Large and Small Scale Distribution of Pollen in the Boreal Zone

The air is full of a large number of different types of particles some of which have a detrimental effect on humans and their environment. In order to delimit those areas which are likely to suffer most from this airborne material it is important to know how the particles behave and what factors affect their behaviour. Pollen is one type of airborne particle and it is considered here with reference to the following questions :

1. What species are being transported ?
2. What quantity of each species is concerned ?
3. Over what distance does the pollen travel ?
4. What is the degree of variation through time ?

All of these aspects can be considered at both the local small-scale level and the regional large-scale level.

The evidence presented here comes from northern Finland (Fig. 1), from the boreal zone, where the dominant vegetation type in the landscape is forest composed of pine, birch and spruce. The situation contrasts with that further south in Europe where the landscape is largely open. The results are based on collections from « Tauber » traps (Tauber, 1974) which record the total quantity of pollen reaching a known area of the ground surface during the course of the sampling period. Although this method of sampling does not enable any calculation of the amount of pollen that is actually in the air at any one time it does show quite clearly where the pollen is coming from and in what way and how far it is travelling. Such factors could well be extrapolated to apply to other airborne particles within the same size and weight range.

WHAT SPECIES ARE BEING TRANSPORTED ?

Large-scale regional situation

It is the light pollen grains (eg. *Betula*) or those which, because of their morphology, are easily transported by the wind (eg. *Pinus*), which are most widely distributed. These usually originate from wind pollinated plants and plants with a high pollen production. In the boreal zone it is the tree species which dominate.

Small-scale local situation

At the local level the widely distributed pollen types mentioned above are joined by the large, heavy pollen grains and those from insect pollinated species growing locally. Pollen from plants with a very low pollen production may still be rare.

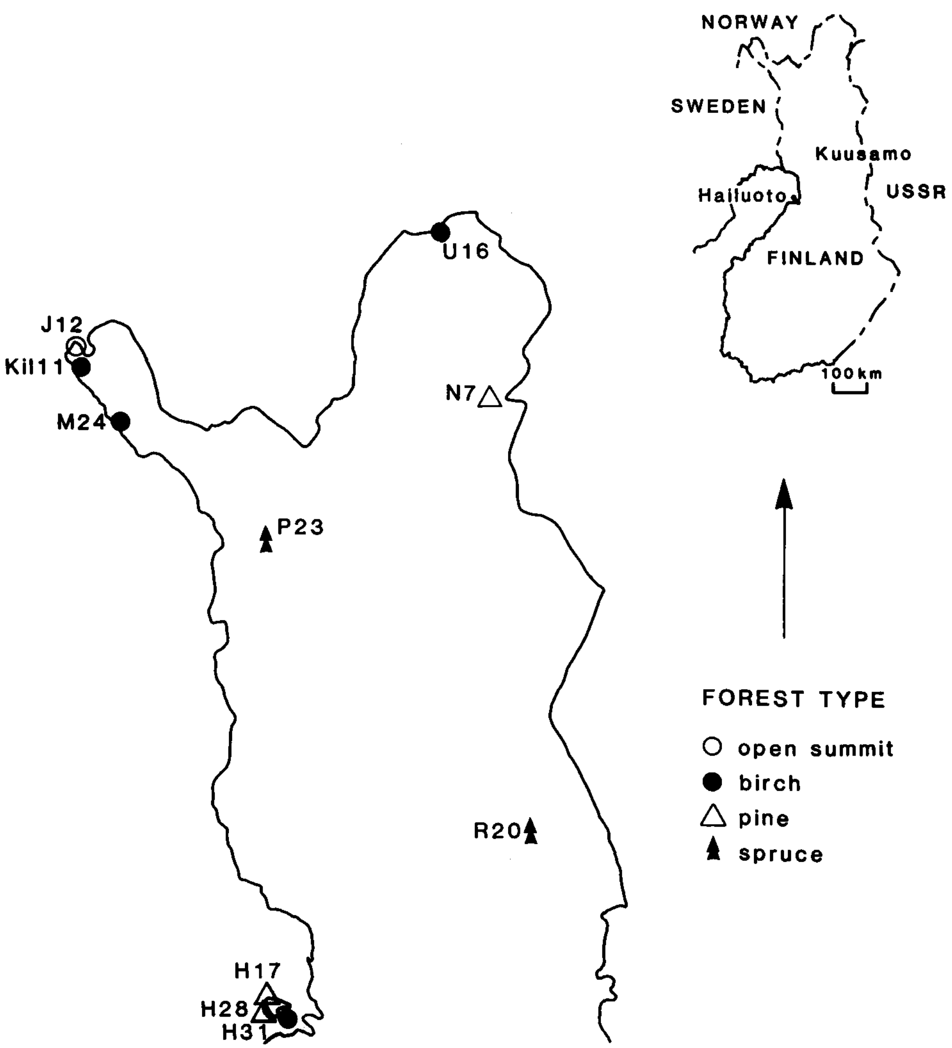

Fig. 1. Location of pollen sampling sites mentioned in the text together with the dominant regional vegetation type.

WHAT QUANTITY OF EACH SPECIES IS CONCERNED ?

In this study the results are primarily expressed in terms of numbers of pollen grains falling on 1 cm^2 in the course of 1 year. The actual quantity varies considerably from year to year but the relationship between the amount of each different species at any one site and of the same species at a number of different sites is significant.

Large-scale regional situation (Fig. 2)

Tree pollen is dominant, particularly in the pine and spruce dominated forests, while the pollen of the low-growing herbaceous plants is both less significant and more variable (note *Betula* and *Pinus* are illustrated at a scale 10x that of the other species in the diagram). More pollen is present in the coniferous forests than in the birch woodland. This is because, in the former, the trees are denser and pollen production higher than in the latter. The bare mountain tops (eg. J12) receive scarcely any pollen at all, the local plant cover being incomplete and pollen production low. However, this is not true of all mountain tops, those which only just rise above the timber line may receive just as large amounts of pollen as a site within the forest itself (Hicks, 1986). In the situation in figure 3 one would expect the quantity of pollen reaching the ground in the various different localities to be in the order :

$$B > C = E > D > A$$

Small-scale local situation (Fig. 4)

The local vegetation provides the majority of the pollen so that if the locally growing species are high pollen producers the quantity of pollen reaching the ground may be enormous (eg. the birch woodland site H31).

Although it is possible to demonstrate numerically how much pollen reaches the ground in different situations when the reasons for these differences are sought it is impossible to avoid the third question of « over what distance is the pollen travelling ? » because what reaches the ground represents a combination of both production and transportation.

OVER WHAT DISTANCE DOES THE POLLEN TRAVEL ?

As a general rule the more open (unforested) the situation the higher the proportion of pollen which has travelled a great distance, in other words, the catchment area of an open site is much larger than that of a densely vegetated one.

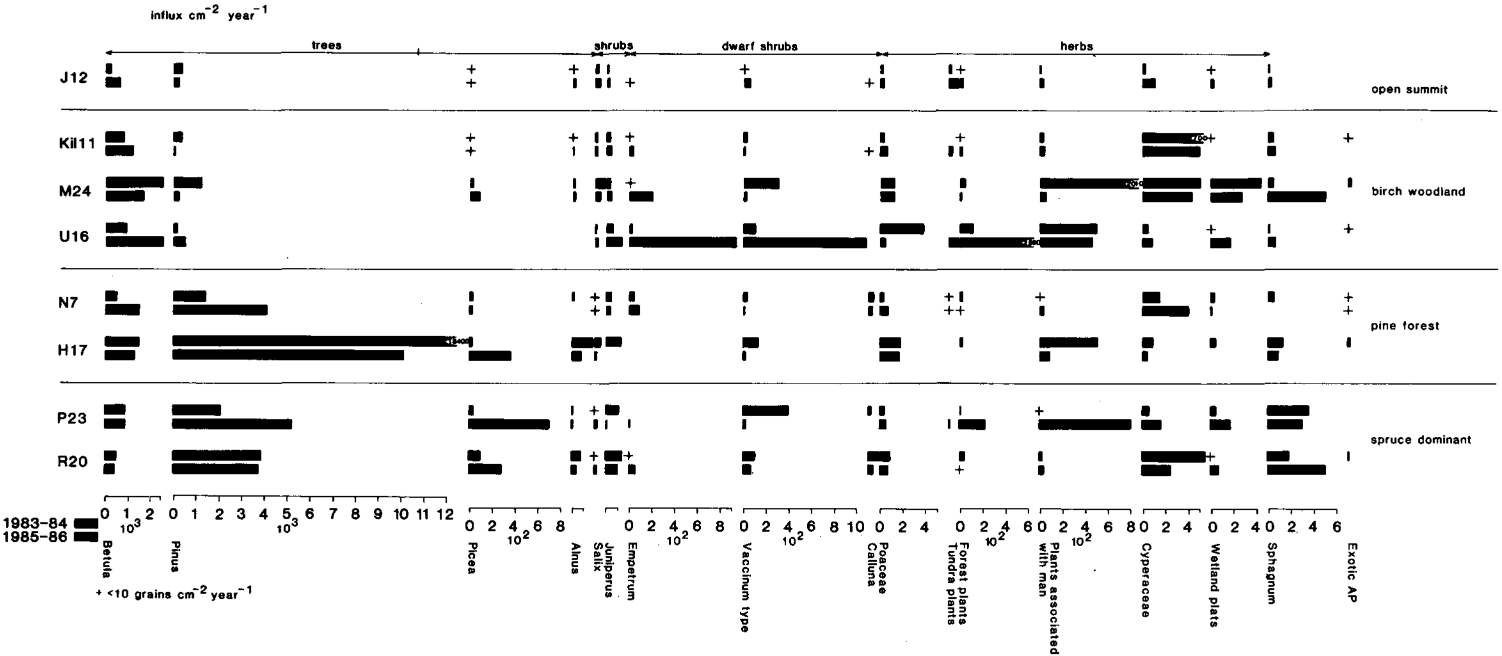

Fig. 2. Annual pollen influx for selected sites in northern Finland grouped according to regional vegetation type.

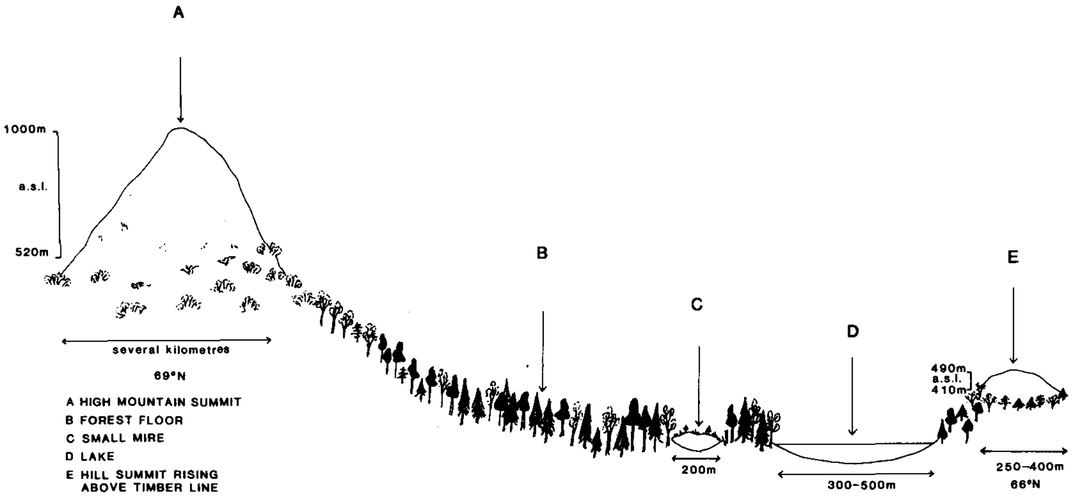

Fig. 3. Schematic cross section illustrating different types of situation sampled for pollen deposition.

Large-scale regional situation

On the open mountain tops well above the timber line (J12, Fig. 2) the tree pollen has come from several kilometres away. Since the local pollen production is very low this tree pollen forms some 70-80 % of the pollen reaching the ground.

Small-scale local situation

Within the open fields (H18, Fig. 4) there is still a fairly high quantity of birch and pine pollen, at least as much as in the open pine forest (H28). In this case, however, the tree species together form only some 40 % of the total pollen because pollen production from the field vegetation itself is high.

At the very local scale the opposite situation may also be encountered. If the site is open but the local herb vegetation is both tall and dense then this vegetation will act as a very effective filter and prevent pollen from further away reaching the ground. This can be seen at site H19 (local vegetation dense reed swamp) where fields and pine forest occur close by but the pollen from both is only poorly represented.

WHAT IS THE DEGREE OF VARIATION THROUGH TIME ?

Seasonally

As is to be expected, the highest quantities of pollen are deposited at the time of flowering but a lot is resuspended and deposited throughout the summer (Tauber, 1965, 1977). There is still some pollen which comes to the ground even during the winter and this may constitute some 10 % of the

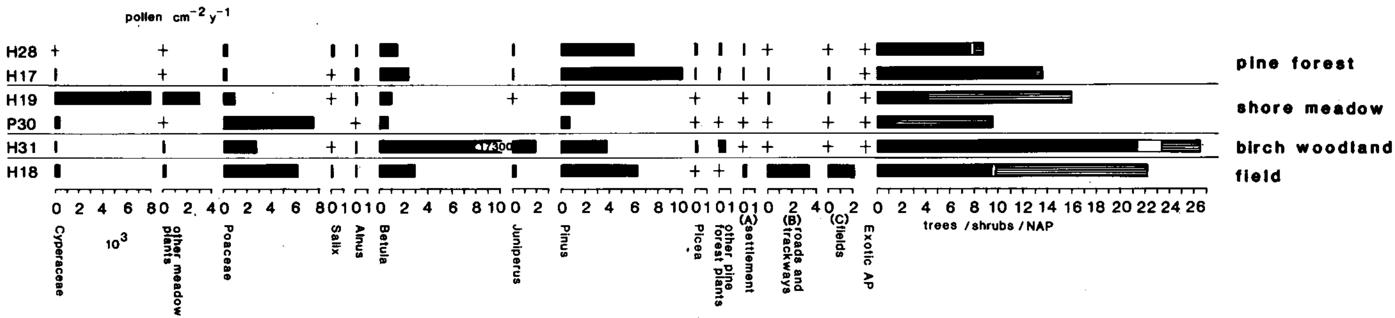

Fig. 4. Annual pollen influx for selected sites on the island of Hailuoto grouped according to local vegetation community.

Sites	Yearly pollen deposition cm^{-2}	Winter pollen	% of whole year	
Ri I	3677 4668	322 238	9.0 5.0	open summit
Ri II	3956 3560	115 144	3.0 4.0	
Ri VI	3016 3874	121 114	4.0 3.0	
Ru XIII	4245 6612	393 412	9.0 6.0	
Ru XIIIb	2921 5984	601 590	20.5 10.0	
Ii XII	4154 3835	156 160	4.0 4.0	
Ri VII	3557 6155	207 104	6.0 1.5	birch important
Ru XIV	2177 5294	199 274	9.0 5.0	
Ii XI	2800 3460	228 177	8.0 5.0	
Ri V	3409 3611	124 214	3.5 6.0	forest limit
Ko III	2465	232	9.5	spruce and pine
Ko IV	4199	256	6.0	
Ru XV	3055 4886	449 386	14.5 8.0	
Na XVI	3623	202	5.5	
Ou XVII	2616 5669	291 458	11.0 8.0	spruce dominant
Ou XIX	2296 4762	199 328	8.5 7.0	
Ri VIII	1799	344	19.0	
Ii X	2098 3139	522 535	25.0 17.0	
Ou XVIII	1527 3375	184 184	12.0 5.5	pine dominant
Ii IX	3845	205	5.5	

Upper figure 1969-70
Lower figure 1970-71

Fig. 5. Winter pollen deposition at a series of sites within the Kuusamo area grouped according to local vegetation type.

yearly total (Fig. 5, Hicks, 1985). Although the quantity of pollen available for deposition in the winter is small it may, nevertheless, be highly significant because, at that time of year, the situation, even in forested areas (particularly areas of deciduous forest) is open and so what pollen there is can potentially be transported over very great distances. In the same way, pollen of those species which flower very early, before there are leaves on the trees, is transported over greater distances than it would be later in the summer.

Annually

There is a certain amount of evidence for annual variation in flowering (Andersen, 1974 ; Hicks, 1985) which can be expected to be related to climate. This variation is likely to be greatest in areas where the species are close to their ecological limits. In northern Finland, for example, spruce flowers prolifically only once in every 15-20 years.

Under abnormal climatic conditions

Occasionally climatic conditions are such as to allow pollen from quite different regions to be transported over great distances. The amount of pollen concerned is small so that such instances are more easily noticed during the winter time (Aartolahti and Kulmala, 1969) when the local pollen production is at a minimum but long distance transportation of this type certainly happens at other times as well.

CONCLUSIONS

The general features of pollen dispersal and deposition can be summarized as follows :

Large-scale regional situation

1. In regions with a closed vegetation cover it is the high pollen producers within the dominant regional vegetation types which are most widely and abundantly reflected in the pollen deposition. In northern Finland this is clearly the pine and birch of the boreal forest.
2. The distance over which pollen is transported can exceed 100's of kilometres, particularly if climatic conditions allow. However, the quantity of pollen travelling so far is relatively small and a high proportion of the pollen deposited within a lowland vegetated area has been transported only a short distance (1 km or less).
3. Open landscapes have a larger pollen catchment area than closed ones. Exposed peaks receive the majority of their pollen from very far away but in quantitative terms this is still quite small.
4. Dispersal of pollen during the winter can be significant because there is little to inhibit movement.

Small-scale local situation and close to the ground

1. Pollen from vegetation in the immediate surroundings dominates and absolute quantities can be high.
2. The distance over which the pollen is transported is usually very short, may be only 20 m in a dense closed vegetation or 200-600 m in more open conditions.
3. The filtering effect of tall growing herbaceous vegetation is significant and may radically prevent pollen transportation near the ground.
4. Deposition is greatest at the time of flowering but, particularly in more open vegetation situations, resuspension and movement of pollen close to the ground surface continues throughout the summer.

Naturally, at any one sampling site these two sets of features will be superimposed since a « local » site is, inevitably, also located within a region. Which set of features assumes dominance depends on the openness of the local situation. The extremes are the exposed mountain summit on which the regional aspects are overwhelmingly dominant and the closed forest with a dense herbaceous undergrowth in which the local aspects assume greatest importance. There will also be a distinct difference between these two extremes in terms of the quantity of pollen involved, with the forest experiencing the highest deposition and the mountain top the lowest.

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