A POLLEN CALENDAR FOR THE MAIN ALLERGENIC POLLEN TYPES IN THE BOROUGH OF LENNOXVILLE (SHERBROOKE), QUEBEC

Elisabeth Levac
Bishop's University

ABSTRACT

Airborne pollen and spores concentrations were monitored daily in the Lennoxville borough (city of Sherbrooke, QC) during the 2006, 2007 and 2008 pollen seasons (spring and summer). The data were used to create a pollen calendar of the anemophilous pollen types that are most abundant in the air of the borough. The calendar shows when these plants can be expected to pollinate. Trees and shrubs (birch, poplar, maple, and alder) pollinate in the late-winter and spring, with pollen season stretching from April to May. The pollination seasons of pine and oak usually extend from mid-May to mid-June.

Grass pollen is abundant from mid-June until the end of August. Pollen from the weed categories, which is composed mainly of ragweed, begins to be recorded in the late summer, usually in early August. The pollen season for weeds ends in September or October, depending on the occurrence of frost.

The pollen season appears to be consistent from year to year for most genera or pollen categories, but the pollen seasons for the earlier pollinators exhibit greater variability, especially for the start of the season. This is easily explained by the great variability in weather (temperature, snow cover) that occurs in April in Lennoxville.

RESUMÉ

Les concentrations aériennes de pollen et de spores ont été étudiées de façon journalière dans l'arrondissement de Lennoxville (à Sherbrooke, QC) durant les saisons de pollinisation de 2006, 2007, et 2008 (printemps et été). Les données récoltées nous ont permis de créer un calendrier pollinique des types de pollen anémophiles les plus abondants dans l'air de cet arrondissement. Les arbres et les arbustes (bouleau, peuplier, érable et aulne) pollinisent à la fin de l'hiver et au printemps, et leurs saisons de pollinisation s'étalent d'avril à mai. Le pin et le chêne pollinisent généralement de la mi-mai à la mi-juin.

Le pollen des Poacées (Graminées) est abondant de la mi-juin jusqu'à la fin août. Le pollen des mauvaises herbes, constitué surtout de pollen d'herbe à poux, est enregistré à la fin de l'été, habituellement à partir du début d'août, et sa période de pollinisation se termine en septembre ou en octobre, avec l'arrivée du gel.

Les saisons polliniques de la plupart des genres d'arbres ou des différentes catégories (Poacées, mauvaises herbes) montrent une certaine constance d'une année à l'autre. Toutefois, le début de la pollinisation des pollinisateurs hâtifs est influencé par les conditions météorologiques du mois d'avril ainsi que par le couvert de neige à Lennoxville.

Introduction

Seasonal allergic rhinitis, also known as "hay fever," affects a large number of Canadians. Worldwide, the prevalence of hay fever is on the rise (Savage and Roy, 2005). Based on a 1996 survey conducted by Health Canada, the prevalence of allergic rhinitis in children aged 5 to 9 is 11% (Dales et al., 2004). The proportion is even higher in Canadian adults: 22% are affected by seasonal (spring-summer) allergic rhinitis (Keith et al., 2007). Allergic rhinitis is an inflammation and hyper-responsiveness of airways caused by an exposure to allergens that triggers an immune reaction and the production of histamine, irritating the lining of nasal passages (Collins, 2005). Pollen is the most common type of allergen found in the atmosphere (Meyer-Melinkian et al., 1996; Burge, 2002) and most of that pollen is from anemophilous plants, i.e. plants that are pollinated by wind, not by insects or other vectors (Bassett, 1978).

The most common symptoms associated with seasonal allergy to pollen include a runny nose, nasal congestion, repeated sneezing, as well as itchy and watering eyes (Perks, 2000). Some 27% of people affected by allergic rhinitis also have asthma, and 17% will develop chronic or recurrent sinusitis (Keith et al., 2007). Exposure to outdoor aeroallergens (pollen and spores) is also an important cause of severe asthma hospitalization and morbidity in Canada (Dales et al., 2004). The direct and indirect costs of asthma in Canada are not negligible, as they are close to those of infectious diseases, hematological diseases or perinatal illnesses (Krahn et al., 1996).

While most seasonal allergy sufferers do not experience life-threatening symptoms, 25% of them cannot tolerate their symptoms without treatment, and about 60% will use over the counter medications, prescriptions, or a combination of both (Keith et al., 2007). Sales of various allergy medications and airborne pollen concentrations are closely linked (Laaidi, 2000). Nevertheless, 20% of allergy sufferers complain that they cannot control their symptoms during the worst month of the year (Keith et al., 2007).

Most types of allergenic pollen and spores affect allergy sufferers during a period of only a few weeks each year which we will call the *pollen season* (or pollinating season). And fortunately, most people are allergic to only a few pollen types, not all. Since this pollen season occurs at about the same time every year for a given plant, it is possible to create a pollen calendar with a few years of data. Typically, in the Eastern Townships, deciduous trees and shrubs tend to release their pollen prior to leafing, usually in April or May. Most coniferous trees pollinate later in the season and produce pollen in May and June, as does oak. The pollination peak for grass is in July and August. Weeds (including ragweed) start pollinating in early August, and produce pollen throughout August and September, until the occurrence of the first frost (Bassett et al., 1978).

Pollen calendars can help allergy sufferers (and health providers) anticipate when the pollen they are allergic to will be present in the air, and can be an important tool to anticipate the seasonal peak in pollen production, since the most severe allergic symptoms coincide with this peak (Chappard et al., 2004). Creating a pollen calendar of the main allergenic pollen types found in the air of the Lennoxville borough of Sherbrooke, Quebec (approximately 150 km east of Montreal) was one of the goals of the pollen monitoring program at Bishop's University, and is the subject of the present paper.

Pollen calendars are available for other cities (e.g. Montreal, Ottawa) but they cannot be used in Sherbrooke as plant pollination times vary with location. Pollen was monitored in 1983–1984 at Sherbrooke Airport (Labre, 1987) but the surrounding vegetation is different there and can pollinate later due to the higher elevation and colder weather conditions (Latorre, 1999). Therefore, the pollen calendar presented here will be the first for the borough of Lennoxville, Sherbrooke.

The usefulness of pollen calendars is limited by the fact that the exact start and length of the pollen season can exhibit large yearly variability at any given location, depending on climatic conditions (McDonald, 1980). For example, a cold late spring will delay the beginning of the flowering season (Latorre, 1999). Daily *in situ* pollen monitoring is therefore necessary to determine if pollination has indeed started for a given plant.

Airborne pollen concentrations can also vary greatly from day to day, and even during the course of a day, with weather conditions. To maximize chances for fertilisation, anemophilous plants release massive amounts of pollen when weather conditions are optimal for dispersal towards individuals of the same species. In general, warm, dry conditions lead to higher airborne pollen concentrations (i.e. sunny days) while rainfall negatively affects pollen concentrations, as pollen grains act as nuclei for rain drops (Makinen, 1977; Rosenfeld, 2001; Levac et al., 2007).

Hence, the daily pollen monitoring programme at Bishop's University was started to study the relationship between various weather parameters and airborne pollen concentrations. The long-term goal is to improve our daily pollen forecasts, an aspect of this research that will be examined in a subsequent article. A survey conducted by *Reactine™* in July of 2006 indicated that 69% of Canada's allergy sufferers would greatly benefit from pollen forecasts that could enable them to avoid triggers and symptoms (Canada NewsWire, 2006) and reduce the costs to the health care system (Krahn et al., 1996).

Setting

Pollen samples were collected at Bishop's University, in the city of Sherbrooke, Quebec. The campus is located in the borough of Lennoxville, which is approximately 7 km from downtown Sherbrooke, at the junction of the St. Francis and Massawippi Rivers. The campus is on the edge of a small urban centre surrounded by agriculture lands and mixed forests. The most common trees are pine (*Pinus*), spruce (*Picea*), balsam fir (*Abies*), cedar (*Thuja*), hemlock (*Tsuga*), larch (*Larix*), maple (*Acer*), birch (*Betula*), poplar (*Populus*), oak (*Quercus*), elm (*Ulmus*), willow (*Salix*), basswood (*Tilia*) and beech (*Fagus*). Shrubs grow in the understory and along the rivers, with alder being the most abundant (Rousseau 1974).

Methods

A Burkard 7-day Hirst-type volumetric sampler (Hirst, 1952) was used to collect pollen samples. This device was selected because it is highly efficient for such purposes (Peng and Chen, 1996). The pollen trap was located on the roof of the Johnson Building at Bishop's University at the recommended height of 10 metres above ground. According to the American Academy of Allergy, Asthma and Immunology (AAAAI) and the National Allergy Bureau (NAB), pollen and spore samplers should be placed a minimum of 10 metres above ground level in order to retrieve a representative pollen sample from the surrounding area. This is what the paleoecologists would call the local pollen rain (Faegri and Iversen, 1989). Because most of the pollen responsible for allergies is produced by plants that evolved to be wind pollinated, it is readily picked up by wind and stirred into the atmosphere. This is why air samplers are typically placed well above the ground.

Air is drawn into the pollen sampler at a rate of 10 litres per minute, thanks to a small electric motor located in the body of the sampler. A vertically-mounted drum is placed inside the sampler, right in front of the intake slit. A piece of Melinex tape covered with a thin layer of petroleum jelly is wrapped around the drum, which turns clockwise at a rate of 2 mm per hour, or 48 mm per day. Therefore, all particles contained in the air, including pollen, stick to the coated tape as the air is pumped through the slit into the sampler. When the tape is removed from the sampler, it is cut in 48 mm-long sections, each section representing a 24 hour period. Each tape section is mounted on a labeled slide. A glass cover slip is placed over the tape section and sealed with clear nail polish.

The pollen grains on each slide were identified, counted and recorded using transmitted light microscopes (usually a Nikon Eclipse 50i) at 400X magnification. Spores were counted but not differentiated. Counts were done for 2 hour intervals (The British Aerobiology Federation Handbook, 1995). Quality control was maintained by ensuring the microscope was carefully calibrated (by measuring the size of the field of view using a micrometer) and by making duplicate counts of pollen from the same slide periodically throughout the season. These duplicates were counted by two different trained specialists.

Pollen was identified to the genus level for trees, and to the family level for some types of grasses (e.g. *Poaceae*) or weeds, using a pollen reference slide collection prepared from flowers harvested on identified trees, grasses and weeds growing locally, and using pollen reference books (Bassett et al., 1978; McAndrews et al., 1973). Raw pollen counts were converted into pollen concentrations (grains/m^3 of air sampled) using a conversion factor (see The British Aerobiology Federation Handbook, 1995).

Pollen samples were collected daily from April until the first frost in 2007 and 2008. Samples were analyzed from April 23 to September 5, 2007 and again from April 8 to September 5 in 2008. Preliminary work was also done in the spring of 2006, when pollen samples were collected from the beginning of May to the middle of June. While the 2006 collection season was of short duration, it nevertheless covered the weeks during which the tree pollen production peaks were observed, but missed most of the grass and all of the weed pollen seasons.

Seasonal calendars were compiled for the 2007 and the 2008 pollen seasons following the method proposed by Andersen (1991) and eliminated the outliers near the beginning and the end of the pollination season. Odd pollen grains can be resuspended in the air by strong winds long after pollination has ended, and even into the following spring. The pollination season is therefore defined as 95% of the season's total pollen for a given genus. Outliers are defined as any pollen occurring outside of the 95% range. The pollination season is considered to start when a species' total pollen count reaches 2.5% of the total amount of pollen collected in that season. The pollination season ends when a species' total pollen count reaches 97.5% of the total amount of pollen collected in that season. Other methods for determining the start and end of the pollination season use different percentages (e.g. Makinen, 1977; Nilsson and Persson, 1981) but Andersen's method allows us to ignore the small percentage of eccentric pollen while still acquiring a good representation of seasonal pollen release.

The average pollen calendar (Table 3) combines data from 2006 to 2008 and is based on the average concentrations. The thresholds used are shown in Table 3a and are from the AAAAI. We combined the low and moderate categories as the pollen concentrations show high interannual variability at the beginning and end of the pollen season. The high or very high categories correspond to the peak of pollination. Note that some taxa can display two peaks.

Results

Trees make up almost 95% of the total airborne pollen load in Lennoxville, the remaining 5% consisting of pollen from the weeds and grass categories (Sandercombe, 2007) (Figure 1). Among the trees, pine and maple are by far the most abundant, accounting for 70% and 13% of the overall tree pollen load, respectively (Figure 2) (Sandercombe, 2007).

Airborne pollen types collected in significant concentrations in Lennoxville are pine (*Pinus*), maple (*Acer*), poplar (*Populus*), birch (*Betula*), oak (*Quercus*), grass (*Poaceae*). Other pollen types were found but in smaller concentrations. These include fir (*Abies*), alder (*Alnus*), walnut (*Juglans*), spruce (*Picea*), tamarack (*Larix*), willow (*Salix*), cedar (*Thuja*), basswood (*Tilia*), elm (*Ulmus*) and ragweed (*Ambrosia*). Mold and fungal spores are ubiquitous in all samples.

The start of the pollen season (as defined by Andersen et al., 1991) for the tree category (as a whole) shows interannual variability (see Tables 1 and 2). The pollen season extended from May 2 to June 20 in 2007, while in 2008, it extended from April 18 to June 21. Year 2006 is not shown in the tables since the sampling season was too short.

When individual tree genera are considered, we can note differences between 2007 and 2008, not only in the timing and length of the pollen season but also in the dates the pollen season peak occurs as well as in the maximum pollen concentrations attained at that peak.

Pine Phenology

The 2007 pollen season for pine extended from May 25 to June 20 (Table 1). In 2008, the season started later (June 3) but ended on the same date (Table 2). Pine pollen concentrations peaked in the middle of June (Figure 3) for all 3 years during which pollen was monitored in Lennoxville (2006–2008), however the maximum pollen

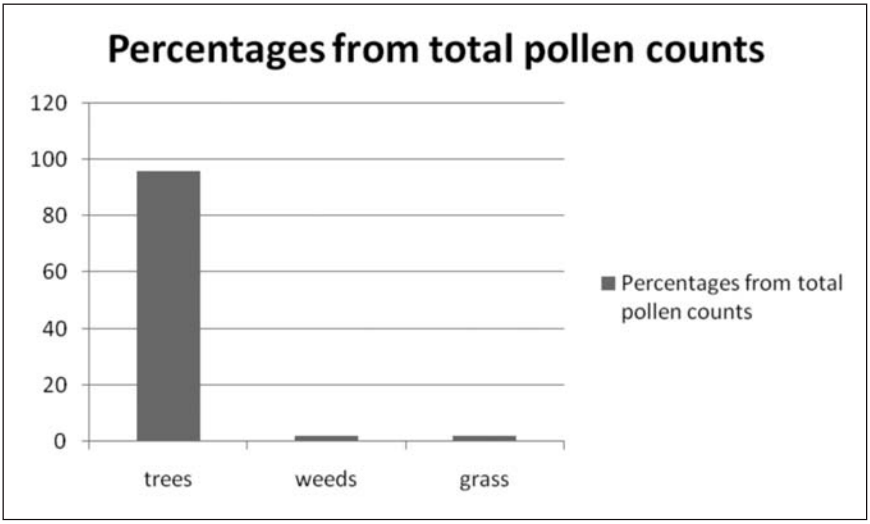


Figure 1: Proportion of the three main pollen categories for Sherbrooke, Quebec, showing percentages from total pollen numbers, based on data from 2006–2008.

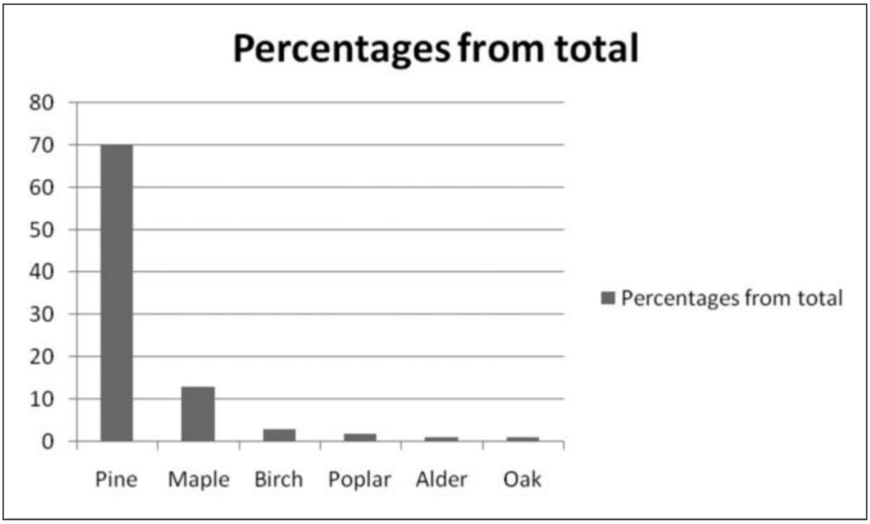


Figure 2: Proportion of various tree genera in the overall airborne pollen load for Sherbrooke, Quebec, based on data from 2006–2008.

concentrations during the peak were greater in 2007, reaching 12,000 grains/m^3 compared to 5000 grains/m^3 in 2008 (Figure 3).

Poplar Phenology

The pollen season for poplar was already underway when the monitoring was started on April 23, 2007 (Table 1) (monitoring was

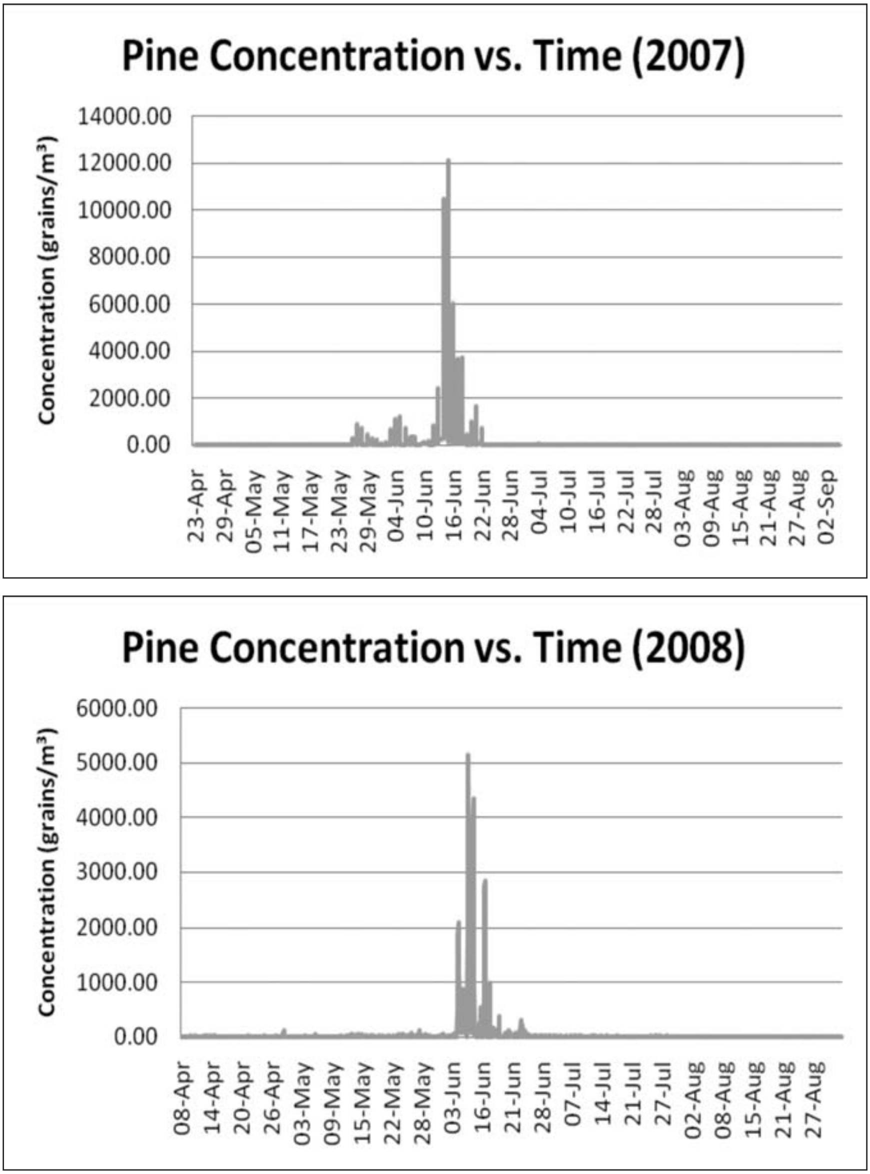


Figure 3: Evolution of pine pollen concentrations in Sherbrooke, Quebec from April to August 2007 and 2008 (From Stretch 2009)

2007 Pollen Calendar																						
	April				May				June				July				August				September	
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Poplar			■	■	■	■																
Maple				■	■	■	■	■														
Oak					■	■	■	■														
Birch						■	■	■														
Pine								■	■	■	■											
Grasses								■	■	■	■	■	■	■	■	■	■					
Weeds																	■	■	■	■	■	■
Spores					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 1: Pollen calendar for Sherbrooke, Quebec, based on data from the 2007 pollen season, for genera or categories with significant concentrations (yearly total concentration >2000 grains/m³) (Modified from Stretch 2009)

2008 Pollen Calendar																						
	April				May				June				July				August				September	
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Poplar			■	■	■	■																
Maple			■	■	■	■	■															
Oak			■	■	■	■	■	■	■	■												
Birch					■	■	■	■														
Pine							■	■	■	■	■											
Grasses								■	■	■	■	■	■	■	■	■	■	■	■	■		
Weeds																	■	■	■	■	■	■
Spores			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 2: Pollen calendar for Sherbrooke, Quebec, based on data from the 2008 pollen season, for genera or categories with significant concentrations (yearly total concentrations >2000 grains/m³) (Modified from Stretch 2009)

started late because of abundant remaining snow on the roofs). In 2008, the pollen season started on April 14 (Table 2) and for both years, it ended on May 12. Pollen concentrations peaked essentially on the same dates for both years (Figure 5), but peak pollen concentrations were greater in 2008, reaching 500 grains/m³ compared to 170 grains/m³ the previous year (Figure 5).

Birch Phenology

Birch is another genus that displays variations in the starting date of its pollen season, but not in the ending date. In 2007, the pollen season stretched from May 8 to 29, while in 2008, it stretched from May 1 to 30 (Tables 1 and 2). However, the peak concentrations and the dates for the peak occurrence were similar for both years (Figure 4).

Maple Phenology

The length of the maple pollen season was the same in 2007 and 2008, but it started later in 2007, when it extended from April 22 to May 30, while it extended from April 15 to May 25 in 2008. Peak concentrations do not show significant differences between the two years.

Oak Phenology

The oak pollen season had a very sudden onset in 2007: oak was not recorded in the sampler for the first week of sampling, but oak started to pollinate suddenly on April 30. The season ended on May 29 that year. The oak pollen season was much longer in 2008 because it started

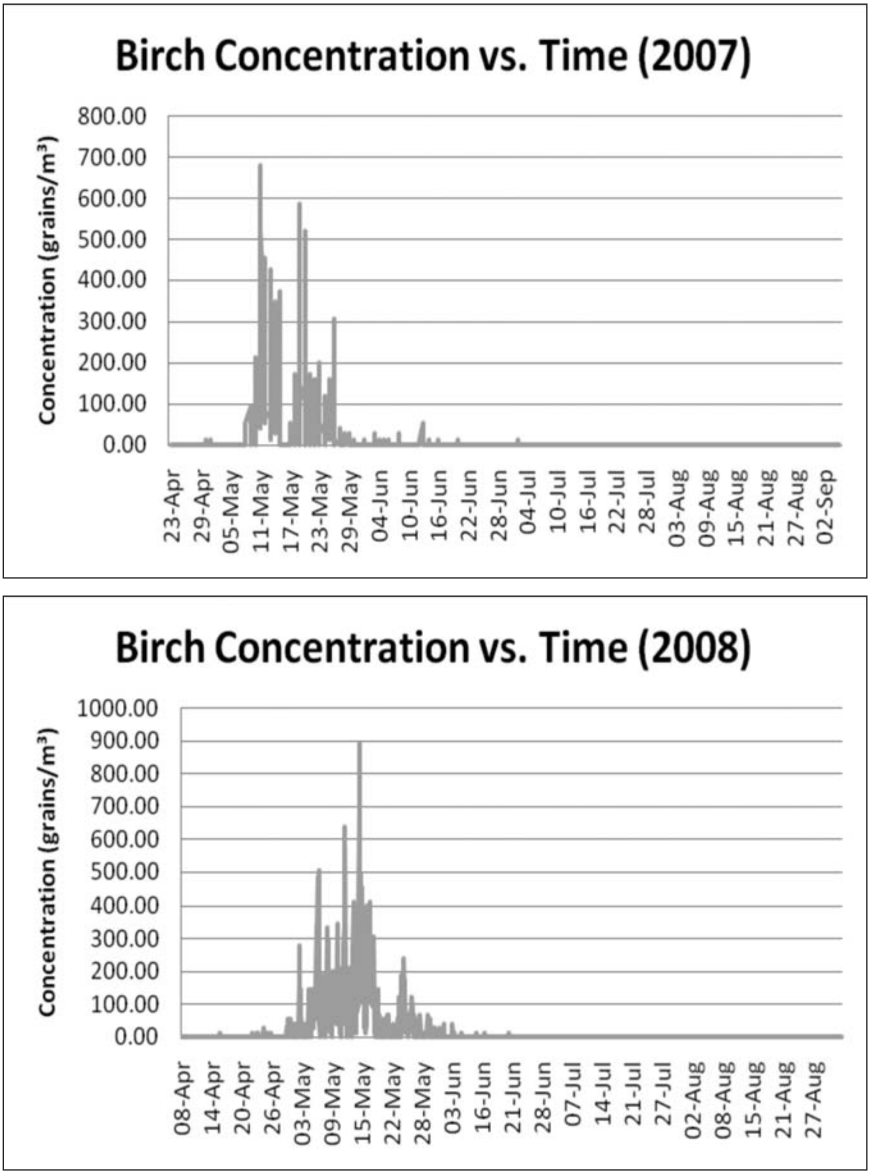
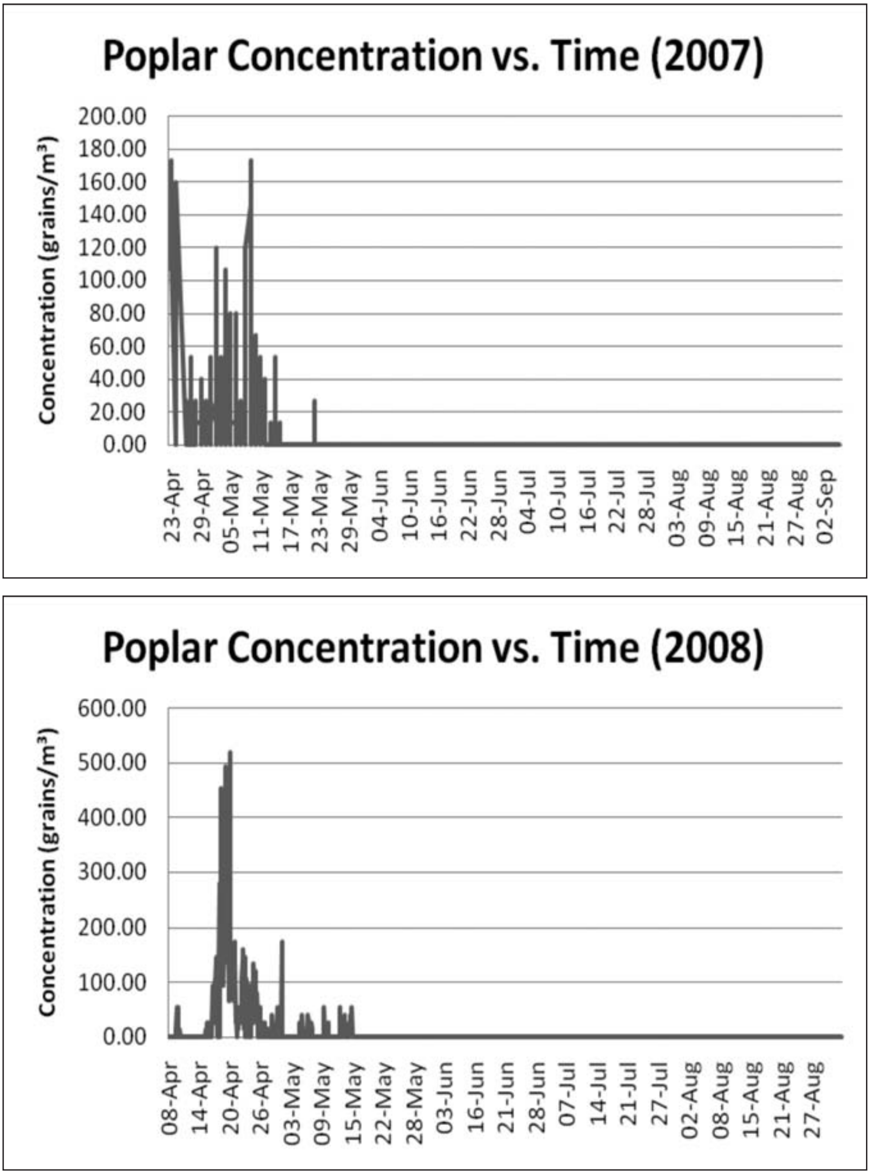


Figure 4: Evolution of birch pollen concentrations in Sherbrooke, Quebec from April to August 2007 and 2008 (From Stretch 2009)

on April 16 and ended on June 16 (Tables 1 and 2). The peak pollen concentrations were the same for 2007 and 2008, but the timing of the peak occurred slightly later in 2008 (Figure 6). The overall season for oak also stretched over a longer period of time (Tables 1 and 2).



Poplar Concentration vs. Time (2007)

Poplar Concentration vs. Time (2008)

Figure 5: Evolution of poplar pollen concentrations in Sherbrooke, Quebec from April to August 2007 and 2008 (From Stretch 2009)

Alder Phenology

Low concentrations of alder pollen were collected in April and May for both years, but alder was not included in the pollen calendar because concentrations remain low and sporadic. We possibly have insufficient data because alder is one of the earliest pollen producers and its pollen season might start in early April, before we could start the monitoring.

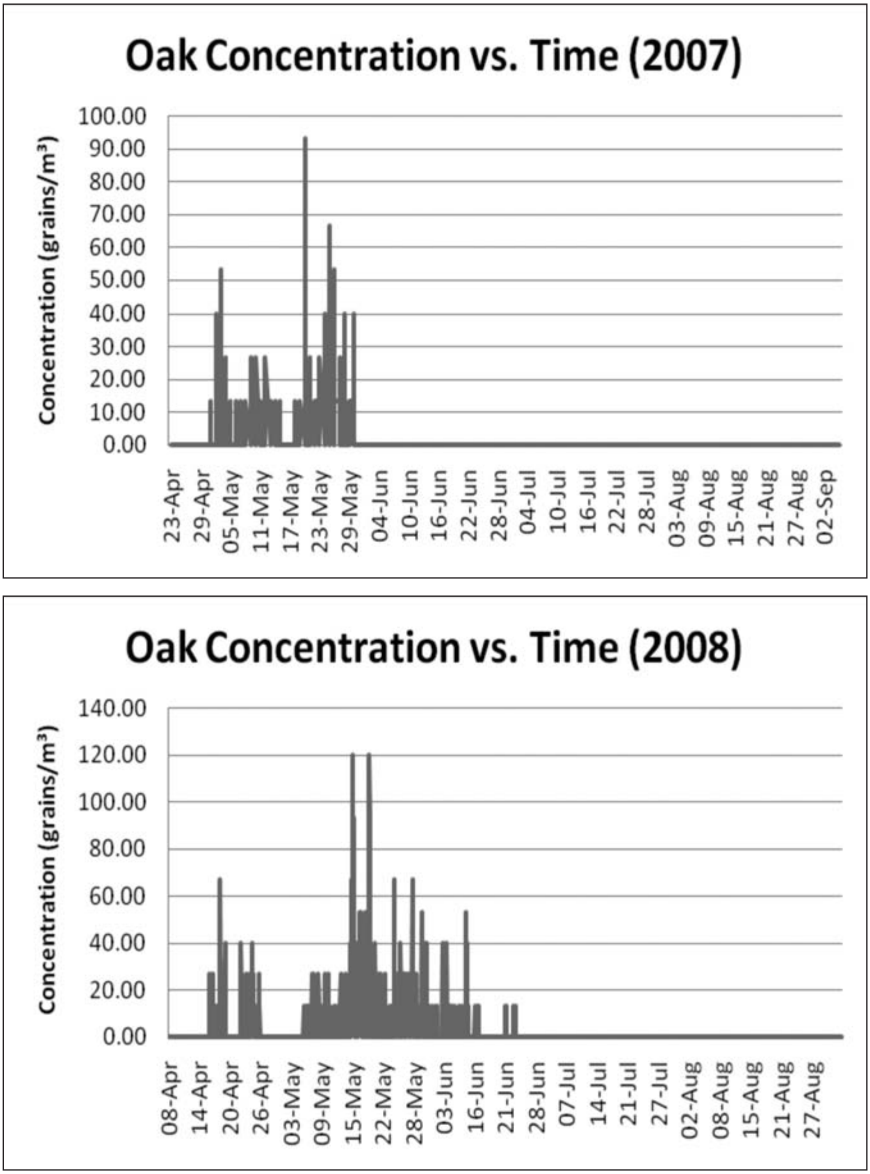
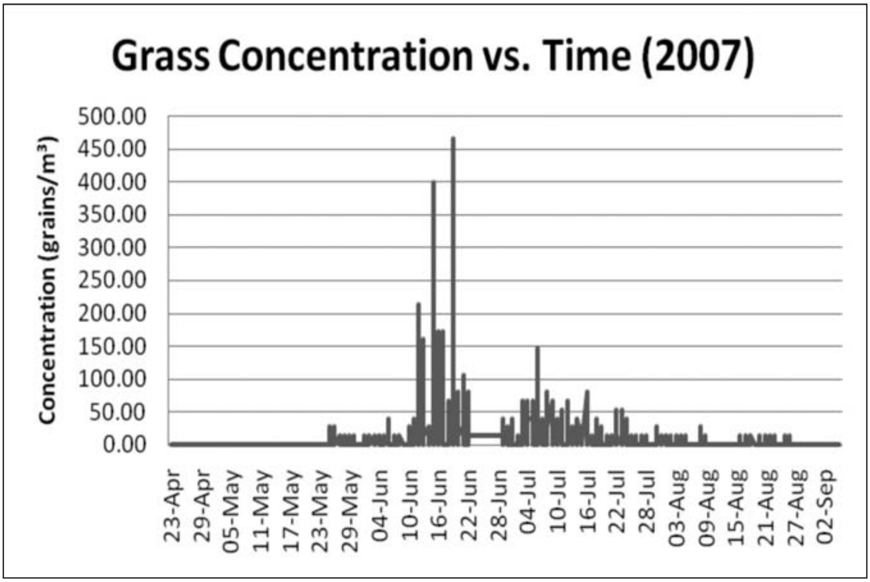


Figure 6: Evolution of oak pollen concentrations in Sherbrooke, Quebec from April to August 2007 and 2008 (From Stretch 2009)

Grass Phenology

The start of the pollen season is more consistent for the grass category, but it is the overall length of the season that varies in this case. In 2007, the pollen season for grass was from May 29 to August 4, while in 2008 the pollen season was three weeks longer, stretching from May 25 until August 27 (Tables 1 and 2). Average grass peak concentrations



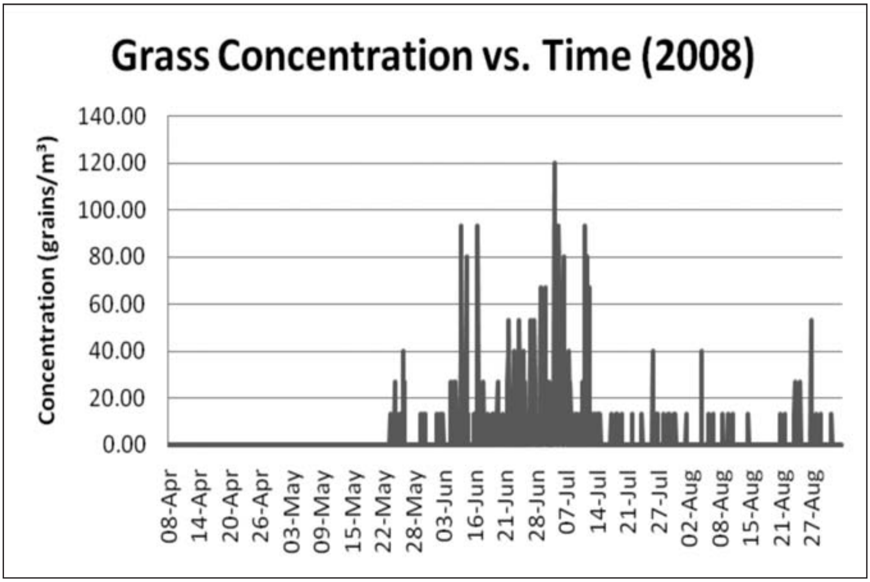
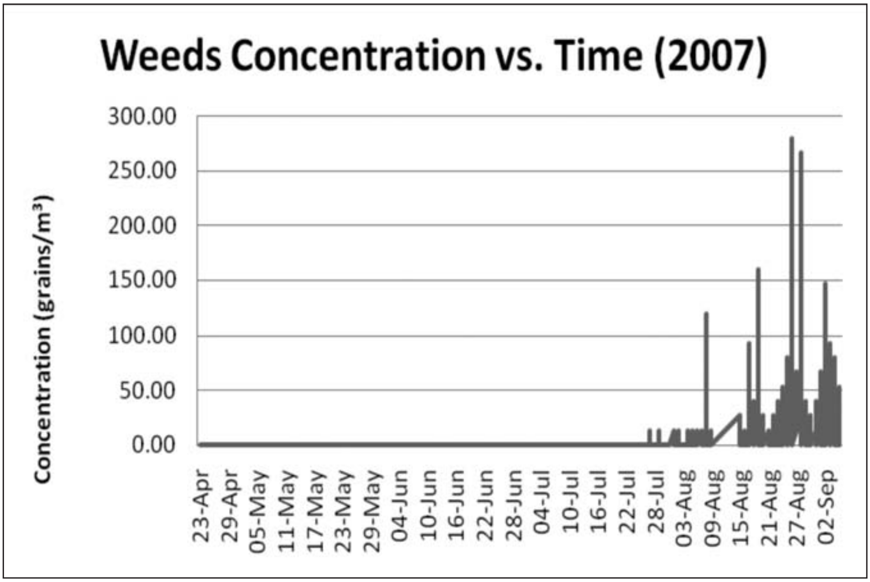


Figure 7: Evolution of grass pollen concentrations in Sherbrooke, Quebec from April to August 2007 and 2008 (From Stretch 2009)

went from 500 grains/m^3 in 2007 to 140 grains/m^3 in 2008 (Figure 7). The peak in grass pollen also occurred later in 2008 (Figure 7).

Weeds Phenology

Among all the pollen categories, weeds are the most constant with pollen seasons starting on August 4 both years and ending on



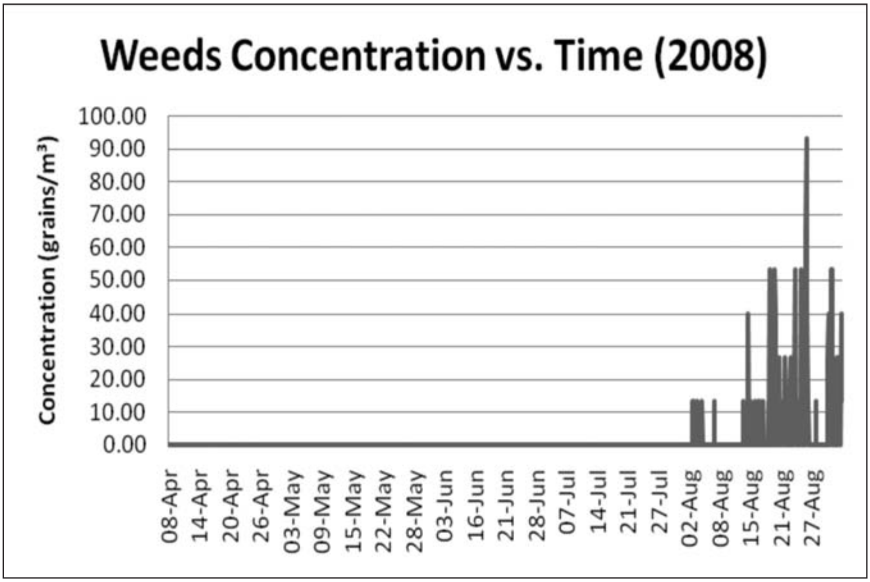
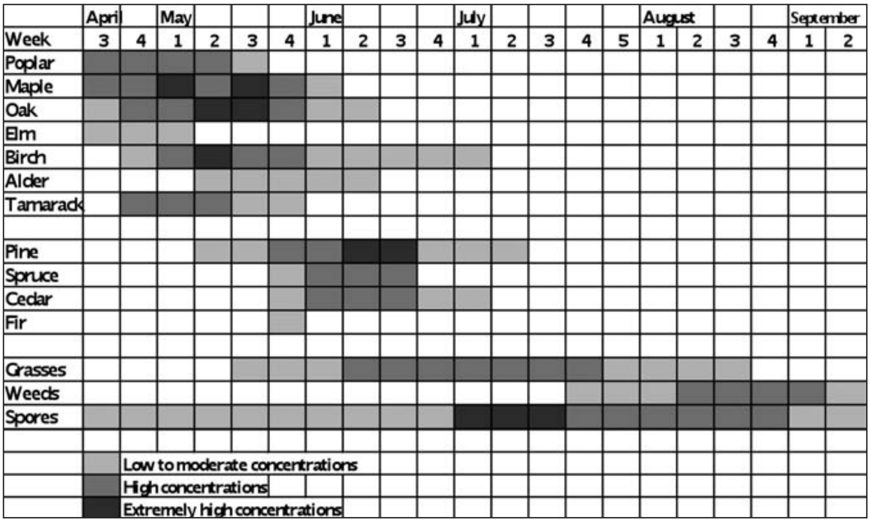


Figure 8: Evolution of weed pollen concentrations in Sherbrooke, Quebec from April to August 2007 and 2008 (From Stretch 2009)



	April		May				June				July					August				September	
Week	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2
Poplar	▒	▒	▒	▒	░																
Maple	▒	▒	▓	▒	▓	▒	░														
Oak	░	▒	▒	▓	▓	▒	░	░													
Elm	░	░	░																		
Birch		░	▒	▓	▒	▒	░	░	░	░	░										
Alder				░	░	░	░	░													
Tamarack		▒	▒	▒	░	░															
Pine				░	░	▒	▒	▓	▓	░	░	░									
Spruce						░	▒	▒	▒												
Cedar						░	▒	▒	▒	░	░										
Fir						░															
Grasses					░	░	░	▒	▒	▒	▒	▒	▒	▒	░	░	░	░			
Weeds														░	░	░	▒	▒	▒	▒	░
Spores	░	░	░	░	░	░	░	░	░	░	▓	▓	▓	▒	▒	▒	▒	▒	▒	░	░
	░	Low to moderate concentrations																			
	▒	High concentrations																			
	▓	Extremely high concentrations																			

Table 3: General pollen calendar for Sherbrooke, Quebec, for the most abundant pollen types, based on data from 2006–2008. The standard thresholds from the AAAAI were used to classify the average pollen concentrations into the low-moderate, high or very high categories. Thresholds are shown in table 3a.

	Trees	Weeds	Grass	Spores
Absent	0	0	0	0
Low	0–14	0–9	0–4	0–6499
Moderate	15–89	10–49	5–19	6500–12999
High	90–1499	50–499	20–199	13000–4999
Very High	˃1500	˃500	˃200	˃50000

Table 3a: Thresholds from the American Academy of Allergy, Asthma and Immunology (2006).

September 5 and September 1 in 2007 and 2008 respectively. Finally, peak concentrations for weed pollen (mainly *Ambrosia*) went down from 300 grains/m^3 in 2007 to less than 100 grains/m^3 in 2008, but the peak in concentrations had essentially the same timing both years (Figure 8).

Table 3 is based on the average concentrations of the three years and it displays taxa that are not discussed here (elm, tamarack, spruce, cedar, fir). These taxa are represented by smaller numbers of pollen grains which obscure annual trends. The occurrence of willow, walnut and beech is too sporadic; hence they are not included in the calendar.

Discussion

The composition of the airborne pollen load does not reflect that of the surrounding vegetation, but this was expected: anemophilous trees produce greater quantities of pollen than trees with entomophilous pollination (Faegri and Iversen, 1989). Among the anemophilous trees, some will also produce much greater quantities of pollen and will tend to be over-represented in the pollen rain. This is the case for pine and maple (Delcourt and Delcourt, 1991).

Weather conditions appear to influence the start of the pollen seasons but the data gathered so far is insufficient to verify this statistically, with only two full pollen seasons (2007 and 2008). Nevertheless, we can link certain trends with the weather conditions we experienced in Lennoxville in the late winter, spring and summer. Snow melted late in April 2006 and April 2007 because temperatures remained relatively cold (this is the main reason why the pollen sampler was not deployed earlier those 2 years). In 2007, the cold April weather was followed in May by a few weeks of above-normal temperatures with dry weather. In 2008, even though snow melted relatively early in April, temperatures for the month of May were colder than normal (Environment Canada, 2008).

If we examine the pollen season of early spring pollinators (poplar, birch, oak, maple), we can identify some common trends. The 2007 birch and maple pollen seasons were delayed by a week relative to 2008. We can only assume the same for poplar, but this genera starts pollinating much earlier in April and the data collection started too late in 2007. The oak season started suddenly on April 30, 2007, as if it was waiting for snow to melt. These results are consistent with Latorre (1999) and McDonald (1980).

While colder weather in April appears to delay the onset of early pollinator pollen seasons, it seems to have little impact on the end of their pollen seasons and on the timing of production peaks. That is the case for poplar, birch and maple, for which the date of pollen production peak seems constant from year to year. For birch and maple, the average concentrations also seem unaffected by climatic conditions. Oak appears to be an exception: the cold April 2007 weather delayed the onset of the pollen season, the colder-than-normal temperatures in May 2008 corresponded with a delay in the peak pollen concentrations.

The data collected for pine, the only abundant late spring pollinator in Lennoxville, suggest that its pollen season and pollen production is also affected by climatic conditions. The warm weather of May 2007 corresponds to an early onset of the pollen season and for concentrations more than twice those of the previous year. It was the reverse situation the following year: the cold weather of May 2008 corresponded with a delayed onset of the pollen season and lower concentrations.

The lower airborne grass pollen concentrations recorded in 2008 can be directly related to abundant and frequent precipitation events in Lennoxville, as also found in other studies (Makinen, 1977; Rosenfeld, 2001). Precipitation amounts were well above normal for the months of May, June, July and August, some months receiving up to three times the normal amounts of rain. The timing of the peak in production was also delayed.

The pollen calendar we created (Table 3) can be a useful tool for pollen forecasting and allergy control. It is now possible to anticipate the start of pollination for the most abundant pollen producers in Lennoxville, and the peak in production for each taxa. However, we have seen that year-to-year variations can be important, and therefore this calendar should be viewed as preliminary work. Numerous years of data are needed to create a valid calendar (Menzel and Fabian, 1999) and pollen data collection will continue. The pollen calendar will therefore be updated in the future.

Continuing pollen monitoring and data collection over many years is justified by the year-to-year variability in climatic conditions, which control the start of pollination. Changes in phenology may also be used to monitor global warming (Menzel and Fabian, 1999; Newham, 1999). Year-to-year variability in the timing of the pollen seasons (either the start or the end) and in the timing of the pollen concentration peaks can easily be detected with this calendar. Continuous monitoring is also relevant in the context of increasing atmospheric CO_2 concentrations, shown to stimulate ragweed's growth and pollen production (Rogers et al., 2006).

Indeed, since global warming could mean warmer spring temperatures, earlier pollination could ensue, as well as longer pollen seasons and greater pollen production (D'Amato et al., 2001). The health impact of pollen could be affected by global warming too, since it could modify plants' geographic distribution, attributes and pollen allergenicity (Beggs, 2004). In Japan, the rise in seasonal allergies is already imputed to climate change (Williams, 2005).

The next step in our research will be to determine the relationship between airborne pollen concentrations and weather parameters. This would improve our ability to improve daily pollen forecasts.

Conclusions

A pollen calendar of the most abundant airborne pollen types has been created for the borough of Lennoxville, Qc. Weather conditions (temperature, snow cover) appear to affect the date at which the pollen season starts for the late-winter/spring pollinators (poplar, birch, maple, oak). Climatic conditions could possibly impact the timing of the peak in pollen production. More data is necessary to confirm these trends statistically. Future work will focus on the relationship between daily weather parameters and the pollen concentrations in order to make daily pollen forecasts for allergy sufferers in the area.

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REFERENCES

American Academy of Allergy Asthma and Immunology. (2006). *www.aaaai.org*

Andersen, T.B. (1991). « A model to predict the beginning of the pollen season. » *Grana*, 30, pp. 269–275.

British Aerobiology Federation, The. (1995). *Airborne pollens and spores: A guide to trapping and counting*. The British Aerobiology Federation, Chatham, 60 p.

Bassett, I.J., C.W. Crompton, and J.A. Parmelee. (1978). *An Atlas of airborne pollen grains and common fungus spores of Canada*. Canada Department of Agriculture Monograph 18, 321 p.

Beggs, P.J. (2004). « Impacts of climate change on aeroallergens: past and future. » *Clinical and Experimental Allergy*, 34, pp. 1507–1513.

Burge, H.A. (2002). « An update on pollen and fungal spore aerobiology. » *Journal of Allergy and Clinical Immunology*, 110, pp. 544–52.

Burkard Manufacturing Company Limited. (2000). *Seven-day recording volumetric spore trap. User manual*, 8 p.

Canada NewsWire (2006). « A crystal ball for allergies? Sixty nine per cent of sufferers say better prediction is key to enjoying the outdoors. » August 9.

Chappard, C., J. Bonnevial, M. Colson, G. Mathern, and A. Emonot. (2004). « Forecast of pollination dates and relation to onset of allergic pathology. » *Aerobiologia,* 20, pp. 35–42.

Collins, P. (2005). « A riot of sneezes. » *New Scientist*, June 11, pp. 52–53.

Dales, R.E., S. Cakmak, S. Judek, T. Dann, F. Coates, J.R. Brook, and R.T. Burnett. (2004). « Influence of outdoor aeroallergens on hospitalization for asthma in Canada. » *Journal of Allergy and Clinical Immunology*, 113, 2, pp. 303–306.

D'Amato, G., G. Liccardi, M. D'Amato, and M. Cazzola. (2001). « The role of outdoor air pollution and climatic changes on the rising trends in respiratory allergy. » *Respiratory Medicine,* 95, pp. 606–611.

Delcourt, H.R., and P.A. Delcourt. (1991). *Quaternary ecology: a paleoecological perspective*. Chapman and Hall, 242 p.

Environment Canada (2008). *Climate date online*. National climate data and information archive. Available from: *http://climate.weatheroffice.gc.ca/climateData/canada_e.html*.

Faegri, K., and J. Iversen. (1989). *Textbook of pollen analysis*. 4th edition. John Wiley and Sons, 328 p.

Hirst, J.M. (1952). « An automatic volumetric spore trap. » *Annals of Applied Biology*, 39, p. 257.

Krahn, M.D., C. Berka, P. Langlois, and A.S. Detsky. (1996). « Direct and indirect costs of asthma in Canada, 1990. » *Canadian Medical Association Journal*, 154, pp. 821–831.

Laaidi, K. (2000). « Ventes de médicaments anti-allergiques et comptes polliniques: un double indicateur de la prévalence des pollinoses. » *Revue Française d'Allergologie et d'Immunologie Clinique*, 40, pp. 527–538.

Labre, L. (1987). *Aéropalynologie comparée des régions de Sherbrooke et de Sainte-Agathe*. Master's thesis, Université de Montréal.

Latorre, F. (1999). « Differences between airborne pollen and flowering phenology of urban trees with references to production, dispersal and interannual climate variability. » *Aerobiologia*, 15, pp. 131–141.

Levac, E., A. Miller, D.L. Waugh, and D.H.S. Richardson. (2007). *Report on the Halifax Experimental pollen and spore forecast program for the summer of 2007*. Meteorological Service of Canada, Atlantic Region, Science Report Series 2007-XX, November 2007.

Makinen, Y. (1977). « Correlation of atmospheric spore frequencies with meteorological data. » *Grana*, 16, pp. 149–153.

McAndrews, J.H., A.A. Berti, and G. Norris. (1973). *Key to Quaternary pollen and spores from the Great Lakes region*. Royal Ontario Museum, Life Science Miscellaneous Series, 64 p.

McDonald, M.S. (1980). « Correlation of air-borne grass pollen levels with meteorological data. » *Grana*, 19, pp. 53–56.

Menzel, A., and P. Fabian. (1999). « Growing season extended in Europe. » *Nature,* 397, p. 659.

Meyer-Melinkian, N., E. Sererova, and S. Polevova. (1996). « Pollen Grains as a cause of pollinosis. » *Journal of Aerosol Science*, 27, pp. 251–252.

Newnham, M. and M. Rewi. (1999). « Monitoring Biogeographical Response to Climate Change: The Potential Role of Aeropalynology. » *Aerobiologia*, 15, pp. 87–94.

Nilsson, S. and S. Perssons. (1981). « Tree pollen spectra in the Stockholm region (Sweden) 1973–1980. » *Grana*, 20, pp. 179–182.

Peng, M., and S. Chen. (1996). « Comparison of counting methods for the study of air-borne pollen with special reference to Broussonetia pollen. » *Taiwania*, 41, 1, pp. 35–42.

Perks, B. (2000). « Beware! Allergens. » *New Scientist*, 22 January 2000, pp. 1–4.

Rogers, C.A., P.M. Wayne, E.A. Macklin, M.L. Muilenberg, C.J. Wagner, P.R. Epstein, and F.A. Bazzaz. (2006). « Interaction of the onset of spring and elevated atmospheric CO2 on ragweed (Ambrosia artemisiifolia L.) pollen production. » *Environmental Health Perspectives*, 114, pp. 865–869.

Rosenfeld, J. (2001). « The itch to forecast: predicting allergy attacks by predicting the weather. » *Weatherwise*, 54, 4, pp. 16–25.

Rousseau, C. (1974). *Géographie floristique du Québec/Labrador: distribution des principales espèces vasculaires*. Les Presses de l'Université Laval, 799 p.

Sandercombe, S. (2007). *The role of weather patterns on the production of allergenic airborne pollen in Lennoxville, Quebec*. Honour's Thesis, Bishop's University, 90 pages.

Savage, J., and D. Roy. (2005). « Allergic rhinitis: and update. » *The Journal of the Royal Society for the Promotion of Health,* 125, pp. 172–175.

Stretch, V. (2009). *Rural airborne pollen fluctuations: an aeropalynological study of Sherbrooke (Lennoxville), Quebec*. Honours thesis, Bishop's University, 94 p.

Williams, R. (2005). « Climate change blamed for rise in hay fever. » *Nature*, 434, p. 1059.