Aerobiologia (2012) 28:295–301
DOI 10.1007/s10453-011-9224-0

BRIEF COMMUNICATION

Assessment of airborne Asteraceae pollen in Brisbane, Australia

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Received: 2 December 2010 / Accepted: 2 September 2011 / Published online: 18 September 2011

Abstract In the southern hemisphere, the airborne prevalence and seasonal distribution of Asteraceae pollen are poorly characterized. In this study, we assessed the longitudinal distribution of Asteraceae pollen using an historic aerobiological dataset. The influence of weather parameters on pollen derived from Asteraceae species was additionally explored. Asteraceae pollen was collected using a static Burkard 7-day spore trap during a 5-year (June 1994–May 1999) aerometric surveillance program in Brisbane, Australia. Two discrete seasonal intervals were identified each sampling year. The first interval (September and October) consisted of small quantities of unidentifiable Asteraceae pollen. The second interval (March and April) was characterized by the highest concentrations of Asteraceae pollen that were predominantly derived from *Baccharis halimifolia*. Associations between daily Asteraceae pollen concentrations and temperature were observed during each sampling year. The results of the study demonstrated that pollen derived from *B. halimifolia*, an invasive weed species introduced in the late nineteenth century, continue to be in the environment of Brisbane. Given the public health burden associated with personal Asteraceae pollen exposure in other geographic locations, future Australian-based clinical studies should characterize the contribution of Asteraceae pollen, in particular *B. halimifolia*, to allergic sensitization and respiratory morbidity.

Keywords Aerobiology · *Baccharis* · Seasonal · Temperature · Public health

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1 Introduction

The Asteraceae is a cosmopolitan assemblage of perennial herbs, shrubs, trees, and occasional climbers. The family is the second largest among angiosperms, and it is characterized by identifiable inflorescences that produce anemophilous or entomophilous tricolporate pollen. In the environment, Asteraceae pollen is abundant, particularly in northern temperate latitudes where daily airborne concentrations may exceed 1,200 grains m^{-3} (Barnes et al. 2001). In contrast, the airborne prevalence of Asteraceae pollen has remained less characterized in many

southern hemisphere environments, including Australia. Aerometric surveys, located on the east coast of Australia, have shown that non-indigenous species such as *Ambrosia artemisiifolia* (ragweed) (Bass et al. 2000) and *Baccharis halimifolia* (groundsel bush) (Moss 1965) contribute pollen to the bioaerosol load. The pollen derived from these species is anemophilous and suspected aeroallergen sources (Bass et al. 2000; Moss 1965, 1967).

Baccharis halimifolia is an invasive weed species that is native to the West Indies and coastal environments of the southern United States. The species was first introduced to southern Queensland as an ornamental in the late nineteenth century (Parsons and Cuthbertson 2001). Prior to World War II, the species had been naturalized in a region spanning from Maryborough to Tweed Heads (Parsons and Cuthbertson 2001). Currently, regions colonized by *B. halimifolia* extend as far north as Gladstone, Queensland, and as far south as Shellharbour, New South Wales (Parsons and Cuthbertson 2001; Ensbey 2001; DNRW 2006) (Fig. 1). *B. halimifolia* is an aggressive pioneer plant species that can rapidly colonize disturbed environments due to physiological adaptations that facilitate growth in saline and acidic soils (Parsons and Cuthbertson 2001). The species is also resistant to livestock herbivory due to the production of various intracellular toxins (Tokarnia et al. 1992; Stegelmeier et al. 2009). As a result of these invasive attributes, the Queensland Government has recognized *B. halimifolia* as a threat to the sustainability of agriculture and other land uses in Queensland (Wilson 2008). Regions of greatest *B. halimifolia* infestation are primarily restricted to Brisbane and the Maroochy shire (Fig. 1) due to the suitable environmental conditions that facilitate rapid growth and colonization of the species (Department of Natural Resources and Water 2006). However, since preliminary gravimetric surveillance programs conducted in 1962 (Moss 1965), it has remained unclear whether pollen counts derived from *B. halimifolia* have decreased following state eradication programs. In addition, the influence of other meteorological parameters on the prevalence of *B. halimifolia* in the environment has also remained uncharacterized.

The public health burden associated with personal exposure to Asteraceae pollen in this region of Australia is well recognized (Bass et al. 2000). One aspect that has been overshadowed in previous studies has been the potential health implications associated with personal exposure to the pollen produced by *B. halimifolia* and other Asteraceae species. Previous studies have proposed *B. halimifolia* pollen exposure to be an etiological agent associated with seasonal exacerbations of respiratory morbidity in Brisbane (Moss 1967). However, the longitudinal distribution of pollen derived from this species and other Asteraceae, in addition to the magnitude of airborne concentrations, has not been assessed since the commencement of gravimetric air sampling and *B. halimifolia* eradication programs in Brisbane (Moss 1965). Given the potential clinical significance of Asteraceae pollen exposure in Brisbane, the aim of this study was to assess the incidence of airborne Asteraceae pollen and explore the influence of meteorological parameters on Asteraceae pollen seasons in this subtropical southern hemisphere environment. This information will ultimately assist public health professionals in planning allergen avoidance strategies for Asteraceae-sensitized subjects in Brisbane, Australia.

2 Materials and methods

2.1 Study location

Brisbane is located in the state of Queensland (27°29′S, 153°8′E) and aligns Moreton Bay and the Pacific Ocean (Fig. 1). The geographic region is classified as a humid subtropical climate with an annual mean temperature of 25.9°C and an average yearly rainfall of 1,114.6 mm as previously described (Green et al. 2002). Prevailing winds are mainly from the southeast between November and March and from the northwest to southwest between April and October (Green et al. 2002).

The trapping site was situated on a Queensland Department of Primary Industries research farm in the suburb of Rocklea, approximately 7 km southeast of Brisbane's central business district and 30 km west of Moreton Bay. Elevation of the site was 12.5 m above sea level, and the sampling apparatus was located 2.5 m above ground as previously described (Green et al. 2002). The vegetation around the trapping site consisted of dry sclerophyll *Eucalyptus* forest with an understory of Poaceae and other herbaceous species. Surrounding creeks and rivers are composed

Fig. 1 Map of Australia depicting the geographic position of Brisbane (27°29′S 153°8′E), southeastern Queensland, and the (*filled star*) sampling region. The distribution of *Baccharis halimifolia* is *shaded*, and areas of infestation appear as *circular dots*. The generation of this map has been adapted from the following references (Department of Natural Resources and Water, Queensland Government 2006; Ensbey 2001; Parsons and Cuthbertson 2001)

of riparian communities as previously described (Green et al. 2002). In addition to indigenous perennial species, surrounding urban and industrial areas are also vegetated by various indigenous and non-indigenous Asteraceae species.

2.2 Pollen sampling methods

Airborne Asteraceae pollen counts were derived from an historic aerobiological dataset collected over a 5-year aerometric survey using a 7-day Burkard volumetric spore and pollen trap (Burkard Manufacturing Co. Ltd., Rickmansworth, Hertfordshire, UK). The survey began in June 1994 and was completed in May 1999 (Green et al. 2002). Although no new aerobiological data have been collected since 1999, comparisons with earlier aerometric surveys by Moss (1965) demonstrated major pollen sources to have similar seasonal intervals (Green et al. 2002). The Burkard trap was calibrated to continuously sample air at 10 l per minute, and the atmospheric particulate matter was deposited onto tapes coated with a thin film of Dow Corning pressure-sensitive silicone adhesive (280A). The 7-day tapes were prepared and counted by the methods previously described (Green et al. 2002). The spore data corresponded to the mean daily values expressed as the number of airborne Asteraceae pollen m^{-3} of air. Airborne Asteraceae and *B. halimifolia* pollen were identified using bright-field microscopy, and pollen morphologies were differentiated with the assistance of Asteraceae photomicrographs provided in Moss (1965).

2.3 Meteorological data

Meteorological data were obtained from the Australian Bureau of Meteorology, Queensland weather station located at Brisbane International Airport. The weather station is situated 10 km northeast of the sampling site. The meteorological data that were acquired from the Australian Bureau of Meteorology included daily readings of maximum temperature, minimum temperature, and precipitation for the period June 1994–May 1999.

2.4 Statistical analysis

Data corresponding to 5 years (June 1994–May 1999) of Asteraceae pollen monitoring and meteorological records were documented graphically and evaluated statistically. Each individual Asteraceae pollen season was calculated using the criteria developed by Nilsson

and Persson (Nilsson and Persson 1981), where the date when 5% of the cumulative Asteraceae pollen count for that year had accumulated corresponded to the beginning of the season and 95% of the total accumulated Asteraceae pollen count corresponded to the end of the season. Associations between mean daily Asteraceae pollen and meteorological values were calculated using Spearman's (nonparametric) correlation analysis for the entire study period and by season. Statistical calculations were performed using GraphPad Prism (GraphPad Software, Inc., La Jolla, CA).

3 Results and discussion

Asteraceae pollen accounted for 0.6% of the total pollen count in Brisbane, Australia (Green et al. 2002). Daily concentrations were recorded throughout the entire year, and peak daily counts were restricted to two short seasonal intervals during spring (September) and autumn months (March and April; Table 1; Figs. 2, 3). Daily concentrations of Asteraceae pollen, within the range documented in the present study, have been observed in several other southern hemisphere sampling locations (Bass and Morgan 1997; Bass et al. 2000; Cadman 1991; Ong et al. 1995). Higher concentrations of Asteraceae pollen have recently been reported in a region south of Brisbane, but these counts were primarily derived from *A. artemisiifolia*, a non-indigenous species that produces anemophilous pollen (Bass et al. 2000). In contrast to other Australian aeropalynological surveys, the predominant airborne Asteraceae pollen in Brisbane is derived from *B. halimifolia*, an exotic species that has become abundant following its introduction to the region in the late nineteenth century (Moss 1965; Parsons and Cuthbertson 2001). *B. halimifolia* is characterized by numerous male florets that produce anemophilous pollen grains (Moss 1965; Parsons and Cuthbertson 2001). During early eradication schedules, Moss (1965) presented aerometric survey results that demonstrated *B. halimifolia* was one of the most prevalent Asteraceae pollen in the atmosphere of Brisbane. Three decades later, the findings of this study demonstrate that pollen derived from *B. halimifolia* is still present in the environment of Brisbane even following remediation and eradication programs.

The peak Asteraceae pollen concentrations were restricted to two brief intervals each year. The first interval was only recorded in three of the five sampling years (Table 1). In this seasonal interval, pollen derived from several unidentifiable Asteraceae species was frequently encountered. In contrast, pollen derived from *B. halimifolia* primarily characterized the second seasonal interval that extended from mid-March through to mid-April (Table 1; Figs. 2, 3); however, *Xanthium* and *Ambrosia*-like pollen grains were additionally recorded during this seasonal interval (data not shown). The duration of the second seasonal interval ranged from 25 to 48 days, with peak counts as high as 8 pollen grains m^{-3} recorded during the season (Table 1). Similar seasonal intervals have also been reported for other non-indigenous aeroallergen Asteraceae species, such as *A. artemisiifolia*, in the Northern Rivers area of New South Wales, Australia (Bass et al. 2000). In the present study, the extent of the *B. halimifolia* pollen season may be dependent on several parameters including the location of the sampler, environmental disturbance regimes, and the distribution of *B. halimifolia* stands in the surrounding sampling region.

Individual sampling years (June–May) plotted against maximum temperature, minimum temperature, and precipitation demonstrated inter- and intraseasonal variations in Asteraceae pollen counts recorded for each seasonal interval (Fig. 3). Peak pollen emissions recorded during the second seasonal interval coincided with an average seasonal maximum temperature within the range of 25.7–28.1°C, minimum temperature of 15.8–17.2°C, and rainfall less than 6 mm (Figs. 2, 3). Intraseasonal variations were observed during each seasonal interval and could be attributed to the different anthesis periods of Asteraceae species. Asteraceae pollen was quantified outside of each seasonal interval, and periods of precipitation throughout each Asteraceae pollen season were also observed to lower the daily airborne spore concentrations (Fig. 3). Interestingly, no Asteraceae pollen was collected during the first seasonal interval in 1995–1996 and 1997–1998 (Table 1). Higher seasonal temperatures and reduced precipitation characterized these sampling years and corresponded to an El Niño-Southern Oscillation (ENSO) event. Variations in climatic parameters may account for the reduced concentrations of Asteraceae pollen reported during these seasonal intervals. Nonparametric (Spearman's) correlation analysis showed significant associations between daily Asteraceae pollen counts and temperature for each of the sampling years (Table 2). These preliminary

Table 1 Seasonal distribution of airborne Asteraceae pollen in Brisbane, June to May, 1994–1999

Asteraceae season	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999
Season 1 (other Asteraceae)					
5%[a]	7/9	–	2/9	–	5/9
Peak day	19/9	–	13/9	–	14/9
Peak count	1.38	–	1.04	–	1.59
95%[b]	29/9	–	14/9	–	26/9
Season duration	23	–	13	–	21
Season 2 (B. halimifolia, and other Asteraceae)					
5%[a]	12/3	22/3	24/3	15/3	22/3
Peak day	11/4	1/4	5/4	27/3	2/4
Peak count	3.19	4.03	2.91	4.65	7.98
95%[b]	26/4	18/4	17/4	18/4	18/4
Season duration	46	28	25	35	28

The seasonal dates where the accumulated sum since the beginning of the year reaches 5 and 95%, the peak pollen date and count (grains m^{-3}) and date, and seasonal duration

[a] Start date of the pollen season

[b] End date of the pollen season

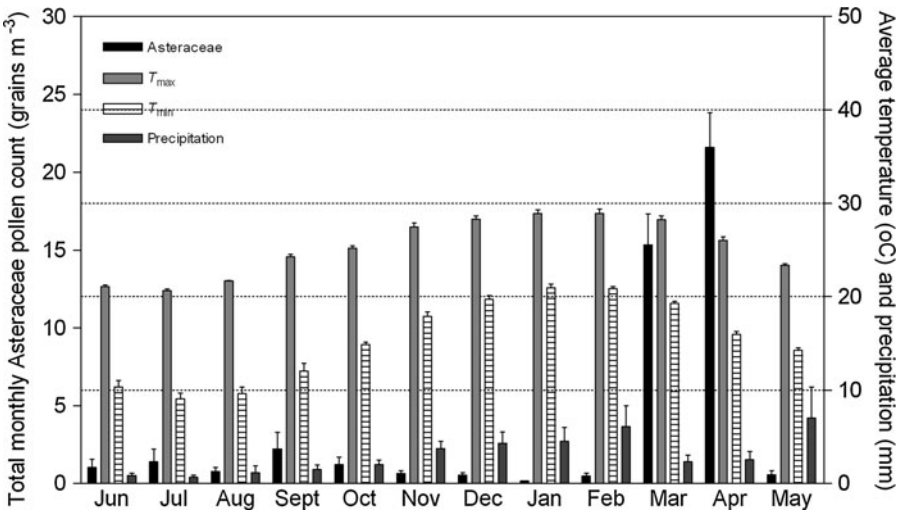

Fig. 2 Average monthly Asteraceae pollen count based on five sampling years (June 1994–May 1999) of daily pollen counts (grains m^{-3}) plotted with maximum temperature (°C), minimum temperature (°C), and rainfall (mm)

observations demonstrated that warmer maximum and minimum temperatures may facilitate elevated concentrations of daily Asteraceae pollen in Brisbane. Increases in temperature parameters have also been observed to intensify seasonal pollen loads of other botanically sourced bioaerosols (Yli-Panula et al. 2009). However, the decadal influences of climatic parameters on airborne Asteraceae concentrations were not explored in this study and currently remain uncharacterized.

In addition to the environmental impacts associated with the findings of the present study, airborne *B. halimifolia* pollen may also be a public health burden. *B. halimifolia* pollen is anemophilous (Moss 1965) and a suspected etiological agent of seasonal exacerbations of allergic rhinitis in Brisbane (Moss 1967). To our knowledge, *B. halimifolia* antigens capable of binding specific human IgE and the extent of cross-reactivity with other members of the Asteraceae have not been reported in the peer-reviewed literature. Given the invasive terrestrial plant characteristics of *B. halimifolia*, future strategies for controlling the spread of this species will be integral in the mitigation of personal exposure to pollen derived from this species.

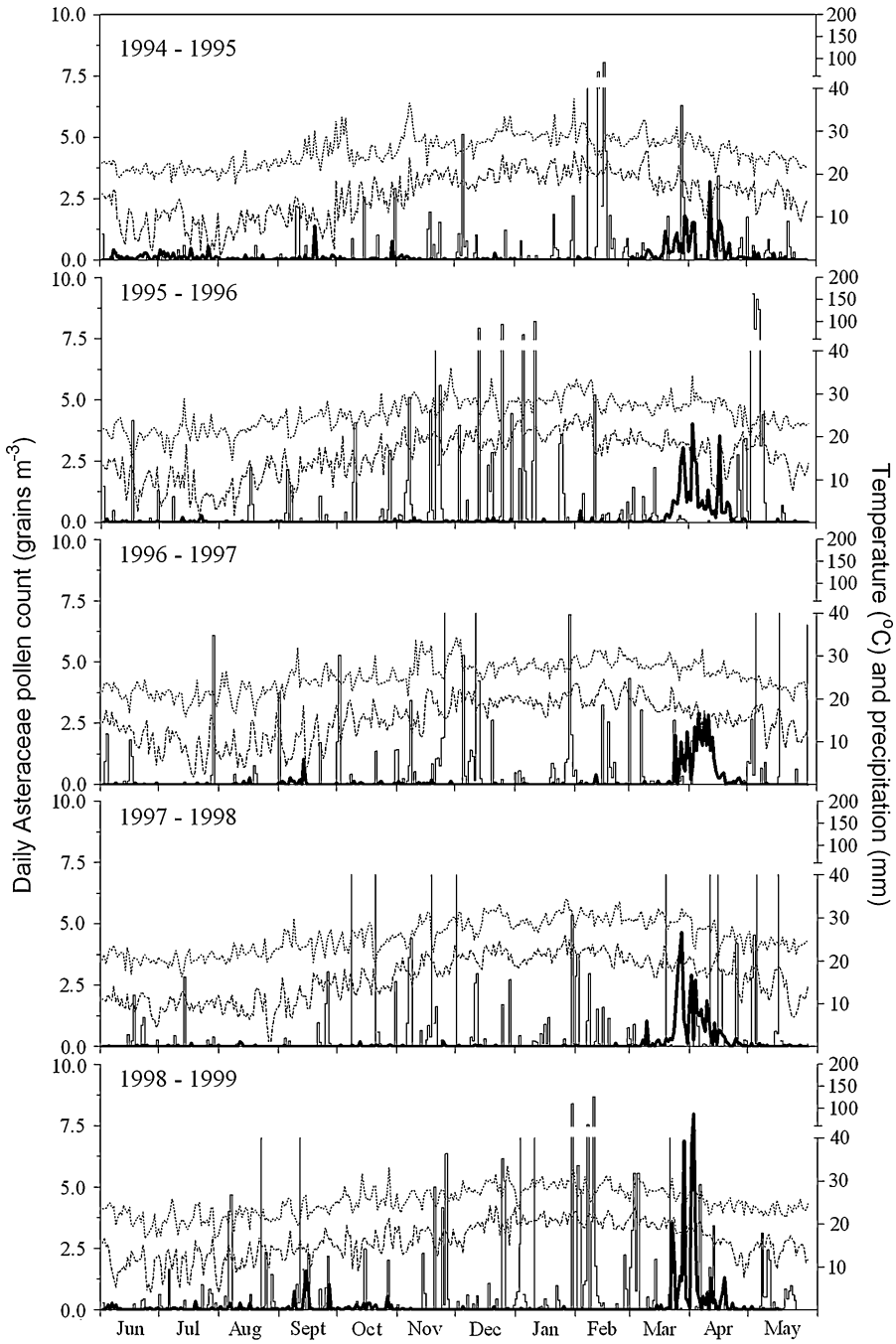

Fig. 3 Seasonal distribution of (*thick solid line*) airborne Asteraceae pollen in the atmosphere of Brisbane, Australia, during five individual years plotted with daily (*dotted line*), maximum (*dashed line*), and minimum temperature (°C) (*solid line*) total daily rainfall (mm)

In conclusion, airborne Asteraceae pollen is present in the atmosphere of Brisbane during two distinct seasonal intervals. Pollen derived from *B. halimifolia* was the predominant Asteraceae pollen quantified during the second seasonal interval (March and April). These findings confirm the presence of airborne pollen derived from *B. halimifolia* three decades following the first aerometric survey conducted in Brisbane. However, since the completion of the aerometric survey in 1999, the presence of *B. halimifolia* may have been reduced by current weed management programs. Further preventative weed management strategies are required in Brisbane and other areas of infestation in southeast Queensland

Table 2 Spearman's correlation coefficients (r_s) between daily meteorological parameters and airborne Asteraceae pollen concentrations

Sampling year	Spearman's correlation coefficients (r_s)		
	T_{max}	T_{min}	Precipitation
1994–1995	−0.0921	−0.2026*	−0.0311
1995–1996	0.2364**	0.0063	−0.0625
1996–1997	0.1558*	−0.0009	−0.1408*
1997–1998	0.1574*	0.1383*	0.04936
1998–1999	−0.0718	−0.1143*	−0.0856
1994–1999	0.0744	−0.0425	−0.06351

T_{max} daily maximum temperature

T_{min} daily minimum temperature

Precipitation daily total precipitation

* $P < 0.05$; ** $P < 0.001$

such as the Maroochy Shire to restrict the spread of B. *halimifolia*. In addition, the future weed prevention management of non-indigenous Asteraceae species may mitigate personal exposure to these aeroallergen sources and reduce exacerbations of respiratory morbidity in the region.

Acknowledgments This research was made possible by financial support from the Asthma Foundation of Queensland. Special thanks to Dr. Shannon Rutherford, and the staff of the School of Public Health, Griffith University, for their technical assistance, as well as the Department of Environment and the Bureau of Meteorology for providing the meteorological data. The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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