Stand dynamics of mountain birch, *Betula pubescens ssp. czerepanovii* (Orlova) Hämet-Ahti, in NW Finnish Lapland

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Antero Järvinen* & Rauni Partanen

Spatial pattern, density, height, diameter, biomass and age structure of a randomly selected mountain birch, *Betula pubescens* ssp. *czerepanovii* (Orlova) Hämet-Ahti, population (200 trees) were studied in NW Finnish Lapland. Productive forest types predominated in the study area. Trees were randomly distributed in the forest, and there were approximately 2 800 stems/ha (stems at least 50 cm high included). Fifty-seven percent of the trees were monocormic. Mean tree height was 5.7 m and mean trunk diameter at ground level was 8 cm. After logarithmic transformation, tree diameter explained 98% of the measured biomass variance. Estimated above-ground biomass was 28 000 kg/ha. Mean tree age was 54 years, the oldest tree being 96 years old. Relatively old individuals predominated in the population. Age correlated significantly with height, diameter and total tree biomass.

Introduction

The mountain birch forest zone is unique to Scandinavia (Hämet-Ahti 1963, Kallio et al. 1983). In northwestern Finnish Lapland the mountain birch, *Betula pubescens* ssp. *czerepanovii* (Orlova) Hämet-Ahti, is the climax tree species and forms the vertical treeline in the mountains (Hämet-Ahti 1963). Birches, especially *B. pubescens*, are relatively short-lived pioneer trees (Sarvas 1964), which quickly spread and occupy spaces such as those created by forest fires and clear cutting. For instance, birch was the first tree species which spread to Finland after the last Ice Age (Hamnelius et al. 1989).

Tree-line dynamics of mountain birch has received a great deal of attention partly because it is an indicator of climate change (Sonesson and Hoogesteger 1983, Kullman 1991a, b, 1993, Oksanen et al. 1995). Primary production of birch forests was thoroughly studied during the International Biological Program (IBP) period (Wielgolaski 1975). However, population biology of the mountain birch is poorly known, probably because this tree is of little economic importance. For recent results, see Wielgolaski (2001).

The aim of our study was to gather ecological data for a randomly chosen population of mountain birches. These data may be useful in tree-line dynamics and conservation studies, and also as background material in game research and other zoological studies. Because the sampling method was random, we probably obtained a more representative picture of the local population than would have been the case if systematic or other non-
random sampling methods had been used. We compare our results with those obtained elsewhere in the Nordic countries.

**Study area, material and methods**

We undertook our study in a Cambro-silurian mountain area at Kilpisjärvi in northwestern Finnish Lapland (about 69°03’ N, 20°50’ E). The study plot consisted of an area of mountain birch forest about 510 m above sea level (a.s.l.) on the western slope of Saana Mountain (Fig. 1). At Kilpisjärvi the mountain birch forest zone extends from the shores of Lake Kilpisjärvi (475 m a.s.l.) to the tree line (about 600 m a.s.l.). The highest mountains reach 1000 m a.s.l. Kilpisjärvi is among the most ‘arctic’ places in Scandinavia with a growing season of 100 days or less (threshold +5 °C; Tuhkanen 1980).

We collected field data in late July and early August 1992, when the leaves of mountain birches were fully grown. The date of birch leafing, i.e. the day when the petioles became visible, was 10 June, earlier than the mean of the previous 20 years (15 June; Järvinen unpublished data). According to data derived from an official climatological station of the Finnish Meteorological Institute situated in the study area (480 m a.s.l.), May and June 1992 were warmer than normal, but July and August 1992 were colder than normal (Finnish Meteorological Institute 1992; Table 1). Long-term mean annual temperature is -2.6 °C and mean annual precipitation 422 mm water equivalent. In the birch forest snow melts at the beginning of June, and the first lasting snow fall occurs after 15 October.

We selected a random starting point within the study area. From this point the observer walked ten meters along a randomly chosen compass course and then selected the nearest tree for the sample. Then the observer chose a new random compass course; walked ten meters and selected another tree. This continued until we had collected data on 200 trees (at least 50 cm tall). The total area thus covered was about two hectares.

At each random point we recorded two distances using a measuring tape:

1) the distance from the random point (O) to the nearest tree (P) in any direction; and

2) the distance from that tree (P) to its nearest neighbour (Q) with the restriction that the angle OPQ must be more than 90° (T-square sampling; Ludwig and Reynolds 1988).

We used these distances to estimate the density and spacing of birches. We calculated density per hectare using Byth’s (1982) robust estimator. To test for spatial randomness, we used the powerful statistic recommended by Hines and Hines (1979).

Clearing of a large forest area was not practical. Instead, we determined the above-ground biomass of whole trees (leaves, twigs, branches and trunks) by harvesting twenty individuals of different size. We felled the trees at ground level and dried leaves, twigs and small branches in an oven at 80°C for one week. We cut and split trunks into pieces and removed the bark to accelerate drying. We initially dried thick branches and debarked trunks at room temperature for one year, and then dried them at 80°C for one week. We developed equations between size variables and biomass, and used the best-fitting regression equation to estimate the total above-ground tree biomass in the study area.

| Table 1. Monthly mean summer temperatures in the study area (Kilpisjärvi, elev. 480 m a.s.l.) in 1992 (Finnish Meteorological Institute 1992) and 1951-1985 (Järvinen 1987). |
|---|---|---|
| May | +2.7 | +1.3 |
| June | +9.2 | +7.2 |
| July | +9.5 | +10.6 |
| August | +8.2 | +9.1 |
We determined the floristic composition of the field-layer around each tree using the system of Hämet-Ahti (1963). We identified three, relatively productive, birch forest types:  

1) suboceanic *Cornus-Vaccinium myrtillus* type (CoMt; least productive);  
2) mesic meadow forest with short herbs; and  
3) mesic-moist meadow forest with tall herbs (most productive; Table 2).  

The forest on Saana Mountain is composed almost exclusively of mountain birch. Single, small, individual rowan trees, *Sorbus aucuparia*, occur here and there, and junipers, *Juniperus communis*, (< 1 m) grow sparsely in dry places. 

We took several measurements of each of the 200 trees. We recorded whether a tree was mono- or polycormic and measured the height of each tree to the nearest 10 cm using an 8 m long measuring rod and a ladder. We measured the diameter at ground level (accuracy 5 mm) with sliding calipers and determined age by counting tree rings in the laboratory under a stereomicroscope. Cores were used in most cases, but some smaller trees were cut off with a handsaw. 

Table 2. Floristic composition of the field-layer around 200 mountain birch trees on Saana Mountain. Classification of forest types according to Hämet-Ahti (1963). Productivity increases from 1 to 3.

<table>
<thead>
<tr>
<th>Forest type</th>
<th>Number of cases</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) <em>Cornus-Vaccinium myrtillus</em> type</td>
<td>98</td>
<td>49</td>
</tr>
<tr>
<td>2) Short herb type</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>3) Tall herb type</td>
<td>64</td>
<td>32</td>
</tr>
</tbody>
</table>
Results

Vegetation, density and spatial pattern

The mountain birch forest on Saana Mountain was quite dense, the mean point-to-nearest-tree (O-P) distance being 1.0 m and the mean point-to-nearest-neighbour (P-Q) distance 1.2 m (cf. Fig. 1). The density of trees at least 50 cm high was 2761/ha (Byth’s robust estimator, 95 % confidence limits 2503 - 3078 trees/ha). The T-square sampling method showed that the spatial distribution of the trees was random. The field layer was relatively homogenous and contained a lot of herbs, indicative of productivity (Table 2). Barren forest types were totally absent.

Height, diameter and number of trunks per tree

The lower height limit for a tree to be included in this study was arbitrarily set at 50 cm. The shortest tree in the randomly selected sample was 80 cm tall and the tallest 10.5 m. The mean height was 5.7 m (Table 3, Fig. 2). Trunk diameter varied between 1 and 20.5 cm, the mean being 8 cm (Table 3). There was a close correlation between tree height and diameter (Table 4). The distributions of height (Fig. 2) and diameter values were nearly normal. Of the 200 trees, 57 % were monocormic, and the polycormic trees had only a few trunks (for the physiognomy of forest, see Fig. 1).

Biomass

Total tree biomass was significantly related to tree diameter, height and age, the diameter of the tree giving the best correlation (Table 4). The power equation explained almost all (98 %) of the measured biomass variance (Table 5, Fig. 3), and it was used to estimate the total above-ground tree biomass in the study forest.

The estimated above-ground birch bio-

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (m)</td>
<td>6.0</td>
<td>5.7</td>
<td>2.1</td>
<td>0.8</td>
<td>10.5</td>
</tr>
<tr>
<td>Diameter (cm)</td>
<td>8.0</td>
<td>8.4</td>
<td>4.1</td>
<td>1.0</td>
<td>20.5</td>
</tr>
</tbody>
</table>

Table 3. Total height (m) and diameter of the trunk (cm) at the ground level of 200 mountain birch trees on Saana Mountain.

Fig. 2. Height distribution of birches (normal distribution superimposed). Saana Mountain, 1992.
dead tree. Thus the observed age structure provides a fair picture of temporal variation in the rate of establishment of the population.

Fig. 4 shows the percentage of trees in each 10-year age class. According to this figure, there has been relatively little recruitment in the past 50 years. Relatively old individuals predominated in the population. In the sample of trees at least 50 cm high (n = 200), the youngest tree was 7 years old (diameter at the ground level 1 cm) and the oldest one 96 years old (diameter 15 cm). The average age was 54 years (SD = 16.4; median = 57 years).

**Age structure**
Field observations confirmed that dead trees of any size were virtually absent. Also, the sample of 200 trees did not contain a single dead tree. Thus the observed age structure provides a fair picture of temporal variation in the rate of establishment of the population.

Table 4. Pearson correlation coefficients between age, height, diameter and above-ground biomass of birch trees. All correlations highly significant. For height and diameter n = 200 (2-tailed 5 % level for correlation coefficient = 0.138), for biomass n = 20 (2-tailed 5 % level = 0.444).

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Height</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>0.793</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>0.787</td>
<td>0.900</td>
<td>-</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.601</td>
<td>0.807</td>
<td>0.955</td>
</tr>
</tbody>
</table>

mass was 28 000 kg/ha (dry weight). The lightest tree in the population weighed 20 g (diameter 1 cm, height 80 cm, age 7 years), the heaviest tree 75.6 kg (diameter 20.5 cm, height 9.0 m, age 70 years). Mean above-ground biomass/tree was 10.3 kg. However, lower weight trees predominated in the population, the median weight being only 5.6 kg.
Age correlated significantly with height, diameter and total tree biomass (Table 4).

**Discussion**

In Finnish Lapland, most mountain birch forests are relatively barren, and their vegetation is dominated by dry heath forests rich in lichens (Hämet-Ahti 1963). Our study area lies only about 50 km south of the Arctic Ocean. Therefore, oceanic features of the mountain birch forests of Fjord Lapland (Hämet-Ahti 1963) are visible in the vegetation (e.g. prevalence of mesic forest types rich in herbs, Table 2). The majority of trees were monocormic (57 %) or oligocormic (few trunks per tree; cf. Fig. 1). The monocormic type of mountain birch grows in areas of rich nutrient conditions and good snow protection (Fries 1913). In our mesic study area the spacing of monocormic birches was random,
but on barren grounds polycormic birches are often dispersed at regular intervals (Kullman 1991b).

Mikkola and Sepponen (1986) give stand characteristics of mountain birch in NW Finnish Lapland. According to them, the number of trees/ha was about 4000 in the Kilpisjärvi area in 1982. Their estimate was based on circular plots and systematic sampling, which may account for the difference from our estimate of 2800 trees/ha. In northern Swedish Lapland (Sonesson and Hoogesteger 1983), the number of birch trees per hectare varies between 1500 and 3000 trees (bushes included as in the present study) which is similar to our estimate. On barren, infertile grounds density is low (about 600 stems/ha) and trees are short (about 4 m; Kullman 1991b).

The height distribution was nearly symmetrical (Fig. 2), but the distribution of plant weights was positively skewed. This is in accordance with earlier studies (Ogden 1970 and references therein) showing that suppressed plants undergo rapid height extension towards the light and so grow closer to the height of the surrounding vegetation. However, these plants increase little in weight and may ultimately die. In our study area the maximum height a birch can reach is about 10 m. The very strong correlation between biomass and diameter (Table 5, Fig. 3) suggests that the standing crop of mountain birch forests can be estimated reliably using this single, easily obtainable measure.

Since the sample was random and small trees were not excluded, the biomass value of about 28 000 kg/ha gives an estimate of the total above-ground birch tree biomass in the area. Although Byth’s (1982) density estimator is not sensitive to a non-random pattern of trees, the observed spatial randomness increases its reliability, and hence the reliability of our density and biomass estimates. In the Kevo area in NE Finnish Lapland, birch forests are barren and birch biomass is about one third of that found in Kilpisjärvi (Kallio 1975).

Size is often an inaccurate measure of age, since size variation increases rapidly as plants age due to increased competition and habitat heterogeneity (Harper 1977). However, in our relatively homogenous study area height and diameter were relatively accurate predictors of birch age (Table 4). The mountain birch seems to be a relatively short-lived tree species, since the age of trees did not exceed 100 years (Fig. 4). This is in good agreement with Kullman’s (1991a) results from Swedish Lapland, where the oldest stems were also about 100 years old and the most frequent age classes 40-60 years. In Kullman’s (1991a) study area age distribution was also bell-shaped.

The rarity of young trees is an indication of a closed forest, in which the dead of the old trees has not created sufficient space for young trees. During the Second World War German troops overwintered in the Kilpisjärvi area in 1944-1945 and they felled mountain birches for their own use. The present-day age distribution of birches may be a remnant of the war. Thus, the bell-shaped age distribution could be an indication of development after a major disturbance or colonization of a previously treeless area. However, in Swedish Lapland, an area not affected by war, young trees were also rare (Kullman 1991a).

Survivorship of individuals in the population cannot be inferred from the age structure in 1992 (‘cohort life-table’), because it is not known whether the numbers of births and age-specific survival rates have remained the same from year to year. As seen in Fig. 4, the population actually seemed to increase in size from years 0 to 60, leading to negative deaths and meaningless mortality rates.

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Kilpisjärvi Notes


Kilpisjärven biologinen asema
Helsingin yliopisto


Kilpisjärvi Biological Station
University of Helsinki

Kilpisjärvi Biological Station (founded in 1964) is a scientific research station belonging to the University of Helsinki. The station (69°03’N, 20°50’E) is situated in the subalpine birch forest zone in Finnish Lapland. The upper boundary of the birch forest lies at about 600 m. Kilpisjärvi is the only part of Finland with altitudes of 1000 m or more. The mean temperature in January is -13,5°C, in February -13,1°C, in June +7,4°C and in July +10,8°C. The snow in the birch forest melts in early June. The situation of Kilpisjärvi in a climatic and geologic border zone results in a great variety of habitats within a restricted area. The unique fauna and flora, which differ from those of any other part of Finland have made the region especially attractive to biologists.

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