



Preliminary study of the atmospheric pollen in Sierra de las Nieves Natural Park (Southern Spain)

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Abstract Sierra de las Nieves is a Natural Park and a Biosphere Reserve located in Southern Spain. This protected area has a high diversity of ecosystems with abundant endangered species which has led to be proposed as a National Park. In January 2018, a pollen trap was installed inside this Natural Park in order to determine the atmospheric pollen behaviour of the main taxa registered during a whole year. Additionally, the results were compared with those registered in the urban and rural stations of Malaga and Ronda, respectively, during the same period. The samplings were made by means of a Hirst-type volumetric pollen trap, and the samples obtained were mounted and counted according to the methodology proposed by the Spanish Aerobiology Network. The highest amount and diversity of atmospheric pollen in the Natural Park was detected during the spring months. Statistical significant differences were found, regarding daily total pollen concentrations, between Sierra de las Nieves (Natural Park) and Malaga (urban city), and between Ronda (rural city) and Malaga. These differences were particularly detected for some pollen types such as *Quercus*. In general, the start of the main pollen season and the maximum concentration peak of the major pollen types occurred later in Sierra de las

Nieves than in Ronda and Malaga. The qualitative and quantitative differences between Sierra de las Nieves and the others nearby locations can be explained by the differences in land use, altitude, climatic characteristics, as well as the distance between the aerobiological stations and the pollen emission sources.

Keywords Protected area · Diversity · Phenology

1 Introduction

Sierra de las Nieves is a Natural Park and a Biosphere Reserve located in Southern Spain. This protected area has a high diversity of ecosystems with abundant endangered species (Cabezudo et al. 1998, 2005) which has led to be proposed as National Park. Two of the most emblematic species, *Abies pinsapo* Boiss. and *Quercus alpestris* Boiss., present anemophilous pollination strategies. Since 1991, the Aerobiology research team of the University of Malaga has been sampling and studying airborne pollen in different cities of the Malaga province. Nevertheless, a pollen trap has never been installed inside this Natural Park for a continuous sampling process. In order to complete this missing information, a pollen trap was installed in Sierra de las Nieves Natural Park on 24th January 2018. The objectives of this study were to determine the atmospheric pollen behaviour of the

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main taxa registered during a whole year in this protected area, and to compare the results obtained with those registered in nearby urban and rural stations during the same period, searching for significant differences. It is important to study both phenology and pollen production in natural areas, where there is no uncontrolled use of soil or air pollution.

2 Materials and methods

Pollen samplings were carried out by means of volumetric pollen traps (Hirst 1952). In the case of the Sierra de las Nieves, it was placed at Las Conejeras recreational area (36°39'N, 5°5'W; 1070 m a.s.l.; 12.1 °C average annual mean temperature; 825 mm average annual rainfall) inside the protected area of the Natural Park. The other pollen traps were situated in the city of Ronda (rural) and Malaga (urban). The samples obtained were mounted and counted according to the methodology proposed by the Spanish Aerobiology Network (REA) (Galán et al. 2007). Days with missing data due to technical difficulties (5 in Sierra de las Nieves and 13 in Ronda) were lineally interpolated by tracing a straight line between both sides of the gap, and applying its equation to calculate the missing pollen concentrations. The interpolation was carried out by using the AeRobiology package of R software (Rojo et al. 2019). Although a pollen calendar would need several years of samplings to be reliable (Galán et al. 2017), we have depicted a preliminary one, based on the Spieksma (1991) model, in order to show the diversity and pollination periods of pollen types that, at least, reached a ten-days average of 1 pollen grain per cubic metre of air. This pollen calendar model transforms 10-day mean pollen concentrations into a series of classes according to Stix and Ferretti (1974) (2°). To study diversity, we have used those pollen types that exceeded 1% per year. This diversity was studied in the different seasons of the year: winter (January–March), spring (April–June), summer (July–September) and autumn (October–December). Statistical tests were performed by using R software, searching for differences among stations in daily mean concentrations of total pollen. Annual pollen index (API, Galán et al. 2017), start and end of main pollen season (MPS, 90%), date and value of the daily maximum were calculated to study the flowering intensity and temporality (phenology) of the

major taxa. Moreover, we compared the results obtained with those of other nearby stations: Malaga (55 km away; 36°42'N, 4°28'W; 58 m a.s.l.; 18 °C; 575 mm) and Ronda (12 km away; 36°44'N, 5°10'W; 768 m a.s.l.; 16.3 °C; 683 mm).

3 Results and discussion

For the first time, an aerobiological study of the atmosphere of Sierra de las Nieves Natural Park has been done. A total of 37 pollen types have been identified from January to December 2018 in this Natural Park, being the most abundant types: *Quercus* (73%), *Olea* (8.2%), Cupressaceae (5.8%), *Castanea* (4.6%) and Poaceae (2.9%). This order of abundance is different to the ones registered in Ronda and Malaga, specially for *Quercus* and *Castanea* (Fig. 1).

The pollination periods and intensity of the different pollen types registered are graphically shown in Fig. 2.

The annual pollen index of the total pollen (sum of the daily mean concentrations) registered during the 2018 (since 24th January) was 76,262, which is widely higher than the annual total registered in the atmosphere of Ronda (57,744) and Malaga (32,540) during the same year. The highest amount and diversity of atmospheric pollen in the Natural Park was detected during the spring (64,210 pollen grains; 32 taxa), and the same occurred in Ronda (33,421 pollen grains; 33 taxa) and Malaga (21,380 pollen grains; 31 taxa). Winter was the season with the lowest pollen register in the Natural Park (1024), while summer was the lowest in Ronda (2876) and Malaga (1485). Since the data of total pollen daily concentrations did not fit a normal distribution according to a Kolmogorov–Smirnov test with Lilliefors correction (p value $< 2.2 \times 10^{-16}$), nonparametric statistical tests were applied. Despite the results of a Friedman test among stations showed significant differences regarding the total pollen daily concentrations (p value $= 3.48 \times 10^{-7}$), when performing pairwise Mann–Whitney–Wilcoxon test, only significant differences were found between Malaga and Sierra de las Nieves (p value 0.031), and between Ronda and Malaga (p value 2.1×10^{-9}) after applying Bonferroni post hoc correction.

In general, the start of the main pollen season, as well as the maximum peaks for some of the major

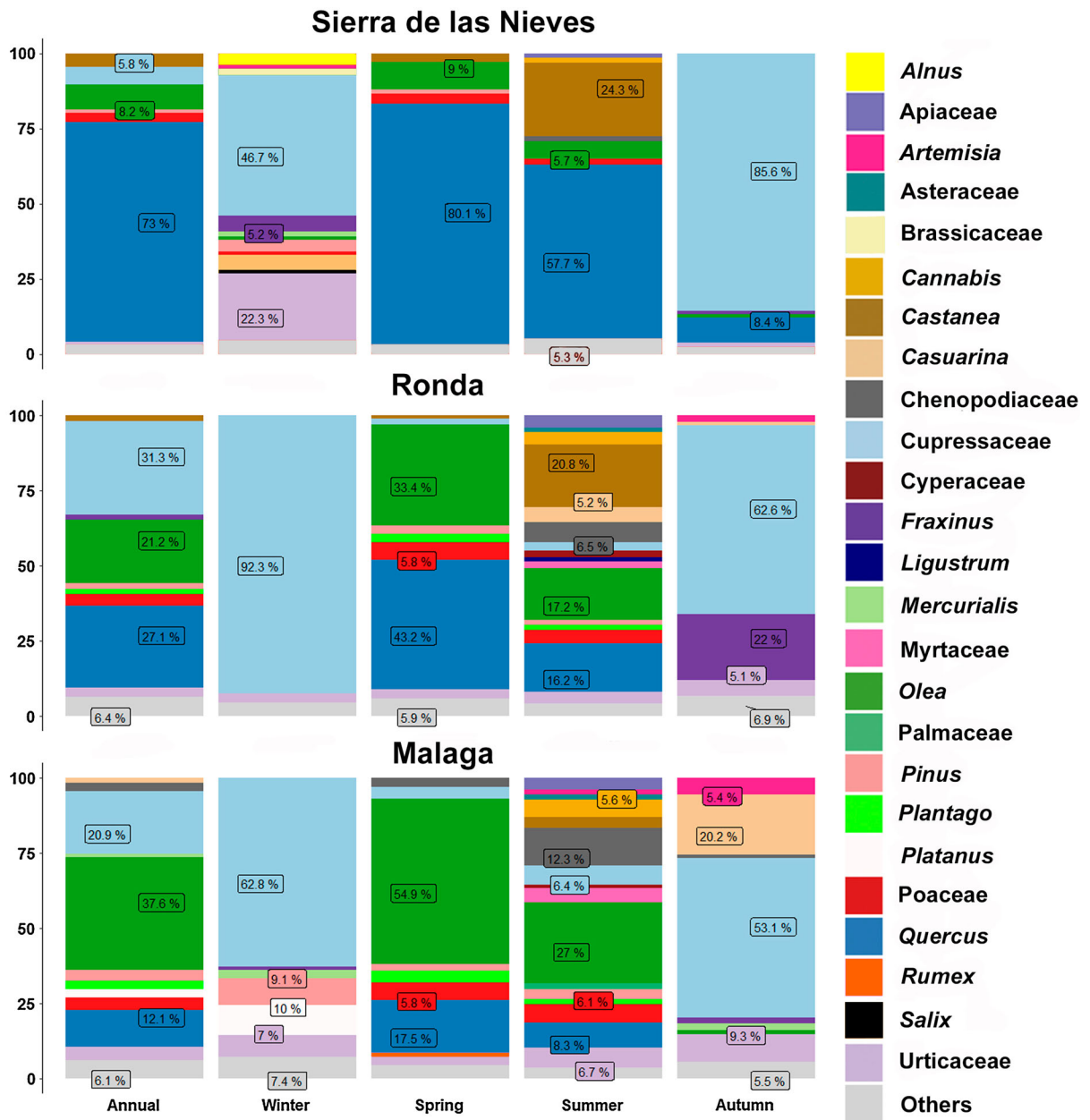
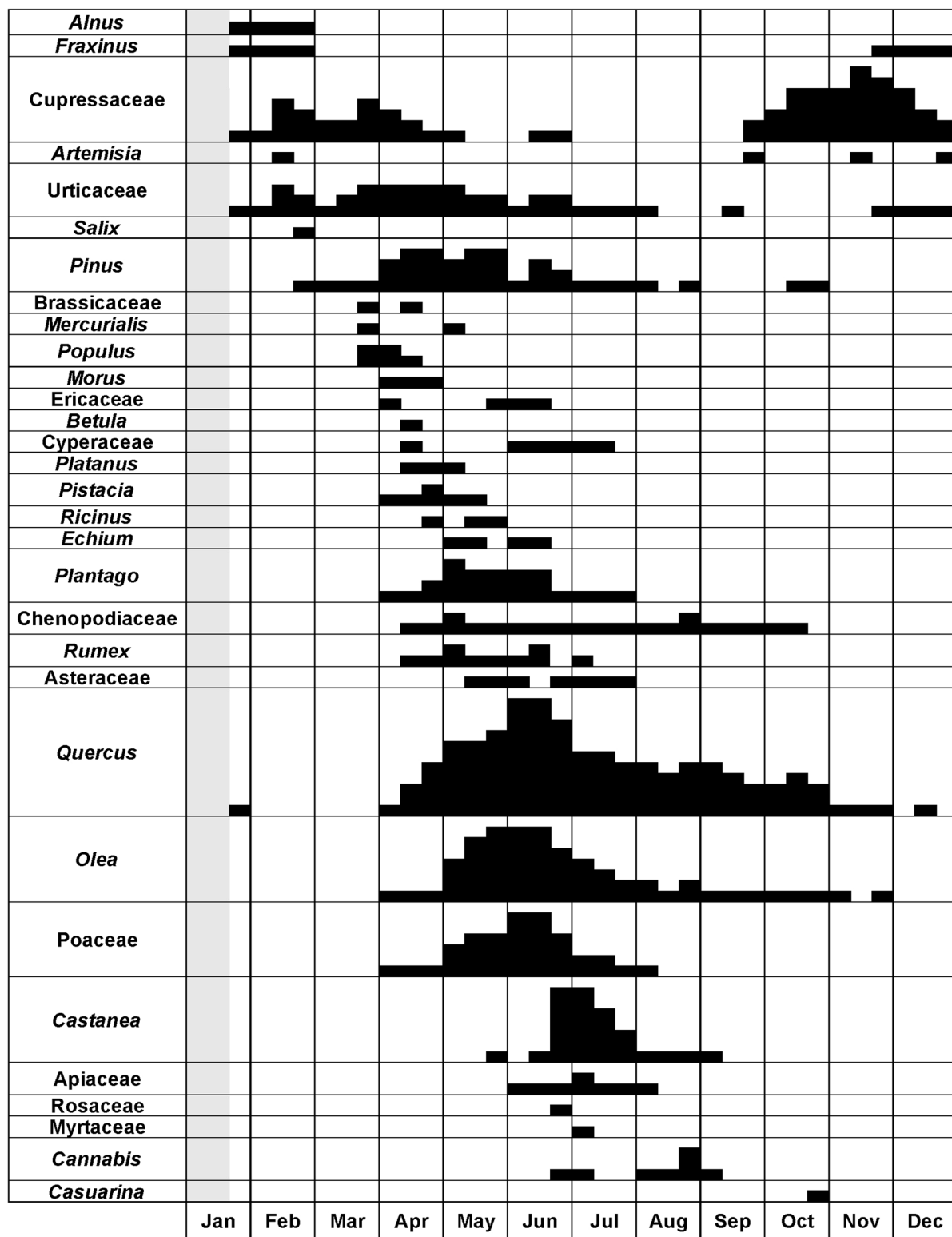


Fig. 1 Percentages reached by the different pollen types in Sierra de las Nieves (Natural Park, 1070 m a.s.l.) during the complete year 2018, winter, spring, summer and autumn, and its comparison with other nearby sampling stations of Malaga

province: Ronda (rural city, 739 m a.s.l., 12 km away) and Malaga (urban city, 45 m a.s.l., 55 km away). Only taxa that exceed 1% of the annual or the seasonal total have been included

pollen types (*Quercus*, *Olea* and *Poaceae*), was delayed in Sierra de las Nieves compared to Ronda and Malaga (Table 1). The end of the season was also delayed in Sierra de las Nieves for *Quercus* compared with the other locations, due to the later flowering of high mountains species, such as *Quercus faginea* Lam.

and *Quercus alpestris* Boiss. On the contrary, the end of the grass pollen season was more advanced. Regarding Cupressaceae, two pollination periods can be clearly observed: one in winter and other more intense in autumn (Fig. 2). Because of that, they were studied separately (Table 1). In autumn is when



◀ **Fig. 2** 2018 pollen calendar of Sierra de las Nieves Natural Park. Grey (no sampled period). Model proposed by Spieksma (1991) and Stix and Ferretti (1974). Each step of the graph corresponds to 10-day mean pollen concentrations between 2^{n-1} and 2^n

Juniperus species flourish, whose abundance is greater in protected natural areas. In addition, two species (*J. sabina* L. and *J. communis* L.) are exclusive of mountainous summits. Cupressaceae autumnal pollen index and its daily maximum value were higher in Sierra de las Nieves than in Ronda and Malaga.

The qualitative and quantitative differences observed between Sierra de las Nieves and other nearby locations can be explained by the differences in land use, altitude, climatic characteristics as well as the distance between the aerobiological stations and

pollen sources (Recio et al. 2009; Velasco-Jiménez et al. 2014; Martínez-Bracero et al. 2015). In general, pollen spectrum of rural and urban areas can be influenced by the presence of cultivated plants of ornamental and economic interest such as cypress, *Platanus* *Casuarina* or olive trees. Additionally, wind dynamics can also influence the distribution of the pollen concentrations, transporting masses of pollen grains from one area to another (Recio et al. 1996, 1999, 2010, 2018). Consequently, pollen from rural areas can reach urban cities and, on the contrary, pollen of cultivate origin can be transported to natural areas where they are not normally present. This results in a similar pollen spectrum in which the different concentrations and phenological periods are what make a difference.

Table 1 Intensity and temporality parameters of airborne pollination for the most abundant pollen types in Sierra de las Nieves Natural Park in 2018 and its comparison with other nearby sampling stations of Malaga province: Ronda (rural city) and Malaga (urban city)

	Sierra de las Nieves	Ronda	Malaga
<i>Olea</i>			
API	6251	11,710	11,930
Start date	12 May	14 May	6 May
Peak date	1 Jun (15 and 17 Jun)	18 Jun	(24 May) 4 Jun
End date	11 Jul	29 Jun	26 Jun
Peak value	453 (328 and 312)	1010	(798) 1047
<i>Quercus</i>			
API	55,598	14,935	3841
Start date	17 May	28 Apr	17 Apr
Peak date	8 Jun	16 May	28 Apr
End date	17 Jul	23 Jun	25 Jun
Peak value	4483	1880	231
Poaceae			
API	2242	2115	1349
Start date	9 May	9 May	27 Apr
Peak date	14 Jun	1 Jun	29 May
End date	4 Jul	13 Jul	12 Jul
Peak value	189	191	91
Cupressaceae			
SPI	4437 (627/3810)	17,252 (3884/266)	6620 (5256/1364)
Start date	14 Feb/13 Oct	31 Jan/5 Oct	15 Feb/26 Sep
Peak date	28 Mar/11 Nov	9 Mar/5 Dec	27 Mar/29 Nov
End date	29 Apr/9 Dec	29 Mar/29 Dec	10 Apr/20 Dec
Peak value	87/450	3884/266	449/137

In Cupressaceae, there are data of two seasons, winter and autumn, separated by a bar

API annual pollen index,
SPI seasonal pollen index

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