Do different logging strategies influence the abundance of epiphytic chlorolichens?

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Abstract: The effects of two logging strategies and edge effects on cover and abundance of the epiphytic chlorolichens *Cavernularia hultenii*, *Platismatia glauca* and *P. norvegica* were studied in an experimentally logged boreal spruce forest. Whether lichen size distribution within the three species was affected by logging regimes was also tested. One hundred and ten branches were sampled at random within: (1) fine-grained clearcuts consisting of 23 cutblocks 0·25 ha each; (2) coarse-grained clearcuts consisting of 3 clearcuts 2·25 ha each; and (3) a control area.

Of the three species studied, *C. hultenii* was the most vulnerable to logging, with an abundance much lower in logged areas than in the control area. By contrast, *P. glauca* was equally abundant in the fine-grained area and in the control area, but significantly less abundant in the coarse-grained area where it seems to have been adversely affected by a pronounced edge effect. No such edge effect, however, was noted in the fine-grained area. Juvenile thalli of *C. hultenii* and *P. glauca* were less frequent in the coarse-grained area than in the fine-grained and control areas, suggesting that the juvenile stage might be more sensitive to logging than mature thalli. These results indicate that creation of large clearcuts (2·25 ha) may not be in accordance with the goal of maintaining population size in either *C. hultenii* or *P. glauca*. However, *P. glauca* does not seem to be negatively influenced by a fine-grained logging pattern. No effect of logging strategy or distance from the forest edge was observed on *P. norvegica*. It follows from the above that any management plans aimed at maintaining population size should be based on an understanding of ecology and life history gleaned from the area in question.

Key words: biodiversity, boreal forest, *Cavernularia*, conservation, edge effects, epiphytic lichens, forest fragmentation, logging, *Picea abies*, *Platismatia*

Introduction

Human disturbance, especially through logging activities, has changed previously continuous forest ecosystems to fragmented landscapes characterized by patches of old forest stands and younger even-aged monocultures. Habitat loss, habitat alteration and fragmentation have reduced species diversity in many forest ecosystems (e.g. Harris 1984; Saunders *et al.* 1991; Forman 1995). Clearcutting of large areas is thought to be

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one reason for recent declines in epiphytic lichen diversity and biomass in boreal forests (Esseen *et al.* 1997).

A fragmented forest landscape can be characterized by the size and the type of clearcuts as well as by the arrangement of these fragments in space and time. The structure of such landscapes can be described using the following properties: (1) patch quality; (2) patch size, and (3) patch context, i.e. how the patches are situated in relation to each other. Patches that are identical with respect to quality and size may be subject to different processes or conditions depending on the surrounding environment, for example the extension of edge effects (Angelstam 1992). Fragmentation generates extensive edges and edges generate microclimatic gradients which in

turn produce an environment that differs from both the open habitat outside and the forest interior (Ranney *et al.* 1981). Documented changes in microclimate at the forest edge bordering a clearcut are increased solar radiation, higher wind speed, lower relative humidity, and increased air and soil temperature (Chen *et al.* 1993, 1995; Matlack 1993). Edge effects are described as differences in biotic and abiotic factors that exist along the borders of a forest fragment relative to the interior environment (Gehlhausen *et al.* 2000). The intensity and depth of the edge effect is influenced by several factors such as the size of the clearcut, orientation and physiognomy of the edge (Matlack 1993; Turton & Freiberger 1997) and the responsiveness of the factor being measured (Cadenasso *et al.* 1997). Moreover, the edge effects can be strongly dynamic (e.g. Esseen & Renhorn 1998).

Epiphytic lichens are well suited for studying the effects of forestry because of their sensitivity to environmental changes (Rose 1992). One significant effect of forest fragmentation on lichens is that it influences dispersal mechanisms and thus population dynamics. Dispersal limitations have been suggested for several lichens in boreal forests (Dettki *et al.* 2000; Sillett *et al.* 2000; Hilmo & Såstad 2001). Several papers have focused on lichen responses to forest edges in boreal spruce forests (e.g. Esseen & Renhorn 1998; Kivistö & Kuusinen 2000; Hilmo & Holien 2002; Moen & Jonsson 2003; Rheault *et al.* 2003). Moen & Jonsson (2003) suggested that the depth of the edge effect was probably <56 m as measured by the response of liverworts and calicioid lichens in forest patches in boreal forests and wetlands.

Different strategies aimed to conserve species diversity within managed forests have been discussed in recent publications (e.g. Kolm & Franklin 1997; Fries *et al.* 1997; Sillett & Goslin 1999; Deal 2001; Hedenås & Ericson 2003; Pykälä 2003). It has been recommended that management techniques mimicking natural disturbance should form the basis of sustainable forest management (Fries *et al.* 1997). In a retrospective study based in central Norway's coastal spruce forest region, Rolstad *et al.* (2001) suggested that moderate selective cuttings might prove an acceptable management option to sustain viable lichen assemblages. Potential harvest strategies include long rotations (much longer than the economic rotation), structural retention and structural restoration (Kolm & Franklin 1997). Structural retention is designed to carry significant structural elements forward from the harvested stand into the new stand. Structural restoration attempts to accelerate the development of structural complexity in young forests.

To understand how environmental patchiness of any sort affects ecological systems, it is necessary to know how and at what scales individual organisms respond to spatial patterns. Thus, what is a highly fragmented landscape to one kind of organism may be relatively homogenous to another. With the exception of Hazell & Gustafsson (1999), Hedenås & Ericson (2003), Rheault *et al.* (2003) and Hilmo *et al.* (2005), few studies of the effect of different logging strategies on lichen species in boreal forest have been reported.

The present study was designed to analyze how logging influences the occurrence of epiphytic chlorolichens. Within an experimentally logged forest we examined the impact of different logging strategies and edge effects on lichen cover and abundance. To obtain a better understanding of biological processes, we tested the effect of different logging regimes on thallus size distribution. Results from this study will contribute to the development of forest management guidelines assisting in the conservation of lichen diversity.

Materials and Methods

Study area

The study was carried out in Mosvik municipality, Nord-Trøndelag county, central Norway (63°47′N, 10°48′E). The study area is a gentle to rather steep NW-facing slope, dominated by old *Picea abies* (Norway spruce) forest, at an altitude of about 250–300 m a.s.l. The landscape consists mostly of managed coniferous forests, some agricultural land and lakes. Mean annual
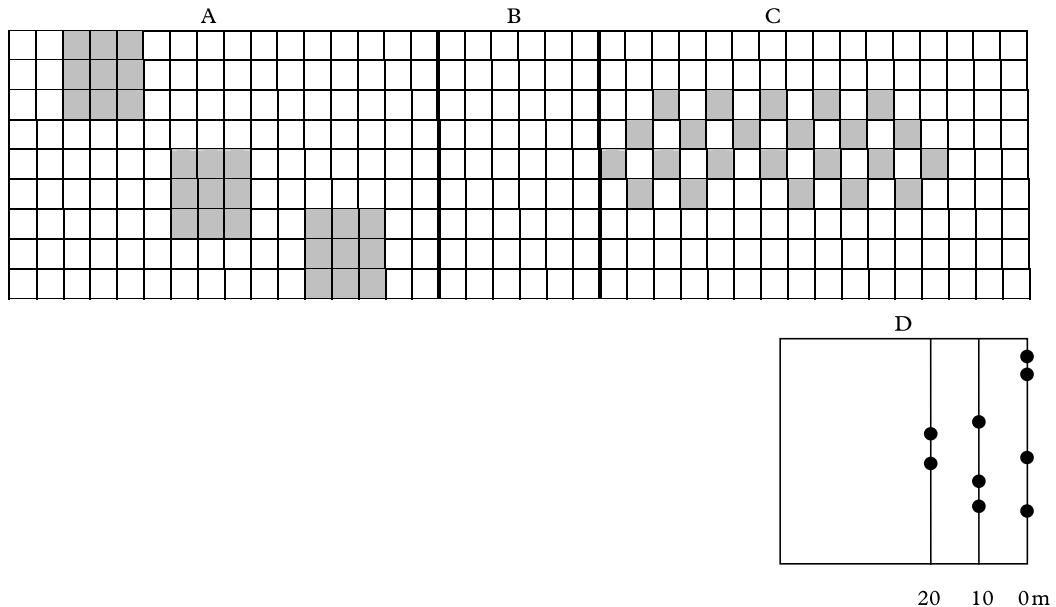
Fig. 1. The subdivision of the study area into three different habitat types based on logging strategy. A, coarse-grained area; B, control area; C, fine-grained area. The hatched squares were logged in the winter of 1995–96. Clearcuts were 50 × 50 m in the fine-grained area, and 150 × 150 m in the coarse-grained area. In each of the logged habitats, 15 branches were selected at random from trees at each of three distances (0 m, 10 m and 20 m) from forest edges. D, illustrates an example of one of the forest fragments from which 4 branches have been sampled at the edge, 3 branches at 10 m from the edge, and 2 branches at 20 m.

precipitation for the period 1970–1990 at the meteorological station Leksvik–Myran (138 m a.s.l.), 15 km south-west of the study site, was 1430 mm (Førland 1993). Phytogeographically the forest lies in the markedly oceanic section O2 of the middle boreal zone (Moen 1999).

The spruce forest is naturally regenerated, multi-layered with an uneven age distribution. Some selective felling and windfalls in the past have formed gaps in the canopy. The oldest spruce trees are more than 150 years old (Abildsnes & Tømmerås 2000). Scattered deciduous trees, mainly *Alnus incana*, *Betula pubescens*, *Salix caprea* and *Sorbus aucuparia*, are present in the north-eastern part of the study area. The ground is characterized by mesic to wet medium, nutrient-rich soil (Tømmerås *et al.* 1997). Bark pH was measured according to Gauslaa & Holien (1998), and varied between 4·1 and 5·3 based on 120 randomly sampled spruce twigs. Vegetation types present in the area are described in Abildsnes & Tømmerås (2000).

The epiphytic vegetation is dominated by ubiquitous lichen species such as *Hypogymnia physodes* and *Platismatia glauca*. Other common chlorolichens include *Alectoria sarmentosa*, *Bryoria capillaris*, *Cavernularia hultenii*, *Parmelia sulcata* and *Usnea* spp. Species of the *Lobarion* association (e.g. *Lobaria pulmonaria*, *L. scrobiculata* and *Nephroma* spp.) are common on deciduous trees, mainly on *Salix caprea* and *Sorbus aucuparia*.

Study design

Within the study area of approximately 1 km², a clearcut experiment was undertaken during the winter 1995/96 (Abildsnes & Tømmerås 2000). Two different logging strategies were carried out, coarse-grained logging and fine-grained logging. The coarse-grained logging consisted of 3 clearcuts each 2·25 ha and the fine-grained logging consisted of 23 clearcuts each 0·25 ha. The clearcuts were created in the pattern of a chessboard (Fig. 1) and in total comprised *c*. 50% of the total stand volume (Tømmerås *et al.* 1997). A control block between the coarse-grained and fine-grained area was left untouched. Eight clearcuts in the fine-grained area that bordered mires, or had a diffuse edge were omitted from the analyses.

A total of 110 trees greater than 40 cm in circumference at breast-height were selected for studies of lichen occurrence: 45 trees in the coarse-grained area, 45 in the fine-grained area and 20 trees in the control area. Within each of the two fragmented areas 15 trees were sampled randomly at 0, 10 and 20 m from the forest edges (Fig. 1) exposed to the south-west. The trees selected at 0, 10 and 20 m in the fine-grained area, were located in 7, 6 and 9 different fragments, respectively. In the coarse-grained area the randomly selected trees, at each distance, were located at each of the three different edges.

TABLE 1. *Variables describing the different tree and branches analysed in the fine-grained (45 branches), coarse-grained (45 branches) and untouched control areas (20 branches). Values are means ± 1 SEM together with maximum values in parentheses*

	Fine-grained area	Coarse-grained area	Control area
Trunk circumf. (cm)	77 ± 3·4 (131)	82 ± 4·4 (169)	71 ± 5·5 (116)
Branch length (cm)	278 ± 8·3 (358)	280 ± 9·6 (466)	275 ± 10·0 (356)
Branch circumf. (cm)	10 ± 0·3 (14)	9 ± 0·3 (15)	8 ± 0·4 (12)
Branch height (cm)	299 ± 9·6 (420)	316 ± 9·8 (448)	311 ± 15·7 (410)
Number of living branches below height of 4.5 m	7 ± 0·8 (19)	5 ± 0·7 (18)	4 ± 0·7 (12)

Tree and branch characteristics are presented in Table 1. Trunk circumference was measured at breast-height, branch circumference was measured 10 cm from the branch base and branch height was measured along the trunk. Except for branch circumference (one-way ANOVA, $P=0.029$) no significant differences ($P>0.005$) were found between the three forest habitats with respect to the tree and branch parameters measured (Table 1).

Fieldwork was carried out in the summer of 2001, nearly 6 years after logging. For each tree, one living branch was selected randomly for lichen analyses. Branches had to be within 4·5 m of the ground, and had to be oriented more or less south-west. Three epiphytic lichen species were included in the present study, *Cavernularia hultenii* Degel., *Platismatia glauca* (L.) Culb. & C. Culb. and *P. norvegica* (Lynge) Culb. & C. Culb. The number of thalli on the main axes of each branch was counted and the largest diameter (mm) of each thallus, irrespective of location along the main axes of the 110 branches, was recorded for each of the three species.

Platismatia glauca is widely distributed in oceanic and less humid forests in different stages of forest succession, and is commonly observed along the whole length of the branch, from base to tip (Hilmo 1994). *Platismatia norvegica* and *C. hultenii* are usually characterized as suboceanic species mainly confined to humid spruce forests (Holien and Tønsberg 1996; Thor and Arvidsson 1999). *Cavernularia hultenii* occurs as a pioneer lichen at the tip of spruce branches (Ahlner 1948; Hilmo 1994), while *P. norvegica* is observed more frequently on the innermost portions of the branches (Bruteig 1994).

Statistical treatment

The cover in cm^2 of *Platismatia glauca* and *P. norvegica* was calculated as the percentage cover of total branch length. The abundance of thalli on a branch was expressed as the number per m^{-1} branch length. For *Cavernularia hultenii* statistical treatment was based on cover in cm and total number of thalli on each branch as no relationship was observed between total branch length and cover (cm) (regression analysis, $P=0.777$) or total number of thalli (regression analysis, $P=0.998$).

Two-way ANOVA was used to assess the effect of logging strategy (fine-grained and coarse-grained) and distance (0 m, 10 m and 20 m from the forest edge) on mean cover and mean number of thalli. Logging strategy and distance were considered as fixed factors. The number of thalli per metre was square-root transformed to achieve homogenous variance among samples (Underwood 1997). For other variables untransformed data fulfilled the assumptions of ANOVA. Differences between the three habitats were analysed with one-way ANOVA and Tukey *post hoc* test.

Kolmogorov-Smirnov two sample test (Sokal & Rohlf 1995) was used to test whether the size-distribution of a species was significantly different in the fine-grained and coarse-grained area. All statistical tests were performed using S-Plus 2000 for Windows.

Results

Platismatia glauca was observed on all the 110 branches examined and was dominant with a mean cover of 26·9% ± 1·3 (± 1 SEM); the mean number of thalli on the branches was 32·2 ± 1·4. Compared to *P. glauca* the old-forest lichen *P. norvegica* was more sparsely distributed and absent from 18 of the 110 branches studied. The mean cover and the mean number of thalli of *P. norvegica* on the branches was 3·6 ± 0·4% and 2·4 ± 0·2%, respectively. *Cavernularia hultenii* covered an average of 3·8 ± 0·3 cm and the mean number of thalli on the branches was 4·8 ± 0·4. *Cavernularia hultenii* was absent from 11 of the 110 branches investigated.

Effect of logging strategy on lichen occurrences

The cover (%) and number of thalli m^{-1} of *Platismatia glauca* were significantly

TABLE 2. *Mean cover and mean number of thalli (± 1 SEM) in the fine-grained (45 branches), coarse-grained (45 branches) and control areas (20 branches). The results from one-way ANOVA are given*

Species	Fine-grained	Coarse-grained	Control area	d.f.	F	P
Platismatia glauca						
Mean cover (%)	30·4 ± 2·0	22·6 ± 2·1	29·1 ± 2·4	2	4·12	0·019
Mean no. of thalli m^{-1}	13·3 ± 0·7	9·15 ± 0·6	13·8 ± 0·8	2	14·46	0·0101
Platismatia norvegica						
Mean cover (%)	3·7 ± 0·6	3·7 ± 0·6	3·0 ± 0·9	2	0·27	0·765
Mean no. of thalli m^{-1}	0·9 ± 0·1	0·9 ± 0·1	0·6 ± 0·1	2	0·96	0·387
Cavernularia hultenii						
Mean cover (cm)	4·2 ± 0·5	2·4 ± 0·4	6·2 ± 0·6	2	11·56	<0·001
Mean number of thalli	5·5 ± 0·5	2·6 ± 0·4	8·4 ± 0·8	2	22·86	<0·001

TABLE 3. *ANOVA investigating the effect of logging strategy (fine-grained and coarse-grained) and distance (0, 10 and 20 m from forest edge) on cover of* Platismatia glauca *(%),* P. norvegica *(%) and* Cavernularia hultenii *(cm)*

	d.f.	MS	F	P
Platismatia glauca				
Logging strategy	1	1373·20	7·40	0·008
Distance	2	295·83	1·59	0·209
Logging strategy × distance	2	440·33	2·37	0·099
Platismatia norvegica				
Logging strategy	1	0·002	<0·001	0·992
Distance	2	3·319	0·20	0·816
Logging strategy × distance	2	12·670	0·78	0·464
Cavernularia hultenii				
Logging strategy	1	69·344	7·50	0·008
Distance	2	14·487	1·57	0·215
Logging strategy × distance	2	7·784	0·84	0·435

affected by logging strategy (Tables 2–4). The mean cover (%) and mean number of thalli were lower in the coarse-grained area than in the fine-grained area (Table 2), but these parameters did not differ between the control area and the fine-grained area (Tukey *post hoc* test). A significant interaction was recorded between logging strategy and distance (Table 4) for number of thalli. In the coarse-grained area the number of thalli increased with increasing distance from the edges (one-way ANOVA, $F=6·80$, $P=0·003$; Fig. 2A). The number of thalli differed between 0 m and 20 m and between 10 m and 20 m (Tukey *post hoc* test). No effects of distance were observed in the fine-grained area (one-way ANOVA,

$F=1·22$, $P=0·304$; Fig. 2A). A nearly significant interaction between logging strategy and distance (Table 3) was found for cover of *P. glauca*. Separate treatment of the two habitats showed a significant effect of distance in the coarse-grained area (one-way ANOVA; $F=4·05$, $P=0·025$; Fig. 3A). The cover differed between 0 m and 20 m and between 10 m and 20 m (Tukey *post hoc* test). In the fine-grained area no effect of distance was observed (one-way ANOVA; $F=0·11$, $P=0·898$; Fig. 3A).

The cover (cm) and number of thalli of *Cavernularia hultenii* were significantly higher on branches in the control area compared to branches situated in the fine-grained area and the coarse-grained area

TABLE 4. *ANOVA investigating the effect of logging strategy (fine-grained and coarse-grained) and distance (0, 10 and 20 m from forest edge) on abundance (thalli m^{-1}) of* Platismatia glauca, P. norvegica. *For* Cavernularia hultenii *the abundance was defined as total number of thalli on each branch*

|	d.f.	MS	F	P
Platismatia glauca				
Graininess	1	9·529	23·211	<0·001
Distance	2	0·546	1·329	0·270
Logging strategy × distance	2	2·721	6·629	0·002
Platismatia norvegica				
Graininess	1	0·029	0·012	0·913
Distance	2	0·072	0·297	0·744
Logging strategy × distance	2	0·165	0·678	0·510
Cavernularia hultenii				
Graininess	1	17·574	25·89	<0·001
Distance	2	2·326	3·43	0·037
Logging strategy × distance	2	1·909	2·81	0·066
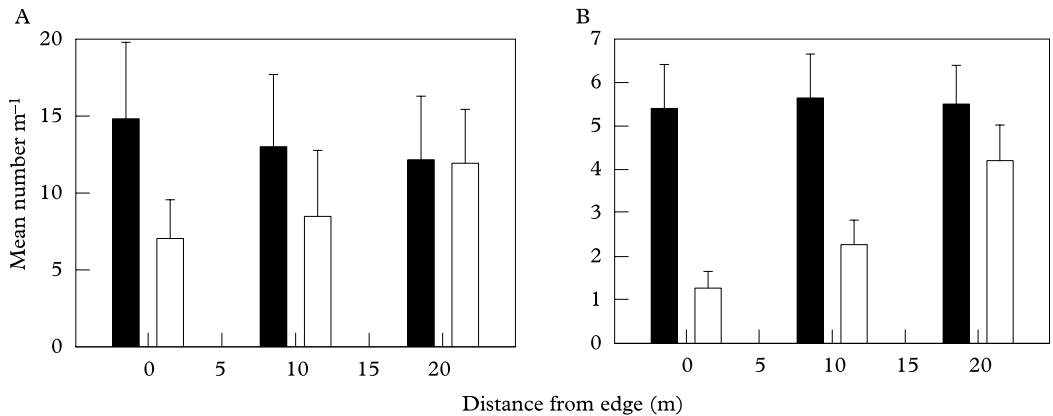
FIG. 2. Mean number (± 1 SEM, $n=15$) of thalli at different distances from the forest edge in the fine-grained (black) and coarse-grained (white) areas. A, *Platismatia glauca*; B, *Cavernularia hultenii*.

(Table 2; Tukey *post hoc* test). The pattern of logging influenced both cover (cm) and number of thalli of *C. hultenii* (Tables 3 & 4). The mean cover (%) and the mean number of thalli were higher by a factor of *c.* 2 in the fine-grained area compared to the coarse-grained area (Table 2). The mean number of thalli of *C. hultenii* was significantly affected by distance from the edge (Table 4). The effect of distance is significant in the coarse-grained area (one-way ANOVA, F=6·02, P=0·004), but not in the fine-grained area (one-way ANOVA, F=0·02,

P=0·976). In the coarse-grained area the number of thalli differed significantly between 0 m and 20 m from the forest edges (Fig. 2B). No significant effect of distance was observed on cover (cm) (Table 3) in spite of increasing cover with increasing distance from the edges in the coarse-grained area (Fig. 3B).

In contrast to *P. glauca* and *C. hultenii,* the abundance of *P. norvegica* did not differ between the habitats (Table 2) and was not affected by either logging strategy or distance from the forest margin (Tables 3 & 4).
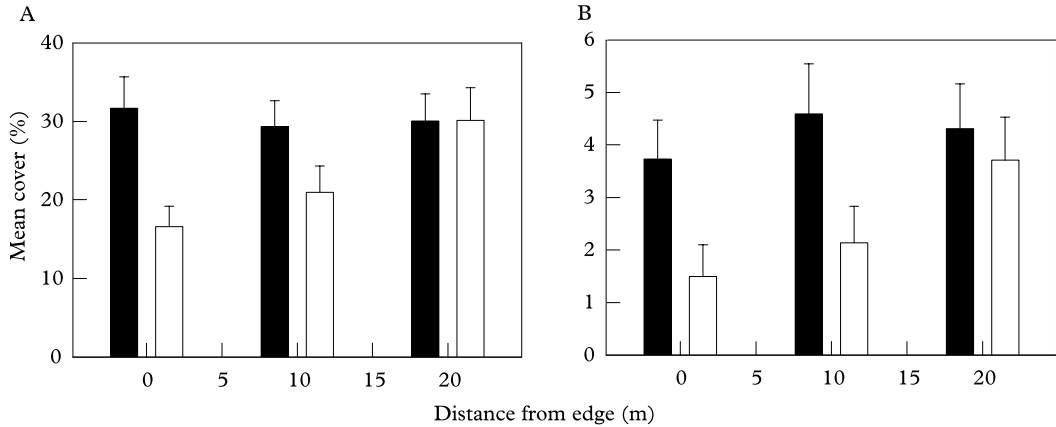
A

B

FIG. 3. Mean cover (± 1 SEM, *n*=15) at different distances from the forest edge in the fine-grained (black) and in the coarse-grained (white) areas. A, *Platismatia glauca*; B, *Cavernularia hultenii*.

Effect of forestry on the size-distribution of the investigated species

The size-distribution of *Platismatia glauca* in the control area was skewed towards a high frequency of small thalli (Fig. 4A). The shape of the thallus size distribution differed significantly between the coarse-grained area and the fine-grained areas (*P*=0·002) and between the coarse-grained area and the control area (*P*=0·003) (Fig. 4A–C). A higher number of small thalli (<15 mm) was found in the control area (55%) compared to the coarse-grained area (45%). The mean thallus size of *P. glauca* was 24·4 mm in the coarse-grained area, 22·7 mm in the fine-grained area and 21·2 mm in the control area. No significant differences were observed in the size-distribution of thalli in the fine-grained area and the control area (*P*=0·477).

The size-distribution of *Cavernularia hultenii* differed significantly between the two logged areas (*P*=0·018) and between the coarse-grained area and the control area (*P*=0·046). This result could be explained by a lower frequency of small thalli (<4·0 mm) in the coarse-grained area compared to both the fine-grained and control areas (Fig. 5A–C). The mean thallus size of *C. hultenii* was 9·5 mm in the coarse-grained area, and 7·6 mm and 7·5 mm in the fine-

grained area and control area, respectively. No significant difference in the size-distribution was observed between the fine-grained area and control areas (*P*=0·820).

Discussion

This study, carried out nearly 6 years after logging, has shown that different logging patterns can influence the occurrence of the epiphytic lichens *Platismatia glauca* and *Cavernularia hultenii*. A lower abundance of the species in the coarse-grained area, compared to the fine-grained area, mainly reflects a decline in number and cover of thalli at the margins of the forest remnants. Larger clearcuts (150 × 150 m) in the coarse-grained area might create a steeper gradient in microclimatic factors between the clear cuts and the remnant forest than in the fine-grained area (clear cuts 40 × 40 m). High wind-speed, low humidity and increased solar radiation at the forest edges, might cause higher rates of thallus desiccation and thus reduced vitality of the lichens. Moreover, harsh weather conditions at the exposed edges (e.g. snow abrasion) could conceivably cause lichen thalli to become detached from their substratum, especially in *P. glauca*, which grows loosely attached to branches. Esseen (1985) pointed out that lichen mortality is often associated with
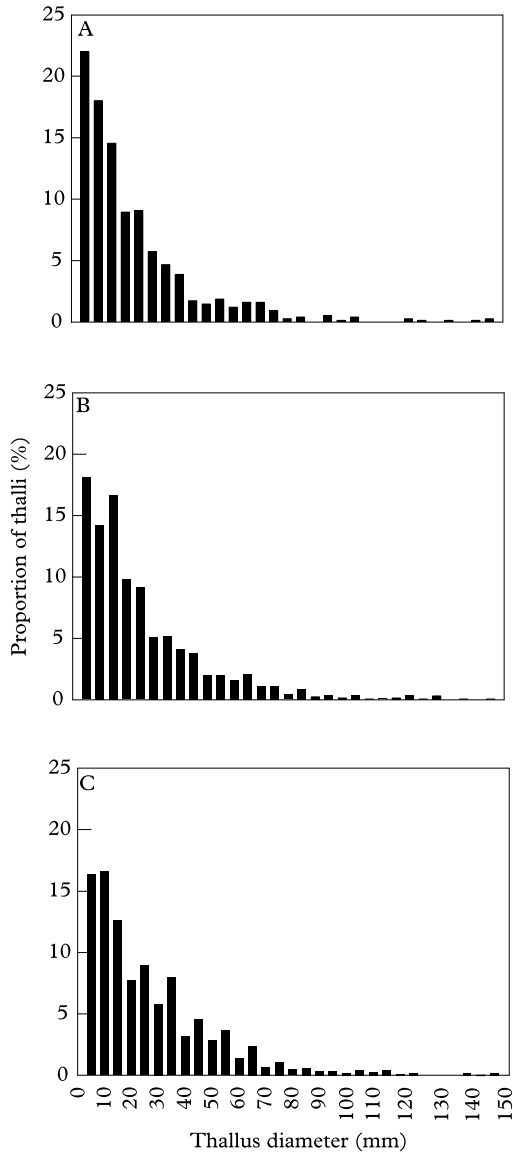
Fig. 4. Thallus size distribution in *Platismatia glauca* in each of the habitats. A, control area; B, fine-grained area; C, coarse-grained area. Values plotted are the relative numbers of thalli in each 5 mm thallus diameter class.
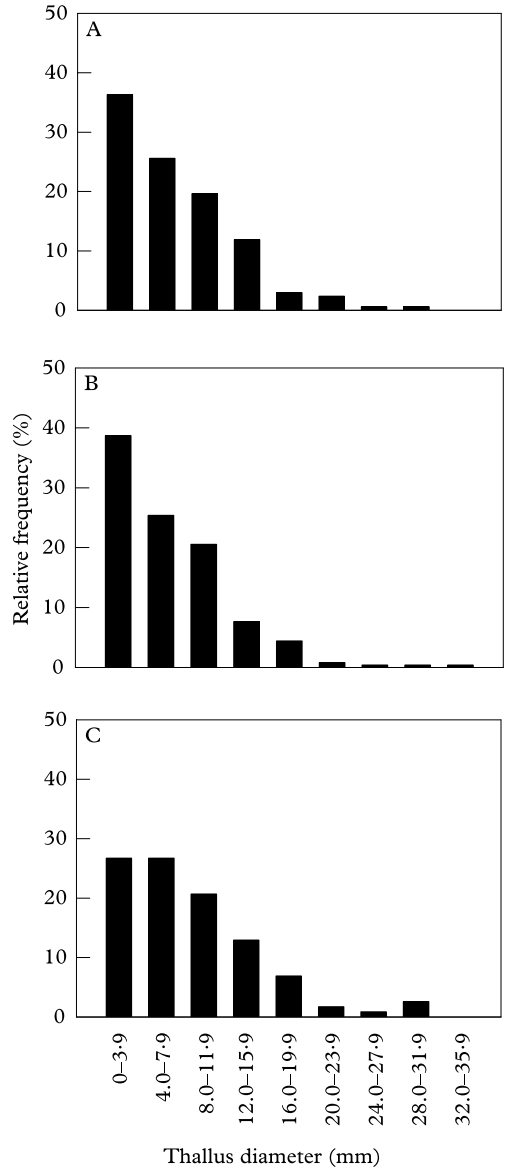

Fig. 5. Thallus size distribution in *Cavernularia hultenii* in each of the habitats. A, control area; B, fine-grained area; C, coarse-grained area. Values plotted are the relative numbers of thalli in each 4 mm thallus diameter class.

storms and heavy snow loading on the branches. A decline in the number of thalli at the edges might also be due to reduced supply of diaspores or an unsuccessful establishment and development of deposited

diaspores. This study has also shown that 'number of thalli' is a more sensitive parameter than 'cover of thalli' when studying edge effects on epiphytic lichens. For both *P. glauca* and *C. hultenii* the effect of distance

from the edges was more pronounced on the number of thalli than on percentage cover.

The size-distribution of *C. hultenii* and *P. glauca* revealed a lower number of small thalli (<5 mm) in the coarse-grained area, compared to the fine-grained and control areas. This indicates that the juvenile thalli are more sensitive to logging than mature thalli. This finding is supported by Hilmo *et al.* (2005); studying lichen colonization on spruce branches in the same experimental forest these authors found that colonization by *C. hultenii* and *P. glauca,* on the 15 youngest annual shoot increments was negatively influenced by a coarse-grained logging pattern, possibly as a result of a low incidence of needles on the branches at the forest edges. Not only might needles be important for catching dispersed diaspores, they might also create microclimatic conditions suitable for diaspore establishment and development. These two studies of chlorolichens in managed forests have clearly shown that the initial stages of the life cycle are sensitive to changed environmental conditions. However, edge effects might be strongly dynamic over time (Esseen & Renhorn 1998). For example, a study undertaken a decade after logging might record a higher number of small thalli at the forest edges than a study after only six years. It is possible that new, climatically adjusted thalli could become established near the forest edges after a long period.

In spite of more edges (measured in metres) in the fine-grained area, compared to the coarse-grained area, no measurable edge effect was observed in the fine-grained regime. The abundance of *P. glauca* was as high in the fine-grained area as in the control area. Accordingly, a fine-grained pattern of logging might be in accordance with the goal of maintaining the size of the *P. glauca* population. However, this strategy of logging might not be appropriate for maintaining the size of the *C. hultenii* population, since the abundance of this species was lower in the fine-grained area compared to the control area. The environmental conditions in small forest patches (0·25 ha) might not be in accordance with the ecological requirements of *C. hultenii*. Hilmo & Holien (2002) and Hilmo *et al.* (2005) argued that the suboceanic species *C. hultenii* might be especially vulnerable to desiccation owing to its location at the tips of branches. They concluded that *C. hultenii* is among the most sensitive chlorolichens in boreal forests and hence a good indicator when analyzing effects of logging in humid boreal forests.

In contrast to *P. glauca* and *C. hultenii*, the oldgrowth lichen *P. norvegica* was not affected by logging strategy or distance from the forest edge. *Platismatia norvegica* is a relatively thick, vigorous species, probably not as vulnerable as *P. glauca* and *C. hultenii* to harsh weather conditions at the forest edge. The less exposed position of *P. norvegica*, on the innermost portion of branches (Bruteig 1994), might also be advantageous. However, this could equally reflect a significantly smaller number of thalli on the branches (<1 thallus m^{-1}). Further, the dispersal ability of *P. norvegica* is probably low (Hilmo & Såstad 2001) possibly causing an aggregated pattern of distribution. An uneven distribution pattern might thus conceal any true edge effects.

This study shows that common chlorolichens respond differently to logging, as well as to specific patterns of logging. We conclude that in the short-term fine-grained logging could help to maintain population size in *P. glauca*, whereas logging, regardless of strategy, might reduce *Cavernularia* population size. Further, juvenile thalli are sensitive to a coarse-grained pattern of logging as reflected in the distinct decline in the frequency of juvenile thalli in patches adjacent to large clearcuts. In a long-term perspective, regeneration of the second-growth forest in the clearcuts, might reduce the intensity and depth of the edge effects and this fact might influence the abundance of the species. Moreover, logging in a pattern of a chessboard secures a nearby source of diaspores important for a rapid colonization of the plantations. If the rotation cycle is extended (>110 years) it is probable that *C. hultenii* might recover within the second-growth stand. *Cavernularia hultenii* as well as *P. glauca*, has been observed by the authors

in several 30–40 year old plantations in suboceanic and oceanic spruce forests in central Norway. Moreover, in a study of edge effects on epiphytic lichens, Esseen & Renhorn (1998) found that at older edges the abundance of *Alectoria sarmentosa* had recovered inside the edge (20–30 m). *Platismatia norvegica* is only rarely observed in younger planted stands. Thus, extended rotation cycles might be a prerequisite if the species is to survive in managed forest ecosystems. Studying long-term effects of forest management Dettki & Esseen (2003) showed that even-aged silvicultural systems with a short rotation (60 years) were detrimental to epiphytic communities.

It may be difficult to generalize on the basis of the present results, because they are dependent on local climatic conditions. In hypermaritime regions coarse-grained clearcuts probably have less effect on the lichens, while even fine clearcuts could be detrimental in more continental areas. Moreover, the observed effects of logging are highly influenced by the species involved. Cyanolichens may be even more sensitive to edge effects than chlorolichens, and the effect of logging on crustose lichens is poorly known. However, the present results support the statement that any management plans aimed at maintaining population size should be based on a local understanding of the species ecology and life cycle within the area in question.

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