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Juniperus oxycedrus ssp. *macrocarpa* in SW Spain: Ecology and conservation problems

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Abstract. Woodlands of the Mediterranean species *Juniperus oxycedrus* ssp. *macrocarpa* (maritime juniper) are both vulnerable and ecologically important. Their ecology and biological status along the SW coast of Spain are not well known; this, the first major study of these juniper populations is a basis for future research and restoration policies. These communities are subject to harsh conditions, the plant composition being controlled by several factors at different scales. On a large scale, climate and soil texture play an important role in controlling the soil water availability to plants, and in separating xerophytic from mesic communities. On a small scale, coastal physiography, and substrate composition are related to differences in the floristic composition. Coastal plantations modify environmental conditions, such as sand mobility and salt spray deposition, inducing important changes in plant communities. The population of maritime juniper on this coast was estimated in ca. 25 000 individuals, of which 93.6% are concentrated in three locations. Large proportions of young individuals were found in extensive and protected populations. However, adult individuals dominated the smaller populations located under pine plantations. This limitation of recruitment may be imposed by several factors. A male biased ratio was detected on the southern coast of Cádiz, which I hypothesize is due to the lower cost of pollen production in a stressful habitat. Preservation of suitable habitats, the recovery of abandoned pine plantations, and the connection between juniper populations, seem to be important requisites for the conservation of maritime juniper in the southwestern coast of Spain.

Keywords: Biological status; Coastal vegetation; Environmental factor; Maritime juniper; Pine plantation.

Nomenclature: Valdés et al. (1987).

Introduction

The maritime juniper *Juniperus oxycedrus* L. ssp. *macrocarpa* (Sibth. & Sm.) Ball 1878 is a Mediterranean species (Post 1933; Maire 1952; Tutin et al. 1964; Jalas & Souminen 1973). Woodlands dominated by this species represent the mature ecosystem on outer dunes and cliffs of the Mediterranean coasts. They constitute a singular vegetation type in an environment that has been traditionally seen as a place for socio-economic development. During the last century, those coastal woodlands (*sensu* Tekke 1993) have been almost destroyed or profoundly disturbed by logging, urban development, pine plantations, and cultivation.

Nowadays, the junipers appear in isolated stands of different extension. Large populations still survive in natural or semi-natural situations within protected or military areas, but others have no legal protection. That decline has led to include *Juniperus oxycedrus* ssp. *macrocarpa* in both the Red Book of the Threatened Wild Flora of Andalucía (Anon. 1999) as endangered, and in the Red List of the Spanish Vascular Flora (Anon. 2000) as critically endangered. Its habitats have been also included in the European Union Habitats Directive as an acknowledgement of its threatened status in Europe (Anon. 1992). The protection of coastal woodlands is a priority because of the high natural values, recreation, sand stabilization, and their vulnerability (Tekke & Salman 1995). In addition to the high landscape values, coastal juniper woodlands are important because they harbour several endangered plant species (Sánchez 2000), such as *Sideritis arborescens* and *Thymus carnosus*, and fruiting individuals are an important food source for vertebrates such as badgers, foxes, wild boars, and rabbits.

In spite of their ecological value, maritime juniper woodlands of SW Spain are poorly known, and most of the references to studies of this vegetation are about the Doñana area (Allier 1975; Rivas Martínez et al. 1980; García Novo & Merino 1993, 1997), where they were considered remnant thickets. In addition, there is a lack of information about their ecology as a basis for future restoration plans. Maritime juniper has been considered resistant to salt and sand-laden marine winds (Géhu et al. 1990), related to a stabilized stage of the dunes (Allier 1975), and linked to competition displacement or substrate requirements (García Novo & Merino 1993).

In this study I analyse the extant juniper populations along the SW coast of Spain, their ecology and biological status, as a basis for future research and management practices. First, the environmental factors conditioning differences in plant composition of juniper communities along the southwestern coast of Spain were analysed. Second, data about the biological status of the maritime juniper, which include population size, age structure, and sex ratio within the different juniper populations, were recorded. Finally, their implications for maritime juniper conservation are discussed.

Study area

The study area comprises the dune systems and cliffs of the Gulf of Cádiz (SW Spain), between El Rompido (Huelva) and Punta Paloma (Cádiz) (Fig. 1), including a variety of coastal features and land use types. The Bay of Cádiz divides the coast into two stretches. To the west, the coast is eroded with sandstone cliffs and beaches (García Novo & Merino 1997). On the spits, which enclose salt marshes, extensive dune systems have developed, such as the mobile dune system of the Doñana National Park (DNP) and the Punta Umbría dunes. Between Mazagón and Matalascañas, a sandstone cliff extends 30 km long, with a mean altitude of 20 m a.s.l., with marine, fluvial and aeolian deposits (Dabrio et al. 1996).

To the east, there is a mixture of parallel sierras of sandstone, calcareous rock and schists reaching the coastal cliffs, capes and points (*puntas*) separated by inlets (*ensenadas*), where beaches and dunes develop

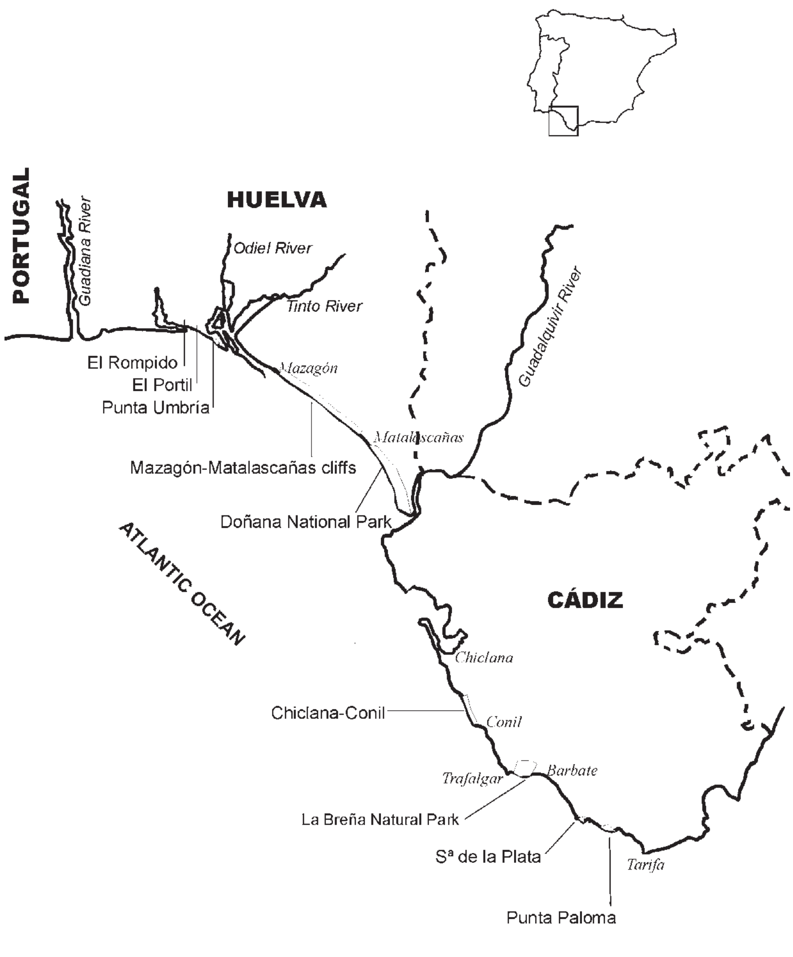

Fig. 1. Location map showing the nine studied populations of *Juniperus oxycedrus* ssp. *macrocarpa*.

(García Novo & Merino 1997). Along the Chiclana-Conil coast elevation increases, from the dunes of La Barrosa towards the cliffs of Cape Roche. In some locations strong eastern winds blow the sands which climb and cover the mother rocks, forming longitudinal dunes, some stabilized, as in La Breña Natural Park, others still active, as eastwards to Punta Paloma.

The climate is Mediterranean with an oceanic influence. Mean temperature is ca. 17 °C, with mild winters and hot summers. Annual precipitation increases from Punta Umbría (496 mm) to Barbate (842 mm), and decreasing to Tarifa (674 mm). The highest precipitation occurs from November to January, with a second peak in March-April. Summer drought is severe, with no rain in July and August and scarce rainfall in June and September. In the western stretch the prevailing winds come from the southwest, while in the eastern stretch the winds are stronger, and come from the east.

Methods

The basic sources of information to locate the populations of maritime juniper distributed along the southwestern coast of Spain were photo-interpretation and field surveys. All the potential sites were surveyed during 1998 and 1999, and some small populations were discovered during the fieldwork. At each population the number of individuals, the age structure and the sex ratio of mature individuals were estimated, and information on coastal physiography, geology, land use, and associated species was recorded.

Gradient analysis

Nine juniper populations were identified along the SW coast of Spain (Fig. 1). Within each population, one or several situations were distinguished according to coastal physiography, management, and plant physiognomy (Table 1) and called sites. The sites were classified in three main types according to the coastal physiography and management as juniper communities on sandy dunes, juniper communities on cliffs, and juniper communities within pine plantations. At each site between two and five 20 m × 50 m plots were laid out, and the presence of woody species was recorded; 68 woody species were recorded. Data for the vegetation analyses were grouped by site. During the period of study several sites were affected by human activities and then excluded from the gradient analysis. The relationship between environmental variables and species presence was examined by Canonical Correspondence Analysis (ter Braak 1987). The species appearing in only one site or in more than 90% of sites were eliminated from the analysis. Finally, a floristic matrix of 24 sites and 45 woody species was obtained. A set of ten environmental variables, including precipitation, temperature of the hottest month, soil pH, soil conductivity, soil texture (percent of sand, silt and clay), salt spray deposition, calcium carbonate content, and sand mobility, was correlated with the floristic matrix. Percent of clay was multi-collinear and then excluded from the analysis. Salt spray, soil conductivity and calcium carbonate content data were logarithmically transformed. The significance of the first axis and the trace were tested by Monte Carlo permutation test (999 runs).

Following the methodology of Goldstein et al. (1996), the salt spray deposition was estimated through the measure of electrical conductivity of water resulting from the washing of juniper twigs (10 cm long). By the end of the spring of 1999, after weather without rain, three twigs (1.5 m above the ground) of the windward side of three junipers were harvested at each site. The twigs were immersed in 30 ml of deionized water for 1 min. The electrical conductivity of the resulting solution was measured with a conductivity meter (Crison mod. 524).

Juniper populations

The size of juniper populations was estimated by counting saplings and mature individuals. The Chiclana-Conil population was counted by the officials of the Delegación Provincial of Cádiz (unpubl.). In large populations, the juniper densities of the different sites were estimated in at least three 0.5 ha plots, and then multiplied by the area covered by the junipers. Juniper individuals were classified into three age-size classes related to the life history stage (Schemske et al. 1994) which could be recognized in the field. Therefore, age-size classes were broadly defined according to plant height as follows: seedlings (lower than 0.25 m), saplings (0.26-1 m), mature (reproductive) plants (taller than 1 m). At each population, the numbers of male and female individuals were estimated in a random sample of at least 100 mature individuals (in smaller populations all the individuals were sexed). Field data were collected during the flowering season of 1999 and deviation from unity was verified with the *G*-test (Zar 1996).

Results

Gradient analysis

The results of the CCA are shown in Table 2 and Fig. 2. The first axis explained 14.5% of species variance and was significantly correlated with environmental variables ($P = 0.02$ for the Monte Carlo test). It had high negative correlation with soil electrical conductivity and precipitation, and positive with the temperature of the hottest month and the percentage of sand. The second axis explained 8.7% of variance and showed high negative correlation with soil pH, percentage of sand, percentage of $CaCO_3$, and sand mobility, and positive with percentage of silt. The third axis explained 6.5% of variance, and showed high negative correlation with salt spray and soil conductivity. The trace was also significant ($P = 0.01$). The first axis was associated to a climatic and soil texture gradient, and separated the Huelva sites with xerophytic shrubs (*Cytisus grandiflorus*, *Halimium commutatum*, *Stauracanthus genistoides*), from the Cádiz sites with mesic shrubs (*Chamaerops humilis*, *Phillyrea angustifolia*, *Olea europaea*, *Quercus coccifera*). The second axis was associated to a soil acidity and texture gradient, ranging from the juniper communities on sandy dune systems to the juniper communities on cliffs. Dune populations, such as Doñana, Punta Paloma and La Barrosa showed a moderate-high sand mobility, higher pH values (mean ± standard deviation; 7.8 ± 0.4), and high content in calcium carbonate (11.0 ± 5.7%), while cliff populations such as El Rompido, Mazagón and Roche showed a higher percentage of silt (10.1 ± 1.6%). *Ononis natrix*, *Sideritis arborescens*, and *Clematis flammula*, among others, characterized the dunes rich in calcium carbonate, while 'silty' cliffs were characterized by *Cistus ladanifer*, *C. crispus*, and *Ulex australis*. The third axis was associated to a salt spray deposition gradient, ranging from juniper communities on dunes and cliffs, with a high

Table 1. Physiography, management and *Juniperus* population sizes along the southwestern coast of Spain.

Populations and sites	Physiography	Management	Population size
Huelva Province:			
I. El Rompido			
1. Cliff	cliff plateau	wasteground, pine plantation	15
2. Los Enebros urbanization	outer dunes	urban, pine plantation	14
II. El Portil Protection Zone	inner dunes	protected, pine plantation	25
III. Enebrales de Punta Umbría Natural Landscape	outer dunes	protected, pine plantation	289
IV. Mazagón-Matalascañas cliff			
1. Mazagón cliff	cliff slope	recreative	98
2. Doñana Natural Park	cliff slope	protected	34
3. Matalascañas	cliff plateau	recreative, pine plantation	17
V. Doñana National Park			
1. Mogotes	inner dunes	protected	400
2. Wet slacks	dunes	protected, pine invasion	520
3. Zalabar	dunes	protected	5000
4. Inglesillo	dunes	protected, overbrowsed	5000
5. San Jacinto	dunes	protected	340
6. Pine invasion	dunes	protected, pine invasion	80
7. Pine plantation	inner dunes	protected, pine plantation	2250
Cádiz Province:			
VI. Chiclana-Conil coast			
1. La Barrosa	dunes	recreative	514
2. La Loma del Puerco	low cliffs	recreative	463
3. Roche cliffs	cliff plateau, gullies	recreative	1736
VII. La Breña Natural Park			
1. Trafalgar Cape	promontory, dunes	protected	64
2. Cliff	high cliff	protected, pine plantation	6600
3. Pine plantation	plateau	protected, pine plantation	
4. Mobile dunes	dunes	protected	
VIII. Sierra de la Plata			
1. Gracia Cape	spur slopes	recreative	100
2. Punta Camarinal	promontory, dunes	military	450
IX. Punta Paloma			
1. El Lentiscal	low cliff	pasture	45
2. Huerto del Gallego	low cliff	pine plantation	200
3. Punta Paloma	dunes	military, pine plantation	250
4. Dulce Nombre	low cliff	pasture, overbrowsed	20

deposition (448.9 ± 268.0 mS.cm^{-1}), to juniper communities as understorey of pine plantations, such as the pine plantations of Doñana, El Portil, Enebrales de Punta Umbría, Punta Paloma y La Breña, with a very low deposition (71.9 ± 32.7 mS.cm^{-1}), and a community composed by *Myrtus communis*, *Cistus libanotis*, *Lonicera* spp., *Halimium halimifolium* and *Rosmarinus officinalis*.

Population size

The maritime juniper population of SW Spain was estimated in ca. 25 000 individuals (Table 1), which concentrates in the DNP (13 500 individuals), La Breña Natural Park (6 600 individuals), and the dunes and cliffs of Chiclana-Conil coast (2 700 individuals). It shows that 93.6% of the population is concentrated along 47 km of the coast, of a total of 225 km between El Rompido (Huelva) and Tarifa (Cádiz). Only on the dunes of the DNP and in La Breña Natural Park the junipers spread inland for several kilometres. The rest of the individuals appear in small (< 50 individuals) or medium-sized populations (50-500 individuals), close to the seashore, more abundantly in Cádiz Province.

Age-size structure

Except for the DNP, mature individuals composed all the juniper populations of Huelva (Table 3). In the dunes of DNP, the juniper population was clearly dominated by adult individuals in the wet slacks (82.8%) and in the pine plantations (92.8%). In contrast, the rest of the stands showed high percentages of seedlings and saplings. At the Inglesillo, most of the individuals were included in the sapling class (63.6%) although they were mature in age. Here, the intense browsing by deer impede the growth of juniper individuals (pers. obs.). In the Pine invasion most of the seedlings appeared under one single juniper.

Seedlings and/or saplings evidencing a natural regeneration were found in all the populations of Cádiz Province (Table 3), although they were rare in the easternmost cliffs of Roche, La Breña cliff, and the dense pine plantations of Punta Paloma. In contrast to the pine plantations of Huelva, the pine plantation of La Breña Natural Park showed a high proportion of young individuals. The saplings were also very frequent in Trafalgar Cape, Gracia Cape and Punta Camarinal (52.2%, 45.0% and 52.3% respectively). In Dulce Nombre the junipers were overbrowsed showing a cushion-like canopy.

Sex ratios

Most of the populations showed a sex-ratio close to 1:1 (Table 3). Several sites (El Portil, Trafalgar Cape, La Breña mobile dunes, Gracia Cape, Punta Camarinal and Punta Paloma) showed a number of males significantly higher than of females ($P < 0.05$). Along the Mazagón-Matalascañas cliff coast, Inglesillo (DNP), and Dulce Nombre it was very difficult to determine the sex of the individuals due to their inaccessibility, small size or the intense overbrowsing.

Table 2. Results of the Canonical Correspondence Analysis: eigenvalues, correlations between species and environmental axes (S/E correlations), percentage of variance of species data, percentage of variance of species-environment relation, and correlations with environmental variables. Abbreviations as in Fig. 2.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.308	0.185	0.139	0.107
S/E correlations	0.958	0.901	0.946	0.826
% variance of species	14.5	8.7	6.5	5.1
% variance of species-env. variables	28.9	17.3	13.0	10.0
Correlations with environ. variables				
PRE	– 0.51	– 0.42	– 0.29	0.23
THM	0.74	0.39	0.32	0.10
pH	– 0.43	– 0.58	0.25	0.32
EC	– 0.58	0.01	– 0.55	0.08
Car	– 0.38	– 0.52	0.23	– 0.28
% Sand	0.51	– 0.52	0.23	– 0.28
% Silt	– 0.43	0.56	– 0.13	0.38
Spr	0.14	– 0.27	– 0.59	0.06
mob	0.38	– 0.54	– 0.20	– 0.01

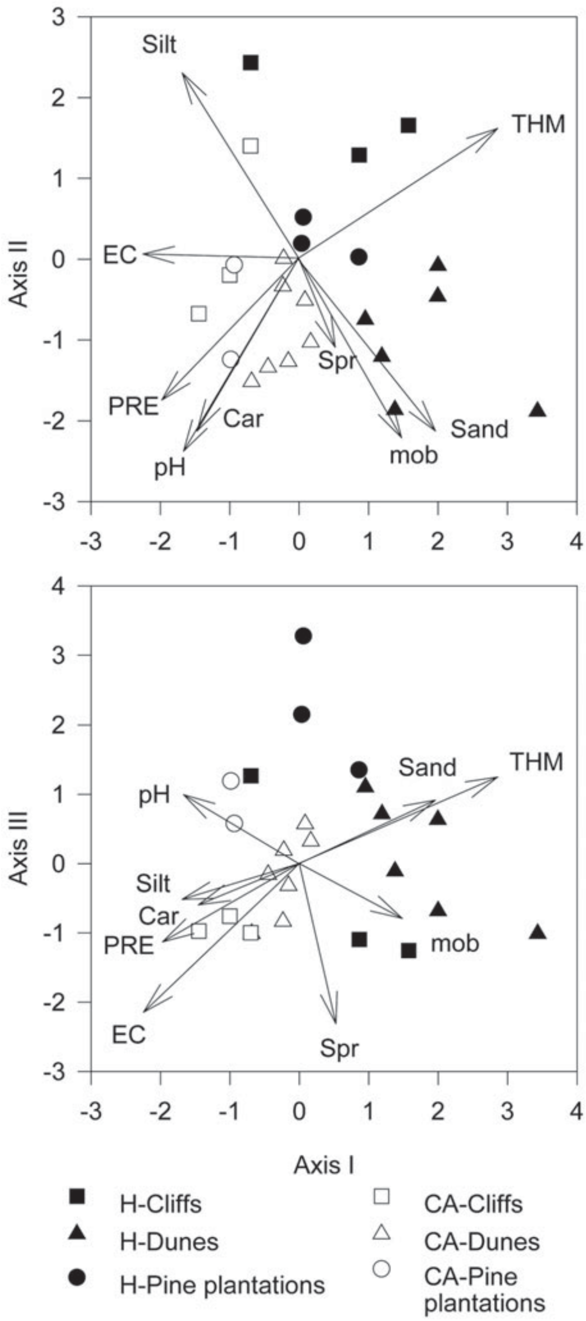

Fig. 2. Canonical Correspondence Analysis showing the position of the studied sites (classified according to the coastal physiography and management) in relation to environmental variables. Abbreviations: H = Huelva; CA = Cádiz; Silt =% silt; THM = temperature of the hottest month;, EC = Electrical conductivity; Spr = salt spray; PRE = mean annual precipitation; Car = Calcium carbonate; pH = soil pH; Sand = % sand; mob = sand mobility.

Fig. 3. Maritime junipers covered by pine needles under a dense canopy of pine trees in Doñana National Park.

Discussion

Juniper communities and environmental factors

Geographic variation in the plant species composition of maritime juniper communities for the Mediterranean Basin has been shown by Géhu et al. (1990). Along the SW coast of Spain, several environmental factors may explain the variation in species composition of maritime juniper communities. A first source of variation seems to be due to climate and soil texture, conditioning the soil water availability to plants, as observed by Reid et al. (1990) and Lane et al. (1998) in semi-arid conditions. There is a west-east gradient, from communities near Huelva characterized by xerophytic shrub, to communities near Cádiz, characterized by mesic species. A second source of variation seems to be due to coastal physiography (depositional versus erosional) and substrate composition (% $CaCO_3$). A third source of variation is related to the presence of pine plantations, which have important effects on the landscape, geomorphology, soils and ecology of coastal ecosystems (Tekke & Salman 1995). Pine plantations imply important changes in plant composition due to sand stabilization and the reduction in salt spray deposition under the pine tree canopy. Thus, species adapted to a moving substrate disappear, and the community is invaded by species less tolerant to coastal stress.

Population size

The populations of maritime juniper along the SW coast of Spain are very heterogeneous, and are exposed to different kinds of threats. The accessibility of the coast may have played a differential role in the conservation of the juniper populations. Thus, the low coast of Huelva has undergone a high human pressure in contrast to the higher

Table 3. Age structure and sex ratio of the *Junipererus oxycedrus* ssp. *macrocarpa* populations along the southwestern coast of Spain. Asterisks show significant differences ($P < 0.05$, G-test); n1 and n2: number of individuals counted per age-structure and sex ratio respectively.

Populations and sites	n1	Size-age classes (%)			n2	Sex ratio males:females
		Seedl.	Sapl.	Adul.		
Huelva Province						
I. El Rompido						
1. Cliff	15	-	-	100	15	1:0.88
2. Los Enebros urbanization	14	-	-	100	-	-
II. El Portil Protection Zone	20		-	100	20	1:0.33*
III. Enebrales de Punta Umbría Natural Landscape	157	-	-	100	157	1:0.99
IV. Mazagón-Matalascañas cliff						
1. Mazagón cliff	98	-	-	100	65	1:0.86
2. Doñana Natural Park	34	-	-	100	25	1:0.70
3. Matalascañas	17	-	-	100	17	0.89:1
V. Doñana National Park						
1. Mogotes	50	-	-	100	-	-
2. Wet slacks	64	1.6	15.6	82.8	111	1:0.72
3. Zalabar	164	23.2	34.1	42.7	210	1:0.89
4. Inglesillo	201	16.5	63.6	19.9	-	-
5. San Jacinto	88	6.8	36.4	56.8	169	1:0.85
6. Pine invasion	63	22.2	27.0	50.8		
7. Pine plantation	297	5.1	2.1	92.8	204	1:0.91
Cádiz Province						
VI. Chiclana-Conil coast						
1. La Barrosa	313	7.0	17.6	75.4	100	0.89:1
2. La Loma del Puerco	209	6.7	19.1	74.2	104	0.82:1
3. Roche cliffs	406	8.6	16.3	75.1	124	1:1
VII. La Breña Natural Park						
1. Trafalgar Cape	64	4.5	52.2	43.3	29	1:0.32*
2. Cliff	-	-	-	-	-	-
3. Pine plantation	341	9.7	47.8	42.5	100	0.96:1
4. Mobile dunes	37	8.1	37.8	54.1	100	1:0.39*
VIII. Sierra de la Plata						
1. Gracia Cape	88	10.2	52.3	37.5	33	1:0.38*
2. Punta Camarinal	305	23.6	45.2	31.1	100	1:0.67*
IX. Punta Paloma						
1. El Lentiscal	45	-	11.1	88.9	38	1:0.90
2. Huerto del Gallego	71	5.1	16.3	78.6	126	0.85:1
3. Punta Paloma	126	1.6	7.1	91.3	105	1:59*
4. Dulce Nombre	20	-	100	-	-	-

and more heterogeneous coast of Cádiz (Vanney & Menanteau 1985). As a consequence, the juniper population of Huelva is concentrated in a protected area, while there still are large populations along the Cádiz coast.

The population of the maritime juniper *Juniperus oxycedrus* ssp. *macrocarpa* of the southwestern coast of Spain was estimated as ca. 25 000 individuals, concentrated in three populations. This relatively large population size is no guarantee of species survival if the habitats are not properly preserved. Thus, out of the protected areas, the junipers are continuously destroyed by coastal urbanization. On the other hand, in the Doñana National Park, with the largest population of maritime juniper, no particular conservation management has been developed. However, 16.7% of the population is under a dense canopy of senescent pine trees and does not regenerate, ca. 37% is overbrowsed, and the rest is being invaded by pine trees spreading from nearby plantations.

Age-size structure of juniper populations

Three different age-size structures for maritime juniper were found, depending on the population size, coastal physiography, and management. Adult individuals, indicating a strong recruitment limitation, dominated the juniper populations located under pine plantations, particularly in the Huelva Province. This limitation may be imposed by several, non-mutually exclusive, factors. Thus, the deposition of pine needles impedes the seedling establishment, and kills the mature junipers (Fig. 3). Other associate problems may be a deficient pollination (Ortiz et al. 1998), and changes in coastal environmental factors favouring more competitive inland species.

On the cliffs, a high proportion of junipers (> 70%) were mature. This may be related to the vegetative multiplication by layering from decumbent branches (Clifton et al. 1997) or by sprouting from roots, as observed at the Mazagón cliff. Here, the environmental stress promoted by salt spray is reduced by the height of the coast (as observed by Barbour 1978), allowing for an increase in plant cover. The junipers and other woody species become large shrubby individuals, covering slopes and gullies. Therefore, there is little room for plant colonization, and young individuals are rare.

Large proportions of young individuals showing high recruitment rates were found in large and protected populations, such as the DNP and La Breña Natural Park. Trafalgar Cape, Gracia Cape, and Punta Camarinal also showed large proportions of young individuals in spite of a smaller population size. All those locations were characterized by a moving substrate, rich in calcium carbonate, and with a high salt spray deposition. However, in similar situations, the recreative use may negatively affect juniper recruitment by trampling as on the Chiclana-Conil coast, especially on the dunes of La Barrosa.

Sex ratios

In several juniper populations the number of the male individuals was significantly higher than female ones (Table 3). There are many reasons why sex ratios might differ from 1:1 (Allen & Antos 1993). In the juniper case, that biased ratio may be due to a differential old tree felling, as in the residual population of El Portil, or to a stressful environment. The maritime juniper populations showing a male biased ratio were exposed to strong winds, such as the populations of the southern coast of Cádiz. Here, the strong eastern winds may promote an increase in evapotranspiration, and thereby important water stress. The results suggest that in those drier sites, poor in nutrients, and consisting of mobile sands, there may be a differential mortality of females that could be due to a higher cost associated to cone production in female individuals (Ortiz et al. 1998). Thus, the sex ratio is biased to male individuals due to the lower cost of pollen production, and a spatial segregation of sexes might be expected (Freeman et al. 1997), with the females individuals in richer and wetter sites.

Factors affecting maritime juniper conservation

Factors affecting maritime juniper conservation are many and diverse. Nowadays, the growing urbanization along the coast seems to be the main threat of habitats where maritime juniper populations survive. Only regional authorities can stop this negative trend. However, most of the remaining maritime juniper woodlands of SW Spain are affected by pine plantations. The plantation of pine trees (*Pinus pinea*) and one-seed brooms (*Retama monosperma*) on the SW coast of Spain (Granados & Ojeda 1994) have changed the environmental conditions of these habitats. The CCA results show how pine plantations have reduced coastal stress, especially salt spray deposition, allowing inland species to colonize coastal habitats. In the new conditions, the maritime juniper is less competitive, and invading species increase the low plant cover and change the species diversity pattern of those fragile coastal habitats. As previously pointed out, pine plantations also reduce seedling recruitment and increase the juniper mortality by pine needles deposition.

From a conservation perspective, the reversion of abandoned coastal pine plantations into maritime juniper woodlands is a necessary management measure. The dunes of Doñana and the coast of Chiclana may be considered as 'natural reference situations' (*sensu* Tekke & Salman 1995). Thus, removal of pine trees may allow the restoration of the original environmental conditions, such as a moderate sand mobility, salt spray deposition, and wind flow. That may favour stress tolerant species such as maritime juniper, and although negative effects on the junipers are not foreseeable, it will be necessary to monitor their acclimatization to the 'new' conditions. An appropriate management of pine plantations would also allow the persistence of juniper populations within them, as at La Breña Natural Park. There, the management of the pine trees and the understorey for pine-seed production has allowed the junipers to regenerate by seeds, showing a strong recruitment.

As noticed by Santos & Tellería (1994) in small forest fragments of *Juniperus*, fragmentation and isolation of juniper populations produce changes in local mammal populations. In the case of the maritime juniper populations, it has important direct and indirect effects. On the southwestern coast of Spain, wild boars, foxes and badgers eat large quantities of juniper fleshy cones during autumn and winter (Muñoz-Reinoso unpubl.), are responsible for seed dispersal (Herrera 1989; Calisti et al. 1990), and contribute to the control of rabbit populations (Rau 1987; Martín et al. 1995). However, the lack of those small carnivorous mammals in small juniper populations such as Enebrales de Punta Umbría Natural Landscape reduce the dispersal possibilities of juniper seeds and favour the proliferation of rabbits which destroy most of the juniper seeds and seedlings.

Germination rate of maritime juniper is low (less than 5%, Muñoz-Reinoso unpubl.), as in other *Juniperus* species (Pack 1921; Young et al. 1988). *Juniperus oxycedrus* ssp. *macrocarpa* shows a large proportion of empty seeds in coastal habitats due to xeric conditions and resource limitation, although sex ratio and spatial location of mates may be also important in pollination (Ortiz et al. 1998). The regeneration by seeds observed in large populations that grow on different environments suggests an effective pollination. Conversely, in the small populations with scattered individuals of Huelva, a deficient pollination and other factors may be responsible for a lack of regeneration by seeds.

In conclusion, the preservation and maintenance of suitable habitats, the recovery of degraded ones (old coastal pine plantations), and the connection between juniper populations, and between those and the inward shrublands, seem to be important requisites for the conservation of *Juniperus oxycedrus* ssp *macrocarpa* on the SW coast of Spain.

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