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F.E. Wielgolaski (Ed.)
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Plant Ecology, Herbivory, and Human Impact in Nordic Mountain Birch Forests

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Volume editor

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Preface

In Fennoscandia and Iceland, large parts of particularly elevated areas are treeless. Below these areas there is often a belt of Nordic mountain birch trees, now often called *Betula pubescens* ssp. *czerepanovii.* In Fennoscandia, this plant is also common in a zone north of the coniferous trees and is found in small forests in the southwestern-most parts of Greenland and more locally in other parts of Europe.

Before the begin of the International Biological Programme (IBP) in the late 1960s and early 1970s, only minor fractions of these ecosystems had been studied. Therefore, alpine and subalpine systems were chosen as the main areas of study in this first, larger interdisciplinary and integrated project in natural science across national borders and, in this way, they made an important contribution to such research in the Nordic countries. In addition to an interdisciplinary steering committee in each country, a Nordic administration was also established for the so-called IBP "Tundra Biome" studies in the region (although permafrost is not common in most of the region). At the end of the IBP, many results from this research in alpine, subalpine and northern Fennoscandian mountain birch forests were published in two early volumes of the Ecological Studies Series (Wielgolaski 1975a, b).

As is common at the end of scientific projects, many questions were not really answered, and this was also the case after IBP. However, the project showed the good collaboration within the Nordic countries. Therefore, in the late 1970s, it was decided to establish a "Nordic Subalpine–Subarctic Ecology" network project (NSSE) across the national borders within the Nordic mountain birch ecosystem at a lower intensity level, as only very limited funding was available for this cooperation after the IBP. In Finland, after some years, this project was accepted as a Man and Biosphere (MAB) network, resulting in a better status of the project in that country than elsewhere. This made it also possible to obtain results from the joint Nordic mountain birch studies more than 20 years after the IBP published their findings in a volume in the UNESCO-MAB Series (Wielgolaski 2001).

Within the EU, international scientific projects, including several European member countries and associated EU countries, are recognized as important to increase the knowledge and cooperation in Europe. Particularly important are natural science projects that also relate to man and socio-economy. Therefore, the 3-year project "Human Interactions with the Mountain Birch Ecosystem: Implications for Sustainable Development" (HIBECO) was funded by the EU from the year 2000. Here, results from new mountain birch studies in the Nordic countries including Greenland are added to older ones concerning both the growth of the birch itself, and the use and limitations of these forests by animals and man, with the objective of finding the best sustainable management for mankind in this ecosystem. Furthermore, Scotland was included in this project because of the good knowledge from earlier projects there on the influence of grazing, e.g. by sheep in their mountain birch regions. The results of this EU project are summarized in this volume.

What has changed in the Nordic mountain birch ecosystem in a long- or short-term perspective? In the short term, a possible increment of the forests in elevation by global climate change may be included, either induced by man or not. In Iceland, large areas of the original birch forests were cleared by man. Later, strong sheep grazing prevented resprouting of the trees and caused heavy erosion (Aradottir and Arnalds 2001). A similar development has, to some extent, taken place in the birch zone of southern Greenland. In addition, in Fennoscandia, the mountain birch forests have been suppressed in subalpine districts due to sheep grazing. In later years, however, this sheep-grazing pressure was lower in those areas. This may be another reason for the recent increased elevation of the upper birch tree line in the region, in addition to climate change. In northern Fennoscandia, the birch forests are strongly influenced by reindeer grazing and trampling, as reported in several chapters.

Modern infrastructure is also very important for development in the Nordic mountain birch region. A denser road net makes a larger fraction of the birch forests accessible for firewood cutting. Similarly, increased tourism after road building may increase the tree cutting and reduce the birch forests. At the same time, in some districts, less forest is used for firewood, because many inhabitants, also from the mountain birch region, are going over to heating by electricity and oil. This shows how sustainable use of mountain birch depends on the political decisions taken in a district.

The main objectives of the various chapters in this volume are to give examples from different sites (see Fig. 1) in the Nordic countries (and Scotland) of the influence of climate change and human decisions on growth of birch and the understorey. It has been discussed how climate change through time may be of importance for the adaptation of the trees in various regions and how such changes may cause variations in attacks, e.g. by insects. Shifts in the grazing pressure, e.g. by sheep and reindeer, will be important for the

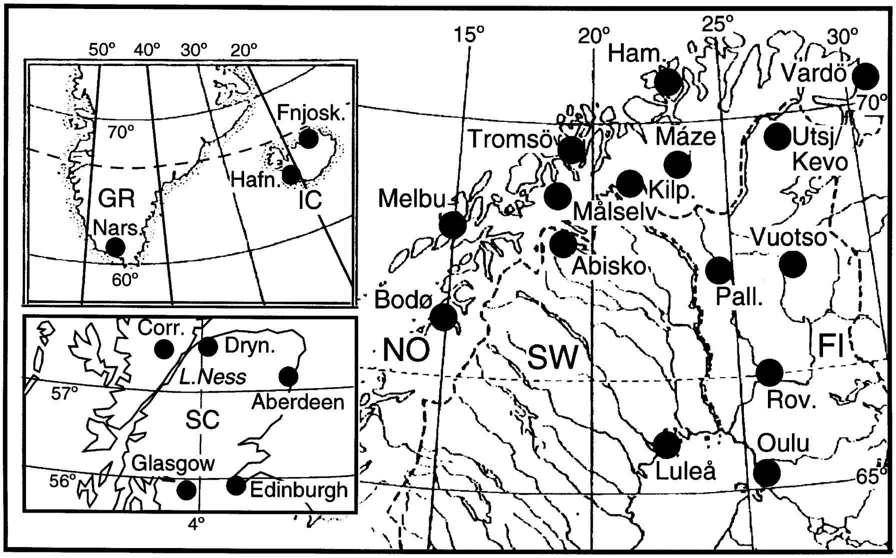

Fig. 1. Map of northern Fennoscandia (*FI* Finland, *SW* Sweden, *NO* Norway), Iceland (*IC*), southern Greenland (*GR*) and parts of Scotland (*SC*), showing sites used in connection with the HIBECO project and some towns in the regions (*Rov* Rovaniemi, *Pall* Pallasjärvi, *Kilp* Kilpisjärvi, *Utsj/Kevo* Utsjoki/Kevo, *Ham* Hammerfest, *Fnjosk* Fnjoskadalur, *Hafn* Hafnarskogur, *Nars* Narssarssuaq, *Dryn* Drynachan, *Corr* Corrimony). *Broken line* at 66°33′N denotes Arctic Circle. Provenance sites used in phenology studies are given in the Fig. 7.1

Nordic mountain birch ecosystem in the future, but probably the greatest change in this system will be the degree of tourism permitted in the region, as influenced by the future infrastructure.

The possibilities for sustainable use of the Nordic mountain birch ecosystem are evaluated in various models presented in the volume, giving answers based on the scenarios chosen. However, it is NOT the aim of the volume to present a preferred future in the Nordic mountain birch ecosystem. That is up to the politicians and other decision-makers to determine, but the chapters in this volume have been planned to make it possible to choose the best solutions in various countries and districts. However, it is recommended that decisions should be made in cooperation with the local people in a district, and should not be made SOLELY by the central authorities in the various districts.

It is very valuable for the Nordic scientists working in the mountain birch regions to present various results from an interdisciplinary and integrated project, including social scientific subprojects, all together in a new volume of the series Ecological Studies as a sort of continuation of the results presented partly from the same region in the same series about 30 years ago. The editor thanks the publisher for making this possible and is very glad to have all these Nordic mountain birch data presented in one place.

October 2004 *F. E. Wielgolaski*
Oslo, Norway

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Section 1

History, Environment and Plant Science

1 History and Environment of the Nordic Mountain Birch

F.E. Wielgolaski

1.1 History-Zonation-Taxonomy-Distribution

Birch is an old inhabitant of the Nordic countries as shown both by palynology and radiocarbon dating of subfossil birch remnants. Woody vegetation, not very different from the present-day mountain birch trees/shrubs in subalpine and northern Fennoscandia, migrated rapidly into the region after the last glacial period, probably first into southwestern Norway 12,000 B.P. (Aas and Faarlund 2001), and to the northernmost part of the region (ca. 71°N) approximately 1000 years later (however, cf. Chap. 2).

The upper and northern tree line has varied with the climate through the centuries ever since. The historical highest tree line in southern Fennoscandia, about 500 m above today's limit, has been dated back to more than 10,000 B.P., using mega-fossil evidence and radiocarbon dating (Kullman and Kjällgren 2000), only about 1000 years after birch had reached northernmost Fennoscandia. In the boreal chronozone about 8500 B.P., birch also reached high elevations (Moe et al. 1978).

The Nordic tree line zone is mainly dominated by what we normally call the northern mountain birch today (Wielgolaski 2002), and generally covers the ecotone between the coniferous forest zone and the treeless areas in the Nordic countries. It is most often referred to as the subalpine zone, which also forms a substantial part of the northern boreal zone (Moen 1999). The zone was first described by Wahlenberg (1812) and includes both the area with birch towards the northern or arctic tree line and towards the maritime tree line mainly to the west, in addition to the tree line towards the alpine zone in the mainly N–S running mountain chain almost throughout the length of the Nordic countries. Similar limits for Nordic mountain birch forests apply today (Hämet-Ahti 1963), particularly in Finland, also called the upper oroboreal zone (Ahti et al. 1968; Haapasaari 1988). However, the delimitation of western and northern Fennoscandia is complicated in places by the local climatic diversity, due to greatly varying topography of the mountain areas and the

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fjords along the coast. Together with edaphic variations, these conditions are responsible for the often diffuse character of the limits of the Nordic birch zone (Haapasaari 1988).

The taxonomy of Nordic mountain birch is difficult and unclear. In its typical form this birch is dominant in the eastern Kola Peninsula and throughout subalpine regions of the Fennoscandian mountain chain. Genes from the dwarf shrub *Betula nana* L. are strongly involved in the Nordic mountain birch (Thórsson et al. 2001), and are sometimes visually shown by small leaves and bright red autumn colours (Nilsen and Wielgolaski 2001). Today, this often polycormic birch is treated as a subspecies of *B. pubescens* Ehrh. called ssp. *czerepanovii* (Orlova) Hämet-Ahti (often also called *B.p.* ssp. *tortuosa* auct. or even *B. tortuosa* Led., a name which today is usually limited to a birch growing in the Altai mountains).

Birch is the only native tree species commonly growing in Iceland. It is also treated as a Nordic mountain birch by most authors today, although it is clearly a specific ecotype compared to the Fennoscandian mountain birch (see e.g., Wielgolaski and Nilsen 2001). Väre (2001) reported that the birch in Iceland has appeared independently of the formation in Fennoscandia, but it is likely the mountain birch has a polytopic history in both regions with introgressive hybridization of *B. nana* where this flowers more or less simultaneously with the other.

The typical *B. pubescens*, often called ssp. *pubescens*, has few, if any, genes from *B. nana*. The subspecies is normally found in richer soil at lower elevation, e.g., in valley bottoms, and at lower latitudes, commonly with only one stem (monocormic). This is generally the type found in Scotland. Sometimes the closely related birch growing in southwestern Greenland is also treated as a Nordic mountain birch, although there is often strong hybridization with the American *B. glandulosa* Michx.

Birch is also found east of the Kola Peninsula, but the taxonomy is very unclear, and many taxa may be involved. Low temperature is suggested to reduce the genetic incompatibility between various birch taxa (Hagman 1971). In this volume, the mountain birch from Fennoscandia, Iceland, Greenland and Scotland is discussed. *B. pendula* Roth. is most common in the southern parts of the region and hybridizes with the Nordic mountain birch, however, it is not included in this project.

1.2 Present Tree Line

Today, the upper mountain birch tree line is above 1200 m a.s.l. in central southeastern Norway (Fig. 1.1), but it is lower in all directions moving away from that district, strongly lower towards the southwest coast of Norway (ca. 500 m a.s.l.), and eastwards in Sweden at similar latitudes (900–800 m a.s.l.).

Fig. 1.1. Map of the upper climatic tree line in Fennoscandia as given by hypsogrammetric curves in solid lines. (Aas and Faarlund 2001)

The birch tree line is also lower to the north, but in inner Scandinavia, at the Arctic Circle, it may still be 700–800 m a.s.l. (Aas and Faarlund 2001). Near the sea in the far north of Fennoscandia it descends dramatically, nearly to sea level at about 71°N, (however, cf. Chap. 2).

Presently, there are several indications for slowly increasing Nordic mountain birch tree lines in the region (Sonesson and Hoogesteger 1983; Kullman 2000, 2002), which are at least partly attributable to a general climate change, but also to human use of the mountain birch forests, particularly reduced grazing by domestic animals. In many places, it has been observed that the mountain birch forest near the forest line grows more vigorously than just a few decades ago (own unpubl. observ.). This is also the case above the height reached for browsing by animals. The tree crowns seem to be considerably denser than they were earlier. This could be a consequence of a better climate for birch tree growth (cf. Kullman 2000). It has also been noted that the extended birch forest towards the tree line is surprisingly even-aged. Could this be because seedlings suddenly were strong enough to survive in a better climate and could grow above the winter snow cover?

Both historically and more recently, man has strongly influenced the presence of birch by logging, e.g. for fuel and by strong animal grazing. On the Faroe Islands native birch has totally disappeared, probably due to the disturbance by man (Aas and Faarlund 2001). In Iceland there has been a strong degradation of birch forests due to anthropogenic influence (Aradottir and Arnalds 2001) since the Viking settlements late in the ninth century. It is, therefore, difficult to define the climatic tree line of Iceland today. Thorhallsdottir (1997) reported that it may be close to 300 m in coastal regions, but up to about 550 m elevation in inland areas, particularly in the northeast.

It has often been discussed why birch is the main tree line species in the Nordic countries (e.g. Oksanen 1995), while in most regions of the world the tree line is formed by coniferous species (e.g. Walter 1974). Ahti and Hämet-Ahti (1969) stressed that timberline forests dominated by birches and other mesomorphic deciduous trees are typical for high-latitude areas adjacent to ice-free oceans. This indicates that the degree of oceanity plays a role in why birch is the main tree line species in the Nordic countries. The author has found in phenology studies in western Norway that high humidity favours the time of leaf bud break more in birch than in most other deciduous trees studied (Wielgolaski 2003).

In the southeastern districts of the Caledonian mountain chain in Scandinavia, which are the most continental parts of the region, there are pockets of spruce at the tree line (own observ.). Again, this indicates humidity as one factor of importance for which tree species dominates the tree line. However, there is also a possibility that strong grazing has caused the upper birch tree line to be depressed. On the other hand, this should also favour coniferous trees at the tree line in more humid districts and in inner, relatively continental districts of northern Fennoscandia, which is generally not found (Oksanen 1995). The last author has presented various hypotheses for the development of certain species to be dominant at the tree line. He suggested that rain shadow areas relatively close to open oceans might be characterized by a mixture of oceanic and continental factors maximally disadvantageous for evergreens, leading to respiratory losses in winter and soil frost-induced drought stress in spring. However, he also followed the hypothesis by, e.g. Fægri (1950), that a dispersal barrier prevented spruce from reaching all areas that otherwise would have fitted the species, and that this is a possibility for the lack of spruce in some Fennoscandian mountain areas. Oksanen (1995) further mentioned the possibility that spruce may have problems defending positions obtained for instance in northernmost Fennoscandia during the historical hypsithermal period and expanding the range under current climatic conditions. On the other hand, elevationally increased tree lines are documented also for coniferous trees at increased temperature by global change (Hofgaard 1997; Kullman 2000, 2002).

1.3 Climate

The growth of Nordic mountain birch is thus, like most other plants species in temperate regions, strongly dependent on temperature and heat sums above certain basic or threshold temperatures in the growing season (Wielgolaski 1999). Odland (1996) found the best correlation with the upper Nordic mountain birch forest line to be with the average maximum temperature isotherm 13.2 °C of the four warmest summer months (tetratherm), although this is not a vital survival limit for birch. The survival of browsing insects, however, is dependent on the minimum winter temperatures (see Chaps. 9 and 12). Helland (1912) already calculated the mountain birch tree line to follow the 7.3 °C tetratherm for the mean diurnal temperature and the coniferous tree line the tetratherm of 8.3 °C. If we compare the present birch tree line with calculated temperature normals near the birch forest limit, e.g. at Kvamskogen, Haugastøl, Fokstua, Bjørnfjell and Kilpisjärvi (Table 1.1), it seems that the birch forest limit is closer to the 8 °C tetratherm. However, mean temperature limits decrease in relatively continental areas with high day temperatures during summer (Wielgolaski 1975) and may increase in more oceanic districts, e.g. Kvamskogen (Tables 1.1–1.2).

Kullman (2000) stressed that the tree height growth increased markedly in the period 1988–1999 with slightly higher (0.3 °C) summer temperatures than the preceding period 1951–1987. He also observed that individual trees, which had been suppressed during the low temperatures in the last-mentioned period, responded by serious winter dieback at the approx. 2.6 °C increase in mean winter temperatures combined with the higher summer temperatures in 1988–1999. In the most probable global change temperature scenarios, meteorologists have suggested that temperatures in Fennoscandia will continue to increase in the period up to 2050 by about 0.4 °C per decade in the north (Hanssen-Bauer et al. 2000).

Although temperature is the most important climatic factor for growth of the Nordic mountain birch, humidity, as mentioned before, also has an influence. The annual precipitation varies greatly in Fennoscandia, from about 300 mm east of the Scandes (Table 1.2) to considerably more than ten-fold in coastal mountains of southwestern Norway. Particularly high precipitation is observed at higher elevations just west of the highest mountain massifs because of the uplift and cooling of the mainly southwesterly winds and cyclonic movements in Fennoscandia. The precipitation is somewhat lower close to the sea in the west and decreases to the far north. Even at the northeasternmost coast of Norway it is often less than 400 mm/year (e.g. Ekkerøy Table 1.2), but fog and drizzle are common.

In precipitation scenarios, the precipitation is normally supposed to increase in the Nordic mountain birch region up to year 2050 (Hanssen-Bauer et al. 2001). This has been estimated particularly for the northwestern coast

Table 1.1. Normal temperature (mean °C). (Kärenlampi 1972; Järvinen 1987; Alexandersson et al. 1991; Lippestad 2003)

Coordinates °N–S; °E–W	Height (m)	Site	Period March	April	May	June	July	Aug.	Sept.	Year	Mean June–Sept.
60.5; 5.5	408	Kvamskogen	−0.8	2.0	7.0	10.9	11.9	11.6	8.4	4.1	10.7
60.5; 8.0	988	Haugastøl	−6.8	−2.8	2.9	7.8	9.8	9.2	5.2	−0.2	8.0
62.1; 9.3	952	Fokstua	−7.0	−2.9	3.8	8.4	10.0	8.9	4.4	−0.7	7.9
62.5; 12.1	680	Fjällnäs	−6.7	−2.4	4.0	9.0	10.5	9.4	5.2	−0.4	8.5
63.2; 12.0	642	Storlien	−4.6	−1.3	4.6	9.3	10.7	10.0	6.0	1.1	9.0
65.5; 16.5	652	Danasjö	−6.9	−2.5	3.6	9.4	11.2	9.5	4.7	−0.6	8.5
66.5; 16.3	500	Vuoggatjolme	−8.7	−2.7	3.4	9.0	11.4	9.9	5.3	−1.7	8.9
67.1; 18.2	530	Aktse	−7.8	−2.6	3.6	9.4	11.6	9.7	4.5	−1.4	8.8
68.3; 18.8	388	Abisko	−8.0	−2.7	3.2	8.4	11.0	9.7	5.2	−0.8	8.3
68.4; 18.1	512	Bjørnfjell	−8.5	−4.0	1.8	7.0	10.5	9.2	4.2	−1.6	7.7
68.5; 14.5	10	Melbu (Bø)	−0.8	1.6	5.2	9.3	11.5	11.5	8.0	4.1	10.1
69.0; 20.8	500	Kilpisjärvi	−10.0	−4.9	1.3	7.2	10.6	9.1	4.4	−2.6	7.8
69.0; 23.2	330	Kautokeino	−10.6	−4.1	2.9	9.7	12.4	10.2	4.8	−2.5	9.3
69.7; 27.0	110	Kevo	−11.0	−3.4	2.8	9.2	11.8	10.2	5.4	−2.4	9.2
70.2; 30.1	6	Vardø (Ekkerøy)	−4.9	−1.1	3.1	7.3	10.4	10.5	6.8	1.4	8.7