Some Impacts of Overgrazing by Reindeer in Finnmark, Norway

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Abstract: Some impacts of reindeer grazing on Finnmark's landscape are briefly described. Information on the impacts was gathered mostly by surveying 17 sample transects in the field, often 90 m in length; as well as by examining other localities in Finnmark, particularly the area around Ifjordfjellet. The results of rhe surveys along fences as well as in the open countryside are given. These show that much degradation has taken place along fences and that adjacent to the fence more than half the soil can be exposed to trampling and the weather. At Ifjordfjellet damage along 22.4 km of fence separating summer grazings from spring and winter grazings was severe or very severe (> 30 % bare soil exposed) over 39 % of its distance. Land alongside an 8.0 km long fence built to aid management of the reindeer herds in summer was even more degraded, with 56 % of its length on the 'inner' side severely or worse damaged, and 70 % on the 'outer' side. In open landscapes erosion by tracking, trampling and the weather is most likely in wet peaty hollows; on slopes steeper rhan 7 degrees where soils are peaty or 13 degrees where they are mineral-based; at the edge of terrace landforms or where drumlins occur; and especially where deep sandy soils occur in eskers or other fluvioglacial landforms. Soil is being denuded at rates of 1-3 mm per year. Evidence for reindeer grazing is widespread throughout Finnmark: from rhe almost ubiquitious presence of dung; to the disappearance of lichens by trampling in summer grazings and by overgrazing in winter grazings; to the presence of bare soil in many localities. Where reindeer grazing is confined either by fences or topography, degradational thresholds are lowered so that, for instance, peaty and mineral soils begin to erode on slopes as low as 4 degrees. This degradation has mostly come about in the last two or three decades as reindeer numbers have increased markedly, often by a factor of 2 or 3.

Key words: soil erosion, lichens, fences, tracking, trampling, thresholds, *Rangifer tarandus*.

Rangifer, 16 (1): 3–19

Introduction

Alongside the fence flanking the road which traverses the fells between Tanafjorden and Laksefjorden (Fig. 2), the impacts of reindeer on Finnmark's landscape, seen during a holiday visit to the area in summer 1989, were visually impressive. They are sufficiently impressive (Fig. 1) that they are recorded on images taken from a satellite orbiting 705 km above the earth's surface.

But it is not only the Ifjordfjellet area which is being damaged by reindeer. The lichens of Finnmark are rapidly disappearing (FORUT, 1990; Pedersen, Johansen & Tømmervik, 1993; Tømmervik, 1990) by being overgrazed in winter or trampled in summer. Only in the remote Øvre Anárjohka National Park is lichen cover probably still as abundant as formerly (Johansen & Tømmervik, 1993). And here, the contrast between the Norwegian side of the frontier and the more grazed Finnish side is most marked (Johansen & Tømmervik, 1990). By the boundary crossing of the road at Kivijärvi, south of Guovdageaidnu/

Fig. 1. Very severely trampled ground on the summer grazed side of the fence, Ifjordfjellet.

Kautokeino, the vegetation and peat hummocks were seen in the summer of 1991 on a short visit to the area, to be more damaged on the Finnish side than the Norwegian side.

Why are these impacts happening? The damage to Finnmark's landscape may be related to the large increase in the number of reindeer now grazing there, an increase by a factor of about two between 1976 and 1988 (Johansen & Tømmervik, 1990); and to the way in which the herds of reindeer are rounded up and managed, especially the construction of fences to separate grazings. This reconnaissance survey was carried out to test if these suppositions are correct.

The aims of the survey were to:

1. Assess more precisely the impacts of reindeer on soils and vegetation in Finnmark.
2. Identify those areas most vulnerable to trampling and overgrazing.
3. Assess the future implications of reindeer herding and grazing.

Material and methods

A route traversing much of north and central Finnmark was taken in September 1993 to link areas where detailed information on ground conditions was collected, and to assess generally the impacts of reindeer grazing on soils and vegetation (Fig. 2). The route was based on information gathered from rapidly examining and manipulating multispectral satellite images of Finnmark, and relating these interpretations to information on geology, soils and vegetation, and to migration routes taken by reindeer and their herders (NOU, 1978). The satellite images clearly showed the most severe damage to the vegetation along the fence at Ifjordfjellet, and where lichens were still the predominant ground cover in southern Finnmark but, because of the scale factor, gave little indication of the state of the ground cover elsewhere.

Sample transects were made where access from a road was easiest and, in open countryside where, from the above information, it was expected that lichens would have been more or less damaged by reindeer depending on the length of time the reindeer were likely to have been grazing in that locality. At two localities (S2 and S3) in spring and autumn grazings transects were made because, from what had been seen, these were localities where damage was greatest. Sampled localities were away from human settlements.

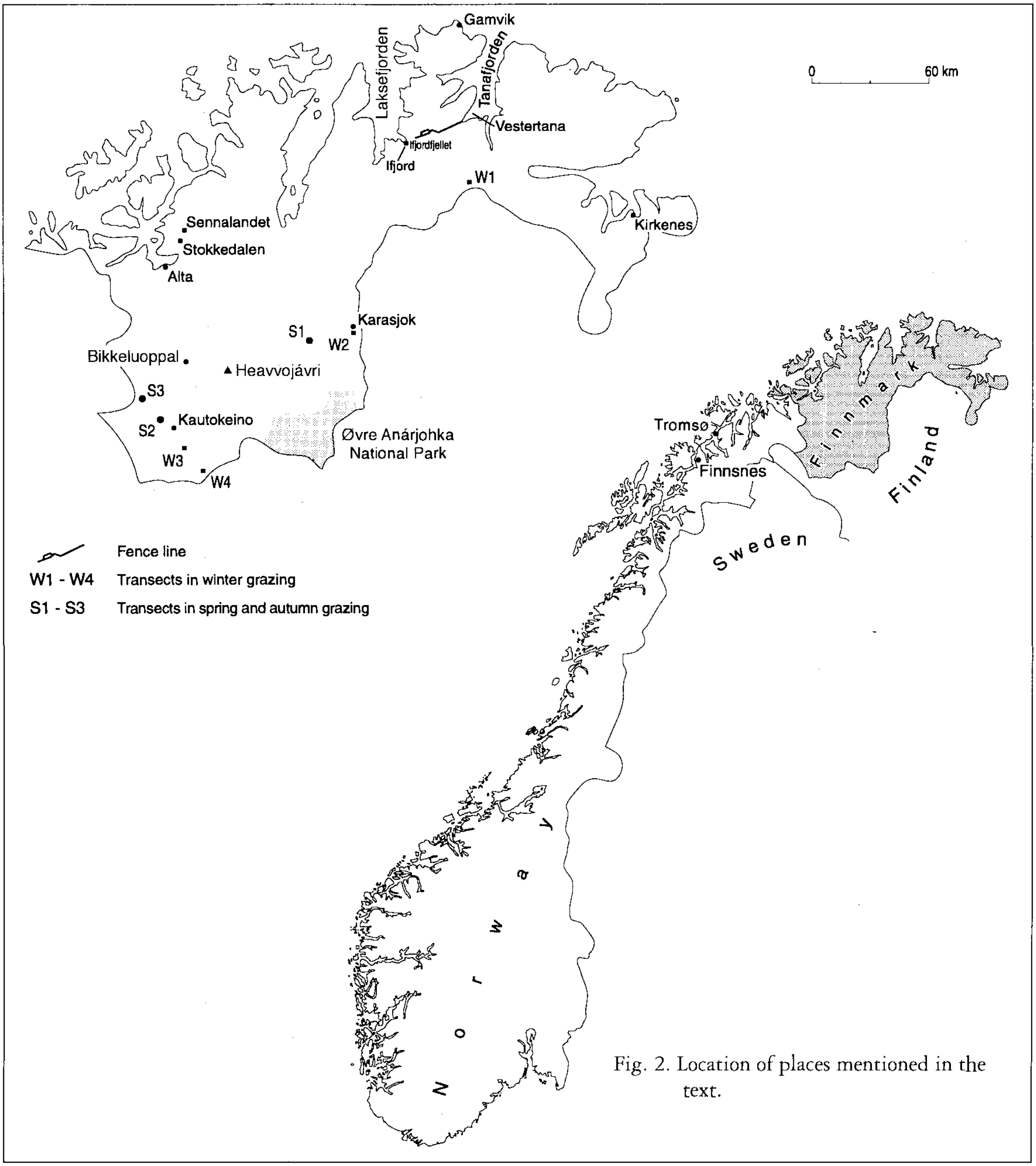

Fig. 2. Location of places mentioned in the text.

Much of the fence separating summer from spring and autumn grazings at Ifjordfjellet was surveyed in detail, as was an adjoining fence enclosing ground in the summer grazings (Fig. 3). Four traverses were made at selected points across the main fence, each traverse comprised two parts, one on each side of the fence and perpendicular to it (Fig. 3).

From the data from the 4 traverses and from estimates made from both horizontal and vertical ground photographs, the extent of bare soil on the summer grazed side of the fence was classified in the field and from ground photographs on a 5 point scale of damage or harm to the landscape - very slight (0-5% bare soil), slight (5-15 %), moderate (15-30 %), severe (30-50 %) and very severe (> 50 %).

A transect was made across a fence near Heavvojávri, roughly midway between Karasjok and Guovdageaidnu/Kautokeino (Fig. 2), constructed in the mid-1980s. The purpose of this fence was to separate winter grazings to the south from spring and autumn grazings to the north.

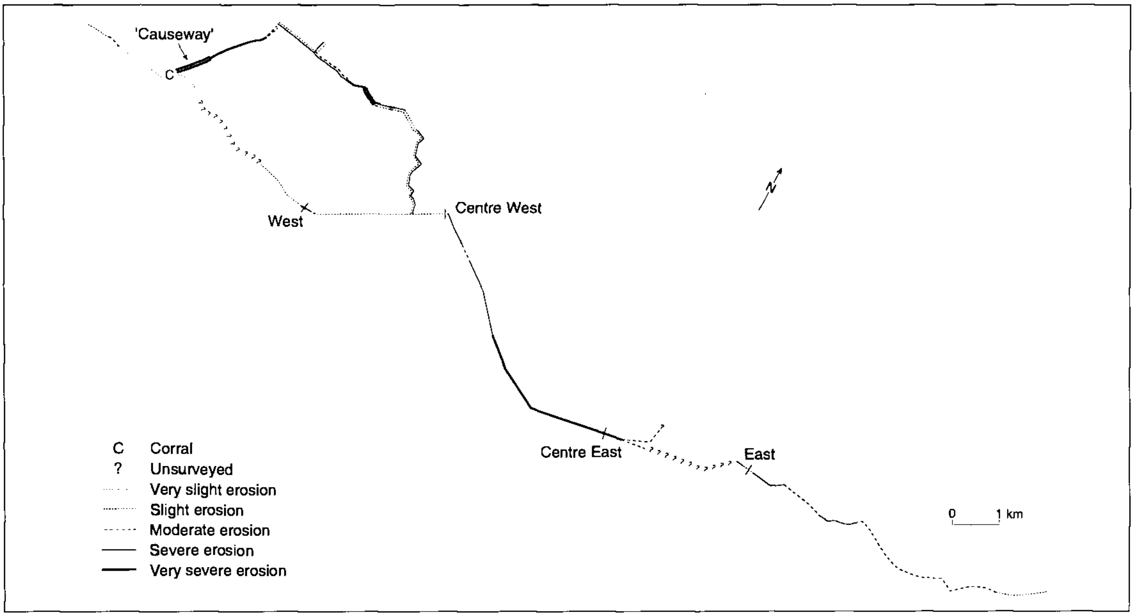

Fig. 3. Fences on Ifjordfjellet and position of the transects.

The transects were started at a predetermined number of fence posts or metres from the point where the route from the road to the fence met the fence, to avoid bias in selecting the starting point. The first site on each part of the traverse was 1 m from the fence.

Seven othet transects were made (Fig. 2) to assess the impacts of reindeer on vegetation and soils in open landscapes in spring, autumn and winter grazing areas.

Along each transect almost-vertical photographs, covering about 0.7 x 0.4 m of ground, were taken at approximately 10 m (12 pace) intervals. The photograph was taken so that a marker placed by the toe of a boot at the twelfth pace was at the bottom left or right corner, depending on which side of the fence the transect was on. Transects at each side of the fence and elsewhere comprised 10 points at 10 m intervals (= 90m), except in two localities where only 9 sites were sampled.

Notes were made of the vegetation present within the area of ground covered by the almost-vertical photograph, and where the reindeer lichen *Cladina stellaris* was present the height of the tallest specimen was measured. Reindeer preferentially graze *Cladina stellaris* (Lyftingsmo, 1965) and *C. arbuscula mitis* (Tømmervik, pers. comm.). Estimates of the extent of bare soil along the transect were made in the field.

A 10 x 10 rectangular grid scribed on transparent film was overlaid on a photograph of the ground and the cover of the vegetation species estimated. Although not precise, the figures are estimated to be correct within 1 or 2 % and no worse than 5 % where the vegetation pattern was complex.

The number of dung pellets was also counted within each photograph and, where counts had been done in the field, the two counts were generally similar.

Slope angle was measured by each site marker with an Abney Level laid on a 20 cm length of wood which had parallel flat sides. Slope angles along linear sections of the transects were also measured.

A small pit was dug into the soil by each marker. The depth of each soil horizon was noted, as well as the total depth of the soil where this was less than 500 mm. Soil texture was assessed by rubbing a sample between fingers and thumb, and soil colour identified by comparing it with a Munsell colour chart.

The angles of tracked and trampled slopes not sampled by the transects in the Ifjordfjellet area and elsewhere were estimated in the field, or from ground photographs or from 1: 50 000 scale topographical maps.

At Ifjordfjellet photographs were taken from six points to replicate those taken on a previous visit in 1989. The 1989 photographs were taken into the field and the exact locations from which the photographs were taken, or as near as possible, were identified.

Also, photographs were taken and notes made describing ground conditions where these were of interest, fot instance on tracked and trampled slopes in the Ifjordfjellet area, north of Gamvik, around and north of Bikkeluoppal between Guovdageaidnu/Kautokeino and Alta, and in Stokkedalen and along a fence at Sennalandet north of Alta (Fig. 2).

The data were analysed statistically using the Minitab 8.21 software package.

Results

Grazing impacts along fences

Ifjordfjellet

The height above sea-level of the four transects ranged from 237 m to 355 m (Table 1; see appendix for all tables). Only nine points were sampled south of the fence on the centre west transect, the 10th point fell on the road. On the less grazed side of the eastern transect, the heath vegetation changed to a grassy one, and so only 4 sample points can be compared with the 10 on the grazed side. Slope angles at sample points and of the transect were generally similar on both sides of the fence, except along the centre west transect.

Soils were very shallow to bedrock and comprised mainly peaty horizons (Table 1). Where mineral soil did occur it was coarse textured but siltier than soils in other localities. Soils were shallower on the summer-grazed side of the fence.

Heath vegetation types were similar in species present, if not their extent, on either side of the fence. The west and east transects crossed bilberry *Vaccinium myrtillus* heaths (Phyllodoco-Vaccinietum myrtilli), the two central transects dwarf birch Empetrum-lichen heaths (Empetro-Betuletum nanae) (Tømmervik, pers. comm.; botanical-sociological terms after Fremstad & Elven, 1987). On the summer-grazed side of the fence vegetation had been trampled or eaten so that bare soil was exposed, in places over more than half the transect (Table 2). Boulders were always more visible on the less-grazed side of the fence (Table 3) because the surrounding vegetation had been damaged.

Where *Betula nana* occurred on both sides of the fence, it was always less vigorous and covered a smaller area of the ground on the summer-grazed side (Table 4) and *Empetrum nigrum* ssp. *hermaphroditum* was generally more widespread on the summer-grazed side of the fence. Crustose lichen species, often *Ochrolechia frigida*, were found on three of the transects (Table 5), and were much less extensive on the summer-grazed side of the fence. Two types of mosses were distinguished, tallet green species (*Dicranum* spp.) and very low dark or paler coloured species (eg *Gymnometrion corrallioides*) which were often characteristic of the more damaged areas. Green mosses often formed a significant part of the ground cover and on two transects were more extensive on the summer-grazed side of the fence (Table 6). Dung pellets were less frequent on the less-grazed side of the fence (Table 7).

The fence between Vestertana and Ifjord which separates the summer from spring and autumn grazings is 26.35 km long, of which 22.45 km (85.2 %) was surveyed (Fig. 3). Almost 38 % of the land adjacent to the fence on the summer-grazed side was severely or very severely damaged, and only a small fraction was very slightly damaged (Table 8).

The fence north of that demarcating the summer grazings, used as an aid in rounding up and herding the reindeer to the corrals at Ifjordfjellet (Fig. 3), is 8.0 km long. The impacts of reindeer on the landscape were obvious on both sides of this fence (Fig. 3), and nowhere was the damage less than slight (Table 9). About 56 % of the land adjacent to the inner (south) side of the fence was severely and very severely degraded, in contrast to 70 % on the outer (north) side. The ground in the 'causeway' leading to the corrals was especially trampled.

Slopes adjacent to fences were well tracked where they were steeper than 4 degrees, both where the soils exposed were dominantly of organic or mineral origin (Fig. 4).

Photographs taken from the same six locations in 1989 and 1993 were compared. Three pairs of photographs were of longer views. On one of these pairs it can be seen that organic horizons have been stripped from a rock outcrop, and tracks within the vegetation look more prominent and in places wider in 1993. However, the evidence for change is equivocal on the other two pairs of photographs, but possibly more rock fragments were exposed at the surface in 1993.

The evidence of change is less equivocal when comparing the three pairs of photographs recording the ground surface from a close distance. In 1993 rocks were more prominent, organic horizons had been stripped off, and vegetation cover had retreated. It is difficult to quantify precisely this surface

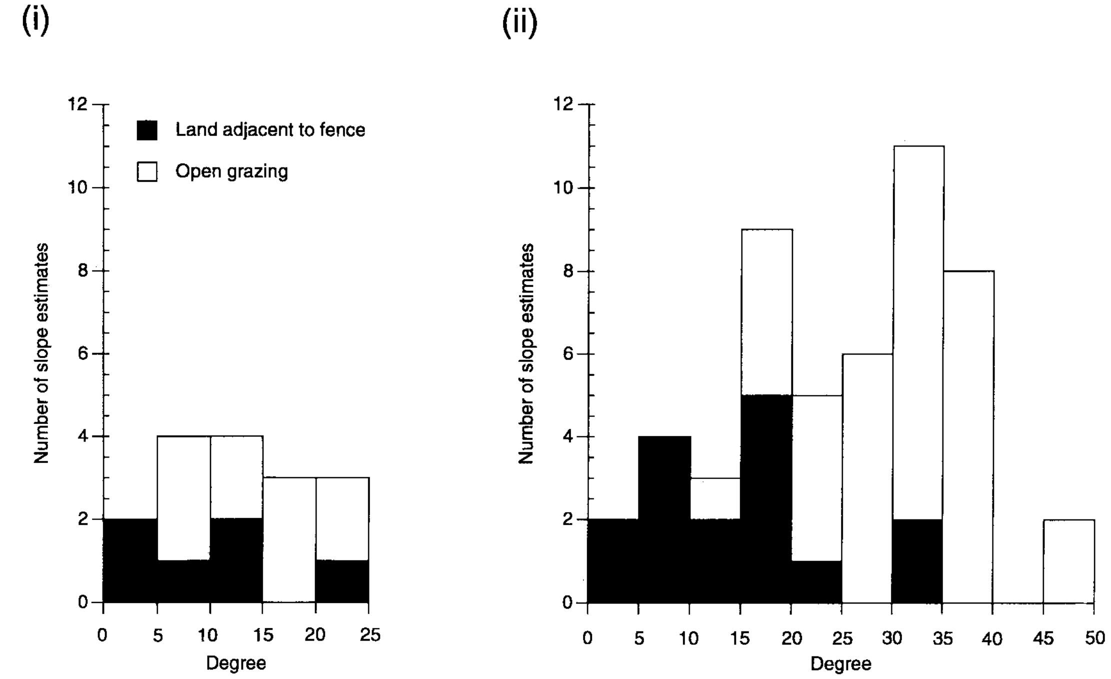

Fig. 4. Steepness of tracked and trampled slopes on (i) peaty and (ii) mineral soils.

lowering but it is probably of the order of about 10 mm.

Heavvojávri

The altitude of the fence is about 350 m above sea level. Slopes at sample points were very similar on either side of the fence, but on the less grazed side of the fence the transect sloped both up- and downhill. Soils were deeper on the less grazed side, and organic horizons significantly thicker (Table 10). The podzolic sandy soils were generally shallow, possibly occasionally to bedrock, but more often to very stony and gravelly layers which were difficult to dig through.

The vegetation was a lichen dominated heath (Table 10) with scattered birch (*Betula :pubescens*) trees, up to about 5 m tall, spaced about every 10 m along the line of the transect. It is classified as a scattered birch forest, *Empetrum*-lichen type (Cladonio-Betuletum) (Tømmervik, pers. comm.). On the grazed side of the fence the lichen had largely been trampled or eaten to a smooth surface and bare litter and fragmented trampled lichens were common. The better condition of the lichens south of the fence is also shown by the presence of *Cladina stellaris.*

Sennalandet

When the field work was carried out snow was thinly covering the ground at this locality 360 m above sea level (Fig. 2). Along the fence south of the road there were no obvious differences in vegetation types or in vigour of the vegetation either side of the fence. North of the road, however, on the north side of the fence, tracks were visible leading to what had been, before it was destroyed, a corral for managing reindeer.

Along a transect paced out north of the fence, there were 26 tracks in 75 m; the tracks covered about 5.2 m (6.9 %) of the ground. Beyond this tracked heath the ground comprised bog and pools.

Grazing impacts in open landscapes

Summer grazings

In the Ifjordfjellet area the initial evidence for reindeer was the stripping of leaves from rowan (*Sorbus aucuparia*), and the removal of leaves from birch (*Betula :pubescens*) trees and willow (*Salix* spp.) shrubs. Indeed, whole copses of willows had been killed in many places by overgrazing, and many other willow shrubs showed severe signs of grazing. Even around Sennalandet, where the impacts of reindeer were much less obvious than around

Ifjordfjellet, willow shrubs were more heavily grazed on the summer-grazed side of the fence.

On level to gently sloping ground (0-3 degrees; Hodgson, 1976) damage to peat tussocks within bogs was seen in places in the Ifjordfjellet locality, but was widespread on the raised beaches of the coast around Slettnes, north of Gamvik (Fig. 2). Here the grazings were considered by a herder to be among the "best".

In the Ifjordfjellet locality tracking was obvious on peaty soils on moderately (4-7 degrees; Hodgson, 1976) or more steeply sloping ground across *Vaccinium myrtillus* species/*Empetrum nigrum* spp. *hermaphroditum*/*Betula nana* heath, especially where the tracks merged toward a river crossing. Away from the fence, in open grazings, tracking was not obvious until slopes were steeper than 7 degrees. On slopes where mineral rather than peaty soils predominated, tracking was obvious near to the fence on 4 degree slopes, whereas away from the fence tracking was not prominent until slope angles were 13 degrees or more. Often on these steeper slopes tracking and trampling were initiating scree formation where soils were shallow or, where deeper, especially on valley sides, shallow slides or gullies.

Wet peaty hollows in woodland and grassland were vulnerable to degradation of the vegetation cover and continuous reworking of the peat surface enlarged the hollows.

In the valley floor of the Stuorrajohka, east of Ifjordfjellet, the overgrazing and death of willow shrubs and the trampling of tributary stream banks by reindeer have led locally to bank erosion and headward retreat of the tributary channels.

Winter grazings

In these localities, reindeer reach the vegetation by scraping away the snow. Lichens comprise an important part of the reindeer's winter diet, up to almost 80 % in places like Finnmarksvidda with abundance of lichens (Skjenneberg & Slagsvold, 1968).

The four sites ranged in height above sea level from 100 m to 475 m (Table 11). Slopes were steeper at Båteng (> 4 degrees) and the relief was complex ('knobbly') along a low ridge crest at Oskál. Soils were shallow podzols, stony with a coarse-textured gritty matrix at three of the sites, but at Båteng soils were less stony sandy loams and were occasionally as deep as 540 mm before rock or stony till was encountered.

All transects traversed heaths under birch woodland but at Karasjok pines were also present; trees were spaced at roughly 6 m intervals along the transects. Three transects (W1–W3) are classified (Tømmervik, pers. comm.) as birch forests of *Empetrum*-lichen type (Cladonio-Betuletum), the other (W4), at Geaðgevárri, as a lichen dominated heath (Empetro-Betuletum nanae). The site at Båteng was much richer in plant species but the lichen *Cladina stellaris* was not found there (Table 11).

At Båteng and Karasjok (Fig. 2, W1 and W2), on the margins of winter grazings (Reindriftsadministrasjonen, 1991), lichens covered over a third of the ground surface (Table 11). Lichen cover was higher near Oskál (Fig. 2, W3), about 20 km south of Guovdageaidnu/Kautokeino, and reached almost two-thirds of the ground cover at Geaðgevárri (Fig. 2, W4), about 4 km north of the Norwegian/Finnish border. At Geaðgevárri the lichens were in better condition, as shown by the taller specimens of *Cladina stellaris*, although they had been recently grazed and dung pellets were more numerous there. Little bare soil was exposed in these grazings.

Spring and autumn grazings

The ttansects lay between 350 m to 455 m above sea level (Table 12). At Jergul (Fig. 2, SI) the transect was on a linear slope, at Cunovuohppi and Guorbavuopmi (Fig. 2, S2 and S3) the transects crossed low ridges.

Heath vegetation at the three sites was similar to those in the winter grazings (Table 12). However, lichen covered a smaller area of ground and always contained *Cladina stellaris*. At Jergul there was a greater cover of low mosses and lichen species on what could have been formerly denuded bare soil. The birch trees at this exposed site were widely spaced, one ttee per 22.5 m of transect. At Guorbavuopmi birch trees were sparse, one tree in 90 m and low in height (< 3 m) whereas at less exposed Čunovuohppi they were more frequent (one per 14 m) and taller (< 8 m). All the transects are classified (Tømmervik, pers. comm.) as birch forests of Empetrum-lichen type (Cladonio-Betuletum).

The deeper podzolic sandy soils at Jergul contained more silt, and were similar to those at Båteng. In the other two localities the podzolic soils were almost stoneless well sorted medium sands mostly deeper than 500 mm (Table 12).

At Guorbavuopmi about one-third of the ground surface was covered by very severely grazed lichens. *Cladina stellaris* was in better condition and taller at the less damaged site at Čunovuohppi (Table 12). Where the soil was exposed, often the upper peaty and leached, pale coloured horizons had been stripped off. At Čunovuohppi the mean depth of these stripped layers, as indicated by the depths at vegetated sites, was 101 mm, at Guorbavuopmi 82 mm. However, at a number of sparsely vegetated sites at Guorbavuopmi a peaty layer had either not formed or, more likely, had been eroded away before being recolonised by low mosses and lichens, so the original mean depth of the peaty layer at this site was probably greater than it is now. At Guorbavuopmi, then, the depth of soil stripped off where the soil was bare could be greater by about another 20 mm. Reindeer tracks were seen in the exposed sand, and dung pellets were found in both localities, but at Guorbavuopmi there was also a burrow and tracks of fox(es).

The transect at Čunovuohppi was across an esker, sand and gravel deposited under an ice sheet. Much of this ridge was not only tracked by reindeer, with recent hoof-prints showing in the sand, but in many places its top had its vegetation cover stripped off and 'blow outs' had formed by wind action.

Around and to the north of Bikkeluoppal (Fig. 2), the edges of river and fluvioglacial terraces had been broken down by reindeer and river banks were badly tracked. In places drumlins occur, these ice-moulded features in glacial drift were often badly tracked and trampled by reindeer.

In Stokkedalen, north east of Alta (Fig. 2), reindeer were seen not only grazing the birch trees but also creating tracks along the valley floor and breaking down stream banks. Tracked slopes here and around Bikkeluoppal were as steep as those around Ifjordfjellet.

Discussion

It should be noted that the author is a geographer/soil scientist, not an ecologist, and is primarily interested in accelerated soil erosion. So here are described only the more obvious changes to vegetation which could be recognised and measured, such as overgrazing and disappearance of trees and shrubs and individual heath species, and the disappearance of lichen species as a whole, rather than as individual species. However, as *Cladina stellaris* is an easily recognised lichen, as well as being a key species, information was gathered on the height of this lichen. The plant communities on the sampled transects (see below) were not classified into their separate components or mosaics. Except for one transect, the easternmost one at Ifjordfjellet, it was considered the vegetation types at each side of the fence had been initially the same. In other words, the complexities of the vegetation types themselves were not part of the study and were not, therefore, taken into detailed consideration when carrying out the field work.

Estimates of the area of ground denuded of vegetation made in the field and from ground photographs were similar when they were less than 10 %. However, when from the photographs more than 10 % of the ground was bare, estimates made in the field were often smaller, by a factor of more than 2. Reindeer tracks often were the dominant bare soil feature on the ground, and drew the eye when looking in the horizontal plane. It was these tracks that formed the basis of the field estimation of bare ground. However, much bare soil was present as small complex patches within vegetation types and could not therefore be easily discerned unless viewed vertically, as was done when the photographs were taken.

Dung was recorded on 15 of the 17 transects surveyed, but the amounts varied between grazings. The mean number of pellets per site along the transects in the Ifjordfjellet summer grazings ranged from 4.1 to 26.3. Fewer pellets were found in spring and autumn grazings (0.0-3.3), except at Guorbavuopmi (6.4). In winter grazings, there were no dung pellets at Båteng, and only 0.1 pellet per site at Karasjok but 9.9 and 13.6 at Oskál and Geaðgevárri respectively. The transects at Båteng and Karasjok were not only at the margins of winter grazings, but also nearer settlements. Presumably, pellet densities were greater in those locations where reindeer spent most time; in spring and autumn they are on the move most of the time migrating between the winter and summer grazings.

Lichens were rare (< 1.1 % ground cover) in the summer grazings at Ifjordfjellet. On the less-grazed side of the fence, they were more common although not covering the ground extensively (< 24.6 %). In other spring and autumn grazings lichens covered between 20.5 and 26.7 % of the ground surface. In the winter grazings lichens covered between 35.5 and 64.4 % of the ground.

Trampling is probably the main cause for the disappearance of lichens in the summer grazings, as well as in the spring and autumn grazings, for dry lichens are very susceptible to damage by trampling (Eriksson *et al.*, 1971). The end result of this trampling is the total loss of *Cladina* species (Tømmervik & Johansen, pers. comm.). Lichens are more extensive in the winter grazings because there they are protected throughout the season by snow, except where it is grazed and scraped away by reindeer.

The distribution and damage to lichens corresponds to that recorded by NORUT researchers (Tømmervik, 1990; Johansen & Tømmervik, 1993). Only at Geaðgevárri were the lichens considered to be not severely overgrazed but even there the evidence for reindeer grazing was marked, more dung and bare soil being found than at the other localities, and the eastern part of the transect had been recently grazed. Presumably, Geaðgevárri too will soon be overgrazed.

The disappearance of lichens, especially from the winter grazings, has been much discussed recently (FORUT, 1990; Prestbakmo, 1990; Tømmervik, 1990; Johansen & Tømmervik, 1990 & 1993; Pedersen, Johansen & Tømmervik, 1993). As early as 1968, however, Skjenneberg & Slagsvold (1968) had noted "..one should clearly recognise that the number of reindeer in Finnmark ordinarily approaches the limits of what the pastures can endure". That the lichen cover would decline in the future should have come as no surprise, therefore.

Unless reindeer can adapt to these changes in lichen cover, the number of animals grazing the lichen heaths in winter will decline, possible catastrophically, as has happened elsewhere (Klein, 1987; Leader-Williams, 1988; Henry & Gunn, 1991).

At Ifjordfjellet and Heavvojávri, as well as lichens, *Vaccinium* species and green mosses often were generally less evident on the summer-grazed side of the fence. *Vaccinium myrtillus* has been shown to be sensitive to trampling by hikers in central Sweden, near Grövelsjön adjacent to the Norwegian border, where the climate was considered similar to that of interior Lapland (Bryan, 1977). Emanuelsson (1980) also noted that in Sweden *Vaccinium* heath was susceptible to trampling by hikers, but so also was *Empetrum* heath.

The disappearance of the lichens from much of Finnmark has taken place over the last two decades (Johansen & Tømmervik, 1993), and the fences have probably been put up over that period. Indeed, some of the fences examined in September 1993 had only been very recently constructed. Between 1976 and 1988 the number of reindeer in Finnmark doubled (Johansen & Tømmervik, 1990).

The trampling damage to lichens, green mosses, and plants and the grazing out of bushes and trees, as well as the possible drying out of the soils as runoff increases because of the poorer cover of lichens and mosses, could all bring about an impoverished grassy landscape. From evidence from northern Finland, adjacent to Norway, the lichen heath winter grazings could change initially to a lichen and dwarf shrub heath and then to a dwarf shrub and grass heath/*Empetrum* heath (Käyhkö & Pellika, 1994). Wind-blown particles from patches of eroding soil, especially on drumlins and eskers, could also damage adjacent plants, leading to further expansion of the area of bare soil.

The impacts of reindeer on the landscape are most severe where fences have been constructed. In a 100-200 m wide zone parallel to the fence, along which the reindeer travel, more than half the ground surface can be denuded of vegetation and soils. Much of this damage is related to trampling, although overgrazing does play a part.

But steep slopes and lakes or wide rivers can also act as 'fences', indeed herders use them for this purpose. In the Ifjordfjellet area damage along fences was very severe along the slopes flanking the Stuorrajohka river, and also between the lake Geŋgejávri and the south side of the fence within the summer grazings; in both these localities the reindeer were confined to a zone often only 200-300 m wide.

Elsewhere along the Ifjordfjellet fences most damage was seen near to corrals; where fences appeared to interrupt a reindeer route-line; where the slopes were underlain by very loose schistose rock; and where fences met streams. Much of the damage was often related more to management practices than to the inherent vulnerability of the landscape.

The passage of reindeer within a confined area lowers the threshold slope angles at which tracking and trampling begin to severely scar the landscape. On peat or peaty-topped soils damage to slopes along fences was initiated where slopes were about 4 degrees, in open landscapes the threshold angle was about 7 degrees (Fig. 4i). On thin stony mineral soils tracks were obvious along fences when slopes exceeded about 4 degrees, whereas in open landscapes the threshold was about 13 degrees (Fig. 4ii).

In open landscapes slopes were particularly vulnerable to tracking and trampling where they were underlain by thin stony mineral soils over fissile rock, as around Ifjordfjellet. Or where deep sands occurred, as to the north and west of Guovdageaidnu/Kautokeino on esker ridges and glaciofluvial terraces. The steep edges of poorly sorted, coarse textured river and fluvioglacial terraces were also susceptible to damage, as were steep-sided drumlins. Staaland *et al.* (1991) noted that reindeer preferred moraine ridges dominated by lichens on Svalbard. Where reindeer route-lines crossed steep sided valleys much disruption of the vegetation and soils could occur, and this could be spectacular, as in a small wooded valley about 3.5 km east of Ifjord. Wet hollows and mires both on slopes and in valley floots, in woodland ot in heath, were also vulnerable to degradation by tracking, a phenomenon noted too on Rideout Island in Arctic Canada (Henry & Gunn, 1991).

The rate at which soil is being eroded by trampling and the weather is probably between 1-3 mm per year along fences, a not inconsiderable rate when soils are generally less than 250 mm deep, and often much shallower than that, as at Ifjordfjellet. In open landscapes, once the infertile and erodible sands are exposed, erosion may be at similar or higher rates to those along fences, as up to 100 mm of topsoil has been lost. However, it is not known when these bare soil surfaces originated.

Erosion caused by overgrazing by reindeer has been noted pteviously in Finnmark (Lyftingsmo, 1965), as well as in other localities in northern Scandinavia (Warenberg, 1977; Haapasaari, 1988) and on the island of South Georgia in the south Atlantic (Leader-Williams, 1988). From the descriptions and photographs reproduced in the literature, erosion was nowhere as severe as it is along fences in Finnmark. Many of the descriptions of erosion in northern Scandinavia refer to the importance of wind erosion once the vegetation cover is disrupted, and such instances seem similar to those described here at Čunovuohppi and Guorbavuopmi.

Stream channel erosion and headward retreat have been initiated by overgrazing in the Stuorrajohka valley, Ifjordfjellet. Overgrazing of temperate and tropical landscapes can be a contributory factor leading to channel incision and gullying, for example, in south west USA (Cooke & Reeves, 1976), New South Wales, Australia (Gardiner & Kawabe, 1983), and many parts of Africa (Chakela, 1981; Valentin, 1985; Seymour & Gerard, 1986). Overgrazing is the world's major cause of soil degradation (Oldeman *et al.*, 1991) and in Australasia and Africa is by far the most important agent of land degradation. The channel erosion on Ifjordfjellet is probably the first instance of such erosion due to overgrazing to be recorded in a subarctic locality.

Conclusions

This study has confirmed that the recent increase in the number of reindeer grazing in Finnmark has, in places, markedly damaged its vegetation and soils. Lichens are disappearing due to trampling and grazing and soil is being exposed to erosional forces. The use of fences for managing the reindeer herd has exacerbated the damage to the vegetation and initiated erosion.

This reconaissance survey was set up to gain information on the most severe impacts of reindeer along the fence traversing the Ifjordfjellet locality. Prior to the survey nothing was known of the fence at Heavvojávri, nor of what would be found at the other localities examined except at Čunovuohppi. Although it is unlikely that damage to the landscape elsewhere in Finnmark is as severe as that at Ifjordfjellet, it seems likely that along other fences grazing impacts will lie within the range recorded at Heavvojávri and Sennalandet. In open landscapes, the impacts of reindeer will probably rarely be as severe as at Guorbavuopmi. However, until more work is done, it will not be possible to give an "average" or overall view of the impacts.

So far only a small part of Finnmark has been examined to assess the impacts of reindeer herding. A much more extensive assessment needs to be made, concentrating particularly on those areas considered most vulnerable, especially along fences.

The landforms and soils which are particularly susceptible to erosion have been identified. Glaciofluvial terraces, especially their steeply sloping margins, as well as eskers and drumlins are the landforms most at risk, whilst peat soils are more vulnerable than mineral soils, and of the latter sandy soils are most susceptible. Once exposed, frost-shattered schists and peats have such unstable surfaces that lichens and plants will have great difficulty in colonising them.

A map should be made which shows the localities most susceptible to damage by reindeer grazing.

Once the extent of the degradation is known a scheme to monitor the impacts on the landscape of reindeer should be devised.

The continuation of reindeer herding at ptesent stocking rates will lead to further damage to the landscape in some localities.

There is a need then to devise schemes which will provide a livelihood for reindeer herders but which will not rely on stocking rates as high as those at present. Better, more sustainable herding practices need to be devised which do not overly rely on fences and the use of other unsustainable modern herding techniques.

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Appendix:

Tables 1–12 (The transects' vegetation with plant sociological cathegories, see text pages 5–7).

Table 1. Transects across the fence in the Ifjordfjeller area separating summer-grazed (SG) from less-grazed (LG) localities - altitude of transect and soil depth (mm).

Transect	West		Centre West		Centre East		East	
Altitude - m above sea level	260		237		325		355	
	SG	LG	SG	LG	SG	LG	SG	LG
Organic horizons								
- mean	23.5*	54.5	55.5	65.0	24.0*	59.0	73.5	87.5
(standard deviation)	(10.8)	(28.4)	(29.5)	(28.0)	(36.6)	(26.5)	(30.9)	(12.6)
Organic + mineral horizons								
- mean	32.0	54.5	55.5	65.0	63.0	73.0	77.5	87.5
(standard deviation)	(26.5)	(28.4)	(29.5)	(28.0)	(24.1)	(25.9)	(24.4)	(12.6)

* - statistically significant at 5 % level.

Table 2. Transects across rhe fence in the Ifjordfjellet area separating summer-gıazed (SG) from less-grazed (LG) localities - % area bare soil.

Transect	West		Centre West		Centre East		East	
	SG	LG	SG	LG	SG	LG	SG	LG
Estimate from photograph								
- mean	34.5*	0.0	20.1	0.1	3.4*	0.0	10.0	0.0
(standard deviation)	(25.3	(0.0)	(29.3)	(0.3)	(30.6)	(0.0)	(19.2)	(0.0)
Estimate made in field	9.6	0.0	9.1	0.0	14.4	0.0	10.3	0.0

* - statistically significant at 5 % level.

Table 3. Transecrs across the fence in the Ifjordfjellet area separaring summer-grazed (SG) from less-grazed (LG) localities - % area covered by boulders.

Transect	West		Centre West		Centre East		East	
	SG	LG	SG	LG	SG	LG	SG	LG
- mean	5.3	3.0	11.4	3.8	15.5	9.0	0.7	0.0
(standard deviation)	(3.2)	(4.4)	(16.4)	(6.2)	(27.2)	(26.4)	(1.2)	(0.0)

Table 4. Transects across the fence in the Ifjordfjellet area separating summer-grazed (SG) from less-grazed (LG) localities - % changes in the presence of *Betula nana* and *Empetrum nigrum* ssp. *hermaphroditum* and height (mm) of *Betula nana.*

Transect	West		Centre West		Centre East		East	
	SG	LG	SG	LG	SG	LG	SG	LG
Betula nana								
- mean	13.9*	40.7	6.5	16.1	4.3	9.6	21.2	0.0
(standard deviation)	(16.8)	(18.5)	(5.1)	(14.7)	(5.6)	(11.6)	(15.5)	(0.0)
Empetrum nigrum ssp. *hermaphroditum*								
- mean	9.8	5.6	35.1	28.8	9.5*	32.5	2.6	0.0
(standard deviation)	(16.6)	(6.0)	(28.2)	(22.6)	(15.4)	(16.0)	(3.2)	(0.0)
Height of *Betula nana*								
- mean	<20.0**	139.0	87.0	112.2	24.0	39.0	nd	nd
(standard deviation)	(-)	(86.6)	(46.0)	(46.6)	(21.2)	(46.8)		

* - statistically significant at 5 % level.
** - estimated, not measured in field.

Table 5. Transects across the fence in the Ifjordfjellet area separating summer-grazed (SG) from less-grazed (LG) localities - % ground cover of lichens.

Transect	West		Centre West		Centre East		East	
	SG	LG	SG	LG	SG	LG	SG	LG
- mean	0.0*	24.6	1.1*	11.0	0.9*	6.0	0.3	0.0
(standard deviation)	(0.0)	(17.7)	(1.9)	(6.9)	(1.6)	(5.4)	(0.8)	(0.0)

* - statistically significant at 5 % level.

Table 6. Transecrs across rhe fence in the Ifjordfjellet area separating summer-grazed (SG) from less-grazed (LG) localities - % ground cover of low mosses.

Transect	West		Centre West		Centre East		East	
	SG	LG	SG	LG	SG	LG	SG	LG
- mean	5.4*	0.0	1.5	0.4	9.1	0.8	0.0	0.0
(standard deviation)	(6.3)	(0.0)	(3.8)	(0.5)	(12.8)	(1.5)	(0.0)	(0.0)

* - statistically significant at 5 % level.

Table 7. Transects across the fence in rhe Ifjordfjellet area separating summer-grazed (SG) from less-grazed (LG) localities - number of dung pellets.

Transect	West		Centre West		Centre East		East	
	SG	LG	SG	LG	SG	LG	SG	LG
- mean	10.2	0.0	4.1*	0.3	5.7	3.3	26.3	0.2
(standard deviation)	(16.1)	(0.0)	(4.8)	(1.0)	(9.3)	(5.3)	(33.0)	(0.5)

* - statistically significant at 5 % level.

Table 8. Severity of damage along the summer-grazed side of the fence at Ifjordfjellet.

Category of damage (% bare soil over 90m perpendicular to fence)	Distance (km)	%
Very slight (0-5)	1.7	7.6
Slight (5-15)	6.0	26.7
Moderate (15-30)	6.25	27.8
Severe (30-50)	4.65	20.7
Very severe (> 50)	3.85	17.1
Total	22.45	100.0

Table 9. Severity of damage along the fence within the summer grazings at Ifjordfjellet.

'Inner' side fence Category of damage (% bare soil over 90m perpendicular to fence)	Distance (km)	%
Very slight (0-5)	-	-
Slight (5-15)	2.85	35.6
Moderate (15-30)	0.7	8.7
Severe (30-50)	3.75	46.9
Very severe (> 50)	0.7	8.7
Total	8.0	99.9
'Outer' side of fence Category of damage (% bare soil over 90m perpendicular to fence)	**Distance (km)**	**%**
Very slight (0-5)	-	-
Slight (5-15)	1.2	15.0
Moderate (15-30)	1.2	15.0
Severe (30-50)	4.2	52.5
Very severe (> 50)	1.4	17.5
Total	8.0	100.0

Table 10. Transect across the fence at Heavvojávri - mean (and standard deviation) values for slope, soil and vegeration parameters.

	North side	South side
Depth soil horizons (mm)		
organic	15.8*	30.0
	(8.7)	(12.5)
organic + mineral	151.5	209.0
	(64.9)	(75.3)
Bare soil + bare litter (% ground cover)		
from photographs	1.6 + 43.1 = 44.7*	0.9 + 0.0 = 0.9
	(27.0)	(1.5)
field estimate	20.3	0.3
Boulder (% ground cover)	4.5	0.3
	(11.5)	(0.9)
Vegetation (% ground cover)		
Betula nana	0.0	1.2
		(3.8)
Empetrum nigrum ssp. *hermaphroditum*	4.4*	21.8
	(8.4)	(18.7)
Vaccinium species	2.2	5.6
	(2.1)	(8.8)
Grasses	0.9	0.4
	(1.6)	(0.7)
Lichens		
- fragmented	21.2*	5.4
	(15.7)	(8.7)
- intact	5.6*	54.4
	(10.0)	(22.4)
Mosses		
- low	12.2	3.5
	(12.3)	(4.7)
- green	0.9	6.4
	(1.9)	(9.7)
Cladina stellaris - height (mm)	0.0*	15.5
		(12.3)
Dung pellet	3.3	1.9
	(3.3)	(2.8)

* - statistically significant at 5 % level.

Table 11. Transects in winter grazings - mean (and standard deviation) values for slope, soil and vegetation paramerers.

Transect	Båteng W1	Karasjok W2	Oskál W3	Geaðgevárri W4
Height above sea level (m)	100	315	360	475
Depth soil horizons (mm)				
organic	70.5	91.0	45.0	30.0
	(32.2)	(39.6)	(15.8)	(14.1)
organic + mineral	251.5	192.0	157.0	208.0
	(166.7)	(43.4)	(137.5)	(79.4)
Bare soil (% ground cover)				
from photographs	0.1	0.0	0.0	0.7
	(0.3)			(1.6)
field estimate	0.1	0.0	0.2	0.6
Boulder (% ground cover)				
	0.8	0.0	11.4	0.0
	(2.5)		(14.0)	
Vegetation (% ground cover)				
Betula nana	0.0	0.0	0.0	0.8
				(2.5)
Empetrum nigrum ssp. *hermaphroditum*	20.7	13.8	9.9	12.6
	(10.5)	(11.4)	(16.8)	(12.0)
Vaccinium species	8.5	14.1	13.3	5.8
	(7.5)	(9.4)	(7.3)	(4.9)
Arctostaphylos uva-ursi	7.8	0.0	0.1	0.0
	(9.3)		(0.3)	
Grasses	6.1	0.9	1.4	1.4
	(12.6)	(2.8)	(1.8)	(2.2)
Lichens	35.5	36.3	40.3	64.1
	(19.6)	(15.8)	(26.7)	(19.4)
Mosses				
- low	5.1	0.0	0.0	0.3
	(6.7)			(0.9)
- green	11.1	34.0	23.4	14.0
	(8.6)	(20.9)	(11.2)	(12.3)
Other species	4.3	0.8	0.2	0.3
Cladina stellaris - height (mm)	-	23.0	18.0	50.5
		(18.3)	(19.5)	(13.2)
Dung pellet	0.0	0.1	9.9	13.6
		(0.3)	(21.0)	(40.6)

Table 12. Transects in spring and autumn grazings - mean (and standard deviarion) values for slope, soil and vegetation parameters.

Transect	Jergul S1	Čunovuohppi* S2	Guorbavuopmi S3
Height above sea level (m)	350	400	455
Depth soil horizons (mm)			
organic	47.0	36.2	8.0
	(25.4)	(23.3)	(9.2)
organic + mineral	240.0	> 500.0	> 500.0
	(101.5)		
Bare soil and litter** (% ground cover)			
from photographs	0.5 + 0.0	10.2 + 0.0	10.6 + 34.8
	= 0.5	= 10.2	= 45.4
	(1.3)	(30.7)	(42.9)
field estimate	0.7	9.7	16.2
Boulder (% ground cover)	0.4	0.0	0.0
	(0.8)		
Vegetation (% ground cover)			
Betula nana	4.5	7.1	1.0
	(8.2)	(10.7)	(1.3)
Empetrum nigrum ssp. *hermaphroditum*	21.7	18.6	16.8
	(12.7)	(20.3)	(18.6)
Vaccinium species	11.5	8.2	1.6
	(7.2)	(7.0)	(1.8)
Arctostaphylos uva-ursi	0.2	0.8	2.4
	(0.6)	(2.3)	(5.4)
Grasses	1.9	8.0	0.8
	(4.1)	(13.3)	(1.5)
Lichens	26.7	23.7	20.5
	(16.6)	(16.0)	(16.8)
Mosses			
- low	8.3	0.0	0.0
	(10.6)		
- green	23.6	23.4	11.5
	(11.4)	(12.8)	(12.5)
Other species	0.7	0.0	0.0
Cladina stellaris - height (mm)	10.5	27.2	4.0
	(17.4)	(20.8)	(8.4)
Dung pellet	1.6	2.9	6.4
	(2.8)	(8.7)	(16.5)

* - 9 samples only; transect ended in pool.
** - remnants of very heavily grazed lichen.