

Stand development in uneven-aged sub-alpine *Picea abies* stands after partial harvest estimated from repeated surveys

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Summary

Eight sub-alpine stands in mid-Sweden, dominated by *Picea abies* (L.) Karst., and subjected to commercial partial harvests in 1972–1973, were inventoried with circular plot surveys in 1973 and 1993. All trees with d.b.h. (diameter at breast height) > 2 cm were included in the analysis. All stands had d.b.h. distributions where number of trees declined over d.b.h. in both 1973 and 1993. The height–diameter relationship had become more linear and less steep in the lower d.b.h. classes during the 20 years. Standing volumes after the 1973 harvests, were 9–37 m³ ha⁻¹. Mean annual volume increments during the 20 years were 0.4–1.4 m³ ha⁻¹ a⁻¹. Using the 1993 height curve to estimate standing volume in 1973 caused a systematic overestimation of volume increment of 0.1–0.4 m³ ha⁻¹ a⁻¹ for the eight stands, i.e. on average an overestimation of ~27 per cent. Ingrowth of Norway spruce past 8 cm d.b.h. was on average ~10 stems ha⁻¹ a⁻¹, and not significantly correlated with either the number of spruce stems 4–8 cm d.b.h., or the standing volume in 1973. The relationship between results from different kinds of studies (repeated surveys, reconstructions, permanent plots) was discussed. The study showed that heavy harvests, creating stands with standing volumes below 50 m³ ha⁻¹, result in low levels of current annual volume increment, and do not positively affect ingrowth.

Introduction

During the first half of the twentieth century, forestry in the northern two-thirds of Sweden was totally dominated by partial harvests and high grading. In 1950, forestry in these areas shifted from partial harvests to clearcutting followed by planting. During the 1960s Swedish

forestry experienced a period of low profitability. To avoid costs for planting, several forest companies once again tried different forms of partial harvests in remote and sub-alpine areas. Today there is again a growing interest in non-clear-cutting methods, albeit for different reasons. Common for most of the suggested alternatives is that the stands are only partially harvested, and

Table 1: Equation components* included in calculations of volume increment in different types of studies

Repeated surveys:	$i_S = (V_1 + V_{in}) - (V_0 + V_{m0})$
Reconstruction:	$i_R = (V_1 + V_{in}) - V_0$
Permanent plots:	$i_P = (V_1 + V_{in} + V_{m1}) - (V_0 + V_{m0})$
'True':	$i_T = (V_1 + V_{in} + V_{m1} + V_{in_{m1}}) - (V_0 + V_{m0} + V_{in_{m0}})$

*Components are defined in Figure 1.

that the future timber production is primarily based on trees and seedlings and saplings remaining in the stand after the harvest. The forest stands resulting from these partial harvests usually become more heterogeneous than is the case after ordinary clearcutting followed by planting, with large variations in tree size and clustered spatial distribution (Lundqvist, 1994). As the advance growth is usually also clustered, the heterogeneity is usually preserved for the future.

Dynamics of uneven-aged forest stands consist of three processes: growth of existing trees; mortality of existing trees; and ingrowth/recruitment of new trees. These processes are not covered to the same extent by studies based on repeated surveys (*S*), reconstructions (*R*), and repeated measurements on permanent plots (*P*). Calculations of volume increment (*i*) and other stand changes (e.g. number of trees and basal area) are done in different ways in these different kinds of studies, and include different components (Figure 1 and Table 1). If there is no mortality at all, neither among trees nor seedlings, all three kinds of studies give the same result and this result is furthermore equal to the 'true' (*T*) increment. When there is mortality among trees and seedlings, $i_T > i_P > i_R > i_S$.

In commercial forestry the residual standing volume (*V*) left by a harvest consists of ($V_0 + V_{m0}$), and the future stand to be harvested by ($V_1 + V_{in}$). From a commercial point of view, i_S thus presents a correct level of increment, whereas both i_R and i_P overestimate the ability of the residual stand to produce merchantable volume (Figure 1 and Table 1).

Although partial harvests were extensively used in Norway spruce (*Picea abies* (L.) Karst.) forests in Fennoscandia during the first half of the twentieth century, few attempts have been made to evaluate the development of stands created by such harvests. Näslund (1942) developed

distance-independent, individual-tree basal area growth equations based on radial growth data reconstructed from increment cores. These were taken from 1859 sample trees on 157 sample plots (500–1000 m²), located in stands subjected to partial harvests of different kinds, at least 15 years before the measurements. Standing volumes were mostly in the interval 100–300 m³ ha⁻¹, but were in some cases as low as 50 m³ ha⁻¹. Sarvas (1944) reconstructed stand development in 45 spruce-dominated stands subjected to high grading 2–14 years before the inventory. Measurements in each stand were restricted to one 0.25 ha sample plot. On each plot all trees higher than 1.3 m were callipered, increment cores taken from about 20 trees, and volume increment estimated from these. Standing volumes were in the interval 11–178 m³ ha⁻¹. Böhmer (1957) evaluated 35 20-year-old

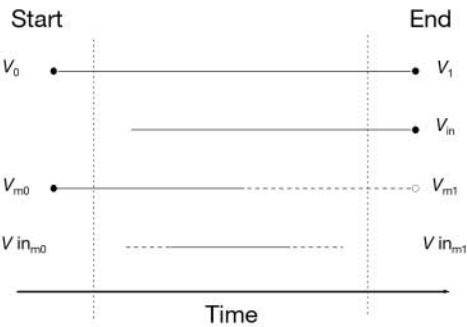


Figure 1. Components included in calculations of volume increment over time. V_0 and V_1 is the observed standing volume at start and end of period, respectively, V_{in} volume of trees recruited, V_m volume of trees present at start that died before period end, and V_{in_m} volume of trees that were recruited but died before the observation at period end. Circles denote measurement of living (solid circle) and dead trees (open circle).

permanent plots in Norway. Plot sizes ranged from 0.57 to 2.6 ha. Results included net growth and yield for each plot. Standing volumes were mostly in the interval 100–200 m³ ha⁻¹, except for one plot where volumes were 56–78 m³ ha⁻¹. Lundqvist (1994) reconstructed volume growth in three stands in central Sweden during 10–16 years after heavy partial harvests, based on increment cores taken from all trees with a d.b.h. (diameter at 1.3 m) of at least 5 cm on 14–19 circular plots with size 314 m². Standing volumes were 29–44 m³ ha⁻¹. The four above-related studies are different in character and methodology – the studies of Näslund (1942), Sarvas (1944) and Lundqvist (1994) were reconstructions of commercial harvests, and that of Böhmer (1957) was of repeated measurements on permanent plots – but the overall picture that emerges is that (1) the large size variation among the trees in the residual stand remains unchanged or increases over time; (2) reductions of the standing volume result in corresponding reductions in current annual volume increment – when standing volume increases, so does volume increment, until the site productivity is reached; (3) trees in the residual stands are more aggregated than random distribution. An important question, from a practical point of view, is to what degree the conclusions drawn from reconstructions and permanent plots, are applicable to large-scale commercial forestry, i.e. how large are the differences between i_P and i_R vs i_S ? To answer this, results from reconstructions and re-measurements of permanent plots must be matched against repeated surveys of stand development after full-scale commercial harvests.

In the late 1960s and early 1970s the Swedish Cellulose Company (SCA) conducted large-scale partial harvests in sub-alpine Norway spruce forests in mid-Sweden. In 1973 company personnel inventoried a number of the treated stands through a circular plot survey. Twenty years later, eight of the stands were re-inventoried in a similar manner (i.e. a repeated survey), with the objective to evaluate and compare the stand development with the conclusions drawn in earlier studies: (1) Does the large size variation increase over time? (2) Do large reductions of the standing volume result in low volume increment? (3) Does the spatial distribution of trees remain aggregated or does it turn more uniform?

Materials and methods

The original company-administrated inventory in 1973 included 23 stands. Of these, 15 were excluded due to the stands (1) not being dominated by Norway spruce (*Picea abies* (L.) Karst.) before the harvest (i.e. <70 per cent of basal area), (2) being too large (>100 ha) and heterogeneous, (3) having too small residual volume (<5 m³ ha⁻¹), or (4) having been clearcut between 1973 and 1993. The remaining eight stands were located between Gäddede and Dorotea (64° 30' N, 15° E), 380–450 m a.s.l. According to company records, the standing volume before harvest ranged from 75 to 140 m³ ha⁻¹ (Table 2). All stands had inversely J-shaped diameter distributions, and were dominated by Norway spruce with white birch (*Betula pubescens* Ehrh.) as major additional species. There were also occasional Scots pines (*Pinus sylvestris* L.) in all stands. In all stands *Vaccinium myrtillus* L. and mosses (mainly *Pleurozium schreberi* and *Hylocomium splendens*) were the dominating ground vegetation, ground moisture was predominantly mesic, and the mineral soil silty till. The site characteristics indicated a site index of 17 m in all stands (dominant height at 100 years of age for an even-aged stand) for Norway spruce, corresponding to a site productivity of 3.1 m³ ha⁻¹ a⁻¹ (Hägglund and Lundmark, 1981).

The stands were partially harvested in 1972–1973, removing 63–94 per cent of the standing volume, mainly as large Norway spruce trees. The diameter distributions remained inversely J-shaped after the harvests in all stands (Figure 2). In 1976–1979, 3–7 years after the harvests, enrichment planting with lodgepole pine was done in stands 1–5, and birches that were deemed as detrimental for the spruces were cut down in stands 1–4 and 8.

Both inventories were performed as systematic circular-plot surveys, with plot size 100 m². The number of plots deployed in each stand (28–39) was the same in both inventories. The deployment pattern from the first inventory (1973) – plots evenly distributed in a quadratic pattern – was mimicked at the second inventory in 1993. At the first inventory, trees higher than 1.3 m were counted in a diameter vs height matrix: 2 cm diameter classes from 0 to 20+ (0–2, 2–4, etc.), and five height classes: 1.3–3, 3–5, 5–10,

Table 2: Stand characteristics in 1973

Stand	Size (ha)	Altitude (m a.s.l.)	Pre-harvest standing volume (m ³ ha ⁻¹)	After harvest				
				Standing volume (m ³ ha ⁻¹)	Volume composition (%)			No. of trees* (stems ha ⁻¹)
					Spruce	Broad- leaves	Scots pine	
1	93	450	115	10	86	14	0	500
2	46	410	75	24	63	37	0	1364
3	20	450	85	15	79	21	0	894
4	62	420	85	18	52	43	5	888
5	61	450	140	9	76	15	9	465
6	38	430	115	28	52	38	10	1103
7	54	380	90	34	42	58	0	1316
8	15	400	85	23	50	50	0	1312

* Includes all trees with height ≥ 1.3 m.

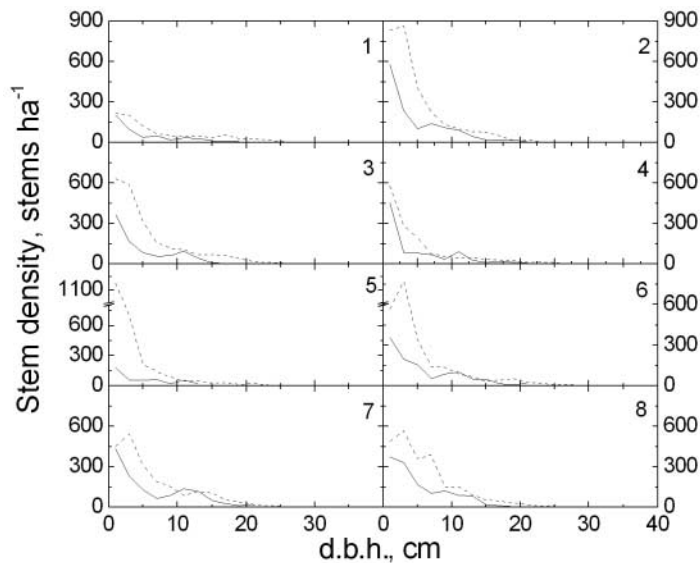


Figure 2. D.b.h. distributions in 1973 after harvest (solid line) and in 1993 (dashed line), with 2 cm d.b.h. classes.

10–15, 15+ m. At the second inventory all trees of at least 1.3 m height were callipered to the nearest millimetre, and tree height was measured on two randomly selected sample trees on each circular plot.

Size variations within the stands were analysed with Lorenz (1905) diagrams. In these the trees are sorted in increasing size order, and plotted in

a relative cumulative size distribution with proportion of number of trees on the abscissa. When all trees are of equal size, the cumulative distribution follows a straight line. With size differences, the cumulative distribution drops below the straight line. In this study the analyses were based on basal area.

Mean height \bar{h} in each 2-cm d.b.h. class was

calculated separately for each stand and tree species in 1973 as:

$$\bar{h} = \frac{\sum_{j=1}^5 h_j n_j}{\sum_{j=1}^5 n_j} \quad (1)$$

where h is the class midpoint and n number of trees in height class j . For the uppermost height class, 15+, 17.5 m was chosen as midpoint. As the \bar{h} values were similar in all stands, they were combined to calculate one height curve for each of spruce and birch. After testing several different forms of equations for the height curves, a 2nd degree polynomial was chosen, as this resulted in the best overall fit:

$$h = c_0 + c_1 d + c_2 d^2 \quad (2)$$

To make the two datasets compatible, the sample trees from the 1993 inventory were distributed over the same d.b.h.–height matrix as used in 1973, for calculation of height curves for 1993. As there were no consistent differences in \bar{h} over the d.b.h. range between stands, the data were combined as in 1973 to calculate one height curve for all stands for each spruce, pine and birch. To check if the d.b.h.–height matrix caused distortions in the height curve, the 1993 sample trees were also entered directly in linear regression to calculate one height curve for each tree species for all stands, using equation (2).

Stem volumes were calculated with Näslund's (1940) equations for Norway spruce, white birch and Scots pine. In all cases the class midpoint for each d.b.h. class and its corresponding tree height according to the height curve was used, resulting in an estimate of the mean stem volume within each d.b.h. class. Total standing volume was finally estimated by simply multiplying with number of trees in each d.b.h. class and summing.

The above procedure usually results in a biased estimate of standing volume, as the d.b.h. class midpoint usually differs from the quadratic mean d.b.h. for the class. To quantify a possible error, standing volume in 1993 was also calculated for each stand as (cf. Eriksson, 1976):

$$V = n \cdot v(d^2/d_3^2) \quad (3)$$

where n is number of trees, v is the tree volume estimated with the height corresponding to the

quadratic mean d.b.h., d is the class midpoint, and d_s the quadratic mean diameter of the 1993 sample trees in each d.b.h. class.

Net ingrowth between inventories was estimated as the net difference in number of trees larger than 4 and 8 cm d.b.h., respectively, between inventories.

The spatial distribution of the trees was described with the variance-to-mean ratio (I) for number of individuals per circular plot, as described by Diggle (1983). Under complete spatial randomness $I = 1$. Lower values indicate uniformity, and higher values aggregation. The statistical significance of deviations from complete spatial randomness was tested by comparing $I(c-1)$ with the X^2_{c-1} distribution, where c is the number of circular plots in each stand.

Results

All stands had d.b.h. distributions where number of trees declined over d.b.h. in both 1973 and 1993 (Figure 2). Both number of trees and the maximum d.b.h. had increased in all stands during the 20 years, and size variation also increased in all stands, although the changes were small in stands 1 and 8 (Figure 3).

Norway spruce constituted 70–100 per cent of basal area in the stands before harvest. Through the harvests, the proportion was reduced to 42–86 per cent, but the proportion increased in all stands during the following 20 years so that at least 60 per cent of basal area was Norway spruce in 1993 (Figure 4).

During the 20 years which had elapsed since the initial inventory, the height curve had become more linear and less steep in the lower d.b.h. classes (Figure 5). The two curves for 1993 – based on the height–d.b.h. matrix and all sample trees, respectively – were almost identical, with the matrix-based curve having a slightly more curved shape. Standing volumes in 1973, after the harvests, were 9–37 m³ ha⁻¹. Twenty years later standing volumes were 25–50 m³ ha⁻¹, indicating annual volume increments of 0.4–1.4 m³ ha⁻¹ a⁻¹ (Figure 6). Using the 1993 height curve to estimate standing volume in 1973 resulted in a 22–23 per cent underestimation of standing volume in all stands, causing a systematic overestimation of volume increment of ~0.1–0.4 m³ ha⁻¹ a⁻¹ for the

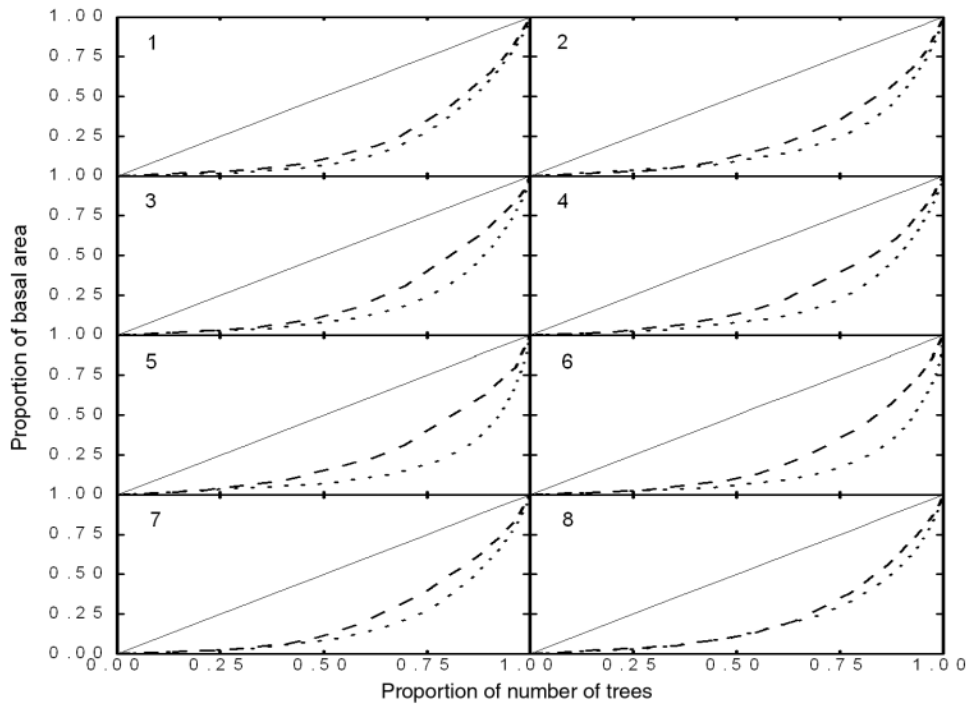


Figure 3. Lorenz curves with relative cumulative distributions of basal area versus number of trees. The straight line shows the relationship when all trees are of equal size, the dashed line the situation in 1973, and the dotted line 1993.

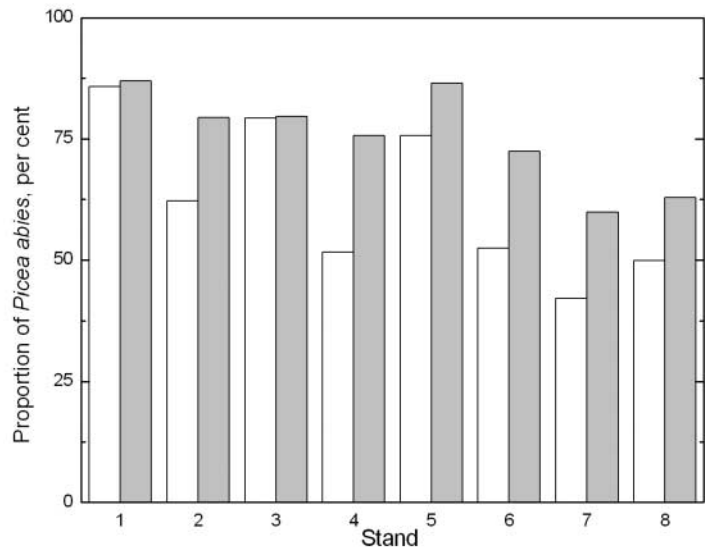


Figure 4. Proportion of stand basal area that was *Picea abies* in 1973 (open) and 1993 (grey).

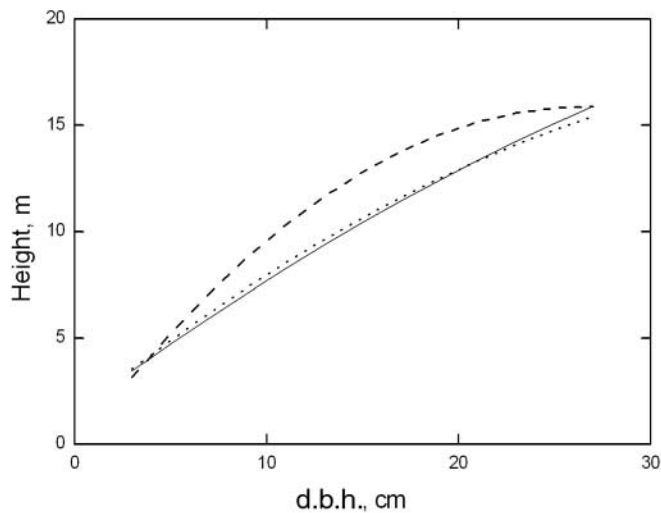


Figure 5. Height curves in 1973 (dashed) and 1993 (dotted), based on d.b.h.-height matrix. Solid line is the 1993 height curve, calculated with linear regression directly from sample tree values.

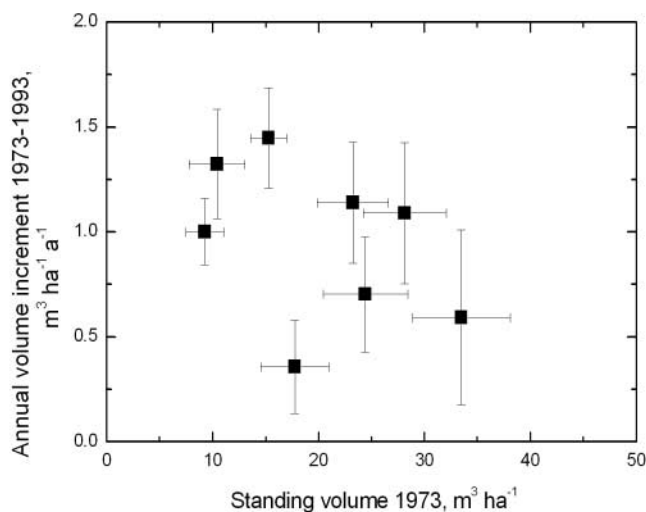


Figure 6. Mean annual volume increment 1973–1993 at stand level including all tree species. Bars denote standard error.

eight stands, i.e. on average an overestimation of ~27 per cent. Using the d.b.h. class midpoint for volume estimates in 1993, resulted as an average in a 1 per cent overestimation of total standing volume, compared with estimates based on the quadratic mean.

Ingrowth of Norway spruce past 8 cm d.b.h.

was on average about 10 stems per hectare and year (Figure 7). As expected, the values for the 4 cm d.b.h. level were consistently higher. The ingrowth of spruce was not significantly correlated with either the number of spruce stems below the ingrowth thresholds (0–4 cm d.b.h. for ingrowth past 4 cm d.b.h., 4–8 cm for

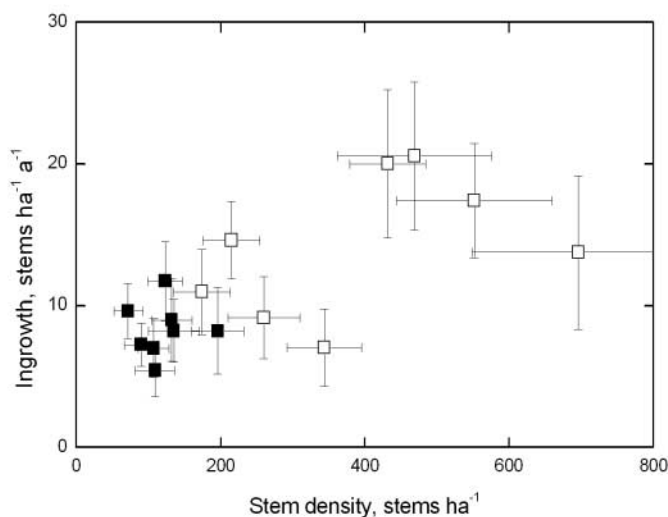


Figure 7. Mean annual ingrowth of Norway spruce 1973–1993 past 8 cm d.b.h. (solid squares) and 4 cm d.b.h. (open squares). Bars denote standard error.

ingrowth past 8 cm), or the standing volume in 1973.

The trees were significantly ($P < 0.001$) aggregated at the first inventory (Table 3). At the second inventory, the spatial distribution of Norway spruce was not significantly different from random in two of the stands. In spite of the non-uniform distribution, all 314 m² circle plots contained trees with d.b.h. ≥ 2 cm in 1993.

Discussion

The d.b.h. distributions were not perfect inverted J-curves, but resembled what has earlier been observed in uneven-aged Norway spruce stands in Sweden (e.g. Lundqvist, 1993). The increased deviation of the Lorenz's curves from the straight line, indicating even-sized distribution, shows that the stand dynamics move towards a more diverse size distribution, closer to a balanced d.b.h. distribution. This is in accordance with the observation made by Lundqvist (1994), who found that the Gini coefficient increased after partial harvests in sub-alpine stands (the Gini coefficient is equal to the proportion of the triangular area between the straight diagonal line and the x -axis that is delimited by the straight line and the Lorenz curve; Weiner and Solbrig,

1984). An uneven-aged structure with a more or less balanced d.b.h. distribution thus appears to be a stand structure that is spontaneously created and maintained by the stand dynamics in boreal Norway spruce forests. Such a conclusion is also supported by studies of virgin Norway spruce forests in northern Sweden, e.g. Hytteborn *et al.* (1987) and Svensson and Jeglum (2001). Consequently it should not be necessary to harvest trees throughout the d.b.h. range to maintain an inversely J-shaped d.b.h. distribution, as suggested by Roach (1974). Instead it should be possible to concentrate partial harvests in these stands to the largest trees without risking the loss of the structure.

The increasing proportion of the growing stock being constituted by Norway spruce was mostly an effect of d.b.h. growth of spruces remaining after harvest, and not of ingrowth from the seedling and sapling strata.

Previous studies have indicated a positive proportionality between annual volume increment and standing volume, with a relative annual volume increment around 3 per cent (Näslund, 1942; Böhmer, 1957; Lundqvist, 1990, 1994). In those studies, the initial standing volumes were above 25 m³ ha⁻¹ in all cases, and mostly in the interval 100–200 m³ ha⁻¹. As the relative volume increment of individual trees is usually much

Table 3: Variance-to-mean ratios for number of trees per circular plot

Stand	All tree species		Norway spruce	
	1973	1993	1973	1993
1	4.56***	2.30***	3.58***	1.70*
2	4.99***	4.43***	4.79***	4.65***
3	2.37***	5.13***	2.26***	6.34***
4	2.06***	1.26 ns	2.45***	1.15 ns
5	3.07***	3.10***	2.98***	2.12***
6	3.31***	3.81***	2.37***	1.41 ns
7	7.55***	3.98***	4.31***	3.09***
8	2.49***	2.02**	2.67***	3.19***

***, $P \leq 0.001$; **, $P \leq 0.01$; *, $P \leq 0.05$; ns, not significant.

higher for small trees than for large trees, one would expect the relative volume increment at stand level to increase when most of the larger trees have been removed. If standing volume is reduced very much, this could possibly change the positive relationship between standing volume and volume increment, to constant or even negative. The results of this study support such a conclusion. However, the conclusion would be valid only if all stands had the same site productivity, a most uncertain assumption, as site productivity was estimated from site characteristics in this study. That method is known to be unreliable for individual stands. The results do, however, clearly indicate that harvests reducing the standing volume to $<50 \text{ m}^3 \text{ ha}^{-1}$, result in reduced volume increment for several decades. In no case did the mean annual volume increment during the 20 years reach even half the estimated site productivity of $3.1 \text{ m}^3 \text{ ha}^{-1} \text{ a}^{-1}$.

In Lundqvist's (1994) reconstructions the residual volumes were $29\text{--}44 \text{ m}^3 \text{ ha}^{-1}$ and volume increments at stand level were $1.0\text{--}1.5 \text{ m}^3 \text{ ha}^{-1} \text{ a}^{-1}$, i.e. somewhat higher than the levels observed in this study for the stands with similar standing volume. However, in that study, Lundqvist (1994) used the height curves from the last measurement for all volume estimations. Assuming that this caused an underestimation of standing volumes after harvest, as suggested by the results of this study, the volume increments presented by Lundqvist (1994) would probably have been lower and more in accordance with the levels observed in this study, if correct height curves had been used. In a study by Øyen and

Nilsen (2002) volume increment was $0.4\text{--}3.2 \text{ m}^3 \text{ ha}^{-1} \text{ a}^{-1}$ during 25 years after partial harvests in mountain forests in Norway, where residual volumes were $10\text{--}50 \text{ m}^3 \text{ ha}^{-1}$, i.e. somewhat higher than found in this study. However, Øyen and Nilsen's (2002) study was based on only 16 400-m^2 plots, and volumes were calculated using the height curve from 25 years after harvest. This stresses the importance of reconstructing not only d.b.h. when doing reconstructions, but also height development. Näslund's (1942) calculations of volume increment were based on a basal area increment model constructed from detailed reconstructions that also included height increment. In his study the model predicted that stands on *Vaccinium myrtillus* sites submitted to 70 per cent harvest intensity and with residual volumes of $\sim 50 \text{ m}^3 \text{ ha}^{-1}$ would have increment levels around $0.7 \text{ m}^3 \text{ ha}^{-1} \text{ a}^{-1}$, i.e. similar to the levels in this study. However, as stated in the introduction, volume increment calculated from repeated surveys should usually be lower than increments from reconstructions, in situations where there is some mortality among the trees. As the levels observed here were similar to the levels presented by Näslund (1942), mortality has probably been low for large- and medium-size trees.

Based on earlier studies it can be assumed that the stands will need to reach $\sim 100 \text{ m}^3 \text{ ha}^{-1}$ to regain full production. Assuming 3 per cent annual increase of the standing volume, as suggested by, for example, Böhmer (1957), it will take about 30 years to grow from the current average of $40 \text{ m}^3 \text{ ha}^{-1}$ to $100 \text{ m}^3 \text{ ha}^{-1}$. However,

the heterogeneity of the stands suggests that this is an underestimation of the time needed. In a previous study, Lundqvist (1994) found a linear relationship between volume increment and standing volume at circular plot level. As standing volume on individual 100 m² circular plots varied between 2 and 60 m³ ha⁻¹ in the stands, the average time needed will be longer than the time corresponding to the average standing volume. Furthermore, as stated in the introduction, the previous studies were all based on reconstructions or permanent plots. Such studies give estimates of volume increment that are closer to the true level than do repeated surveys, but they overestimate the development of the standing, harvestable volume. As the standing volume slowly increases, mortality is likely to increase as well, slowing down the increase of the standing volume. The total restoration time needed to reach ~100 m³ ha⁻¹, including the 20 years elapsed so far, can thus be expected to be at least 50–60 years. Note that the long time needed to restore the stands to full production is not a result of too little ingrowth, but of too small standing volume in the residual stands, which is in turn a result of the harvests removing too many large- and medium-sized trees.

The ingrowth levels estimated for Norway spruce corresponded well with what has been observed earlier in Sweden in uneven-aged Norway spruce stands (Lundqvist, 1990, 1991, 1993, 1994). The average stem volume of trees growing past 8 cm d.b.h. in this study was ~0.015 m³, which means that of the total volume increment, ingrowth was responsible for ~0.15 m³ ha⁻¹ a⁻¹. Neither this nor earlier studies indicate a negative correlation between standing volume and level of ingrowth in partially harvested uneven-aged Norway spruce stands. However, Chrimes and Nilsson (2001) found a significantly negative correlation between stand basal area and sapling height increment in a partially harvested uneven-aged Norway spruce stand in northern Sweden. As basal area was reduced by the harvests in the current stands, the harvests should have caused an increased height increment for the regeneration and consequently higher ingrowth rates (cf. Lundqvist, 1995). For ingrowth not to be affected by increased sapling height increment, sapling mortality must increase

so that number of saplings is reduced. Granhus (2001) showed that the number of saplings remaining after harvests in uneven-aged stands is negatively correlated with harvest intensity. As the number of small spruces present in 1973 did not influence ingrowth during the following 20-year period, increased mortality among the small trees after the harvests seems to be a plausible explanation.

The aggregation of trees observed was a result of either the stand dynamics or the harvests. In a study of three selectively logged sub-alpine stands, Lundqvist (1994) found that the harvests had changed the spatial distribution of trees from random to aggregated in two of the stands, and that there were no significant changes in the spatial pattern during the 10–16 years which had elapsed since the harvest. In this study there was a tendency for spruce to gradually turn to a more random distribution. As aggregation of trees can be assumed to have a negative effect on future yield (cf. Eriksson, 1976), precautions should be taken at the harvests to avoid creating an aggregated distribution of the trees, e.g. by avoiding creation of gaps.

The study only partially confirms the three general conclusions drawn from earlier studies: (1) stands with small standing volume do have low volume increment, but reducing the standing volume below 50 m³ ha⁻¹ does not seem to result in any further reductions of current annual volume increment; (2) the stand dynamics appear to slowly change the spatial distribution from aggregated towards random; (3) the large size variation is maintained or increases over time. As a fourth conclusion one can add: (4) ingrowth is rather low and not positively affected by increasing harvest intensity.

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