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ORIGINAL PAPER

Annual pollen spectrum in the air of Palma de Mallorca (Balearic Islands, Spain)

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Abstract This aeropalynological study documented the pollen of 13 taxa with the highest concentration in the air of Palma de Mallorca during the years 2004–2010, using a Hirst-type volumetric spore trap. The taxa were Cupressaceae, *Olea europaea*, *Platanus hispanica*, *Pinus* spp., *Parietaria judaica*, *Urtica membranacea*, *Quercus ilex*, Poaceae, Chenopodiaceae/Amaranthaceae, *Plantago* spp., *Castanea sativa*, *Pistacia lentiscus* and *Betula* spp. These taxa accounted for 91.85 % of the total annual pollen recorded during the period. The mean annual pollen index was 20,027. The highest pollen counts occurred in February–June, representing 88.74 % of the annual total collected. Every year, there was a substantial increase in the concentration and types of pollen from March to May, followed by a decrease from July to January. The maximum annual total pollen count was recorded in 2005 with 25,870 and the minimum in 2009 with 14,726. The mean daily average pollen concentration count showed a declining trend over the study period. With respect to seasonal phases analysed, the later phase of the pollen season is more variable than the beginning. To observe the overall dynamics of the different pollen types better, a pollen calendar was established for Palma de Mallorca. The pollen calendar had typical Mediterranean features and is a useful tool for allergological and botanical awareness.

Keywords Aerobiology · Palma de Mallorca · Pollen calendar · Allergenic pollen

1 Introduction

Interest in the contribution of airborne pollen to allergies has increased around the world over recent times. Allergic symptoms like asthma or rhinitis are related to the composition, timing and abundance of allergenic airborne material together with other environmental contaminants. Airborne pollen content has been monitored in a large variety of countries, and records which stretch back to the final decades of the last half century exist for different sites in Europe, Japan, and North America (D'Amato et al. 2007).

In each geographic area, there is a succession of different flowering species throughout the year, so it is important to document the timing, floral intensity and types of airborne pollen in different locations, especially in highly populated cities. To date, only a few papers have described airborne pollen in the Balearic Islands (Belmonte et al. 1995; Boi and Llorens 2008). In the Mediterranean region, pollen calendars have been developed for several cities, such as Cagliari in Sardinia (Italy) (Ballero and Maxia 2003), Zagreb in Croatia (Peternel et al. 2005), Didim and Kastamonu in Turkey (Aycan et al. 2008; Çeter et al. 2012),

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Chirivel, (Cariñanos et al. 2004), Malaga (Recio et al. 1998) and Nerja on the Iberian Peninsula (Docampo et al. 2007), or Oporto in Portugal (Abreu et al. 2003).

The main goal of this paper was to study the airborne pollen content of Palma de Mallorca, one of the most popular tourist resorts in Europe, which welcomes about seven million tourists per year. The study of airborne pollen in this city contributes to modelling the behaviour of airborne pollen throughout the Mediterranean. The results of this investigation, which have been illustrated in a pollen calendar, along with future research into climatic change, are expected to assist allergists in diagnosing the cause and treatment for allergy cases.

2 Materials and methods

2.1 Study area

Palma de Mallorca (39° 57′ lat. N, 02° 65′ long. E) is located on Mallorca, the largest of the Balearic Islands to the east of the Iberian Peninsula (centre of the western Mediterranean basin) (Fig. 1).

Bioclimatically, Palma de Mallorca lies within the thermo-Mediterranean belt (Rivas-Martínez 1987). The annual mean temperature is 16.8 °C, and daily temperature never goes below 10 °C. The mean annual rainfall is 449 mm. The highest rainfall level is recorded in autumn and winter, and there is a hydric deficit from May to October. The mean annual humidity is 74 %, and the entire city is influenced by winds from the southeast and north.

The ombroclimate is dry or sub-dry with a vegetation of Quercetea ilicis, Rosmarinietea officinalis and Rhamno Prunetea. The area surrounding the city is a natural refuge for the Mediterranean vegetation dominated by *Pinus halepensis* and *Olea europaea*.

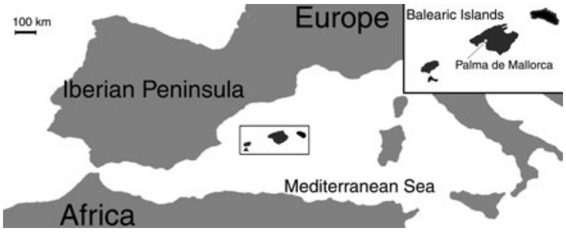


Fig. 1 Location of the aerobiological monitoring centre of Palma de Mallorca

There are natural pastures with a preponderance of ruderal plants mixed with fruit trees. On the other hand, the parks and gardens around the aerobiological station include ornamental plants like *Platanus hispanica*, *Casuarina cunninghamiana* and different species from the Cupressaceae and Palmae families.

2.2 Pollen content in the air

Airborne pollen was monitored from 2004 to 2010 using a Hirst-type volumetric pollen trap (Hirst 1952). The sampler was situated on a flat roof in the centre of Palma de Mallorca, 30 m above ground level. This monitoring station is currently included in the Spanish Aerobiology Network (REA) and has provided information about the Balearic Islands since October 2003 (Boi and Llorens 2008). Pollen sampling and data management were performed in accordance with the *Spanish Aerobiology Network Management and Quality Manual* (Galán et al. 2007).

Airborne pollen was expressed as daily averages of pollen grains/m^3 of air (pg/m^3). The annual pollen index was defined as the annual sum of the daily airborne pollen content.

The main pollen season (MPS) for the most abundant pollen types was calculated as described by Andersen (1991) and modified by Jato et al. (2006). The pollen season was defined retrospectively as the period with 95 % of the annual pollen index. The pollen season started when 2.5 % of the annual pollen index was reached, and the season ended on the day in which 97.5 % of the cumulative total of annual pollen was registered.

The pollen calendar was developed following Spieksma's model (Spieksma 1991), which transforms 10-day mean pollen concentrations into a series of classes in accordance with Stix and Ferretti (1974). Pollen types were ordered on the basis of abundance. Subsequently, the average pollen sums were placed in exponential classes represented in a pictogram by columns of increasing height, as suggested by the *International Association for Aerobiology* (Spieksma 1991). In the pollen calendar, minimum 10-day mean values equal to, or greater than, 1 pollen grain/m^3 of air were included.

2.3 Statistical analysis

Statistical analysis was performed using the *Statistica* program version 8.0 (StatSoft, Inc. 1984–2008).

Makensens application version 1.0 (freeware copyright Finnish Meteorological Institute 2002) was used to perform the nonparametric Mann–Kendall test (Hollander and Wolfe 1999) of a linear regression on the pollen time series as suggested and modified by Sen (1968) to verify the null hypothesis (HO) that no temporal trend occurred in the pollen concentration time series. This nonparametric method was employed for the pollen concentrations series because the trend was considered to be linear.

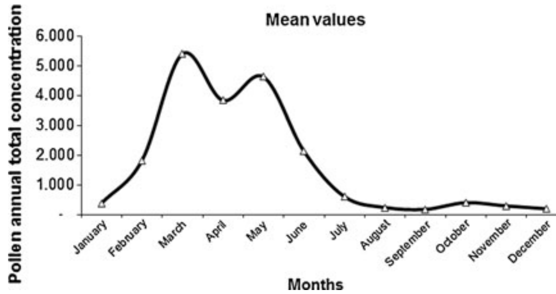


Fig. 2 Monthly mean values

3 Results

During the study period (2004–2010), 13 pollen types with the highest presence in the air of Palma de Mallorca were monitored. The types collectively accounted for 91.85 % of the total pollen count, of which 67.63 % represented woody plants (*Betula* spp., *Castanea sativa*, Cupressaceae, *Olea europaea, Pinus* spp., *Pistacia lentiscus*, *Platanus hispanica*, *Quercus ilex*) and 24.22 % represented herbs and grasses Chenopodiaceae/Amaranthaceae, *Plantago* spp., Poaceae, *Parietaria judaica* (including a species of *Urtica*) and *Urtica membranacea*.

The mean annual pollen index was 20,027. The highest annual concentration was registered in 2005 (25,870) and the lowest in 2009 (14,726).

The seasonal pollen dynamics of the studied taxa varied. The pollen curve built on the basis of mean annual concentrations showed the general course of the pollen concentration during the year, with the highest levels in the months of March, April and May. The airborne pollen concentration had a pronounced seasonality. From February to June, a higher pollen concentration was detected, representing 88.74 % of the annual average pollen count. The monthly distribution was as follows: February, 9.06 %; March, 26.94 %; April, 19.10 %; May, 23.06 %; and June, 10.58 %. In contrast, lower concentrations occurred from July to January with a cumulative value of less than 3 % of the annual pollen count average (Fig. 2).

As the year progressed, several pollen peaks were detected due to the successive flowering of the different taxa. Some pollen types, like Cupressaceae, Poaceae, Chenopodiaceae/Amaranthaceae, were detected over longer periods of time, because, in the main, they represented several species that bloomed at different times. The first peak was detected during winter, owing to the pollination of species such as Cupressaceae, *Parietaria judaica* and *Urtica membranacea*. A second peak arose in early spring from species like *Pinus*, *Platanus* and *Quercus*. During the late spring, pollen concentrations from *Olea europaea*, *Plantago*, Poaceae and *Parietaria* reached their highest values, whereas pollen from *Castanea sativa* and Chenopodiaceae/Amaranthaceae were mainly present in summer. During late summer, autumn and early winter, the daily pollen counts fell significantly.

The pollen types which were most abundant in the air of Palma de Mallorca during the period studied were, in order of decreasing pollen index: Cupressaceae, *Olea*, *Platanus*, *Pinus*, *Parietaria*, *Urtica membranacea*, *Quercus*, Poaceae, Chenopodiaceae/Amaranthaceae, *Plantago*, *Castanea*, *Pistacia* and *Betula* (Table 1).

The pollen which was most prevalent during the study period was that of the natural woody plants of the surrounding areas and from the ornamental species of Cupressaceae and *Platanus*. Cupressaceae, *Olea*, *Platanus* and *Pinus* represented 59.82 % of the total pollen counts recorded during the period. *Quercus*, *Pistacia*, *Betula* and *Castanea* make up 7.1 %, and herb pollen mostly associated with *Parietaria* and *Urtica* accounted for 24.21 % of the total count.

The highest daily pollen peak registered in Palma de Mallorca by the different pollen types arose from *Platanus* (1,962 pg/m^3, 28 March 2006), followed by *Olea* (1,101 pg/m^3, 20 May 2007), Cupressaceae (967 pg/m^3, 11 March 2005), *Pinus* (710 pg/m^3, 26 March 2010), *Quercus* (297 pg/m^3, 10 May 2005), *Castanea* (108 pg/m^3, 29 June 2004), *Betula* (95 pg/m^3, 27 April 2007) and *Pistacia* (75 pg/m^3, 6 April 2006). In the case of herbaceous plants, the highest daily concentrations came from *Urtica* (203 pg/m^3, 16 March 2005), *Parietaria* (118 pg/m^3, 21 April 2004), Poaceae (91 pg/m^3, 4 May 2005),

Table 1 Seasonal pollen index for the main pollen season types from 2004 to 2010 and the mean values over the entire period

Taxa	2004	2005	2006	2007	2008	2009	2010	Mean (04–10)
Betula	273	71	117	170	65	86	76	122
Castanea	501	118	173	111	243	125	174	206
Cupressaceae	2,239	6,263	3,881	3,204	3,015	2,693	2,598	3,413
Cheno/Amara	404	285	511	464	350	245	348	372
Olea	3,345	3,061	2,381	5,670	1,450	5,145	2,624	3,382
Pinus	1,322	3,289	2,342	2,400	1,772	1,920	2,797	2,263
Pistacia	217	260	366	78	109	80	112	175
Plantago	473	353	285	361	461	267	402	372
Plantanus	2,809	4,711	5,930	2,433	1,828	617	2,126	2,922
Poaceae	844	807	928	736	602	514	531	709
Quercus	526	1,872	1,190	1,034	733	951	1,059	1,052
Parietaria	4,451	1,550	2,063	1,402	2,298	929	988	1,954
Urtica	1,924	1,948	2,594	997	1573	284	772	1,442
Pollen annual	22,025	25,870	25,063	20,867	15,924	14,726	15,717	20,027

Plantago (54 pg/m^3, 19 April 2005) and Chenopodiaceae/Amaranthaceae (31 pg/m^3, 29 August 2010) (Table 2). Allergy risk thresholds depend on the pollen type. Moderately allergenic values are 25–50 pg/m^3 in the case of herbaceous taxa and 50–00 pg/m^3 in the case of arboreal taxa, whereas highly allergenic levels are >50 pg/m^3 and >100 pg/m^3 for herbaceous and arboreal taxa, respectively (Galán et al. 2007). Given these thresholds, there was a considerable variation in the number of days during which each taxon presented risks for allergy sensitivity (Table 2).

Variability in the timing of phases in consecutive pollen seasons was analysed for each taxon. The pollen seasons started with *Urtica*, followed by Cupressaceae, *Parietaria, Betula, Pinus, Pistacia*, *Platanus, Plantago,* Poaceae, Chenopodiaceae/Amaranthaceae, *Quercus, Olea* and ending with *Castanea*. The beginning of the season for each type of pollen was more homogeneous than the subsequent phases. The irregular progression of the flowering phase and the pollen stage for each taxon caused greater variability in the 50, 75 and 97.5 %, compared to the first percentiles (5, 25) (Fig. 3).

The mean daily average pollen concentration in Palma de Mallorca shows a downward trend over the study period observed. The lowest values occurred in 2008–2010. The trend was significant according to a Mann–Kendall test ($n = 20$; $S = 3.11$; $p = 0.017$). Given the p value, the null hypothesis of no trend was rejected. Sen's method showed a decrease in the mean daily pollen of about 5 grains every year (slope value $Q = -4.64$, intercept value $B = 70.98$) (Fig. 4).

The pollen calendar for Palma de Mallorca developed for the 13 most abundant pollen types during the period between 2004 and 2010 was produced with an exponential scale where each step was approximately twofold greater than the previous. The calendar showed that March, April and May were the months with the highest pollen content in the air. Longer pollen seasons usually include pollen types from different species, whereas shorter pollen seasons usually represent pollen from only one species or from different species that flower at the same time. In general, the pollen season for arboreal taxa, such as *Betula*, *Castanea*, *Pistacia*, *Platanus* and *Quercus,* was shorter than the season for Cupressaceae, *Olea* and *Pinus*. Cupressaceae, the most abundant pollen type, had two different peaks each year. One of these occurred from February to March, and another peak with lower intensity occurred from October to November. *Olea* was the second most abundant pollen type in the air of Palma de Mallorca with a high concentration during the month of May. *Pinus* pollen during the first peak of April–May corresponded to the local species *Pinus halepensis* and to other species (*P. canariensis*, *P. sylvestris*, *P. pinea* and *P. pinaster*) during the second peak. The herbs, *Parietaria judaica*, Chenopodiaceae/Amaranthaceae and Poaceae, had longer pollen seasons than *Urtica membranacea* or *Plantago* (Fig. 5).

Table 2 Length of the pollen season for the most abundant pollen types

	2004	2005	2006	2007	2008	2009	2010
Betula spp.							
Pollen season	14 Feb–27 May	17 Feb–2 Jul	31 Mar–5 May	17 Apr–18 May	25 Mar–11 Jun	23 Feb–24 May	15 Mar–4 Jun
Season length	104	136	36	32	79	91	82
Daily maximum value (date)	63 (26 Apr)	23 (13 Apr)	23 (27 Apr)	95 (17 Apr)	21 (25 Apr)	11 (3–4 May)	15 (9 Apr)
No. days 50–100 pg/m^3	2	0	0	1	0	0	0
No. days 100–1,000 pg/m^3	0	0	0	0	0	0	0
Castanea sativa							
Pollen season	25 Jun–30 Jul	5 Jun–31 Jul	22 Jun–7 Aug	20 Jun–9 Sep	26 Jun–9 Aug	16 Jun–25 Jul	15 May–28 Aug
Season length	36	57	47	82	45	40	75
Daily maximum value (date)	108 (29 Jun)	16 (22 Jun)	28 (30 Jun)	15 (23 Jun)	24 (11–15 Jul)	24 (24 Jun)	25 (4 Jul)
No. days 50–100 pg/m^3	2	0	0	0	0	0	0
No. days 100–1,000 pg/m^3	1	0	0	0	0	0	0
Cupressaceae							
Pollen season	18 Jan–2 Dec	24 Feb–22 Jun	23 Jan–14 Nov	28 Jan–4 Dec	31 Jan–18 Nov	24 Jan–18 Nov	24 Feb–28 Nov
Season length	327	119	296	311	293	199	278
Daily maximum value (date)	96 (18 Mar)	967 (11 Mar)	276 (1 Mar)	239 (1 Mar)	204 (15 Feb)	327 (10 Feb)	351 (5 Mar)
No. days 50–100 pg/m^3	8	11	11	10	11	5	6
No. days 100–1,000 pg/m^3	0	10	5	5	5	7	5
Olea europaea							
Pollen season	5 May–30 Jun	3 May–17 Jun	3 May–27 Jun	14 May–27 Jun	27 Mar–10 Jul	15 May–16 Jun	8 May–19 Jul
Season length	57	46	56	45	106	33	73
Daily maximum value (date)	652 (8 Jun)	271 (29 May)	261 (8 May)	1,101 (20 May)	152 (18 May)	636 (26 May)	325 (31 May)
No. days 50–100 pg/m^3	7	9	8	3	0	5	3
No. days 100–1,000 pg/m^3	7	11	5	11	3	15	8
No. days >1,000 pg/m^3	0	0	0	1	0	0	0
Pinus spp.							
Pollen season	27 Feb–6 Oct	24 Mar–17 Jun	11 Mar–12 Jun	2 Mar–11 Jul	17 Feb–12 Jul	1 Mar–2 Jul	12 Mar–26 Jul
Season length	223	86	94	132	147	124	137
Daily maximum value (date)	100 (22 Mar)	326 (4 Apr)	306 (22 Mar)	472 (7 Mar)	260 (4 Mar)	201 (5 Mar)	710 (26 Mar)
No. days 50–100 pg/m^3	3	9	6	7	3	6	5
No. days 100–1,000 pg/m^3	1	0	6	4	4	3	4
No. days >1,000 pg/m^3	0	0	0	0	0	0	0

Table 2 continued

	2004	2005	2006	2007	2008	2009	2010
Pistacia lentiscus							
Pollen season	1 Apr–16 Apr	9 Apr–5 May	28 Mar–17 Apr	19 Mar–14 Apr	12 Mar–31 Mar	18 Apr–19 Jul	24 Mar–6 May
Season length	16	27	21	27	20	93	44
Daily maximum value (date)	58 (14 Apr)	52 (18 Apr)	75 (6 Apr)	24 (24 Mar)	24 (30 Mar)	15 (9–12 May)	18 (10 Apr)
No. days 50–100 pg/m^3	1	1	2	0	0	0	0
No. days 100–1,000 pg/m^3	0	0	0	0	0	0	0
No. days >1,000 pg/m^3	0	0	0	0	0	0	0
Platanus hispanica							
Pollen season	26 Mar–6 May	27 Mar–25 Apr	23 Mar–11 Apr	18 Mar–6 May	11 Mar–18 Apr	17 Mar–6 Oct	26 Mar–28 Apr
Season length	71	30	20	50	39	204	34
Daily maximum value (date)	533 (3 Apr)	875 (8 Apr)	1962 (28 Mar)	205 (19 Mar)	247 (18 Mar)	51 (24 Mar)	201 (5 Apr)
No. days 50–100 pg/m^3	8	10	4	7	8	1	3
No. days 100–1,000 pg/m^3	6	13	13	9	4	0	8
No. days >1,000 pg/m^3	0	0	1	0	0	0	0
Quercus ilex							
Pollen season	24 Apr–29 Nov	23 Apr–17 Jun	15 Apr–10 Jul	27 Apr–25 Jun	9 Apr–19 Jul	26 Apr–27 Jul	2 May–9 Aug
Season length	220	56	87	60	102	93	100
Daily maximum value (date)	42 (6 Jun)	297 (10 May)	50 (22 Apr–30 May)	90 (7 May)	79 (30 Apr)	79 (6 May)	86 (22 May)
No. days 50–100 pg/m^3	0	5	2	7	1	5	5
No. days 100–1,000 pg/m^3	0	3	0	0	0	0	0
No. days >1,000 pg/m^3	0	0	0	0	0	0	0
Chenop/Amarant							
Pollen season	14 Apr–17 Oct	8 Apr–28 Oct	8 Apr–25 Oct	8 Apr–14 Nov	9 Apr–12 Oct	14 Apr–3 Nov	8 Apr–7 Nov
Season length	187	204	201	211	187	204	214
Daily maximum value (date)	17 (19 May)	18 (4 May)	19 (21 Apr)	16 (20 May)	12 (8 May)	12 (2 May)	31 (29 Aug)
No. days 25–50 pg/m^3	0	0	0	0	0	0	1
No. days 50–100 pg/m^3	0	0	0	0	0	0	0
No. days >100 pg/m^3	0	0	0	0	0	0	0
Plantago spp.							
Pollen season	26 Apr–8 Oct	7 Apr–13 Jul	18 Apr–28 Sep	17 Apr–16 Sep	8 Apr–13 Aug	19 Apr–25 Jul	5 Apr–27 Jul
Season length	166	98	164	153	128	98	114
Daily maximum value (date)	19 (2 6 Apr)	54 (19 Apr)	26 (22 Apr)	20 (20 May)	34 (25 Jun)	18 (25 Apr)	22 (21,23 Apr)

Table 2 continued

	2004	2005	2006	2007	2008	2009	2010
No. days 25–50 pg/m^3	0	2	2	0	1	0	0
No. days 50–100 pg/m^3	0	0	0	0	0	0	0
No. days >100 pg/m^3	0	0	0	0	0	0	0
Poaceae							
Pollen season	26 Apr–21 Sep	4 Apr–4 Oct	25 Mar–2 Oct	7 Mar–22 Oct	25 Mar–20 Nov	22 Mar–22 Sep	5 Apr–24 Sep
Season length	149	184	192	230	241	185	173
Daily maximum value (date)	45 (2 Jun)	91 (4 May)	44 (21 May)	37 (11 May)	31 (7 May)	32 (3 Jun)	21 (31 May)
No. days 25–50 pg/m^3	8	7	8	2	2	2	0
50–100 pg/m^3	0	1	0	1	0	0	0
No. days >100 pg/m^3	0	0	0	0	0	0	0
Parietaria judaica							
Pollen season	26 Jan–26 Sep	11 Mar–21 Oct	9 Mar–8 Nov	23 Feb–7 Dec	22 Feb–5 Nov	8 Feb–14 Nov	1 Mar–27 Nov
Season length	245	225	245	288	258	280	272
Daily maximum value (date)	118 (21 Apr)	75 (18, 21 Mar)	66 (6 Apr)	31 (18 Apr)	68 (3 Jun)	42 (3 Jun)	32 (4 Jul)
No. days 25–50 pg/m^3	36	12	20	2	17	4	1
No. days 50–100 pg/m^3	23	3	4	0	3	0	0
No. days >100 pg/m^3	1	0	0	0	0	0	0
Urtica membranacea							
Pollen season	10 Jan–23 May	24 Feb–2 May	29 Jan–3 May	12 Feb–20 Dec	12 Jan–4 Jun	20 Jan–23 Sep	26 Feb–29 May
Season length	135	68	95	312	145	247	124
Daily maximum value (date)	71 (30 Mar)	203 (16 Mar)	122 (25 Mar)	96 (18 Apr)	63 (4 Mar)	31 (15 Mar)	65 (27 Feb)
No. days 25–50 pg/m^3	13	10	25	4	13	1	6
No. days 50–100 pg/m^3	9	2	11	2	1	0	1
No. days >100 pg/m^3	0	7	3	0	0	0	0

The start date, end date and length of each season are listed, along with the peak value, peak date and the number of days in which the daily pollen concentration was over an allergenically significant value

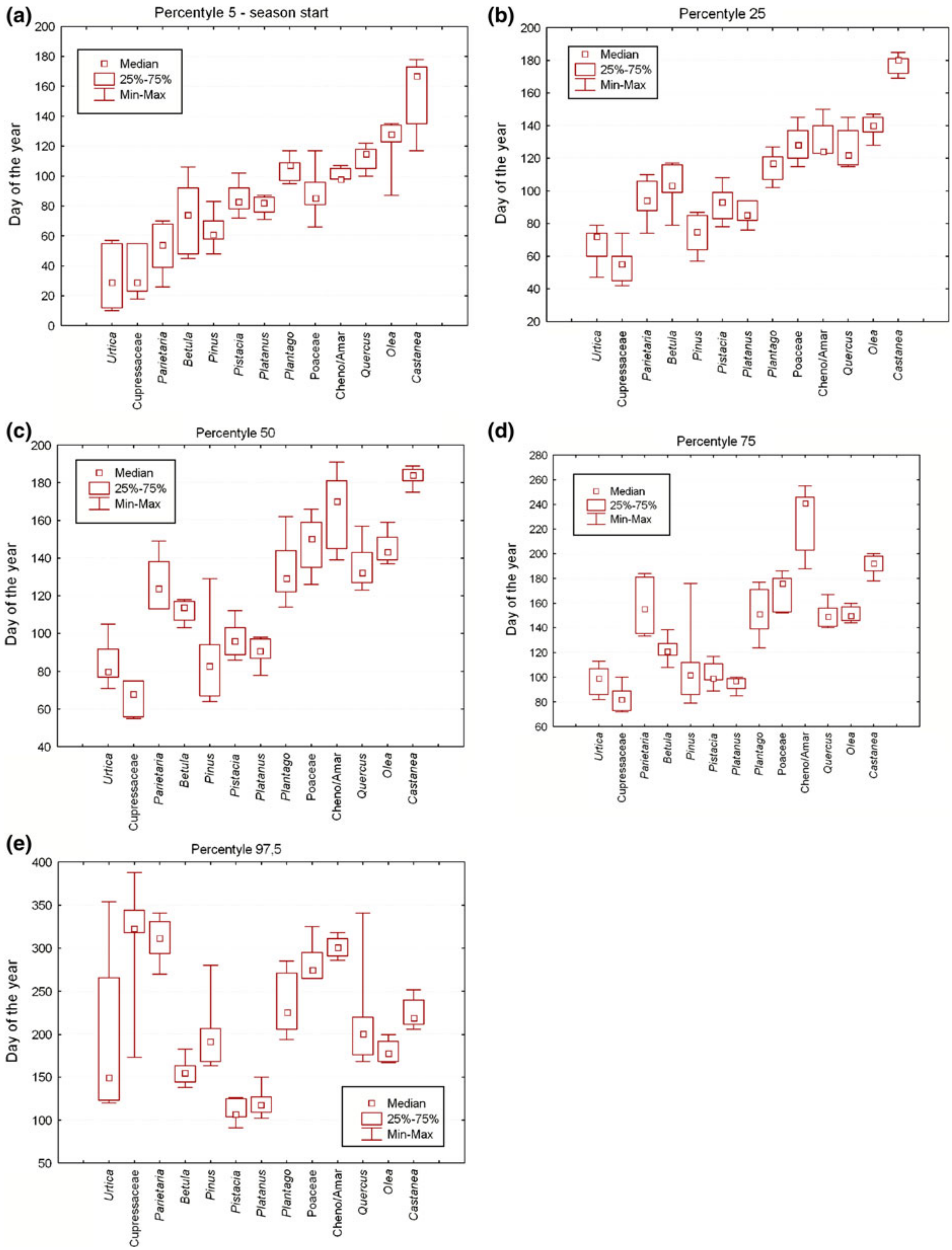


Fig. 3 Pollen season variability

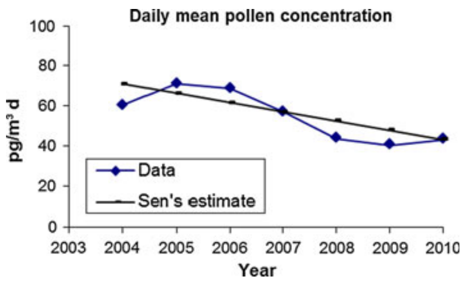


Fig. 4 Mean daily airborne pollen concentration in Palma de Mallorca over the period 2004–2010

4 Discussion

One of the main goals of aerobiological observations is to define the pollen spectrum in a given region. In general, our study offers relevant information on the pollen content in the air of Palma de Mallorca. Medium–high levels of different types of airborne pollen with considerable allergenic capacity were found, consistent with other reports (Belmonte et al. 1995; Boi and Llorens 2008). This information is useful in the treatment and diagnosis of hay fever (Marshall 2004) or in studies of local and long-range airborne pollen transport (Makra et al. 2010).

The annual pollen index in Palma de Mallorca is lower than in other cities of the Mediterranean region, such as Cagliari (Italy) (Ballero and Maxia 2003), Nerja (Spain) (Docampo et al. 2007), Didim or Kastamonu (Turkey) (Aycan et al. 2008; Çeter et al. 2012). The pollen compositions broadly reflect the contribution of Mediterranean local vegetation, which consists of natural woodlands surrounding each town and anthropogenic ornamental flora in the cities.

The exceptions are *Castanea* and *Betula* pollen, which were detected at low levels, a finding which is noteworthy because these species are not present in the Balearic Islands (Castroviejo et al. 1993). This pollen was probably carried across to Mallorca by dominant winds from Europe, demonstrating long-range, distant transport and deposition in areas far from the source (Peeters and Zooler 1988; Skjøth 2007).

Analysing the pollen season dynamics, the highest concentrations during March or May coincided mostly with the flowering of woody plants. The allergenic pollen of Cupressaceae was the most predominant type, followed by *Olea*, *Platanus*, *Pinus* and *Parietaria* in terms of peak values and daily pollen count. These species (excluding *Pinus*) are the most important taxa in the whole of Mediterranean region, as regards pollen severity and allergenic potency. *Urtica*, *Quercus*, Poaceae, Chenopodiaceae/Amaranthaceae, *Plantago*, *Castanea*, *Pistacia* and *Betula*, in order of abundance, make up the rest of the pollen types which are considered important for human health (D'Amato et al. 2007).

Cupressaceae pollen was the most prevalent in air, consistent with reports from some eastern Mediterranean areas such as Sardinia (Ballero and Maxia 2003) and Greece (Gioulekas et al. 2004). Cupressaceae has a longer pollen season, and different species have distinct timing of pollination. For example, *Juniperus phoenicea* L. subsp. *turbinata* (Guss.) Nyman and *Cupressus arizonica* E.L. flower in autumn, while *Cupressus sempervirens* L. and *Thuya orientalis* L. release pollen in winter.

Olea is the second most important taxa analysed. It is considered one of the most important causes of respiratory allergic disease in the Mediterranean region (Florido et al. 1999) and the major cause of allergies in southern Spain (Domínguez-Vilches et al. 1993; Vázquez et al. 2003, Alba et al. 2006).

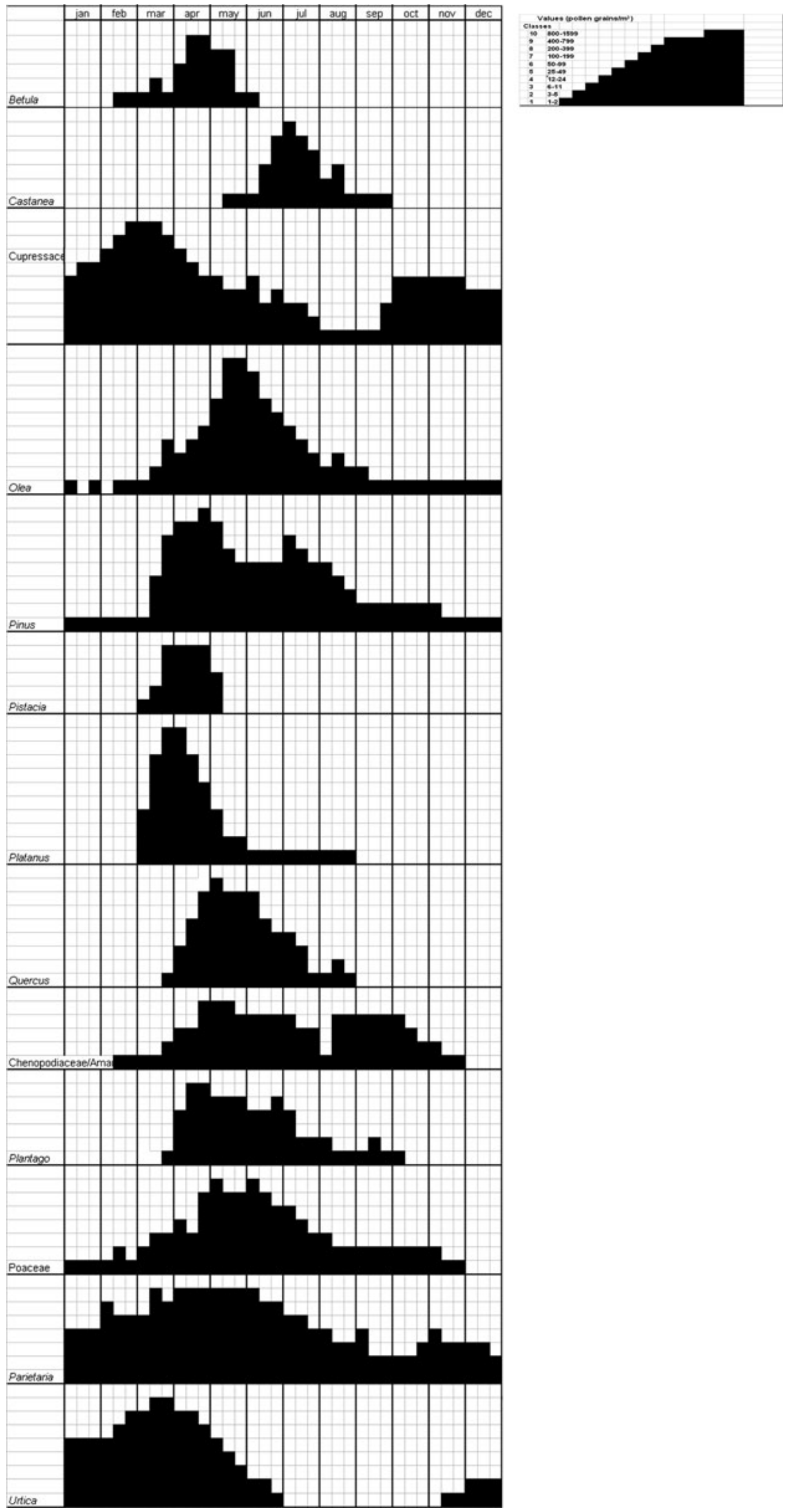
Platanus is the third pollen type in prevalence. It is an allochthonous plant which is common in the gardens, streets and parks of Palma de Mallorca. It is a probable source of allergy problems for the population, given that these taxa have allergenic importance in some Mediterranean areas (Alcázar et al. 2011).

Pinus, the fourth pollen type in abundance, is the most significant pollen-producing taxa in other Mediterranean areas, like Didim or Nerja (Aycan et al. 2008; Docampo et al. 2007), and it has exhibited a positive trend in pollen intensity over time.

Parietaria judaica, as the fifth most important pollen type, is seen as one of the most common causes of allergies in the Mediterranean region (D'Amato et al. 1991). *Parietaria* has a longer blooming period and a longer pollen season in warm and wet conditions (Galán et al. 2000).

According to Szczepanek (1994), herbaceous taxa, like Chenopodiaceae/Amaranthaceae or *Plantago*, usually show longer pollen seasons (60–120 days). Poaceae is one of the most important causes of pollinosis in many parts of the world, but low levels have been observed in Palma de Mallorca compared to other places such different sites in Spain (García-Mozo et al. 2009), or Thessaloniki in Greece (Gioulekas et al. 2004), and Zagreb in Croatia (Peternel et al. 2005).

Fig. 5 Pollen calendar for Palma de Mallorca 2004–2010



Our pollen calendar offers a preliminary view of the spectrum of dominant pollen types during a 7-year period (2004–2010), which is considered to be the minimum time required to obtain a representative view of the behaviour of airborne pollen in any area (Rodríguez et al. 2004).

Knowledge of the pollen season variability, in terms of timing and intensity, has an important role in public health. All the species examined showed variability in the progression of the pollen season. Depending on the taxa, the consecutive phases (percentiles) of the pollen season are achieved at different times. The start of the pollen season (the 5 %) is the most important phase to predict because it is associated with the appearance of allergy symptoms, although aeroallergen sources may occur even before a pollen season starts (Madeja et al. 2005).

The downward trend in the airborne pollen in Palma de Mallorca during the period studied conflicted with reports from other sites where the mean pollen count has increased (Cristofori et al. 2010; Myszkowska et al. 2011). Although we detected a declining trend in average daily pollen levels, no significant modification in the composition of local vegetation has been observed. Future studies with longer data sets, integrating measurements of local climate parameters may provide useful insights which would show whether these results were long-term trends, or just short-term fluctuations.

Global warming over the last decades can significantly impact animal and plant populations (Root et al. 2003) and affect the reproductive processes that underpin pollen production (Mayer et al. 2011). Variation in meteorological conditions affect plant responses in terms of phenology and floral intensity (Ziska et al. 2008; Davies and Smith 2006), so future research of the presence of airborne pollen takes on great importance.

5 Conclusions

Documentation of the composition of dominant airborne pollen in the city of Palma de Mallorca contributes to understanding the flowering behaviour of local vegetation. It also assists allergologists and allergy patients. The mean annual pollen index over the 7-year study period was 20,027. The highest daily counts occurred between February and June, in particular in March and May, while the lowest counts were in July–January. The most important airborne pollen types in Palma de Mallorca are Cupressaceae, *Olea*, *Platanus, Pinus* and *Parietaria*. Pollen from *Olea* or Poaceae did not reach the significant levels seen in other parts of Europe. We also found that the average daily pollen count, inclusive of all taxa, showed a clear, declining trend over time.

The pollen calendar of Palma de Mallorca is the first one to have been produced for the Balearic Islands. It shows the species which are typically Mediterranean and included a range of taxa, many of which have a long pollen season.

Future research will focus on the production of pollen and pollen allergens, and their relationship to climate change may help us to understand the modification in the island's vegetation.

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