetic capacity and production of smaller individual podetia. Thus, the effects of nitrogen on *Cladina* lichens is a complicated process, an interaction of several factors. The long-term effects of forest fertilization and air transported nitrogen are not always comparable. Forest fertilization is done once or twice during a period of ten-fifteen years with a dose of about 150 kg N ha^{-1} compared with atmospheric nitrogen which distributes considerably lower single doses of nitrogen more frequently. During the life span of the stand, the amount of nitrogen distributed as long distance air transport is, however, considerably larger than two instant standard treatments.

Practical remarks

Scots pine stands of xeric and of dry dwarf-shrub type (Arnborg, 1990) are ranked among the most important reindeer winter pastures in Sweden. The field and bottom layer is dominated by dwarf-shrubs and reindeer lichens which, together with some graminides, form the most valuable winter forage. Among lichens, the *Cladina* species are by far the most important component of the winter diet since they are very rich in carbohydrates and are highly palatable (Danell *et al.* 1993, Eriksson & Raunistola 1993). In this investigation, fertilization reduced the standing crop of *Cladina spp.* considerably. Linear regression figures showed a reduction of 23 % - 73 %. At the same time, the standing crop of *Cladina* species in the control plots increased by about 52 %, which corresponds to a yearly average standing crop increase of 4.7 % calculated from the regression equation.

From the point of view of the reindeer industry, an increase in standing crop of phanerogams after fertilization will not compensate for a loss of lichens since, firstly, phanerogams are not in short supply in any case, and secondly, their proteins will not subsitute the lichen carbohydrates. However, the value of these dwarf-shrubs is high simply because they grow together with *Cladina spp.* and the feeding reindeer can reach them and utilize them together with lichens without extra energy expenditure.

Stands of xeric and dry dwarf-shrub type (Arnborg, 1990) should not, according to Möller (1975), be fertilized, as these forest types do not yield enough to cover treatment costs. Occasionally, however, such stands are included in a treatment programme for various reasons. Stands of mesic dwarf-shrub type (Arnborg, 1990), which cover a large proportion of the Swedish taiga, are commonly fertilized. In 1981–82, for instance, about 89 % of the fertilized forest area owned by the National Forest Enterprise of Sweden in the northern part of Sweden belonged to this type (Remröd, 1984). The mesic dwarf-shrub forest type is fairly important to the reindeer husbandry because it is quite common and it contains patches of lichens, usually shielded by dwarf-shrubs. The protective field layer is very important when adverse snow conditions arise (skarta, bodni, vikhi, tsaevas) (Eriksson, 1976), since it may keep the lichens available.

This investigation has shown that forest fertilization with ammonium nitrate or urea, doses around or over 150 kg N ha^{-1}, gives a clearly negative effect on the standing crop of *Cladina spp.* for a period of time exceeding eleven years. The magnitude of the loss depends on the amount of lichens before treatment (i.e. on forest type and previous grazing pressure) and on the type of treatment. A rough estimate based on range work conducted by the Reindeer Section, together with results of this study, would suggest a range of 20–1200 kg d.w. ha^{-1} prevailing for more than a decade (Eriksson 1979, 1983, and unpublished data). Since statistic units in terms of acreage within forestry (i.e. forest rangers-districts etc.) do not coincide with those of the reindeer husbandry (i.e. Saami communities), large-scale evaluations are not readily made. This should be taken into account when negotiations between the forest industry and the Saami communities are held concerning future fertilization programmes. Additionally the average fertilization activities over time should also be considered when the carrying capacity of the winter range in Saami communities is calculated.

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