Monitoring Retention of Trees and CWD on Clearcuts in South-Western Sweden

Honour’s Thesis

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Contents..............................................................................page

Abstract......................................................................................1

Introduction.................................................................................1
  History.....................................................................................1
  The lack of living and dead wood...............................................1
  The new Forestry Act.................................................................2
  A follow-up of the VÅK-study......................................................3

Study areas and methods..........................................................3
  The two forest landscapes.........................................................3
  Maps.........................................................................................4,5
  Aspects of retention..................................................................6
  Two different analysis...............................................................7
  Handling the data......................................................................7

Results.........................................................................................8
  Initial tree/CWD retention.........................................................8
  Distribution of initial tree/CWD retention....................................9
  Comparison of initial tree/CWD retention between landscapes.......10
  Correlations between tree/CWD retention and site size..............12
  Retained areas.........................................................................12
  Damage done after the VÅK-study.............................................12
  Comparison Before-After.........................................................12
    Analysis 1.............................................................................12
      Comparison of decrease between landscapes........................12
    Analysis 2.............................................................................13

Discussion.................................................................................13

Footnote.......................................................................................15

References..................................................................................16
Abstract

For the preservation of biodiversity, the Swedish forestry Act recommends that at least some old-growth forest elements, i.e. old trees and CWD (coarse woody debris), be retained at the final harvest. Monitoring is needed, however, of the fate of such retained elements over longer periods.

During the spring 2000, I studied 40 four- to five-year-old clear-cuts in two forest landscapes in the county of Västra Götaland, with respect to the amount of retained living trees, CWD and other retention structures. The study was based upon an earlier survey by the Regional Board of Forestry in 1996-1997, and for the following four-year period I recorded a significant decrease in the density of retained living trees (-6.8%) and CWD (-7.4%) on the 40 clear-cuts. There was no significant difference in the relative decrease of old-growth features between the two landscapes. There was, however, a significant difference in initial tree-retention levels.

The observed decrease in density of old-growth features is alarming, and more effective measures for biodiversity protection are probably needed.

Introduction

History

Forests in southern Sweden have been used mainly for commercial purposes during the last 400 years, but utilisation of forest resources started long before that (Berg et al. 1994, Lagerqvist & Lindqvist 1999). Shortly after World War II, forest harvesting techniques evolved rapidly, making forestry Sweden’s largest industry, producing 1% of the world’s wood products at a value of 136 billion SEK (8% of Sweden’s GNP 1996). Forests cover 59% of Sweden’s total land area, and 95% of these are used for commercial purposes (Linder et al 1997). This has put considerable strain on the forest ecosystem, leaving only 2% virgin, old-growth forests today (Berg et al. 1994). Modern forestry has created mono-specific, even-aged stands with short rotation periods, and clear-cutting regimes have dominated forest management during recent decades. Forest management has thus had large effects on the Swedish flora and fauna, and many species have declined in number (Ahlén & Tjernberg 1992, Berg et al. 1994). With only 4% of the forests protected, current forest managers have a heavy responsibility to increase the environmental considerations in the managed forests (SEPA 1997).

The lack of old and dead wood

One obvious problem for the preservation of Swedish forest biodiversity is the lack of old-growth forest features, i.e. large, living trees and CWD. Modern forestry has created forests with very small amounts of old-growth features compared with natural, unmanaged forests.

In a Swedish old-growth, high-land spruce forest, the densities of fallen logs and dead, standing trees were estimated to 72 m³/ha and 7 m³/ha, the relative proportion of dead wood being 40% of the total wood amount (Linder 1986). In a study in Finnish Lapland the amount of CWD in old-growth forests was 19-60 m³/ha, more than 100 times the amount found in 40-year-old stands (Sippola et al. 1998). Siitonen et al. (2000) compared mature and over-mature managed forests with old-growth forests and estimated the amount of dead wood at 14, 22 and 111 m³/ha respectively. Also, most of the dead wood in the old-growth forest consisted of logs and snags (standing dead trees) with diameters of 20-40 cm, as opposed to the thinner branches that dominated in the younger, managed stands (Siitonen et al. 2000). Linder et al. (1997) studied 12 virgin forests in northern Sweden within forest reserves, and found the
amount of dead wood to be 27-201 m$^3$/ha, approximately 30% of the standing wood volume. In German managed forests the current volume of dead wood is 1-3 m$^3$/ha, while in 7 forest reserves the amount was 9-79 m$^3$/ha (Meyer 1999).

In Västra Götaland the average volume of dead wood on clear-cuts was estimated to 1.3 m$^3$/ha (VÅK 1997). Ammer (1991) suggests that an increased proportion to at least 5-10 m$^3$/ha, i.e. 3-6% of the standing volume, is justified, of which half should be standing trees with d.b.h.>20 cm (diameter at breast height). McComb and Lindenmeyer (1998) estimated the optimal snag and log densities per hectare for all species of vertebrates that could use snags, cavity trees or logs for reproduction in the stand establishment stage of forest development. Their calculations suggest a total amount of 34 snags and logs per hectare, approximately equivalent to 90 m$^3$ CWD per hectare (diameter~40 cm). The required amounts apparently differ considerably, and a final estimate for optimal CWD-densities is difficult to give. All the estimates are, however, much higher than the current average density of snags and logs with d>40 cm in Swedish forests, which is less than 0.1/ha, approximately equivalent to 0.3 m$^3$/ha or 0.06% of the standing volume (Skogssstatistik årsbok 1999, Fridman 2000).

While living trees are abundant in Swedish forests, coarse, old-growth trees are not. In two forest areas in Sweden, living trees with a d.b.h.>30 cm declined from 77 and 44 m$^3$/ha to 13 and 7 m$^3$/ha respectively during the years 1890-1966 and 1985-1991, due to the impact of modern forestry (Linder & Östlund 1992). Linder (1986) estimated the density of coarse, living trees (d.b.h.>40 cm) to 18 trees/ha or 54 m$^3$/ha in a virgin spruce forest. The short rotation periods, often no longer than 70 years, that are frequently used in modern forestry, effectively reduce the density of old-growth trees, snags and logs. In Swedish forests, the overall average density of living trees with a d.b.h.>40 cm is 5.3 trees/ha or 15.9 m$^3$/ha (Skogssstatistik årsbok 1999). The density of coarse, living trees (d.b.h.>40 cm) in managed forests in the study area (southern former county of Älvsborg) has been estimated at 10 trees/ha, constituting 30 m$^3$/ha or 0.4% of all trees (RT 1998).

Siitonen et al. (2000) suggest that in a country with little old-growth forest, as in Finland and Sweden, harvesting methods retaining old-growth characteristics should be used in order to increase structural diversity and old-growth attributes. Swedish forestry has, during the last 15-20 years, increasingly been using a retention model, and we are now beginning to evaluate this approach (Eckerberg 1996, de Jong 1998).

More than half of the Swedish endangered red-listed forest species need large, old-growth trees or CWD, during at least some period of life. One third of these species depend exclusively on dead wood, while 8% also use dead wood in old, living trees. 18% of the species require old-growth trees (>100 years old) (Samuelsson & Ingelöf 1996). Retention of old-growth features can create biodiversity links and increases the structural diversity of habitats, favouring lichens, bryophytes species and insects considered to be sensitive to forest operations (Ahlén & Tjernberg 1992, Samuelsson et al. 1994, Appelqvist & Nordén 1998, Kuusinen & Siitonen 1998, Hazell & Gustafsson 1999).

The New Forestry Act

In 1994 the Swedish government presented a new Forestry Act. The first section of the Forestry Act in force from 1st January 1994 reads:

"The forest is a national resource. It shall be managed in such a way as to provide a valuable yield and at the same time preserve biodiversity."

The National Board of Forestry and its regional administrations implement the forest policy, in line with the principles of sustainable management of forests. The new Swedish Forest Policy is giving the maintenance of biodiversity the same priority as efficient
utilisation of forests for production of commercial wood as well as of non-wood goods and services. In 1996, subsequently, the Regional Board of Forestry conducted the VÄK-study (Swedish abbreviation for What Is Left), to examine if the new policy had been successfully implemented. During the winter of 1996-1997, 232 sites (clear-cuts) in the county of Älvsborg were visited and the number of retained trees, amount of CWD, consideration of sensitive areas and damage to the environment (i.e. surface-damage due to forestry vehicles) were estimated. The inventory resulted in detailed knowledge of the environmental consideration in managed forests in Älvsborg, with a new follow-up planned within 10 years.

A follow-up of the VÄK-study

To determine whether the environmental consideration remains, or if, for instance, trees are removed after some time, this monitoring study was conducted during the spring of 2000, four years after the harvest and three years after the earlier study. Using the same methods and criteria as in the VÄK-study, 40 of the old sites were revisited and all changes since the last inventory recorded. Because of changes in the regional administration during 1999, what was formerly Älvsborg is now part of the larger Västra Götaland. The forestry administration was split into districts within the new region and began using a new classification of forest landscapes, based mainly on their potentials for biodiversity and forestry (SVSVG 1999) (see figure 1). In this follow-up, the study area was stratified so that 20 randomly chosen sites in two different landscapes were visited, enabling a comparison between landscapes as well as an assessment within a larger region.

Study areas and methods

The two forest landscapes

Landscape 71 is situated immediately west of Borås and is defined by the National Board of Forestry as a “Conifer-dominated valley landscape”. The landscape is hilly with much exposed bedrock and thin soil layers, as well as many lakes and bogs. Historically, the proximity to Gothenburg has made the area subject to intensive forestry for a long time, with less agriculture than in other areas of the region. Most of the forest is coniferous, with deciduous trees only near water and around farms.

Landscape 85 is the southernmost forest landscape in Västra Götaland, and lies between the west coast and the highlands of Småland. There are many lakes and the area is defined as “Fir-forest on mesic soil”. As with landscape 71, the forests have been cut for many rotations, especially near the early-inhabited areas around the lakes and in the west. The forests are dominated by conifers, with spruce (Picea abies) in the damper areas and pine (Pinus sylvestris) in the dryer plateau areas.

The sites

In 1996 the National Board of Forestry randomly selected 50 sites per district from a total of 550-800 harvest reports in each of the five districts in former Älvsborg. I marked the sites on a map, so as to determine within which forest landscape they belonged. I then selected the only two landscapes that had more than 20 studied sites (landscape 85:n=37; 71:n=21, see figure 2 and 3), and randomly chose 20 sites in each landscape to revisit. The sizes of the clear-cuts ranged from 0.4 ha up to 12.3 ha, with an average of 2.8 ha. The size of the whole study area was approximately 3000 km². To be able to study long-term retention, only sites with initial retention of trees and/or CWD were chosen. One site from each landscape was omitted due to no initial retention. The sites all had different owners, and were visited during March and April in 2000.
Figure 1. Västra Götalands Län and the forest landscapes.
Figure 2. Forest landscape 71 with the 20 sites marked by stars.

Figure 3. Forest landscape 85 with the 20 sites marked by stars.
Aspects of retention

To quantify the environmental considerations on clear-cuts, the VÄK-study used the instructions in the Swedish Forestry Act §30. This study used the same form but concentrated on the following aspects:

- **Low-productive areas:** If a low-productive (e.g. damp or poor soil) area larger than 0,1 hectare occurred on the site, it was recorded as well as any logging within the area.

- **Retention clusters:** Clearly distinguishable concentrations of retained elements, often clusters of trees, within the site and their size were recorded. (Retained elements can be either evenly distributed across the area, or clustered in groups to facilitate future forest management. The clusters are often placed in steep, rocky, damp or otherwise “hard-managed” areas.)

- **Protection zones:** Potential and existing protection zones (against, for example, a swamp or other sensitive area), what they bordered to and any logging were recorded.

- **Trees:** The species, number and size of trees were visually assessed and recorded (table 1).

### Table 1. Size (d.b.h.) of trees in their respective groups.

<table>
<thead>
<tr>
<th>Species</th>
<th>Thin</th>
<th>Normal</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conifers</td>
<td>10-20 cm</td>
<td>20-60 cm</td>
<td>&gt;60 cm</td>
</tr>
<tr>
<td><em>Sorbus aucuparia</em></td>
<td>5-10 cm</td>
<td>10-20 cm</td>
<td>&gt;20 cm</td>
</tr>
<tr>
<td><em>Salix caprea</em></td>
<td>5-10 cm</td>
<td>10-30 cm</td>
<td>&gt;30 cm</td>
</tr>
<tr>
<td>All other deciduous trees</td>
<td>10-20 cm</td>
<td>20-40 cm</td>
<td>&gt;40 cm</td>
</tr>
</tbody>
</table>

- **CWD:** The dead wood was sorted as the trees, except that species was replaced by conifer/deciduous. Furthermore, the dead wood was grouped into:
  - snags (dead, standing trees)
  - natural and man-made high-stumps (stumps higher than 3m)
  - logs (fallen trees except new wind-throws).

- **Damage:** Damage to soil and water caused by harvesting was assessed and recorded.

Retained, living trees that had fallen due to wind or other natural causes during the last three years (~20% of the retained trees) were considered and counted as still standing, leaving only anthropogenic causes to changes in tree- or CWD-density.
Two different analyses

Since some of the areas showed an increase in the amount of trees and dead wood, two different analytical approaches were made:

1. Under the assumption that the number of trees and dead wood does not increase during a five-year period, this study over-estimated the number of trees and CWD-elements on all or some of the sites, justifying the following procedure. Once 100% retention was found on a site, all extra trees (102) and CWD-elements (44) were excluded from the analysis, so that none of the sites were allowed to have more than 100% retention. However, on sites with less than 100% retention, a correction is difficult, if not impossible, to make. The size of any decrease in retention would therefor be under-estimated.

2. Under the assumption that both the first VÄK-study and this follow-up, have a large variance in the estimates of retained trees and CWD, a second analysis was made in which all data were included, also for sites exceeding the initial retention amount.

Handling the data

This study collected data on all aspects of environmental consideration, but the data only allowed detailed analysis of tree- and CWD-retention (n for low-productive areas, retention clusters and protection zones were 8, 14 and 17 respectively).

Since the different wood-types within a particular site cannot be said to be independent, Repeated Measures-ANOVA (RMA) was used for comparing Before (VÄK-data) and After (follow-up data). Mann-Whitney U test (MWU) was used when comparing initial retention between the two landscapes. Spearman Rank Correlation test (SRC) was used to check correlations between retention and site size.

All counts of trees and/or CWD-elements were divided by the area of the site, to produce the relative density (abundance) of each variable. Densities were not normally distributed and therefore log-transformed for ANOVA analyses.
**Results**

**Initial tree/CWD retention**

Most of the retention trees found during the initial VÄK-study were of normal size, and all coarse trees were found in forest landscape 85. No coarse conifers were recorded (not even when reducing the d.b.h. limit to >40 cm in the follow-up) (table 2).

**Table 2. Initial retention of trees (numbers, in the sum-column also percentage of all trees).**

<table>
<thead>
<tr>
<th>Species</th>
<th>71</th>
<th>85</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thin</td>
<td>Normal</td>
<td>Coarse</td>
</tr>
<tr>
<td>Pinus sylvestris</td>
<td>6</td>
<td>253</td>
<td>0</td>
</tr>
<tr>
<td>Picea abies.</td>
<td>33</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Betula pendula</td>
<td>43</td>
<td>44</td>
<td>0</td>
</tr>
<tr>
<td>Populus tremula</td>
<td>0</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Sorbus aucuparia</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Salix caprea</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Fagus sylvatica</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Quercus ssp.</td>
<td>6</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Tilia ssp.</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Alnus ssp.</td>
<td>10</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Larix decidua</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
<td>370</td>
<td>0</td>
</tr>
</tbody>
</table>

Conifer of normal size was clearly the dominant wood-type among the CWD-elements. Coarse elements (d>40 cm) were found only in landscape 85 (table 3 and 4).

**Table 3. Initial retention of CWD in landscape 71 (numbers).**

<table>
<thead>
<tr>
<th>CWD-element</th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thin Normal</td>
</tr>
<tr>
<td>Logs</td>
<td>20</td>
</tr>
<tr>
<td>High-stumps</td>
<td>24</td>
</tr>
<tr>
<td>Dead, standing trees</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>73</td>
</tr>
</tbody>
</table>

**Table 4. Initial retention of CWD in landscape 85 (numbers).**

<table>
<thead>
<tr>
<th>CWD-element</th>
<th>85</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thin Normal</td>
</tr>
<tr>
<td>Logs</td>
<td>9</td>
</tr>
<tr>
<td>High-stumps</td>
<td>7</td>
</tr>
<tr>
<td>Dead, standing trees</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
</tr>
</tbody>
</table>
Distribution of initial tree/CWD retention

For trees and CWD, the data showed a skewed distribution toward more areas with few trees and/or little CWD (Figure 3-8).

Figure 3-8. Distribution of initial retention of trees and CWD on all 40 sites. Note the difference in X-axis scale between figures 3, 5 and 7.
Comparison of initial tree/CWD retention between landscapes

Landscape 71 had more than three times higher initial retention of both living conifers (MWU: p=0.008, two-tailed test) and living deciduous trees (MWU: p=0.016, two-tailed test) than landscape 85. The difference in initial density of CWD, however, was non-significant (MWU: p=0.28, two-tailed test) (Figure 9). One site with zero initial retention from each landscape was excluded in the analysis.

![Graph showing average initial density (number/ha) for Conifers, Leaf, and CWD (logs, snags and high-stumps) for Landscape 71 and Landscape 85.]

**Figure 9.** Comparison between landscape 71 (n=20) and 85 (n=20) with respect to initial retention of trees and CWD. SE-bars are included in the figure.
Correlations between tree/CWD retention and site size

When analysing all the data together (both landscapes), no significant correlation between size of the site and initial (VÅK-data) density of trees (SRC: p=0.29) or CWD (SRC: p=0.86) was found. However, when only the sites with an initial retention of the respective wood-type were analysed, small-sized sites where found to have more initial tree-retention (SRC: p=0.0143; n=36) and deciduous CWD (SRC: p=0.001; n=14) (Figure 10-12).

Figure 10-12. The scattergrams indicate that small sites tend to have more initial retention of trees in general, deciduous trees specifically and deciduous CWD.
Retained areas

Table 5 shows the fate of the low-productive areas, retention clusters and protection zones found in the VÄK-study and revisited during this study.

Table 5. Fate of the initially retained areas after 3-4 years.

<table>
<thead>
<tr>
<th>Structure</th>
<th># Remaining intact</th>
<th># Partially or completely removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-productive areas</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Retention clusters</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Protection zones</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>

Damage done after the VÄK-study

One site had been further damaged since the VÄK-study, showing deep tracks from a recent timber take-out with harvesting machines. No seed-trees were recorded on the site in the VÄK-study.

Comparison Before-After

Analysis 1. (No excess trees or dead wood included)

For both landscapes combined, the total number of trees and dead wood of all categories decreased by 6.3% and 7.2% respectively. Table 6 shows the changes in density and the one-tailed RMA-significance for some wood groups (zero initial-retentions omitted from the analysis).

Table 6. Changes in density for some retention categories (one-tailed tests, since difference in only one direction may occur).

<table>
<thead>
<tr>
<th>Wood category</th>
<th>Conifer</th>
<th></th>
<th>Deciduous</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>p</td>
<td>n</td>
<td>%</td>
<td>p</td>
</tr>
<tr>
<td>Living trees</td>
<td>-9.5</td>
<td>0.02</td>
<td>40</td>
<td>-4.4</td>
<td>0.02</td>
</tr>
<tr>
<td>CWD-total</td>
<td>-6.2</td>
<td>0.002</td>
<td>36</td>
<td>-37</td>
<td>0.03</td>
</tr>
<tr>
<td>Logs</td>
<td>-6.3</td>
<td>0.04</td>
<td>19</td>
<td>-34</td>
<td>0.30</td>
</tr>
<tr>
<td>High-stumps</td>
<td>-3.3</td>
<td>0.01</td>
<td>9</td>
<td>-47</td>
<td>0.06</td>
</tr>
<tr>
<td>Dead, standing trees</td>
<td>-11</td>
<td>0.05</td>
<td>27</td>
<td>Missing</td>
<td></td>
</tr>
</tbody>
</table>

Landscape 71:

The density of trees and CWD of all categories decreased with 6.5% (RMA: p=0.02; n=18) and 7.8% (RMA: p=0.09; n=19) respectively.

Landscape 85:

The density of trees and CWD of all categories decreased by 7.7% (RMA: p=0.09; n=18) and 6.9% (RMA: p=0.01; n=17) respectively.

Comparison of decrease between landscapes

There was no significant difference in the relative decrease of retained trees/CWD between the two landscapes (MWU: Trees: p=0.63; CWD: p=0.71).
Analysis 2. (All data included)

Table 7 shows the changes in density and RMA-significance for some wood groups (all zero initial-retentions were omitted from the analysis, unless an increase in density occurred, in which case the data were included). Only two categories (dead, standing trees (total) and dead, standing, deciduous trees) showed significant changes. Both were positive, indicating measurement errors (retained wood would not increase).

Table 7. Changes in density for some retention categories.

<table>
<thead>
<tr>
<th>Dead wood</th>
<th>Conifer</th>
<th></th>
<th></th>
<th>Deciduous</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>P</td>
<td>n</td>
<td>%</td>
<td>P</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Living trees</td>
<td>7.3</td>
<td>0.08</td>
<td>32</td>
<td>5.1</td>
<td>0.15</td>
<td>35</td>
<td>6</td>
</tr>
<tr>
<td>CWD</td>
<td>-2.4</td>
<td>n.s.</td>
<td>37</td>
<td>-21</td>
<td>n.s.</td>
<td>16</td>
<td>-3.1</td>
</tr>
<tr>
<td>Logs</td>
<td>-2.8</td>
<td>n.s.</td>
<td>21</td>
<td>-21</td>
<td>n.s.</td>
<td>8</td>
<td>-3.7</td>
</tr>
<tr>
<td>High-stumps</td>
<td>-3.5</td>
<td>n.s.</td>
<td>32</td>
<td>-55</td>
<td>0.09</td>
<td>10</td>
<td>-5.4</td>
</tr>
<tr>
<td>Dead, standing trees</td>
<td>0.03</td>
<td>n.s.</td>
<td>30</td>
<td>93</td>
<td>0.01</td>
<td>5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

n.s. = No significant change (all p>0.15). The total-column is complete for clarification.

Discussion

Compared to the VÄK-study, an additional 102 trees (landscape 85: 19 leaf, 18 conifer, mostly normal-sized; landscape 71: 49 leaf, 16 conifer, mostly normal-sized) were found. Furthermore, an additional amount of CWD was found (landscape 85: 7 leaf, 21 conifer; landscape 71: 2 leaf, 14 conifer). When summed up, these amounts cover the whole decrease in over-all old-growth feature density. Two different explanations can be given, based on two different assumptions of the collected data (see assumptions under “Two different analyses”).

1. This follow-up may, because of weak definitions of what should and what should not be counted, have over-estimated the amount of trees and CWD, and the actual densities are, therefore, lower.

2. Both, or either one, of the original VÄK-study and this follow-up were inaccurate, because of weak definitions of what should and what should not be counted, or other differences in methods.

The main problems when monitoring retained trees and CWD, are to define the study area, avoid miscounting and find all elements to count. Most of the sites in this study were clearly distinguishable from the surrounding stands, and the initial numbers of trees and CWD-elements were relatively small (only 7 sites with >40 trees, and 5 sites with >40 CWD-elements). Also, the initial data from each site was available during the fieldwork of this follow-up, and all sites with an apparent decrease in retention were thoroughly checked to avoid the risk of missing elements. It therefore seems unlikely that the actual densities were under-estimated, thereby producing a false impression of decrease in retention.

Since the VÄK-study was conducted by highly experienced staff at the Regional Board of Forestry, it is unlikely that the VÄK-study under-estimated the initial densities.
In analysis 2, only two significant changes occurred, involving increases in the densities of dead, standing trees. The increase of dead, standing, deciduous trees (93%) is, although high, based on only five sites (n=5), making the result unreliable. The increase of dead, standing trees is small (1.7%), and highly influenced by the deciduous category, which makes it unreliable as well.

Analysis 1 provides us with results that probably reflect the real situation. With an average decrease of the density of trees with 6.3% in 5 years, half of the retention-trees, would be gone after only 55 years, due only to further harvesting by man. If calculating not with percentage (exponential decrease), but instead with an estimated, fixed number of trees being removed annually (linear decrease), all retention-trees would be gone within 80 years, that is, after only one rotation period. Thus, considering today’s amount of retention, even personal, small-scale harvesting, e.g. collecting firewood or building material, can have a large impact on the future amount of old-growth features in our production forests.

Although this study did not examine why trees and dead wood declined, it became apparent that the most common reason was gathering of firewood, based on the assumption that a second harvest would remove all, not some, of the trees. Also, wood was often missing close to buildings, where findings of newly made firewood piles suggested small-scale wood gathering (pers. obs.).

The biased distribution of retention is in accordance with reports suggesting that too little is being done, at present, in forestry for the conservation of biodiversity (Eckerberg 1996, VÅK 1997, de Jong 1998). The fact that there was no normal distribution of the density of trees and CWD signals a general lack of strict rules and control in Swedish forestry. Also, RRR (the Swedish National Audit Office, an independent institution for central government auditing in Sweden) concludes that the National Board of Forestry has difficulties in implementing the new Forestry Act with its equal emphasis on biodiversity and production (RRR 1999). A report from the National Board of Forestry, however, shows that the environmental awareness is increasing in Swedish forestry, and that more environmental care was taken in 1992 than just two and a half years earlier (GRÖNSKA, still being analysed).

One striking aspect was the species composition of the initial retention-trees. Not surprisingly, Pine (Pinus sylvestris) was common, constituting 24% of all retention-trees. The dominant tree, however, was Birch (Betula pendula) comprising 46% of the trees on the clearcuts. The remaining 30% include all other species. The forestry goal to increase the amount of deciduous trees in our conifer dominated forests should consequently not be difficult to implement, even though only few species will be adequately represented. There were, for example, only 33 other deciduous trees (10% of the retained deciduous trees, 4% of all retained trees), of which only 6 were coarse, even though these other deciduous trees are considered the most valuable for biodiversity.

Another interesting result is that landscape 71 had three times higher initial tree-retention than landscape 85. Only the latter landscape, however, contained coarse trees (although no more than 3% of the total retention-tree amount). Furthermore, although landscape 71 contained more dead wood, coarse elements again were found only in landscape 85. It would appear that the forest managers in landscape 71 focus on quantity rather than quality retention, as opposed to the managers in landscape 85. It might of course also reflect the pre-harvest conditions of the forest, i.e. if there were any coarse trees to begin with.

The negative correlation between retention and site size might be explained by the fact that small clear-cuts per se represent some kind of environmental consideration. It is generally understood among foresters that small clear-cuts are better, from an environmental point of view, than large ones. A forest manager that creates small clear-cuts may therefore be more predisposed to retain old-growth features in consideration of biodiversity, than his colleague creating large clear-cuts. This would also explain why the correlation seems more valid for
deciduous trees than for conifers, since deciduous trees are known to be more important for the biodiversity. If the environmental awareness were equal among forest managers, one would expect the large clear-cuts to have more retention, since these constitute a greater negative environmental change than small clear-cuts. Another possibility is that forest managers tend to retain a certain number of old-growth elements per clear-cut, regardless of its size. The number then represents the fixed economical sacrifice each manager is prepared to make for the sake of the environment.

Low-productive areas, protection zones and retention clusters are important aspects of environmental consideration in Swedish forestry. The costs of retaining these structures are small compared with the benefits that they constitute for the forest environment. It is therefore alarming that only 50% of the protection zones and 70% of the retention clusters have been left during the first four-year period. Low-productive areas, on the other hand, seem to be more resistant to this "post-harvesting"; only one out of eight had been affected by forestry during the period. This might be explained by the fact that low-producing areas contain small values, which, combined with rocky or wet land complicating harvest, makes them less interesting from an economical perspective than the other retention structures.

This study roughly estimated the amount of windfalls to approximately 20% of the retained trees. Assuming that this figure is representative for Swedish clear-cuts, the retained structures will eventually consist of few living trees and much dead wood. Such structural change will have a large impact on the biodiversity, and should therefore be considered in the long-term forestry planning. Interesting subjects for further studies might include the exact amount of windfalls among the retained structures, as well as how different structures affect the extent of windfalls.

Damage to soil and water should, of course, be minimal since no further large-scale forestry operation is expected after a final clear-cutting. The single example found can be considered an exception.

If once retained elements that have disappeared from a site are replaced by newly discovered elements elsewhere, the estimated initial retention densities will remain. A non-reversible decrease will still have occurred, however, affecting the true initial densities, and an observed decrease in one site can therefore not satisfactorily be explained by an additional amount in another. Overestimating the densities will consequently not produce a false observation of a non-existent decrease, although the quantitative estimate of the decrease may be too small.

Any decrease in retained old-growth features constitutes a serious threat to the health of our forest biodiversity. Forestry cannot be considered sustainable when the efforts of today last less than one rotation period. Considering the long-term planning that normally applies to forestry, it is surprising that long-term environmental planning is so difficult. This study shows that stronger efforts must be made for the conservation of forest biodiversity. These efforts should include stricter and clearer retention rules, combined with control and long-term follow-up of the retained structures.

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References


Fridman, J. 2000. Damaged and Dead Trees in Swedish Forests - assessment and prediction based on data from the National Forest Inventory. SLU (Swedish University of Agricultural Sciences).

GRÖNSKA. National Board of Forestry. (Still being analysed)


RRV (The Swedish National Audit Office) 1999. Skogsvårdsorganisationens arbete för att jämställa miljöområdet med produktionsmålet.

RT (Riksskogstaxeringen) 1998. Skogmark, myr, berg enligt RT.


