

The start of the birch pollen season in Finnish Lapland: separating non-local from local birch pollen and the implication for allergy sufferers

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Determining the start of the birch pollen season requires the reliable separation of non-local from locally produced birch pollen. The research was undertaken close to the latitudinal birch tree line at the Kevo Subarctic Research Institute (69°45'N 27°01'E) in northern Finland. By comparing phenological and aerobiological observations, the proportion of birch pollen present in the air before local anthesis commences can be delimited. We coupled this with data of pollen deposition monitored by means of a modified Tauber trap. The dominant birch species at Kevo is the mountain birch *Betula pubescens* ssp. *czerepanovii*, whereas *B. pubescens* ssp. *pubescens* is very rare, hence we consider the proportion of the southerly *B. pubescens*-type pollen deposited in the pollen trap to be non-local in origin.

We did not observe any trend towards an earlier start of the phenologically observed mountain birch anthesis at Kevo as predicted from work elsewhere. Moreover, the fixed 2.5% threshold method for determining the birch pollen season proved not to be applicable since in many years this threshold was reached before the end of continuous snow cover. The results indicate that in some years non-local birch pollen contributes considerably to the allergen load in Lapland with up to 57% of the total birch pollen sum being recorded before the day on which local anthesis commenced, and up to 70% of the annual birch pollen deposited being of the southerly birch type.

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Earlier publications have suggested that, as a result of climate change, the beginning of the birch pollen season in northern Finland has shifted to a later date, while in central and southern Europe climate change has induced an earlier start in birch flowering (Emberlin et al. 1997, 2002). Over the last 30 years, climate change has caused an increase of 10 – 11 days in the growing season in Europe (Menzel & Fabian 1999). Birch pollen present in the air before local birches have begun flowering produces a bias in the estimation of the beginning of the local birch pollen season, especially in northernmost Europe, where flowering starts much later than anywhere else. Earlier birch flowering in more southerly regions and the subsequent earlier appearance in the air of non-locally produced birch pollen can have significance for birch allergy sufferers.

Our aim here is to look at the start of the birch pollen season close to the latitudinal birch tree line at the Kevo Subarctic Research Institute (69°45'N; 27°01'E) in northern Finland (Fig. 1) and attempt to distinguish between locally produced and non-local birch pollen using a combination of phenological and aerobiological observations and the record of pollen deposition as monitored by a Tauber trap (Hicks & Hyvärinen 1986).

MATERIAL AND METHODS

Birch trees

The most abundant tree at Kevo is the mountain birch, *Betula pubescens* ssp. *czerepanovii* (N.I. Orlova) Hämet-Ahti syn. *Betula tortuosa* (Auct.) (Hämet-Ahti et al. 1998). Mountain birch is considered to be an introgressive hybrid between the dwarf birch *Betula nana* and *B. pubescens* (Kallio & Mäkinen 1978), and its history during the Holocene has been reviewed by Mäkelä (1999). Dwarf birch, *Betula nana*, is also commonly present at Kevo. In the analyses presented here, locally produced pollen is assumed to come from these two species, while the pollen of the southerly tree birch, *Betula pubescens*-type is regarded as non-local.

Pollen sampling and phenological observations

Three sets of data were used in the analyses; phenological observations, aerobiological daily pollen counts, and annual pollen deposition data as recorded by a Tauber trap.

Phenological data of mountain birch anthesis were based on daily observations by the same person at Kevo with the beginning of flowering being defined as observed anthesis in at least one mountain birch tree. Data were available for the period 1977 – 2001. On the basis of earlier observations at Kevo, the time of

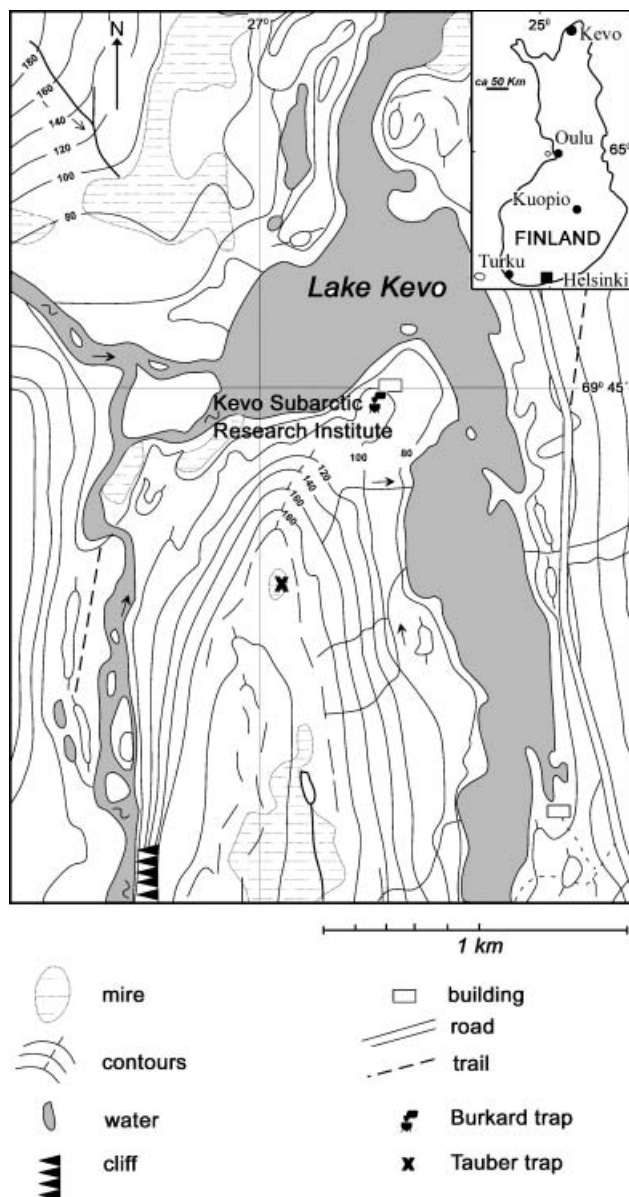


Fig. 1. Map of the area around the Kevo Subarctic Research Institute (Kevo, Utsjoki, 69°45'N, 27°01'E, 107 m a.s.l.), showing the location of the Burkard sampler and the modified Tauber trap (Ke8 in Hicks 2001). Three of the other Finnish aerobiological monitoring sites are also shown in the inset map: Turku (60°32'N, 22°28'E, 40 m a.s.l.), Kuopio (62°53'N, 27°38'E, 100 m a.s.l.) and Oulu (65°04'N, 25°31'E, 25 m a.s.l.).

anthesis was considered to be concurrent in mountain birch and dwarf birch (Hicks et al. 1994).

For the aerobiological data, pollen was collected throughout the growing season from April to September with a continuous-flow sampler, the Burkard trap (Hirst 1952), which is the European standard sampling method for airborne pollen and spores (EAN, European Aeroallergen Network). The trap was located on the roof of a building at the Kevo Subarctic Research Institute. Daily counts of airborne birch pollen were analysed under a light microscope. Burkard sampling tapes were mounted on slides in polyvinyl alcohol Gelvatol (Burkard) in 48 mm pieces and dried for a few hours before analysis. Daily pollen concentrations are based on random

counts of 48 microscopic fields per slide (Mäkinen 1981). The pollen sum for the growing season was calculated as the sum of daily averages per cubic meter of air. Counts were available for the same period as the phenological observations i.e. 1977 – 2001. A fixed percentage method was used to determine the day when 2.5% of the total growing season pollen was reached in the aerobiological data.

Identifying birch pollen types in sedimentation samples

A modified Tauber trap (Tauber 1974, Hicks & Hyvärinen 1986, Hicks et al. 1996, 1999), with the opening at ground level, was situated within the vicinity of the Burkard monitoring site at Kevo, in a mire at a slightly higher altitude than the field station (Fig. 1). Pollen was collected for a full calendar year (September to September) and results are expressed as the number of pollen grains deposited on cm² of land surface during that period (grains cm⁻² year⁻¹). Results were available for the period 1982 – 2001. The Tauber trap collections were prepared by the acetolysis method followed by treatment with 10% KOH (Berglund & Ralska-Jasiewiczowa 1986, see also Hicks 2001 for exact details) and the extracted pollen was identified under a light microscope at a magnification of ×400.

On the basis of a combination of size and morphology *Betula* pollen grains were separated into three classes: *Betula tortuosa*-type, *B. pubescens*-type and *B. nana*-type. Grains, which were triangular in shape in polar view, with a thick exine and clearly raised pore, were considered to originate from tree birch (*Betula pubescens* or *B. pendula*) and were termed *Betula pubescens*-type. Those, which were almost circular in polar view, with a thin exine and very shallow pore, (which additionally were small in size, smaller than the *B. pubescens* type) were termed *Betula nana*-type. Grains with the same shape and exine features as *B. nana*-type but much bigger in size (bigger than *B. pubescens*-type) were termed *Betula tortuosa*-type (Terasmaä 1951, Hicks 2001), and this latter type occasionally had four pores. This type was considered as originating from the local mountain birch *Betula pubescens* ssp. *czerepanovii* (using the earlier name of *B. tortuosa*). There is a certain amount of gradation between these three types but the analysts felt confident about assigning ca 95% of the birch pollen encountered.

Some workers (Birks 1968, Mäkelä 1999) have investigated whether it is possible to separate the birch pollen types on the basis of grain size (with or without pore depth) but have not taken into account shape and exine thickness. Moreover, many have been more concerned with the separation of the two tree birch species *Betula pubescens* and *Betula pendula* from the dwarf birch *Betula nana*. Because of the genetic history and restricted distribution of the mountain birch (as described above) the need to separate this pollen type only arises in northernmost Fennoscandia, and has, therefore, received less attention in the literature (Blackmore et al. 2003).

The calculations of pollen quantity were made relative to an added exotic particle type (*Lycopodium* spores, Stockmarr 1971) using the formula recommended by Maher (1981). The confidence limits on these calculations are published by Hicks (2001). In the case of the aerobiological pollen samples, a morphological separation of the different birch species was not attempted, since with the preparation method used, the pollen grains are fixed to a position and cannot be observed from different angles, and the cell contents are still present and obscure the features.

Separation of non-locally produced birch pollen

We determined non-locally produced birch pollen as the proportion of pollen, which had accumulated in the aerobiological samples before the phenologically observed beginning of local anthesis. We appreciate, however, that this must be a minimum value since

non-local pollen certainly continues to reach Kevo even after local anthesis has commenced. We therefore used the proportion of *Betula pubescens*-type pollen deposited in the modified Tauber trap samples as an estimate of the annual proportion of non-local pollen, although even this must be a minimum value because some of the *Betula tortuosa* type pollen may have a non-local origin. We used Pearson correlation to study correlation between variables and linear regression to detect trends.

Meteorological and snow cover data

Air temperature data were obtained from the Finnish Meteorological Institute for the period 1980–2001. The accumulated growing degree days were calculated from January 1st to the day of local flowering beginning as the cumulative sum of 24-hour mean temperatures over +5°C (dd +5°C). Data on the duration and ending of continuous snow cover (the day when 50% of the continuous snow cover had melted) from 1977–2000 at Kevo were kindly provided by Lasse Iso-Iivari. No data were available on the average depth of snow cover or snow water content.

RESULTS AND DISCUSSION

When considering the phenological data, we discovered no significant trend towards an earlier spring in either the beginning of mountain birch anthesis or in the five-year moving averages (Fig. 2, Table I). The phenologically determined anthesis day did not correlate with the day of snow melting (Fig. 3A) or with the accumulated temperature (Fig. 3B, Pearson's correlation coefficient, 0.232). Therefore, it would seem that the observed earlier tree flowering in Central and Southern Europe does not apply to mountain birch. We observed a weak trend towards a later ending of the continuous snow cover, while the accumulated temperature at phenological start day showed great variation (Table I).

In terms of the aerobiological data, we observed a trend towards a later date for reaching the widely used 2.5%

Table I. Linear regression equations and *r*-squared values of the 5-year moving averages of the variables analysed.

Variables	Linear regression equations, <i>r</i> -squared values
2.5% threshold date	$y = 0.5995x + 135.34$, $r^2 = 0.3068$
Phenological start date	$y = -0.147x + 165.01$, $r^2 = 0.1185$
Accumulated dd (+5°C) at phenological start date	$y = 0.1011x + 132.03$, $r^2 = 0.0021$
Ending of snow cover	$y = 0.2975x + 135.74$, $r^2 = 0.1894$
Percentage of pre-local birch anthesis birch pollen in the Burkard sampler accumulated by phenological start date	$y = 0.7377x + 11.934$, $r^2 = 0.0726$

threshold (Fig. 2, Table I), which is in keeping with earlier observations (Emberlin et al 2002). However, a fixed threshold percentage, such as 2.5%, proved not to be applicable as a marker of the beginning of the local pollen season in our data (Fig. 2), because on average 9.6% (range 0–55%) of the whole growing season's pollen catch had already accumulated by the phenological start day. Furthermore, between 0 and 45.6%, (average 6.3%) of the whole growing season's pollen sum had been reached before the end of continuous snow cover. Before the frost has melted, the birch trees cannot absorb water from the soil and anthesis is not possible. Obviously, a large amount of non-locally produced pollen is present in Finnish Lapland.

Birch pollen, being abundantly produced and easily dispersed, is certainly present at all latitudes, even at locations where birches do not grow. This non-locally produced pollen, however, is of seminal importance in determining the beginning of the birch pollen season in northernmost Europe, since the *Betula* pollen sum in the north is considerably smaller than those in more southerly monitoring sites in Finland (Fig. 4). Despite the fact that the hybrid nature of mountain birch causes a degree of uncertainty in the morphological separation of the three *Betula* pollen types deposited in the modified Tauber trap, there is a wide variation in the proportion of the southerly *Betula pubescens*-type between years (Fig. 5A). This is also reflected in the aerobiological records where there is a wide variation in southerly *Betula pubescens*-type prior to local anthesis.

The average proportion of *B. pubescens*-type pollen was 49.0%, ranging from 15.8% to 70.3% (Fig. 5A), suggesting that in some years a very substantial part of the airborne pollen in Lapland has a more southerly origin. Indeed, there was a significant correlation between the actual numbers of non-local airborne *Betula* pollen and deposited *B. pubescens* type pollen (Fig. 5B; $r = 0.607$, $p < 0.005$), just as there was a significant correlation between the amount of *Betula* pollen recorded after local anthesis had commenced and the sum of *B. nana* and *B. tortuosa* pollen types ($r = 0.757$, $p < 0.0001$), showing that the trend observed on the shorter data series (Hicks et al. 1994) continues in this longer series. However, when expressed as percentages, although the trends in terms

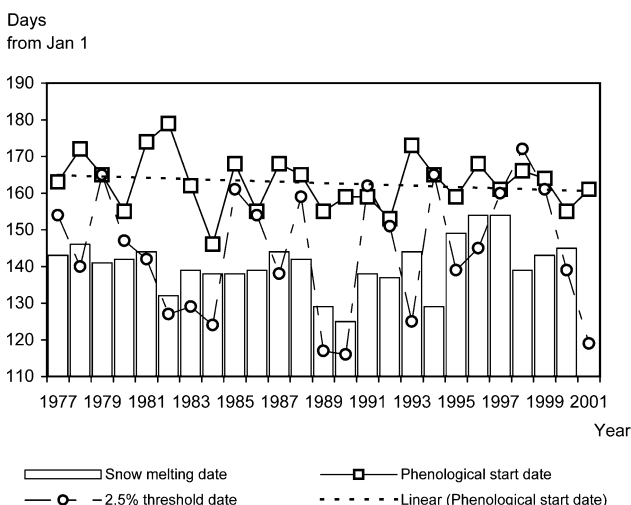


Fig. 2. The date of the beginning of the birch pollen season (Phenological start date), the date of the ending of continuous snow cover (Snow melting date), the threshold day when 2.5% of the total growing season's birch pollen sum was recorded in the Burkard sampler at Kevo, for the period 1977–2001.

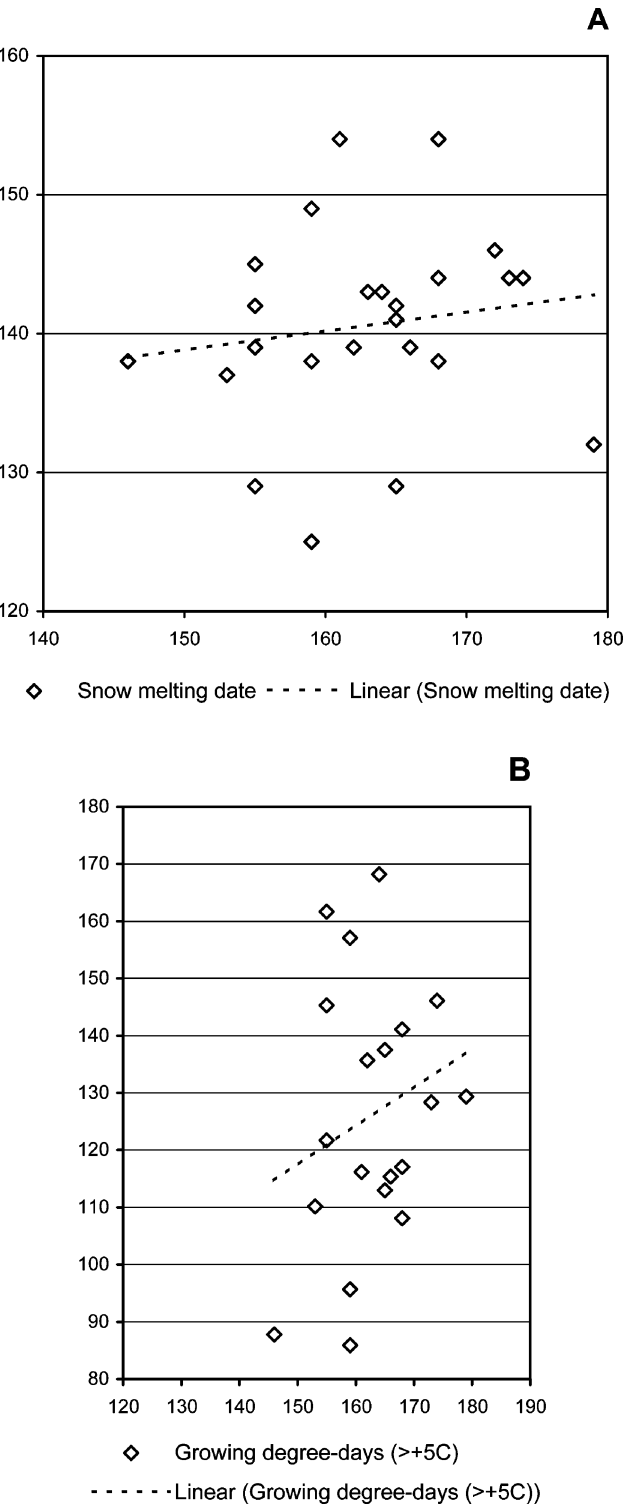


Fig. 3. Relationship between the phenological start date and: (A) the snow melting day; (B) growing degree-days (> +5°C).

of high and low years are clearly similar, there was no statistical correlation (Fig. 5C; $r=0.316$, $p=0.175$). In northern Europe, non-locally produced birch pollen, which occurs in the air before the local birch season is a significant source of potent aeroallergens (Wallin et al.

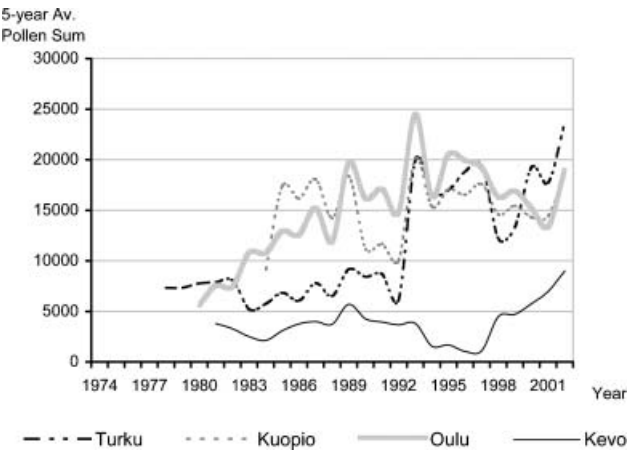


Fig. 4. Five-year moving averages (MA) of the total growing season *Betula* pollen sums at four selected Burkard monitoring sites in Finland (for location see Fig. 1) (Note that the four first observations are lost in the 5-year MA procedure.).

1991). Our data indicate that in some years most of the airborne birch pollen at Kevo is non-locally produced pre-local pollen season pollen. If birch pollen can remain allergenic, potentially even viable while travelling thousands of kilometres, the viability and allergenicity as well as the geographical origin of this non-locally produced pollen deserve to be studied. Birch flowering in more southerly regions and the subsequent presence of pre-local season birch pollen may trigger the onset of allergic symptoms in people with birch allergy in northern Finland before the local birch flowering season begins. There is also a possibility of gene flow to remote populations, but because male and female flower dehiscence is typically synchronised within a given geographical region and the female flowers are only receptive for fertilization for a very limited period, pre-local season non-local pollen probably has much more significance as an aeroallergen.

Phenological data are presently used by some European aerobiological groups for predicting the pollen seasons (e.g. J. Emberlin, British Aerobiology Network: Pers. Commun.). An integration of aerobiological and phenological networks in Europe would enable an estimation of the probability of gene flow as well as predicting the initiation of allergic symptoms. In addition, meteorological information about the origin and movement of air masses is needed to predict the occurrence of non-locally produced pollen. The meteorological data show that spring temperatures at Kevo fluctuate greatly. Since we found no significant correlation between temperature and the beginning of anthesis, further study is needed to identify the underlying factors affecting the timing of mountain birch anthesis at Kevo.

CONCLUSIONS

The birch pollen season, as defined by phenology, has not shifted towards either a later or an earlier beginning in Finnish Lapland. The fixed 2.5% threshold method based on aerobiological data was not applicable for determining the local birch pollen season since, in many springs, this

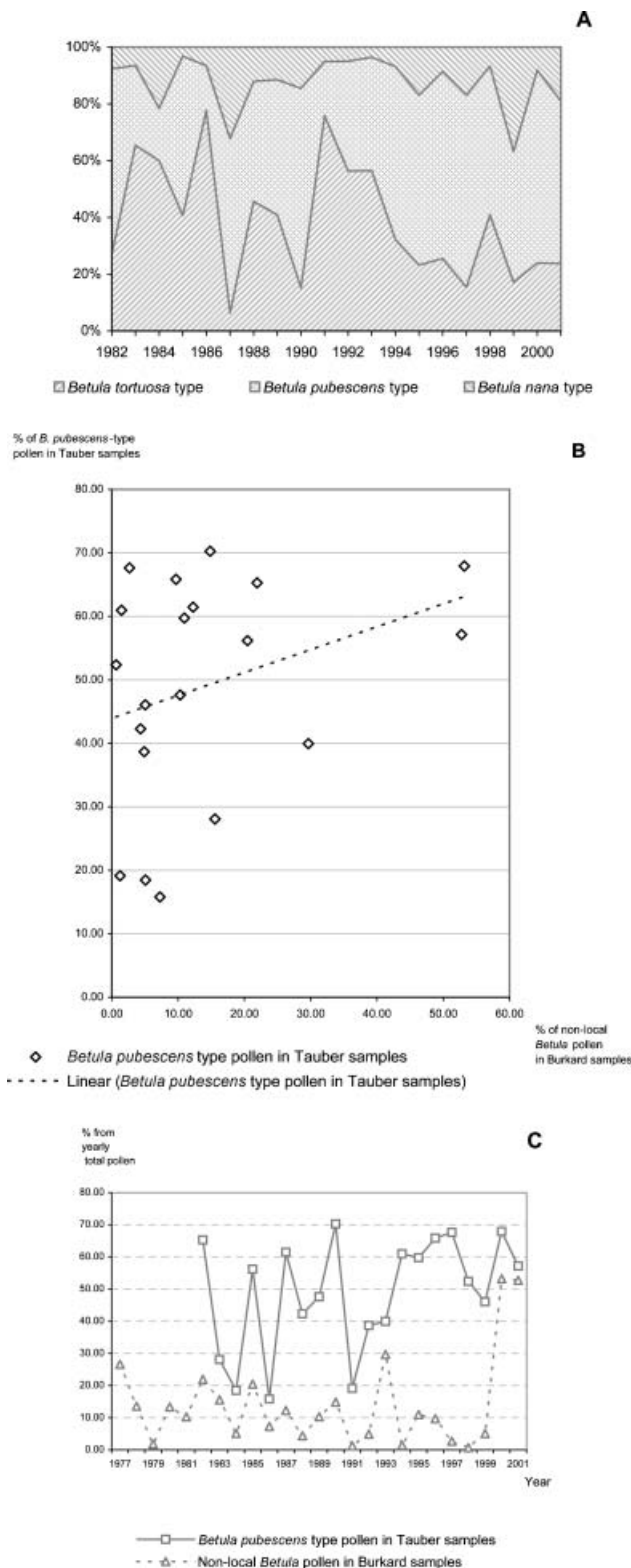


Fig. 5. **A.** The relative proportions of the annual deposition of the three birch pollen types for the period 1982–2001. **B.** The percentage of non-local airborne birch pollen recorded by the Burkard sampler relative to the percentage of *Betula pubescens* type pollen deposited in the modified Tauber traps. **C.** Percentage of pre-local anthesis birch pollen recorded in the Burkard sampler during the growing season (open circles) and percentage of *Betula pubescens* type pollen (solid squares) deposited during the whole calendar year.

threshold was reached before the ending of the continuous snow cover. This is because the average proportion of non-locally produced birch pollen at Kevo is large. A variety of subarctic climate parameters need to be investigated when interpreting aerobiological data from the extreme north in order to identify the reason for any shift in flowering times. In some years non-locally produced birch pollen may contribute considerably to the allergen load in Lapland.

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