

A 3-year airborne pollen and fungal spores record in San Carlos de Bariloche, Patagonia, Argentina

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Abstract Airborne pollen in San Carlos de Bariloche was sampled from September to March 2001–2004 with a Hirst-type volumetric spore trap placed at a height of 15 m in a city extending from the humid forests, through the mesic forests, to the steppe. The total amount of pollen recorded varied widely from year to year. The pollen index was 4,395 in the sampling period 2001/2002; 9,055 in 2002/2003 and 2,756 in 2003/2004. The main pollen period extended from October to January. In October, pollen concentration was the highest. Sixty-six pollen types were identified. Cupressaceae and *Nothofagus* were the major contributors. *Betula*, *Prunus*, *Pinus* and *Populus*, the most abundant ornamental taxa in the city, also contributed to the pollen record. Pollen of *Maytenus* and *Lomatia* was representative of the mesic forest, while pollen in the lower layers of the humid forest was present in trace amounts. Cupressaceae, *Nothofagus* and *Betula* prevailed during spring (September–December), and *Plantago*, *Rumex* and Poaceae during summer (December–March). The association of daily pollen concentration and meteorological variables, temperature

(mean, maximum, minimum), dew point, rainfall and wind speed, was significant. Correlations showed to be negative, with the exception of that to wind speed. The total sum of fungi spores increased from 1,771 in 2001/2002; through 8,441 in 2002/2003 to 13,782 in 2003/2004. Relative concentration rose to 29%, 48% and 84% of the total number of pollen and fungal spores recorded during each sampling period.

Keywords Aerobiology · Pollen · Fungal spores · Native forest · Patagonia, Argentina

1 Introduction

Pollen calendars are useful for the treatment of respiratory disorders caused by airborne pollen and fungal spores in order to identify the taxa and season of acute sensitivity. Continuous investigations of airborne pollen was started in Argentina approximately 20 years ago in the city of Mar del Plata, with a Burkard volumetric spore trap (Bianchi, 1992, 1994; Latorre & Pérez, 1997). Similar studies were carried out with different kinds of impact samplers in the most populated cities of the country (Gattuso et al., 2003; Majas, Noetinger, & Romero, 1992; Nitiu, Mallo, & Romero, 2003; Noetinger, 1993; Noetinger, Romero, & Majas, 1994). Although

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the importance of aerobiology is known by allergists and biologists alike, great portions of the Argentinean population still lack information on the concentration of airborne pollen.

Patagonia, the southern region of Argentina, has undergone a dramatic demographic change in recent decades, due to immigration from larger urban areas in the north. A large portion of the population of western Patagonia is concentrated in small cities at the foothills of the Andes, at the forest–steppe boundary.

In spring many inhabitants show symptoms that could be related to pollinosis, and the use of antihistamines and visits to allergy clinics greatly increase (Vega, Bianchi, & Nordestrom, 2001; Vega et al., 2003). However, aerobiological studies in Patagonia are still very scarce, and the allergenic impact of the native flora is unknown.

During 1996–1997, pioneer studies were performed in the city of Neuquén (39° lat. S, 68° long. W), located 450 km to the north of San Carlos de Bariloche. Atmospheric pollen was recorded, and, at the same time, symptoms of pollinosis were registered among residents. Sensitization to pollen of the local flora in patients was consistent with aerobiological findings (Vega, Bianchi, & Nordestrom, 1999; Vega et al., 2004).

Except for the Neuquén study case, studies relating airborne pollen and pollinosis are still lacking in the whole country.

San Carlos de Bariloche, the second largest city in western Patagonia, has experienced striking population growth, and monitoring of the airborne pollen has been underway since 2001 (Bianchi, Olabuenaga, Dzendoletas, & Crivelli, 2004). We present here the first results of continuous sampling from 2001 to 2004 and the first step towards a project relating airborne pollen trends to pollinosis in the region.

2 Materials and methods

2.1 Site characteristics and climate

The city of San Carlos de Bariloche (41°10′ lat. S, 71°15′ long. W; 850 m elevation), with an area of 220 km² and a hilly topography, is located within the boundaries of the Nahuel Huapi National

Park (NHNP). The city extends 45 km along the southern coast of Lake Nahuel Huapi (Fig. 1) in one of the strongest moisture gradients in the world. The city ranges from the easternmost boundary of the humid forests at the west (3,000 mm mean annual precipitation) to mesic forests and steppe at the east (800 mm mean annual precipitation).

The climate of the region is Cs type, temperate with dry summers (Koeppen, 1948). Mean annual temperature is 8.1°C, ranging from 2.5°C in July to 14°C in January. Of the precipitation, 64% falls from May to August, mostly in the form of snow. The mean annual relative humidity is 68%. Westerly winds prevail during the whole year, with an annual mean speed of 22.6 km/h (National Meteorological Service, period 1961–1990) (Table 1).

The Sub-Antarctic, Alto Andean and Patagonian phytogeographic provinces are well represented in the region. The total of 1,031 plant species, 438 genera and 116 families occur in the NHNP; 770 species (75%) are native and 261 (25%) are alien. The 1,031 species include 42 trees, 114 shrubs, 19 climbers, eight hemiparasites and 848 herbs (Ezcurra & Brion, 2005). The native flora is highly endemic and depends mostly on animals for pollination (Aizen & Ezcurra, 1998). The city is also densely vegetated, and exotic plants are cultivated in private gardens and parks. Trees are planted along sidewalks, and urban weeds grow on abandoned areas and vacant lots.

2.2 Pollen monitoring

Pollen sampling was performed with a Hirst-type volumetric spore trap (Lanzoni VPPS 2000, Lanzoni, Bologna, Italy) placed at a height of 15 m in the urban area. The sampler was located on a building at the foothills of Cerro Otto [1,440 m above sea level (a.s.l.)]. The building was surrounded by a lawn and a few scattered trees of *Maytenus boaria* Molina, *Cupressus macrocarpa* Hartw. and *Pinus contorta* Douglas ex Loud.

The air intake was 10 l/min. Slides were prepared according to standard methods, stained with fuchsin and mounted in glycerine jelly

Fig. 1 Map of Nahuel Huapi National Park showing main vegetation units (modified from Mermoz et al., 2000)

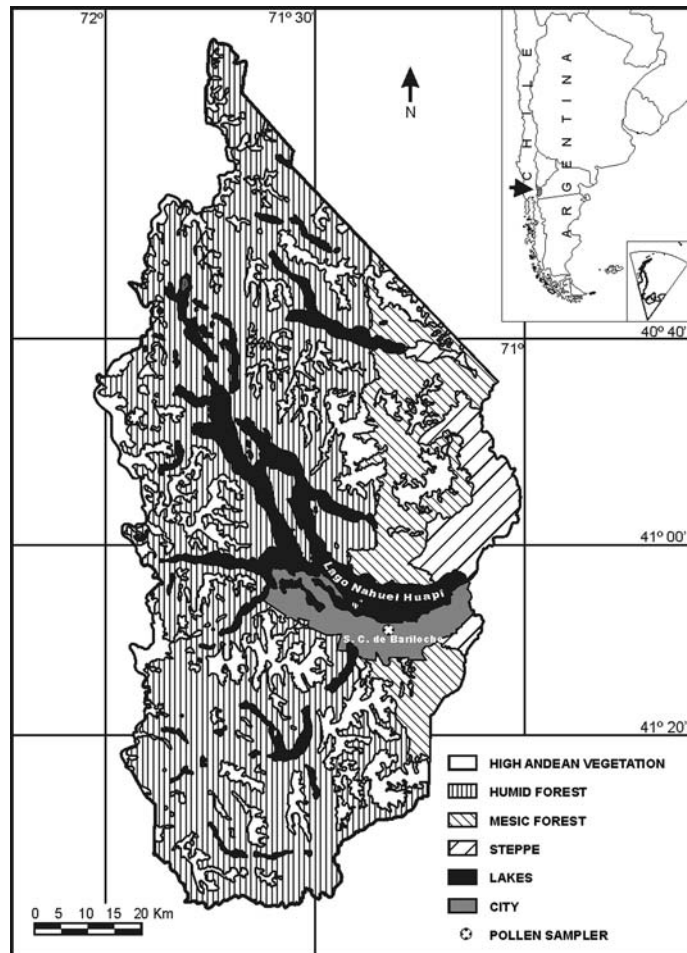


Table 1 Average climatic parameters of San Carlos de Bariloche for the period 1961–1990 (T mean temperature, $T_{\max}$ maximum temperature, $T_{\min}$ minimum temperature, u wind speed, RH relative humidity, Pr total precipitation)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dec	Year
T (°C)	14	13.8	11.5	8.2	5.4	2.9	2.5	3.5	5.1	7.5	10.4	12.6	8.1
$T_{\min}$ (°C)	6.4	5.7	4.0	1.8	0.6	−1.0	−1.4	−0.9	−0.5	1.1	3.5	5.4	2.1
$T_{\max}$ (°C)	21.5	21.8	19.0	14.6	10.1	6.7	6.4	7.9	10.7	14.0	17.3	19.7	14.1
u (km/h)	26.9	22.6	21.1	20.7	20.5	20.0	17.8	20.4	20.8	24.8	27.5	28.5	22.6
RH (%)	57	58	63	73	77	81	81	77	70	63	58	56	68
Pr (mm)	21	20	33	59	126	145	133	108	58	43	26	30	802

(Käpylä & Penttinen, 1981). The pollen grains were examined under a microscope at a magnification of 400 $\times$. The pollen was identified from pollen atlases and the pollen collection of the local flora (D'Antoni & Markgraf, 1978; Heusser, 1972). Fungal spores were classified into morphologic types, most of which were related to *fungi imperfecti* (Kapp, Davis, & King, 2000). Pollen and

spores were counted along six longitudinal transects to estimate daily mean pollen concentration (Mandrioli, 1987). The sampling was started in September 2001 and continued for 19 months to establish the main pollen period (Nilsson & Persson, 1981). Winter atmosphere was monitored during winter 2002, and only scattered pollen grains were found. The airborne pollen grains

were sampled thereafter from 8th September to 31st March. No records were taken from 1st April to 7th September (autumn and winter). Three pollen seasons were defined: 2001/2002 (Sept 2001–March 2002); 2002/2003 (Sept 2002–March 2003) and 2003/2004 (Sept 2003–March 2004).

2.3 Meteorology and pollen

The data used included daily mean, maximum and minimum temperatures, daily mean dew point, daily mean wind speed and total daily rainfall at Bariloche Airport Station (lat. 41.9 S, long. 71.1 W) for the three periods studied.

The association between daily pollen concentration and meteorological parameters was examined with Spearman's rank correlation.

3 Results

Daily pollen concentration showed significant variations during the three sampling periods (Fig. 2). Total pollen recovered was 4,395, 9,055 and 2,756 in 2001/2002, 2002/2003 and 2003/2004, respectively. The main pollen period (MPP) extended from October to January, and October had the highest pollen concentration, 63% on average (Fig. 3). Arboreal pollen accounted for 60–80% of the total pollen recovered. Sixty-six different pollen types were identified at family, genus and, occasionally, species level (Table 2). Although most pollen came from native plants in the NHNP, pollen of *Betula*, *Prunus* and *Pinus* originated from public parks and private gardens.

Cupressaceae, *Nothofagus* and *Betula* prevailed in October, November and December (Fig. 4). The Cupressaceae family was the highest and most ubiquitous contributor to the airborne pollen spectrum. *Austrocedrus chilensis* (D. Don) Pic. Serm. & Bizzarri, *Fitzroya cupressoides* (Molina) I. M. Jhonst. and *Pilgerodendron uviferum* (D. Don) Florin are among the native taxa, and *Cupressus* spp. and *Thuja* spp. are present as exotics. It was assumed that most of the pollen in this family was produced by *Austrocedrus chilensis*, which is the most abundant species in the region.

Nothofagus dombeyi type included pollen grains from *Nothofagus antarctica* (G. Forst)

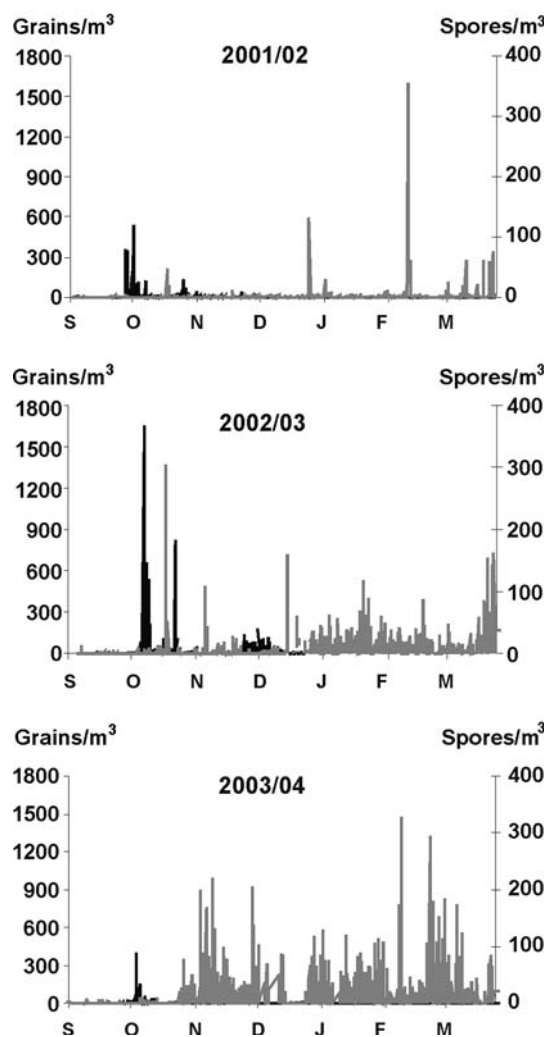


Fig. 2 Daily pollen (black line) and fungal spore (grey line) concentrations, expressed as grains or spores per cubic meter, in San Carlos de Bariloche for the periods 2001/2002, 2002/2003 and 2003/2004

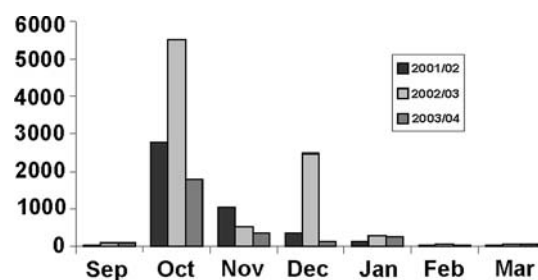


Fig. 3 Monthly total pollen concentrations (pollen grains per cubic meter) for the three periods studied

Table 2 List of pollen types, native (*) and exotic (**), identified in San Carlos de Bariloche for the periods studied

ACERACEAE	JUGLANDACEAE
<i>Acer</i> sp. (**)	<i>Juglans</i> sp. (**)
ANACARDIACEAE	MISODENDRACEAE
<i>Schinus</i> sp. (*)	<i>Misodendrum</i> sp. (*)
APIACEAE (*) (**)	MYRICACEAE
ARAUCARIACEAE	Myrica-type (**)
<i>Araucaria araucana</i> (*)	MYRTACEAE (*)
ASTERACEAE	OLEACEAE
Echinate type (*) (**)	<i>Fraxinus</i> sp. (**)
Fenestrate type (*) (**)	<i>Ligustrum</i> sp. (**)
Mutisia type (*)	<i>Olea</i> sp. (**)
BERBERIDACEAE	PINACEAE
<i>Berberis</i> sp. (*)	<i>Pinus</i> sp. (**)
BETULACEAE	PLANTAGINACEAE
<i>Alnus</i> sp. (**)	<i>Plantago</i> sp. (*) (**)
<i>Betula</i> sp. (**)	POACEAE (*) (**)
<i>Corylus</i> sp. (**)	PODOCARPACEAE
BRASSICACEAE (*) (**)	<i>Podocarpus nubigenus</i> (*)
CAPRIFOLIACEAE	<i>Saxegothea conspicua</i> (*)
<i>Sambucus</i> sp. (**)	POLYGONACEAE
<i>Viburnum</i> sp. (**)	<i>Rumex</i> sp. (**)
CARYOPHYLLACEAE (*) (**)	PROTEACEAE
CELASTRACEAE	<i>Lomatia hirsuta</i> (*)
<i>Maytenus</i> sp. (*)	<i>Lomatia ferruginea</i> (*)
CORNACEAE	ROSACEAE
Cornus-type (**)	<i>Rosaceae</i> undiff. (**)
CUNONIACEAE	<i>Prunus</i> sp. (**)
<i>Weinmannia trichosperma</i> (*)	<i>Acaena</i> sp. (*)
CUPRESSACEAE (*) (**)	RUBIACEAE
CYPERACEAE (*)	<i>Galium</i> sp. (*) (**)
CHENOPODIINEAE (*) (**)	SALICACEAE
<i>Gomphrena</i> sp. (*)	<i>Populus</i> sp. (**)
EPHEDRACEAE	<i>Salix</i> sp. (**)
<i>Ephedra</i> sp. (*)	SANTALACEAE
ERICACEAE	<i>Quinchamalium chilense</i> (*)
<i>Gaultheria</i> sp. (*)	SAXIFRAGACEAE
EUPHORBIACEAE (*)	<i>Ribes</i> sp. (*)
FABACEAE	SOLANACEAE (*)
<i>Cytisus</i> sp. (**)	TILIACEAE
<i>Vicia</i> sp. (*)	<i>Tilia</i> sp. (**)
<i>Lotus</i> sp. (*)	ULMACEAE
<i>Trifolium</i> sp. (**)	<i>Ulmus</i> sp. (**)
FAGACEAE	URTICACEAE (*) (**)
<i>Nothofagus dombeyi</i> -type (*)	VALERIANACEAE
<i>Nothofagus obliqua</i> -type (*)	<i>Valeriana</i> sp. (*)
<i>Fagus</i> sp. (**)	WINTERACEAE
<i>Quercus</i> sp. (**)	<i>Drimys winteri</i> (*)
FLACOURTIACEAE	ZYGOPHILLACEAE
<i>Azara</i> sp. (*)	<i>Larrea</i> sp. (*)
GUNNERACEAE	
<i>Gunnera</i> sp. (*)	
HIPOCASTANACEAE	
<i>Aesculus hippocastanum</i> (**)	

Oerst., *N. pumilio* (Poepp. & Endl.) Krasser and *Nothofagus dombeyi* (Mirb) Oerst., of which pollen cannot be differentiated under the light

microscope. Together with Cupressaceae, they accounted for 71%, 79% and 42% of the total pollen recorded along the three periods studied

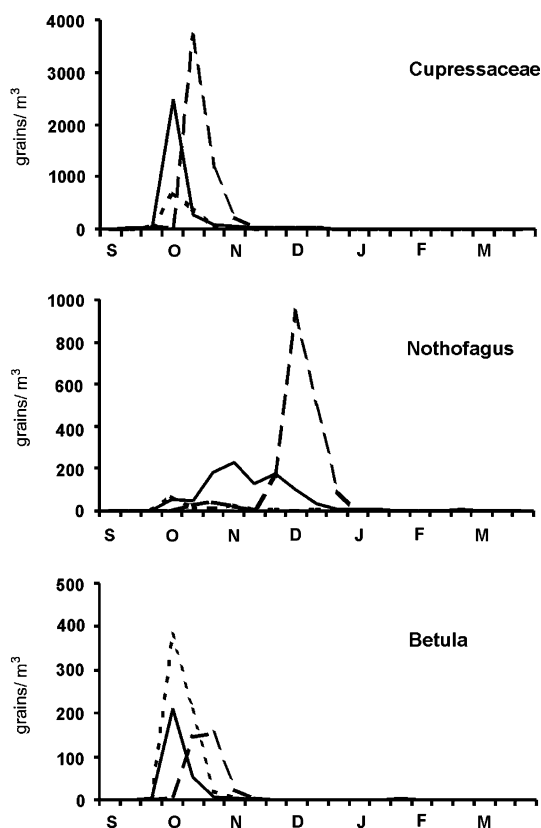


Fig. 4 Ten-day cumulative pollen concentration (grains per cubic meter) of the three principal pollen types for the sampling periods 2001/2002 (solid line), 2002/2003 (dashed line) and 2003/2004 (dotted line)

(Table 3). The number of exotic pollen grains ranged from 15% to 35% of the total pollen count.

Table 3 Percentages of the ten dominant pollen types in San Carlos de Bariloche for the periods studied

Pollen types	Percentage contribution		
	2001/2002	2002/2003	2003/2004
Cupressaceae	50.9	58.7	37.7
Nothofagus	20.2	20.1	4.0
Pinaceae	10.3	4.9	12.1
Betula	5.0	3.7	17.1
Poaceae	4.0	5.9	7.3
Rosaceae-Prunus	1.7	0.1	3.9
Plantago	1.4	0.8	1.5
Rumex	1.0	0.8	0.4
Salix	0.6	1.0	5.6
Populus	0.2	0.2	0.9
Others	4.7	3.9	9.5

Remarkable temporal variations in pollen amount were observed for *Nothofagus* and *Betula*. In 2003/2004 the values of *Nothofagus* were about 10–20 times lower than in the previous years. On the other hand, the values of *Betula* in 2003/2004 was double that recorded in 2001/2002 and 2002/2003 (Fig. 4, Table 3). *Plantago* and Poaceae were the major types recorded from November to March (Fig. 5).

Concerning fungal spores, the main genera were *Alternaria*, *Cladosporium*, and a variety of conidiospores and basidiospores, with concentration peaks in October, March and April (Fig. 2). The totals were 1,771 in 2001/2002; 8,441 in 2002/2003 and 13,782 in 2003/2004, representing 29%, 48% and 84% of the total counts (pollen + spores), respectively.

3.1 Association of pollen and meteorological variables

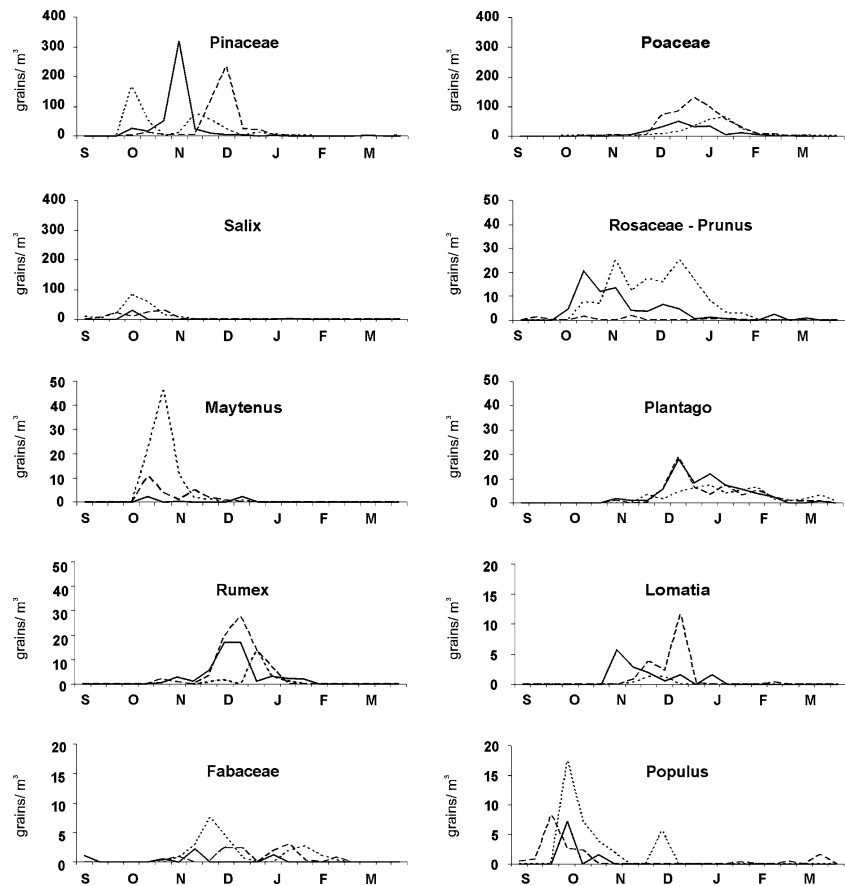
Climatological averages for the period 1961–1990 (Table 1) were compared with the monthly mean meteorological data for the periods studied (Table 4). Large differences in meteorological parameters were observed among the three periods studied and also compared to the climatological averages. In general terms, temperature was high and precipitation was low at the beginning of the pollen season both in 2001/2002 and 2003/2004. The opposite situation was observed in 2002/2003.

Daily pollen concentrations and meteorological parameters revealed significant associations during the periods studied. There was a weak negative correlation with most of the analyzed variables, with correlations ranging from -0.19 ($P < 0.05$) for dew point to -0.09 ($P < 0.05$) for rainfall (Table 5). Wind speed was the only variable showing a positive correlation with pollen concentration: 0.12 ($P < 0.05$).

4 Discussion

The results of this study revealed a diverse airborne pollen record, with taxa related mostly to the native flora but also to the introduced urban vegetation. The strong seasonality of the region was also reflected in the airborne pollen

Fig. 5 Ten-day cumulative pollen concentration (grains per cubic meter) of significant pollen types for the sampling periods 2001/2002 (solid line), 2002/2003 (dashed line) and 2003/2004 (dotted line)



record. The highest pollen concentration was observed during spring and early summer (September–December) when pollination was underway in the native forests. Non-arboreal pollen grains were best represented in summer (December–March).

Airborne pollen findings were compared with data on the flowering periods of the local vegetation. *Nothofagus* spp. and Cupressaceae dominate the pollen spectrum. All the species of both taxa are wind-pollinated and high pollen producers. During spring, large quantities of *Austrocedrus* and *Nothofagus* pollen is transported from the native forest.

Austrocedrus chilensis, most likely the major contributor to the airborne pollen record, grows in a variety of forest types along the Andes between 36° S and 43° S (Dezzotti & Sancholuz, 1991). It is a dominant species in the mesic forests (Fig. 1), and the flowering of forest stands is

synchronous within the area of NHNP (Rovere, 2000). *Nothofagus dombeyi*, the dominant species in the humid forests, flowers during October and November. Growing in a broad range of ecological environments, *Nothofagus antarctica* and *N. pumilio* are deciduous trees and shrubs that flower in November and December.

Many plants of the diverse and endemic flora contributed trace amounts of pollen during their pollination periods. *Lomatia hirsuta* (Lan.) Diels ex J. F. Macbr. and *Maytenus boaria*, insect- and wind-pollinated species in the mesic forests, produced small amounts of pollen from October to January (Fig. 5).

A variety of species of shrubs such as *Azara*, *Berberis*, *Ribes*, *Misodendrum* (hemiparasitic) and *Gaultheria* flower in September and October (Brion, Punteri, Grigera, & Calvelo, 1988). Evergreen trees in the humid forests, such as *Pilgerodendrum uviferum*, *Fitzroja cupressoides*,

Table 4 Monthly mean meteorological data at San Carlos de Bariloche Airport for the sampling periods 2001, 2002 and 2003 (T mean temperature, $T_{\max}$ maximum tempera-ture, $T_{\min}$ minimum temperature, T_d dew point, u wind speed, Pr total precipitation)

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar
2001/2002							
T (°C)	5.67	9.74	9.83	15.9	16.3	16.8	10.3
$T_{\max}$ (°C)	12.64	18.48	18.45	25.46	25.9	26.53	16.83
$T_{\min}$ (°C)	0.61	2.3	2.38	6.38	7.56	7.36	3.99
T_d (°C)	1.05	1.48	0.68	2.70	4.29	2.87	2.75
u (km/h)	4.80	4.60	7.44	6.22	6.52	5.75	6.53
Pr (mm)	26.6	40.5	33.1	11.9	32.7	29.0	46.5
2002/2003							
T (°C)	5.67	6.68	9.73	13.8	15.1	14.1	13.8
$T_{\max}$ (°C)	12.24	13.77	16.47	21.23	21.97	24.21	23.97
$T_{\min}$ (°C)	1.17	1.46	3.77	5.51	7.41	4.55	3.43
T_d (°C)	0.04	0.25	1.76	2.95	5.29	3.12	3.37
u (km/h)	6.62	6.84	7.62	6.69	8.80	6.39	4.33
Pr (mm)	37.7	66.7	40.4	5.0	4.0	1.5	12.6
2003/2004							
T (°C)	5.53	8.58	11.5	10.8	16.9	17.2	13.1
$T_{\max}$ (°C)	11.49	15.57	18.13	18.32	25.79	26.74	21.63
$T_{\min}$ (°C)	0.14	2.25	5.67	5.29	7.08	7.13	4.50
T_d (°C)	0.11	0.20	1.99	1.53	4.87	4.46	4.77
u (km/h)	5.70	7.62	8.48	8.55	5.79	4.63	4.86
Pr (mm)	36.8	18.9	18.9	37.2	3.0	10.1	19.28

Table 5 Spearman's rank correlation matrix for daily total pollen concentration and daily values of meteorological parameters along the study periods (2001/2002–2003/2004)

Variables	N	Spearman R	t ($N-2$)	P -level
Mean temperature	531	-0.164	-3.82283	0.000148*
Maximum temperature	531	-0.127	-2.95589	0.003257*
Minimum temperature	531	-0.112	-2.58630	0.009967*
Dew point	531	-0.189	-4.42645	0.000012*
Wind speed	531	0.121	2.80481	0.00522*
Rainfall	531	-0.09	-2.05734	0.040143*

* $P < 0.05$

Podocarpus nubigenus Lindl. and *Saxegothaea conspicua* Lindl., flower in November and December. *Weinmannia trichosperma* Cav. and *Drimys winteri* J. R. & G. Forst, in the shrub layer, flower in December and January.

Pollen of Myrtaceae was recorded from October to March during the flowering period of the evergreen trees *Amomyrtus luma* (Molina) D. Legrand & Kansel and *Luma apiculata* (D. C.) Burret. Poaceae, characteristic of the High Andean and Patagonian steppe are well developed in the NHNP, where the 139 species (Ezcurra & Brion, 2005) showed overlapping pollination periods from August to March.

On the other hand, a high number (more than 60) of plant families in the NHNP left no pollen record. Their absence may be related to the composition and structure of the forest. Its diverse flora shows a high number of relatively low pollen producer species in relation to insect- and bird-pollination (Aizen & Ezcurra, 1998). Flowering is also not profuse in the lower forest layers, where the low wind velocity and the evergreen foliage limit pollen dispersal.

A variety of exotic plants dominates the urban vegetation. The most abundant cultivated species in the neighborhood of the sampling site were *Maytenus boaria*, *Pinus contorta*, *Populus nigra* L.

and *Betula pendula* Roth (Bianchi et al., 2004). These wind-pollinated taxa were well represented throughout the sampling period. *Betula* species, well known as highly allergenic pollen producers, are cultivated as ornamentals. *Pinus contorta*, Douglas ex Loud. and *Pinus radiata* D. Don were planted in Bariloche over 60 years ago, and, during the past two decades, extensive plantations of *Pinus ponderosa* Douglas ex Laws. & Laws. have spread over the steppe forest margin. Pollen of *Salix* and *Populus* in early spring is attributed to willow thickets along stream banks and poplars in farms and orchards, where they are planted as wind barriers. Both taxa were planted in Patagonia at the beginning of the last century and are, today, highly naturalized. *Cytisus scoparium* L. Link, an aggressive invader enhanced by urbanization, was likely the major contributor among Fabaceae in October–December. During summer, *Rumex* and both native and exotic species of *Plantago* contributed small amounts to the airborne pollen spectrum. The Eurasian weeds *Rumex acetosella* L. and *R. acetosa* L. have efficiently expanded in Patagonia with grazing.

Concerning pollen concentration values, the three periods studied were markedly different and did not show a similar pattern. In 2002/2003 the concentration values of Cupressaceae were the highest, and *Nothofagus* attained the lowest values in 2003/2004. On the other hand, the values of *Betula* in 2003/2004 were twice as high than in the previous year.

Different meteorological characteristics among the study periods, mainly in winter and spring, could explain, to some extent, the remarkable variations observed in fungal spores but not in pollen concentrations.

The associations between pollen and meteorological parameters were shown to be relatively weak but consistent. The negative correlation between pollen and temperature could be explained by the early occurrence of pollen concentration peaks at the beginning of the pollen season, when temperature reached its lowest values. After this explosive blooming, the total pollen concentration showed a decreasing trend while temperature (maximum, mean and minimum) continued to increase to reach the highest values during summer.

Moderate wind speed, generally related to anticyclonic conditions, favored the uplift and permanence of pollen in the air. Moisture (measured as dew point) and precipitation removed the pollen from the atmosphere, either by raising the pollen weight, which increased sedimentation, or by washing the pollen out.

The observed meteorological relationships could not explain the strong differences in pollen concentration seen between the different sampling periods. For example, pollen concentration was the highest in 2002/2003, when rainfall during the blooming season was the highest of the three sampling periods. Rainfall values largely exceeded average climatological values, while temperature showed values similar to the long-term mean for the same period. Plant phenology strongly determines the number of pollen grains in the air, and the high year-to-year variations might indicate remarkable inter-annual variability in the pollen production. For example, *Austrocedrus chilensis* flowered every season, but the intensity of flowering showed significant differences over a 4-year study (Rovere, 2000). Unfortunately, pollen production studies on other significant taxa are not available for this region.

Concerning fungal spores, although concentrations may vary considerably from year to year, the increasing trend observed could be related to the high temperature and high variability in precipitation registered during the sampling periods. However, a detailed examination of possible relationships between spore concentration and meteorological conditions deserves a special treatment that exceeds the scope of this study.

Airborne pollen in San Carlos de Bariloche, dominated by the native vegetation, showed remarkable differences in comparison with pollen calendars from other Argentinean cities. The calendars from Buenos Aires, Mar del Plata and Rosario (Bianchi, 1994; Gattuso et al., 2003; Nitiu et al., 2003), as well as preliminary results from Córdoba, Mendoza and Bahía Blanca, are principally defined by pollen of exotic urban trees and weeds (Baena-Cagnani et al., 2001; Gandur et al., 2001). *Platanus* spp., *Fraxinus* spp. and *Cupressus* spp. are the most important arboreal pollen types, and Poaceae, *Ambrosia* spp., *Artemisia* spp. and *Chenopodium* spp. are the most frequent

non-arboreal ones (Majas et al., 1992; Strass, Arduzzo, & Crisci, 2002). Although Poaceae and Asteraceae are major taxa in Patagonia vegetation, and dominant types in pollen calendars elsewhere, pollen of these families was registered only in moderate amounts in Bariloche.

5 Conclusions

The airborne pollen record in Bariloche during the three periods studied showed unique features related to the phytogeographical richness and the environmental heterogeneity of the region. In contrast to what has been observed in big cities, the natural vegetation dominated the pollen spectrum. *Nothofagus* and Cupressaceae are co-dominant in the forests and the major pollen contributors. A variety of exotic plants in the urban vegetation significantly contributed to the pollen record. Arboreal pollen prevailed in spring and early summer, when pollen concentrations were highest. Moderate concentrations of non-arboreal pollen were recorded in summer.

In our study the total concentration of pollen and fungal spores varied considerably from year to year. Association of pollen with meteorological parameters were shown to be significant but rather weak. Correlation analyses with meteorological parameters at intra-diurnal scale could contribute to a better understanding of the possible relationships. However, floral phenology and pollen production studies are strongly needed in order to explain the year-to-year variations. Long-term sampling and a more extended network at local and regional scales could make possible the development of predictive models of airborne pollen concentrations in the area of the Sub-Antarctic forest. Increased urbanization in western Patagonia suggests that allergenic diseases will become more prevalent in the nearest future. Therefore, the continuation of aerobiological–epidemiological studies at a regional scale is strongly necessary.

The lack of a standard methodology to measure pollen concentration means that results are not easily comparable among the cities in Argentina, where a great portion of the aerobiota in the few records available is supposedly allergenic, and the

antigenic value of the native species is largely unknown.

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