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Comparative analysis of recovery after experimental fire in three shrub ecosystems along a climatic gradient

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Keywords: shrublands, burning, community recovery, diversity, *Cistus ladanifer, Erica australis, Calluna vulgaris*

ABSTRACT: The aim of this study is to compare the recovery dynamic in three shrub ecosystems submitted to experimental fire and situated on an altitude gradient. Climatic features are different in each area, but all of them had the common characteristic of being very homogeneous before burning, with only one shrub species clearly dominant (different in each area). The first area was a heathland dominated by *Calluna vulgaris*, situated at an altitude of 1600 m, with a continental climate (mean annual precipitation 1320 mm). The second area was a heathland dominated by *Erica australis,* located at an altitude of 1000 m (mean annual precipitation 840 mm). The third area was a *Cistus ladanifer* shrubland, located at 900 m altitude, with a Mediterranean climate like the previous area, but with lower mean annual precipitation (470 mm). *Erica australis* recovers after fire by vegetative resprouting, but *Cistus ladanifer* is an obligate seeder as is *Calluna vulgaris* in these areas. The burning was carried out in summer simulating a wildfire on a surface of 100 m^2 in each area. Recovery is faster in *Cistus ladanifer*: two years after fire its cover value was 40% *versus* less than 20% in the other two species. There was high mortality in *Calluna vulgaris* in the 3rd and 4th year and then recovery was very slow, with only a mean cover of 20% ten years after fire *versus* 70% for *Cistus ladanifer* and 50% for *Erica australis*. The recovery of dominant shrub species determined the cover and richness of herbaceous species. This induced a different community dynamic in each area with the lowest diversity values in the *Cistus* community, except during the first years, the highest cover values of herbaceous species in the *Calluna* plot and the highest number of herbaceous species in the *Erica* plot.

1 INTRODUCTION

Shrub communities are very abundant in Spain, covering 33% of León province (Ministerio de Agricultura, 1984). Most of them are a result of human activity and usually very resilient to disturbances and recover by an autosuccession process (Luis et al., 2000). Fire is one of the common management methods used by shepherds to reduce the proliferation of woody species and maintain pasturage, both in the mountains (higher than 1500 m above sea level) and on the plains (800-1000 m). Most of the shrub species in these communities recover by vegetative resprout, but others, like Cistus species, are considered obligate seeders, with seeds whose germination is stimulated by heat (Valbuena et al., 1992; Trabaud, 2000)

The aim of this study is to compare the recovery dynamic in three shrub ecosystems submitted to experimental fire and situated on an altitude gradient (900 – 1600 m). Climatic features are dif-

ferent in each area, but all of them had the common characteristic of being very homogeneous before burning, with only one shrub species clearly dominant, although different in each area *(Calluna vulgaris, Erica australis* and *Cistus ladanifer)*. The post-fire response is also different in the three species: *Erica australis* recovers by vegetative resprouting (Calvo et al., 1998, 2002a); however, *Cistus ladanifer* is an obligate seeder (Luis et al., 2000, Tárrega et al., 2001) as is *Calluna vulgaris* in these areas (Calvo et al., 2002b).

2 MATERIALS AND METHODS

Three shrub areas situated in the province of León (NW Spain) were chosen for the study. All of them had a very homogeneous structure, the dominant shrub plants being more than 20 years old. They were secondary stages started as a consequence of old fields or pastures being given up. The dominant species was different in each area, as were the soil (Mapa de Suelos de Castilla y León, 1988) and climatic features (Ministerio de Agricultura 1980).

The first area is a *Calluna vulgaris* heathland situated in the San Isidro mountain pass, at an altitude of 1600 m; its UTM coordinates are 30TUN072695. The soils are rankers and the climate is typically continental (mean annual temperature 5.5°C, mean annual precipitation 1320 mm). The dominant species, *Calluna vulgaris*, had a mean cover higher than 80%, other woody species were *Erica tetralix, Erica australis* and *Vaccinium myrtillus* (mean cover less than 5%). Herbaceous species were not abundant (total cover less than 5%).

The second area is an *Erica australis* heathland situated at an altitude of about 1000 m, its UTM coordinates are 30TUN248336. The soils are humic cambisols and the climate is cool temperate Mediterranean (mean annual temperature 10.3°C, mean annual precipitation 840 mm). *Erica australis* had a mean cover higher than 75%, other woody species *(Calluna vulgaris, Halimium alyssoides, Halimium umbellatum* and *Thymus zygis)* had less than 1% cover. That of herbaceous species was also less than 1%.

The third area is a *Cistus ladanifer* shrubland situated at an altitude of about 900 m, its UTM coordinates are 29TQG3929. The soils are lithosols and the climate is cool temperate Mediterranean (mean annual temperature 10.5°C, mean annual precipitation 470 mm). The dominant species was *Cistus ladanifer* with mean cover higher than 70%. The other woody species that appeared, *Lavandula stoechas* and *Halimium umbellatum,* were less abundant (less than 5%). Herbaceous species were scarce with mean cover below 4%.

The experimental burning was carried out in summer (July 1985 in the *Erica* community, July 1986 in the *Calluna* community and July 1989 in the *Cistus* community) simulating a wildfire in a plot of 100 m^2 in each area. To record changes in the plant community 5 quadrats (1 m^2 each) were randomly chosen in the first sampling and sampled annually in June for 10 years (data from the first year after fire were not available for the *Erica* community). The cover in vertical projection of each species was estimated. The percentage cover values of the species in the 5 quadrats in each plot and sampling period, considered as a whole, (sampling unit 5 m^2), were taken into account for the following data analysis.

Temporal tendencies in woody, annual and perennial herbaceous species cover were analysed by testing the quality of the adjustment to the more usual growth curves.

Diversity was studied by comparing temporal changes in richness and dominance for each plot by means of graphs of dominance-diversity (Whittaker, 1965), including all the species found, arranged from higher to lower abundance, and represented by an importance value corresponding to the percentage of cover with respect to the total plant cover.

In order to establish whether there were general tendencies in the post fire recovery in the three shrublands, a principal components analysis was carried out considering 7 variables: woody, annual and perennial herbaceous species richness (species number), and woody, annual and perennial herbaceous species cover, as well as cover of the dominant species before the experimental fire.

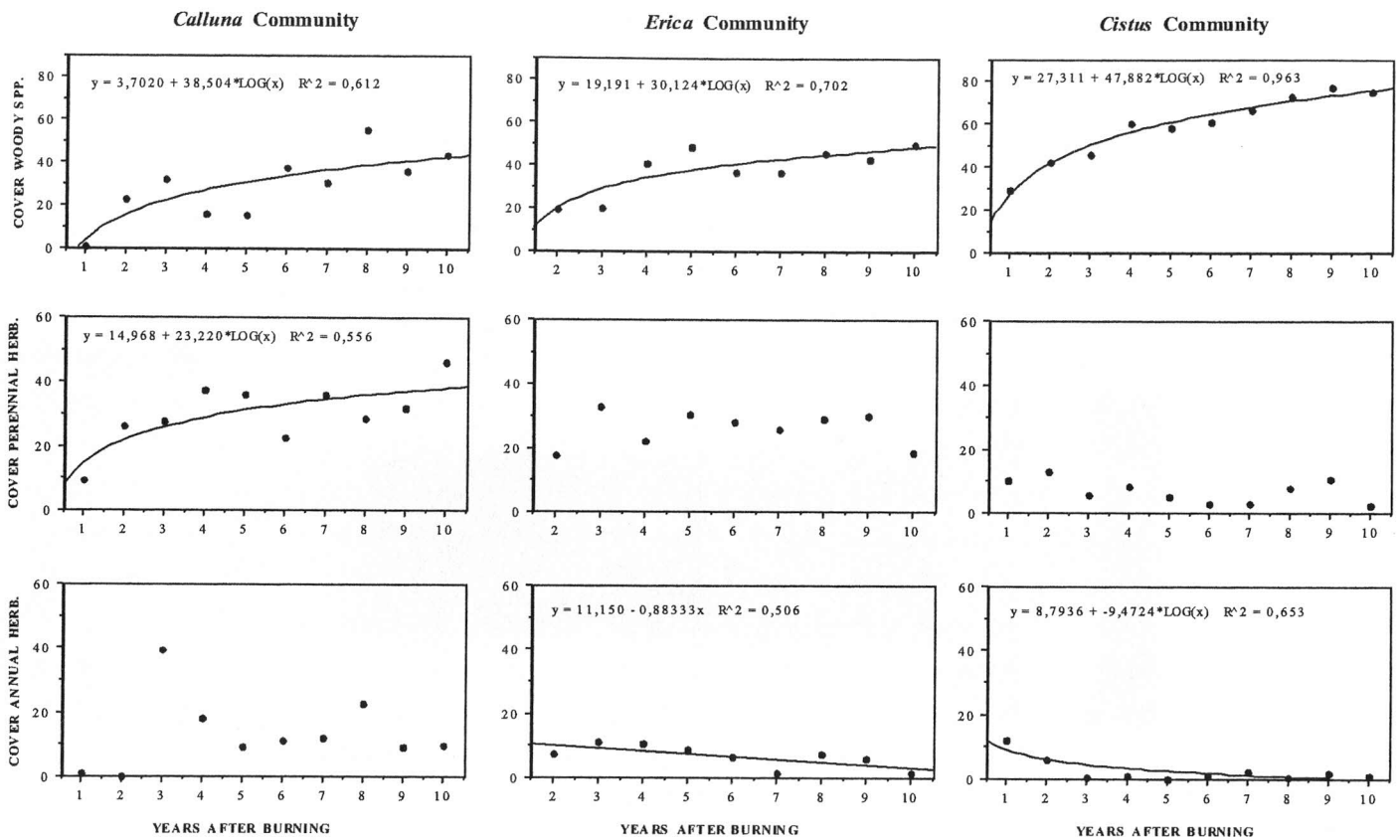

Figure 1. Cover values for woody, perennial herbaceous and annual species in the three communities during the study period. Curve fitting is only included when the fit is significant (> 95%).

3 RESULTS

A tendency for cover of woody species to increase in the three plots, with a significant adjustment ($p > 0.99$) to a logarithmic curve (Fig. 1) is observed. However, recovery is more rapid in the plot dominated by *Cistus*, with values close to 30% one year post-fire and above 40% from the second year. In contrast, in the *Calluna* plot woody cover is below 1% one year post-fire and from then on it is the plot with the greatest annual oscillations. The *Erica* plot has intermediate characteristics, with 20% cover in the second year and values of approximately 40% from the fourth year. The perennials herbaceous show no clear temporal tendency in the two plots with a Mediterranean climate, although their cover is lower in the *Cistus* plot. The perennials herbaceous in the *Calluna* plot are also abundant and tend to increase cover in time, with a significant adjustment ($p > 0.95$) to a logarithmic type curve; in addition, an interannual variation is observed which, in some cases, is opposed to that of the woody species. In this plot the annual species have no temporal tendency, with covers below 1% in the first two years and close to 40% in the third. However, their cover is always below 20% in the other two plots and, moreover, tends to diminish with a significant logarithmic adjustment ($p > 0.99$) in the *Cistus* plot, while the adjustment is linear in the *Erica* one ($p > 0.95$).

Total cover increases in time, although with oscillations. In the *Calluna vulgaris* plot this species contributes minimally to total cover with values always below 20% (Fig. 2). In contrast, the highest cover in the *Cistus ladanifer* plot corresponds to this species. There is an intermediate situation in the *Erica australis* plot.

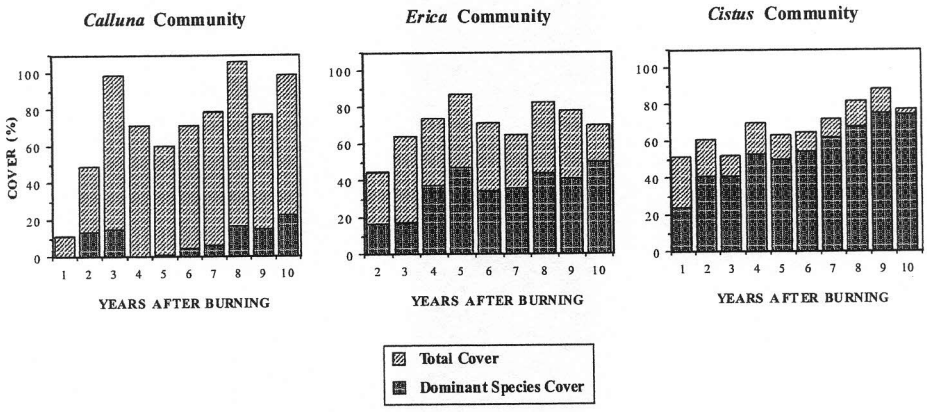

Figure 2. Changes of total plant cover and cover by the dominant species before experimental fire in each community, during the study period.

The diversity dominance graphs (Fig. 3) also show the worse recovery of *Calluna vulgaris*, which is the most abundant species in the second year, but is exceeded in the following years by herbaceous species (until year 5) or by another woody one *(Vaccinium myrtillus)* and only becomes the species with the greatest cover again in the tenth year, although the dominance effect is not clear. The greatest richness corresponds to the perennials herbaceous on comparing the number of species of the different life forms. In time a tendency for richness to increase is observed. This, together with the lack of dominance, indicates greater diversity. In the *Erica australis* plot, this species is the most abundant throughout the study period, with a clear dominance from the fourth year;

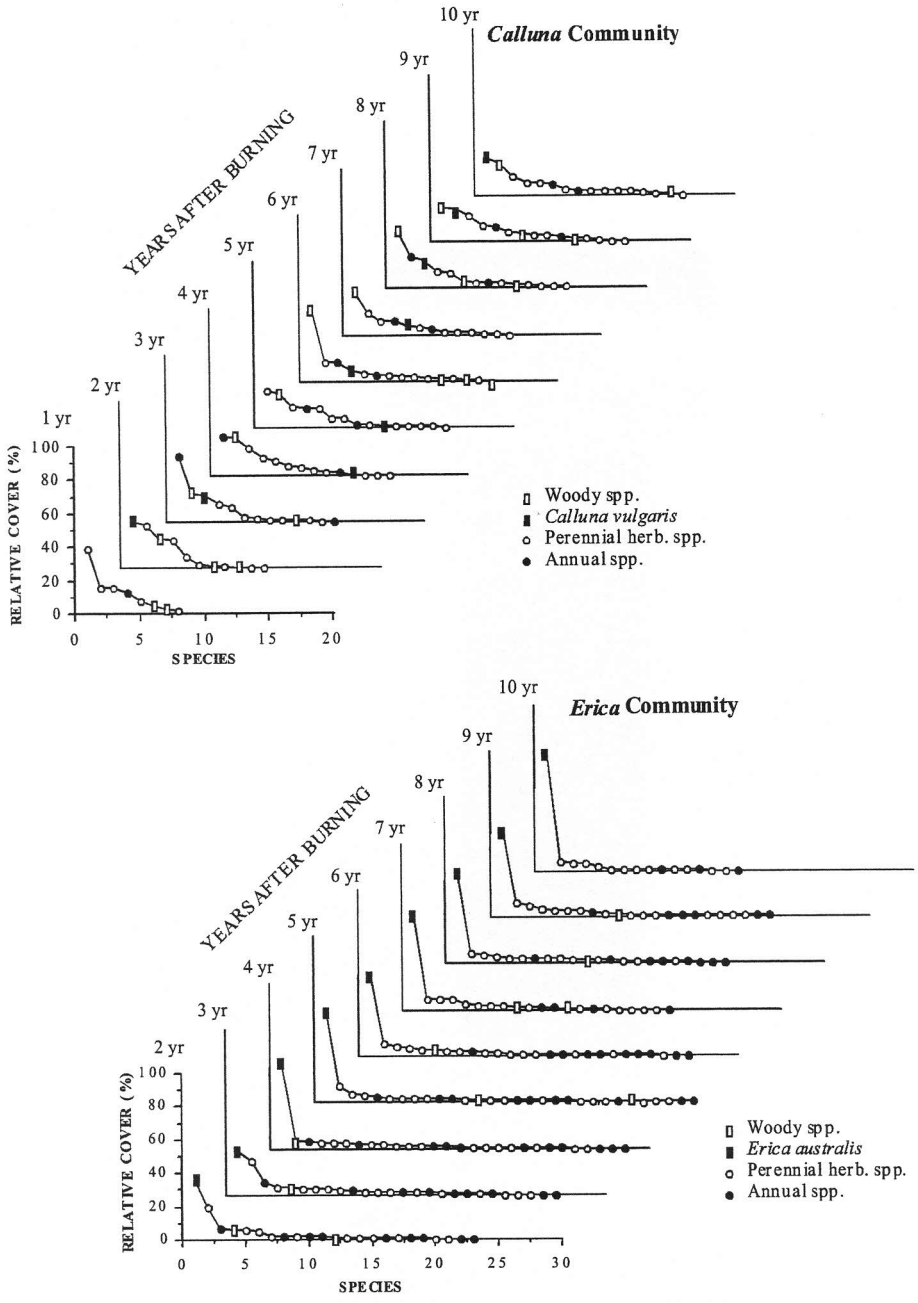

Figure 3. Dominance-diversity graphs (or rank-abundance graphs) for each community in each sampling year. (Woody, perennial herbaceous, annual species and before-fire dominant species are indicated by different symbol).

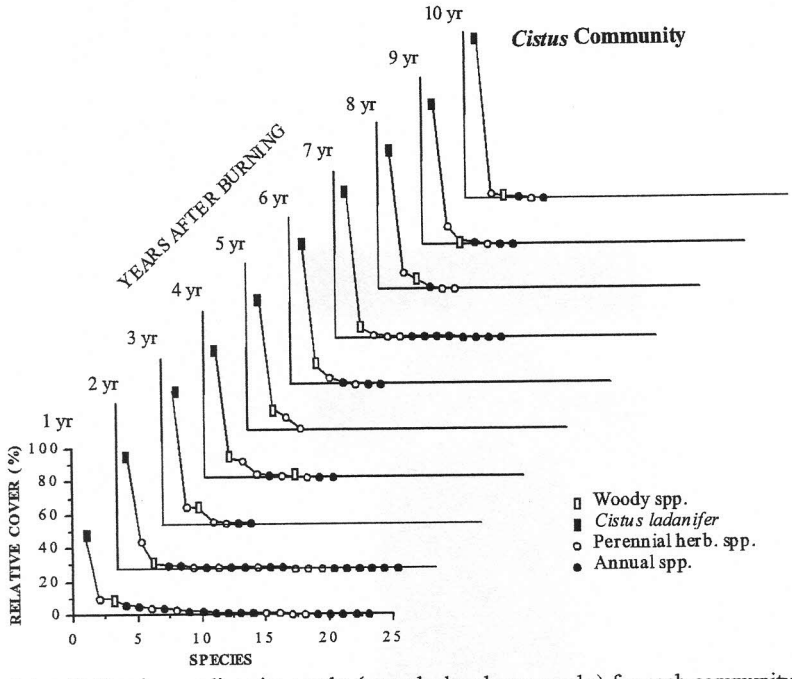

Figure 3 (cont.) Dominance-diversity graphs (or rank-abundance graphs) for each community in each sampling year. (Woody, perennial herbaceous, annual species and before-fire dominant species are indicated by different symbol).

however, there is great richness of annuals and perennials herbaceous, so diversity shows no clear tendency. In contrast, the greater richness of herbs, basically annuals but also perennials, in the *Cistus ladanifer* plot, appears in the first two years and then decreases considerably, although with some exceptions, as the great richness of annuals observed in the seventh year. *Cistus ladanifer* is dominant from the beginning and tends to increase the dominance effect in time. All of this produces a lower diversity.

To make a joint comparison of all the results an ACP was carried out. The first axis (explained variance = 46%) separates cover of herbaceous species, at the positive axe, and cover of woody species and of the dominant species before burning, at the negative axe (Fig. 4). The second axis (explained variance = 22%) separates richness of woody species at the positive part, and richness of annuals at the negative one. As regards the samples, a separation is observed between the samplings corresponding to each plot, with those of the *Calluna* plot being situated in the first quadrant, because of its greater richness in woody species and cover of annual species, as well as the lower cover of woody species and especially of the dominant species before the experimental fire. The samplings from the *Erica* plot and the first two from the *Cistus* plot are associated with greater richness in both annual and perennial herbaceous species. The rest of the samplings from the *Cistus* plot are towards the negative part of the first axis because of their greater cover of woody species and, specifically, of *Cistus ladanifer*. Except in the *Cistus* plot, where the first two samplings are widely separated from the rest and more similar to those of the *Erica* plot, no temporal tendency is shown in the others.

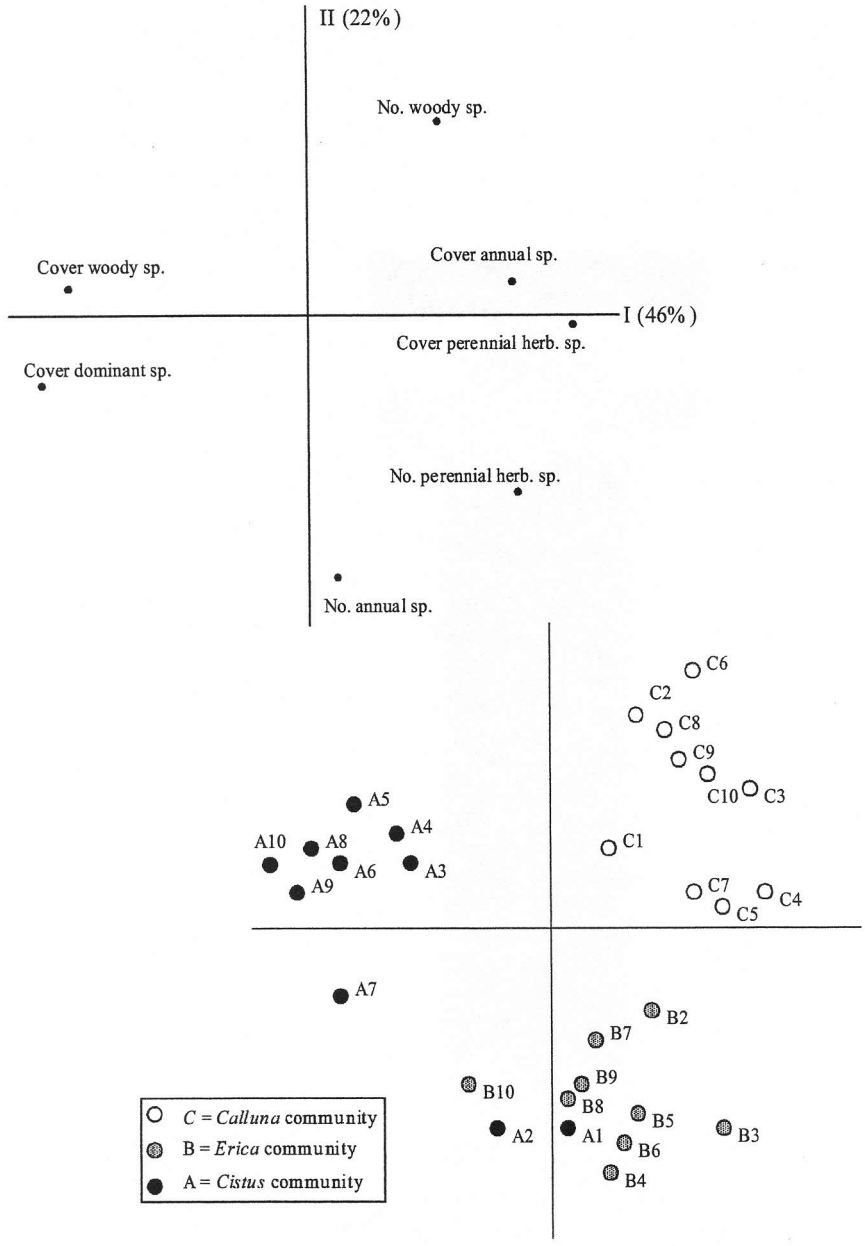

Figure 4. Location of variables and samples in the plane defined by the two first axes of the principal components analysis. (Numbers after the letters representing each community indicate years after experimental fire).

4 DISCUSSION

When the recovery of the species which was dominant before the experimental fire in each community is compared, clear differences are observed among the three plots. Many authors have stated the advantage of vegetative resprout in comparison with germination in post-fire recovery (Keeley, 1986; Trabaud, 1987; Terradas, 1996). However, it is not clear why regeneration of cover is faster in Cistus ladanifer, an obligate seeder, than in Erica australis, a resprouter, in the study zones. Heat stimulates the germination of Cistus ladanifer seeds (Valbuena et al., 1992; Trabaud, 2000), which explains its good recovery, but Erica australis also has a rapid resprout response and the fact that it only has to recover its aboveground biomass, since it starts from an intact root system, should to be an advantage over seeder species. However, seeders can spread and colonize new microsites whereas resprouters are restricted to the microsites previously occupied. On the other hand, Calluna vulgaris, which is an obligate seeder in these areas (Vera & Obeso, 1995; Calvo et al., 2002b), is the slowest to recover. A good initial response was observed in this species, because heat stimulates its germination (Gonzalez-Rabanal & Casal, 1995; Webb, 1998; Valbuena et al., 2000). However, there was seedling mortality in the fourth year probably due to the long period during which this species was under snow (Calvo et al., 2002b). It only becomes the most abundant species once again 10 years after burning, but with no great differences in comparison with Vaccinium myrtillus, which can regenerate vegetatively by resprout and was the dominant species between the 6th and 9th years.

The faster recovery of *Cistus ladanifer,* clearly dominant from the first year, restrains proliferation of other species and determines the progressive decrease of the annuals herbaceous, which are only relatively abundant in the first two years, although with values below 15%. The other two plots maintain much greater herb cover than that before burning throughout the study, and a tendency to increase perennial herbaceous cover in time is even observed in the *Calluna vulgaris* plot. Other authors have observed an increase in richness and abundance of herbs in the first few years after a fire (Trabaud & Lepart, 1980; Casal et al., 1990; Bond & van Wilgen, 1996; Cowling et al., 1996; Ne'eman & Goubitz, 2000), but it is usually restricted to the first five years.

5 CONCLUSION

Recovery response of the dominant woody species before the experimental fire is different in the three studied communities, depending on their adaptative traits. This seems to be the factor with the greatest influence on the dynamic of the plant community in each plot, determining species richness and diversity. The different climate characteristics may partially cause these differences. The recovery of *Calluna vulgaris* is slowed down by the low temperatures, and the summer drought in the *Cistus ladanifer* plot contributes to restraining the proliferation of herbs, which have to compete with the woody species for water.

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The recovery is faster in *Cistus ladanifer*, whose germination is stimulated by heat. Two years after fire its cover value was 40% *versus* less than 20% in the other two species. There was a high mortality in *Calluna vulgaris* in the 3rd and 4th year and then the recovery was very slow, with only a mean cover of 22% ten years after fire *versus* 70% for *Cistus ladanifer* and 50% for *Erica australis*. The recovery of dominant shrub species determines the cover of herbaceous species, that spread out while it is no abundant but they are removed by competition afterwards. This induced a different community dynamic in each area with the lowest diversity values in the *Cistus* community, except during the first two years, the highest cover values of herbaceous species in the *Calluna* plot and the highest number of herbaceous species (richness) in the *Erica* plot. The different climate characteristics may partially cause these differences. The recovery of *Calluna vulgaris* is slowed down by the low temperatures, and the summer drought in the *Cistus ladanifer* plot contributes to restraining the proliferation of herbs, which have to compete with the woody species for water.