



Aerobiological notes in the Biosphere Reserve “Sierras de Béjar y Francia” (MW Spain)

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Abstract Aerobiological studies in urban areas are quite abundant in recent decades, but not in rural areas with a high environmental value. In this work, we analyze the airborne levels of pollen and fern spores in year 2012 collected by means of a volumetric sampler located in an ecological vineyard and in the Biosphere Reserve “Sierras de Béjar y Francia.” The results showed a high atmospheric representation of the natural vegetation of the environment, with almost half of the airborne pollen coming from the most represented tree formations such as chestnut and oak trees. Airborne concentrations of grass pollen reached approximately a 25% of the total, with high levels during 33 days of the year, 18 of them in January, February and March. The seasonal and intradaily

behavior of the most abundant pollen types was focused on the months of May, June and July and the central hours of the day, respectively. Temperature had a positive influence on the levels of the main pollen types, while rainfall had a negative effect on pollen types from herbaceous species.

Keywords Aerobiology · Natural areas · Pollen · Fern spores · Seasonal and intradiurnal variation · Iberian Peninsula

1 Introduction

Aeropalynological data are not only important for medical and agricultural studies, but they also have a great interest from an ecological point of view, in order to get a better knowledge of plant phenology and, subsequently, its implications in studies that could assess phenomena linked to climate change (Monahan et al. 2016). However, there are few studies on the atmospheric content of biological particles in sites with high natural values (Murray et al. 2008), even despite being considered as important sources of allergenic particles in many cases (Skjøth et al. 2013). This paper shows the results of monitoring the pollen and pteridophyte spores in the atmosphere of the Biosphere Reserve UNESCO-MAB (2006) «Sierras de Béjar y Francia» (MW Spain) which includes seven

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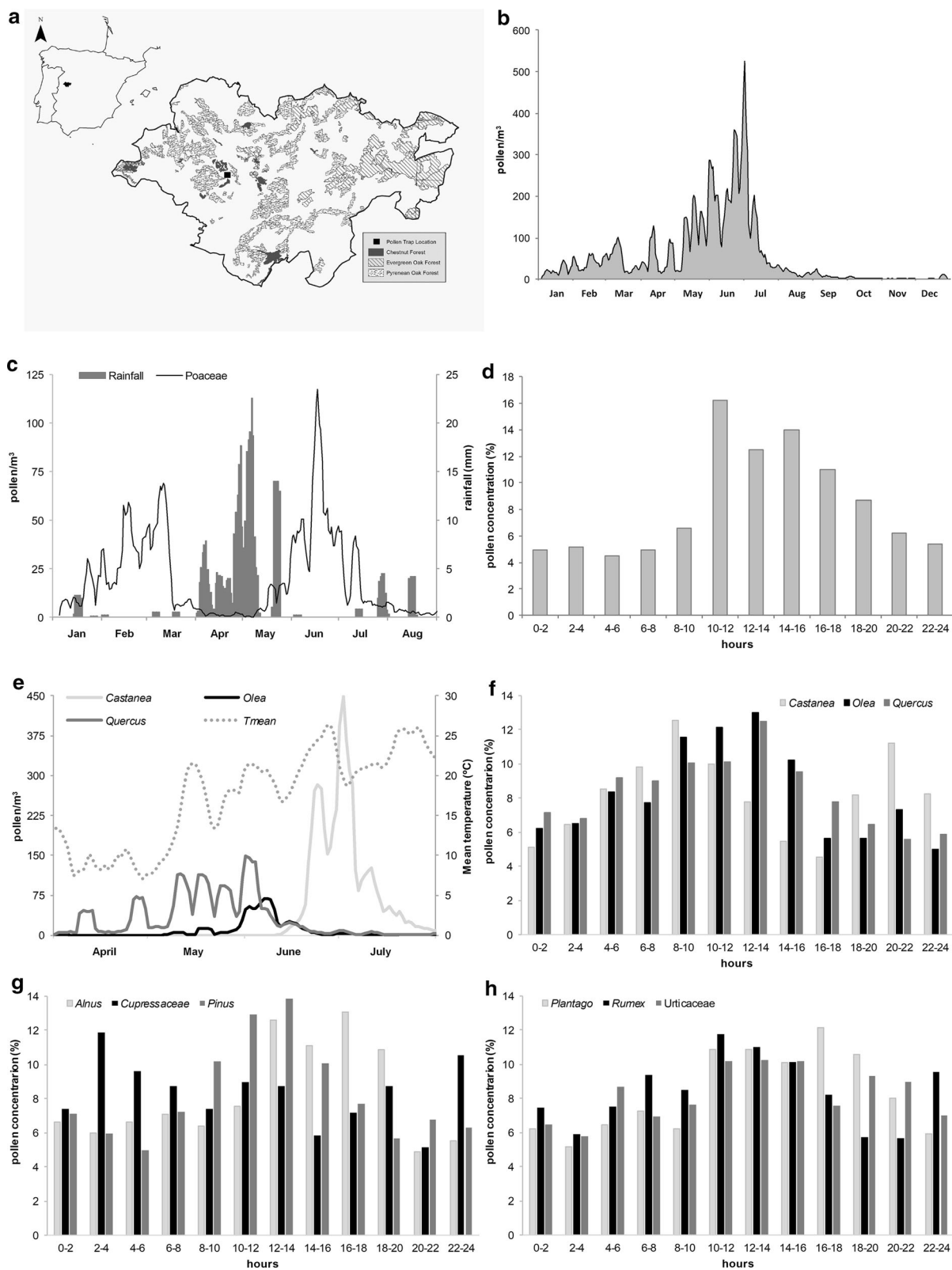


Fig. 1 **a** Geographical location of the Biosphere Reserve and the spore trap. Main forests in the study area. **b.** Seasonal variation of total pollen airborne levels during 2012 (5-day running mean). **c.** Seasonal variation of Poaceae pollen from January to August 2012 (5-day running mean) and total daily rainfall (mm). **d.** Poaceae pollen intradiurnal pattern. **e.** Seasonal variation of *Castanea*, *Olea* and *Quercus* pollen from April to July 2012 (5-day running mean) and mean temperature (°C). **f.** *Castanea*, *Olea* and *Quercus* pollen intradiurnal pattern. **g.** *Alnus*, Cupressaceae and *Pinus* pollen intradiurnal pattern. **h.** *Plantago*, *Rumex* and Urticaceae pollen intradiurnal pattern

areas belonging to the Natura2000 Network, giving evidence of its environmental importance.

2 Materials and methods

The aerobiological monitoring was performed by a Hirst-type volumetric spore trap (Lanzoni VPPS 2000—Lanzoni Srl-), located in an ecological vineyard (Viñas del Cámbrico, S. L.; 40° 30' N, 6° 0' W) during year 2012 (Fig. 1a). The situation of the sampler was chosen as a basis to develop fungal spore monitoring studies. The landscape has steep mountains, with altitudes ranging between 360 and 2425 meters, with green leafy forests formed mainly by Pyrenean oak trees (*Quercus pyrenaica* Willd.) and chestnuts (*Castanea sativa* Mill.). Evergreen oak (*Quercus ilex* subsp. *ballota* (Desf.) Samp.) is also one of the most important tree formations, as well as olive (*Olea europaea* L.) crops to the South. The methods standardized according to the Spanish Aerobiology Network were used for sampling, slide preparation, pollen counting and data interpretation (Galán et al. 2007). The sum of the average daily concentrations of pollen and spores (expressed as pollen or spores/m³) is reflected in the annual pollen/spore integral (API_n/ASIn), following the recommendations of Galán et al. (2017). The term “main pollen season” (MPS) was used to delimit the period during which the most pollen is recorded (Galán et al. 2017) for main pollen types, and it was defined using the methodology proposed by Nilsson and Persson (1981) as the period of the year that accounts for 90% of the total pollen counts. The prepeak period (PRE) includes the period between the starting date of the APS and the date on which the highest concentration is reached. A 5-day running mean was calculated during the studied

period and plotted to assess the seasonal trend. The intradiurnal airborne pollen concentration was determined for main pollen types on the basis of the bihourly values registered during the APS, and it was represented by the average of the values (Sánchez-Reyes et al. 2009). To evaluate the influence of the most relevant meteorological parameters on atmospheric pollen concentrations, the Spearman's non-parametric test was used with SPSS software v.23. The meteorological information was provided by AEMET for different meteorological stations near the spore trap: Herguijuela de la Sierra, 8.8 km from the sampling site (temperature and rainfall), El Maillo, 15.1 km (relative humidity, wind speed and wind direction), and La Covatilla, 32.2 km (sunshine hours).

3 Results and discussion

During year 2012, 62 pollen types and spores from vascular plants were identified in the atmosphere of the analyzed area, resulting in an API_n = 20,060 pollen and fern spores/m³. Of these biological particles, two types of pteridophyte spores (*Pteridium*, *Blechnum*) appeared in low values mainly in September and October (API_n = 29 spores/m³ and 1 annual spores/m³, respectively). These levels could be related to interannual differences in fern phenology, especially in the case of *Pteridium* (Rodríguez-de la Cruz et al. 2009). Data of main pollen types are represented in Table 1. The pollen grains of the two most representative tree genera in the area (*Castanea*, *Quercus*) accounted for almost 50% of the atmospheric pollen levels in the year of study, reflecting the importance of natural vegetation in the emission of these biological particles. The relationship between native forests and atmospheric pollen content was also highlighted in other studies carried out in protected natural environments (García-Mozo et al. 2007), where pollen from the most abundant trees can account for almost three quarters of the pollen content (Picornell et al. 2019). In the case of *Castanea* pollen, similar levels were reported in other semiurban areas also located in the Biosphere Reserve (Sánchez Blanco et al. 2017). However, pollen grains from ornamental non-native species widely used in cities such as *Platanus* (API_n = 56 pollen/m³) showed low annual values, much lower than those in nearby urban

Table 1 Seasonal behavior of airborne pollen in the study area

Pollen type	APIn (pollen/m ³)	% Total	Peak value (pollen/m ³)	Peak day	MPS length (days)	Start MPS	End MPS	PRE length (days)
<i>Castanea</i>	5662	28	828	1 July	29	20 June	18 July	13
Poaceae	4846	24	156	16 June	179	23 January	20 July	145
<i>Quercus</i>	4011	20	342	31 May	82	10 April	30 June	22
<i>Olea</i>	1071	5	150	6 June	48	17 May	3 July	21
Urticaceae	824	4	26	5 June	166	23 March	4 September	75
<i>Rumex</i>	760	4	49	23 May	69	17 April	24 June	37
<i>Pinus</i>	600	3	140	12 April	74	4 April	16 June	9
<i>Alnus</i>	352	2	31	1 February	62	8 January	9 March	25
Cupressaceae	328	2	13	7 January	156	6 January	9 June	2
<i>Plantago</i>	295	1	17	31 May	100	9 April	17 July	53

APIn annual pollen integral, MPS main pollen season, PRE prepeak period

areas (Rodríguez-de la Cruz et al. 2010). Atmospheric concentrations of Cupressaceae pollen also did not reach levels detected in urban environments, although it should be noted that in the study area there are presented not only specimens of this family cultivated, as Arizona cypress (*Cupressus arizonica* Greene), but also native individuals such as prickly juniper (*Juniperus oxycedrus* L.), with different flowering periods (winter and late spring, respectively). In both cases, the number of individuals present in the area is low.

The greatest presence of pollen in the atmosphere was centered from late spring to early summer (Fig. 1b). June was the month with the highest atmospheric pollen content in relation to the annual total (29%), due to the phenology of the main pollen types (Table 1), especially for the four most abundant types (Fig. 1c, e). However, it should be stressed that during 18 days of the first 3 months of the year, high atmospheric levels of Poaceae pollen were recorded, according to Galán et al. (2007), which establishes daily mean concentrations higher than 50 pollen/m³. This fact would be probably linked to the flowering of some winter species (Kay 1987) such as early sand grass (*Mibora minima* (L.) Desv.). In the other months analyzed these high concentrations of Poaceae pollen were overcome for 15 days, mainly during June, with the possible implications in allergic processes for

sensitized patients. Nevertheless, the rest of the more abundant pollen types with incidence in allergic pathologies (Cupressaceae, *Olea*, *Plantago*, *Rumex*, Urticaceae) did not show high airborne levels during 2012.

The monthly distribution of the main pollen types (Table 1) corresponded to that described in nearby areas (Rodríguez-de la Cruz et al. 2010; Sánchez Blanco et al. 2017), although differences were observed in the dates and maximum daily mean concentration values. These differences could have been related not only to the vegetation around the studied areas but also to variations in meteorological and phenological conditions (García-Mozo et al. 2007).

The intradaily variation displayed slightly higher levels of atmospheric pollen during the central hours of the day in the most abundant pollen types (Fig. 1d, f, h), except in the case of Cupressaceae (Fig. 1g) with higher concentrations in the early morning. This type of intradiurnal cycle could indicate a long-distance transport of Cupressaceae pollen grains, as observed in other work in non-urban areas for other pollen types with distant producing species (Kasprzyk, 2006). Conversely, the intraday pattern shown by the main pollen types would indicate closer proximity to pollen production sources, both trees and herbaceous.

Table 2 Spearman's correlation coefficients established for airborne pollen concentrations and meteorological parameters along year 2012, the main pollen season (MPS) and the prepeak period (PRE)

	$T_{\max}$	$T_{\min}$	T_{mean}	Sunshine h	Rainfall	RelHum	WindSpeed	CF	Wind NE	Wind SE	Wind SW	Wind NW
Total pollen	.321**	.240**	.299**	.391**	-.101	-.195**	-.040	-.081	-.061	-.014	.001	.118*
<i>Castanea</i>												
Year 2012	.251**	.236**	.254**	.237*	-.063	-.155**	-.056	-.034	-.032	-.041	-.024	.142**
MPS	-.126	-.093	-.130	.200	-.203	.219	.132	.073	-.176	-.127	.220	-.082
PRE	-.688*	-.384	-.594*	.718		.578*	.168	.296	.078	-.476	-.081	.042
<i>Poaceae</i>												
Year 2012	.136*	.004	.086	.331**	-.150**	-.158**	.001	-.075	.126*	-.017	-.119*	.030
MPS	.328**	.138	.254**	.335*	-.477**	-.353**	-.092	-.141	.130	.236**	-.282**	.018
PRE	.286**	.012	.177*	.407*	-.510**	-.384**	-.077	-.206*	.211*	.241**	-.358**	-.012
<i>Quercus</i>												
Year 2012	.162**	.108*	.146**	.290**	.015	-.074	.026	-.061	-.120*	.060	.093	-.031
MPS	.250**	.388**	.290**	.432*	.044	.168	.034	-.148	-.335**	-.076	.284**	.045
PRE	.257*	.491**	.309**	.732**	.121	.213	.026	-.098	-.363**	-.076	.310**	.037
<i>Olea</i>												
Year 2012	.208**	.197**	.211**	.166	-.059	-.059	.021	-.059	-.114*	-.037	.124*	.024
MPS	-.078	-.010	-.028	-.274	-.181	.113	.199	-.168	-.108	-.010	.152	-.265
PRE	.658**	.665**	.782**	-.400	-.345	-.586*	.219	.204	.004	.305	-.043	-.341
<i>Urticaceae</i>												
Year 2012	.437**	.366**	.424**	.378**	-.138*	-.226**	-.082	-.115*	-.099	.012	-.019	.184**
MPS	.274**	.160*	.231**	.088	-.445**	-.214**	-.133	-.182*	.066	.187*	-.267**	.171*
PRE	.704**	.489**	.686**	.692**	-.596**	-.567**	-.233*	-.224	.227	.457**	-.435**	.100
<i>Rumex</i>												
Year 2012	.209**	.150**	.192**	.306**	-.048	-.063	-.065	-.081	-.108*	.013	.020	.129*
MPS	.481**	.401**	.437**	.689**	-.510**	-.493**	-.318**	-.327**	.181	.327**	-.454**	.291*
PRE	.615**	.597**	.621**	.837**	-.542**	-.546**	-.301	-.305	.206	.370*	-.487**	.270
<i>Pinus</i>												
Year 2012	-.062	-.070	-.067	.280**	-.002	.123*	-.033	.014	-.061	-.103	.068	.102
MPS	-.380**	-.586**	-.458**	.126	.140	.372**	.073	.341**	.170	-.268*	.108	-.041
PRE	.536	-.368	.385		.594	-.333	.333	-.245	-.143	-.117	-.033	-.050
<i>Alnus</i>												
Year 2012	-.272**	-.351**	-.314**	-.005	-.064	.071	.012	.143**	.192**	.037	-.163**	-.091
MPS	.030	-.087	-.026		.038	.134	-.281*	.157	-.083	.118	.036	.223

Table 2 continued

	$T_{\max}$	$T_{\min}$	T_{mean}	Sunshine h	Rainfall	RelHum	WindSpeed	CF	Wind NE	Wind SE	Wind SW	Wind NW
PRE	.347	-.135	.311		.023	-.221	-.080	.081	-.084	.070	.024	.188
<i>Cupressac.</i>												
Year 2012	-.127*	-.233**	-.176**	.083	-.095	-.100	-.017	-.019	.139**	.119*	-.166**	-.081
MPS	.177*	.021	.149	.122	-.204*	-.235**	-.052	.015	.150	.255**	-.146	-.128
PRE												
<i>Plantago</i>												
Year 2012	.317**	.252**	.301**	.360**	-.082	-.135*	-.038	-.088	-.128*	.009	.074	.077
MPS	.359**	.289**	.330**	.178	-.344**	-.375**	-.116	-.115	.056	.308**	-.161	-.036
PRE	.599**	.520**	.592**	.543*	-.452**	-.602**	-.224	-.154	.184	.474**	-.359**	-.050

T_{mean} = mean daily average temperature (°C). $T_{\max}$ = maximum daily average temperature (°C). $T_{\min}$ = minimum daily average temperature (°C). Sunshine = daily average sunshine (h). Rainfall = total daily rainfall (mm). RelHum = daily average relative humidity (%). WindSpeed = daily average wind speed (km/h). CF = daily average frequency of calms (%). Wind NE = daily average frequency of northeasterly winds (%). Wind SE = daily average frequency of southeasterly winds (%). Wind SW = daily average frequency of southwesterly winds (%). Wind NW = daily average frequency of northwesterly winds (%). Significance levels: *0.95%; **0.99%

The influence of the meteorological parameters considered in this study on atmospheric pollen levels was variable according to the results of the Spearman's test (Table 2). In general terms, as some studies found (Majeed et al. 2018), temperature and insolation had a positive effect on pollen concentrations, while rainfall and relative humidity had a negative influence. Thus, temperature could be related to atmospheric pollen levels in the three most important arboreal genera in the area (Fig. 1e) and with a late-spring and summer flowering phenology. Other pollen types from winter or early spring flowering trees (*Alnus*, Cupressaceae) showed negative correlation values with temperature, as other studies have pointed out (Sánchez-Reyes et al. 2009), due to their particular phenology linked to low temperatures. In the airborne levels of pollen produced by herbaceous species, there was also a positive influence of temperature together with the known washing effect of the atmosphere caused by rain (Majeed et al. 2018), well represented in the case of Poaceae (Fig. 1c). Wind speed and direction did not have an obvious effect on the atmospheric levels of the different pollen types (Table 2), a fact that highlights the need for more studies in these areas of high environmental interest in order not only to increase knowledge about the content of biological particles but also to have more tools to assess the effects of climate change and its impact on environmental health.

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