GEOGRAPHICAL REPORTS
OF TOKYO METROPOLITAN UNIVERSITY 44 (2009) 47-53

PRELIMINARY FIELD ASSESSMENT OF TREE SIZE DISTRIBUTION AT UPPER FOREST LIMITS IN FINNMARK, NORTHERN NORWAY

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Abstract The purpose of the study is to obtain a brief outlook on the influence of upper forest limits due to the recent temperature change in Finnmark, northern Norway. The forest of this region is dominated by mountain birch (*Betula pubescens*) and Scots pine (*Pinus sylvestris*). In most areas, upper forest limits are formed by trees of mountain birch at the elevation of ca. 300 m a.s.l., and in some areas Scots pine takes the place too. Former studies of the tree age structure show that trees forming forest limits germinated in warmer period of the 1940s. Recent warming can make recruits on and above the forest limits. We set five quadrat plots in July 2007 and counted individuals of tree species and measured the tree size. Many seedling and sapling were counted in the birch forest plots, but there is a clear gap in size distribution. Individuals with the height from 50 to 100 cm were almost missing maybe because of heavy reindeer grazing. Scots pine forest also shows a gap in height but it is not clear. This gap is considered to be formed during the colder period of the 1960s to 1980s.

Key words: forest limit, Scots pine, mountain birch, grazing, Norway

1. Introduction

In Finnmark region, the northern part of the arctic Norway, the area with the elevation above ca. 300 m a.s.l. and the northernmost part are treeless tundra, and the other areas are dominated by the forest of mountain birch (*Betula pubescens*) and Scots pine (*Pinus sylvestris*). This situation of vegetation had been established at least 8,000 years ago (Seppä 1998). We can find forest limits almost everywhere in this region at the relatively low elevation on mountain slopes. The tree species forming forest limits are usually mountain birch but in some places that is Scots pine.

Forest limit is a simple appearance of landscape boundary delineating forest margins on mountain slopes, but the transition mechanisms from forests to alpine zones are very complex. Körner (1998, 2003: 88-95) summarized it into five categories: stress, disturbance, reproduction, carbon balance, and growth limitation. The importance of these mechanisms varies from place to place. In Finnmark, for example, stress of frost damage and disturbance of reindeer/sheep grazing should be considered specially. These mechanisms function under the physical environment such as air temperatures, solar radiations, winds, and

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so forth. Air temperature may be a controlling environmental factor to make forest limits on mountain slopes. So we can expect that forest limits rise in warmer periods and decline in colder periods.

Surface temperature data observed at meteorological stations in this region show a great warming in early 20th century centered in the 1930s and a cooling from the 1960s to the 1980s, and another warming from the 1990s up to now (Hanssen-Bauer 2007). Holmgren and Tjus (1996) showed summer temperature in Abisko (northwestern Sweden) rose by about 1.5°C from the 1910s to the 1930s, and fell by about 0.5°C afterward. They reported saplings of Scots pine invaded into alpine zone during the 1940s and died in severe winters of the 1970s. Kullman (2001, 2002) showed the situation of Swedish mountains in detail that tree limit rose by about 100 m and saplings of mountain birch, Scots pine, and Norway spruce (*Picea abies*) rose by about 400 m. He also showed the marked decline (defoliation) of trees in tree limit zones during cool period of the late 20th century (Kullman 1997, 2005), and invasion of saplings of thermophilic tree species into subalpine zone after the 1990s (Kullman 2008). Almost the same temperature variations were observed in wide area of northern Europe. Vertical shift of forest limits due to such temperature changes is also reported. Shiyatov (2003), for instance, showed an upward shift with the rate of 4-6 m/decade for recent 90 years in the polar Ural mountains. The early 20th century warming generated upward shift of tree or forest limit in many places in the world (Walther *et al.* 2005).

The period of last 10 years' warming shows a nearly same magnitude of warmth compared with the 1930s, so that we have possibility to find some indication of the forest limit advance in Finnmark. The purpose of the present study is to find some influence of the recent temperature change in trees of forest limits by means of field assessment.

2. Method and Results

The localities of the field sites were selected in order to observe two types of the forest limits on the mountain slopes. The one is the forest limit of mountain birch, and the other is of Scots pine. The author added one more site for comparison where we can observe a mixed forest or woodland of both tree species on a horizontally flat lowland with the elevation much lower than the upper forest limit. Figure 1 shows the selected five sites; Sites-A, -D, and -E are for the mountain birch forest, site-B is for the Scots pine forest, and site-C is for the mixed forest on the coastal flat land. Before the site selection, the author firstly checked all sheets of 1:50,000 topological maps covering Finnmark region published by the Norwegian mapping authority and nominated 26 localities. Secondly, he operated an on-site inspection in July 2007 and omitted inaccessible localities and ecologically problematic localities where severe damages by outbreaks of geometrid moths were observed.

In each site, the author set a quadrat plot, and counted numbers and measured heights of tree species. The size of quadrat plots were measured in horizontal distances by using a simple mechanical transit (Ushikata Tracom LS-25) and an ultrasonic distant-measuring device (Haglöf VERTEX III) attached to a tripod but the quadrat sizes were not same due to the local topography.

The landscapes of the site-A, -B, and -C are showed in Fig. 2. The site-A is an upper limit zone of dense mountain birch forest on the northwest-facing slope of the coastal mountain Kaffetinden. The elevation of the site is ca. 200 m (by means of map-reading with a GPS receiver calibrated by an analog altimeter). The site-B represents the upper forest limit of Scots pine on the east-facing slope of the inland mountain Blærefjellet. The surface of the site is flat with some outcrops of substrate rock and erratics. The elevation is ca. 170 m. Scots pine is the dominant tree species but some mountain birch tree is found. The site-C is situated in the broad coastal flat with the elevation of ca. 20 m near the town of Lakselv. The vegetation is open woodland of Scots pine and mountain birch on the wave- like land surface of rocky whalebacks and shallow hollows covered with heath.

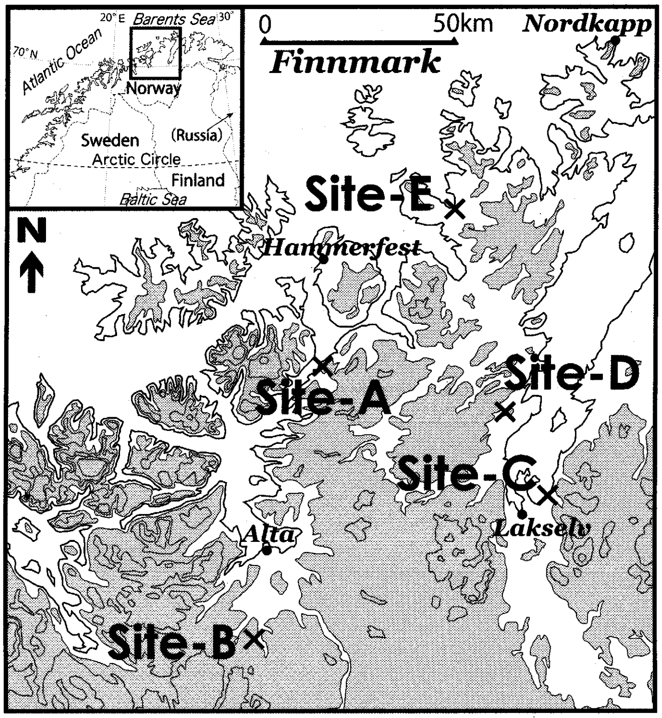

Fig. 1 Location of the study area in Finnmark, northern Norway. Contour line: 300 m intervals, shaded area: above 300 m a.s.l., site-A (70°26′ N, 23°45′ E, 200 m a.s.l.), site-B (69°48′ N, 23°14′ E, 170 m a.s.l.), site-C (70°05′ N, 25°11′ E, 20 m a.s.l.), site-D (70°17′ N, 24°57′ E, 350 m a.s.l.), site-E (70°52′ N, 24°42′ E, 100 m a.s.l.).

Fig. 2 Views of two forest limits and an open woodland (Photos: July 2007). (A) Site-A: mountain birchdominated forest limit on the northwest-facing slope, ca. 200 m a.s.l., (B) Site-B: Scots pine dominated forest limit on the east-facing slope, ca. 170 m a.s.l., (C) Site-C: woodland of Scots pine and mountain birch on the coastal terrace-like flat surface, ca. 20 m a.s.l..

Figure 3 shows the height distribution of tree species in quadrat plots of above three sites. The 30 x 30 m plot of the site-A for the trees taller than 1.0 m shows a mixture of many sizes of birch trees (top, right). However, the inset 10 x 10 m plot for individuals shorter than 1.0 m shows the abundance of the seedling size individuals and the absence of saplings with the height taller than 60 cm (top, left). On the other hand, the 40 x 20 m plot of the site-B for the trees taller than 1.0 m indicates that the number of relatively short (therefore young) Scots pine trees is smaller (middle, right). The inset plot of 20 x 20 m for saplings of Scots pine shows the absence of individuals taller than 40 cm (middle, left). The bottom two panels show the woodland of Scots pine and mountain birch. No marked gap in height distribution is found.

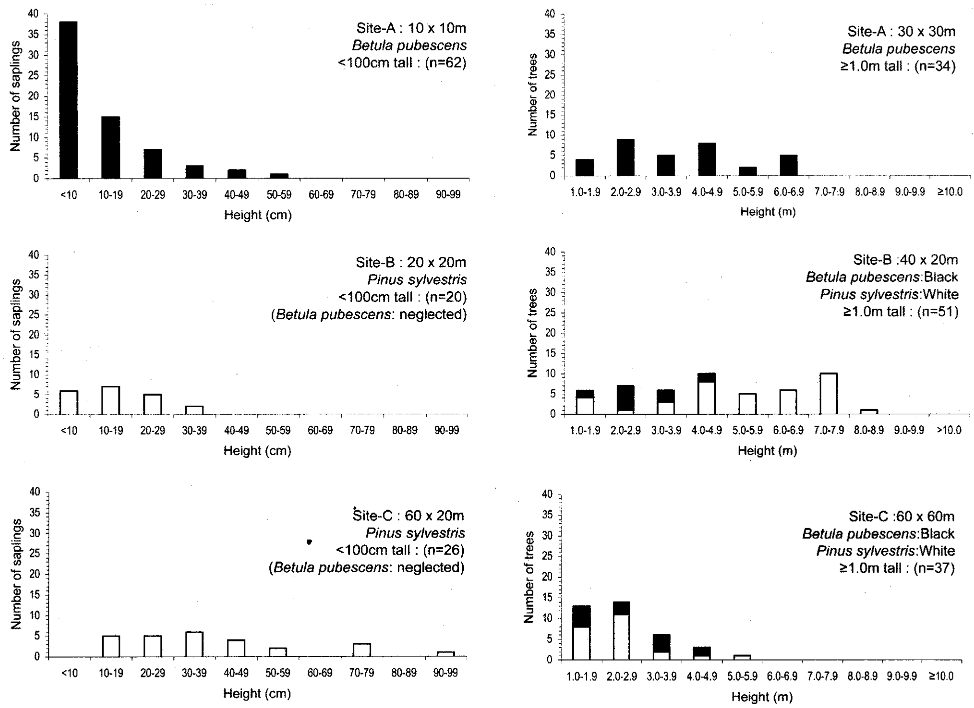

Fig. 3 Size distribution of the dominant tree species in quadrat plots at sites-A, -B and -C. The left three panels show the distribution of height shorter than 100 cm, and the right panels show taller than 1.0 m. The horizontal sizes of quadrat plots showed in the corners of panels are not same because of the local topography. The smaller plots of left panels for sapling counting are insets of the larger ones of right panels.

In order to pay special attention to the grazing and browsing by reindeers and sheep, two sites of the upper forest limit of mountain birch were added (Fig. 4). The site-D is located for a low grazing pressure example on the south-facing steep slope of the isolated mountain Stuorra Jœkkir. This site is a lower part of the steep slope covered with debris due to snow avalanches, and fringed by very wet mire with some earth hummocks in the downslope direction. The author thinks that this situation prevents summer grazing and winter herding. On the other hand, the site-E was selected for an example of heavy grazing. This site is a very gentle southwest-facing slope of the coastal mountain Bakkačåk'ka. A 30 x 30 m quadrat plot was set at each site and all individuals of tree species taller than 1.0 m were counted. In the site-D, the author found some rowan (*Sorbus aucuparia*) trees that sometimes occur at forest limits in northern Europe (Crawford 1989: 95).

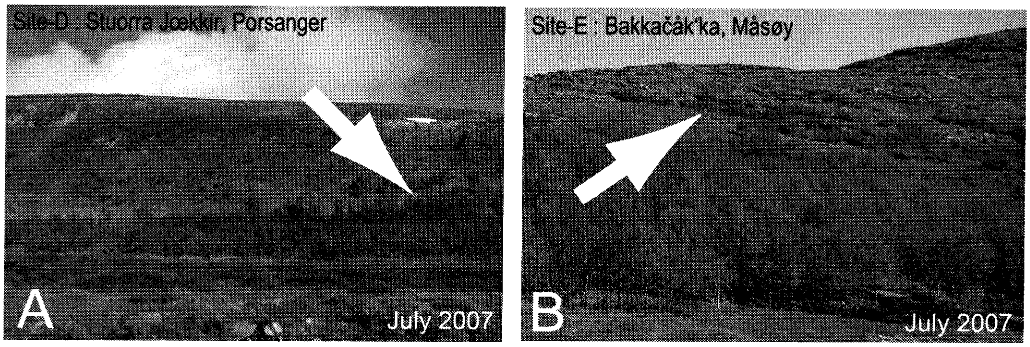

Fig. 4 Distant views of site-D and site-E (Photos: July 2007). (A) Site-D: mountain birch dominated forest limit on the south-facing slope, 350 m a.s.l., (B) Site-E: mountain birch forest limit on the southwest-facing slope, 100 m a.s.l.. Arrows show the positions of quadrat plots.

Figure 5 shows the height distribution of the both sites. The site-D (left) has no remarkable peak but shows fairly even frequencies. Some birch trees have the height of about 9 m, this size is very high for this region. The number of trees shorter than 3 m is small. The site-E (right) shows a striking feature of height distribution. The most trees have nearly same heights of about 2 or 3 m. We cannot find any saplings with the height shorter than 2 m in and around the quadrat plot. Moreover the author observed only a few seedlings losing most leaves maybe by the reindeer browsing in the quadrat plot of the site-E.

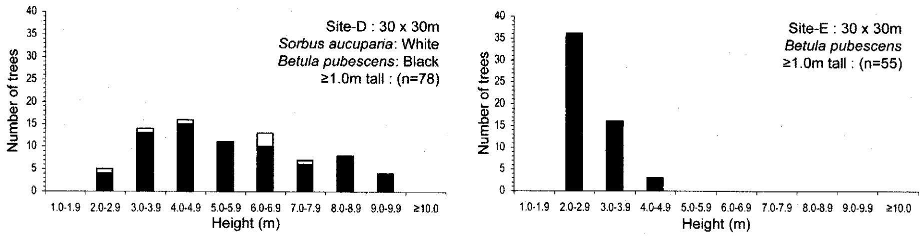

Fig. 5 The size distribution of trees in quadrat plots across the forest limits at sites-D and -E. Left: site-D, right: site-E. Plot size is 30 x 30 m in horizontal distances. All individuals of tree species taller than 1.0 m were counted.

3. Discussion

The mountain birch forest of the site-A shows absence of saplings with the height from 60 to 100 cm (Fig. 3 top). One possible cause for this absence is that the saplings had been eaten up by reindeers during some period in the past. This heavy grazing had already finished because we can find plenty of seedlings and short saplings. Skonhoft (1998) reported that the number of half-domestic reindeer in Finnmark showed its maximum in the 1980s and overgrazing situation had occurred. However, the author could not get more precise statistics on the local population of reindeers. Another possibility is that the cool period from 1960 to 1980 caused germination and growth failure. The mountain birch around the forest limit in this region needs about 45 years to grow up to about 2 m tall, and the most of the individuals germinated during the warm period from the 1930s to the 1950s (Dalen and Hofgaard 2005). These information about growth rate and age structure support the possibility. The low temperature period also affects Scots pine forests, therefore the similar gap in the height distribution of Scots pines at the site-B (Fig.3 middle) can be explained by the same reason. The author considers that the low frequency of saplings with the height from 50 to 100 cm at the site-C (Fig.3 bottom) is also explained in the same way.

In heavy grazing areas, trees of mountain birch tend to show a unique form. Oksanen *et al.* (1995) stated that heavy summer grazing of reindeer and sheep made the birch trees in forest limit zones into relatively large monocormic forms with leaves only above the ground by about 2 m. Helle (2001) stated that the form of forest under the high pressure of reindeer grazing shows the savanna-like woodland and the size or age of birch trees is even. The site-E looks like such conditions.

In this work of preliminary assessment, the influence of recent warming from the 1990s to the present was not found at all. Moreover, the severe defoliations of mountain birch stands caused by outbreaks of caterpillars of geometrid moth were observed in many places on the upper slopes of mountains especially in the southern part of Finnmark region. On the other hand, the previous great warming in the early 20th century and the cooling from the 1960s to the 1980s left a maximum and a minimum in tree height distribution respectively.

Acknowledgment

I would like to dedicate this paper to Professor Shuichi Oka in commemoration of his retirement from Tokyo Metropolitan University, he showed me a guide to the world of vegetation science when I was one of his undergraduates. This study was supported by a research grant from Institute of Humanities, Meiji University. I thank Mr. Takushi Koyama and Mr. Kazuyuki Iizuka (graduate students of Meiji University) for their helpful assistance during the fieldwork in Norway.

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