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Dendrochronological study of the endangered shrub *Vella pseudocytisus* subsp. *paui* (Brassicaceae): implications for its recovery and conservation

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Abstract

Génova, M., Sánchez Espejo, J., Domínguez Lozano, F. & Moreno Saiz, J.C. 2013. Dendrochronological study of the endangered shrub *Vella pseudocytisus* subsp. *paui* (Brassicaceae): implications for its recovery and conservation. *Anales Jard. Bot. Madrid* 70(2): 178-186.

Dendrochronology is useful to determine plant longevity, to provide insights into the structure and dynamics of plant populations and to study the relationships between growth and environmental determinants. The dendrochronology of endangered shrubs is unexplored, although their use represents an opportunity to produce better conservation guidelines. We collected for this study 63 samples from already dead specimens of *Vella pseudocytisus* subsp. *paui* (Brassicaceae), an endangered Spanish endemism from three localities. We analyzed the relationship between ring data and plant size to determine the accuracy of using size as a proxy for plant age. We also explored the relationships between ring data and environmental variables to detect growth determinants. This shrub showed a high longevity as older individuals presented nearly 50 growth rings. The relationship between age and size is weak although it could be established based on the logarithmic function of plant biovolume. Significant relationships were found between rainfall and ring widths, showing that water limited annual growth. Finally, age structure characterized differences among populations, highlighting the effects of disturbance and land use. These results provided new opportunities for management within the ongoing recovery plan for the species.

Keywords: Allometry, secondary growth, xylem, climate-growth relationships, plant conservation, dendrochronology, semiarid scrubland, Spain.

Resumen

Génova, M., Sánchez Espejo, J., Domínguez Lozano, F. & Moreno Saiz, J.C. 2013. Estudio dendrocronológico del arbusto amenazado *Vella pseudocytisus* subsp. *paui* (Brassicaceae): implicaciones para su recuperación y conservación. *Anales Jard. Bot. Madrid* 70(2): 178-186 (en inglés).

La dendrocronología es útil para determinar la longevidad de la planta, proporcionar información sobre la estructura y dinámica de las poblaciones vegetales y estudiar las relaciones entre el crecimiento y las variables ambientales. Hasta ahora no se había hecho uso de la dendrocronología en arbustos en peligro de extinción, aunque su empleo puede mejorar las directrices de conservación. En este estudio se han recolectado 63 especímenes ya muertos de tres localidades de *Vella pseudocytisus* subsp. *paui* (Brassicaceae), un endemismo español en peligro de extinción. Se han analizado las relaciones entre los grosores del anillo de crecimiento y el tamaño de la planta para determinar si es posible utilizar el tamaño como estimador de la edad, y también entre la correlación entre el grosor de los anillos y las variables ambientales para detectar factores determinantes del crecimiento. Este arbusto mostró una elevada longevidad, con un máximo próximo a los 50 años. La relación entre la edad y el tamaño es débil aunque se incrementa si se utiliza la función logarítmica del biovolumen. Se encontraron relaciones significativas entre la precipitación y la anchura de los anillos, mostrando que el déficit hídrico es un factor limitante del crecimiento. Finalmente, se han caracterizado las poblaciones por las diferencias en la estructura de edades, destacando los efectos de las perturbaciones y del uso del suelo. Los resultados proporcionan nuevos datos para la gestión de la especie dentro de su plan de recuperación en marcha.

Palabras clave: Alometría, crecimiento secundario, xilema, relaciones clima-crecimiento, conservación de plantas, dendrocronología, matorrales semiáridos, España.

INTRODUCTION

The distribution of life-forms among vascular plants follows a complex latitudinal pattern, being the shrubs the most represented biotype at some temperate bands, particularly in the northern Hemisphere (Moles & al., 2009). Nevertheless, in spite of its role on terrestrial biomes most shrubs and dwarf bushes have received little attention in terms of their natural history. For instance, little is known about longevity or growth patterns among shrubby species, though such traits condition the life history and are critical for management or conservation purposes (Schwartz, 2003; Monks & al., 2012). Dendrochronological techniques offer the most precise estimation of age and growth rate based on ring measurements. Although few studies have focused on shrubs, the range of longevities has proved to be rather wide. Very high ages have been found in alpine and desert shrubs, as in *Pteronia pallens* L., which can live for 150 years (Milton & al., 1997) or *Empetrum hermaphroditum* Lange ex Hagerup, which can live for 80 years (Bär & al., 2006). Much lower maximum ages have been observed in some Mediterranean species such as *Helianthemum squamatum* (L.) Dum. Cours. and *Lepidium subulatum* L., which can live for 10 and 26 years, respectively (Eugenio & al., 2011). There is also growing interest in the potential use of dendrochronological analyses to support studies on vegetation dynamics (Kyncl & al., 2006; Soliveres & al., 2010), influence of climate on vegetation growth and fitness (Poore & al., 2009), etc. Especially significant are those studies on taxa from habitats where trees are not the dominant woody form or under stressful conditions for vegetation such as high mountains or Mediterranean environments (Keeley, 1993; Pornon & Doche, 1995; Nagel & Taylor, 2005; De Micco & Aronne, 2009; Copenheaver & al., 2010). However, growth studies of shrubs living in arid or semiarid environments are scarce (Mil-

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ton & al., 1997; Eugenio & al., 2011), and even rarer are references regarding the influence of climate on shrubby plant growth in such demanding habitats (Srur & Villalba, 2009). In fact, the physiological roles of wood are critical to plant survival, as woody tissues determines the resistance to water flow from roots to leaves, the capacity for water storage, and resistance to drought- and freeze-induced embolism (Domec & al., 2008; Choat & Pittermann, 2009; Poorter & al., 2009), which are typically limiting factors in Mediterranean climates.

Growth, size and population structure are closely related in modular organisms (Harper, 1977; Hart & Keough, 2009) and can be used to measure demographic patterns and fitness. Usually, faster growth means larger sizes, which in turn may have a positive effect on survival and fecundity (van Mantgem & al., 2003; Stephenson & al., 2011). In addition, growth, survival and fecundity determine the population structure (García & Antor, 1995). The relationships among these variables are strong but not simple, involving thresholds in reproduction effort (Hanzawa & Kalisz, 1993), no close relation between shoot demography and age (López & al., 2001) and the linkage between mortality and size depending on ecological factors (Perkins & al., 2006; Picó & Retana, 2008). Likewise, closely related to the latter, perturbation and ulterior colonization events are fundamental when explaining population structure. Dendrochronological techniques can also be used to strengthen the studies on the relationship between climate and growth. To the best of our knowledge, the effect of climate variables on ring growth in threatened populations has only been only explored on trees (e.g., Gareca & al., 2010; Génova & Moya, 2012), but this study can provide a basis for long-term management guidelines in the light of predicted effects of Global Change in shrubs as well. The expansion of environments that are subject to these climatic semiarid conditions in the Iberian Peninsula has been predicted to occur in the future, although projections on future tendencies concerning xerophytes remain controversial suggesting both range expansions and contractions (Thuiller & al., 2005; Felicísimo, 2011).

In this paper we aim to take advantage of a dendrochronological approach to deepen the demographic and ecological knowledge about *Vella pseudocytisus* L. (Brassicaceae), a threatened shrub of semiarid zones in the Western Mediterranean basin. This shrub has been considered as a flagship species for plant conservation in Spain and therefore subject of a number of applied studies and management projects (Domínguez Lozano & al., 2005, 2011a).

Then, using dendrochronological tools, our work had three main objectives to estimate the plant longevity of the species; to assess age-size relationships in order to check this link on a threatened plant to nondestructive methods to characterize population structures.; and to analyze radial growth and determine its variability depending on environmental determinants, particularly land use and climatic variables.

MATERIAL AND METHODS

Natural history of the species and sampling procedure

The Brassicaceae is a widespread family of approximately 3,400-3,700 species with a large predominance of annual or perennial herbs (Al-Shehbaz & al., 2006; Mabberley, 2008). However, there are few representatives of chamaephyte and nano-phanerophyte life-forms, mainly concentrated in the Western Mediterranean area (Domínguez Lozano & al., 2011a). This is particularly true for *Vella* L., an endemic genus with 8-9 woody taxa found on both sides of the Strait of Gibraltar. *Vella pseudocytisus* L. is the type species, occupies the most derived position in the phylogeny of the genus (Crespo, 2011) and exhibits the widest distribution (Spain, Morocco and Algeria). The northernmost populations of *Vella pseudocytisus* have been described as the subspecies *paui* Gómez Campo, endemic to the Aragonese region (Fig. 1a). It has been included in the Spanish Red Book of threatened vascular plants under the IUCN category of Endangered (Bañares & al., 2003), and because of its risk of extinction, the Government of Aragón passed a recovery plan in 2003 (Alcántara & al., 2007). The plant is found in open scrublands of fragmented distribution with other shrubby or perennial gypsophytes (*Ononis tridentata* L., *Gypsophila struthium* subsp. *hispanica* (Willk.) G. López, *Lepidium subulatum* L. and *Agropyron cristatum* (L.) Gaertn., for example), and its distribution is particularly shaped by the grazing of cattle. It plays a pioneering role in anthropogenic environments such as abandoned fields, slopes between farming terraces and road shoulders; it can even adopt a sub-rupicolous strategy in slopes of ravines, reaching great size and strength, and can be accompanied by other plants including *Antirrhinum litigiosum* Pau, *Reseda luteola* L. and *Sedum sediforme* (Jacq.) Pau.

The study site is part of the upper basin of the Alfambra-Turia River (Teruel, Spain; Fig. 1a). *Vella pseudocytisus* subsp. *paui* lives between 860 and 1,030 m a.s.l. and grows in soils composed of limonite, gypsum and gypsum marl of Cenozoic origin. These substrata give rise to reliefs of variable topography with mixes of low hills with deep ravines carved into the most erodible rocks. The climate is Mediterranean with a marked continental character (Fig.1b). Although the area currently maintains a low human population density, it is under intense anthropogenic influence. Cereal or tree crops and low-productivity pastures for sheep and goats are the main industries. The combination of climate, substrata and human activities has modeled the vegetation shape and composition, and produced a scrubland covering hills and rough terrain across the landscape.

Because *Vella pseudocytisus* subsp. *paui* is under legal constraints, it could not be extensively and systematically sampled for dendrochronological purposes. For 15 years, in the course of data gathering for demographic monitoring, dead individuals, usually from unknown causes, were collected from abandoned fields in the municipality of Villel (hereafter named subpopulation A1) and in the slopes of a ravine in the municipality of Villalba Baja (hereafter named population B) (Fig. 1a). In addition, unauthorized agricultural practices that were conducted in 2007 at Villastar resulted in the uprooting of a number of shrubs as reported by the Aragonese conservation authorities (hereafter named subpopulation A2). Therefore, a more extensive sampling could be performed here. The total sample consists of 63 harvested specimens (see Appendix 1), of which 35 correspond to the subpopulation A2 study site.

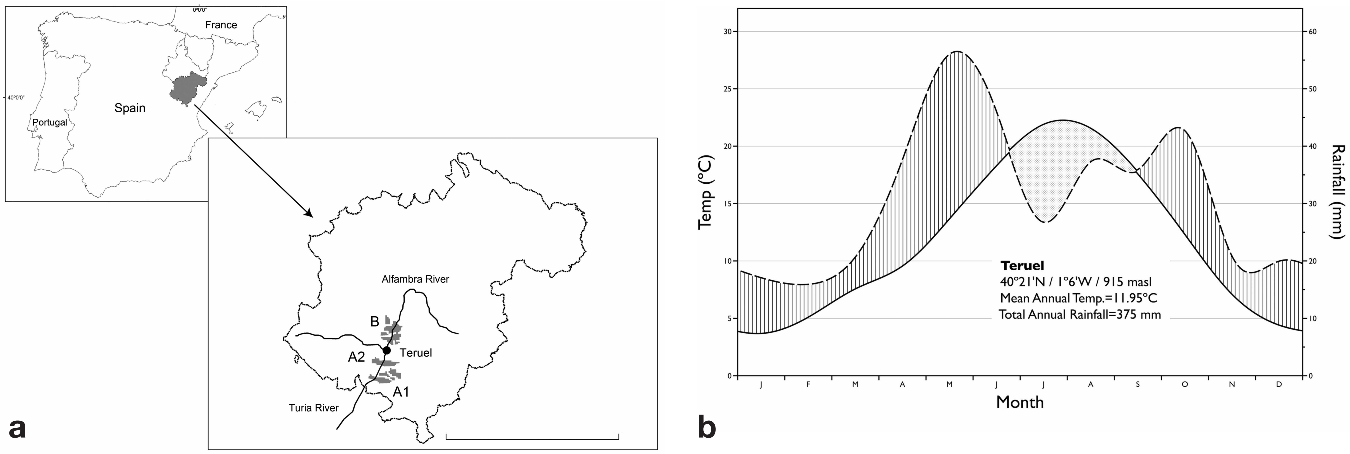

Fig. 1. a, location map of the Aragonese Region and the study area; codes indicate the sampling sites of *Vella pseudocytisus* subsp. *paui*: A1 (Villel), A2 (Villastar) and B (Villalba Baja). **b,** climate diagram of Teruel; temperature and rainfall values are averages for the period 1970-2009.

Height and two perpendicular diameters of the bush crown were measured *in situ* for later calculation of the biovolume.

Ring measurement, age estimation and dating

The analyses of ring variability and age estimation were conducted by measuring the ring width at several positions along the main trunk following the methodology proposed by Kolishchuk (1990). This type of procedure has frequently been used in studies of growth in shrubs (i.e., Perfors & al., 2003; Vila & al., 2004; Bär & al., 2006). From most of the 63 collected trunks, generally two slices were prepared: one close to the root collar and a second near the apex of the main branch. In some cases, up to six slices along the main branch were gathered. A total of 129 slices were sanded by mechanical and manual procedures to properly display the growth rings. In every slice, at least two rays were selected for measurement, avoiding common trunk anomalies or damages. Semi-automatic LINTAB equipment associated with the TSAP program (Rinn, 2005) linked to a PC was used for the measurement of the growth rings with an accuracy of 1/100 mm.

The growth ring series were analyzed to estimate the age of each specimen by overlapping and synchronizing the different sequences measured from each trunk with visual and graphical techniques, first with the radii of each slice and second with the slices of each trunk (Génova & Sánchez, 2011). After checking the synchrony between the sequences obtained and identifying and correcting anomalies such as discontinuous rings, we developed a mean sequence for estimating the age of each specimen with precision. The use of statistical procedures to crossdating the series was not possible due to their low overall length.

In many cases the absolute dating of the growth series was possible. In the case of subpopulation A2, the last ring was formed in 2007 for all samples because all individuals were uprooted the autumn of that year. Samples corresponding to population B could also be dated with visual and graphical crossdating techniques and field information from studies of permanent plots that had been conducted for more than 10 years (Domínguez & al., 2009) that allowed us to know the date of their death. However some individual growth series from subpopulation A1 could not be dated. Dated growth series for subpopulation A2 and population B allowed to developed local chronologies by standardizing the individual growth series with linear or exponential detrending models and following the classical methodology described by Cook & Kairiukstis (1990).

Age and size relationships

Simple linear regression method was used to explore the relationships between age and size. We performed several linear regressions of size by age each time. Thus, we progressively regressed the size variable to the age variable, removing outliers at each regression exercise. This method provides a way to effectively select data points that do not contribute to the model slope for each regression event. The identification of outliers was performed using standard residuals. Thus, we standardized the variance associated with the regression model by avoiding the effect of the high values of unstandardized residuals that did not contribute significantly to the regression line (Sokal & Rohlf, 1995). Large residuals were identified using percentiles (0.975 and 0.025). We used progressive regression until no more data points fell outside the selected percentiles.

Thus, we used this method to analyze which is the most powerful size variable to explain the variation in age: basal stem diameter and biovolume. The basal stem diameter was calculated by averaging the maximum and minimum diameters, whereas biovolume was approximated as the volume of an irregular cylinder. We then regressed the age by using these two size variables; linear fits were used for both variables, although the biovolume was log-transformed first. Finally, we used a Fisher's exact test to study the differences in proportions of outliers depending on populations (Pagano & Halvorsen, 1981).

Growth and climate relationships

To test the correlation between climate and growth, we selected meteorological data from the period 1970-2010 that overlapped with the tree ring chronologies of *Vella pseudocytisus* subsp. *paui*. We used data from the meteorological station at Teruel (AEMET, Spanish Agency of Meteorology).

This station was the closest one and was in between the two main areas studied at a similar altitude. Missing data for some months of the period 1984-1986 were estimated using the MET program from the DPL statistical package (Holmes, 1999). The mean annual rainfall was 375 ± 80.8 mm, with peaks in May-June and October. The years of minimum rainfall were 1978, 1983, 1992-95, 2001 and 2005, while the years of maximum rainfall were 1989 and 2002-03. The mean annual temperature was 12 ± 0.53 °C, with a warming trend in recent years (1994-2007). The De Martonne aridity index (De Martonne, 1926) was 16.64, which is classified as semiarid. Using the DendroClim 2002 program (Biondi & Waikul, 2004), both standard and bootstrap correlations with different climate variables were performed to identify the climatic signal.

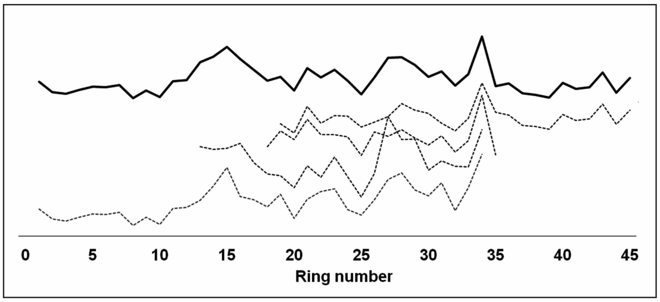

Fig. 3. Synchronized growth ring sequences from four slices located at different heights on the stem of specimen number 53. Dashed lines represent individual radial series whereas the average series is plotted as a solid line.

RESULTS

Growth ring characteristics, age and chronologies

We were able to identify growth rings in cross sections of the woody stem of *Vella pseudocytisus* (see Fig. 2). Its woody anatomy has not been formally described to date, although we recognized structural traits similar to those of *Vella spinosa* Boiss. as detailed by Schweingruber (1990) and recorded in the Xylem Data Base (http://www.wsl.ch/dendro/xylemdb/). In *Vella pseudocytisus* the xylem is formed by distinct rings diffuse-porous, with fibers and often uniseriate rays. The annual growth limit is marked by a layered band of cells at the end of the latewood. The usual secondary growth anomalies of shrubs (asymmetric, lobed and eccentric pith axes) were also observed in some samples, and some of the older ones presented damage caused by xylophagous insects and fungal infections. After discarding such anomalies, 258 growth series were measured, synchronized and averaged into 63 individual growth series (Fig. 3).

The estimated age revealed a minimum of 6 years in a specimen of subpopulation A1 (#3) and a maximum age of 47 years in a specimen of population B (#60); the average age was 21.7 ± 8.6 years (see Appendix). Longevity differences between populations were observed. In population A the average age was c. 20 years, fairly contemporary for the 35 individuals sampled in the plowed field (subpopulation A2) in which the average age was 19.2 ± 4.3 years, and the oldest individual was 32 years of age. In contrast, individuals from population B were older (32.6 ± 10 years on average). Growth is also significantly different among populations, being the mean ring of population A (0.70 mm) narrower than of population B (0.92 mm) (Mann-Whitney test, $p = 0.0114$). Two local chronologies were resolved, one from subpopulation A2 (1976-2007) and the other from population B (1955-2009).

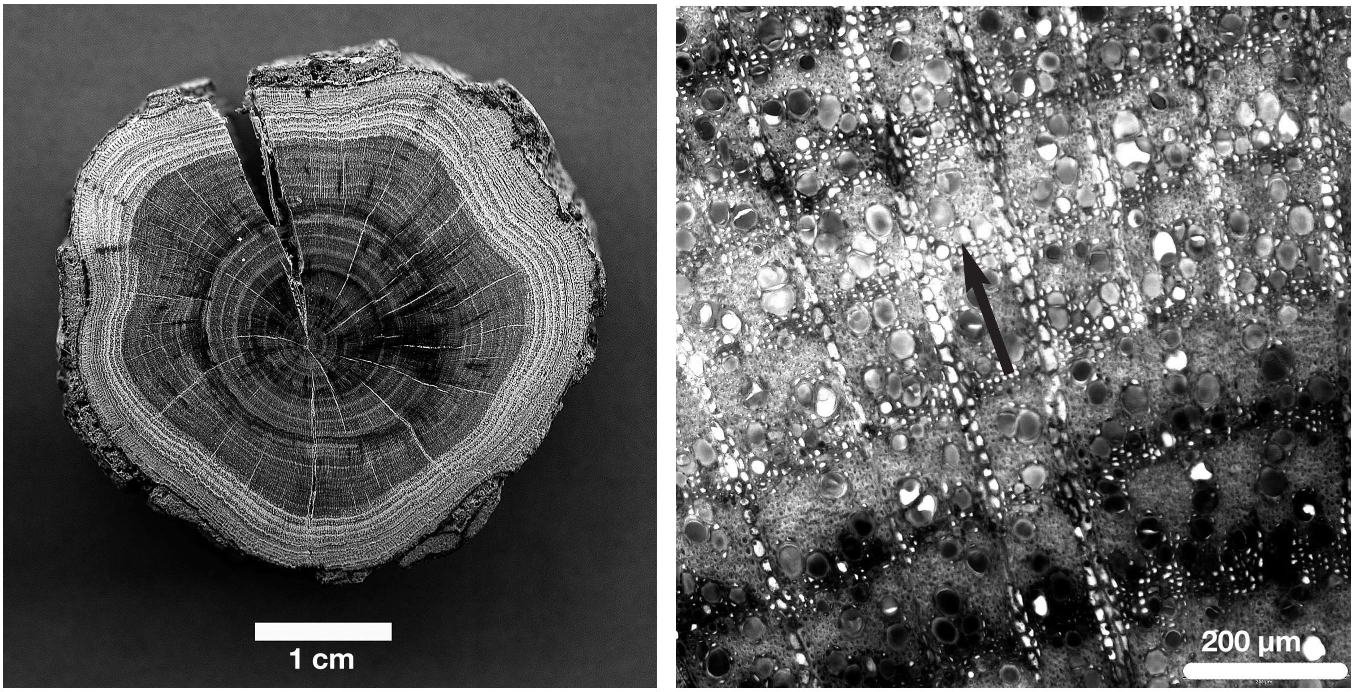

Fig. 2. Cross sections of *Vella pseudocytisus* subsp. *paui*. A complete tree ring is marked by an arrow from the earlywood to the latewood in the histological preparation at the right.

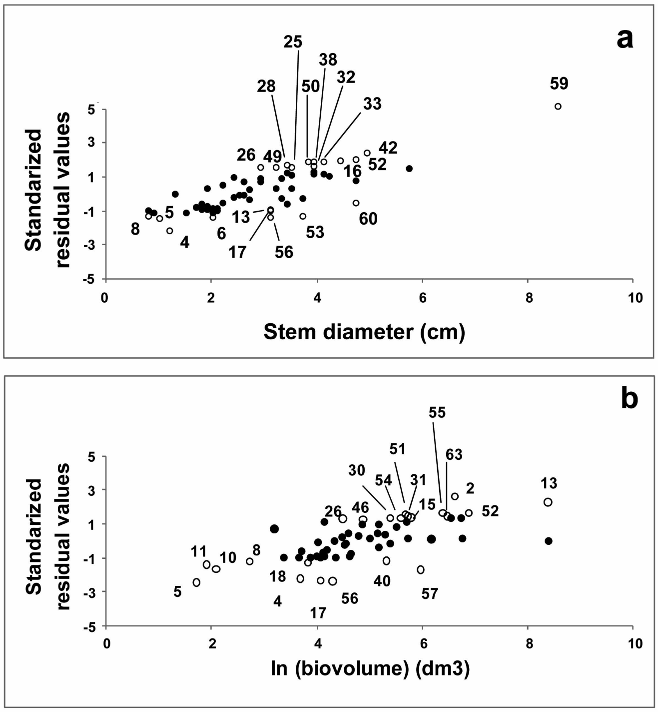

Fig. 4. Average standard residual plots of the two size-related variables used in the analysis: a) basal stem diameter and b) biovolume. Blank circles mark the individual outliers for each progressive regression. For chart clarity, only the outliers were labeled.

Age and size analysis

Figure 4 shows the standard residuals plots for the basal stem diameter and biovolume variables. Overall, there is a better fit using biovolume because the averaged R coefficient were larger for this variable compared with R values for stem diameter (t test, T stat. = -5.354; df = 12, two sided p = 0.0001; see Table 1). This means that it is preferable to use a log function of the biovolume rather than a linear function, especially true if some strong outliers are removed from the fit at first place.

Another noteworthy result was that residuals were related to biovolume; larger residuals tended to belong to oversized individuals and undersized individuals produced smaller residuals, so lack of fit is associated with the size of individuals (F = 44.6033, df = 57, p<0.0001).

Table. 1. Results of progressive regression coefficients showing average square R coefficient with standard deviation values for each size variable.

Variable	Number of progressive regressions	Average adjusted R^2	SD
Diameter	13	0.59	0.13
Biovolume	15	0.71	0.17

A Fisher's exact test did not reveal any difference between the amount of outlier individuals depending on populations (see Table 2). The three sub-populations produced similar amounts of outliers for both, biovolume and diameter, size variables.

The relationship between growth and climate

Our analyses found the best relationships between growth and climate by correlating the indices of the chronologies of populations A2 (abandoned field crop) and B (seminatural ravine) with rainfall, and lesser with other variables including temperature. Standard correlations between A2 and B indices with annual rainfall were determined for the year of growth (0.49 and 0.25, respectively) and even with the previous year of growth (0.38 and 0.16, respectively). Table 3 shows the correlations between the A2 chronology and monthly rainfall, which were much higher than those correlations with the B chronology.

In addition, the significant bootstrap correlation values among the climate variables and ring growth again highlighted the close relationship between rainfall and plant growth in subpopulation A2. The significance test (95% percentile range) showed that the monthly rainfall in April (0.42) and May (0.32) of the year of growth and in January (0.33), August (0.39), and December (0.34) of the previous year were all significant. A similar pattern with respect to the rainfall was found for the chronology of population B, even though the values were not significant.

Figure 5 shows the temporal variation of the annual rainfall and mean growth and chronology of the subpopulation A2. The parallelism between growth and rainfall oscillations deserves mention with an emphasis on the sharp decline in growth that occurred in the first half of the 1990s, which was consistent with consecutive years of dryness (minimum rainfall) occurred during this period (especially between 1992-1995).

DISCUSSION

Our work shows that *Vella pseudocytisus* generates annual rings that are suitable to assess ages on individulas, to infer radial growth trends, and to establish a relationship between growth pattern and climate. The observed rings, consisting on mainly dispersed and small vessels can be easily identified since the annual limit is marked by a layered band at the end of the latewood.

Considering that we have aged individuals of *Vella pseudocytisus* between 6 and 47 years we can assume that an age of 50 years is a possible estimate for its maximum longevity. However the prospect of older ages cannot be dismissed because an exhaustive sampling of specimens with high biovolume

Table. 2. The proportion of outliers and fitted individuals in each population for every size variable, stem diameter and biovolume.

	Individual type	Subpopulation A1	Subpopulation A2	Population B	Fisher exact test
Diameter	Outliers	7	11	5	p-value = 0.9104
	Fitted	10	24	6	
Biovolume	Outliers	11	14	5	p-value = 0.3082
	Fitted	5	21	2	

Table. 3. Correlation values between monthly and annual rainfall with the chronology of subpopulation A2; n is the year of growth, and n-1 is the previous year of growth.

Year	**Rainfall**												
	J	F	M	A	M	J	J	A	S	O	N	D	Annual
n	0.12	0.18	0.25	0.31	0.41	0.21	0.15	0.04	-0.06	0	-0.07	0.1	0.49
n-1	0.31	0.08	-0.2	0.25	-0.03	0.16	0.15	0.41	0.11	-0.27	0.1	0.32	0.38

has not been conducted so far. Such longevity is a very unusual trait in the mustard family, which is mainly composed of annual or short-lived herbs, and in which only a few genera have evolved to increase their life spans and sizes to become woody chamaephyte and nano-phanerophytes. This evolution has only taken place in the Mediterranean basin and in the Atlantic archipelagos of Macaronesia (Schweingruber, 2006).

From a population structure perspective, the age analysis allows us to propose hypotheses about some population dynamics and conservation. The subpopulation A2 was developed on an abandoned plot, which was illegally plowed in 2007, causing the death of all individuals. The maximum age in that population was slightly over 30 years; therefore, the cultivation of this plot was approximately abandoned in 1975 when the first specimens germinated, although most specimens sprouted in the 1990s. Stems corresponding to population B showed the widest measured rings, suggesting more favorable conditions for growth. Thus, although the characteristics of this habitat (a deep ravine carved in soft and highly erodible substrata) are seemingly harder for survival, less competition for resources and a virtual lack of grazing may have contributed to a higher local growth.

Studies of the relationship between ring growth and climate in bushes are scarce and mostly correspond to American or European mountain-dwelling species (e.g. Bär & al., 2006; Au & Tardif, 2007; Srur & Villalba, 2009; Forbes & al., 2010). To our knowledge, no previous work has identified the climate signal contained in the ring growth of shrubs with a distribution area circumscribed to the semiarid Mediterranean climate region. Although our study species is a shrub adapted to inhabit semiarid conditions, the correlation values indicated that growth is limited by water. There was a relationship between growth rings and rainfall in April and May of the current growing year (the period of higher cambial activity), and after this last month, the correlation was reduced, possibly because the main growth for the year had ceased. The same case applies, for example, in *Artemisia tridentata* subsp. *vaseyana* (Rydb.) Beetle*,* a species that covers large arid areas in western North America (Poore & al., 2009). Conversely, in *Vella pseudocytisus* there was a noteworthy correlation with precipitation in August and December months of the previous year, which gives value to the past summer rainfall for the formation and accumulation of nutrient reserves for the next year and the winter rain for the ground water recharge. Finally, it is worth highlighting that the driest period recorded at the weather station in Teruel (1992-1995) matches with the maximum growth-ring decrease in the subpopulation A2 (Fig. 5). This strong and specific relationship between growth and climate had also been previously observed in the chronologies of *Abies pinsapo* Boiss. in the south Iberian mountains for the same period of time (Génova, 2007).

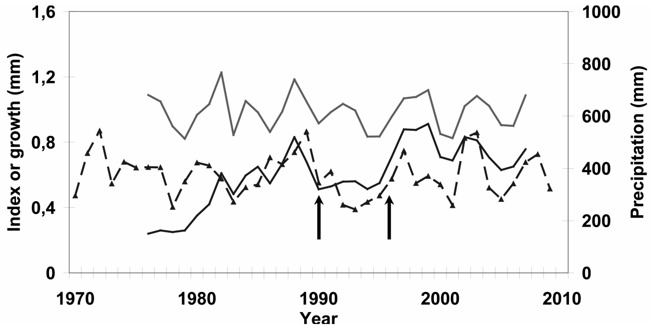

Fig. 5. The mean growth for each year in subpopulation A2 (dark gray solid line), A2 chronology (gray solid line), and annual rainfall (dashed line with markers) are overlapped. Arrows point to the period of maximum drought that corresponds with the longest decline of growth, which is especially marked in the mean growth.

There are no simple functions that directly fit the age-size relationship in a given species (Gilliland & al., 2006), and sometimes more complex models apply (Drezner, 2003). The long-lived shrub *Vella pseudocytisus* does not perform different, as neither stem diameter nor biovolume are good predictors of age, although the last could be considered as a preliminary surrogate, provided that some important outliers were identified. The study of residuals is useful to explain the lack of a simple link between age and size. Two factors may contribute to this: growth rates and population structure imbalances. We have identified that alterations in growth rates produce unbalanced sizes. More precisely, larger departures from fit, whether denoted by negative or positive residuals values, occur for individuals that grow faster or slower than expected. Although larger individuals are unequivocally old, smaller individuals are not always young, which is the case for individuals 4, 5, 17 and 56 (see lower group in Fig. 4b).

Why do some plants grow more slowly and become smaller than others? Growth suppression is a probable explanation for this pattern as it has been already reported in different environments including Mediterranean-type ecosystems (Keeley, 1993; Martín-Benito & al., 2008). In our case, some individuals may slow down their growth rates and behave as do young plants (small size, low productivity), ready to respond faster to newly favorable conditions as have been reported (Forbes & al., 2010; Boudreau & Villeneuve-Simard, 2012).

Implications for conservation strategies

Dendrochronology has proved to be a potential tool in studies of threatened shrubs to provide information about patterns of growth and survival factors of interest in both environmental and demographic aspects of species conservation plans.The high longevity recorded for *Vella pseudocytisus* subsp. *paui* by this dendrochronological analysis opens opportunities for management within the recovery plan approved for this plant in 2003. The demographic monitoring of the species for a decade has shown that adult survivorship is crucial in any projections of population dynamics (Domínguez Lozano & al., 2011a). Changes in vital rates of adult individuals produce large responses in general demographic dynamics; therefore, the long life span of the species ensures its ability to cover several windows of opportunity in what can be interpreted as a remnant population model (Eriksson, 1996). Low mortality and great longevity could provide more lead time for medium-term studies and for management purposes (Domínguez Lozano & al., 2011b). But in the other hand this resilience could be a double-edged sword because the effectiveness of these measures could probably be observed only after several years.

Different management guidelines can be proposed for both populations according to our dendrochronological study. Northern population B assembles the most long-lived samples and with a more vigorous annual growth. *Vella pseudocytisus* finds in such communities the chance to reach the adult reproductive condition for many years, in spite of presumably more stressing habitat (steep slopes, slightly deep soils of scanty quality). The maintenance of the status quo, keeping these fragile ravines virtually aside of any land use, could be a requirement in the conservation of demographically stable populations.

Current demographic structure of population A derive from past land uses in the area. Now, this population dynamic has its major expression in patches and borders devoted to cattle rising. Although based on limited samples, growth seems to be more constant but slower under this anthropogenic influence, something that may be related to previous results showing a negative demographic trend for this population type (Domínguez Lozano & al., 2011a). Both facts may support a scenario where those populations occupying certain open habitats may turn to a sink demographic dynamic.

Modeled scenarios of Global Change give us a new perspective for conservation of the species. While mean annual rainfall is predicted to decrease within the next decades, May and June precipitations would increase (Felicísimo, 2011; although see De Castro & al., 2005). The close relationship between growth and spring rains according to our results provides a slightly optimistic outlook for the *in situ* conservation of *Vella pseudocytisus* subsp. *paui* in the near future. Climate model scenarios suggest that concatenated years of drought (as experienced in 1992-1995) will be more frequent in the coming future as well (De Castro & al., 2005) but apparently the species has proved to overcome such periods in the past without severe mortality. The preservation of refuges where the species was able to cope with periodic unfavourable conditions will be a priority for its conservation in the mid-long term. Active management policies in open areas should be oriented to allow connectivity among suitable patches within a complex landscape (Murphy & Lovett-Doust, 2004).

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APPENDIX 1. Data from sampled individuals

Individual	Population (sampling site)	Height (cm)	Basal diameter (cm)	Biovolume (dm^3)	Ring Mean Width (mm)	Estimated Age (# rings)
1	A1	69	4.2	853.5	0.79	28
2	A1	85	2	751	0.949	10
3	A1	25	1.4	24.3	1.057	6
4	A1	35	1.3	39.7	0.515	30
5	A1	18	1.1	5.6	0.369	16
6	A1	43	2.2	150.8	0.362	21
7	A1	39	1.9	88.8	0.328	17
8	A1	23	0.9	15.2	0.275	11
9	A1	75	3.8	861.9	0.629	33
10	A1	24	1	8.1	0.689	9
11	A1	16	0.9	6.8	0.636	7
12	A1	27	1.8	41.6	0.754	15
13	A1	110	3.2	4354.2	0.850	32
14	A1	108.5	3.6	703.1	0.897	27
15	A1	62	2.7	327.7	0.602	20
16	A1	108.5	4.5	1677.5	0.963	22
17	A1	54.2	3.2	58.6	0.735	33
18	A2	36.8	2.2	46.3	0.502	20
19	A2	31	2.6	59.4	0.578	19
20	A2	33	3	67.5	0.75	18
21	A2	26	1.6	39	0.367	16
22	A2	35	2	61.8	0.53	18
23	A2	38	2.1	63.9	0.469	19
24	A2	31	3	55.6	0.749	18
25	A2	33	2.5	63.1	1.074	11
26	A2	34	3	89.5	1.072	12
27	A2	38.7	2.8	95	0.635	19
28	A2	25.1	3.6	49.1	0.851	18
29	A2	11	2.5	93.1	0.581	19
30	A2	42.5	3.5	219.3	0.868	17
31	A2	46.5	3.5	308.8	0.716	17
32	A2	34	4	105.9	0.695	22
33	A2	34.8	4.2	79.4	0.805	21
34	A2	38.8	3	101.3	0.738	17
35	A2	46.5	3.6	201.0	0.756	22
36	A2	46.5	3.3	177.3	0.622	24
37	A2	47.5	3.4	174.8	0.706	21
38	A2	46.5	4	178.3	0.777	19
39	A2	42.5	4	224.6	0.698	25
40	A2	49	3.5	203.8	0.426	32
41	A2	56.1	4	311.5	0.689	26
42	A2	69.7	5	301.6	0.872	22
43	A2	64	2.3	123	0.435	19
44	A2	46.5	2	78.1	0.597	17
45	A2	80	2.1	252.2	0.451	22
46	A2	77.5	2.3	130.8	1.059	12
47	A2	59	1.9	56.7	0.519	15
48	A2	54.2	2.8	104.2	0.518	23
49	A2	58	3.3	29.3	0.934	14
50	A2	62	3.9	132.1	1.007	17
51	A2	64	2.7	291.8	0.739	15
52	A2	93	4.8	977.5	0.968	26
53	B	115	3.8	4425	0.890	45
54	B	77.5	2.3	269.7	0.852	19
55	B	65	3.5	596.7	0.843	20
56	B	23.3	3.2	73.5	0.677	39
57	B	100	5.8	390.4	0.793	43
58	B	-	4.8	-	0.934	37
59	B	90	8.6	522.5	1.634	27
60	B	-	4.8	-	0.877	47
61	B	-	4.3	-	0.649	30
62	B	60	3.4	477.7	0.883	29
63	B	83	2.1	648.2	0.939	25

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