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Lichens as indicators of a perturbation/stability gradient in the Asperillo dunes, SW Spain

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Abstract. In the Asperillo dune system, Southwest Spain, lichen vegetation covering the dune sand, has a low species diversity but is an important component of the perennial vegetation, providing stability, nutrients, and moisture to the soil layer. The Asperillo dunes harbour (1) natural ecosystems, (2) disturbed systems affected by forestry activities where the natural vegetation is eliminated, and (3) pine forest resulting from afforestation with *Pinus pinea* since the end of the 1940s where the composition and abundance of the lichen flora has been drastically changed.

Our hypothesis was that the lichen species composition and distribution are influenced by the type and period of human intervention. To test this hypothesis a 1.2 km × 1.1 km area, which includes zones with different degrees of conservation and perturbation, consisting of five different habitats, was selected: well preserved *Juniperus* woodland, *Pinus pinea* plantations with dense scrub, dense scrub, *P. pinea* plantations cleared from scrub, and pioneer scrub in recent pine afforestation. In each area, randomly located 5 m × 5 m homogeneous plots were sampled. In each plot the cover of shrub and lichen species was recorded.

The first results show that lichen cover is higher in the most preserved areas, *Cladonia mediterranea* being the dominant species under the *Juniperus phoenicea* canopy. The lichen community changes in composition and abundance depending on the time elapsed since the last perturbation.

Keywords: *Cladonia*; Conservation; Doñana Natural Park; Juniper woodland; Pine woodland.

Nomenclature: Valdés et al. (1987) for shrubs; Ozenda & Clauzade (1970) for lichens.

Introduction

Lichen communities have been used to identify ancient and relatively undisturbed forests (Rose 1976; Carleton 1990), to interpret changes following alterations of forest types (Lesica et al. 1991) by management and fire perturbation (Arseneault & Payette 1992; Wolseley & Aguirre-Hudson 1991), and to monitor atmospheric changes (Ferry et al. 1973).

On the aeolian sand sheets of the Asperillo dunes (SW Spain) a mosaic occurs including patches of *Juniperus phoenicea* ssp. *turbinata* and distinct stands with *Pinus pinea* plantations, varying in year of planting and time since the last management (clearing from scrub). Communities of dune macrolichens are found in all parts of this mosaic.

The main purpose of this study was to investigate the exact occurrence and distribution of dune lichen and woody species in these areas, to compare their efficiency as biological indicators of the preserved patches, and to detect differences in composition and abundance according to the time elapsed since the last perturbation.

Study area

The Asperillo coastal dune system is situated along the Atlantic Ocean in the province of Huelva (SW Spain), where it borders the famous Doñana National Park (Fig. 1). According to Capel Molina (1981) the southwestern coast of Spain receives an annual irradiance ranging from 619 to 661 kJ/cm^2, corresponding to 2800 sun hours per year. Mean temperature is 18 °C.

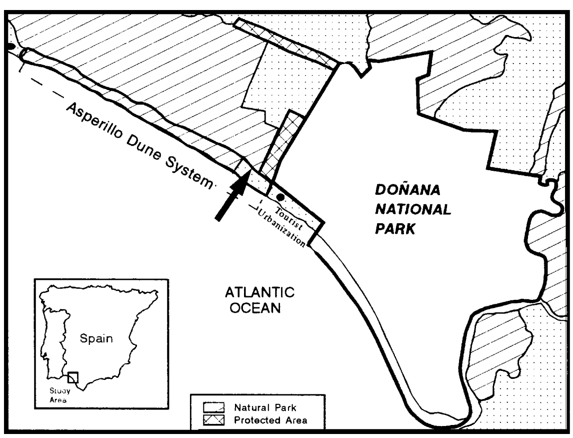

Fig. 1. Location of the Asperillo dune system and the study area on the southwest coast of Spain.

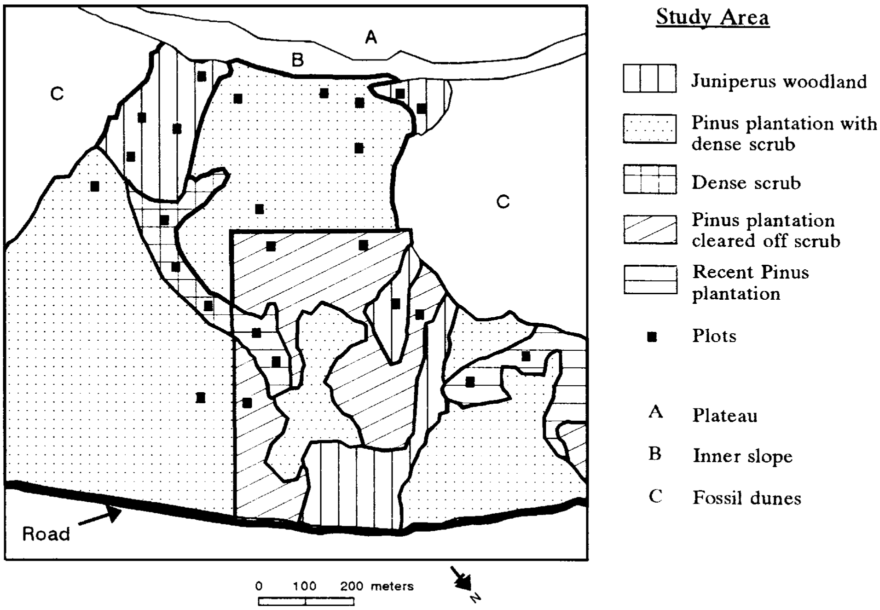

Fig. 2. Vegetation units of the study area based on the interpretation of air photographs and field mapping. Location of the sampling plots.

Precipitation is 550 mm/yr; most rain falls in November-December and March-April. The climate is Mediterranean with temperate winters.

The aeolian sands of the dune system are largely composed of quartz grains. They correspond to two depositional stages of the Pleistocene and Holocene ages (Vanney & Menanteau 1979, 1985).

The study area is 1.2 km × 1.1 km and is located on aeolian sand sheets (Fig. 2), described by Díaz Barradas & Muñoz Reinoso (1992) and Díaz Barradas & Gallego Fernández (1996). The Asperillo dunes are protected from direct oceanic influence by a fossil dune cliff, which is over 700 m wide and has a maximum height of 100 m above sea level.

The vegetation of the study area is formed by small woodlands of *Juniperus phoenicea* ssp. *turbinata*, relics of the original forest that once covered the dunes (Stevenson 1984; Granados et al. 1988). The dominant components of the vegetation are extensive plantations of *Pinus pinea* and small patches of secondary mediterranean scrub. Afforestations of umbrella pine (*Pinus pinea*) were started in 1938 (Kith y Tassara 1946) and fully expanded in the beginning of the 1950s. Descriptions of the vegetation of the Asperillo area are found in Sancho Royo (1981), Díaz Barradas & Muñoz Reinoso (1992); Díaz Barradas et al. (1992); García Novo & Merino (1993).

The study area borders the Doñana National Park and a Natural Park 'Surroundings of Doñana', the latter including different protected areas, but not being under any management program.

Table 1. List of the shrub and lichen species found in Asperillo and their location in each of the five managed areas. JpW = *Juniperus phoenicea* woodland; PpS = *Pinus pinea* with scrub; DS = Dense scrub; PpC = *Pinus pinea* cleared from scrub; PpSC = *Pinus pinea* plantation with scrub.

		JpW	PpS	DS	PpC	PpSC
Shrubs						
ARP	*Armeria pungens*			+	+	
CAV	*Calluna vulgaris*			+	+	
CLI	*Cistus libanotis*	+	+	+	+	+
CSA	*C. salvifolius*	+	+	+		+
COA	*Corema album*	+		+		+
CYT	*Cytisus grandiflorus*		+	+		
EUM	*Erica umbellata*	+			+	+
ESC	*E. scoparia*		+		+	+
HCO	*Halimium commutatum*	+	+	+	+	+
HHA	*H. halimifolium*	+	+	+	+	+
HCR	*Helianthemum croceum*				+	+
HPI	*Helichrysum picardii*		+	+	+	+
JPH	*Juniperus phoenicea*	+	+			
LVS	*Lavandula stoechas*	+	+	+	+	+
OSY	*Osyris quadripartita*			+		
PHI	*Phillyrea angustifolia*	+	+			
PLE	*Pistacia lentiscus*	+	+	+		
PPI	*Pinus pinea*		+		+	+
ROS	*Rosmarinus officinalis*	+	+	+	+	+
SCF	*Scrophularia frutescens*				+	
THY	*Thymus mastichina*	+	+	+	+	+
Lichens						
CCL	*Cladonia chlorophaea*		+			
CCO	*C. convoluta*	+	+	+	+	
CFO	*C. foliacea*	+	+	+	+	+
CME	*C. mediterranea*	+	+	+	+	+
CNE	*C. nylanderii*	+	+	+	+	+
CRN	*C. rangiformis*		+	+		+
CAC	*Cornicularia aculeata*		+	+	+	+
DBI	*Diplochistes bryophilus*	+	+	+		
DIP	*Diplochistes* spp.	+		+		

Methods

Field methods

Photo-interpretation

From vertical air photographs (1:10 000; 1988) and field identification, different management units may be distinguished in the study area (Fig. 2). These are: (1) patches of *Juniperus phoenicea* ssp. *turbinata* woodland; (2) *Pinus pinea* plantations with dense scrub; (3) dense scrub; (4) *Pinus pinea* plantations cleared from scrub (5 yr ago); (5) recent *Pinus pinea* plantations with scarce scrub.

Sampling

To sample the vegetation, 25 plots of 5 m × 5 m were distributed over the whole study area, according to Fig. 2. In each plot two types of measurements were made: in the scrub plots, plant cover was measured along six parallel lines of 5 m; in the macrolichen plots cover was measured along three parallel lines of 5 m. Species cover was expressed as the percentage of each species' cover relative to the total cover of the plot. The lichen species were identified in each observation plot; a reference number was assigned to species which could not be identified in the field. Species were identified in the laboratory afterwards. Herbs and grasses were not included in this study because the sampling period was in 1993, a very dry year (335 mm annual rainfall), and most species occurred with very low abundance.

Data analysis

The field data of scrub and lichen cover were summarized in a matrix of species × plots, whose elements represent the percentage of each species cover in each plot. In this way four matrices were elaborated: (1) all plots with only scrub, (2) all plots with only lichens, (3) all plots with both scrub and lichens, and (4) all plots except the *Juniperus* woodland plots containing lichens. Each of the four matrices was ordinated, using Correspondence Analysis (Benzécri 1973).

In order to interpret the meaning of the ordination axis of these analyses, two linear regressions were performed. Total lichen cover in each vegetation unit (except *Juniperus*) was regressed against the mean coordinate values on the first axis for each unit. Also, the cover of the lichen *Cladonia mediterranea* was regressed against the coordinates of the first axis for each of the *Juniperus phoenicea* plots.

Following the plot ordinations along the first axis of the analysis of the lichen matrix, the plant cover of the more abundant species was plotted in order to interpret the single species response curves.

Results and Discussion

The presence of both shrub and lichen species in the five management units is indicated in Table 1 (above). There are few species according to Mediterranean standards because the sandy soil is very poor in nutrients. This was also found in Doñana (García Novo 1979).

The ordination of the three matrices: 'shrubs', 'lichens' and 'shrubs and lichens', are shown in Fig. 3. The plots with *Juniperus phoenicea* woodland are part of the remaining plots. In this way the contrast between the two situations is clearly shown: the stable areas with *Juniperus phoenicea* woodland against the perturbed areas.

In the ordination of the shrub data (Fig. 3a), the *Juniperus phoenicea* plots are separated from the others because of the presence of the dominant species *Erica umbellata* and other species which are almost confined to this unit, notably *J. phoenicea* and *Cistus salvifolius*.

Using the lichen data only, the ordination diagram is generally clearer (Fig. 3b). The plots are distributed along the first axis in a decreasing order of *Cladonia mediterranea* cover. The linear regression between the coordinates of the first axis of the *J. phoenicea* plots and the cover of *Cladonia mediterranea* was highly significant ($R^2 = 0.988$; $p < 0.001$).

Each of the *J. phoenicea* plots corresponds to stable zones, except one, which has a position distant from the other *J. phoenicea* plots. It corresponds to a degraded *Juniperus* patch where the scrub was cleared and some *Juniperus* trees were removed.

The remaining plots correspond to managed areas. Along the second axis of the ordination of the scrub matrix (Fig. 3a) the contrast is between the more perturbed areas with recent plantations, characterized by *Armeria pungens* and *Helianthemum croceum*, vs. the umbrella pine woodlands with a dense scrub, a high cover of *P. pinea* and the presence of *Halimium commutatum*.

The plots of the other two units; dense scrub and cleared umbrella pine plantations, are not clearly separated in the ordination, because the composition of the scrub is similar in both units. Only *Scrophularia frutescens* is a characteristic species of cleared pine plantations.

However, the ordination following the lichen composition, without *Juniperus* plots (Fig. 3d), clearly separates all groups of managed plots. The first axis of this ordination is significantly related to the total cover of lichens (linear regression with $R^2 = 0.979$, $p < 0.001$).

Species response curves

The response curves of the six more abundant lichen species are shown in Fig. 4. Four types of lichen strategies were distinguished following their response to a perturbation:

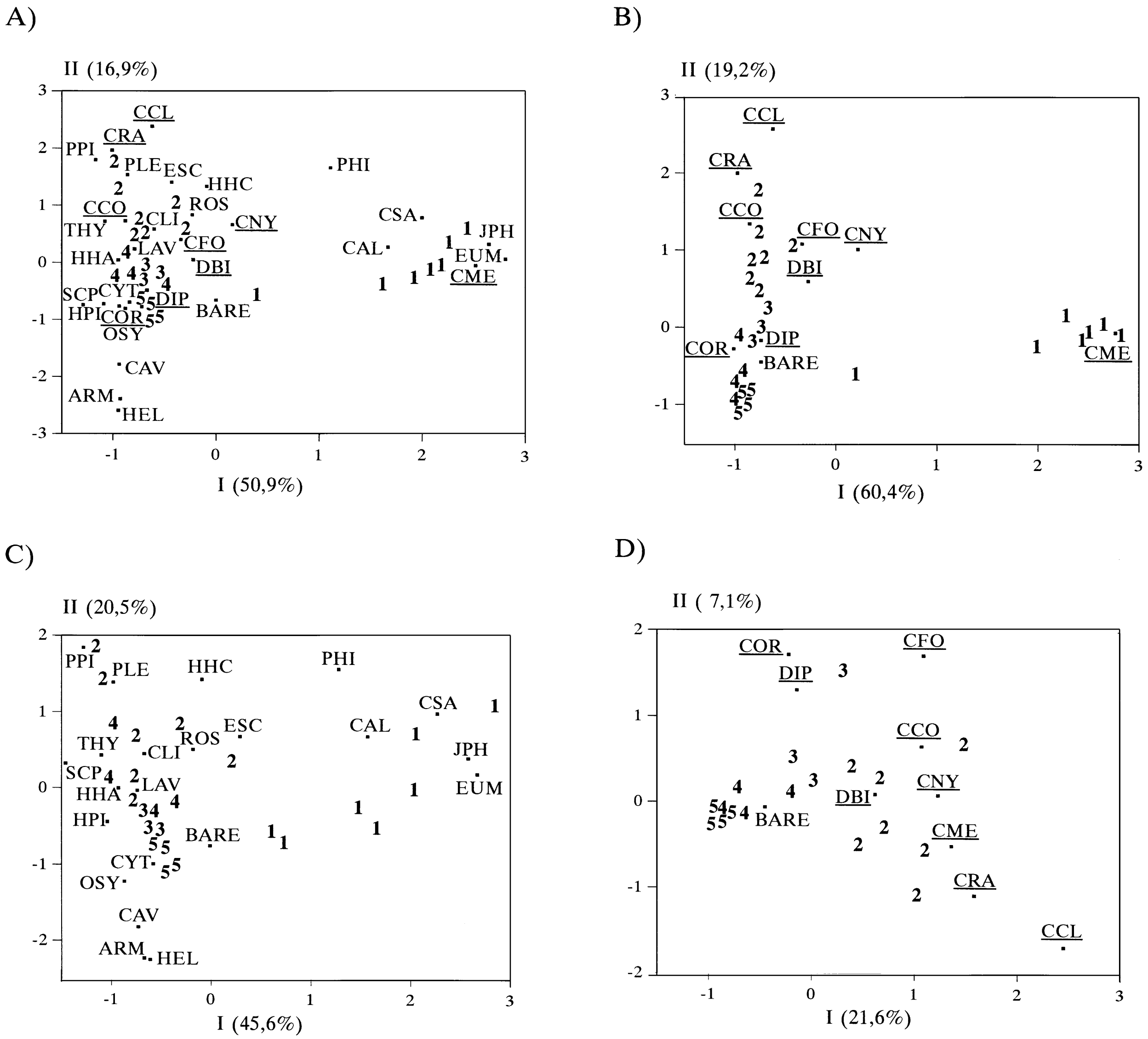

Fig. 3. Correspondence Analysis of species × plots matrices. **A.** Only shrub species; **B.** Only lichen species; **C.** Lichen and shrub species; **D.** Lichen species, *Juniperus phoenicea* plots excluded. Percentage variance values for each axis are given in brackets. Numbers indicate the vegetation units: 1 = *Juniperus* forest; 2 = *Pinus pinea* plantation with dense scrub; 3 = Dense scrub; 4 = *P. pinea* plantation cleared from scrub; 5 = Recent *P. pinea* plantation. For abbreviations of species names see Table 1. The lichen species are underlined.

1. The *Cladonia mediterranea* group (Fig. 4a), may reach 80 % of the plant cover in the *Juniperus phoenicea* forest, but occurs with very low cover or is even absent in the other plots. This species can reach 20 cm of height in the stable areas and is the best biological indicator of non-perturbation in the zone, because any kind of intensive management diminishes its abundance in a spectacular way reducing the *C. mediterranea* cover to less than 9 %. In view of the development of the cover from the recent perturbation zones to zones not perturbed for a long time, the rate is considered very low, and sometimes recovery is impossible. Different reasons can be pointed out: the soil perturbation, the changes in the vascular plant canopy or competition with other lichen species, although the exact reason has not been determined in this study.

2. *Cladonia convoluta*, *C. foliacea* and *C. nylanderii* are present in almost all plots, but with a higher cover in the plots of umbrella pine woodland and scrub, and with a lower cover towards the ends of the gradient: *Juniperus phoenicea* on the right hand and recent plantations on the left. The behaviour of these species suggests that they are less sensitive to perturbation, in the sense that they are able to recover and even to

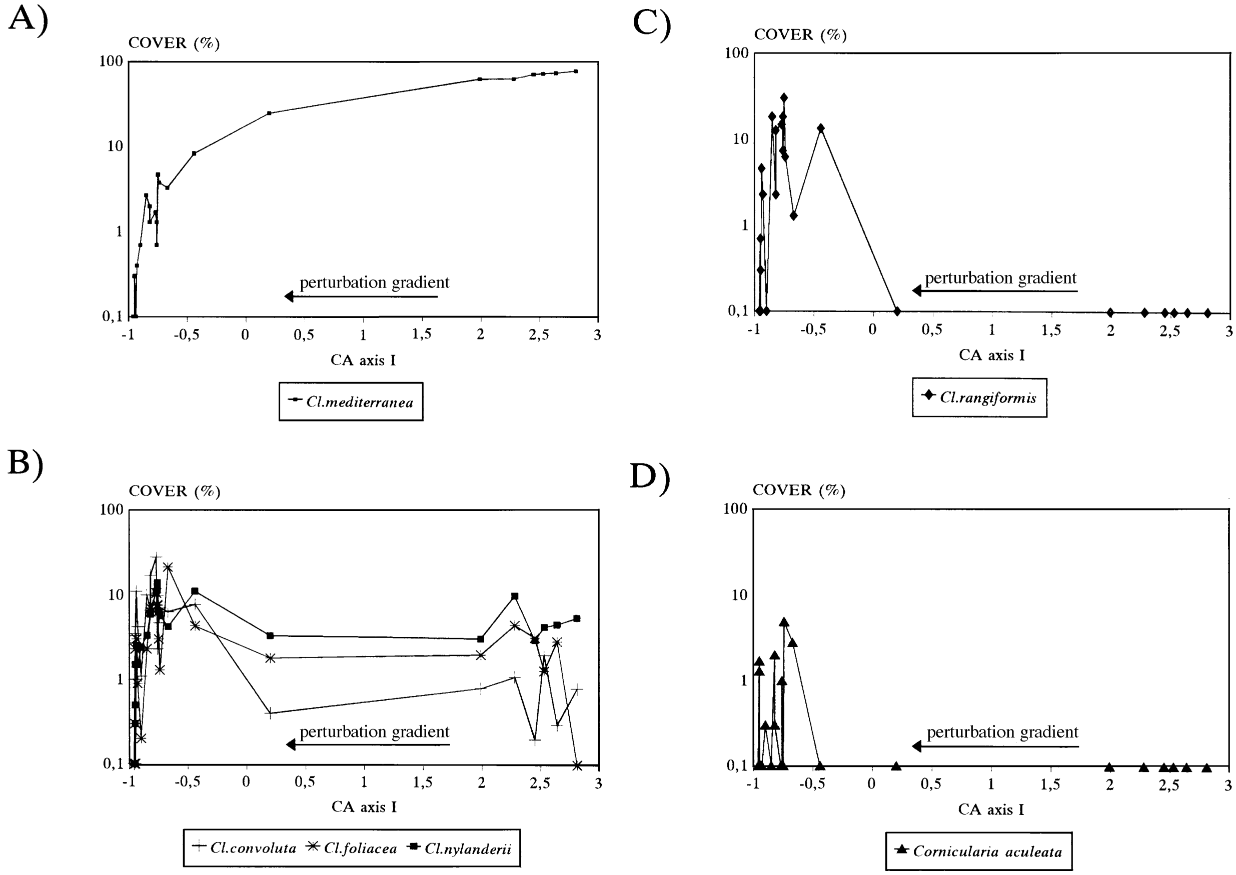

Fig. 4. Species response curves obtained by plotting the percentage cover of lichen species in each sampling plot against the position of the plot along ordination axis I of the Correspondence Analysis of the 'only lichen species' matrix. **A.** *Cladonia mediterranea*; **B.** *C. convoluta, C. foliacea* and *C. nylanderii*; **C.** *C. rangiformis*; **D.** *Cornicularia aculeata*.

surpass the percentage cover they reach in the stable areas, as is the case with *C. nylanderii*. This response to perturbation can explain the substitution of *C. mediterranea*, which is apparently outcompeted.

3. *Cladonia rangiformis* does not appear in the *Juniperus phoenicea* forests, neither in the recent plantations; it occurs exclusively in the umbrella pine woodland. Its distribution suggests that this species needs some time of stability between perturbations. It is unclear why it does not appear in the stable areas; maybe this is because of competition with *C. mediterranea* for a long period.

4. *Cornicularia aculeata* is almost entirely restricted to the perturbed area where it occurs with low cover in the umbrella pine woodland. This distribution suggests that this is a good indicator of recent perturbations.

Conclusions

Any human activity which causes the elimination of the vascular vegetation, or perturbation of certain soil components, leads to an elimination of the dune macrolichen flora. *Cladonia mediterranea* shows a high cover and biomass and a well-developed structure in the more stable areas where human activity is almost absent; this distribution makes this species a good biological indicator of stable situations on these sand sheets. After perturbation the macrolichen flora starts to recover, with a different abundance and species composition compared to natural conditions.

Four different types of species strategies have been found in the lichen community in response to human perturbation:

1. *Cladonia mediterranea* response: with higher cover and greater height in the *Juniperus phoenicea* forests than in the managed areas.
2. *Cladonia convoluta, C. foliacea* and *C. nylanderii*

are distributed all over the study area, but with a higher cover in the pine woodlands and Mediterranean dune scrub.

3. *Cladonia rangiformis* is absent at the ends of the perturbation/stability gradient, both in the *Juniperus* woodland and in the recent pine plantations.
4. *Cornicularia aculeata* is almost always restricted to the more perturbed areas.

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