Differences in the vertical distribution pattern of *Betula pubescens* in Norway and its ecological significance

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Summary

Several factors influence the altitudinal position of the climatic forest-limit. In addition to variations due to different "forest-limit" definitions, topographic factors are very important. In Western Norway, a range of slope steepness between 10 and 60° has been found to result in a 100 m difference. The differences between S and N aspect are regionally very variable. The difference is greatest (>150 m) in the middle fjord areas of Western Norway. It decreases towards areas with an oceanic climate (coastal areas), and towards areas with increasing aridity (interior Fennoscandia). For different parts of Norway the altitudinal position of the forest limit is discussed in relation to four summer temperature variables, extracted from meteorological stations. The results support the idea that the forest limit is mainly regulated by summer temperatures. Correlations between the altitudinal position of the forest limits and interpolated values of the different summer temperature variables indicate that maximum values rather than mean monthly temperatures are decisive. Temperature conditions at the forest limits are not constant all over Norway with regard to July mean or the mean temperature of the three warmest months. They show an increasing value towards oceanic areas. The July mean maximum and the mean maximum of the four warmest months at the forest limit are fairly constant everywhere. The *Betula pubescens* forest limit is significantly correlated with the isotherms of 15.8°C for the mean maximum temperature of the warmest month (July), and of 13.2°C for the mean maximum temperature for the four warmest months (June-September). Consequently, if the birch forest-limit is being used as a summer temperature indicator, mean maximum temperatures rather than mean temperatures should be applied.

Zusammenfassung

Verschiedene Faktoren beeinflussen die Höhe der klimatischen Waldgrenze. Abgesehen von der Frage der Waldgrenzdefinition kommt der Topographie wesentliche Bedeutung zu. In Westnorwegen schwankt die Höhenlage der Waldgrenze in Abhängigkeit von der Hangneigung (10° bis 60°) um 100 m. Der Einfluß der Exposition variiert regional stark. In den mittleren Fjordgebieten verursacht sie die größten Differenzen (>150 m). Diese nehmen zur Küste hin aufgrund größerer Ozeanität und zum Inland hin aufgrund größerer Trockenheit ab. Für verschiedene Regionen Norwegens wird die Höhenlage der Waldgrenze hinsichtlich ihrer Beziehung zu vier Sommertemperaturvariablen diskutiert. Die Resultate stützen die Vermutung, daß die Höhe der Waldgrenze hauptsächlich von der Sommertemperatur bestimmt wird. Die Korrelationen zwischen Waldgrenze und interpolierten Sommertemperaturparametern zeigen, daß eher Maximaltemperaturen als Monatsmittel entscheidend sind. Die Temperaturbedingungen an der Waldgrenze sind in Bezug auf die Mittelwerte des Juli bzw. dreier Sommermonate nicht über ganz Norwegen gleich. Die Werte steigen zur Küste hin an. Die mittleren Maxima des Juli und der vier wärmsten Monate dagegen sind an der Waldgrenze überall ziemlich konstant. Die Waldgrenze der Birke, *Betula pubescens*, korreliert signifikant mit der 15.8°C-Isotherme des mittleren Julimaximums, und der 13.2°C-Isotherme des mittleren Maximums der vier wärmsten Monate (Juni-September). Die Lage der Birkenwaldgrenze ist daher eher als Indikator für mittlere Maxima als für einfache Mittelwerte der Sommertemperatur anzusehen.

1. Introduction

The position of the forest-limit is commonly used as an important boundary in biotic and phytogeographical zonations, and presence or absence of birch is often used as a climatic indicator both in recent and palaeocological studies (PAYETTE, 1983). In Fennoscandia special attention has been paid to the alpine and arctic *Betula pubescens* forest-limits, both of which are regarded by most phytogeographers as the northern or altitudinal boundary of the Boreal zone (e.g. AHTI et al., 1968). The main distributional pattern of birch is fairly well known in Fennoscandia, both horizontally and vertically (AAS, 1964). However, investigations have shown that there may be major local variations in the altitudinal position of the forest limit. These are generally associated with factors such as topography, soil, climate, or cultural influence. Different opinions as to the definition of the forest limit may also be significant (HUSTICH, 1966; AAS, 1969; TRANQUILLINI, 1979).

The appearance of the uppermost forest zone is very varied. The forest may reach its upper limit as a closed stand, and cease abruptly as a sharp line. It may also, however, gradually dissolve from a dense high stand to isolated trees and finally to stunted individuals. This has led to different opinions as to which limit, i.e., with or without a transition zone with single trees and krummholz, represents the natural situation uninfluenced by man. One theory suggests that the gradual opening of the stands results from declining growth conditions and survival with increasing altitude. Isolated trees receive more light and heat, ensuring greater productivity than is possible in the closed stands. They are therefore capable of existing above the stand. A consequence of trees standing in isolation is winter damage. According to this argument, a transition zone (ecotone) would be a natural condition. The alternative theory states that wherever a single tree occurs a closed forest can also exist. Thus wherever soil and topography allow, the forest will continue as a closed stand up to its upper limit (TRANQUILLINI, 1979:1).

In Fennoscandia, most authors dealing with forest limits maintain that there is a gradual opening of the forest canopy and consequently a broad forest-limit ecotone towards the alpine zone. Consequently, there have been many opinions about how to define the forest limit. Different definitions have been proposed by HUSTICH (1966), DAHL (1986), MORK (1968), AAS (1969), KULLMAN (1981:100), TUHKANEN (1980:66), and PAYETTE (1983:5).

The vertical difference between the tree and forest limits may vary. According to TENGWALL (1920:289), NORDHAGEN (1928:46), VE (1930:37, 1940:85), KILANDER (1955:53) and AAS (1964:25), this difference is very small, from 10-25 m. However, in areas with much snow, the difference may be 75 m. KULLMAN (1983:32) has shown that the tree limit fluctuates in parallel with the forest limit, and the mean differences are 36.3 and 54.1 m respectively for west- and east-facing sides of the Handölan valley. The differences were, however, clearly greater in the northernmost part. The forest limit here was probably depressed by snow accumulation. A review of data on the difference between tree and forest limits for different parts of Fennoscandia is given by ODLAND et al. (1992).

Both WARDLE (1971:371) and TRANQUILLINI (1979:111) maintain that outliers of single trees or small stands and krummholz above the closed forests are due to a favourable microclimate. KULLMAN (1983:32) shows that in snowy areas the forest limit, in particular, may be depressed, and the vertical distance between the tree and forest limits may be larger. Therefore, in this case the tree limit may be a better indicator of the thermal component of the climate than the forest limit. In general, however, the forest and tree limits seem to run fairly parallel, and the difference is, in most cases, less than 40 m.

It is generally accepted that tree growth is regulated by summer temperature conditions, though many other external factors can be locally important. WARDLE (1974) suggests that: "... timberline is the sharpest temperature-dependent boundary in nature." Thus many climatologists and phytogeographers have attempted to discover a general climatic indicator that defines the location of the forest limits. It has been generally accepted that the birch forest-limit is correlated with the 10°C isotherm for the warmest month, but also correlations with other climatic variables have been established (cf. GRIGGS, 1946; TUHKANEN, 1980; ARNO & HAMMERLY, 1984:28; TRETER, 1984). Others, e.g. BROCKMANN-JEROSCH (1913, 1919) and DAUBENMIRE (1954, 1956) suggest that timber lines are more closely related to the isotherm representing the mean of daily maximal temperatures in midsummer than to any other temperature variables.

The importance of topography and aspect was particularly emphasized by SHREVE (1924:128) who stated: "Regions of rugged topography in the temperate latitudes of both the northern and southern hemispheres exhibit an almost unfailing dissimilarity in the character of the vegetation occupying slopes of different orientation. - In regions of extreme aridity such dissimilarity is not to be found, and in regions which are extremely moist it is either poorly marked or else obscured by the difference between the vegetation of valleys, slopes and ridges. In all localities the vegetational differences due to the orientation of the surface are most marked when contrasted for slopes facing south, or slightly west of south, and due north, or slightly east of north. The influence of slope exposure on vegetation is most conspicuous in regions with intermediate moisture conditions, or regions with great seasonal fluctuations."

The main aims of the present investigation are to describe and quantify local and regional differences in the altitudinal position of the birch forest-limit in Norway and to discuss these differences in relation to ecological factors.

2. Methods

The investigation is based on measurements of the altitudinal position of the birch forest-limits in different areas of Norway (with a THOMMEN altimeter with a ±10 m accuracy). Special emphasis has been put on local altitudinal differences between slopes with different aspects. In addition, other available published data have also been used.

In this paper the term "forest limit" follows the definitions of FRIES (1913), RESVOLL-HOLMSEN (1918:140), NORDHAGEN (1943:18), and AAS (1969:120). This limit is defined as an imaginary, theoretical line drawn between the uppermost forest tongues or isolated stands. This line should coincide with the climatic forest-limit (SMITH, 1920) and it is assumed to lie where macro- or local-climatic factors prevent further forest growth. It is thus a potential forest-limit, and it does not always coincide with the empirical forest-limit, which is often determined by other factors than summer temperature, such as avalanches, wind, unfavourable topography, grazing and other disturbances.

Climatic data are based on temperature measurements from the nearest meteorological station (DNMI, 1982) and BRUUN (1967). A lapse rate of 0.57°C per 100 m has been used for all interpolations and extrapolations. LAAKSONEN (1976) calculated the general lapse rate in Fennoscandia based on 612 meteorological stations situated between sea level and 2062 m a.s.l. Regression analyses (between altitude and mean July temperature) gave a highly significant correlation (mean 0.569±0.014°C, r^2=0.899). This is, however, a simplification for ecological purposes, since the lapse rate may vary in relation to topography, regional climatic character, from month to month, different altitudinal span, and for different temperature variables (e.g. MOOK & VORREN, 1996).

3. Results

3.1 Local differences due to aspect

In order to describe the local variations in the position of the climatic forest-limit, case studies have been carried out within the valleys Røldal and Valldal, situated in the eastern part of Western Norway (ODLAND, 1981). Here 64 forest stands, interpreted as climatic forest-limits, representing different aspect and slope have been measured. The main results are given in Table 1 and Figure 1. The results show that locally there may be substantial differences between the altitudinal position of the forest limit. The general trend is a significant decrease from slopes with a SW to a NE aspect, which in these valleys averages approximately 125 m. For sites with the same aspect, the differences may be 100 m in vertical direction. This variation is mainly associated with slope steepness. The lowest values are found on moderately sloping hillsides (10-20°), while the highest values represent very steep hillsides or cliffs with a slope of 45-60° or more.

Table 1 Mean values for the the altitude of forest limit (Alt in m), standard deviation (SD), and number of measurements (n) in Røldal and Valldal measured at different aspects

	Røldal			Valldal		
	Alt	SD	n	Alt	SD	n
1: SW	967	22	10	1050		1
2: S	969	29	7	1040	14	2
3: SE	902	33	5	1000	42	2
4: W	901	25	10	984	8	4
5: E	872	13	5	950		1
6: NW	863	6	3	915	21	2
7: N	838	30	5	925	35	2
8: NE	845	13	4			

3.2 Regional differences between S and N aspect

The pattern of altitudinal differences between south- and north-facing slopes has been investigated from west to east in Western Norway. For each area investigated, the altitudinal difference is plotted in relation to its distance from the coast in km.

This pattern is shown in Fig. 2. The relationship is not linear, and the data are fitted to a quadratic regression model. The largest differences (mainly between 100 and 150 m) are measured within the central fjord areas of Western Norway, and from there decrease in all directions. The smallest differences (often less than 20 m) are measured in coastal areas.

3.3 Differences in the altitudinal position of the forest-limit from west to east within Western Norway

Along the coast-interior gradient, the vertical limit of *B. pubescens* forests (Alt) is plotted against distance (D) from a coast reference line (c.r.l.). 79 sites have been investigated, and the correlations are shown in Figure 3. The data show that the forest limit gradually rises from the coast to the interior.

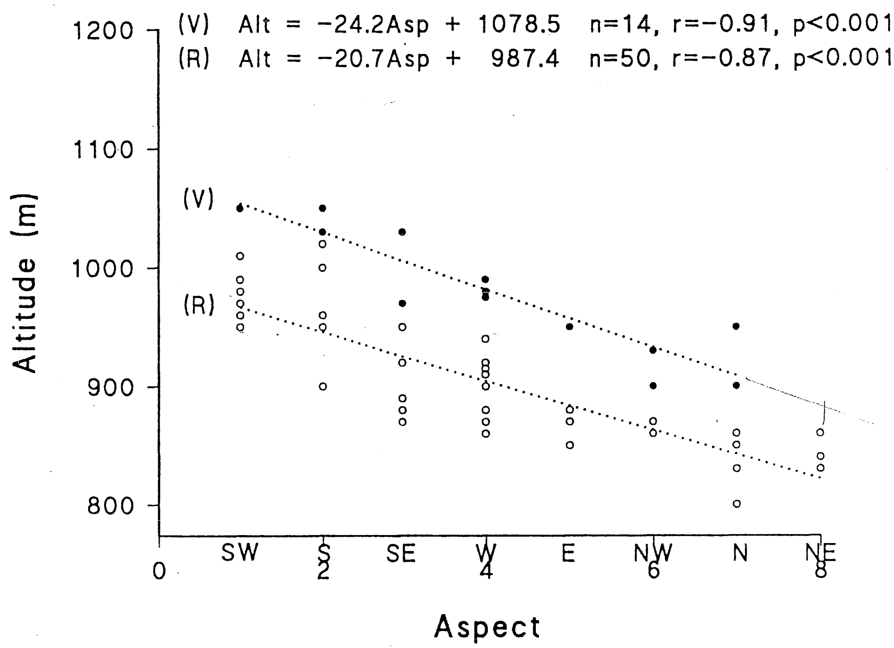


Fig. 1 Variation in the altitudinal position of the forest limit at different aspects within the Røldal (R) and Valldal (V) areas, Western Norway. Given aspect values from 1 (SW) to 8 (NE), correlation and regression analyses indicate a significant linear relationship between aspect and altitude

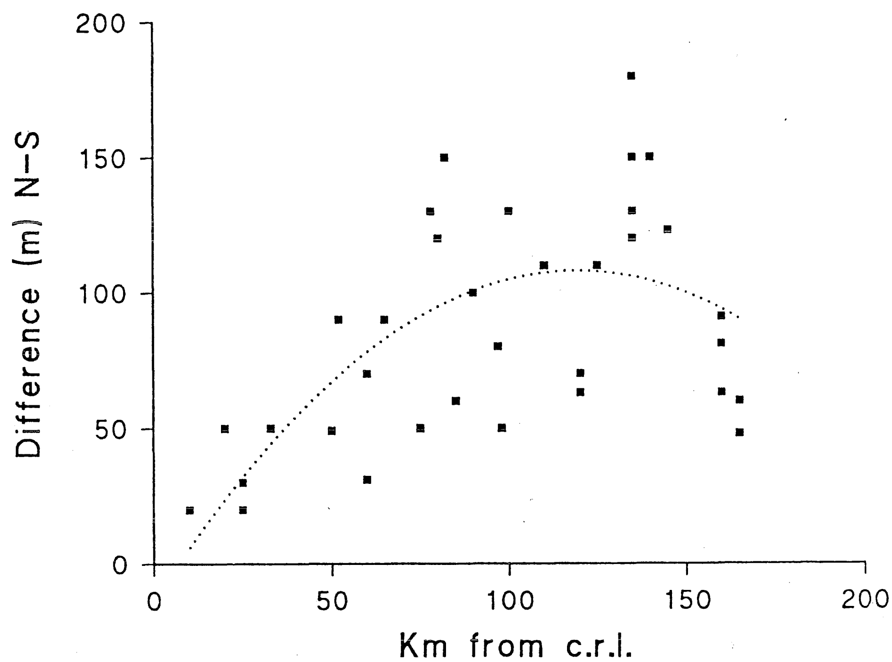


Fig. 2 Variation in the altitudinal difference between the forest limit on north- and south-facing slopes in relation to distance from the coastal reference line (c.r.l.). The data indicate a non-linear relationship, and a quadratic regression model has been fitted

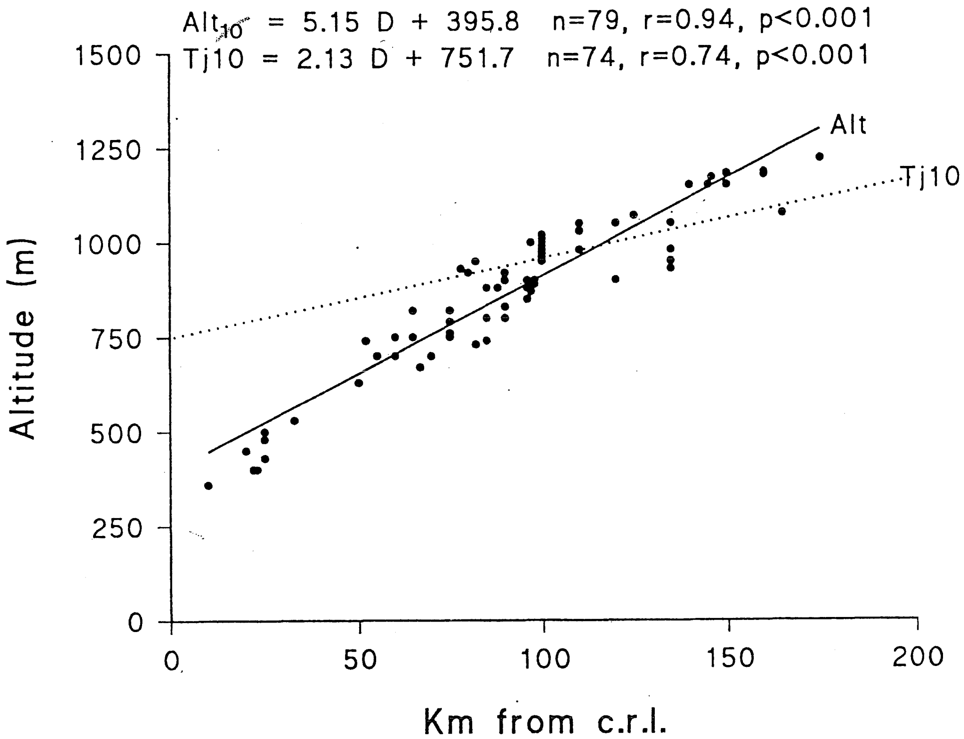


Fig. 3 Position of the forest limit (Alt) is plotted against distance from the coastal reference line (c.r.l = D) and fitted to a linear model. This shows a significant linear relationship as shown by the regression equation. The altitudinal position of the 10°C July isotherm has been calculated for 74 meteorological stations in Western Norway and related to distance from the coast. The equation is shown and the regression line (Tj10) is drawn

In order to compare the position of the birch forest-limit with summer temperatures, data are interpolated from meteorological stations in Western Norway. The forest limits are compared with isotherms for Tj=10°C (altitudes where the mean temperature of the warmest month Tj equals 10°C). The altitudinal position of this isotherm (Alt_{10}) can be calculated for every station by using the equation

$$Alt_{10} = Alt_x + \frac{(Tj_x - 10)}{0.57} \, 10^2$$

where Tj_x is the mean temperature of the warmest month and Alt_x is the altitude (in m) of the actual meteorological station.

Alt_{10} for each station has been related to the distance from the coast reference line, and regression analysis gives an equation shown in Figure 3. Comparison of the two regression lines shows that the slope gradient for the birch forest-limit is much steeper than for the 10°C isotherm. Consequently, in coastal areas the birch forest does not "reach" the 10°C isotherm, while in eastern areas birch forests occur "above" this isotherm.

3.4 The relation between the altitudinal position of birch forests and different summer temperature variables

The investigation is based on forest-limit measurements from 59 localities in different areas of Norway (cf. MOE & ODLAND, 1992). For each area the altitude of the forest limit has been related to 1: Mean temperature of the warmest month (July) (Tj), 2: mean maximum July temperature (Tmj), 3: mean maximum temperature for the four warmest months (June-September) (Tmjs), and mean temperature for the three warmest months (June-August) (T3), all reduced to sea level. The position of the birch forest limit can be given as linear functions of these temperature variables:

(1)	$Alt_{Betula} = 255.7\ Tj - 3174.3$	$n = 59, r = 0.92, p<0.001$
(2)	$Alt_{Betula} = 141.1\ Tmj - 2068.6$	$n = 59, r = 0.89, p<0.001$
(3)	$Alt_{Betula} = 124.1\ Tmjs - 1416.8$	$n = 59, r = 0.87, p<0.001$
(4)	$Alt_{Betula} = 209.4\ T3 - 2181.5$	$n = 59, r = 0.90, p<0.001$

The regression analyses show highly significant correlation coefficients, which indicate that all investigated summer temperature variables are highly correlated with the altitudinal position of the forest limit. However, the regression lines do not run parallel. Tj and T3 give a steeper slope gradient than Tmj and Tmjs (Fig. 4).

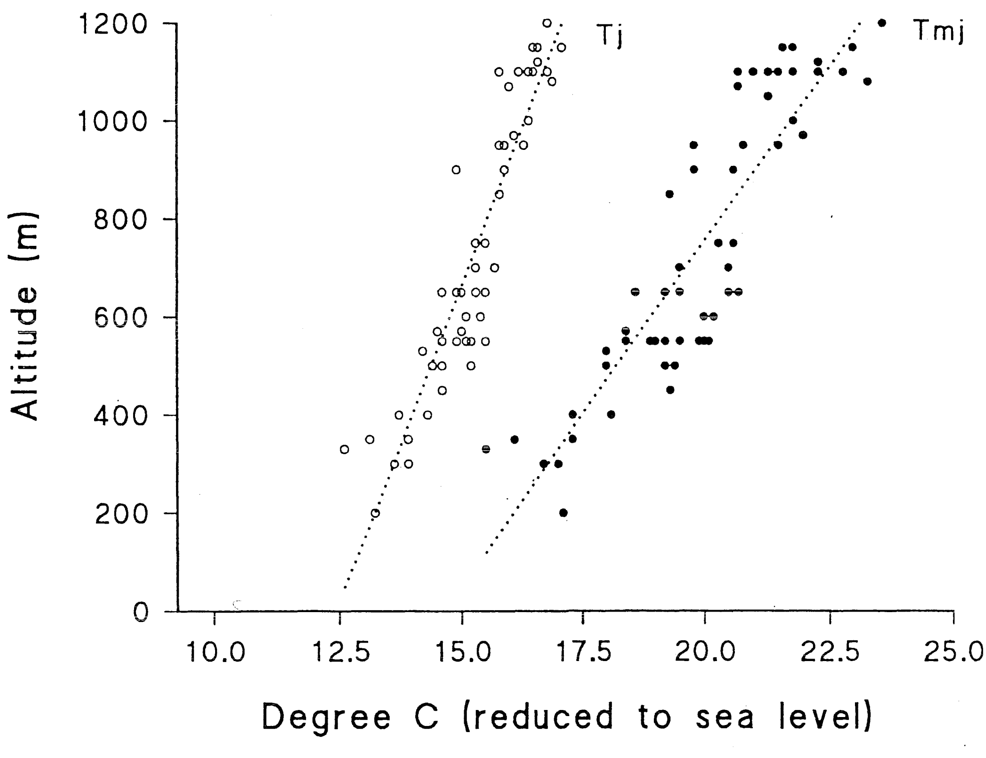


Fig. 4 The altitudinal position of the birch forest limit in 59 investigated areas has been plotted in relation to two temperature variables (reduced to sea level). The mean temperature of the warmest month (Tj) and the mean maximum temperature of the warmest month (Tmj) show both significant linear relationship with the altitude of the forest limit, but the regression lines are not parallel

3.5 Temperature conditions at the forest limit

Mean values for the temperature variables at the forest limit (± standard deviation) are: Tj=11.2±0.8, Tmj=15.8±0.9, T3=9.8±0.7, and Tmjs=13.2±0.9°C.

Assuming that temperature is critical for the vertical distribution of birch forests in Norway, we should expect the different temperature variables to be fairly constant at the forest limits all over Norway (DAHL, 1986:38). This hypothesis has been tested by linear regressions. The values for four different temperature variables, interpolated to the forest-limits have been calculated, and related to the actual forest-limit level with linear regression analysis. The relationships are shown in Figs. 5a-d. These results show that for Tj and T3 the hypothesis must be rejected, i.e the temperature conditions are not equal at the forest limits all over Norway. In fact, in areas where the forest reaches its highest levels (continental areas), the Tj, and T3 values are 1-2°C lower than in areas where the forest limits are situated at low altitudes (oceanic areas). Regression of Tmj, and Tmjs values at the forest limits with the actual level of the forest limit give very low, non-significant correlations. This shows that the Tmj, and Tmsj values at the forest limits are fairly constant all over Norway. There is no tendency for lowering the Tmj value with increasing altitudinal forest-limit.

4. Discussion

Forest-limit measurements are available from different parts of Fennoscandia. TOLLAN (1937), EKRHEIM (1935:49), and KNABEN (1950:44) found that the altitudinal difference between the forest limit on north- and south-facing slopes is small in oceanic areas. It has also been pointed out that the forest limits are higher on west-facing slopes than on east-facing (MORK, 1968; PERTTU, 1972; ØKLAND & BENDIKSEN, 1985).

In northern Fennoscandia the difference related to aspect is mostly reported to be less than 30 m (FRIES, 1913, 1921; FRÖDIN, 1916; HUSTICH, 1937; KALLIOLA, 1939; KALLIO & MÄKINEN, 1978; WISTRAND, 1981). In the eastern part of Western Norway and in Central South Norway the differences are, in most areas, reported to be 60-80 m (RESVOLL-HOLMSEN, 1920; VE, 1930, 1940; NORDHAGEN, 1943; MORK, 1968; AAS, 1969; ØKLAND & BENDIKSEN, 1985).

Within the central mountains of Sweden, SMITH (1920) measured the altitudinal position of the birch forest-limit, on different aspects on several mountains. The forest limit lies mostly between 800 and 900 m a.s.l. on south-facing slopes. For 14 mountains, the mean difference between south- and north-facing slopes was calculated to 30.3 m, with a standard deviation of 22.3 m. SALISBURY (1926:322) maintains that in the Alps, the limits for the dominant species are often from 150 to 200 metres higher on south-facing slopes compared to north-facing slopes.

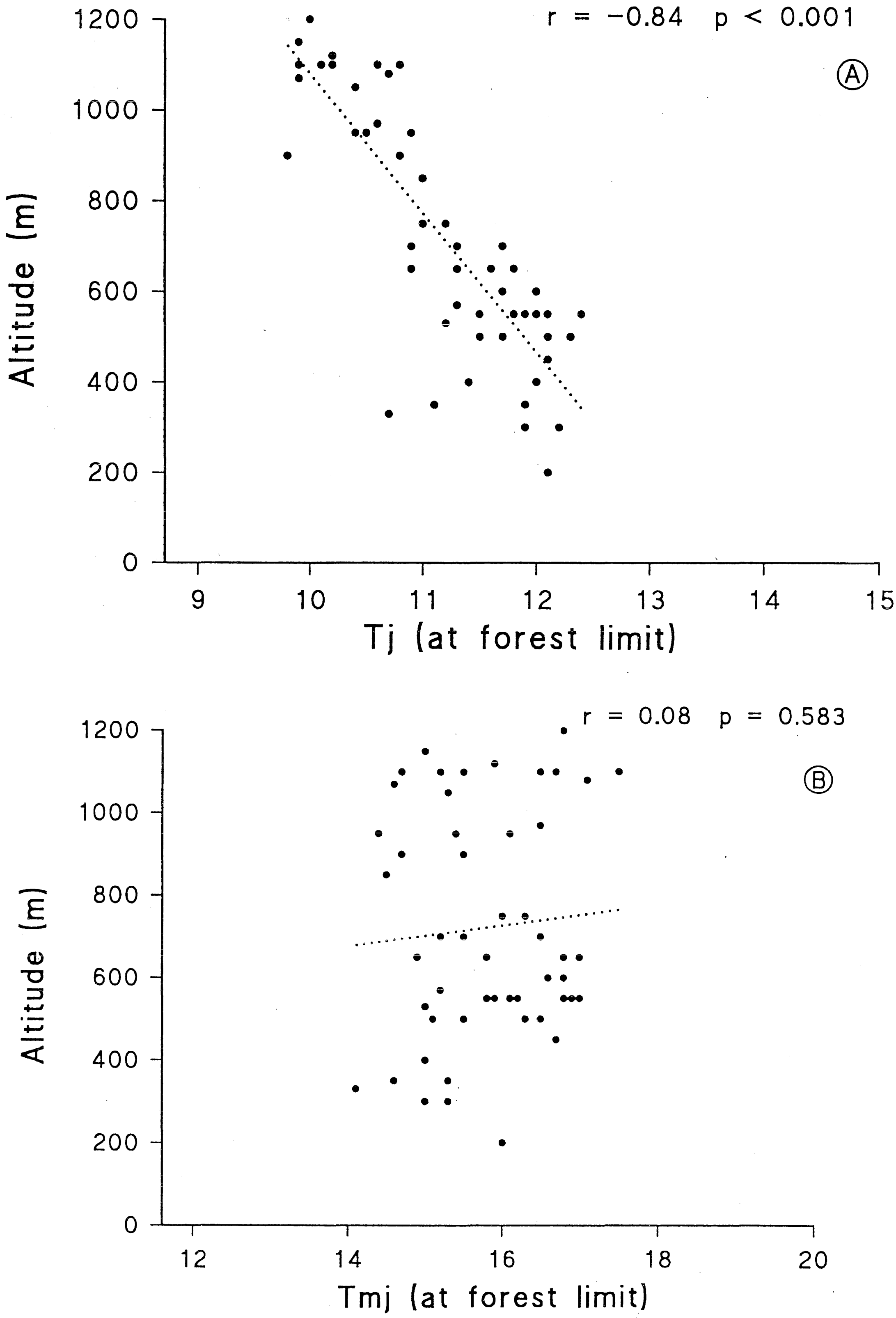
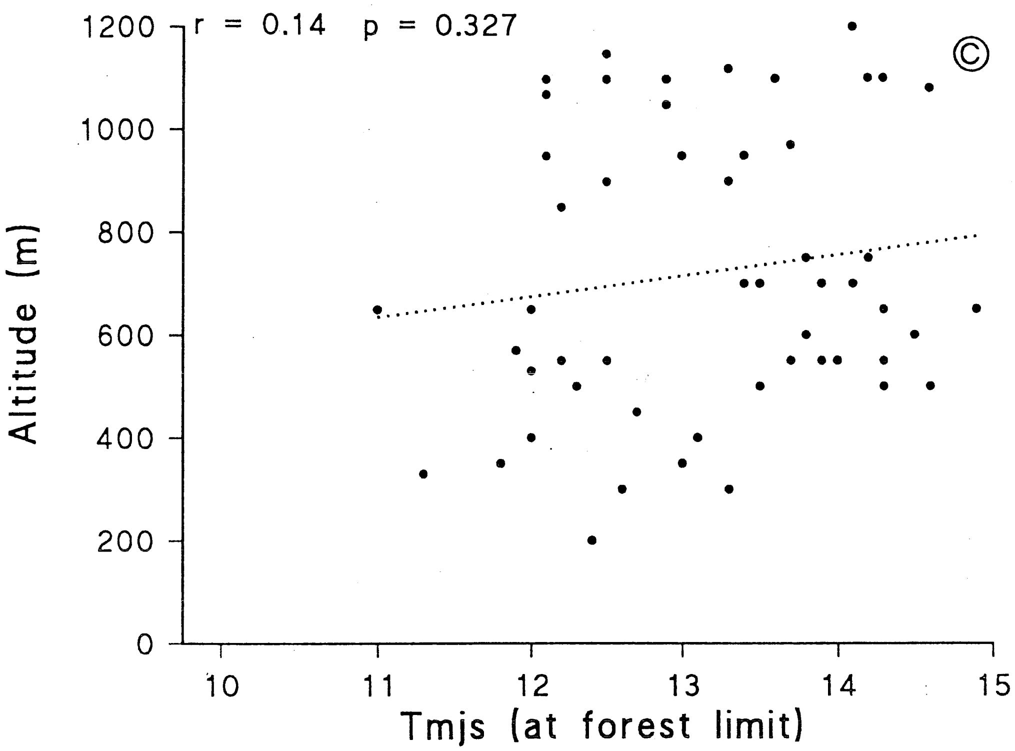


Fig. 5 Relation between the altitudinal position of the birch forest limit within 59 areas all over Norway, and mean temperatures at the forest limit. A) Mean temperature of the warmest month (Tj), B) mean maximum temperature of the warmest month (Tmj)



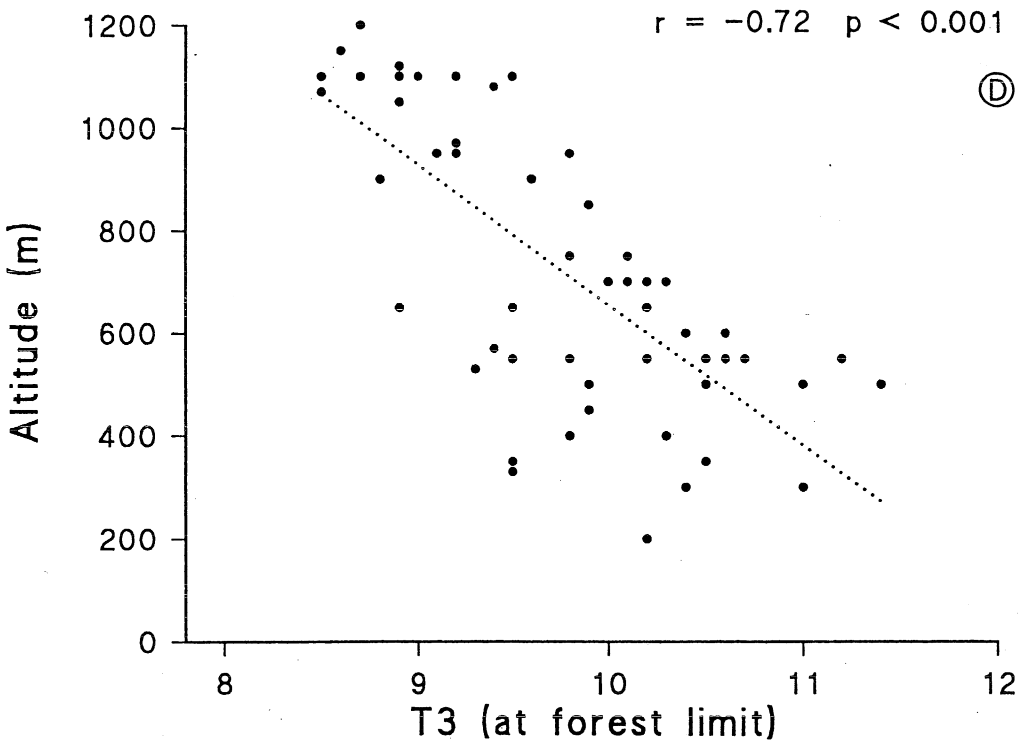


Fig. 5 (continued) C) mean maximum temperature during the period June-September (Tmjs), D) Mean temperature for the three warmest months (T3). The figure shows that Tj and T3 are significantly negatively correlated to the position of the forest limit, indicating that this temperature variable is not equal at the forest limit all over Norway, while Tmj and Tmjs are fairly constant

The results of this investigation support the idea of SHREVE (1924) that general macro-climatic conditions (oceanity, humidity, and continentality) are highly associated with the differences between north- and south-facing slopes, and BARRY & VAN WIE (1974:76) who state that slope angle and aspect are the key determinants of topo- and microclimates which give major differences especially between north- and south-facing slopes.

Many climatologists and phytogeographers have attempted to discover a general climatic index that would serve to define the location of forest or tree lines, and they have been almost unanimous in assuming from the outset that this must be a thermal limit of some kind. Forest limit/temperature isotherm relations, based on temperature interpolations, have been investigated by several authors (see TUHKANEN, 1980:66; TRETER, 1984), and often good correlations are found. There are, however, several sources of error associated with such methods (MORK, 1968; TUHKANEN, 1980:94; CARTER & PRINCE, 1985), and even the best correlation does not give a satisfactory explanation of causes for the forest-limit phenomenon. Causal analysis is best attained by continuous observations and monitoring of the life processes of the trees in relation to measured changes in environmental factors (cf. GROSS, 1989).

The oldest and best known climatic indicator for the polar forest-limit, is the 10°C isotherm for the warmest month (July) (KÖPPEN, 1919). In Scandinavia, several botanists have maintained that mean July temperature is the reliable, single indicator for climate/forest-limit correlations (HUSTICH, 1966:41; TUHKANEN, 1980:11).

OHSAWA (1990) investigated latitudinal patterns of forest limits in south and east Asian mountains, and found that forest limits were most correlated with the mean temperature of the warmest month (Tj) (maximum values were not investigated). In Japan, China, and Nepal the temperature at the forest limits varied between 8.3 and 13.9°C (using a lapse rate of 0.6°C). The general pattern was that areas which had the lowest Tj value at the forest limit had a relatively high mean value for the coldest month (-5.0°C), while in areas where the Tj value was highest, the mean temperature for the coldest month was low (-17.9°C). MALYSHEV (1993) investigated correlations between the arctic forest limit and mean temperatures of the warmest month (Tj) in eastern Europe and Siberia. He found a mean July temperature of 11.2±1.2°C for the arctic forest-limit, and also a duration of the growing season of 128 days with stable temperature of the air exceeding 0°C, amounting to a temperature sum of 876°. Along the relatively humid Appalachian Mountains of eastern North America, COGBILL & WHITE (1991) found that the July temperature at treeline varied from 11.8 to 13.8°C (mean 12.9°C). All these results show that forest limits elsewhere in the world are generally correlated with a Tj value around 10°C, but with some variation due to the general climatic character.

There has been some criticism of the use of mean monthly temperatures in this connection. BROCKMANN-JEROSCH (1913, 1919) suggested that the forest limit stretches further north in continental areas than in oceanic areas, crossing the 10°C isotherm for the warmest month in the continental regions. It is maintained that forest limits are obviously more related to the daily maximum temperatures during the day than to the daily mean temperature (BROCKMANN-JEROSCH, 1913, 1919; FRÖDIN, 1916; DAUBENMIRE, 1954, 1956; MORK, 1968; PERTTU, 1972; RETUERTO & CARBALLEIRA, 1992). This observation is supported by the present investigation, cf. Figure 3.

The temperature data calculated for each forest-limit position are relatively crude estimates due to errors connected with local variations in the lapse rate. This can, in part, explain the relatively large standard deviations (0.7-0.9°C) of the mean values. Despite these sources of errors, the results are in accordance with more detailed local investigations. For example, experiments at Hirkjølen (Eastern Norway: MORK, 1968) have shown that the climatic forest-limit is determined by summer warmth and the length of the growing season. MORK proposed that mean maximum temperature gives a better estimate of the heat effect than the mean temperature. For *Betula pubescens* and *Picea abies* respectively, the mean maximum air temperature was measured to be 13.3 and 14.0°C during June-September, and the mean July temperature was 8.4 and 9.3°C (MORK 1968). BERGAN (1974) found that the mean maximum temperature for the period June - September at the forest limit, was nearly the same (12.1°C) in both coastal and interior areas of Troms, Northern Norway. For two mountains in Lule Lappmark FRÖDIN (1916:20) has given the following values for the temperature conditions at the birch forest-limit: 12.5 and 11.6°C for the mean June temperature, 10.7 and 10.0°C for the mean temperature during the period May 12 to August 31, and 13.8 and 12.8°C for the mean maximum temperature for the same period.

The effect of topography on local- and microclimate explains much of the altitudinal variation in forest limit. (1) The heat effect or "growing units" (MORK, 1968:578) is much higher in continental areas than in oceanic areas even though they have the same July mean. This is because the temperature amplitude during day and night is much greater in a continental climate (FRÖDIN, 1916:21; BROCKMANN-JEROSCH, 1919:69). (2) Local climatic investigations show that the summer temperatures are much higher on south-facing than on north-facing slopes (CANTLON, 1953; GEIGER, 1966; UTAAKER, 1993). In addition, the west-facing side of a valley receives more solar insolation during the warmest times of the day than does the east-facing (GEIGER, 1966; PERTTU, 1972). According to CANTLON (1953), various environmental differences are associated with exposure-induced differences in vegetation. In general, it has been found that north-facing slopes may differ from adjoining south-facing slopes in soil and air temperatures, soil and atmospheric moisture, light intensity and wind velocity. KARRASCH (1973) also maintains that numbers of ice-free days, frost-free days, daily temperature ranges, and duration of extreme temperatures are different between north- and south-facing slopes. (3) Amount of insolation is also highly correlated with slope steepness (GEIGER, 1966; UTAAKER, 1993).

5. Conclusions

Both this investigation and other available data show that it is very difficult, or impossible, to give exact values for the altitudinal position of the climatic forest-limit. Several local factors can depress or modify its position. Therefore, if we wish to give an absolute value to a certain limit, we must refer to which limit it is supposed to be (species, tree or forest limit, empiric, climatic or edaphic limit), and for which aspect and slope steepness. Consequently, when the position of the forest limit is compared from one area to another, several environmental variables should be taken into consideration. All summer temperature variables tested are significantly correlated with the altitudinal position of the forest limit. However only variables based on maximum values are constant at the forest limit all over Norway. The present investigation indicates that the *Betula pubescens* forest-limit is significantly correlated with the isotherms of 15.8°C for the mean maximum temperature of the warmest month (July), and of 13.2°C for the mean maximum temperature for the four warmest months (June-September), which supports values obtained by detailed local studies.

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