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Postfire Regeneration in *Pinus pinea* L. and *Pinus pinaster* Aiton in Andalucia (Spain)

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ABSTRACT / The objective of this study was to examine postfire regeneration of tree, shrub, and dwarf shrub species, in relation to levels of damage in four planted pine forests (*Pinus pinea, Pinus pinaster*) in Andalusia. A prefire vegetation map was used for detailing species composition, vertical structure, and density and another for detailing the extent and intensity of fire damage. Between 3 and 7 years after the fires, an inventory was made of the vegetation in each area, using the step-point method. The information thus obtained was used to determine the amount of cover in the dwarf/shrub and tree layers, the frequency of species in each of the layers, floristic richness, and diversity (Shannon index). The botanical composition of the dwarf and shrub layer was analyzed using TWINSPAN. Variables were poorly correlated with level of fire damage, which suggests that the forests in this study followed the autosuccession model. Because of the artificial origin or seminatural condition, regeneration of the dominant tree species is poor, and it seems unlikely that forests will recover to their prefire state. Therefore action is recommended to restore these ecosystems.

Forest fires represent one of the most serious disturbances in the Mediterranean area. Several factors have contributed to this: dry summers, with rainfall deficits and high temperatures, and the accumulation of a great deal of combustible material, owing to the underexploitation of forests, rural depopulation, and increasing recreational pressure. Fire occurrence in the Mediterranean countries of the European Union has increased markedly during the last three to four decades because of a change in the type of areas burned and land use (Delattre 1993, Moreno and others 1998).

Fire has a direct adverse effect on surviving vegetation, but this is generally short lived if fire does not recur. The indirect effects, on the other hand, caused by alterations in the soil (Giovannini and others 1990, Kutiel and others 1990) and water cycle may be much more persistent and may affect soil fertility.

The effects of fire in the Mediterranean region are very diverse, not only because of the very complex plant communities and the influence of grazing and forestry management, but also because of differing responses to the type and intensity of the fire, season, and frequency (Agee 1998, Ne'eman 2000), quantity and quality of combustible material, period of growth, and age of the vegetation (Trabaud 1990); environmental factors (Mazzoleni and Pizzolongo 1990); and different adaptation characteristics, which enable species to resist, avoid, or recover from fire (Mazzoleni and Pizzolongo 1990, Naveh 1990).

Generally, due to the presence of fire as an environmental factor, Mediterranean ecosystems are very well adapted and possess a variety of strategies that enable them to recover after fire (Naveh 1990, Mazzoleni and Pizzolongo 1990). Nevertheless, when there is an increase in the severity and frequency of fire, this leads to a cycle of environmental degradation. The soil becomes impoverished through depletion and washing out of nutrients, loss of plant cover, and consequent erosion (Giovannini and others 2001).

In Andalucia, an average of 28,700 ha are affected by fire every year (I.A.R.A. 1989). The Forestry Services, which are responsible for forest management and restoration, have for some time been proposing measures to preserve and restore burnt areas (Navarro and others 2000, Ne'emani and Perevolotsky 2000). Unfortunately, the level of understanding of the mechanisms of succession is poor, so these measures are not always properly implemented.

It is generally agreed (Trabaud 1994, 2000) that the postfire development of Mediterranean plant communities follows the pattern described by Egler (1954) for initial floristic composition or that of inhibition (Connell and Slatyer 1977). There is no floristic relief, nor

KEY WORDS: *Pinus pinea; Pinus pinaster;* Postfire regeneration; Layer cover; Botanical composition; Floristic richness; Diversity

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*Author to whom correspondence should be addressed; *email:* ir2qapey@uco.es are there different and separate communities in the same site, as is characteristic of a secondary succession. Instead, there is a process of autosuccesion, enabling plant communities that existed before the fire to regenerate. Fire, however, not only influences this regeneration, but also produces changes in the diversity, number, and structure of species.

There are numerous studies of postfire behavior of forests of *Pinus halapensis* Mill. (Trabaud and others 1985a, b; Tsitsoni 1997, Trabaud 1998, 2000, Martinez-Sanchez and Herranz 1999, Eshel 2000), and of non-Mediterranean pines (Elliot and others 1999, Everett and others 2000, Agee 1998). To date, however, there have been few studies of the postfire regeneration and development of forests of *Pinus pinea* L. and *Pinus pinaster* Aiton (Castro and others 1990), which cover large areas in the Mediterranean environment.

The objective of this research is to analyze postfire regeneration of tree, shrub, and dwarf species, according to different levels of damage, in four areas of pine forests in Andalucia, Spain: closed and open forests of *Pinus pinea* and *Pinus pinaster,* respectively.

Materials and Methods

Area Studied

The effects of forest fires were studied in four planted or seminatural pine forests (*Pinus pinea* and *Pinus pinaster*) in Andalucia, Spain: El Madroñalejo (Sevilla), Sierra Bermeja (Málaga), Dehesa de Beas (Granada), and Hoyo de Don Pedro (Cadiz) (Figure 1). Before fieldwork started, two types of maps were consulted: maps of prefire vegetation, detailing species composition, vertical structure, and density (Table 1), using the interpretation and verification of aerial photographs in the field, and maps of fire damage, using the image classification from LANDSAT (Navarro and others 1996). The levels of fire damage were defined as follows: Extreme—the majority of trees (>50%) were completely destroyed, with fire reaching the crowns; trunks were frequently found dead or blown down by the wind, the whole shrub layer was damaged). Moderate—only some parts of the trees, the trunk, crown, and branches, were damaged (25%–50%), all were still standing and the majority were alive, the vegetation was not entirely destroyed. None—the forests were either in the same state after the fire as before, or damage was insignificant (<5%).

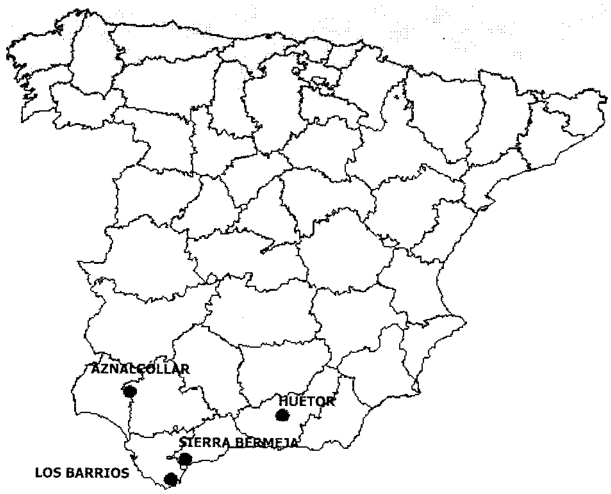

Figure 1. Location and date of fires: El Madroñalejo (1995, Sevilla), Sierra Bermeja (1995, Málaga), Dehesa de Beas (1991, Granada) and Hoyo de Don Pedro (1995, Cadiz).

Field Inventory

We have used a synchronous approach, on which different plots are compared at the same time, assuming that the study plots are in the same ecological condition and chronological stage. Studies performed by this method are common on postfire research on Mediterranean forests (Trabaud 2000). The method requires, for statistical analysis of the data, at least two transects per site. The most important factor in obtaining usable data is selecting representative areas in which to run the study. Study sites have been located within a two uniform communities (Table 1). Several transects were used for the same type of vegetation and level of damage (Table 1). Transects and sampling points have been randomly located with regard to the critical or key areas.

In spring 2000, an inventory of vegetation in each area was made. Regular observations were carried out along a lineal transect using the step-point method (USDA 1996), each consisting of 50 points 2 m apart.

Variables Obtained

The variables were:

(1) Dwarf/shrub layer cover (%)—expressed as a function of shrub and dwarf species present. This was calculated as the number of observations of dwarf or shrubs × 100 and divided by 50.
(2) Tree cover (%)—calculated in similar way as the number of observations of trees × 100 and divided by 50.
(3) Species frequency in the tree and dwarf/shrub

Table 1. Dominant types of ecosystems[a]

Type of vegetation	Aznalcóllar	Estepona	Huétor	Los Barrios
Closed pine forest (*Pinus pinea* L.)	● ($N = 5$)			
Open pine forest (*Pinus pinea* L.)	● ($N = 5$)			
Closed pine forest (*Pinus pinaster* Aiton)		● ($N = 6$)	● ($N = 6$)	● ($N = 6$)
Open pine forest (*Pinus pinaster* Aiton)		● ($N = 4$)	● ($N = 4$)	

[a] Based on Navarro and others (1996) studied in each burnt area.

N = number of transects.

Table 2. Richness and diversity as a function of type of forest, using Shannon Index, location, and level of damage[a]

	Aznalcóllar					
	Closed pine forest (*Pinus pinea* L.)			Open pine forest (*Pinus pinea* L.)		
	None	Moderate	Extreme	None	Moderate	Extreme
Richness	8	10	9	10	9	9
Diversity	0.8	0.8	0.7	0.9	0.8	0.7

	Level of Damage								
	None			Moderate			Extreme		
	Estepona	Huétor	Los Barrios	Estepona	Huétor	Los Barrios	Estepona	Huetor	Los Barrios
Closed pine forest (*Pinus pinaster* Aiton)									
Richness	7	8	16	6	8	13	14	13	13
Diversity	0.4	0.6	1.1	0.7	0.7	1.1	0.8	0.7	0.9
Open pine forest (*Pinus pinaster* Aiton)									
Richness	12	13		12	9		15	14	
Diversity	0.9	0.8		0.8	0.8		0.8	0.7	

[a] Mean and standard deviation are shown.

layer (%)—all species present were taken into account when calculating this variable, including those under the tree canopy (bare soil was not included), i.e., [observations (N) of a particular species × 100]/ total observations (N) of species in the layer].

(4) Richness—this is a measure of the heterogeneity of the vegetation and provides information on the floristic composition of the plant community. Richness is defined as the total number of different species present.

(5) Diversity—calculated using the Shannon-Wiener index, which relates the total number of different species in the transect to the proportions of each species.

Statistical Analysis

Analysis of variance (ANOVA), with a level of significance of 0.05, was used to compare the different variables. The factors used were level of damage, location, and botanical composition. Where significant differences were found, the Tukey test was used, with the same level of significance. The botanical composition of the dwarf/shrub layer in each transect was analyzed by using the numerical classification technique TWINSPAN (two-way indicator species analysis) (Hill 1979) developed specifically for hierarchical classification of community data. The computer program used for TWINSPAN was PC-ORD (Version 3.04, MjM Software).

Results

Closed Forest of *Pinus pinea* L.

There were significant differences in diversity, with greater diversity in areas of moderate damage and without damage (Table 1). In areas where there was no damage, diversity was similar to those where damage was moderate.

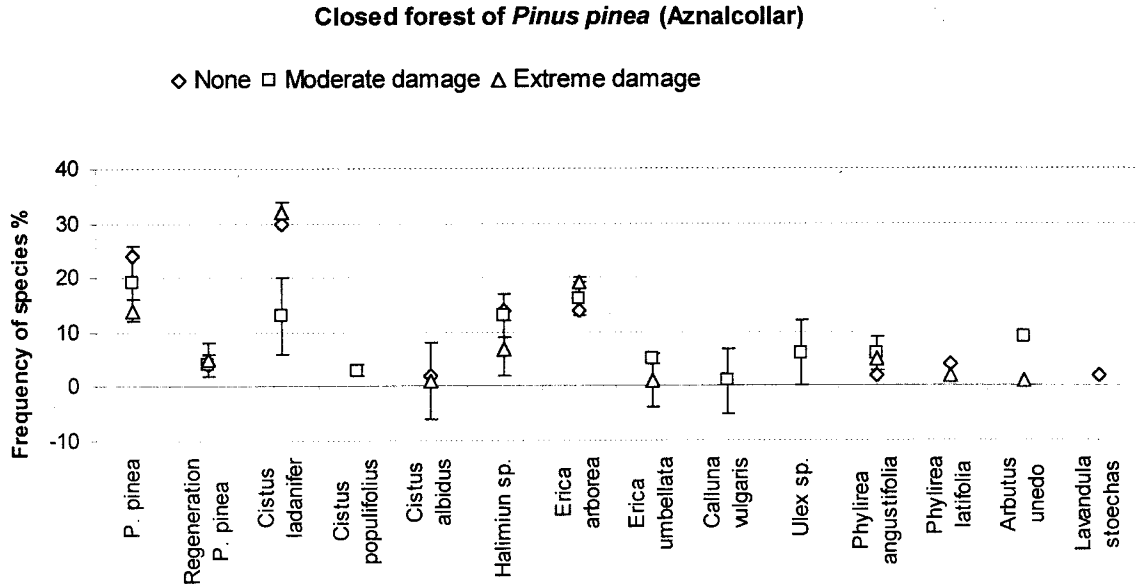

Figure 2. Frequency of species (%) in closed forests of *Pinus pinea* L. in Aznalcollar (Sevilla), with different levels of damage. Mean and standard error are shown.

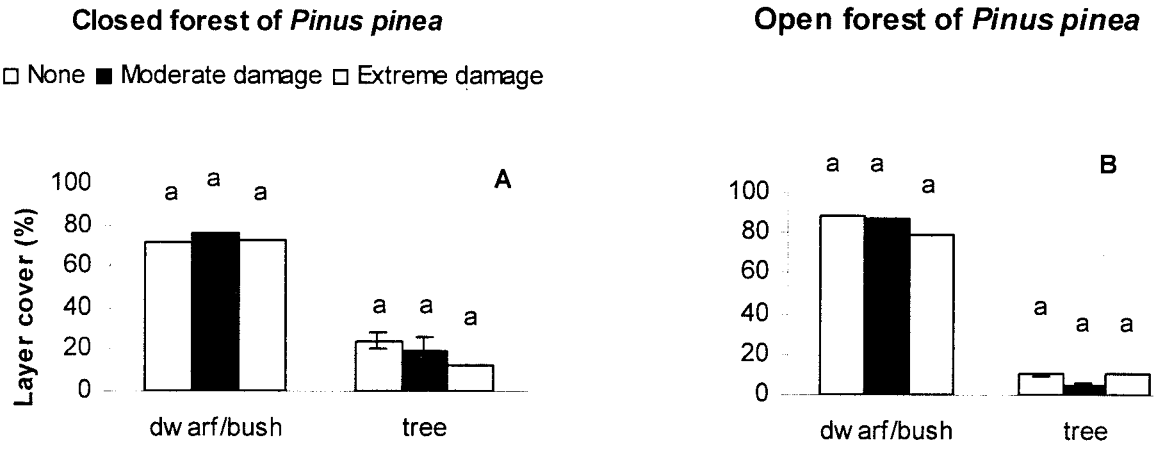

Figure 3. Layer cover in closed and open forests of *Pinus pinea* L. (Azalcollar) with level of fire damage. Mean and standard error are shown. Means with the same letter do not differ significantly, using the Tukey test ($P < 0.05$).

Some other results are worth commenting on, although they were not significant. If areas where there was no damage are compared with their prefire state, it is clear that there was a slight increase in floristic richness after the fire (Table 2). The dominant tree species declined with the increase in the degree of damage, while regeneration was unaffected by fire (Figure 2).

The most abundant understory species in undamaged areas, *Cistus ladanifer* L., *Halimium* sp., and *Erica arborea* L., were also the most abundant in those affected by fire. *Arbutus unedo* was abundant in areas of moderate damage, but declined significantly where damage was extreme and was absent in areas without damage (Figure 2).

The structure of the forest was affected, the drastic reduction on stand density and dwarf/shrub cover have been justified for fire damage (Figure 3A).

Open Forest of *Pinus pinea* L.

Although no significant differences were found in damaged versus undamaged areas, some of the results obtained are relevant. In contrast to the closed forest of Pinus pinea, richness declined in damaged, compared

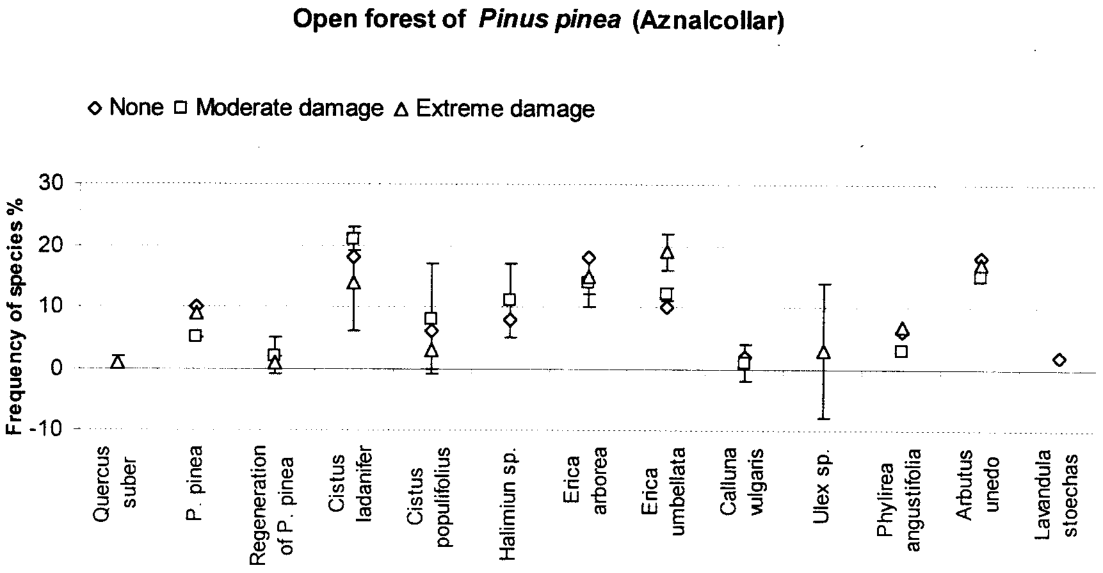

Figure 4. Frequency of species (%) in open forests of *Pinus pinea* L. in Aznalcollar (Sevilla), with different levels of damage. Mean and standard error are shown.

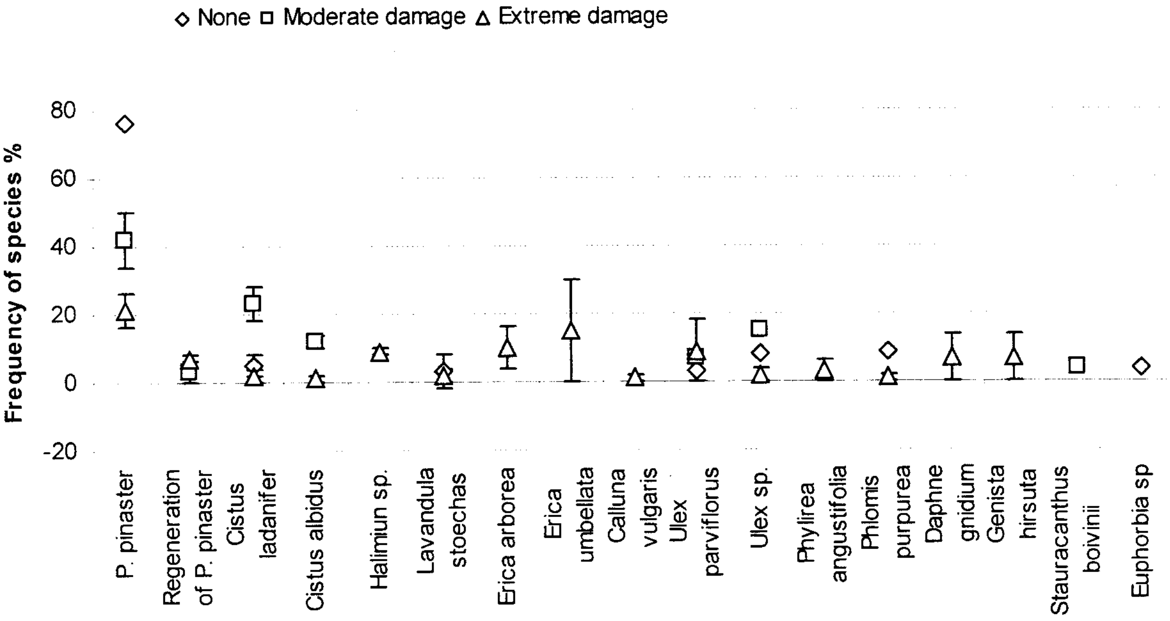

Figure 5. Frequency of species (%) in closed forests of *Pinus pinaster* Aiton in Estepona (Málaga) with different levels of damage. Mean and standard error are shown.

with undamaged, areas. Diversity declined as the level of damage increased (Table 2).

Understory species present in undamaged areas, with the exception of *Lavandula stoechas* L., were also present in damaged areas, with the most abundant species being *Cistus ladanifer* L., *Erica umbellate* L., *Erica arborea* L., and *Arbutus unedo*. Species most affected were *Lavandula stoechas* L., which was present only in undamaged areas, and *Halimium* sp., which was absent in areas where damage was extreme (Figure 4).

No regeneration was detected in undamaged areas, while it was present in damaged areas (Figure 4). By

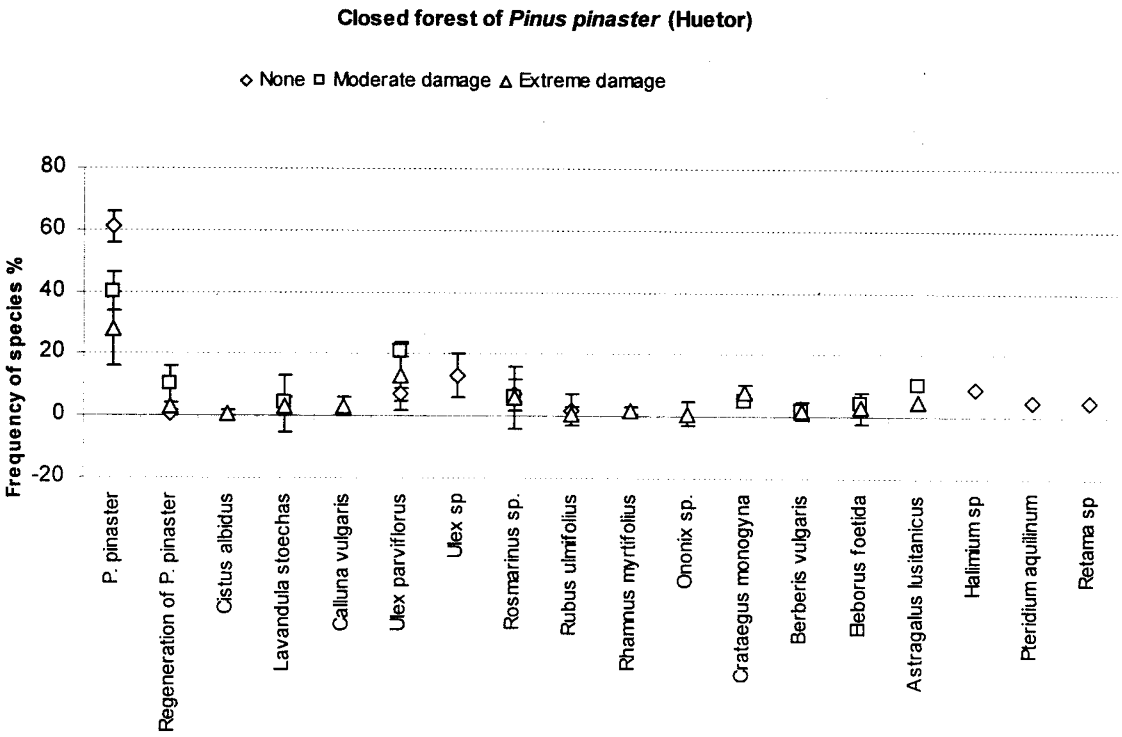

Figure 6. Frequency of species (%) in closed forests of *Pinus pinaster* Aiton in Huetor (Granada), with different levels of damage. Mean and standard error are shown.

contrast, there were no significant differences in structural variations in terms of the levels of damage (Figure 3B).

Closed Forest of *Pinus pinaster* Aiton

Although no significant differences according to the levels of damage were recorded in Huetor and Estepona (5 and 7 years after fire), floristic richness increased only in areas of extreme damage, whereas in Los Barrios (3 years after fire) it declined slightly in undamaged areas. Diversity increased slightly as the level of damage increased, in Huetor and Estepona while the reverse happened in Los Barrios (Table 2).

In all three localities there was a noticeable reduction in the frequency of *Pinus pinaster,* as the level of fire damage increased, although this was significantly only in Estepona and Los Barrios. In all three locations, however, regeneration seems to have been slightly enhanced in damaged areas, compared with those where there was no damage, although the differences were not significant (Figures 5–7).

Of the understory species in the three locations, the postfire recovery of *Ulex parviflorus* Pourret; the Cistaceae, *Cistus ladanifer, Cistus albidus* L., *Cistus populifolius* L., *Cistus salvifolius* L.; and the Ericaceae *Erica arborea* and *E. umbellata,* was good in Los Barrios and Estepona.

In general, there was an appreciable reduction in tree cover as the level of fire damage increased, while the reverse was true for the dwarf/shrub layer, although the difference was not always significant (Figure 8A–C).

Open Forest of *Pinus pinaster* Aiton

In the analysis of variance, no significant differences according to the level of damage, were found for any of the locations, in any of the variables. In the two locations, richness and diversity followed similar patterns: floristic richness was somewhat greater in areas of extreme damage than in areas of either moderate or no damage, while the reverse was true for diversity (Table 2).

Postfire regeneration of *Pinus pinaster* was better in undamaged areas, except in Huetor, where regeneration was detected only in moderately damaged areas (Figures 9 and 10). In neither location were there significant differences in tree and dwarf/shrub cover, in terms of level of damage (Figure 8D).

Of the dwarf/shrub species, legumes of the *Ulex* genus responded well after fire in both locations. There were, however, differences. In Estepona, the Cistaceae,

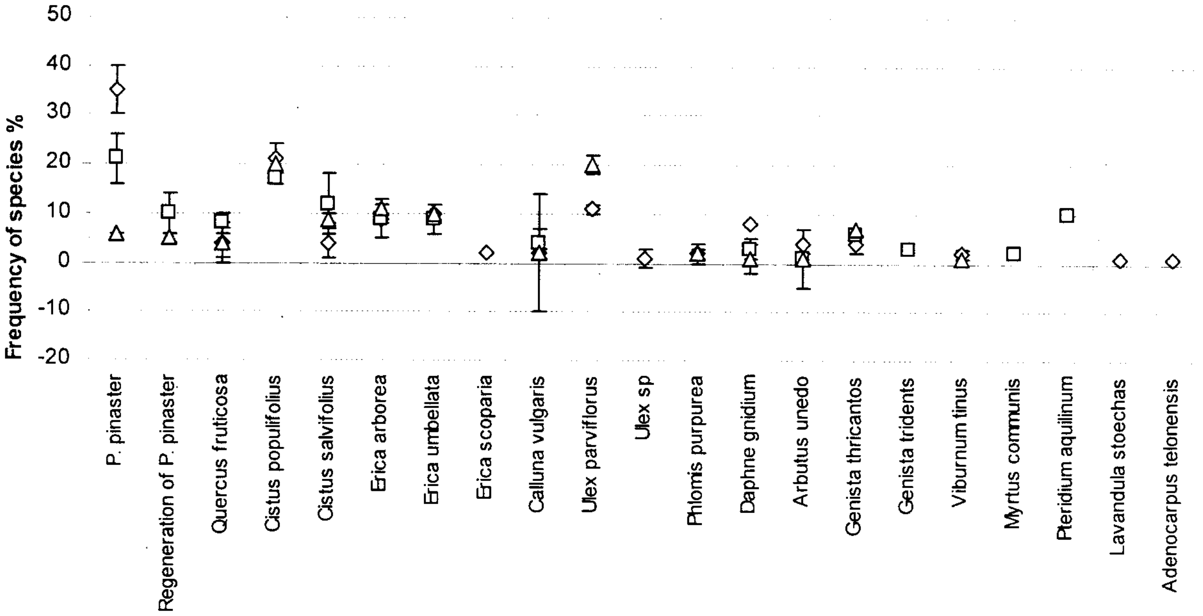

Figure 7. Frequency of species (%) in closed forests of *Pinus pinaster* Aiton in Los Barrios (Cadiz), with different levels of damage. Mean and standard error are shown.

Ericaceae, and leguminous species of the *Ulex* genus were most frequent before and after fire, while in Huetor, *Rosmarinus* sp. and *Ulex parviflorus* showed a better postfire response.

TWINSPAN Analysis

TWINSPAN analysis divided the transects into 14 groups, according to the frequency of dwarf/shrub species present in each one (Table 3). In the first division, two groups were formed, the first consisting of transects made in Aznalcollar, Los Barrios, and Estepona, and the second of Huetor, which also included a transect belonging to Estepona.

In the second division, the first group consisted of transects made in Los Barrios, which also included a transect for Aznalcollar. The second group was made up of transects of the fires in Aznalcollar and Estepona. The dominant transects in the third group in this division belonged to open *Pinus pinaster,* forests while those in the fourth group were predominantly closed *Pinus pinaster* forests.

In the third division, the locations were well differentiated in the four first groups, and those with similar vegetation began to be detected. One of these four was definitive and was defined as group 1. At the same level, the other four groups formed were also definitive and were named groups 11,12,13, and 14. The preferential species in each group are shown in Table 3.

In the fourth division, for Los Barrios, transects for areas of moderate damage were separated from those made in undamaged or extremely damaged areas. These formed groups 2 and 3 (Tables 3 and 4). At the same level, for Aznalcollar, a distinction was made between one of the transects, which formed group 6, and the rest. These formed the fifth division, with two groups, 4 and 5 (Tables 3 and 4). For Estepona, a fourth division was made, which was divided again into a fifth level, forming four groups, defined as groups 7–9 and 10 (Tables 3 and 4).

Discussion

Although some differences in richness and diversity were detected in relation to level of damage, these were not significant. Other authors have observed that pine forests return to metastable state several years following fire similar to those that existed before the fire (Trabaud 1985a, 2000, Agee 1998).

From the point of view of structure, in dense forests there was generally an increase in cover in the dwarf/shrub layer, where fire damage was greatest, while tree cover declined. Where competition between individual trees is reduced, growing conditions for understory species are enhanced. The trend to the dwarf-dominated layer after the fire in Mediterranean pine forests is well documented (Naveh 1975, Barbero and others 1990, Aranoutsou and Ne'eman 2000). It is generally the result of the thinning out of

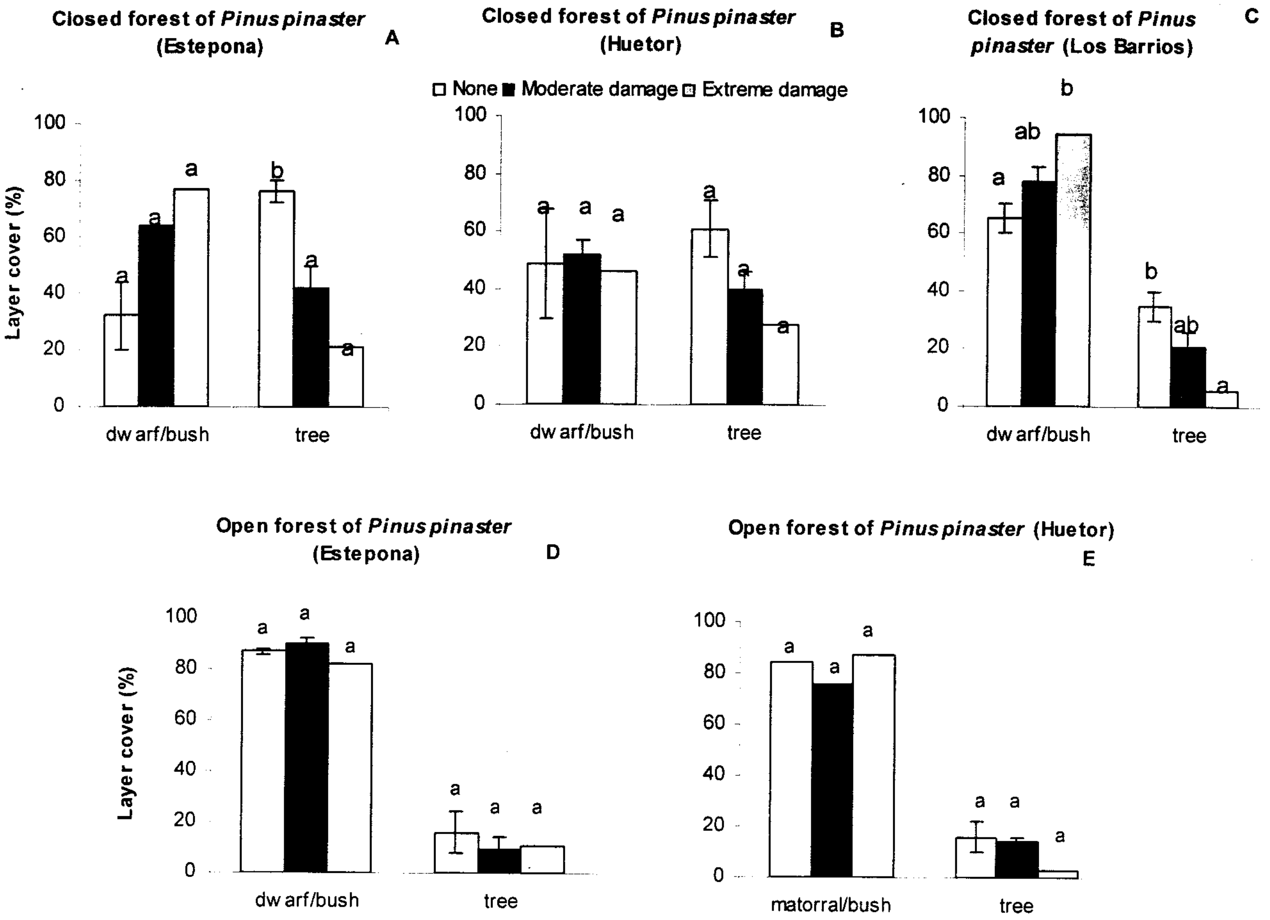

Figure 8. Layer cover in closed and open forests of *Pinus pinaster* Aiton in different locations and level of fire damage. Means with the same letter do not differ significantly, using the Tukey test ($P < 0.05$).

the trees by fire. If fire occurrence is high, pine forest will evolve to dwarf ecosystems. This could lead to the "steppization" (*sensu* Barbero and others 1990), if fire recurs on a large scale and erosion increases (Barbero and others 1990). This process represents a potential risk for these forests because of their topography, with steep slopes, particularly in the Sierra de Huetor.

Open forests, on the other hand, continue to be open after fire because fire here tends to run along the ground, and damage to the trees is generally less than in closed forests, where fire can quite easily reach the canopy.

The frequency of regeneration of *Pinus pinaster* improved in areas of moderate damage in Huetor and Los Barrios. The high temperatures reached during the fires enhanced seed release and germination by generating new establishment opportunities, with reduced inter-and intraspecific competition and favorable microscale conditions for germination and establishment (Izhaki and Ne'eman 2000). If, however, the fire is intense, it may pass the temperature threshold and cause irreversible damage to the seed (Habrouk 1999). Regeneration of *Pinus pinea* in closed forests, on the other hand, and of *Pinus pinaster* in both closed and open forests in Estepona, was enhanced by extreme damage. This can perhaps be explained by the total or partial elimination of the tree canopy in areas that suffered the worst fire damage: thus more light reached the soil, enhancing seed germination, due to the marked shade-intolerant characteristic of *Pinus* sp. (Pausas and others 1999, Izhaki and Ne'eman 2000).

In general, the regeneration frequency of the dominant tree species was less than 10%. Those factors that encourage regeneration are, among others, the ability of Mediterranean pines to adapt to fire, a large seed bank in the soil, and favorable climatic and soil conditions. On the other hand, regeneration

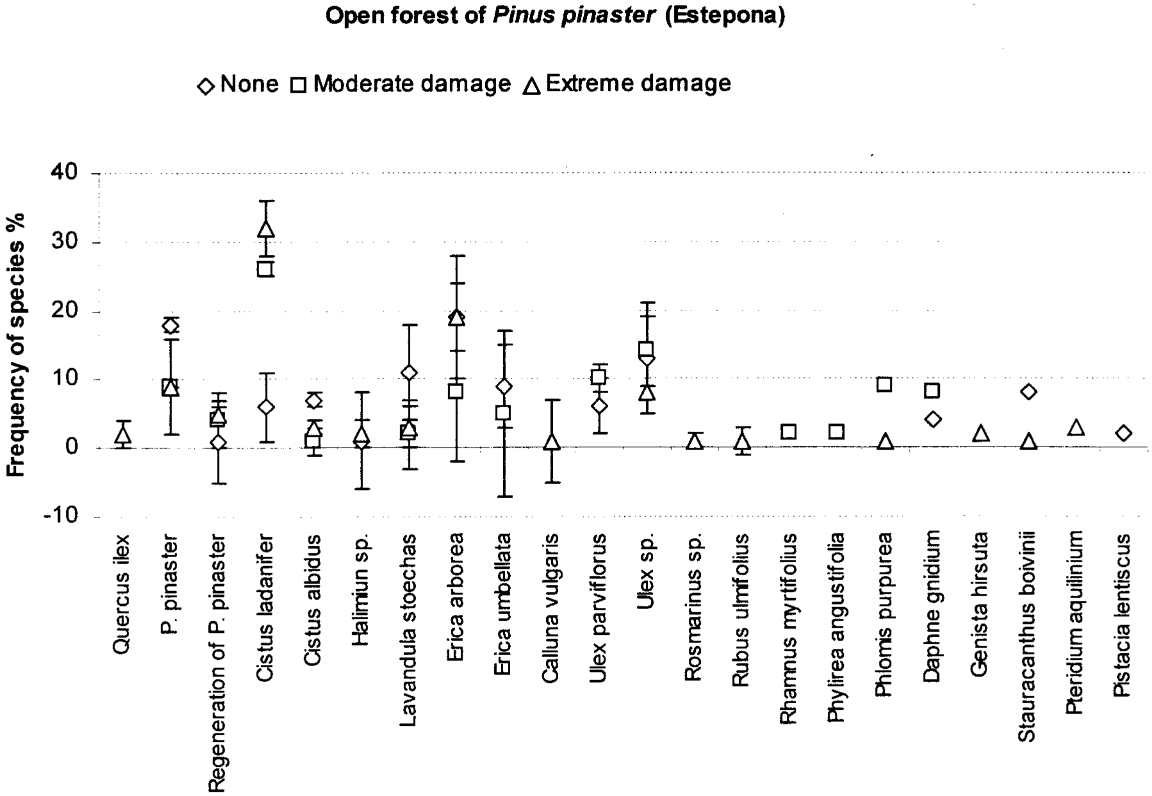

Figure 9. Frequency of species (%) in open forests of *Pinus pinaster* Aiton in Estepona (Málaga) with different levels of damage. Mean and standard error are shown.

is threatened by seed loss through high temperatures, predation, or soil movement caused by erosion, while already established seedlings can be damaged by grazing and cutting (Castro and others 1990, Trabaud 2000). The fact that the forests in this study were planted artificially in a seminatural way suggests a poor seed bank, but, given that the burned areas had been grazed, it is also necessary to take into account the effect this has on regeneration. These low levels of regeneration cannot guarantee the recovery of the forests to their former state (closed and open forests of *Pinus pinaster* and *Pinus pinea*).

The dwarf/shrub layer, however, recovered well after fire. There was no significant difference in the frequency of understorey species in relation to the level of damage. Most Mediterranean species are capable of rapid postfire regeneration by resprouting or seed bank (Trabaud 1987). It was, however, possible to distinguish different types of response to fire and to the level of fire damage, although these differences were not significant.

Cistaceae, particularly *Cistus ladanifer,* followed by *Cistus albidus, Cistus populofilius,* and *Cistus salvifolius,* responded remarkably after the fire. Various studies (Naveh 1975, Ferrandis and others 1999, Ne'eman and Izhaki 1999, Eshel and others 2000) have shown an increase in populations of some Cistaceae after fire in Mediterranean ecosystems. Rockrose regenerate from seeds and are often typical active pyrophytes, because their germination is enhanced after fire (Ne'eman and Izhaki 1999, Aranoutsou and Ne'eman 2000). They are among the least palatable and most combustible of the species that regenerate after fire (Naveh 1990).

Ericaceae are another important group in these ecosystems capable of postfire regeneration, both vegetative and from seeds, (Naveh 1990). The response of *Erica arborea* and *Erica umbellate* was particularly noteworthy (Table 4).

In the three locations where there were forests of *Pinus pinaster,* leguminous species of the *Ulex* genus, particularly *Ulex parviflorus,* recovered well after both moderate and intense fire (Table 4). This is due to the massive germination of their dormant hard-coated seeds in the soil bank and the direct effect of heat

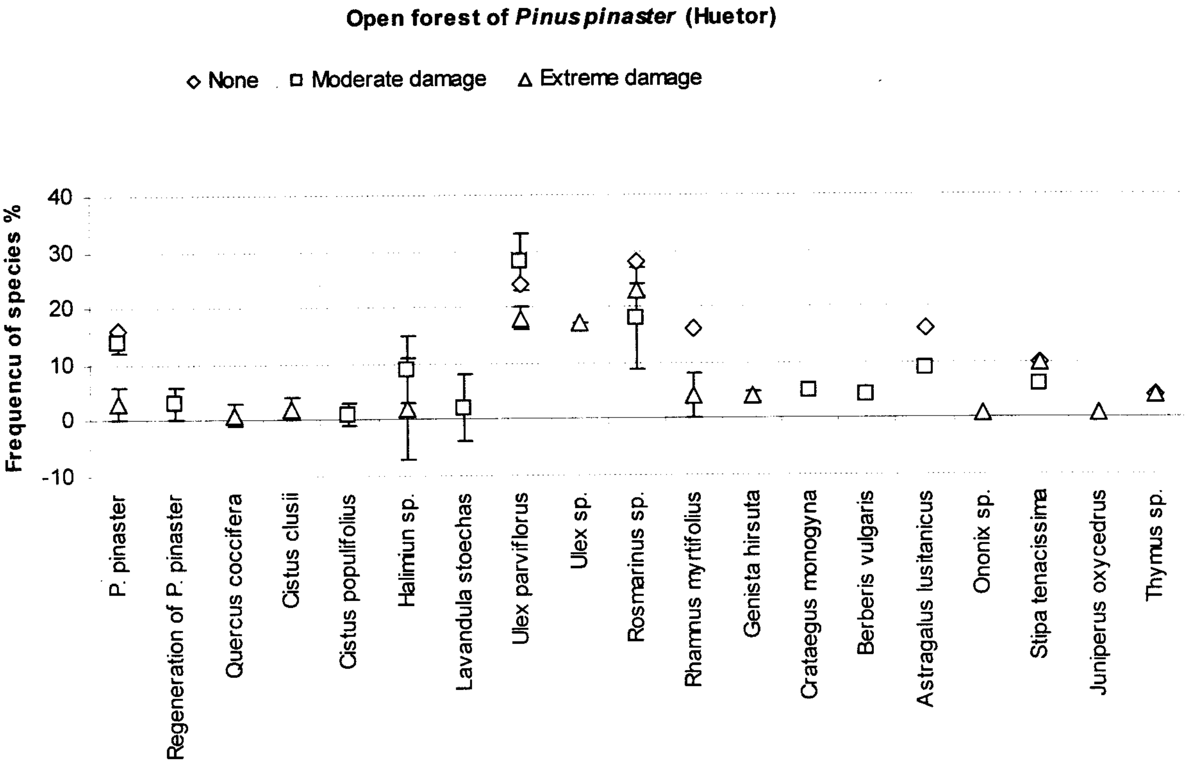

Figure 10. Frequency of species (%) in open forests of *Pinus pinaster* Aiton in Huetor (Granada) with different levels of damage. Mean and standard error are shown.

(Herranz and others 1998). Beside that, they are facultative resprouters, which dwarf legumes increased population size after the fire areas (Martinez-Sanchez and Herranz 1999; Pausas and others 1999). Various authors have noted this species' remarkable ability to adapt to fire and its high level of inflammability (Martinez-Sanchez and others 1994; Aranoutson and Thomos 1996).

Other species that recovered well after fire were *Rosmarinus* sp., especially in open forests, and *Astragalus lusitanicus. Rosmarinus* sp. can regenerate both vegetatively and from seeds, with fire recorded as having a neutral (May 1990) or positive effect.

In forests of *Pinus pinea,* the group of species that recovered after fire were also Cistaceas (*Cistus ladanifer*) and Ericaceas (*Erica arborea, Erica umbellate,* and *Arbutus unedo*), an less importantly, dwarf legumes (Table 4).

On the other hand, dominant pine species in Mediterranean pine forests regenerate after fire exclusively from canopy-stored seeds or seed bank (Agee 1998, Izhaki and Ne'eman 2000, Eshel and others 2000), although *Pinus pinea* and less *Pinus pinaster* have shown an absence of natural germination.

The lack of significant differences in the variables, richness, diversity, tree and dwarf/shrub cover, and species frequency points to an autosuccesion model after fire, as various studies on postfire regeneration in Mediterranean ecosystems have shown (De Lillis and Testi 1990, Trabaud 2000, Arianoutsou and Ne'eman 2000).

TWINSPAN analysis distinguished clearly between the different locations, as might be expected from the differences in the flora, which resulted from the geographical locality of the fires. The final groupings of transects, however, did not cluster by type of forest or level of fire damage, except in the case of Los Barrios. The initial density, therefore, of the forest, does not appear to determine the floristic composition of the dwarf/shrub layer. This may be due to the characteristic mosaic of these forests, which consist of small stands, rather than homogeneous woodland. The level of fire damage proved not to be a factor in distinguishing groups with differences in the species composition of the understory. This corroborates the great capacity these species have for postfire recovery and confirms once again that the model for regeneration is one of autosuccession.

Table 3. Transects grouped according to understory species, using TWINSPAN

Locality	Type of forest	Level of damage	Group
Aznalcóllar	Open pine forest (*Pinus pinea* L.)	Extreme	1
Los Barrios	Closed pine forest (*Pinus pinaster* Aiton)	Moderate	2
	Closed pine forest (*Pinus pinaster* Aiton)	Moderate	2
	Closed pine forest (*Pinus pinaster* Aiton)	None	3
	Closed pine forest (*Pinus pinaster* Aiton)	None	3
	Closed pine forest (*Pinus pinaster* Aiton)	Extreme	3
	Closed pine forest (*Pinus pinaster* Aiton)	Extreme	3
Aznalcóllar	Closed pine forest (*Pinus pinea* L.)	Moderate	4
	Closed pine forest (*Pinus pinea* L.)	Extreme	4
	Open pine forest (*Pinus pinea* L.)	Extreme	4
	Closed pine forest (*Pinus pinea* L.)	Extreme	4
	Open pine forest (*Pinus pinea* L.)	None	5
	Open pine forest (*Pinus pinea* L.)	Moderate	5
	Open pine forest (*Pinus pinea* L.)	Moderate	5
	Closed pine forest (*Pinus pinea* L.)	None	6
	Closed pine forest (*Pinus pinea* L.)	Extreme	7
Estepona	Closed pine forest (*Pinus pinaster* Aiton)	Extreme	7
	Open pine forest (*Pinus pinaster* Aiton)	None	7
	Open pine forest (*Pinus pinaster* Aiton)	Moderate	7
	Open pine forest (*Pinus pinaster* Aiton)	None	8
	Open pine forest (*Pinus pinaster* Aiton)	Extreme	8
	Closed pine forest (*Pinus pinaster* Aiton)	Moderate	8
	Closed pine forest (*Pinus pinaster* Aiton)	Moderate	8
	Closed pine forest (*Pinus pinaster* Aiton)	Moderate	9
	Closed pine forest (*Pinus pinaster* Aiton)	Extreme	9
	Open pine forest (*Pinus pinaster* Aiton)	Extreme	9
	Closed pine forest (*Pinus pinaster* Aiton)	None	9
Huétor	Closed pine forest (*Pinus pinaster* Aiton)	None	10
	Open pine forest (*Pinus pinaster* Aiton)	Extreme	11
	Closed pine forest (*Pinus pinaster* Aiton)	None	12
	Open pine forest (*Pinus pinaster* Aiton)	None	12
	Open pine forest (*Pinus pinaster* Aiton)	Moderate	12
	Open pine forest (*Pinus pinaster* Aiton)	Extreme	12
	Closed pine forest (*Pinus pinaster* Aiton)	Moderate	13
	Closed pine forest (*Pinus pinaster* Aiton)	Extreme	13
	Closed pine forest (*Pinus pinaster* Aiton)	Extreme	13
	Open pine forest (*Pinus pinaster* Aiton)	Moderate	13
Estepona	Closed pine forest (*Pinus pinaster* Aiton)	None	14
	Closed pine forest (*Pinus pinaster* Aiton)	Moderate	14

Conclusions

Fire affected only the horizontal structure of closed forests of *Pinus pinea* and *Pinus pinaster*. If damage was moderate, they were able to maintain their density, but if it was extreme, pine forest tended to became open because of very low natural germination of burned areas and patchy establishment. Only intense fire, caused a definite transformation of these forests from dense to open.

Forests of *Pinus pinea* and *Pinus pinaster* affected by fire in southern Spain follow an autosuccession model, which allows plant communities to recover to their prefire state. Species present after the fire are the same as those that existed before the fire and appear again immediately after, although amounts may differ. In the dwarf/shrub layer, the response of the Cistaceas, Ericaceas, and leguminous species of the *Ulex* genus was very good.

Postfire restoration management should be applied to burned areas and a plan of action must be prepared. Knowledge of vegetation development may supply a tool for landscape design and degrees of treatment (Ne'eman and Perevolotsky 2000). Therefore, on forests of *Pinus pinea* and *Pinus pinaster,* silvicultural intervention must be limited and reforestation should be done according of vegetation damage and expected natural regeneration process (Navarro and others 2001).

Table 4. Groups obtained, using TWINSPAN, and preferential species in each

- Group 1
  - *Cistus ladanifer*
  - *Erica umbellata*
  - *Arbutus unedo*
- Group 2
  - *Quercus fruticosa* Brot.
  - *Genista tridents* (Cav.) DC.
  - *Myrtus communis* L.
  - *Pteridium aquilinum* (L.) Kuhn
- Group 3
  - *Erica scoparia* L.
  - *Lavandula stoechas*
  - *Ulex parviflorus*
  - *Ulex* sp.
  - *Phlomis purpurea* L.
  - *Vibumum tinus* L.
  - *Adenocarpus telonensis* (Loisiel.) DC.
  - *Cistus populifolius*
  - *Ulex parviflorus*
- Group 4
  - *Phylirea angustifolia* L.
  - *Cistus ladanifer*
  - *Erica arborea*
- Group 5
  - *Cistus populifolius*
  - *Halimium* special
  - *Calluna vulgaris* (L.) Hull
  - *Lavandula stoechas*
- Group 6
  - *Cistus albidus*
  - *Lavandula stoechas*
  - *Phylirea angustifolia* L.
- Group 7
  - *Halimium* special
  - *Erica arborea*
  - *Erica umbellata*
  - *Ulex parviflorus*
  - *Phlomis purpurea*
  - *Phylirea latifolia*
  - *Daphne gnidium* L.
  - *Pistacia lentiscus* L.
- Group 8
  - *Ulex* special
  - *Stauracanthus bovinii* (Webb) Samp.
  - *Erica arborea*
- Group 9
  - *Cistus ladanifer*
  - *Cistus albidus*
  - *Erica arborea*
  - *Calluna vulgaris*
  - *Lavandula stoechas*
  - *Phlomis purpurea*
  - *Rosmarinus* special
  - *Rubus ulmifolius* Schott.
  - *Phylirea angustifolia*
  - *Euphorbia* special
  - *Rhamnus myrtifolius* Willk.
  - *Genista hirsuta Vahl*
  - *Ulex* special
- Group 10
  - *Halimium* special
  - *Retama* special
- Group 11
  - *Cistus clusii* Dunal
  - *Ulex* special
  - *Rhamnus myrtifolius*
  - *Ononix* special
  - *Stipa tenacissima* Kuntze
  - *Juniperus oxycedrus* L.
  - *Genista hirsuta*
- Group 11
  - *Cistus clusii* Dunal
  - *Ulex* special
  - *Rhamnus myrtifolius*
  - *Ononix* special
  - *Stipa tenacissima* Kuntze
  - *Juniperus oxycedrus* L.
  - *Genista hirsuta*
- Group 12
  - *Quercus coccifera* L.
  - *Cistus populifolius*
  - *Halimium* special
  - *Lavandula stoechas*
  - *Ulex parviflorus*
  - *Rubus ulmifolius*
  - *Thymus* special
  - *Pteridium aquilinum*
  - *Astragalus lusitanicus* Lam.
  - *Ulex parviflorus*
  - *Pteridium aquilinum*
- Group 13
  - *Cistus albidus*
  - *Calluna vulgaris*
  - *Rosmarinus sp*
  - *Rubus ulmifolius*
  - *Rhamnus myrtifolius*
  - *Ononix sp*
  - *Stipa tenacissima*
  - *Crataegus monogyna Jacq.*
  - *Berberis vulgaris L.*
  - *Eleborus foetida*
  - *Astragalus lusitanica*
  - *Ulex parviflorus*
- Group 14
  - *Lavandula stoechas*
  - *Ulex sp*
  - *Phlomis purpurea*

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