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The trend to earlier birch pollen seasons in the U.K.: A biotic response to changes in weather conditions?

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The trend to earlier Birch pollen seasons in the U.K.: A biotic response to changes in weather conditions?

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Records of the start of Birch pollen seasons monitored at three sites in the UK for periods of up to forty two years indicate a recent trend for the pollen seasons to begin earlier. This trend shows a close relationship to an increase in cumulative temperatures in the months of January, February and March recorded near each of the sites during the study period.

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Evidence has emerged that the flowering times of Birch trees in the United Kingdom are getting notably earlier in response to the warmer springs of recent years. Three sites, London, Derby and Cardiff, have records of monitoring airborne pollen extending over several decades giving the longest continuous data sets of this type anywhere in the world. This provides a unique opportunity to look at the response of pollen seasons to climatic fluctuations. Among the records examined so far, some of the most striking changes feature for the trees, especially for Birch.

A shift in the timing of the pollen season for Birch (*Betula* spp.) is important because it is well known as a significant aeroallergen especially in Northern-European countries where it appears among the top ranked allergenic pollen types. Estimates suggest that between 10–20% of the population of Northern and Central Europe are allergic to Birch pollen (Spieksma 1990). In the U.K. there is an increased awareness of its significance, especially because of its cross reactivity with apple via the *Bet v 1* allergen molecule and its potential cross reactivity with a variety of allergens of vegetable origin via profilin (Ott et al. 1981, Flovaag et al. 1982).

Birch flowering results in the release of large numbers of pollen grains into the air. Erdtman (1954) estimated the pollen output of one inflorescence of *Betula pubescens* as 6,000,000. These are the most abundant of the tree pollens in the airspora of the UK and much of North West Europe. The genus *Betula* includes some 40 species distributed throughout the northern hemisphere. For example *Betula pendula* (Silver birch) grows wild throughout the whole of Europe, east to Siberia, and closely related species extend through North America. Birches can grow both in dry and damp conditions and form part of many natural plant communities. They are also planted extensively as ornamental trees.

In Britain the *Betula* pollen season typically lasts from mid April to mid May but analysis of the trends in start dates over the last three decades shows a clear shift towards earlier starts at the three separate geographical locations that have long term pollen records. Previous work (Emberlin et al. 1993) has shown that the main controls on the timing of Birch pollination are winter chilling to break dormancy, and cumulated daily average temperatures (over 5.5°C) in the months of January through to April. Cumulative temperatures are a better indication of growth conditions than averages that may mask high daily maximums. Rainfall at the time of pollen release may effect dispersal. Temperature records from the last 300 years in Central England (Manley 1974 and data from monthly mean temperatures published in *Weather*) indicate a trend to gradual warming. Since 1970 this has been at about 0.1–0.2°C per decade for annual averages although the increase has not been steady. This pattern is matched in temperature series from many areas of temperate Europe including Amsterdam, Vienna and Stockholm (Emberlin 1994). Such a trend may be expected to influence the species distribution of plants and to influence the time of flowering but little research has been done so far on the relationships between the warmer conditions and the phenology of trees.

MATERIALS AND METHODS

This paper draws together evidence from pollen sampling that has been undertaken using Volumetric Spore Traps (Hirst 1952) at city centre sites in Cardiff (1954–1995), Derby (1969–1995) and London (1961–1983, 1987–1995). In London birch pollen was monitored from 1961–1983 at Paddington then from 1987–1995 at Holloway, 5.4 km to the ENE but in the same general environment. Statistical analysis of the pollen data from the two sites in London showed that they could be treated as one data set. Meteorological data was supplied from Cardiff Rhooose Weather Station (14.5 km SW of the pollen trap), and from sites within 0.5 to 3 km of the pollen trap at

Derby and from Rothamsted, 39 km N of the pollen trap within the source region of pollen for London. Previous work has shown that the start dates of the pollen seasons are more closely related to weather in the source areas than in central London where the influence of the urban climate predominates (Emberlin et al. 1993, Jones 1995).

Typically the Birch pollen season begins with a period of low counts before the main season starts. This may bias any statistical analysis and is usually excluded by defining the start date by set criteria, (Mullenders 1974, Nilsson & Persson 1981). It is not easy to define the start of the season, and many methods have been used by different workers (Jones 1995). In this analysis two different methods have been used to define the start of the season. One method identifies the start date as the day when the cumulative daily average pollen count reaches 75 (known as the sum75 method), as used by Driessen et al. (1990). This method is useful in forecasting but is liable to bias by the differing abundance of pollen from year to year. The second way is to define the start of the pollen season as the date when 2.5% of the total pollen census for the year has been trapped. This method has the disadvantage that it can be applied only retrospectively, but the method does allow comparisons from year to year and between sites. The start dates defined by the two methods give slightly different results but they follow the same patterns from year to year. The Spearman's rank correlation coefficients between the results for the two methods are $r_s=0.59$, $p<0.01$ for Cardiff, $r_s=0.71$ $p<0.01$ for Derby and $r_s=0.74$, $p<0.01$ for London.

RESULTS

The pollen records

The data for pollen season start dates was expressed as five year running means to avoid short term fluctuations. It was found that there was a trend for the start date, expressed by both methods, to become earlier by one day every two years (Fig. 1).

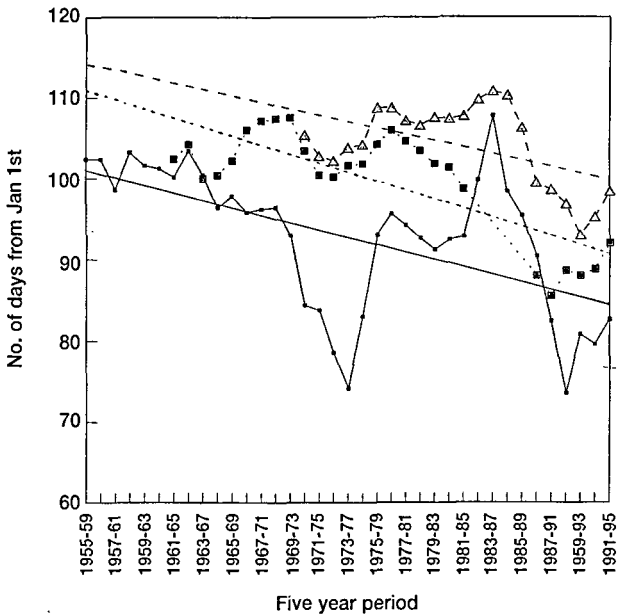


Fig. 1. Start of the Birch Pollen Season. Data as five year running means at London, Derby and Cardiff with trend lines. (Start dates are defined as date when 2.5% of total annual pollen catch has been trapped).

The results from the analysis of the trends are reinforced by detailed examination of the distribution of five year average start dates within the data set (Table I, Fig. 1). At Derby (taking the 2.5% start definition) the five year running means from 1987 to 1995 are at least one standard deviation earlier than the average and during the period 1986–90 the running means are within 0.4 of this. In comparison, no other five year running means in the data set approach one sd below the average. Similarly for the sum75 start date, the results for the running mean data from 1986 onwards are all at least one sd below average. The same pattern is evident in the data for London. From both the 2.5% and sum75 start definitions the results for the five year running means from 1986 to 1995 are all at least one sd earlier than the average for the data set. Similarly at Cardiff for both start date definitions the five year running means from 1987–1995 are all at least one sd earlier than the average for the forty year period.

Trends in the weather

Five year running means for rainfall and cumulated temperatures for individual months were calculated to reduce the influence of annual variations. On a monthly basis the most notable trends for five year running means are apparent in the temperatures for January, February and March (Figs. 2, 3 & 4) although there are some differences between the sites. For example in the London data cumulative temperatures for February and March have been notably higher in recent years (Fig. 2) but this trend is not apparent in the results for January. Considering monthly cumulative temperatures for individual years, the results for February and March from 1988 to 1991 are all above the long term average for the data set. Three out of the ten warmest Februarys and Marchs for the period 1961–91 are 1989, 1990 and 1991. March has the most marked trend in the London area. In the records for Derby (1969–92) the most notable trends in cumulative temperatures are for the months of February and March (Fig. 3) which both show marked tendencies to recent warming. The three years with the highest monthly cumulative temperatures for February (1989, 1990 & 1992) have results that are more than one sd above the average for the data set. In the case of March there is also a very marked trend in recent years. Five of the warmest ten March months in the data set occur between 1988–92. Results for April show

Table I. Descriptive statistics for the start of the Birch pollen seasons

	Cardiff		Derby		London	
	2.5%	Σ75	2.5%	Σ75	2.5%	Σ75
N	37	37	22	22	27	27
Earliest start	74	66	93	96	86	70
Latest start	108	112	111	116	108	113
Mean	93	103	104	108	100	105
Median	95	107	106	110	102	107
s.d.	8.7	8.2	5.1	5.8	6.5	9.0

Start dates for the season are shown as days from January 1st

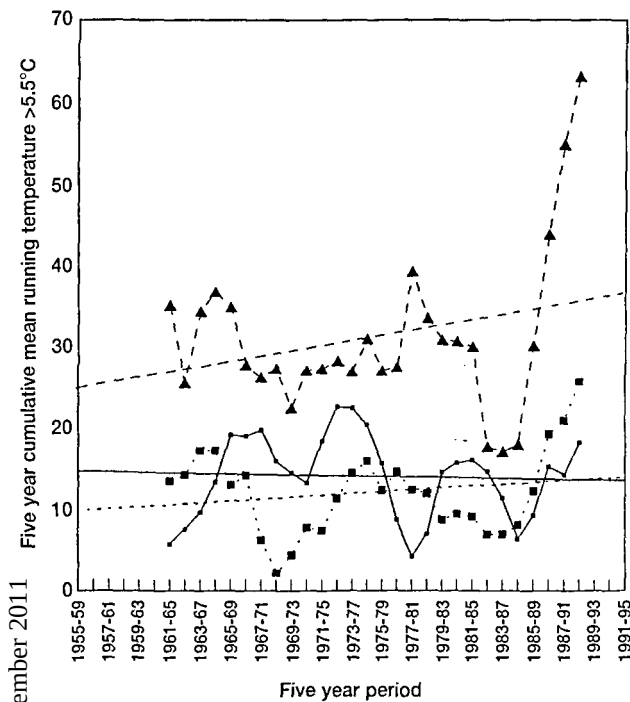


Fig. 2. London. Five year running mean cumulative monthly temperatures $>5.5^{\circ}\text{C}$ with trend lines.

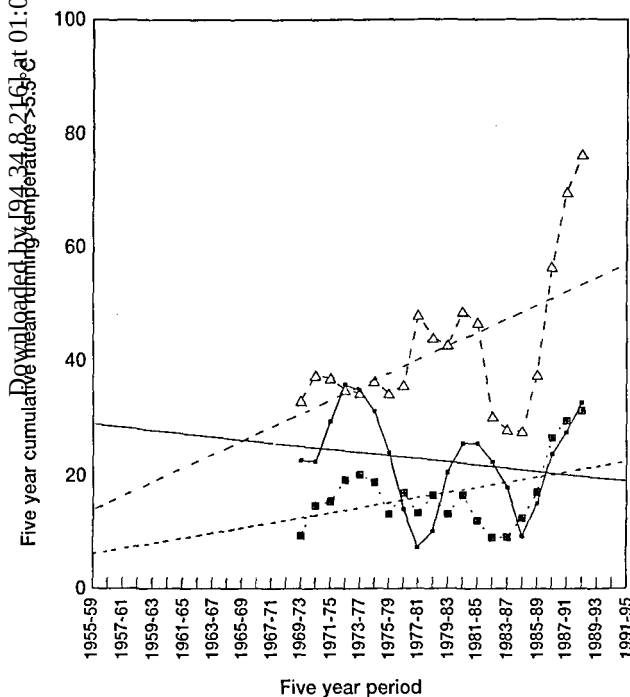


Fig. 3. Derby. Five year running mean cumulative monthly temperatures $>5.5^{\circ}\text{C}$ with trend lines.

fluctuations but there is a trend towards recent warming with running means showing high cumulative temperatures for the years 1987–92.

The local climate at Cardiff is generally more equable than that of Derby because of its coastal location. Cumulative

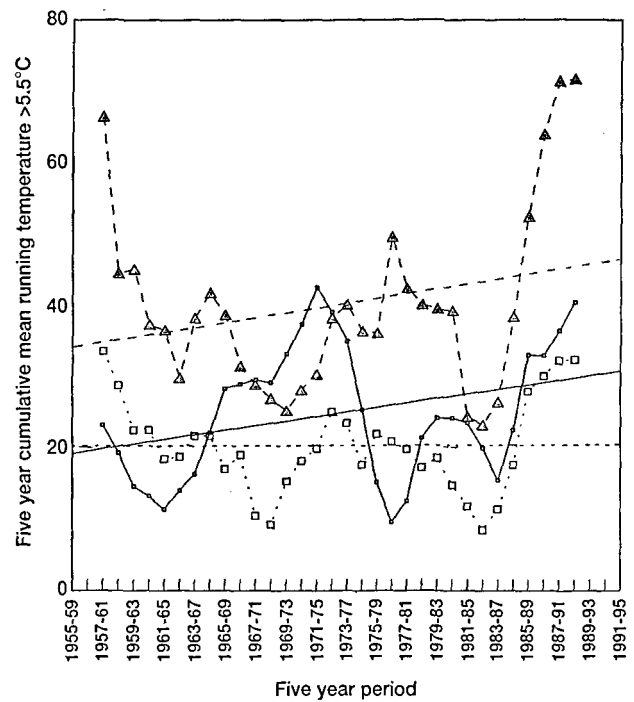


Fig. 4. Cardiff. Five year running mean cumulative monthly temperatures $>5.5^{\circ}\text{C}$ with trend lines.

temperatures for the months of January, February and March have fluctuated a lot over the study period but there have been trends towards increasing warmth in recent years (Fig. 4). These are most notably in Januarys since 1984 and in Februarys and Marchs since 1985. Five of the ten warmest Marchs by cumulative temperature between 1957 and 1993 have all occurred within the period 1988–92.

Rainfall totals have fluctuated in all months over the study period at all the three sites. No significant trends were identified from the five year running means.

Earlier birch pollen seasons due to warming trend

The importance of temperatures in the months before pollination can be demonstrated clearly by analysis of the annual variations. Significant relationships were identified between the start dates of the birch pollen season and monthly temperatures for late winter and early spring both as average and cumulated figures for all three sites (Jones 1995). For example, in London 62% of the annual variation in start dates could be accounted for by temperatures in February and March ($p < 0.01$), (Emberlin et al. 1993). Similarly significant relationships are evident between the trends in start dates for the birch pollen seasons and cumulative temperatures for January, February and March. Correlations between the sets of five year running means (Table II) revealed significant relationships at all three sites, but they were most marked at Derby. This may be a result of the inland position and the proximity of the pollen sources to the trap. The more equable climate of Cardiff may account for the lack of significant correlations in February and March. However significant correlations are found for the

Table II. Spearman's rank correlations between five year running means of monthly cumulated temperatures and start dates for the Birch pollen seasons

n.s.= $p>0.05$

	Cardiff		Derby		London	
	2.5%	sum75	2.5%	sum75	2.5%	sum75
Start definition						
January	-0.719	-0.847	-0.639	-0.052	-0.177	-0.171
	$p<0.005$	$p<0.005$	$p<0.005$	n.s.	n.s.	n.s.
February	-0.197	-0.162	-0.861	-0.374	-0.532	-0.465
	n.s.	n.s.	$p<0.005$	n.s.	$p<0.005$	$p<0.05$
March	-0.203	-0.144	-0.600	-0.653	-0.617	-0.534
	n.s.	n.s.	$p<0.01$	$p<0.005$	$p<0.05$	$p<0.005$

relationship between cumulative temperatures and start dates if only the most recent twelve years are considered rather than the entire data set.

DISCUSSION AND CONCLUSIONS

The latest forecasts from the Intergovernmental Panel on Climatic Change (IPCC) sponsored by the World Meteorological Organisation and the United Nations Programme predict that the trend towards gradual warming in the climates of North West Europe will continue although there is debate about its rate (Houghton et al. 1992, Houghton et al. 1995). It is not clear whether the recent climatic trends towards warmer springs evident in the data for Cardiff, London and Derby are part of a short term oscillation within this longer term trend or whether the five year average cumulated temperature profiles of the early spring months will continue to increase at the current rate. However it is clear that a biotic response in the timing of the birch pollen seasons is occurring. The analyses have indicated that birch pollen seasons in the areas examined have become earlier by about 5 days over the last decade compared with the previous ten years. The change has been in response to an increase in cumulative temperature (over 5.5°C) for the months of February and March together of about 25–30°C degrees. This indicates the scale of effect that temperature changes due to global warming may have on the timing of pollen seasons and has implications for several aspects including allergy and plant distributions.

Similar changes in phenology are likely in other early flowering trees including Alder and Hazel that require winter chilling to break dormancy and then have a direct thermal response to warmth in spring months. These are mildly allergenic but cross react with birch so producing an extended season for this aeroallergen group. The major allergens of Alder (*Ahn gI*), Birch (*Bet vI*), and Hazel (*Cor aI*) have many features in common (Ipsen et al. 1992). Alder pollen acts as a primer making allergic people more sensitive to other pollens later in the season. An earlier Alder pollen season may invoke stronger reactions during the birch pollen season itself by giving a longer period of priming in susceptible people such that their allergic reactions occur at lower thresholds of birch pollen concentrations.

Many trees and herbaceous plants that reproduce later in the year require the stimulus of lengthening days to initiate flowering and do not respond to warmer conditions until

mid to late spring. Most of the species of grass in the UK (the main source of allergenic pollen) are in this category but in a small proportion the initiation of flowering does not depend on photoperiod. This group can flower in the early spring months as soon as conditions are warm enough. The amounts of pollen in the air are small but can exert a priming effect on allergic people and can make the grass pollen season notably longer.

Monitoring airborne pollen gives a record of the times when pollen is present in the air not when it matures on the plants. The start of pollen season dates perceived by this method may be different from those of the start of flowering. A delay may occur in the release or dispersal of pollen for example because of adverse weather (e.g. rainfall, lack of wind). However, the trends observed are derived from data averaged over several years and are evident in the results from all three sites. There is no indication from the weather records of a trend towards drier conditions during the birch pollen seasons that would account for the change in start dates. The methods used to collect the information on airborne pollen have been constant over the sampling periods and have been the same at all three sites. An objection that the trends towards earlier start dates for the pollen seasons may be due to the changing abundance of birch pollen could be raised against the sum75 start date method but the same patterns are evident for 2.5% start definition that is independent of pollen amounts. The analyses of the long term pollen data sets from Cardiff, Derby and London have shown that a clear biotic response in the timing of the birch pollen seasons is occurring in relation to the warmer spring temperatures of recent years. Current opinion on climatic change suggests that this general pattern will continue but it is uncertain whether it will be steady or spasmodic.

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