6.1. Changes in diversity, abundance and flowering phenology in plant communities: a 25-year study of high-mountain meadows (*borreguiles*)

Pérez-Luque, A.J.[1]; Sánchez-Rojas, C.P.[2]; Zamora, R.[1] and Bonet, F.J.[1]

[1] Andalusian Institute for Earth System Research. University of Granada [2] Environment and Water Agency of Andalusia

Abstract

High-mountain meadows (*borreguiles*) in Sierra Nevada are very sensitive ecosystems with respect to changes in water availability and temperature, serving as ideal communities to study climate change. A diachronic analysis of 25 years has revealed that these communities do not present significant changes either in composition or in species abundance. However, the phenological attributes do differ at the community level between the two periods analysed. In general, a delay in flowering was noted for the early-flowering species, which appear to be the most sensitive ones.

Aims and methodology

Changes in composition, abundance, and flowering phenology were analysed in the plant communities of the wet pasture-like communities (*borreguiles*) in two different periods: 1988-1990 and 2009-2012. For this purpose, permanent plots of 1 x 1 m were distributed in the *borreguiles* at the medium elevation site (San Juan) [1, 2]. The plots were visited every two weeks (from May to October). For each species, the presence/absence, cover, and number of flower structures were noted. With these data, flowering profiles were constructed and phenological indicators were established: onset and end of flowering, duration of flowering, and date of maximum flowering. Afterwards, changes were analysed for flower abundance (quantity of flowers) and flowering phenology at the community level, differentiating between early-, middle-, and late-flowering species. These comparisons were made for 19 taxa.

Results

At the community level, no significant differences were detected between the two periods in terms of species composition. In the period 1988-1990, the number of taxa was 23 as opposed to 32 identified at present, with 20 taxa detected in both periods. The abundance of flowering did not significantly change between the two periods at the community level. Nor were changes noted in flowering abundance for the early- or middle-flowering species. Significant changes were found only in flower abundance for two late-flowering species of the genus *Trifolium* (*T. pratense and T. repens*). On the contrary, significant changes were found for flowering attributes. At the community level, significant differences were found for all the flowering attributes between the two periods analysed (Table 1, Figure 1). The results show a mean lag of 7 days for the onset of flowering and of 12 days for the end of flowering. The period of maximum flowering was delayed a mean of 5 days. The late-flowering species did not present any changes in their phenological attributes between the two periods compared, while the early-flowering species showed significant changes for the onset and end of flowering as well as the date of maximum flowering (Figure 2).

Table 1

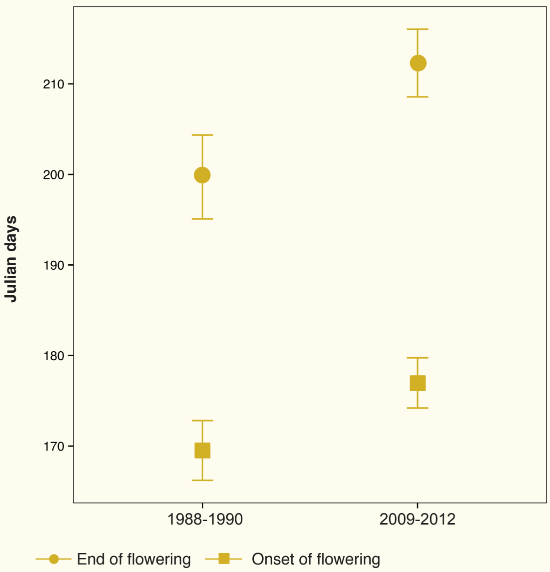
	p-value	Periods	Mean ± SD
Flowering onset	0.0001	1988-1990 2009-2012	169.52 ± 3.30 176.98 ± 2.78
End of flowering	0.0003	1988-1990 2009-2012	199.72 ± 4.63 212.30 ± 3.74
Duration of flowering	0.0312	1988-1990 2009-2012	30.20 ± 2.32 35.33 ± 2.50
Date of maximum flowering	0.0190	1988-1990 2009-2012	181.20 ± 3.91 186.16 ± 3.14

Mean values for different flowering attributes for the periods 1988-1990 (1990) and 2009-2012 (2010). The mean values and standard deviation are shown. Julian Day values are shown for all variables except for the duration of flowering expressed in number of days.

Discussion and conclusions

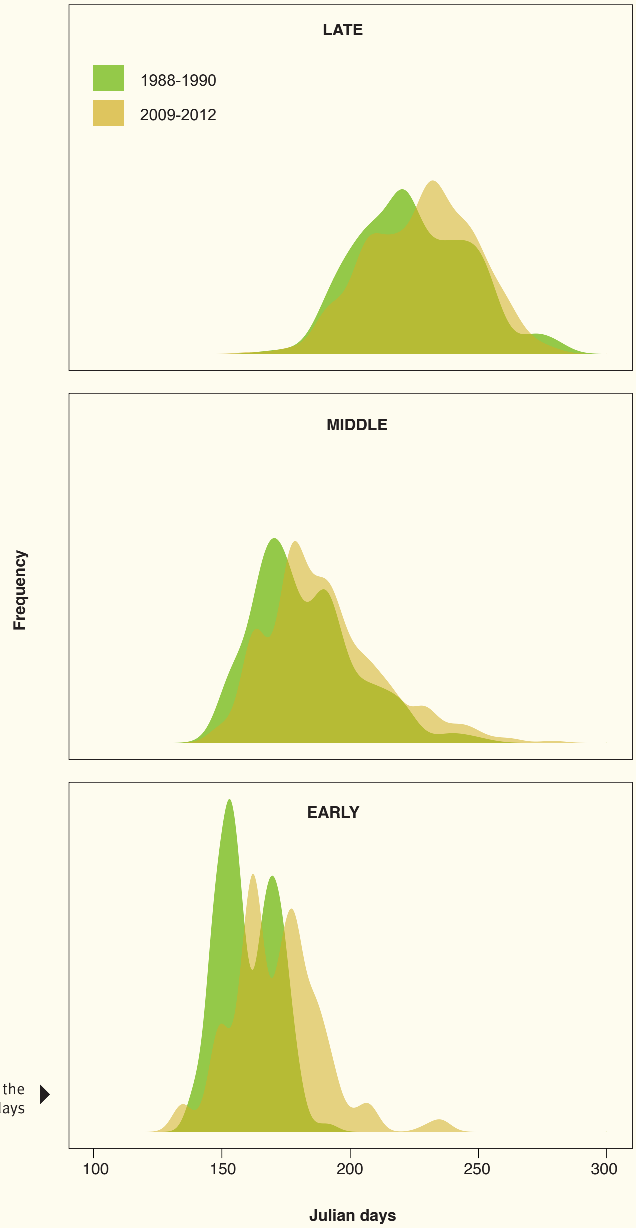
The taxonomic diversity found in the *borreguiles* was very high, both at the level of species as well as genera and families, as occurred in the summits of Sierra Nevada [3]. Our results showed no significant changes either in plant diversity or in flower abundance or in the *borreguiles* during the last 25 years. The close link of the borreguiles to the areas that remain wet all summer in the high mountain can determine the stability of the system studied. However, the flowering phenology has in fact changed between the two periods, although in different ways. A general delay was noted for all the phenological attributes analysed, a delay that proved statistically significant in the case of the species with the earliest flowering.

Figure 1



Day of onset (squares) and end of flowering (circles) at the community level between the periods 1988-1990 (1990) and 2009-2012 (2010). The date is indicated in Julian days (1 Jan: day 1; 31 Dec: day 365)

Figure 2



Flowering profiles for the periods 1988-1990 (1900; green) and 2009-2012 (2010; ochre) for the early- (lower), middle- (centre), and late-flowering (upper). The date is indicated in Julian days (1 Jan: day 1; 31 Dec: day 365)

6.2. Changes in flowering phenology along environmental gradients

Muñoz, J.M.
Environment and Water Agency of Andalusia

Abstract

Results for the flowering phenology of 13 plant species at 5 different sites in Sierra Nevada are shown. During the time of the study (five years), a significant earliness in flowering was detected in 2011, which was related to higher temperatures in the first months of the year. The response detected differed among species and between years. The silver broom *Adenocarpus decorticans* was the species with the broadest flowering range, while *Anthyllis citisoides* showed a special sensitivity towards winter precipitation, and *Genista versicolor* hardly differed between years.

Aims and methodology

The aim of the present monitoring was to determine the trend for flowering of some abundant and widely distributed species in Sierra Nevada. The flowering phenology for a set of species from different bioclimatic belts of Sierra Nevada was studied. For this purpose 4 fixed plots located in an elevational gradient were monitored during 5 years.The phenological status of each individual was recorded using a categorical scale: "-": without flowering,"0": with flower structures, "1": up to 5 flowers, "2": more than 5 flowers; "3": maximum flowering", "4": flowers and fruits, and "5": full fruiting. Each plot was visited between 5 to 9 times each year. The day of maximum flowering (MFD hereafter) was estimated by regression. The annual deviation of MFD with respect to the mean value of the series was used as the reference parameter to establish comparisons between years.
The results were compared with temperature and precipitation data between January and April for the study area (600 to 2150 m.a.s.l.).

Results

No clear trend was detected in the flowering phenology of the species studied, probably due to the need for a more extensive time series in order to explore the role of temperature and precipitation variations as key predictive variables. However, the intensity of the sampling enabled the establishment of relations between the phenological behaviour of the species studied and the climatic characteristics of the year (temperature and precipitation), and provided an understanding of the influence of elevation over flowering phenology in these species.

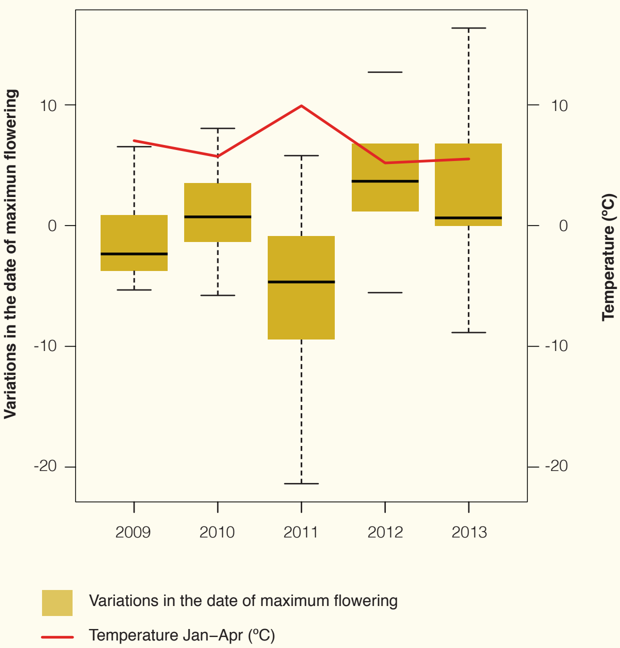
Temperature

Early flowering was found in the year 2011, when the highest temperatures were recorded in the first months of the year (Jan-Apr) in comparison with the rest of the series. The response to the higher temperature differed according to the species [4]. The early-flowering species (*Prunus dulcis, P. avium, Adenocarpus decorticans, Cytisus oromediterraneus*) showed the greatest earliness in flowering in 2011, while the late-flowering ones (*Anthyllis cytisoides, Genista umbellata, G. versicolor, and Retama sphaerocarpa*) did not show this behaviour.

Precipitation

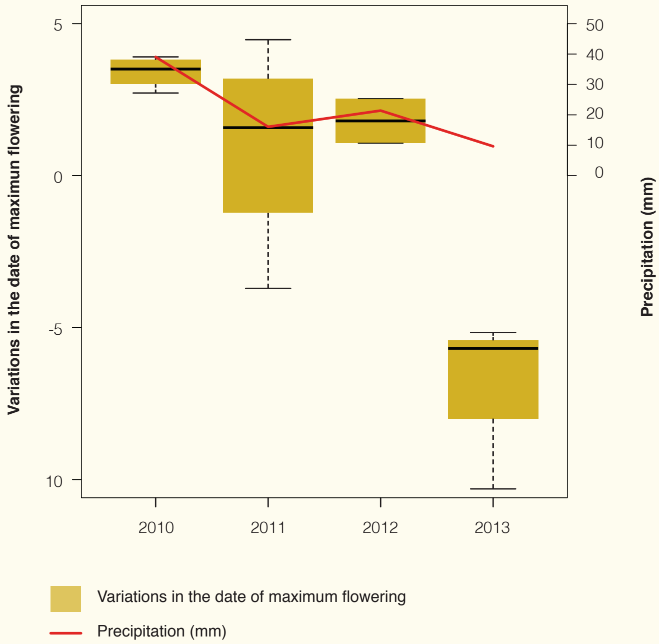
In the south-eastern part of the Sierra Nevada the sparse precipitation notably determined the flowering phenology. *Anthyllis cytisoides* flowered in these areas in years with low rainfall from January to April (Figure 2). Years with low precipitation in the beggining, only individuals at the upper elevation flowered, afterwards aborted and didn´t bear fruits.

Figure 1



Relation between the annual variation in MFD of the species studied and the mean temperature (red line).

Figure 2



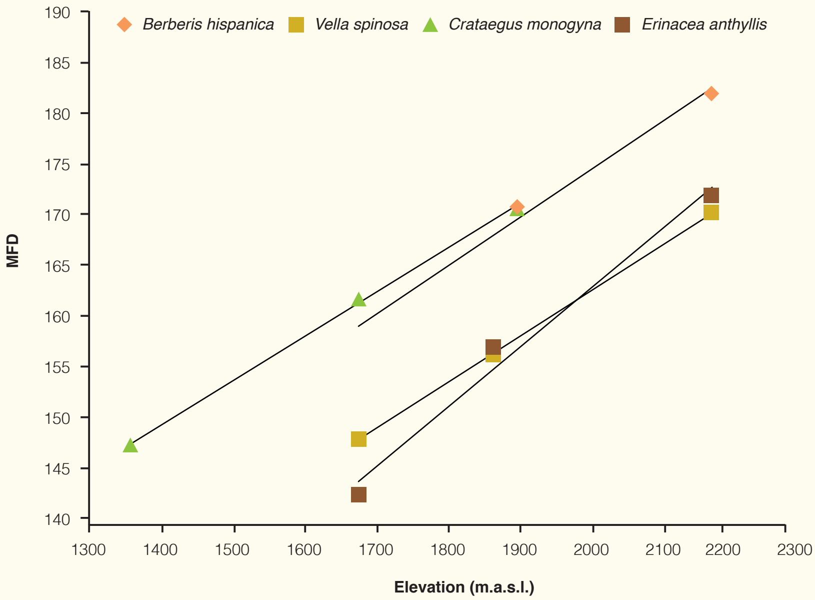
Relation of the annual variation in MFD of *Anthyllis cytisoides* and the accumulated precipitation during the months of January and April (red line).

Elevation

The elevational lag varied in each species. The rate of the shift was not uniform and often was recorded with delays of different magnitudes between sites situated at the same elevation but where the habitats differed. In 2013, the monitoring was undertaken with the intent of avoiding differences in habitat, resulting in a directly proportional relation between the MFD and elevation.

An elevational delay of 56.3 days/km was found for *Erinacea anthyllis* (r_s= 0.98, p=0.080), of 45.6 days/km for *Berberis hispanica* (r_s= 0.99, p= 0.060), 41.8 days/km for *Crataegus monogyna* (r_s= 0.99, p= 0.023), and of 43.3 days/km for *Vella spinosa* (r_s= 0.99, p=0.009; Figure 3).

Figure 3



Date of maximum flowering along an elevational gradient of *V. spinosa*, *C. monogyna*, *E. anthyllis*, and *B. hispanica* in 2013.

Discussion and conclusions

The response of the phenology of the different species to biophysical variables was heterogeneous. Of the 5 years in which flowering was monitored in Sierra Nevada, 2011 registered the highest temperatures in the first 4 months of the year. The expected earliness of the flowering was notable in the species with the earliest flowering while hardly influencing the flowering of the later-flowering species. Other factors apart from temperature, such as precipitation and elevation, strongly influenced flowering. The scant precipitation of the last few years has sharply depressed the number of flowers while causing the phenology of *Anthyllis cytisoides* to be earlier, this species being key in the landscape of the eastern sector of Sierra Nevada. These results have provided greater knowledge concerning the environmental variables that determine the phenology in different species of Sierra Nevada flora.

Cytisus galianoi in full flowering on the slope of the north face of Chullo peak.