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# Changes in species occurrence and phytomass after clearfelling, prescribed burning and slash removal in two Swedish spruce forests

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# Abstract

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In two old Norway spruce stands, the one at Garpenberg in middle Sweden, the other at Flakaträsk in northern Sweden, the phytomass of the field- and ground-layer was measured before clearfelling and one and four years later. The phytomass of the field-layer was also measured 10 and 16 years after clearfelling.

Of 13–14 plant species originally in the field-layer, 2–3 were not found after clearfelling. In contrast, 15 and 9 new species appeared on the plots on which slash was left, at Garpenberg and at Flakaträsk. Some were short-lived, and 16 years after clearfelling, only 11 and 7, respectively, persisted. Corresponding figures for the plots from which slash was removed were 9 and 8, and for the burnt plots 11 and 9.

Clearfelling of the old forests at Garpenberg and Flakaträsk also increased the phytomass of the field-layer. Removal of slash decreased the phytomass of some species, increased it for others. During the first few years after burning, phytomass on the burnt plots was less than that on the controls, but three years later it was similar to that on the unburnt plots. The spatial variation in phytomass was great, and no significant difference was found between treatments after clearfelling.

The biomass of the most common moss species of Swedish coniferous forests declined strongly after clearfelling. Two new mosses appeared on the clearfelled plots, viz. *Polytrichum* spp. and *Ceratodon purpureus*; the latter being found only on burnt plots at Flakaträsk four years after burning.



*Key words:* Field-layer vegetation, mosses, *Picea abies*, *Pinus sylvestris*, plantations, age.



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# Introduction

In recent decades, the effects of forest management on the diversity of plant species have been debated both in Sweden and elsewhere. Clearfelling, in particular, has been recognised as influencing profoundly the number of species present in forests. It is believed by many that clearfelling decreases the number of plant species.

The clearfelling of a forest stand results in drastic changes in site conditions, especially if it is followed by the burning or removal of slash. Competition for water, plant nutrients and light from the trees comes to a sudden end, and plant nutrients increase as slash and dead roots decompose, creating good growth conditions for certain plants.

This paper describes a long-term study of aboveground phytomass before and after the clearfelling of two old Norway spruce stands. The clearfelled areas were treated in different ways: (1) slash was left *in situ*, as in conventional forestry; (2) slash was removed, as in whole-tree harvesting; and (3) controlled burning was carried out, as was common practice in northern Sweden about 40 years ago. The phytomass of the field-layer vegetation was determined 1, 4, 10 and 16 years after clearfelling. The phytomass of the ground-layer vegetation was measured one and four years after clearfelling.

The diverse epiphytic lichen flora, which is common in old coniferous forests in Sweden, was not investigated. There were no ground lichens in the two experimental areas.

# Materials and methods

### Study areas and phytomass sampling

The investigation began in 1966 in a 100-year-old Norway spruce (*Picea abies* (L.) Karst.) stand at Garpenberg, situated in southern Dalecarlia. A year later, a similar study was made in a 140-year-old Norway spruce stand at Flakaträsk, ca. 100 km WNW of Umeå. Site and stand characteristics are given in Table 1.

In each area, all plants except mosses were cut at the soil surface, on 50 × 50 cm quadrats laid out at random. There were 57 quadrats at Garpenberg and 31 at Flakaträsk. Mosses were sampled from 15 randomly distributed quadrats at Garpenberg and 14 at Flakaträsk. Two 10 × 10 cm samples were taken from each quadrat. These were separated into green parts and brownish, dead parts.

The spruce stands were clearfelled, and in the following spring, six 50 × 50 m plots were laid out on each site. The slash was left on two of them and removed from two others. On the two remaining plots, the slash was burnt. After manual soil scarification, half of each 50 × 50 m plot was planted with Norway spruce and the other half with Scots pine (*Pinus sylvestris* L.). About two months later, the phytomass of the field-layer vegetation was determined on each of five 50 × 50 cm quadrats distributed at random in each 25 × 50 m plot. Small deciduous trees were sampled from five 10 × 10 m sample plots adjacent to the quadrats. No sampling was carried out in the scarified areas, which occupied about 100 $m^2$ of each 2 500 $m^2$ plot.

The dense vegetation of *Deschampsia flexuosa* (L.) Trin. was sampled by means of cylinders with a cross-sectional area of 37.5 $cm^2$. From each plot, ten composite samples were taken, each containing 16–18 separate samples. Mosses were sampled from ten 10 × 10 cm quadrats on each plot, one and four years after clearfelling.

Phytomass sampling was repeated 4, 10 and 16 years after clearfelling. Since phytomass varies with season, the samplings were always carried out in early July. In 1978, spring was very late in northern Sweden, and the phytomass was therefore low at Flakaträsk ten years after clearfelling.

All samples were dried in an oven for 15 h at 105°C, then weighed. Mean phytomass ±95% confidence interval was calculated per hectare.

Nomenclature for vascular plants follows Flora Europaea (1964, 1993). That for mosses follows Hallingbäck & Holmåsen (1985).

# Results

### Small deciduous trees and field-layer vegetation

When the old spruce forests at Garpenberg and Flakaträsk were initially sampled, 14 and 13

Table 1. *Description of sites and stands before clearfelling. NS – Norway spruce; SP = Scots pine; BL = broadleaved; $m^3sk$ = forest cubic metres*

| Characteristic | Site | |
|---|---|---|
| | Garpenberg | Flakaträsk |
| Situation | lat. N 60°16′<br>long. E 16°13′ | lat. N 64°15′<br>long. E 18°30′ |
| Altitude | 200–220 m | 420–450 m |
| Aspect, slope | ENE 4% | SSE 7% |
| Area, ha | 3.7 | 2.9 |
| Bedrock | Granite | Granite |
| Soil texture | Sandy till | Sandy till |
| Soil type[a] | Haplic Podzol | Haplic Podzol |
| Humus layer | Mor | Mor |
| Forest type | Mesic dwarf-shrub | Mesic dwarf-shrub |
| Stand age, years | 100 (45–132) | 139 (128–160) |
| Tree height, m | 22.6 | 17.0 |
| No. trees $ha^{-1}$ (by species) | 544 (NS 493, SP 40, BL 11) | 1002 (NS 988, SP 9, BL 5) |
| Basal area at 1.3 m, $m^2$ $ha^{-1}$ | 29.8 | 33.5 |
| Basal-area-weighted mean diameter, cm | 26.4 | 20.6 |
| Form factor | 0.464 | 0.486 |
| Mean volume, $m^3sk$ $ha^{-1}$ | 331 | 278 |
| Site quality class | 4.9 $m^3sk$ $ha^{-1}$ $yr^{-1}$ | 2.6 $m^3$ $ha^{-1}$ $yr^{-1}$ |

[a] FAO-UNESCO system.

different plant species were found in the field layer. After clearfelling, two plant species, viz. *Rubus saxatilis* L. and *Polypodium vulgare* L., were not found at Garpenberg and three, viz. *Empetrum nigrum* L., *Lycopodium selago* L. and *Plantago major* L., were not found at Flakaträsk. On the other hand, 18 and 11 new plant species had colonised the clearfelled areas, some of them only temporarily during the first few years after clearfelling (Appendix, Tables 11–12).

The total aboveground phytomass, excluding the ground-layer vegetation, before and after clearfelling, is shown in Fig. 1. During the first year after clearfelling of the old spruce forest at Garpenberg, phytomass increased in the unburnt plots, after which it decreased. In the burnt plots, the greatest phytomass was found four years after clearfelling.

In the more northerly situation of Flakaträsk, phytomass accumulated more slowly after clearfelling. The comparatively low total phytomass ten years after clearfelling can be attributed mainly to the delayed development of plants caused by the late spring in that year.

One and four years after clearfelling, phytomass was somewhat higher in the plots with slash removed than in plots with slash remaining. However, the reverse was true at all later samplings, with the exception of Flakaträsk 16 years after clearfelling. The differences were, however, not significant ($p > 0.05$).

### *Small deciduous trees*

The old spruce forest at Garpenberg also contained pine (*Pinus sylvestris* L.), birch (*Betula verrucosa* Ehrh.) and rowan (*Sorbus aucuparia* L.), which increased in number after clearfelling (Appendix, Table 11). At Flakaträsk, there was also willow (*Salix* spp.) and aspen (*Populus tremula* L.) in the old forest. Root suckers of aspen, which developed after clearfelling from a single large tree on one of the burnt spruce plots, strongly competed with the planted trees on part of the plot (Appendix, Table A12). However, grazing elk (*Alces alces* L.) kept the aspen from taking over, and the spruce plants survived, although they remained smaller than those in the other burnt plot. The root suckers also spread to part of the adjacent pine plot.

### *Dwarf shrubs*

*Vaccinium myrtillus* L. dominated the field-layer vegetation of the old spruce forests at Garpenberg and Flakaträsk. This species was found in 44% of the sample plots at Garpenberg and 97% of the Flakaträsk plots. After clearfelling, its phytomass decreased on the unburnt plots at Garpenberg but increased on the

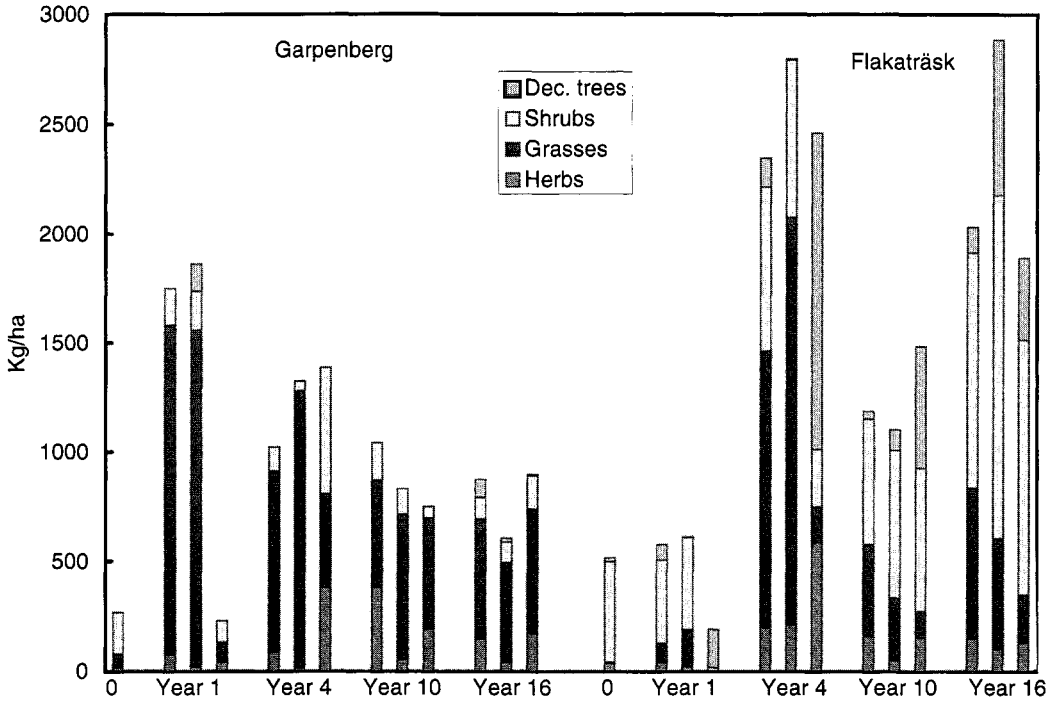


*Fig. 1.* Total phytomass of small deciduous trees, dwarf shrubs, grasses and herbs before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. The first column in a series of three for each sampling period refers to plots with slash left on-site; the second and third columns refer to plots with slash removed and burnt plots respectively. Average figures for spruce and pine plots.

Flakaträsk plots, with the exception of the first year (Fig. 2). The phytomass of *V. myrtillus* on the burnt plots at Garpenberg was lower 1, 10 and 16 years after clearfelling compared with that in the old forest, but was greater at Flakaträsk 10 and 16 years after clearfelling. A significant difference was found for all treatments at Flakaträsk between the phytomass of *V. myrtillus* in the plantation 16 years after clearfelling and that in the old forest (Appendix, Table A1).

In the old forests, *Vaccinium vitis-idaea* L. was found on 12% of the sample plots at Garpenberg and 81% of the Flakaträsk plots. Its phytomass decreased in the first year after clearfelling, but increased thereafter (Fig. 3). The greatest phytomass of *V. vitis-idaea* was found on the burnt plots at Flakaträsk 16 years after clearfelling. However, differences in the phytomass of this species between the clearfelled and the old forest areas were not significant, because of its great spatial variation (Appendix, Table A2).

No specimens of *Linnaea borealis* L. were found in the burnt plots at Garpenberg, with the exception of the pine plot 16 years after clearfelling, when the phytomass was about the same as that in the old forest. In the unburnt plots, the phytomass of *L. borealis* was greater than that in the old forest one year after clearfelling, but subsequently it was consistently lower (Fig. 4). At Flakaträsk, the phytomass of *L. borealis* increased on the unburnt plots during the early years after clearfelling but later decreased. Burning reduced the phytomass during the early years, after which it gradually increased.

### *Grasses*

The phytomass of *Deschampsia flexuosa* in the old forests at Garpenberg and Flakaträsk was 60 and 4 kg ha$^{-1}$, respectively. In spite of the low phytomass, tiny plants were found on 89% of the sample plots at Garpenberg and 84% of those at Flakaträsk. The phytomass of *D. flexuosa* increased from ca. 60 to ca. 1 500 kg ha$^{-1}$ during the first year after clearfelling on the unburnt plots at Garpenberg, but subsequently

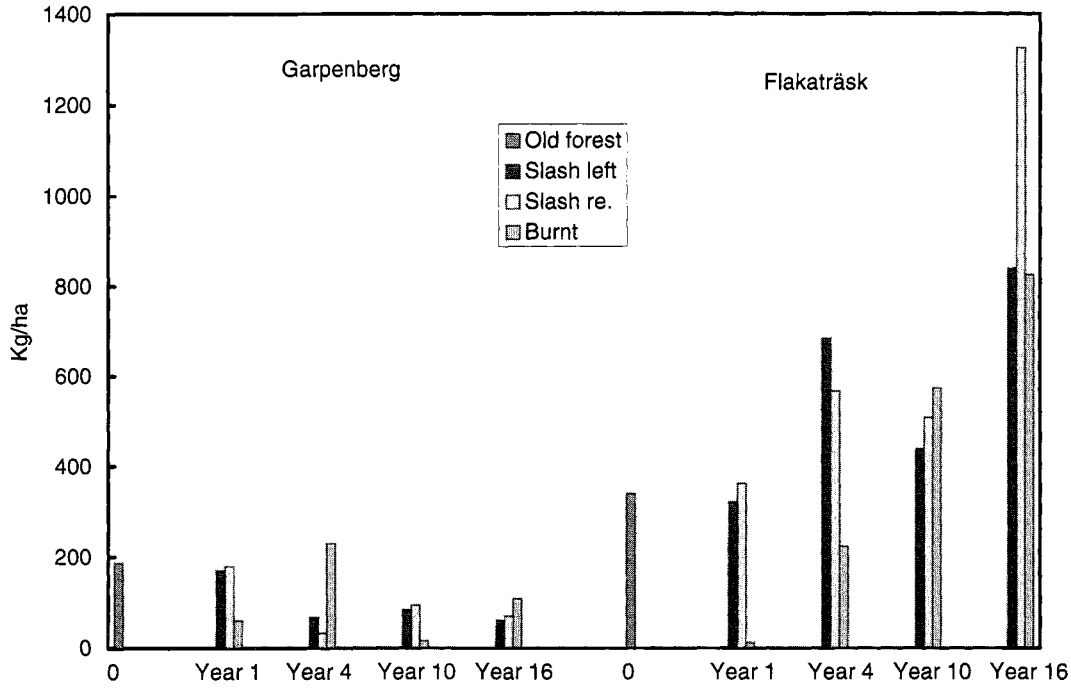


*Fig. 2.* Phytomass of *Vaccinium myrtillus* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

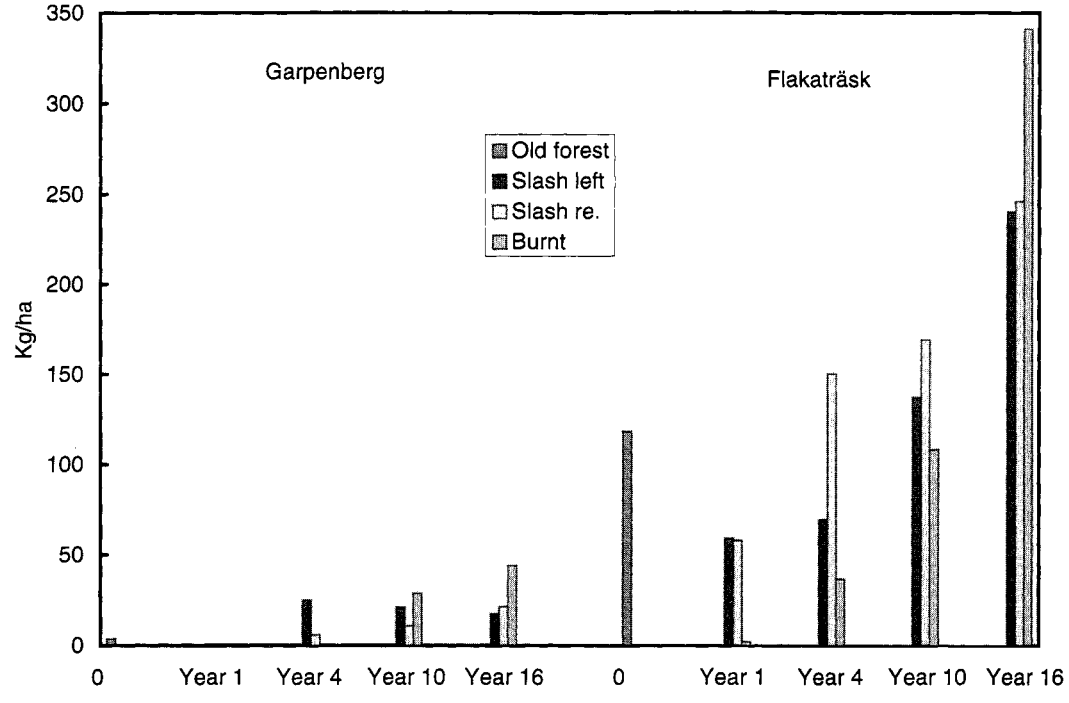


*Fig. 3.* Phytomass of *Vaccinium vitis-idaea* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

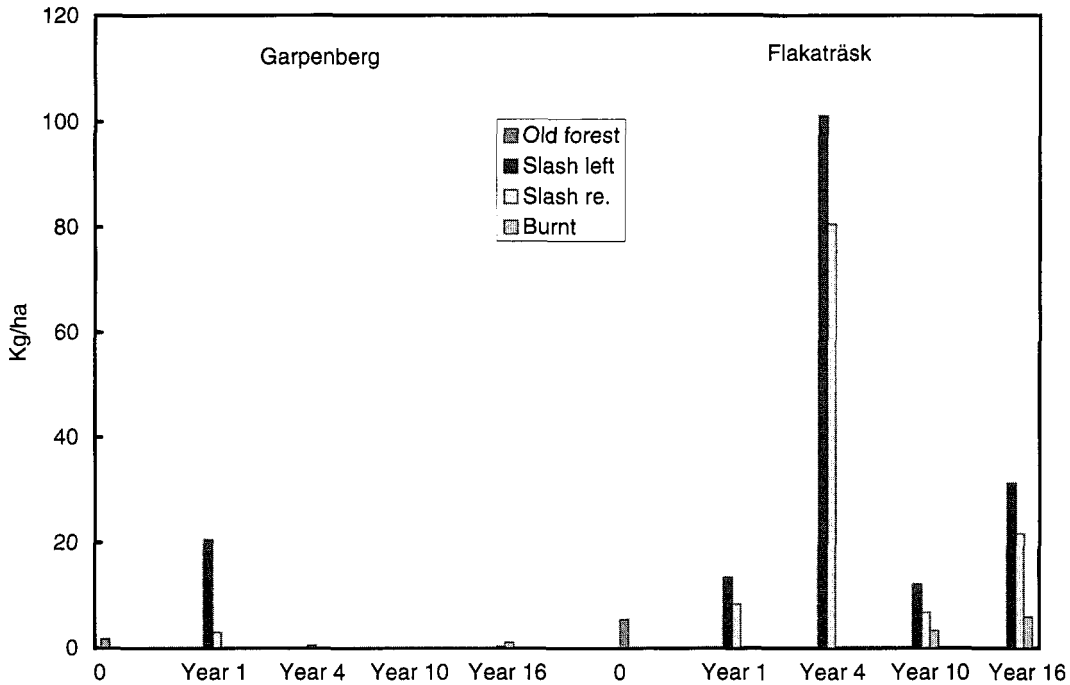


*Fig. 4.* Phytomass of *Linnaea borealis* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

decreased (Fig. 5). On the burnt plots, its phytomass increased gradually after clearfelling.

In the more northerly situation of Flakaträsk, the increase in the phytomass of *D. flexuosa* was delayed compared with that on the Garpenberg plots. However, four years after clearfelling, the phytomass of *D. flexuosa* was greater on plots at Flakaträsk from which slash had been removed, than on unburnt plots at Garpenberg one year after clearfelling. Burning was more intense at Flakaträsk than at Garpenberg, because weather conditions there were more favourable for burning. The phytomass of all plants was therefore very low the first year after burning at Flakaträsk.

### *Other common plants of Swedish coniferous forests*

The most common herbs in the old spruce forests were *Maianthemum bifolium* (L.) Schmidt, *Melampyrum* spp. and *Trientalis europaea* L.

One year after clearfelling at Garpenberg, the phytomass of *Maianthemum bifolium* was higher on plots with slash left, but lower on those from which slash was removed, as compared with the phytomass in the old spruce forest (Fig. 6). On all sampling occasions, the phytomass of *M. bifolium* had decreased on the burnt plots (except the pine plots one year after clearfelling; Appendix, Table A7). At Flakaträsk, its phytomass increased after clearfelling, especially on the burnt plots.

In the inventory, two closely related plant species, *Melampyrum pratense* L. and *M. silvaticum* L., were not separated. Burning depressed their growth during the first four years after clearfelling but increased it thereafter (Fig. 7). On the unburnt plots at Garpenberg, it took some years for the *Melampyrum* species to become established after clearfelling, but after 10 and 16 years their phytomass was much greater than in the old forest, with the exception of the pine plots from which slash was removed (Appendix, Table A8). *Melampyrum* species were less common at Flakaträsk than at Garpenberg. Their phytomass had increased on all sampling occasions after clearfelling, with the exception of the burnt plots one and four years after clearfelling.

The phytomass of *Trientalis europaea* and

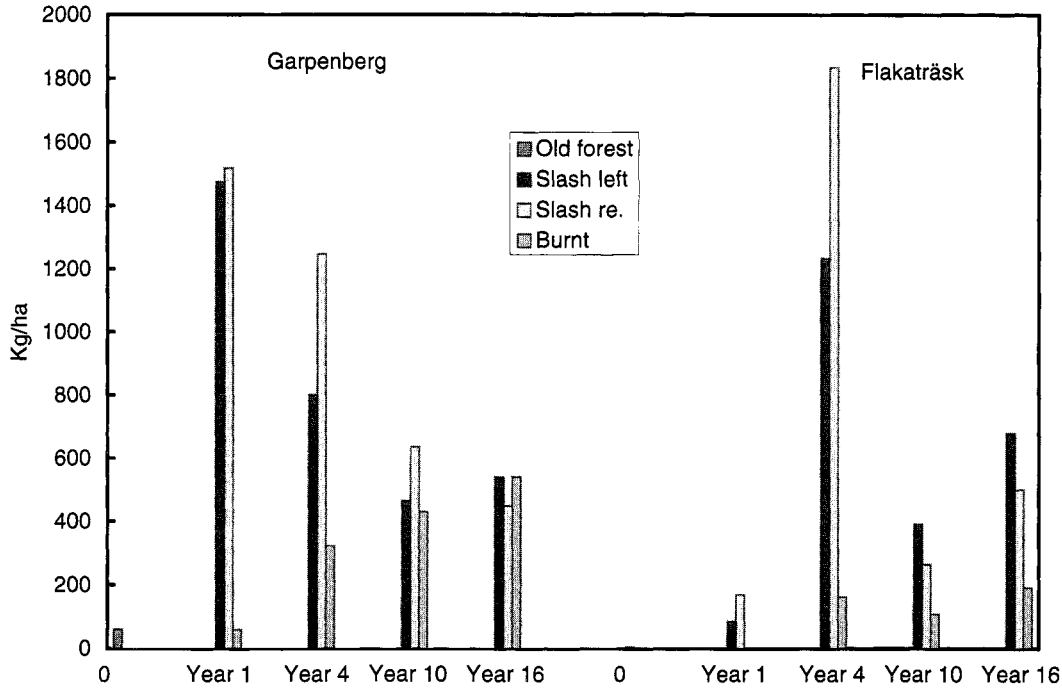


*Fig. 5.* Phytomass of *Deschampsia flexuosa* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

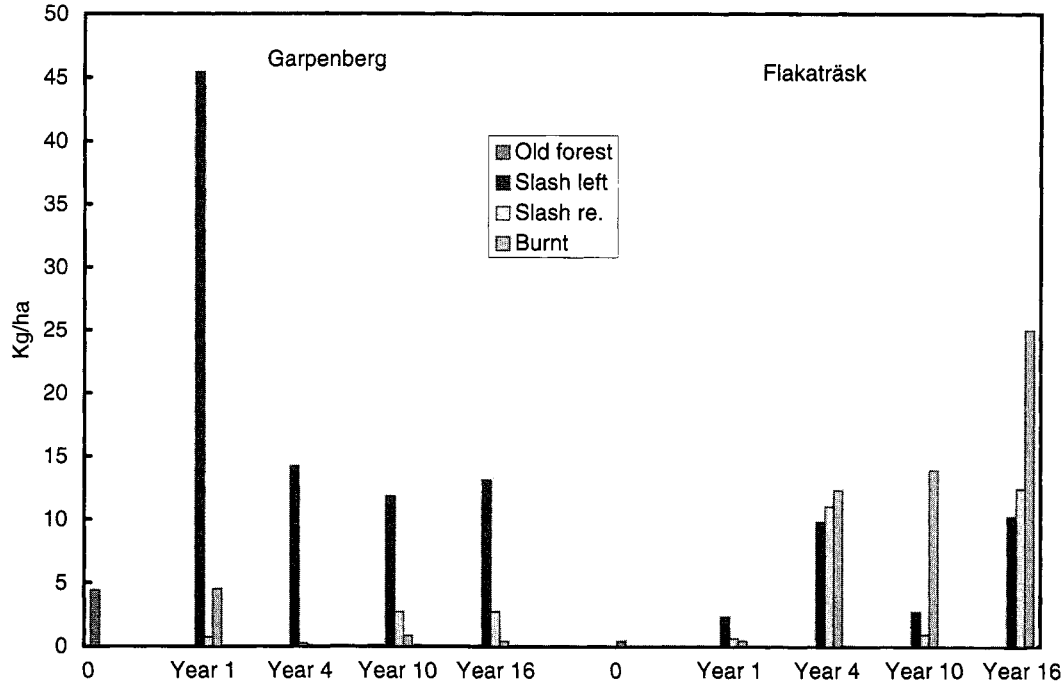


*Fig. 6.* Phytomass of *Maianthemum bifolium* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

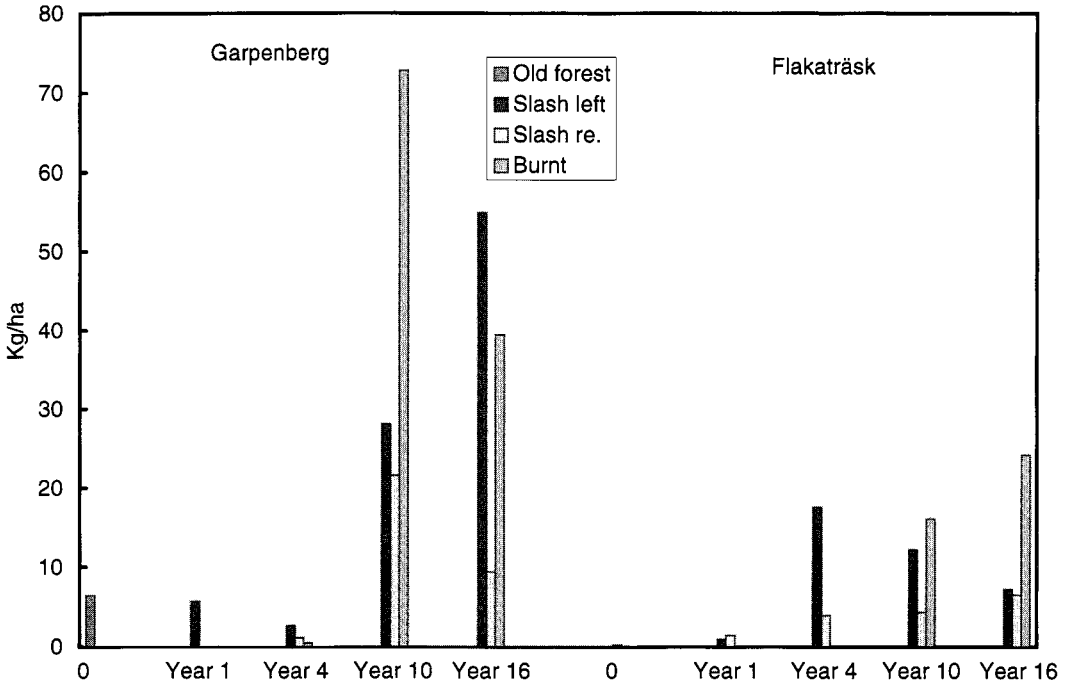


*Fig. 7.* Phytomass of *Melampyrum* spp. before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

*Luzula pilosa* (L.) Willd. increased after clearfelling at both Garpenberg and Flakaträsk (Figs. 8 and 9).

*Oxalis acetosella* L., another plant common in most spruce forests in Sweden, was found at Garpenberg but not at Flakaträsk (Appendix, Table A11). After clearfelling, its phytomass had increased on the spruce plots on all sampling occasions, except for the burnt plots one and four years after clearfelling, and the plot from which slash had been removed, ten years after clearfelling. On the pine plots, *O. acetosella* was found only four and ten years after clearfelling on plots with slash remaining.

In the old forests, the vascular plants tended to grow mainly in small gaps, where light conditions were more favourable. As growth conditions improved after clearfelling, the plants grew taller and spread to surrounding areas. Although the phytomass of the most common plant species in the field-layer vegetation increased after clearfelling (except *V. myrtillus* and *Linnaea borealis* at Garpenberg), the increases were not significant at the 95% level, owing to the great spatial variation (Appendix, Tables A1–A9).

For the phytomass of *Maianthemum bifolium*, one of the most common herbs in the old forests of Garpenberg and Flakaträsk, the number of samples required to attain a standard error of 10% of the mean was more than 4 000 and 2 000, respectively. The corresponding numbers of samples 16 years after clearfelling were 65 and 73 for one of the spruce plots with slash left *in situ* (Appendix, Table A7). Similarly large differences between old forests and clearfelled plots were found for *Melampyrum* spp. and *Trientalis europaea*. The increase of phytomass after clearfelling, the occurrence of vascular plants in gaps, and the small size of trial plots (25 × 50 m) compared with the sampling area of the old forests (3.7 and 2.9 ha, respectively), probably account for the great difference in the number of plots required to attain a standard error of 10% of the mean.

### *Other plant species in the old spruce forests*

Although *Hieracium pilosella* L., *Potentilla erecta* (L.) Räusch. and *Rubus saxatilis* are not common plants in old spruce forests, they were found at Garpenberg. *Hieracium pilosella* was rediscovered on the burnt plots 1, 10 and 16

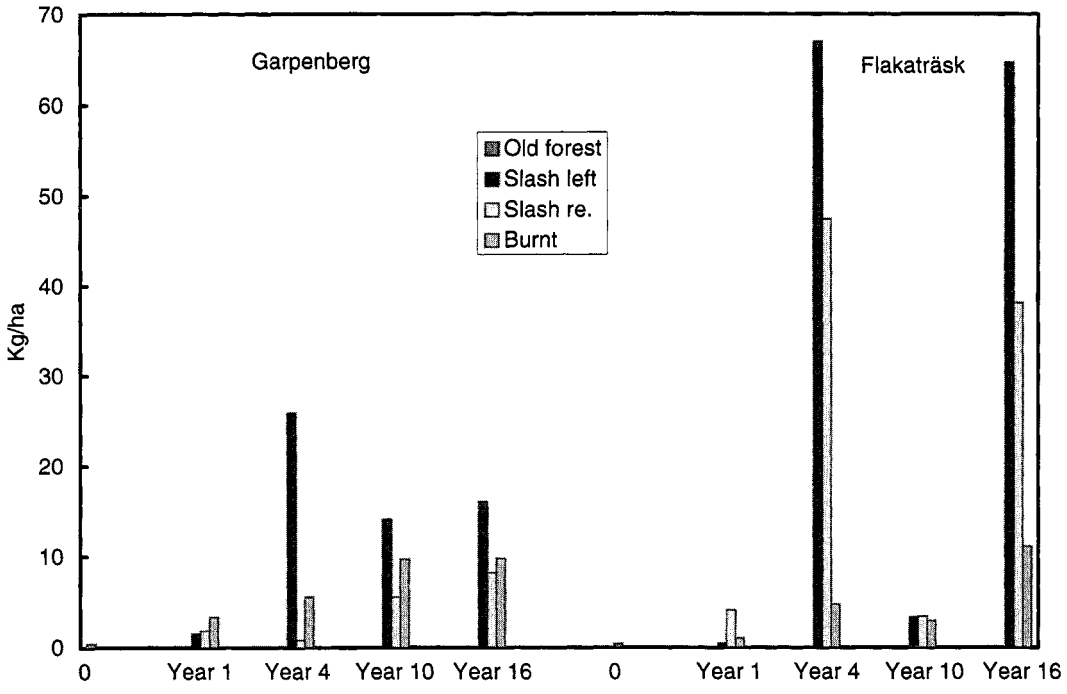


*Fig. 8.* Phytomass of *Trientalis europaea* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

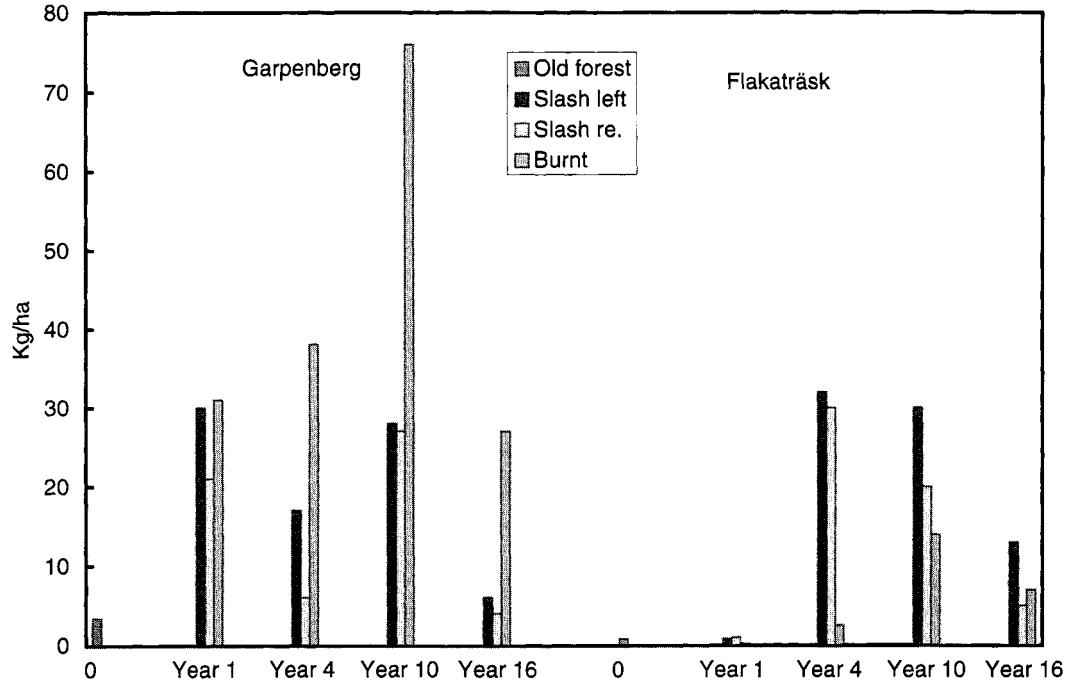


*Fig. 9.* Phytomass of *Luzula pilosa* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

years after clearfelling and *Potentilla erecta* was found on both burnt and unburnt plots (Appendix, Table A11). *Rubus saxatilis* was not found after clearfelling. Two species of fern, viz. *Thelypteris dryopteris* (L.) Slosson and *Polypodium vulgare* L., occurred in the old spruce forest at Garpenberg. Only *Thelypteris dryopteris* was found on two plots 16 years after clearfelling (Appendix, Table A11).

At Flakaträsk, the small orchid *Listera cordata* (L.) R.Br. was found in very small numbers both in the old spruce forest and 16 years after clearfelling, on spruce plots with slash left (Appendix, Table A12). It was also found one year after clearfelling on the pine plots without slash. Plants of *Empetrum nigrum*, *Plantago major* and *Lycopodium selago* occurred in the old forest, but were not found after clearfelling.

### *Plants present only on the clearfelled plots*

Many plant species not found in the old forests appeared on the clearfelled plots. A common plant which invades clearfellings in Sweden is *Epilobium angustifolium* L. No plants were found in the old spruce forests or on the plots one year after clearfelling. Four years after clearfelling, the phytomass of *E. angustifolium* on the burnt plots at Garpenberg and Flakaträsk was greater than 200 and 500 kg $ha^{-1}$, respectively (Fig. 10). The phytomass of *E. angustifolium* subsequently decreased, and was ca. 6 and 50 kg $ha^{-1}$, respectively, 16 years after clearfelling.

In the old spruce forests at Garpenberg and Flakaträsk, there were no plants of *Rubus idaeus* L. (raspberry; Fig. 11). By contrast, four years after clearfelling at Garpenberg, the phytomass of *R. idaeus* on the burnt spruce and pine plots was ca. 500 and 300 kg $ha^{-1}$, respectively. At Flakaträsk, only a few small plants were found on the burnt plots some years after clearfelling (Appendix, Table A3).

Other plants not found in the old spruce forests, but present on some of the plots after clearfelling at Garpenberg and Flakaträsk, were *Geranium sylvaticum* L., *Solidago virgaurea* L. and *Pteridium aquilinum* (L.) Kuhn; see Appendix, Tables A11 and A12.

At Garpenberg, *Achillea millefolium* L., *Anemone nemorosa* L., *Galeopsis tetrahit* L., *Geranium bohemicum* L., *Lathyrus montanus* Bernh., *Lotus corniculatus* L., *Rumex* spp., *Veronica officinalis* L. and *Viola* spp. also occurred on the plots after clearfelling (Appendix, Table A11). Although *Geranium bohemicum* is generally restricted to burnt areas, it was found at Garpenberg one year after clearfelling, on a spruce plot with slash remaining. The plot in question adjoined one of the burnt plots.

In addition to the plant species found after clearfelling at both Garpenberg and Flakaträsk, six other species seemed to be stimulated by clearfelling at Flakaträsk, viz. *Hieracium pilosella*, *Goodyera repens*, *Orchis maculata* L., *Thelypteris dryopteris*, *Lycopodium annotinum* L. and *Equisetum silvaticum* L. (Appendix, Table A12).

## Ground-layer vegetation

The biomass of mosses in the old spruce forests of Garpenberg and Flakaträsk was 520 and 1 075 kg $ha^{-1}$. The decrease of moss biomass one year after clearfelling was greater at Flakaträsk than at Garpenberg. Compared with the biomass in the old forest of Flakaträsk, the decrease was significant (Fig. 12 and Appendix, Table A13). Thereafter it increased slightly, except on plots with slash left *in situ*.

No lichens were found in the ground-layer vegetation before or after clearfelling at Garpenberg or Flakaträsk.

The most common moss species in the old spruce forests at Garpenberg and Flakaträsk was *Pleurozium schreberi*, which was found on 93% of the sample plots at Garpenberg and on all plots at Flakaträsk. The biomass (i.e. the green parts of the moss) was 313 and 351 kg $ha^{-1}$, respectively.

Clearfelling of the forests decreased the biomass of *P. schreberi*, especially on the burnt plots (Fig. 13). On the unburnt plots at Flakaträsk, there were living plants on 0–6% of the sample plots one year after clearfelling, but on 31–43% three years later. At Garpenberg, the proportion of sample plots with living *P. schreberi* was 25–38% both one and four years after clearfelling. There were no significant differences in biomass between plots with slash remaining and those with slash removed (Appendix, Table A13). The brownish, dead part of the moss individuals was completely burnt off at Flakaträsk, but not at Garpenberg, where the fire was less intense.

The biomass of *Dicranum* spp. (mainly

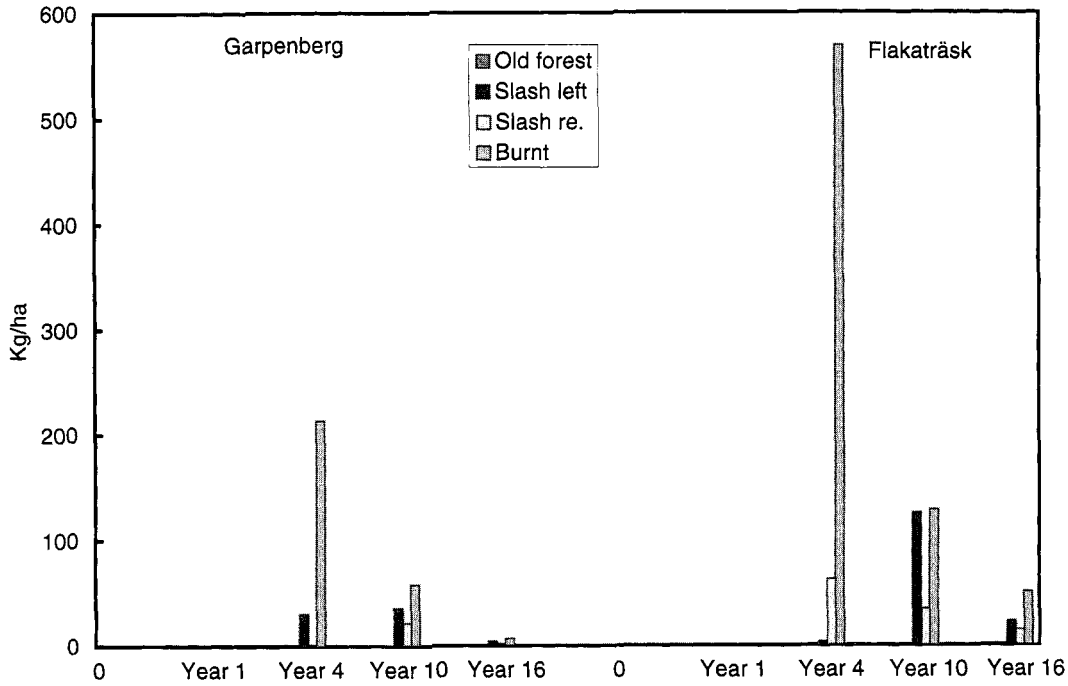


*Fig. 10.* Phytomass of *Epilobium angustifolium* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

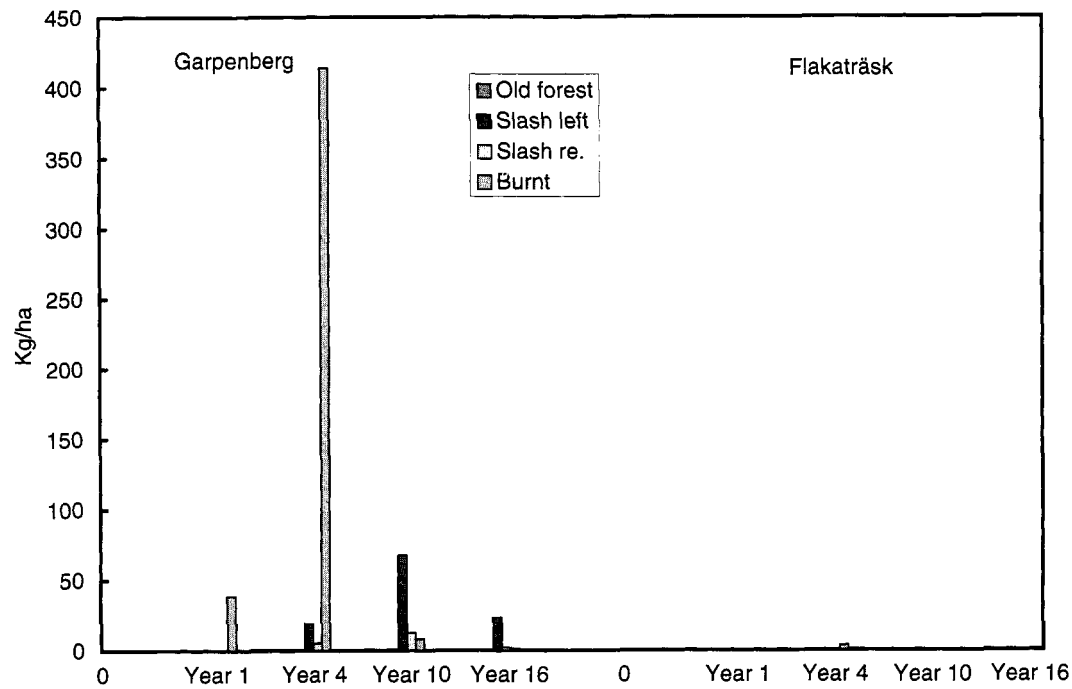


*Fig. 11.* Phytomass of *Rubus idaeus* before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

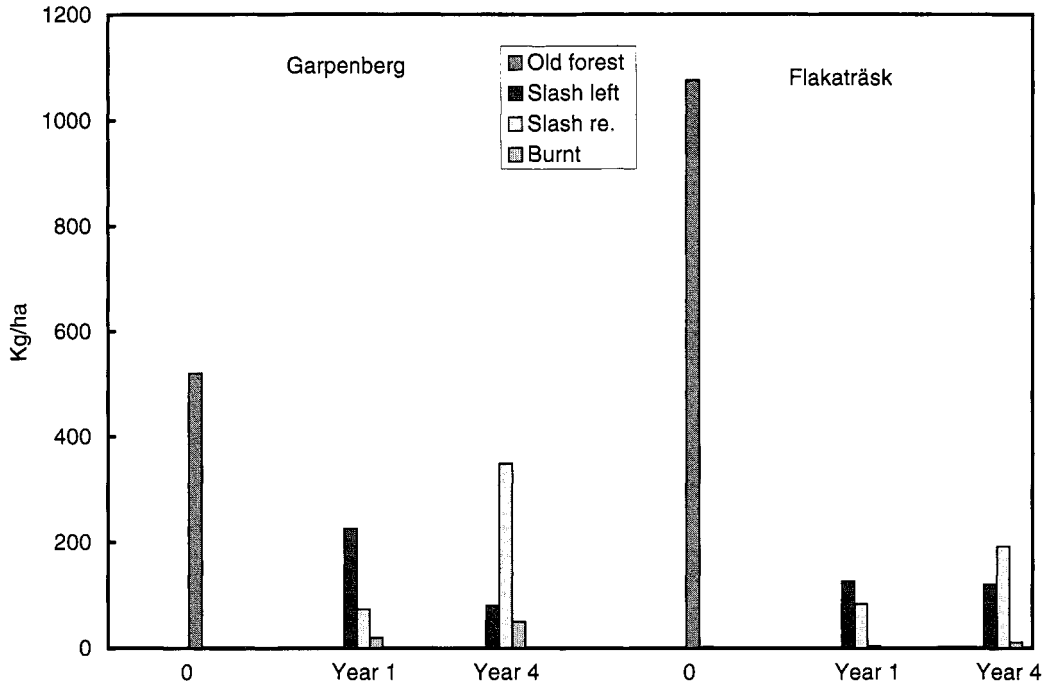


*Fig. 12.* Total biomass of mosses before and one and four years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Average figures for spruce and pine plots.

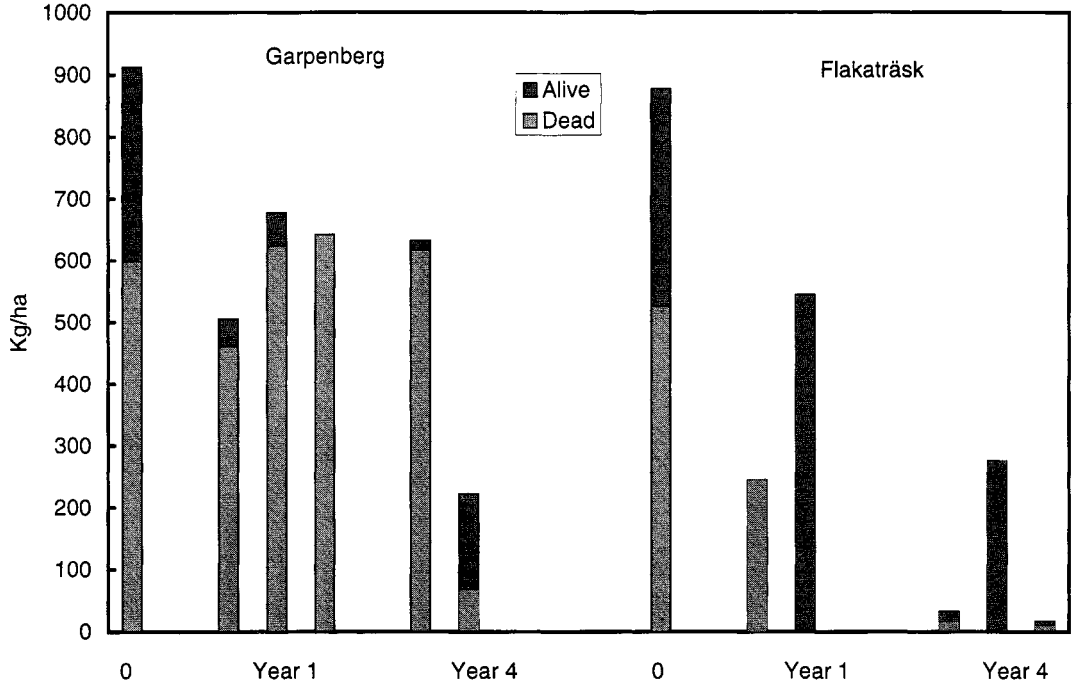


*Fig. 13.* Biomass and dead parts of *Pleurozium schreberi* before and one and four years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. The first column in a series of three for each sampling period refers to plots with slash left *in situ*; the second and third columns refer to plots with slash removed and burnt plots respectively. Average figures for spruce and pine plots.

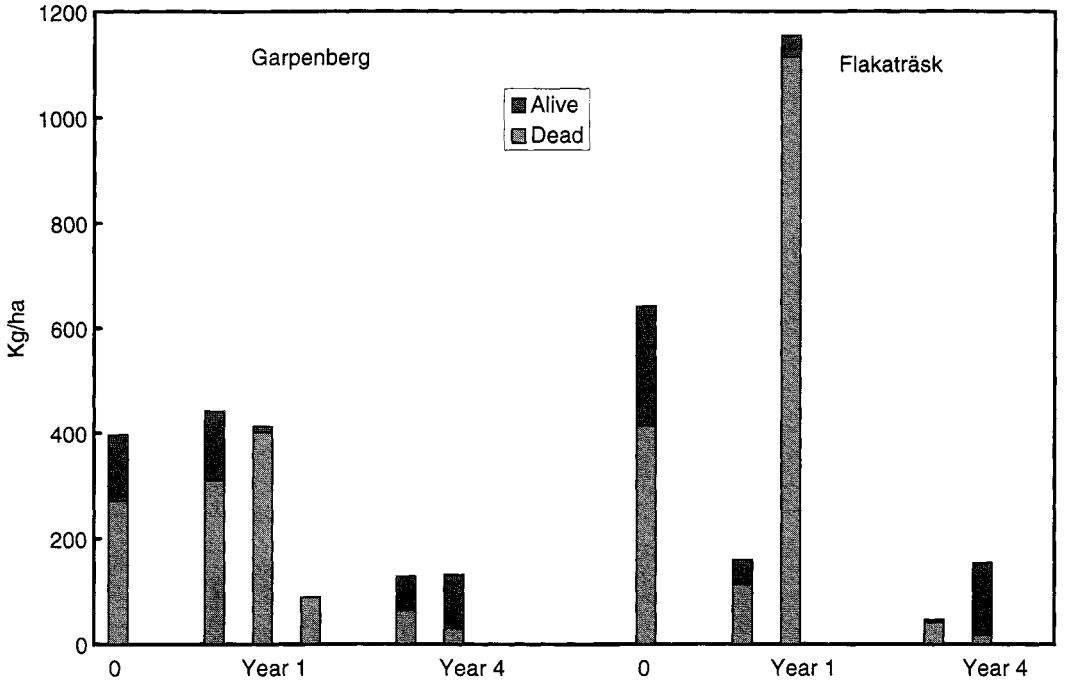


*Fig. 14.* Biomass and dead parts of *Dicranum* spp. Otherwise as in Fig.13.

*D. scoparium*) in the old forests of Garpenberg and Flakaträsk was 125 and 228 kg $ha^{-1}$ and the proportion of sample plots with plants was 73 and 86%, respectively. Burning killed the living part of the plants completely but left some of the dead part of the moss at Garpenberg (Fig. 14; Appendix, Table A13). Biomass decreased slightly with time on the plots with slash left *in situ* after clearfelling, but increased on those from which slash had been removed.

In the old spruce forests at Garpenberg and Flakaträsk, the biomass of *Ptilium crista-castrensis* was 43 and 102 kg $ha^{-1}$, and the proportion of sample plots with plants 27 and 71%, respectively. One year after clearfelling, there were no living plants at Flakaträsk in any of the treatments (Fig. 15 and Appendix, Table A13). Three years later, the biomass was 3 kg $ha^{-1}$ on the plots with slash remaining and 1 kg $ha^{-1}$ on the plots from which slash had been removed. The proportion of plots with living plants was 6% at both places. At Garpenberg, living plants were found on 6% of the unburnt plots one year after clearfelling, and on 13% of the plots four years after clearfelling.

One of the most characteristic mosses in Swedish coniferous forests is *Hylocomium splendens*. The proportion of sample plots with living plants was 47% at Garpenberg and 100% at Flakaträsk. The biomass of this moss in the old spruce forests at Garpenberg and Flakaträsk was 39 and 308 kg $ha^{-1}$, respectively (Fig. 16 and Appendix, Table A13).

After clearfelling, all plants of *H. splendens* died. New plants appeared four years later on 6% of the plots from which slash had been removed at Garpenberg, and on 31 and 13% of the plots with slash remaining and slash removed, respectively, at Flakaträsk.

In addition to the mosses already described, which are the most common species in coniferous forests in Sweden, *Barbilophozia lycopodioides* was also found at Flakaträsk on 50% of the sample plots in the old forest and on 19–25% of the unburnt sample plots one year after clearfelling (Appendix, Table A13).

*Polytrichum commune* was not found in the old forests (Appendix, Table A13). At Garpenberg it appeared on 6% of the burnt sample plots one year after clearfelling and on 13% after three years. At Flakaträsk, *P. commune* appeared on 14% of the sample plots with slash remaining and on 6% of the burnt plots

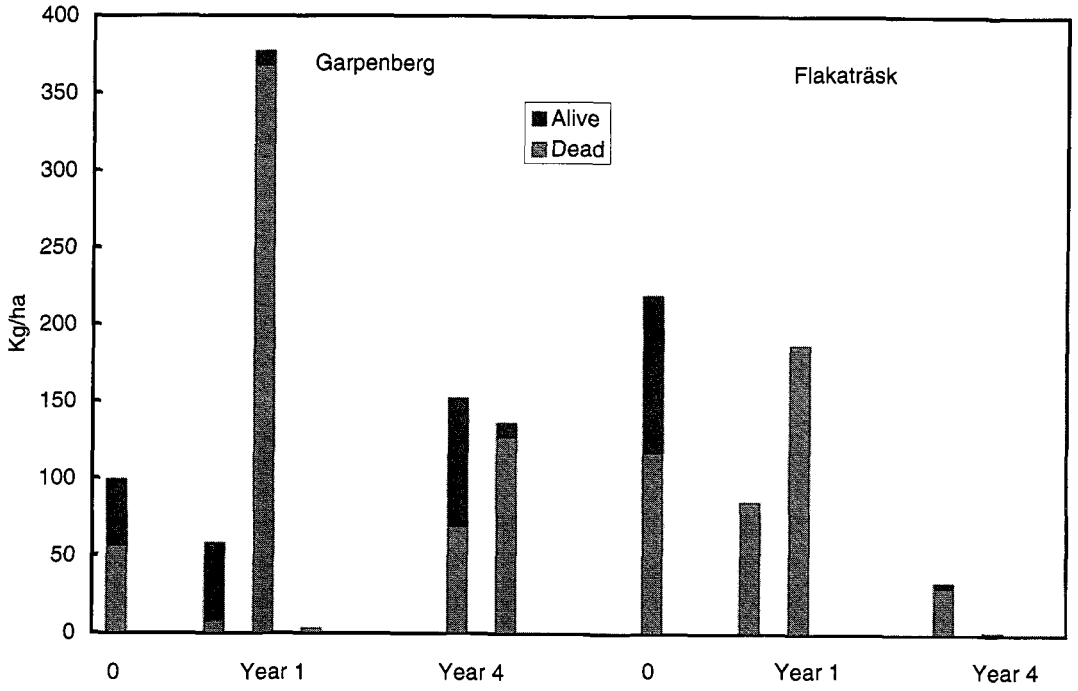


*Fig. 15.* Biomass and dead parts of *Ptilium crista-castrensis*. Otherwise as in Fig. 13.

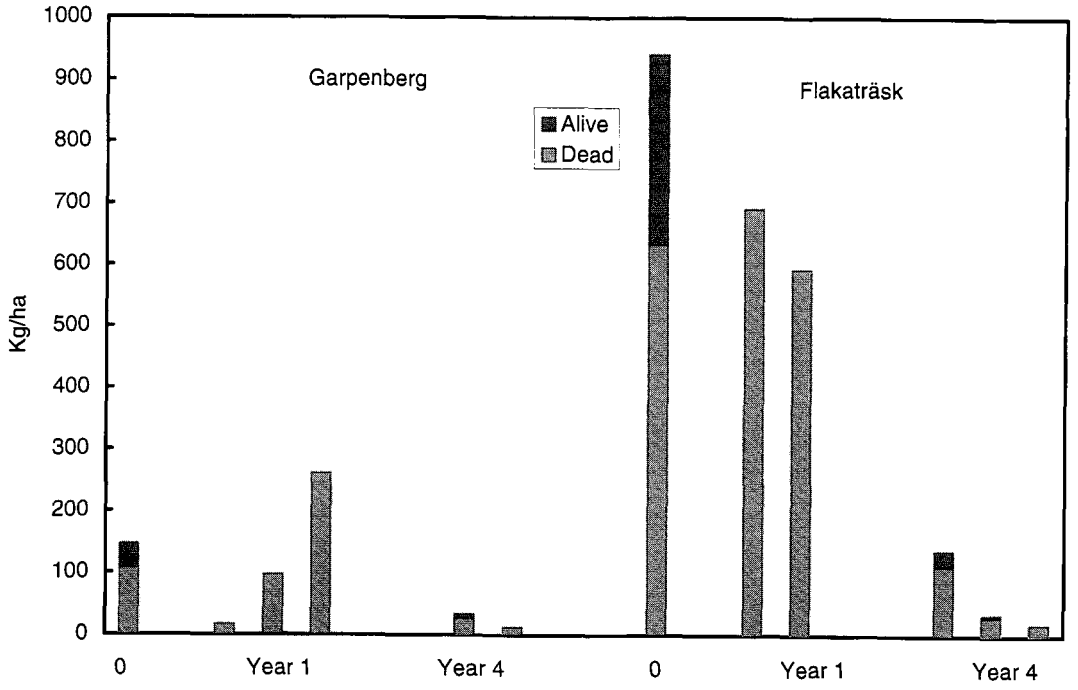


*Fig. 16.* Biomass and dead parts of *Hylocomium splendens*. Otherwise as in Fig. 13.

one year after clearfelling. Three years later, it was found on 13% of the sample plots with slash remaining and on 6% of those from which slash had been removed.

*Ceratodon purpureus*, a characteristic moss species in newly burnt areas, was found four years after burning at Flakaträsk (Appendix, Table A13).

# Discussion

## Effects of clearfelling

Most vascular plant species increased in number and phytomass after clearfelling. In Table 2, changes in the phytomass of some important plant species in coniferous forests and on clearfellings are compared with figures from the literature, on the basis of visual estimates of cover. This method is customarily used for investigating the occurrence of different plant species in a certain area.

Kardell (1992) investigated the effects of clearfelling followed by slash and stump removal on the cover of different plant species and on berry production in 1 800 permanent, 2-$m^2$ quadrats situated at nine localities in southern, middle and northern Sweden. The permanent sample plots were laid out in 1978. After cover in the old forest had been recorded, observations were continued during the first six years after clearfelling. Kardell found an average of 19 species in the forests before clearfelling, which is somewhat higher than the 13–14 at Garpenberg and Flakaträsk. Three disappeared after clearfelling, but 18 new ones colonised the clearfellings more or less permanently during the six-year observation period. Small deciduous plants were excluded from these counts but mosses were included. There were great differences between the investigated sites. At the most fertile site, 50 new species were found in the clearfellings during the follow-up period. Corresponding figures for less fertile sites were 20–30 in southern and middle Sweden and 4–16 in northern Sweden.

The effects of clearfelling, thinning, nitrogen fertilisation and stump removal on the cover and berry production of *Vaccinium myrtillus* and

Table 2. *Changes in phytomass or cover of certain plant species after clearfelling coniferous forests in Sweden with slash left on-site. G = Garpenberg. F = Flakaträsk. Differences in phytomass are not significant ($p > 0.05$)*

| | | Increase (+) or decrease (−) | | | | | |
|---|---|---|---|---|---|---|---|
| | | The present study<br>Years after clear-felling | | | | Kardell (1992) | |
| Plant species | | 1 | 4 | 10 | 16 | Year 6 | Other studies |
| *Betula* spp. | G | 0 | 0 | 0 | + | + | |
| | F | 0 | + | + | + | | |
| *Populus tremula* | G | 0 | 0 | 0 | 0 | | |
| | F | 0 | 0 | 0 | + | | |
| *Sorbus aucuparia* | G | 0 | 0 | 0 | + | | |
| | F | + | + | + | + | | |
| *Vaccinium myrtillus* | G | − | − | − | − | − | −[1] |
| | F | − | + | + | + | | −[2] |
| *Vaccinium vitis-idaea* | G | − | + | + | + | − | −[1] |
| | F | − | − | + | + | | −[2] |
| *Rubus idaeus* | G | 0 | + | + | + | + | +[1] |
| | F | 0 | 0 | 0 | 0 | | +[2] |
| *Deschampsia flexuosa* | G | + | + | + | + | + | +[1] |
| | F | + | + | + | + | | +[2] |
| *Luzula pilosa* | G | + | + | + | + | + | |
| | F | − | + | + | + | | |
| *Linnaea borealis* | G | + | − | − | − | − | |
| | F | + | + | + | + | | |
| *Maianthemum bifolium* | G | + | + | + | + | + | |
| | F | + | + | + | + | | |
| *Melampyrum* spp. | G | ± | − | + | + | − | |
| | F | + | + | + | + | | |
| *Trientalis europaea* | G | + | + | + | + | + | +[1] |
| | F | ± | + | + | + | | |
| *Oxalis acetosella* | G | + | + | + | + | − | |
| | F | 0 | 0 | 0 | 0 | | |
| *Epilobium angustifolium* | G | 0 | + | + | + | + | |
| | F | 0 | + | + | + | | |

[1]Kardell & Eriksson, 1990.
[2]Ingelög, 1974

*V. vitis-idaea* were investigated by Kardell & Eriksson (1990) on 27 sites distributed throughout Sweden. They followed the changes in vegetation during the first nine years after clearfelling.

Ingelög (1974) investigated the effects of clearfelling and different amounts of slash on the cover of plants and berry production during the first six years after the clearfelling of a spruce stand in middle Sweden.

Differences between the results of the present investigation and those of the other studies were greatest for *V. myrtillus* and *V. vitis-idaea* (Table 2). The phytomass or cover of *V. myrtillus* decreased after clearfelling, except in the case of the northerly situation of Flakaträsk. It is, however, interesting to note that Kardell & Eriksson (1990) found an increase in the production of berries from *V. myrtillus* in northern Sweden, but a decrease in southern Sweden.

The biomass of the most common moss species in the old forests, *Pleurozium schreberi*, was 313 kg ha$^{-1}$ at Garpenberg, which is of the same order of magnitude as the figure obtained by Tamm (1953) for dry annual shoots of *P. schreberi* sampled in May from a spruce forest ca. 150 km ESE of Garpenberg.

On the same site, Tamm (1953) also investigated the annual growth of *Hylocomium splendens*. His figure is considerably higher than the biomass of 39 kg ha$^{-1}$ for this species at Garpenberg.

At Flakaträsk, the biomass of *H. splendens* was 308 kg ha$^{-1}$, which is of the same order of magnitude as the annual production figures for this species obtained by Tamm (1953) in a slow-growing spruce forest at Kulbäcksliden, ca. 60 km ENE of Flakaträsk.

Romell (1939) reported an annual production of almost 700 kg dry mass of green mosses per hectare (mainly *Hylocomium proliferum* and *H. parietinum*) in spruce forests in central Sweden. In denser moss carpets, the dry mass of the green parts of *Hylocomium parietinum* can reach 4 000 kg ha$^{-1}$ (Stålfelt, 1937), which is considerably greater than the figures for the green parts of all mosses at Garpenberg (520 kg ha$^{-1}$) and Flakaträsk (1 075 kg ha$^{-1}$).

When it is considered that the figures given by Tamm (1953) and Romell (1939) represented the annual production of mosses, the figures for moss biomass in the old forests of Garpenberg and Flakaträsk seem low.

Clearfelling of the forests at Garpenberg and Flakaträsk decreased the biomass of the most common moss species of coniferous forests. A decrease in the cover of *Pleurozium schreberi*, *Hylocomium splendens* and *Dicranum* spp. was also observed by Kardell (1992). *H. splendens* was considered by Kardell & Eriksson (1992) to be the moss species most sensitive to clearfelling.

The only moss species that increased in biomass after clearfelling at Garpenberg and Flakaträsk were *Polytrichum* spp. Increases in the abundance of these species after clearfelling were earlier reported by Kardell & Eriksson (1990) and Kardell (1992).

Some years after clearfelling, the cover of the mosses increased (Kardell & Eriksson, 1990; Kardell, 1992; Olsson & Staaf, 1995). Nine years after clearfelling, the total cover was about 50% of the original (Kardell & Eriksson, 1990).

In an investigation of moss biomass, mainly *Pleurozium schreberi* and *Dicranum* spp., 7 and 15 years after clearfelling, Olsson and Staaf (1995) also found an increase with time. The biomass was 300–400 g m$^2$ 15 years after clearfelling at Lövliden, ca. 60 km ENE of Flakaträsk. This value corresponds to 3 000–4 000 kg ha$^{-1}$, which is more than three times greater than the total biomass of all mosses in the old spruce forest at Flakaträsk.

Since the Rio Conference in 1992, interest in species diversity has greatly increased, especially as regards those species most threatened by human activities. Many threatened species of mosses, lichens and fungi live on cld trees, which are often cut down in the course of clearfelling. This may be the reason for the widespread opinion that the number of species decreases after clearfelling.

The present investigation shows that the number and phytomass of most vascular plant species increased, whereas the most common moss species decreased, after clearfelling of two old spruce forests at Garpenberg and Flakaträsk. Similar results were obtained by Kardell (1992) when the cover of different plant species was investigated on 1 800 permanent, 2-m$^2$ quadrats situated at nine localities in southern, middle and north Sweden before, and during the first six years after, clearfelling.

Table 3. *Phytomass or cover of plant species on plots with slash removed in relation to plots with slash left on-site. G = Garpenberg. F = Flakaträsk. Differences in phytomass are not significant ($p > 0.05$)*

| Plant species | | Increase (+) or decrease (−) | | | | | |
|---|---|---|---|---|---|---|---|
| | | The present study Years after clear-felling | | | | Kardell (1992) | |
| | | 1 | 4 | 10 | 16 | Year 6 | Other studies |
| *Vaccinium myrtillus* | G | + | − | + | + | + | +[1] |
| | F | + | − | + | + | | +[2] |
| *Vaccinium vitis-idaea* | G | + | − | − | + | + | −[1] |
| | F | ± | + | + | + | | +[2] |
| *Rubus idaeus* | G | 0 | − | − | − | − | −[1] |
| | F | 0 | 0 | 0 | 0 | | −[2] |
| *Deschampsia flexuosa* | G | + | + | + | − | + | +[1] |
| | F | + | + | − | − | | +[2] |
| *Linnaea borealis* | G | − | 0 | 0 | 0 | + | |
| | F | − | − | − | − | | |
| *Maianthemum bifolium* | G | − | − | − | − | + | −[1] |
| | F | − | + | − | + | | |
| *Melampyrum* spp. | G | − | − | − | − | 0 | |
| | F | + | − | − | − | | |
| *Trientalis europaea* | G | + | − | − | − | + | −[1] |
| | F | + | − | + | − | | |
| *Luzula pilosa* | G | − | − | − | − | + | +[1] |
| | F | + | − | − | − | | |
| *Epilobium angustifolium* | G | 0 | − | − | − | + | −[1] |
| | F | 0 | + | − | − | | −[2] |

[1]Olsson & Staaf, 1995.
[2]Ingelög, 1974.

Many of the new vascular plant species established on clearfelled areas will probably disappear, and the biomass of mosses increase, when the trees grow up and light intensity and the availability of plant nutrients and water decrease. Compared with the clearfelling of spruce forests, lack of thinning is therefore a more serious threat to species diversity of vascular plants.

## Effects of slash removal

During recent decades, interest has increased in utilising not only stems but also other parts of the trees, especially branches. Removal of the slash from fellings, however, increases losses of plant nutrients from the site and alters light conditions, which may affect species diversity.

In Sitka spruce plantations in North Wales following clearfelling, Fahey, Hill, Stevens, Hornung & Rowland (1991) reported that the phytomass of regrowing vegetation on plots subjected to whole-tree harvesting was about 50% higher than that on plots with slash left *in situ* for 2–5 years. Similarly, in clearfelled loblolly pine (*Pinus taeda*) plantations in the southeastern USA, Cox & Van Lear (1985) reported that herbaceous biomass two years after whole-tree harvesting was 25–50% higher than that found on plots with slash remaining. The trend was, however, reversed after five years.

These investigations indicate that the growth of field-layer vegetation during the first years after clearfelling is suppressed by the presence of logging residues, which act as a physical barrier (Fahey et al., 1991). Thereafter, phytomass increases. Kardell (1992) found that the visible cover of slash decreased from 40 to 10% during the first six years after clearfelling, which indicates that the slash had decomposed or was covered by vegetation.

In Table 3, the phytomasses of the most common plant species in the field-layer vegetation of the Garpenberg and Flakaträsk forests are compared with the cover of these plants, as investigated by Kardell (1992), Olsson & Staaf (1995) and Ingelög (1974). The greatest differences were found for *Linnaea borealis* and *Luzula pilosa.*

Four years after the clearfelling of the forests at Garpenberg and Flakaträsk, the biomass of the mosses *Pleurozium schreberi* and *Dicranum* spp. was greater on plots from which slash had been removed, than on those with slash remaining. For *Ptilium crista-castrensis* and

Table 4. *Changes in phytomass or cover of some plant species after clearfelling coniferous forests in Sweden and burning the slash. G = Garpenberg. F = Flakaträsk. Differences in phytomass are not significant ($p > 0.05$)*

| Plant species | | Increase (+) or decrease (−) The present study Years after clear-felling 1 | 4 | 10 | 16 | Uggla (1957) (1958) |
|---|---|---|---|---|---|---|
| *Betula* spp. | G | 0 | 0 | 0 | 0 | + |
| | F | 0 | 0 | ± | + | |
| *Populus tremula* | G | 0 | 0 | 0 | + | + |
| | F | + | + | + | + | |
| *Salix* spp. | G | 0 | 0 | 0 | 0 | |
| | F | 0 | 0 | + | + | |
| *Sorbus aucuparia* | G | 0 | 0 | 0 | + | |
| | F | 0 | 0 | + | + | |
| *Vaccinium myrtillus* | G | − | ± | − | − | −[1] |
| | F | − | − | + | + | |
| *Vaccinium vitis-idaea* | G | − | − | + | + | −[1] |
| | F | − | − | − | + | |
| *Rubus idaeus* | G | + | + | + | + | + |
| | F | 0 | + | + | + | |
| *Deschampsia flexuosa* | G | ± | + | + | + | −[1] |
| | F | − | + | + | + | |
| *Luzula pilosa* | G | + | ± | + | + | +[1] |
| | F | − | + | + | + | |
| *Linnaea borealis* | G | − | − | − | − | |
| | F | − | − | − | ± | |
| *Maianthemum bifolium* | G | ± | − | − | − | ±[1] |
| | F | ± | + | + | + | |
| *Melampyrum* spp. | G | − | − | + | + | +[1] |
| | F | − | − | + | + | |
| *Trientalis europaea* | G | + | + | ± | + | −[1] |
| | F | + | + | + | + | |
| *Oxalis acetosella* | G | − | − | + | − | |
| | F | 0 | 0 | 0 | 0 | |
| *Epilobium angustifolium* | G | 0 | + | + | + | + |
| | F | 0 | + | + | + | |

[1]Comparisons of permanent sample plots before and one year after burning.

*Hylocomium splendens* at Flakaträsk, the opposite result was obtained (Appendix, Table A13). Kardell (1992) found that the cover six years after clearfelling was greater for *Hylocomium splendens*, *Dicranum* spp. and *Polytrichum* spp. when slash had been removed from the sample plots. For *Pleurozium schreberi*, the cover was lower, which does not agree with the results from Garpenberg and Flakaträsk.

## Effects of burning

Controlled burning was commonly used about 40 years ago for regenerating forests after clearfelling in northern Sweden. Although plant growth during the first few years after burning was good, compared with adjacent unburnt areas, a period of decreased growth occurred on many sites (Kardell & Laestadius, 1987). This growth reduction, in combination with higher costs for burning, led to the almost complete cessation of all controlled burning.

For most of the common vascular plant species in coniferous forests, clearfelling followed by burning increases the phytomass and cover (Table 4). This increase may, however, be an effect of clearfelling alone. Figures for burnt plots were therefore compared with those for unburnt plots with slash left *in situ* after clearfelling (Table 5). The growth of some plant species, such as *Rubus idaeus* and *Epilobium angustifolium*, was stimulated by burning, at least during the first few years, which was earlier reported by Uggla (1958) and many others. However, the growth of most other common species of vascular plant was suppressed by burning the slash after clearfelling.

Burning in the experimental areas at

Table 5. *Phytomass or cover of plant species on burnt plots in relation to plots with slash left after clearfelling. G = Garpenberg. F = Flakaträsk. Differences in phytomass are not significant ($p > 0.05$)*

| Plant species | | Increase (+) or decrease (−) | | | | |
|---|---|---|---|---|---|---|
| | | The present study<br>Years after clear-felling | | | | |
| | | 1 | 4 | 10 | 16 | Other studies |
| *Betula* spp. | G | 0 | 0 | 0 | 0 | −[2] |
| | F | 0 | 0 | + | + | +[3] |
| *Populus tremula* | G | 0 | 0 | 0 | + | |
| | F | + | + | + | + | |
| *Salix* spp. | G | 0 | 0 | 0 | 0 | −[2] |
| | F | 0 | 0 | + | + | |
| *Sorbus aucuparia* | G | 0 | 0 | 0 | − | −[2] |
| | F | − | − | − | − | |
| *Vaccinium myrtillus* | G | − | + | − | + | +[1] |
| | F | − | − | + | ± | −[2] |
| | | | | | | −[3] |
| *Vaccinium vitis-idaea* | G | − | − | + | + | +[1] |
| | F | − | − | − | + | −[2] |
| | | | | | | −[3] |
| *Rubus idaeus* | G | + | + | − | − | |
| | F | 0 | + | + | + | |
| *Deschampsia flexuosa* | G | − | − | − | ± | −[1] |
| | F | − | − | − | − | −[2] |
| | | | | | | −[3] |
| *Luzula pilosa* | G | ± | + | + | + | −[1] |
| | F | − | − | − | − | ±[2] |
| | | | | | | +[3] |
| *Linnaea borealis* | G | − | 0 | 0 | + | −[1] |
| | F | − | − | − | − | −[2] |
| | | | | | | −[3] |
| *Maianthemum bifolium* | G | − | − | − | − | |
| | F | − | + | + | + | |
| *Melampyrum* spp. | G | − | − | + | − | −[1] |
| | F | − | − | + | + | +[2] |
| *Trientalis europaea* | G | + | − | − | − | |
| | F | ± | − | ± | − | |
| *Oxalis acetosella* | G | − | − | ± | − | |
| | F | 0 | 0 | 0 | 0 | |
| *Epilobium angustifolium* | G | 0 | + | + | + | +[1] |
| | F | 0 | + | ± | + | 0[2] |
| | | | | | | +[3] |

[1]Uggla (1967). The cover of vegetation 22 years after burning.
[2]Kardell & Laestadius (1987). The cover of vegetation 43 years after burning.
[3]Schimmel & Granström (1995). The cover of vegetation in burnt plots in relation to plots with cut field layer four years after burning.

Garpenberg and Flakaträsk almost completely killed the most common moss species in coniferous forests, viz. *Pleurozium schreberi*, *Hylocomium splendens*, *Ptilium crista-castrensis* and *Dicranum* spp. On the other hand, *Polytrichum* spp. and *Ceratodon purpureus* were found on the burnt plots. Uggla (1958) and Schimmel (1995) found that the covers of these moss species reached their highest levels about 15 years after fires in northern Sweden. As the stand canopies closed, pleurocarpous moss species, which are common in coniferous forests in Sweden, gradually replaced the other species. Kardell & Laestadius (1987) reported from a spruce plantation at 375 m a.s.l. in northern Sweden, somewhat greater covers of *P. schreberi* and *Dicranum* spp. on burnt plots than on unburnt ones, 43 years after burning, but a lower cover of *H. splendens*.

Efficient fire protection has decreased the frequency of wild fires, which used to occur on most forest land in northern Sweden about every 100 years (Schimmel, 1995). Consequently, some species of plants and animals that prefer burnt areas have decreased in number during the past several decades. Controlled burning on a small scale has therefore been carried out during recent years, in an effort to protect these species.

Most of the vascular plants in the spruce forests of Garpenberg and Flakaträsk increased but the mosses decreased after clearfelling and burning. The number and phytomass of most vascular plants were, however, lower in the burnt plots compared with the unburnt plots with slash left, which indicates that burning the slash decreases the growth of vascular plants (with the exception of *Rubus idaeus* and *Epilobium angustifolium*).

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# Appendix tables

Tables A1–A10. *The aboveground phytomass, kg ha$^{-1}$, of the most common plants of the field-layer vegetation before and 1, 4, 10 and 16 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Means ± 95% confidence intervals (n = 5). SL = Slash left; SR = Slash removed; B = Burnt.*

Tables A11–A12. *The aboveground phytomass, kg ha$^{-1}$, of less common plant species of Swedish coniferous forests before and 1, 4, 10 and 16 years after clearfelling two spruce forests at Garpenberg and Flakaträsk. Means ± 95% confidence intervals (n = 5).*

Tables A13. *Phytomass and dead parts of various moss species, kg ha$^{-1}$, before and 1 and 4 years after clearfelling two old spruce forests at Garpenberg and Flakaträsk. Means ± 95% confidence intervals.*

Table A1–A10

| | Plots (50 × 50 m) | |
|---|---|---|
| Terms | Garpenberg | Flakaträsk |
| SL1 | C | A |
| SL2 | F | E |
| SR1 | B | B |
| SR2 | D | C |
| B1 | A | D |
| B2 | E | F |

Table A1. *Aboveground phytomass of* Vaccinium myrtillus

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 186 ± 157 | | 339 ± 116 | |
| SL 1 | 401 ± 896 | 48 ± 133 | 115 ± 136 | 296 ± 852 |
| SL 2 | 41 ± 96 | 184 ± 320 | 345 ± 422 | 522 ± 549 |
| 1 SR 1 | 326 ± 572 | 8 ± 21 | 373 ± 591 | 384 ± 305 |
| SR 2 | 0 | 380 ± 1052 | 168 ± 132 | 520 ± 362 |
| B 1 | 6 ± 15 | 1 ± 3 | 7 ± 21 | 0 |
| B 2 | 0 | 231 ± 337 | 9 ± 12 | 28 ± 52 |
| SL 1 | 241 ± 324 | 4 ± 10 | 142 | 286 ± 438 |
| SL 2 | 7 ± 17 | 13 ± 25 | 1610 ± 1190 | 692 ± 821 |
| SR 1 | 53 ± 71 | 54 ± 148 | 515 ± 501 | 768 ±1270 |
| 4 SR 2 | 13 ± 36 | 7 ± 20 | 654 ± 361 | 329 ± 444 |
| B 1 | 0 | 0 | 58 ± 70 | 436 ± 436 |
| B 2 | 257 ± 513 | 399 ± 776 | 192 ± 202 | 202 ± 275 |
| SL 1 | 94 ± 153 | 8 ± 20 | 315 ± 313 | 205 ± 292 |
| SL 2 | 9 ± 14 | 221 ± 391 | 566 ± 383 | 662 ± 299 |
| 10 SR 1 | 104 ± 120 | 253 ± 700 | 838 ± 233 | 538 ± 221 |
| SR 2 | 11 ± 32 | 2 ± 6 | 298 ± 144 | 352 ± 247 |
| B 1 | 0 | 13 ± 23 | 597 ± 233 | 613 ± 226 |
| B 2 | 2 ± 7 | 45 ± 78 | 508 ± 224 | 495 ± 236 |
| SL 1 | 79 ± 50 | 87 ± 117 | 573 ± 361 | 389 ± 214 |
| SL 2 | 40 ± 58 | 29 ± 31 | 1087 ± 443 | 1308 ± 346 |
| 16 SR 1 | 100 ± 79 | 6 ± 8 | 1559 ± 577 | 1070 ± 412 |
| SR 2 | 169 ± 180 | 0 | 1363 ± 487 | 1306 ± 383 |
| B 1 | 27 ± 55 | 71 ± 66 | 754 ± 270 | 894 ± 310 |
| B 2 | 31 ± 65 | 297 ± 194 | 632 ± 325 | 1021 ± 292 |

Table A2. *Aboveground phytomass of* Vaccinium vitis-idaea

| | Garpenberg Spruce | Garpenberg Pine | Flakaträsk Spruce | Flakaträsk Pine |
|---|---|---|---|---|
| Old forest | 3 ± 4 | | 118 ± 59 | |
| SL 1 | 1 ± 2 | 0 | 50 ± 125 | 31 ± 55 |
| SL 2 | 0 | 0 | 54 ± 106 | 100 ± 132 |
| 1 SR 1 | 4 ± 12 | 0 | 83 ± 63 | 61 ± 108 |
| SR 2 | 0 | 0 | 21 ± 38 | 66 ± 113 |
| B 1 | 0 | 0 | 7 ± 17 | 2 ± 3 |
| B 2 | 0 | 0 | 2 ± 5 | 0.3 ± 1 |
| SL 1 | 0 | 45 ± 119 | 8 | 80 ± 144 |
| SL 2 | 0 | 54 ± 149 | 65 ± 120 | 124 ± 187 |
| SR 1 | 22 ± 62 | 0 | 139 ± 131 | 255 ± 304 |
| 4 SR 2 | 0 | 0 | 74 ± 72 | 134 ± 148 |
| B 1 | 0 | 0 | 0 | 10 ± 28 |
| B 2 | 0 | 0 | 64 ± 132 | 72 ± 166 |
| SL 1 | 44 ± 86 | 1 ± 3 | 62 ± 46 | 135 ± 118 |
| SL 2 | 0 | 38 ± 106 | 156 ± 86 | 195 ± 82 |
| 10 SR 1 | 42 ± 118 | 0 | 273 ± 74 | 156 ± 63 |
| SR 2 | 0 | 0 | 138 ± 127 | 107 ± 55 |
| B 1 | 0 | 0 | 49 ± 36 | 106 ± 75 |
| B 2 | 55 ± 153 | 59 ± 92 | 129 ± 119 | 117 ± 106 |
| SL 1 | 31 ± 40 | 16 ± 31 | 138 ± 189 | 180 ± 194 |
| SL 2 | 15 ± 24 | 7 ± 14 | 231 ± 125 | 410 ± 144 |
| 16 SR 1 | 55 ± 67 | 0 | 296 ± 78 | 173 ± 59 |
| SR 2 | 30 ± 66 | 0 | 319 ± 105 | 195 ± 78 |
| B 1 | 11 ± 22 | 0 | 424 ± 273 | 268 ± 123 |
| B 2 | 7 ± 14 | 158 ± 144 | 227 ± 113 | 446 ± 210 |

Table A3. *Aboveground phytomass of* Rubus idaeus

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 0 | | 0 | |
| SL 1 | 0 | 0 | 0 | 0 |
| SL 2 | 0 | 0 | 0 | 0 |
| 1 SR 1 | 0 | 0 | 0 | 0 |
| SR 2 | 0 | 0 | 0 | 0 |
| B 1 | 25 ± 70 | 0 | 0 | 0 |
| B 2 | 98 ± 272 | 30 ± 65 | 0 | 0 |
| SL 1 | 25 ± 69 | 49 ± 125 | 0 | 0 |
| SL 2 | 0 | 0 | 0 | 0 |
| SR 1 | 12 ± 21 | 0.6 ± 1.6 | 0 | 0 |
| 4 SR 2 | 0.4 ± 1.2 | 8 ± 22 | 0 | 0 |
| B 1 | 257 ± 591 | 146 ± 314 | 13 ± 36 | 0 |
| B 2 | 844 ± 1278 | 408 ± 775 | 0 | 0 |
| SL 1 | 0 | 99 ± 188 | 0 | 0 |
| SL 2 | 7 ± 13 | 162 ± 404 | 0 | 0 |
| 10 SR 1 | 0 | 0 | 0 | 0 |
| SR 2 | 2 ± 5 | 47 ± 123 | 0 | 0 |
| B 1 | 12 ± 14 | 8 ± 10 | 0.7 ± 1.4 | 0.3 ± 0.7 |
| B 2 | 10 ± 11 | 1 ± 3 | 0 | 0 |
| SL 1 | 2 ± 3 | 9 ± 12 | 0 | 0 |
| SL 2 | 1 ± 3 | 79 ± 162 | 0 | 0 |
| 16 SR 1 | 0.1 ± 0.1 | 0.02 ± 0.05 | 0 | 0 |
| SR 2 | 4 ± 9 | 3 ± 4 | 0 | 0 |
| B 1 | 0.1 ± 0.2 | 4 ± 6 | 0.15 ± 0.32 | 0 |
| B 2 | 0.04 ± 0.09 | 0 | 0 | 0.2 ± 0.5 |

Table A4. *Aboveground phytomass of* Deschampsia flexuosa

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 60 ± 26 | | 4 ± 2 | |
| SL 1 | 1653 ± 1466 | 1698 ± 1407 | 128 ± 134 | 99 ± 262 |
| SL 2 | 1379 ± 1594 | 1165 ± 915 | 44 ± 74 | 63 ± 53 |
| 1 SR 1 | 869 ± 1327 | 1906 ± 1764 | 73 ± 108 | 292 ± 384 |
| SR 2 | 2284 ± 1932 | 1010 ± 1045 | 203 ± 201 | 106 ± 62 |
| B 1 | 115 ± 285 | 4 ± 7 | 0 | 2 ± 4 |
| B 2 | 92 ± 255 | 22 ± 23 | 0 | 1 ± 3 |
| SL 1 | 752 ± 810 | 630 ± 634 | 1150 | 1857 ± 2128 |
| SL 2 | 709 ± 671 | 1113 ± 1344 | 788 ± 951 | 1131 ± 1761 |
| SR 1 | 1779 ± 1261 | 886 ± 741 | 2398 ± 1351 | 1078 ± 1567 |
| 4 SR 2 | 872 ± 417 | 1447 ± 800 | 936 ± 896 | 2922 ± 1888 |
| B 1 | 115 ± 148 | 478 ± 475 | 171 ± 473 | 468 ± 702 |
| B 2 | 510 ± 676 | 185 ± 361 | 6 ± 10 | 0 |
| SL 1 | 365 ± 120 | 515 ± 220 | 458 ± 97 | 587 ± 325 |
| SL 2 | 446 ± 236 | 528 ± 179 | 313 ± 272 | 203 ± 183 |
| 10 SR 1 | 428 ± 169 | 486 ± 255 | 101 ± 70 | 244 ± 113 |
| SR 2 | 638 ± 278 | 983 ± 547 | 249 ± 142 | 461 ± 166 |
| B 1 | 242 ± 122 | 543 ± 279 | 149 ± 96 | 132 ± 82 |
| B 2 | 505 ± 331 | 427 ± 188 | 17 ± 18 | 133 ± 91 |
| SL 1 | 236 ± 194 | 706 ± 915 | 805 ± 452 | 780 ± 261 |
| SL 2 | 463 ± 285 | 757 ± 129 | 332 ± 276 | 779 ± 1233 |
| 16 SR 1 | 284 ± 124 | 419 ± 254 | 244 ± 126 | 316 ± 126 |
| SR 2 | 345 ± 159 | 744 ± 363 | 420 ± 237 | 1020 ± 585 |
| B 1 | 381 ± 196 | 699 ± 487 | 249 ± 218 | 269 ± 253 |
| B 2 | 617 ± 202 | 463 ± 129 | 88 ± 205 | 244 ± 175 |

Table A5. *Aboveground phytomass of* Luzula pilosa

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 3.4 ± 3.5 | | 0.8 ± 0.9 | |
| SL 1 | 55 ± 86 | 40 ± 49 | 0 | 3 ± 8 |
| SL 2 | 8 ± 16 | 16 ± 34 | 0 | 0 |
| 1 SR 1 | 0 | 0 | 0 | 0 |
| SR 2 | 62 ± 63 | 23 ± 62 | 0 | 4 ± 10 |
| B 1 | 59 ± 150 | 23 ± 55 | 0 | 0.5 ± 1.4 |
| B 2 | 43 ± 103 | 0 | 0 | 0 |
| SL 1 | 5 ± 13 | 3 ± 7 | 114 | 6 ± 18 |
| SL 2 | 11 ± 30 | 49 ± 125 | 3 ± 5 | 4 ± 12 |
| SR 1 | 6 ± 17 | 10 ± 28 | 0 | 30 ± 82 |
| 4 SR 2 | 5 ± 11 | 3 ± 7 | 1 ± 4 | 87 ± 155 |
| B 1 | 0 | 0 | 0 | 0 |
| B 2 | 150 ± 373 | 0 | 2 ± 3 | 8 ± 22 |
| SL 1 | 64 ± 58 | 19 ± 23 | 36 ± 36 | 35 ± 50 |
| SL 2 | 0.3 ± 0.8 | 27 ± 28 | 37 ± 31 | 11 ± 10 |
| 10 SR 1 | 28 ± 39 | 0 | 15 ± 14 | 12 ± 17 |
| SR 2 | 14 ± 13 | 66 ± 63 | 12 ± 17 | 41 ± 36 |
| B 1 | 45 ± 43 | 40 ± 46 | 3 ± 5 | 18 ± 27 |
| B 2 | 156 ± 126 | 62 ± 21 | 6 ± 9 | 30 ± 27 |
| SL 1 | 4 ± 4 | 7 ± 7 | 16 ± 15 | 18 ± 18 |
| SL 2 | 6 ± 10 | 8 ± 8 | 6 ± 9 | 10 ± 6 |
| 16 SR 1 | 5 ± 8 | 0.1 ± 0.1 | 2 ± 2 | 5 ± 5 |
| SR 2 | 4 ± 8 | 8 ± 7 | 1 ± 1 | 11 ± 10 |
| B 1 | 15 ± 14 | 45 ± 30 | 3 ± 4 | 6 ± 5 |
| B 2 | 28 ± 16 | 19 ± 15 | 2 ± 5 | 15 ± 9 |

Table A6. *Aboveground phytomass of* Linnaea borealis

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 1.7 ± 1.8 | | 5.3 ± 2.9 | |
| SL 1 | 61 ± 97 | 11 ± 22 | 0.6 ± 1.8 | 20 ± 55 |
| SL 2 | 0 | 11 ± 27 | 0 | 33 ± 39 |
| 1 SR 1 | 0 | 0 | 11 ± 17 | 14 ± 15 |
| SR 2 | 5 ± 12 | 7 ± 18 | 5 ± 15 | 2 ± 5 |
| B 1 | 0 | 0 | 0 | 0 |
| B 2 | 0 | 0 | 0 | 0 |
| SL 1 | 0 | 0 | 45 | 161 ± 427 |
| SL 2 | 0 | 0 | 46 ± 51 | 152 ± 252 |
| SR 1 | 0 | 0 | 42 ± 75 | 204 ± 238 |
| 4 SR 2 | 0 | 2 ± 4 | 28 ± 74 | 47 ± 110 |
| B 1 | 0 | 0 | 0 | 0 |
| B 2 | 0 | 0 | 0 | 0 |
| SL 1 | 0 | 0 | 4 ± 6 | 16 ± 15 |
| SL 2 | 0 | 0 | 4 ± 5 | 24 ± 21 |
| 10 SR 1 | 0 | 0 | 7 ± 8 | 17 ± 23 |
| SR 2 | 0 | 0 | 2 ± 2 | 0.2 ± 0.4 |
| B 1 | 0 | 0 | 5 ± 11 | 0 |
| B 2 | 0 | 0 | 0 | 8 ± 15 |
| SL 1 | 0 | 0 | 1 ± 2 | 56 ± 51 |
| SL 2 | 0.3 ± 0.6 | 0.1 ± 0.2 | 21 ± 27 | 46 ± 23 |
| 16 SR 1 | 0 | 0 | 34 ± 24 | 22 ± 21 |
| SR 2 | 0.7 ± 1.1 | 0.1 ± 0.3 | 9 ± 9 | 22 ± 27 |
| B 1 | 0 | 0 | 0.3 ± 0.6 | 3 ± 6 |
| B 2 | 0 | 3.9 ± 5.9 | 3 ± 7 | 16 ± 25 |

Table A7. *Aboveground phytomass of* Maianthemum bifolium

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 4 ± 7 | | 0.4 ± 0.7 | |
| SL 1 | 56 ± 82 | 120 ±167 | 0 | 4 ± 10 |
| SL 2 | 0 | 5 ± 9 | 1 ± 2 | 5 ± 14 |
| 1 SR 1 | 0 | 0 | 0.1 ± 0.2 | 0 |
| SR 2 | 3 ± 7 | 0 | 1 ± 4 | 1 ± 3 |
| B 1 | 0 | 0 | 0 | 1 ± 4 |
| B 2 | 0 | 18 ± 35 | 1 ± 4 | 0 |
| SL 1 | 3 ± 4 | 10 ± 14 | 0 | 2 ± 5 |
| SL 2 | 22 ± 41 | 22 ± 50 | 38 ± 100 | 0 |
| SR 1 | 0 | 0 | 0 | 2 ± 7 |
| 4 SR 2 | 0 | 1 ± 3 | 9 ± 19 | 33 ± 65 |
| B 1 | 0.1 ± 0.4 | 0 | 0 | 6 ± 17 |
| B 2 | 0 | 0 | 43 ± 80 | 0 |
| SL 1 | 3 ± 7 | 25 ± 37 | 0 | 2 ± 3 |
| SL 2 | 14 ± 31 | 6 ± 12 | 2 ± 2 | 7 ± 7 |
| 10 SR 1 | 0.3 ± 0.9 | 1 ± 2 | 1 ± 1 | 0 |
| SR 2 | 8 ± 27 | 0 | 1 ± 2 | 1 ± 2 |
| B 1 | 0.4 ± 1.1 | 3 ± 8 | 10 ± 11 | 7 ± 11 |
| B 2 | 0 | 0 | 22 ± 16 | 5 ± 11 |
| SL 1 | 13 ± 13 | 22 ± 19 | 0 | 5 ± 10 |
| SL 2 | 8 ± 7 | 8 ± 9 | 18 ± 19 | 17 ± 24 |
| 16 SR 1 | 0 | 4 ± 6 | 5 ± 8 | 0 |
| SR 2 | 2 ± 5 | 4 ± 9 | 12 ± 8 | 32 ± 47 |
| B 1 | 0.1 ± 0.1 | 2 ± 3 | 29 ± 35 | 18 ± 18 |
| B 2 | 0 | 0 | 43 ± 48 | 10 ± 6 |

Table A8. *Aboveground phytomass of* Melampyrum *spp.*

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 6 ± 10 | | 0.2 ± 0.2 | |
| SL 1 | 23 ± 63 | 0 | 0 | 0 |
| SL 2 | 0 | 0 | 0 | 3 ± 9 |
| 1 SR 1 | 0 | 0 | 5 ± 11 | 0 |
| SR 2 | 0 | 0 | 0 | 1 ± 3 |
| B 1 | 0 | 0 | 0 | 0 |
| B 2 | 0 | 0.2 ±0.4 | 0 | 0 |
| SL 1 | 0 | 0 | 0.3 | 4 ± 14 |
| SL 2 | 0 | 10 ± 29 | 12 ± 32 | 53 ±141 |
| SR 1 | 4 ± 9 | 0 | 8 ± 12 | 4 ± 7 |
| 4 SR 2 | 0 | 0 | 0 | 4 ± 10 |
| B 1 | 1 ± 4 | 0 | 0 | 0 |
| B 2 | 0 | 0 | 0 | 0 |
| SL 1 | 83 ±197 | 29 ± 47 | 1 ± 2 | 3 ± 7 |
| SL 2 | 0 | 0 | 22 ± 21 | 23 ± 23 |
| 10 SR 1 | 86 ± 76 | 0 | 15 ± 11 | 0.6 ± 1.2 |
| SR 2 | 0.4 ± 0.7 | 0.4 ±1.0 | 1 ± 2 | 1 ± 1 |
| B 1 | 14 ± 35 | 54 ±142 | 0 | 0 |
| B 2 | 97 ±177 | 127 ±162 | 43 ± 45 | 1 ± 1 |
| SL 1 | 71 ± 45 | 27 ± 25 | 5 ± 8 | 3 ± 5 |
| SL 2 | 52 ± 40 | 70 ± 64 | 20 ± 14 | 2 ± 2 |
| 16 SR 1 | 20 ± 13 | 5 ± 6 | 8 ± 10 | 0.04 ± 0.1 |
| SR 2 | 10 ± 12 | 2 ± 4 | 5 ± 5 | 13 ± 10 |
| B 1 | 41 ± 23 | 27 ± 24 | 9 ± 5 | 12 ± 8 |
| B 2 | 43 ± 26 | 46 ± 23 | 63 ± 35 | 13 ± 11 |

Table A9. *Aboveground phytomass of* Trientalis europaea

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 0.4 ± 0.6 | | 0.4 ± 0.4 | |
| SL 1 | 1 ± 2 | 5 ± 9 | 0.5 ± 0.9 | 0.7 ± 2.2 |
| SL 2 | 0 | 0 | 0 | 0.5 ± 1.3 |
| 1 SR 1 | 1 ± 2 | 0 | 0 | 9 ± 24 |
| SR 2 | 5 ± 13 | 1 ± 3 | 0.6 ± 1.0 | 7 ± 19 |
| B 1 | 7 ± 19 | 3 ± 8 | 0 | 0.2 ± 0.6 |
| B 2 | 0 | 4 ± 10 | 1 ± 4 | 2 ± 5 |
| SL 1 | 16 ± 21 | 7 ± 16 | 145 | 0 |
| SL 2 | 0 | 80 ±167 | 123 ±190 | 0 |
| SR 1 | 2 ± 5 | 1 ± 2 | 12 ± 35 | 80 ±167 |
| 4 SR 2 | 0 | 1 ± 2 | 29 ± 67 | 69 ± 88 |
| B 1 | 8 ± 16 | 0 | 0 | 0 |
| B 2 | 12 ± 22 | 2 ± 7 | 19 ± 52 | 0 |
| SL 1 | 12 ± 13 | 16 ± 24 | 5 ± 3 | 1 ± 3 |
| SL 2 | 18 ± 47 | 10 ± 16 | 3 ± 3 | 4 ± 5 |
| 10 SR 1 | 19 ± 18 | 0 | 2 ± 3 | 3 ± 4 |
| SR 2 | 1 ± 2 | 2 ± 5 | 1 ± 1 | 7 ± 5 |
| B 1 | 6 ± 14 | 5 ± 7 | 3 ± 4 | 1 ± 2 |
| B 2 | 18 ± 35 | 9 ± 12 | 2 ± 3 | 4 ± 4 |
| SL 1 | 12 ± 9 | 12 ± 9 | 50 ± 45 | 114 ± 89 |
| SL 2 | 15 ± 10 | 25 ± 17 | 22 ± 15 | 73 ± 63 |
| 16 SR 1 | 12 ± 9 | 2 ± 3 | 13 ± 7 | 55 ± 42 |
| SR 2 | 7 ± 7 | 12 ± 7 | 22 ± 12 | 63 ± 27 |
| B 1 | 1 ± 1 | 17 ± 14 | 4 ± 6 | 24 ± 32 |
| B 2 | 6 ± 6 | 15 ± 13 | 6 ± 7 | 10 ± 14 |

Table A10. *Aboveground phytomass of* Epilobium angustifolium

| Years, Treatment | Garpenberg *Spruce* | Garpenberg *Pine* | Flakaträsk *Spruce* | Flakaträsk *Pine* |
|---|---|---|---|---|
| Old forest | 0 | | 0 | |
| SL 1 | 0 | 0 | 0 | 0 |
| SL 2 | 0 | 0 | 0 | 0 |
| 1 SR 1 | 0 | 0 | 0 | 0 |
| SR 2 | 0 | 0 | 0 | 0 |
| B 1 | 0 | 0 | 0 | 0 |
| B 2 | 0 | 0 | 0 | 0 |
| SL 1 | 0 | 78 ± 215 | 0 | 0 |
| SL 2 | 43 ± 118 | 0 | 12 ± 29 | 0 |
| SR 1 | 4 ± 12 | 0 | 106 ± 175 | 86 ± 234 |
| 4 SR 2 | 0 | 0 | 26 ± 71 | 31 ± 84 |
| B 1 | 125 ± 133 | 279 ± 793 | 469 ± 562 | 605 ± 387 |
| B 2 | 252 ± 633 | 197 ± 270 | 356 ± 638 | 845 ± 820 |
| SL 1 | 3 ± 9 | 32 ± 51 | 94 ± 62 | 220 ± 122 |
| SL 2 | 76 ± 77 | 30 ± 44 | 91 ± 77 | 95 ± 58 |
| 10 SR 1 | 4 ± 9 | 0 | 69 ± 47 | 16 ± 16 |
| SR 2 | 73 ± 135 | 8 ± 14 | 24 ± 26 | 27 ± 19 |
| B 1 | 53 ± 24 | 38 ± 44 | 124 ± 60 | 101 ± 55 |
| B 2 | 68 ± 76 | 71 ± 124 | 46 ± 29 | 202 ± 79 |
| SL 1 | 0.6 ± 0.7 | 6 ± 6 | 8 ± 14 | 43 ± 29 |
| SL 2 | 3 ± 3 | 6 ± 9 | 13 ± 9 | 23 ± 15 |
| 16 SR 1 | 1 ± 2 | 0.2 ± 0.4 | 19 ± 14 | 10 ± 19 |
| SR 2 | 1 ± 2 | 5 ± 6 | 17 ± 17 | 10 ± 11 |
| B 1 | 9 ± 8 | 9 ± 8 | 49 ± 21 | 72 ± 39 |
| B 2 | 5 ± 4 | 3 ± 3 | 24 ± 13 | 56 ± 24 |

Table A11. *Aboveground phytomass of less common plant species of Swedish coniferous forests before and 1, 4, 10 and 16 years after clearfelling at Garpenberg, kg ha$^{-1}$. Mean values ± 95% confidence intervals (n = 5)*

| Plant species | Plantation | Year | Treatment | Plot |
|---|---|---|---|---|
| *Betula verrucosa* | | | | |
| 492 ± 1362 | Spruce | 1 | Slash removed | B |
| 250 ± 527 | Spruce | 16 | Slash left | F |
| 7 ± 15 | Pine | 16 | Slash removed | B |
| 45 ± 95 | Pine | 16 | Slash removed | D |
| *Populus tremula* | | | | |
| 1 ± 2 | Pine | 16 | Burnt | A |
| *Sorbus aucuparia* | | | | |
| 40 ± 59 | Spruce | 16 | Slash left | C |
| 7 ± 16 | Pine | 16 | Slash left | C |
| 28 ± 58 | Pine | 16 | Slash left | F |
| 12 ± 26 | Spruce | 16 | Slash removed | D |
| 11 ± 23 | Pine | 16 | Slash removed | D |
| 5 ± 11 | Spruce | 16 | Burnt | A |
| 10 ± 21 | Pine | 16 | Burnt | A |
| 11 ± 23 | Spruce | 16 | Burnt | E |
| *Rubus saxatilis* | | | | |
| 0.20 ± 0.51 | Old forest | | | |
| *Anthoxanthum odoratum* | | | | |
| 9 ± 25 | Spruce | 1 | Slash left | F |
| 6 ± 16 | Spruce | 4 | Burnt | E |
| *Carex* spp. | | | | |
| 9 ± 24 | Spruce | 4 | Slash left | C |
| 25 ± 71 | Spruce | 4 | Slash left | F |
| 5 ± 13 | Spruce | 4 | Slash removed | B |
| 40 ± 86 | Spruce | 4 | Slash removed | D |
| 17 ± 29 | Pine | 4 | Slash removed | D |
| 246 ± 683 | Spruce | 4 | Burnt | A |
| 23 ± 98 | Pine | 4 | Burnt | E |
| 1 ± 2 | Spruce | 16 | Burnt | A |
| *Thelypteris dryopteris* | | | | |
| 0.19 ± 0.31 | Old forest | | | |
| 3 ± 6 | Pine | 16 | Slash left | C |
| 2 ± 3 | Spruce | 16 | Burnt | E |
| *Pteridium aquilinum* | | | | |
| 66 ± 182 | Spruce | 1 | Burnt | A |
| 5 ± 13 | Pine | 4 | Slash removed | D |
| 83 ± 230 | Spruce | 4 | Burnt | A |
| 124 ± 256 | Spruce | 4 | Burnt | E |
| 690 ± 1914 | Spruce | 10 | Slash left | F |
| 416 ± 1152 | Pine | 10 | Slash left | F |
| 185 ± 314 | Pine | 10 | Burnt | A |
| 16 ± 34 | Spruce | 16 | Slash left | C |
| 128 ± 174 | Spruce | 16 | Slash left | F |
| 50 ± 106 | Pine | 16 | Slash left | C |
| 1 ± 2 | Spruce | 16 | Slash removed | B |
| 5 ± 7 | Spruce | 16 | Slash removed | D |
| 18 ± 26 | Pine | 16 | Slash removed | D |
| 170 ± 173 | Spruce | 16 | Burnt | A |
| 70 ± 92 | Spruce | 16 | Burnt | E |
| 157 ± 125 | Pine | 16 | Burnt | A |
| *Polypodium vulgare* | | | | |
| 0.87 ± 2.16 | Old forest | | | |
| *Oxalis acetosella* | | | | |
| 0.02 ± 0.03 | Old forest | | | |
| 0.8 ± 2.1 | Spruce | 1 | Slash left | C |
| 1.5 ± 4.2 | Spruce | 1 | Slash left | F |
| 0.08 ± 0.2 | Spruce | 1 | Slash removed | D |
| 0.11 ± 0.3 | Spruce | 4 | Slash left | F |
| 0.22 ± 0.6 | Pine | 4 | Slash left | C |
| 0.83 ± 2.3 | Pine | 4 | Slash left | F |
| 0.24 ± 0.67 | Spruce | 4 | Slash removed | B |
| 0.29 ± 0.54 | Spruce | 10 | Slash left | C |
| 0.34 ± 0.93 | Spruce | 10 | Burnt | A |
| 0.18 ± 0.26 | Spruce | 16 | Slash left | C |
| 0.51 ± 0.80 | Pine | 16 | Slash left | C |
| < 0.02 | Pine | 16 | Slash left | F |
| 0.20 ± 0.42 | Spruce | 16 | Slash removed | B |

| Plant species | Plantation | Year | Treatment | Plot |
|---|---|---|---|---|
| *Anemone nemorosa* | | | | |
| 0.5 ± 1.3 | Spruce | 4 | Slash left | C |
| 0.9 ± 2.4 | Spruce | 4 | Slash left | F |
| 9.7 ± 27 | Pine | 4 | Slash left | C |
| 1.3 ± 2.2 | Spruce | 4 | Slash removed | B |
| 3.6 ± 9 | Spruce | 4 | Slash removed | D |
| 22 ± 43 | Pine | 4 | Slash removed | D |
| 15 ± 36 | Spruce | 4 | Burnt | E |
| 4.9 ± 11 | Pine | 4 | Burnt | A |
| 2.2 ± 6 | Spruce | 10 | Slash left | C |
| 0.9 ± 1.7 | Pine | 10 | Slash left | C |
| 4.7 ± 9 | Pine | 10 | Slash left | F |
| 1.1 ± 3.1 | Spruce | 10 | Slash removed | B |
| 0.3 ± 0.9 | Pine | 10 | Slash removed | D |
| 2.2 ± 2.5 | Spruce | 16 | Slash left | C |
| 8.2 ± 10 | Spruce | 16 | Slash left | F |
| 0.8 ± 1.6 | Pine | 16 | Slash left | C |
| 3.1 ± 2.6 | Pine | 16 | Slash left | F |
| 0.3 ± 0.7 | Spruce | 16 | Slash removed | B |
| 10.5 ± 12 | Spruce | 16 | Slash removed | D |
| 8.3 ± 7.4 | Pine | 16 | Slash removed | D |
| 4.9 ± 4.7 | Spruce | 16 | Burnt | A |
| 4.7 ± 6.5 | Spruce | 16 | Burnt | E |
| 3.9 ± 6.1 | Pine | 16 | Burnt | A |
| 0.5 ± 0.8 | Pine | 16 | Burnt | E |
| *Galeopsis tetrahit* | | | | |
| 2.7 ± 7.5 | Spruce | 1 | Burnt | A |
| 0.8 ± 2.1 | Pine | 1 | Burnt | E |
| 0.2 ± 0.5 | Pine | 10 | Slash left | C |
| 4.1 ± 11.5 | Spruce | 10 | Slash removed | B |
| 1.7 ± 4.9 | Spruce | 10 | Burnt | A |
| 2.1 ± 4.2 | Pine | 16 | Slash left | F |
| *Geranium bohemicum* | | | | |
| 0.8 ± 2.3 | Spruce | 1 | Slash left | C |
| *Geranium silvaticum* | | | | |
| 3 ± 10 | Spruce | 1 | Slash left | C |
| 24 ± 66 | Spruce | 1 | Slash removed | D |
| 2 ± 5 | Spruce | 1 | Burnt | A |
| *Hieracium* spp. | | | | |
| 1.3 ± 3.1 | Old forest | | | |
| 0.8 ± 2.1 | Spruce | 1 | Burnt | E |
| 4.3 ± 11.9 | Pine | 10 | Burnt | E |
| 1.1 ± 2.3 | Spruce | 16 | Burnt | A |
| 0.4 ± 0.7 | Spruce | 16 | Burnt | E |
| 1.8 ± 2.7 | Pine | 16 | Burnt | A |

| Plant species | Plantation | Year | Treatment | Plot |
|---|---|---|---|---|
| *Potentilla erecta* | | | | |
| 0.1 ± 0.2 | Old forest | | | |
| 28 ± 77 | Spruce | 1 | Slash removed | D |
| 59 ± 162 | Pine | 1 | Burnt | E |
| 28 ± 78 | Pine | 4 | Slash left | C |
| 2 ± 6 | Spruce | 4 | Slash removed | B |
| 9 ± 26 | Pine | 10 | Slash left | C |
| 0.7 ± 1.8 | Pine | 10 | Burnt | A |
| 0.1 ± 0.1 | Spruce | 16 | Slash left | C |
| 2.0 ± 3.2 | Pine | 16 | Slash left | C |
| 4 ± 8 | Spruce | 16 | Slash removed | B |
| 9 ± 13 | Spruce | 16 | Slash removed | D |
| 5 ± 11 | Pine | 16 | Slash removed | D |
| 12 ± 25 | Spruce | 16 | Burnt | A |
| 14 ± 21 | Spruce | 16 | Burnt | E |
| 1.1 ± 2.3 | Pine | 16 | Burnt | A |
| *Rumex* spp. | | | | |
| 158 ± 678 | Pine | 4 | Burnt | A |
| 0.9 ± 2.5 | Spruce | 10 | Slash left | F |
| 0.3 ± 0.8 | Pine | 10 | Slash left | C |
| 0.3 ± 0.9 | Spruce | 10 | Slash removed | D |
| 0.4 ± 1.1 | Pine | 10 | Slash removed | B |
| 0.5 ± 1.2 | Spruce | 10 | Burnt | E |
| 0.6 ± 1.6 | Pine | 10 | Burnt | E |
| 0.2 ± 0.4 | Spruce | 16 | Slash left | F |
| *Solidago virgaurea* | | | | |
| 2.4 ± 5 | Spruce | 16 | Slash removed | B |
| 12 ± 27 | Spruce | 16 | Slash removed | D |
| 0.1 ± 0.1 | Spruce | 16 | Burnt | E |
| 0.8 ± 1.7 | Pine | 16 | Burnt | E |
| *Veronica officinalis* | | | | |
| 10 ± 27 | Spruce | 4 | Slash left | C |
| 3 ± 8 | Pine | 4 | Slash left | C |
| 24 ± 61 | Spruce | 4 | Burnt | A |
| 135 ± 255 | Spruce | 4 | Burnt | E |
| 92 ± 395 | Pine | 4 | Burnt | A |
| 0.7 ± 2.0 | Spruce | 10 | Burnt | E |
| 3.5 ± 9.6 | Pine | 10 | Burnt | E |
| 2.4 ± 3.5 | Spruce | 16 | Slash left | C |
| 0.9 ± 1.9 | Spruce | 16 | Slash left | F |
| 0.3 ± 0.7 | Pine | 16 | Slash left | C |
| 1.0 ± 1.5 | Spruce | 16 | Burnt | A |
| 0.1 ± 0.2 | Spruce | 16 | Burnt | E |
| 4 ± 6 | Pine | 16 | Burnt | A |
| 0.7 ± 1.5 | Pine | 16 | Burnt | E |

| Plant species | Plantation | Year | Treatment | Plot |
|---|---|---|---|---|
| *Viola* spp. | | | | |
| 3.7 ± 10 | Spruce | 4 | Burnt | E |
| 0.9 ± 2.6 | Spruce | 10 | Slash left | C |
| 1.4 ± 3.9 | Spruce | 10 | Burnt | E |
| 7 ± 7 | Spruce | 16 | Slash left | C |
| 3.7 ± 8 | Pine | 16 | Slash left | C |
| 0.4 ± 0.8 | Pine | 16 | Slash left | F |
| 2.4 ± 4.8 | Spruce | 16 | Slash removed | D |
| 0.2 ± 0.2 | Spruce | 16 | Burnt | A |
| 6 ± 7 | Spruce | 16 | Burnt | E |
| 0.3 ± 0.6 | Pine | 16 | Burnt | A |
| 0.2 ± 0.4 | Pine | 16 | Burnt | E |
| *Achillea millefolium* | | | | |
| 0.9 ± 1.5 | Spruce | 16 | Slash removed | D |
| *Lathyrus montanus* | | | | |
| 0.4 ± 0.9 | Spruce | 16 | Burnt | A |
| *Lotus corniculatus* | | | | |
| 3.0 ± 8.3 | Pine | 10 | Burnt | A |
| 0.4 ± 0.9 | Pine | 16 | Slash left | F |

Table A12. *Aboveground phytomass of less common plant species of Swedish coniferous forests before and 1, 4, 10 and 16 years after clearfelling at Flakaträsk, kg ha$^{-1}$. Mean values ± 95% confidence intervals (n = 5)*

| Plant species | Plantation | Year | Treatment | Plot |
|---|---|---|---|---|
| *Betula verrucosa* | | | | |
| 1.4 ± 4.3 | Pine | 4 | Slash left | A |
| 22 ± 60 | Pine | 4 | Slash removed | B |
| 0.9 ± 2 | Pine | 10 | Slash left | A |
| 6 ± 13 | Spruce | 10 | Slash removed | C |
| 73 ± 94 | Pine | 10 | Slash removed | B |
| 9 ± 16 | Pine | 10 | Slash removed | C |
| 0.1 ± 0.6 | Spruce | 10 | Burnt | D |
| 118 ± 150 | Spruce | 10 | Burnt | F |
| 59 ± 86 | Pine | 10 | Burnt | D |
| 59 ± 56 | Pine | 10 | Burnt | F |
| 17 ± 39 | Spruce | 16 | Slash left | A |
| 200 ± 432 | Pine | 16 | Slash left | A |
| 7 ± 10 | Pine | 16 | Slash removed | B |
| 2396 ± 4615 | Pine | 16 | Slash removed | C |
| 3 ± 6 | Spruce | 16 | Burnt | D |
| 37 ± 79 | Pine | 16 | Burnt | D |
| 311 ± 601 | Pine | 16 | Burnt | F |
| *Populus tremula* | | | | |
| 690 | Spruce | 1 | Burnt | F |
| 5793 | Spruce | 4 | Burnt | F |
| 160 ± 210 | Pine | 10 | Slash removed | B |
| 1872 ± 1299 | Spruce | 10 | Burnt | F |
| 14 ± 30 | Pine | 10 | Burnt | F |
| 48 ± 104 | Pine | 16 | Slash left | A |
| 295 ± 470 | Pine | 16 | Slash removed | B |
| 956 ± 624 | Spruce | 16 | Burnt | F |
| 88 ± 185 | Pine | 16 | Burnt | F |
| *Salix* spp. | | | | |
| 1.4 ± 3 | Spruce | 10 | Burnt | D |
| 5.4 ± 9 | Spruce | 10 | Burnt | F |
| 40 ± 78 | Pine | 10 | Burnt | D |
| 0.5 ± 1.0 | Pine | 16 | Slash removed | B |
| 36 ± 66 | Spruce | 16 | Burnt | D |
| 1.6 ± 3.4 | Spruce | 16 | Burnt | F |
| 1.9 ± 4.0 | Pine | 16 | Burnt | D |
| 6.7 ± 14 | Pine | 16 | Burnt | F |
| *Sorbus aucuparia* | | | | |
| 18 ± 33 | Old forest | | | |
| 109 ± 327 | Pine | 1 | Slash left | A |
| 173 ± 479 | Pine | 1 | Slash left | E |
| 5 ± 13 | Spruce | 1 | Slash removed | C |
| 10 ± 26 | Pine | 1 | Slash removed | B |
| 484 ± 1340 | Spruce | 4 | Slash left | E |
| 36 ± 99 | Pine | 4 | Slash left | E |
| 14 ± 31 | Spruce | 10 | Slash left | A |
| 20 ± 30 | Spruce | 10 | Slash left | E |
| 29 ± 65 | Pine | 10 | Slash left | A |
| 70 ± 121 | Pine | 10 | Slash left | E |
| 8 ± 17 | Spruce | 10 | Slash removed | B |
| 10 ± 16 | Spruce | 10 | Slash removed | C |
| 67 ± 86 | Pine | 10 | Slash removed | B |
| 43 ± 47 | Pine | 10 | Slash removed | C |
| 13 ± 26 | Spruce | 10 | Burnt | D |
| 44 ± 78 | Spruce | 10 | Burnt | F |
| 2 ± 4 | Pine | 10 | Burnt | F |
| 151 ± 184 | Spruce | 16 | Slash left | E |
| 23 ± 50 | Pine | 16 | Slash left | A |
| 30 ± 52 | Pine | 16 | Slash left | E |
| 76 ± 161 | Spruce | 16 | Slash removed | B |
| 40 ± 84 | Spruce | 16 | Slash removed | C |
| 17 ± 36 | Pine | 16 | Slash removed | B |
| 8 ± 17 | Spruce | 16 | Burnt | D |
| 12 ± 25 | Spruce | 16 | Burnt | F |
| 0.1 ± 0.3 | Pine | 16 | Burnt | D |
| 43 ± 64 | Pine | 16 | Burnt | F |
| *Empetrum nigrum* | | | | |
| 2.0 ± 4.1 | Old forest | | | |
| *Juniperus communis* | | | | |
| 0.8 ± 1.6 | Pine | 10 | Slash removed | C |
| 0.6 ± 1.2 | Pine | 10 | Burnt | D |
| *Equisetum silvaticum* | | | | |
| 1.6 ± 3.8 | Spruce | 16 | Slash left | A |
| *Lycopodium annotinum* | | | | |
| 11 ± 33 | Spruce | 1 | Slash left | A |
| 21 ± 59 | Pine | 1 | Slash removed | B |
| 18 ± 27 | Spruce | 16 | Slash left | E |
| 19 ± 38 | Pine | 16 | Slash left | E |
| 3 ± 5 | Spruce | 16 | Slash removed | B |
| 4 ± 9 | Pine | 16 | Slash removed | C |
| 4 ± 5 | Spruce | 16 | Burnt | D |
| 17 ± 20 | Spruce | 16 | Burnt | F |
| 20 ± 28 | Pine | 16 | Burnt | F |

| Plant species | Plantation | Year | Treatment | Plot |
|---|---|---|---|---|
| *Lycopodium selago* | | | | |
| 29 ± 42 | Old forest | | | |
| *Pteridium aquilinum* | | | | |
| 32 ± 89 | Pine | 4 | Slash removed | B |
| *Thelypteris dryopteris* | | | | |
| 4.8 ± 14 | Pine | 1 | Slash left | A |
| 0.6 ± 1.5 | Spruce | 1 | Burnt | D |
| 0.3 ± 0.7 | Spruce | 4 | Burnt | F |
| 6 ± 12 | Pine | 16 | Slash left | A |
| 9 ± 19 | Spruce | 16 | Slash removed | C |
| 4 ± 8 | Pine | 16 | Slash removed | B |
| 4 ± 8 | Pine | 16 | Slash removed | C |
| *Geranium silvaticum* | | | | |
| 81 ± 243 | Pine | 1 | Slash left | A |
| *Hieracium pilosella* | | | | |
| 0.9 ± 2.2 | Spruce | 16 | Slash left | A |
| 0.1 ± 0.1 | Spruce | 16 | Burnt | D |
| 0.6 ± 1.2 | Spruce | 16 | Burnt | F |
| 0.5 ± 1.1 | Pine | 16 | Burnt | D |
| 1.2 ± 1.2 | Pine | 16 | Burnt | F |
| *Listera cordata* | | | | |
| 0.1 ± 0.2 | Old forest | | | |
| 0.6 ± 1.3 | Pine | 1 | Slash removed | B |
| 0.04 ± 0.09 | Spruce | 16 | Slash left | E |
| *Plantago major* | | | | |
| 0.2 ± 0.5 | Old forest | | | |
| *Solidago virgaurea* | | | | |
| 7 ± 17 | Pine | 10 | Slash left | A |
| 1.0 ± 1.6 | Spruce | 10 | Slash removed | C |
| 12 ± 25 | Spruce | 10 | Burnt | F |
| 1.6 ± 3.4 | Pine | 10 | Burnt | F |
| 0.3 ± 0.6 | Spruce | 16 | Slash removed | B |
| 0.3 ± 0.4 | Spruce | 16 | Slash removed | C |
| 3.9 ± 8 | Pine | 16 | Slash removed | B |
| 1.1 ± 2.3 | Pine | 16 | Slash removed | C |
| 0.2 ± 0.3 | Spruce | 16 | Burnt | F |
| 0.1 ± 0.1 | Pine | 16 | Burnt | D |
| 1.9 ± 2.8 | Pine | 16 | Burnt | F |
| *Orchis maculata* | | | | |
| 0.4 ± 0.9 | Pine | 16 | Slash removed | B |
| *Goodyera repens* | | | | |
| 0.7 ± 1.5 | Spruce | 10 | Burnt | F |

Table A13. *Biomass and dead parts of various moss species, kg ha$^{-1}$, before and 1 and 4 years after clearfelling two old spruce stands at Garpenberg and Flakaträsk. Means ± 95% confidence intervals (n = 5)*

| | | Garpenberg | | Flakaträsk | |
|---|---|---|---|---|---|
| | | *Alive* | *Dead* | *Alive* | *Dead* |
| *Pleurozium scheberi* | | | | | |
| Old forest | | 313 ± 207 | 599 ± 328 | 351 ± 272 | 526 ± 254 |
| | SL | 44 ± 58 | 461 ± 403 | 0 | 244 ± 290 |
| Year 1 | SR | 53 ± 76 | 624 ± 652 | 20 ± 44 | 524 ± 372 |
| | B | 0 | 642 ± 721 | 0 | 0 |
| | SL | 15 ± 20 | 617 ± 833 | 20 ± 16 | 12 ± 25 |
| Year 4 | SR | 157 ± 282 | 65 ± 65 | 43 ± 55 | 232 ± 386 |
| | B | 0 | 0 | 10 ± 22 | 6 ± 13 |
| *Dicranum* spp. | | | | | |
| Old forest | | 125 ± 96 | 271 ± 262 | 228 ± 151 | 413 ± 413 |
| | SL | 131 ± 233 | 310 ± 371 | 46 ± 47 | 112 ± 119 |
| Year 1 | SR | 11 ± 18 | 401 ± 408 | 40 ± 61 | 1114 ± 916 |
| | B | 0 | 88 ± 162 | 0 | 0 |
| | SL | 64 ± 63 | 63 ± 121 | 5 ± 7 | 40 ± 83 |
| Year 4 | SR | 101 ± 159 | 29 ± 41 | 136 ± 99 | 17 ± 32 |
| | B | 0 | 0 | 0 | 0.3 ± 0.5 |
| *Ptilium crista-castrensis* | | | | | |
| Old forest | | 43 ± 88 | 56 ± 114 | 102 ± 71 | 117 ± 87 |
| | SL | 50 ± 106 | 8 ± 18 | 0 | 83 ± 72 |
| Year 1 | SR | 9 ± 19 | 368 ± 480 | 0 | 187 ± 127 |
| | B | 0 | 3 ± 6 | 0 | 0 |
| | SL | 0 | 0 | 3 ± 6 | 30 ± 64 |
| Year 4 | SR | 83 ± 175 | 69 ± 146 | 1 ± 2 | 0 |
| | B | 9 ± 20 | 127 ± 271 | 0 | 0 |
| *Hylocomium splendens* | | | | | |
| Old forest | | 39 ± 55 | 107 ± 135 | 308 ± 138 | 633 ± 318 |
| | SL | 0 | 17 ± 35 | 0 | 692 ± 512 |
| Year 1 | SR | 0 | 96 ± 205 | 0 | 594 ± 456 |
| | B | 0 | 261 ± 550 | 0 | 0 |
| | SL | 0 | 0 | 25 ± 27 | 112 ± 151 |
| Year 4 | SR | 7 ± 14 | 26 ± 55 | 4 ± 7 | 30 ± 45 |
| | B | 0 | 12 ± 25 | 0 | 18 ± 25 |
| *Barbilophozia lycopodioides* | | | | | |
| Old forest | | | | 86 ± 76 | 130 ± 123 |
| | SL | | | 29 ± 35 | |
| Year 1 | SR | | | 22 ± 31 | |
| | B | | | 0 | |

| | | Garpenberg | | Flakaträsk | |
|---|---|---|---|---|---|
| | | *Alive* | *Dead* | *Alive* | *Dead* |
| *Polytrichum commune* | | | | | |
| Old forest | | 0 | | 0 | 0 |
| | SL | 0 | | 50 ± 95 | 98 ± 139 |
| Year 1 | SR | 0 | | 0 | 65 ± 96 |
| | B | 19 ± 40 | | 3 ± 6 | 0 |
| | SL | 0 | 0 | 66 ± 125 | 138 ± 279 |
| Year 4 | SR | 0 | 0 | 7 ± 16 | 79 ± 121 |
| | B | 40 ± 60 | 52 ± 78 | 0 | 0 |
| *Ceratodon purpureus* | | | | | |
| Year 4 | B | | | 37 ± 79 | |