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Regressive psammophilous plant formations at "Monte Algaida" pine forest, Doñana Natural Park, SW Spain

Abstract

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While many scientific studies have been developed at the wide territory of Doñana area (SW Spain) which extends in Huelva and Sevilla provinces, especially at the Doñana Biological Reserve, Doñana National Park and parts of Doñana Natural Park, very little attention has been paid to the area covered by the Natural Park in Cádiz province ("Monte Algaida"), at the other side of Guadalquivir river. Monte Algaida covers a band of aeolian sands developed over a sedimentary clay substrate. A study of this area has shown that it is covered by seven woody vegetation units: juniper woodlands; "monte blanco", a scrubland dominated by *Halimium halimifolium*; "Lentiscar", a scrubland dominated by *Pistacia lentiscus*; scrublands dominated by *Corema album; Tamarix formations*, and in more reduced proportion some formations of *Populus alba* and herbaceous communities dominated by *Juncaceae*. An interesting herbaceous community has been detected and analyzed. Floristic composition of the woody vegetation units of "Monte Algaida" is analyzed in comparison with the same units in Huelva province. This shows that plant communities at "Monte Algaida" are rather degraded and are in clear regression, owed, most probably, to the lack of new sand input by wind from the coast, and mainly to antropic pressure.

Introduction

To preserve wild fauna in one of the most important regions used by many migrating bird species, the Spanish Council of Scientific Research (C.S.I.C.) and the World Wildlife Fund bought, in 1964, 7000 ha of a territory located at the right side of the Guadalquivir river which had been a hunting area for centuries. The C.S.I.C. formed with these 7000 ha a reserve: Doñana Biological Reserve. But this relatively small area was not enough to guaranty protection to the reach fauna which permanently or temporary inhabits this area. This was the reason why the Spanish Government declared in 1969 as National Park a wider area of 37000 ha which was later declared as a Biosphere Reserve by the UNESCO. But even this area was not enough to preserve the biological richness of the Guadalquivir marshes and surrounding sands, owed mainly to the increasing anthropic activity (agriculture, urban expansion, hunting, etc.), and in 1989 the Andalusian Government declared as

Natural Park an area of 54000 ha surrounding the National Park. As a result, the Doñana area, traditionally known as “Coto de Doñana” (coto meaning “hunting area”) forms one of the widest Spanish protected areas with more than 100000 ha.

Doñana area is located on the Atlantic coast of SW Spain bordering the estuary of Guadalquivir river (Fig. 1). Most Doñana area extends at the right side of the Guadalquivir, covering a wide area of SE Huelva and SW Sevilla provinces, but a part of the area, which belongs to Doñana Natural Park, is located in Cádiz province, at the left side of Guadalquivir river, close to the river mouth. This area is known as “Monte Algaida”.

Doñana area extends over three large land units: the stabilized aeolian sands, the mobile sand dunes and the Guadalquivir marshes, which include both salty and fresh-water marshes. Vegetation is very reach, with over 75 different plant communities covering the three land units.

The “Monte Algaida” includes only two of these land units: an area of stabilized aeolian sands, the “Monte Algaida pine forest”, and a wide area of salty marshes, which limit

Fig. 1. The study area.

the sands to the North and West. The stabilized aeolian sands form a band SW-NE oriented at the Doñana Natural Park, Cádiz province. The sands were formed at the coast and blown inland during the Quaternary over a sedimentary clay substrate on which the surrounding salty marshes develop. Isolated from the coast for centuries, the "Monte Algaida" pine forest does not receive any new sand input.

The salty marshes extends from the stabilized sands to the Guadalquivir river on the sedimentary clay platform. They hold a characteristic plant community dominated by *Arthrocnemum macrostachyum* (Moric) Moris, with a wide band of *Spartina densiflora* Brongn. community which extends along the river side and at the edges of several artificial chanels. Include four salt-works (Monte Algaida, Santa Teresa, San Carlos and Nuestra Señora del Rocío) two currently abandoned.

To the East, the stabilized sands are limited by arable fields resulting from drainage and reclamation of the salty marshes. To the South, the limits are formed by a small artificial lagoon (Laguna de Tarelo) and a series of orchards which extends towards the village of Bonanza and the city of Sanlúcar de Barrameda, and completely separate the stabilized sands from the Guadalquivir river mouth, c. 7 km away, and from the coast.

While many scientific studies have been developed at the wide territory which extends in Huelva province, especially at the Doñana Biological Reserve, Doñana National Park and parts of Doñana Natural Park, very little attention has been paid to the area covered by the Natural Park in Cádiz province ("Monte Algaida"), at the other side of Guadalquivir river.

As a part of a wide study of the flora and vegetation of Doñana area, this paper includes some observations on the main woody plant formations of the stabilized sands of "Monte Algaida" in comparison to what are considered the best preserved and representative plant communities of the same type of the main territory of Doñana area in Huelva province.

Material and methods

The study covers the area known as "Monte Algaida pine forest", this is, the stabilized aeolian sands, which form a band SW-NE oriented at the Doñana Natural Park, Cádiz province (Fig. 2). Neither the surrounding fresh-water communities, which form a very narrow and discontinuous band around the sands, nor the surrounding salty marshes vegetation are including.

The area has been regularly visited from January to the end of July 2004. Plant communities have been identified, and the species listed. When wanted, plant material has been collected and identified in laboratory.

For the recognized woody plant communities only woody species, including climbers, are listed, with the exception of the "Monte blanco" and the riparian *Populus alba* dominated community, where also perennial herbs are mentioned, as they are important components of these two communities.

Plant formations have been mapped at 1:10000 scale by using GPS and aerial photographs.

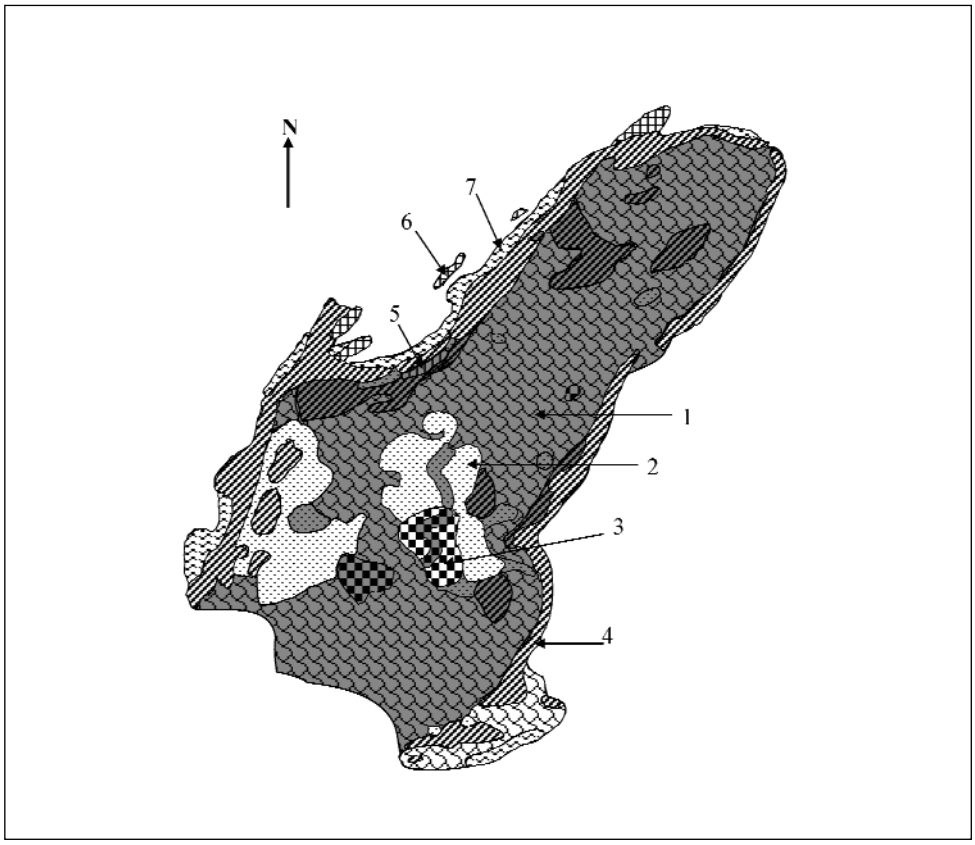

Fig. 2. Vegetation map of “Monte Algaida” pine forest: 1 - the juniper woodland, 2 - the “Monte Blanco”, 3 - the “Camarinal”, 4 - the “Lentiscar”, 5 - the *Tamarix* formations, 6 - riparian formations, 7 - herbaceous communities (gray: area planted with *Pinus pinea*).

Results

Plants in “Monte Algaida pine forest” exclusively depend from rain water. Water drains through the sands and accumulates at the bottom on the impermeable clay substrate. The slow flowing away of this water at the ridges of the sands during Autumm, Winter and Spring allows the presence of some fresh-water depending communities, such as some *Populus alba* L. communities, and herbaceous communities dominated by *Juncaceae*, mainly *Juncus effusus* L. and *J. acutus* L.

On the stabilized aeolian sands, as it is the general rule in Doñana area (see Allier & al. 1974), plant formations distribute according to water availability. Three plant formations cover the central higher parts of the stabilized sands, where water-table is deeper: the “sabinar”, a juniper woodland dominated by *Juniperus phoenicea* subsp. *turbinata* (Guss.) Nyman; the “Monte blanco”, a scrubland dominated by *Halimium halimifolium* (L.)

Willk., and the "camarinal" a scrubland dominated by *Corema album* (L.) D. Don.; they distribute according to the topography of the area and the distance of the surface to the water-table. A fourth community, non existing today in this area, is the coastal juniper plant community dominated by *Juniperus oxycedrus* subsp. *macrocarpa* (Sibth. & Sm.) Ball. Most probably this formation covered a certain area in Monte Algaida pine forest, as the only specimen still growing in the SE part of these sands was burned in 1994. Most of the characteristic species of this juniper forest are coincident with the *Juniperus phoenicea* woodland; and in any case its potential area has been covered by the later formation.

Two other plant formations occupy a more reduced marginal area, more or less in direct contact with the sedimentary clay substrate, where water is available most of the year: *Tamarix* plant formations and some communities dominated by *Populus alba*.

Another rather interesting floristically rich formation occupies a wide band between those two groups of communities (see Fig. 2): the "lentiscar", a scrubland dominated by *Pistacia lentiscus* L.

Most of the stabilized sands are covered by a planted forest of *Pinus pinea* L. It is not too dense, though, and allows the presence of the above indicated native plant formations.

The Juniper woodland

This low forest, which rarely exceedes 5 m in height, represents the most mature stage of succession in the xeric zones of the stabilized sands (Villar & al. 1997).

In Monte Algaida, the dominant species are: *Juniperus phoenicea* subsp. *turbinata* (Guss.) Nyman, *Rhamnus lycioides* subsp. *oleoides* (L.) Jahandiez & Maire, *Phyllirea angustifolia* L., *Cistus salvifolius* L., *Halimium calycinum* (L.) K. Koch, *Halimium halimifolium* (L.) Willk. and *Asparagus acutifolius*, and in a lower proportion, *Osyris quadripartita* Decne, *Rosmarinus officinalis* L., *Myrtus communis* L. and *Daphne gnidium* L.

All characteristic components of this juniper forest are present in Monte Algaida, but the main difference with the juniper forest of the main nucleus of Doñana area is the constant presence of *Pancratium maritimum* L., a species which characterizes coastal dunes, but which is very frequent in Monte Algaida, more than 7 km away from the coast.

The "Monte Blanco"

This is a scrubland dominated by *Halimium halimifolium* (L.) Willk., which substitutes the juniper forest in many areas and covers a wide area of the stabilized sands in Doñana area. The floristic composition in "Monte Algaida" is very poor, and in many zones is only represented by *H. halimifolium*, a species which also occurs in all plant formations on sandy soils, as a consequence of its plastic character and its ecophysiological control of water potential (Zunzunegui & al. 1997).

In "Monte Algaida" the Monte Blanco is formed by only two species: *H. halimifolium* and *H. calycinum* (L.) K. Koch, with a single specimen observed of *Stauracanthus genistoides* (Brot.) Samp. In Doñana area, Huelva province, the Monte Blanco is a very rich community formed mainly by *Cistaceae*, *Labiatae* and *Leguminosae*. Apart from the former three species, the following are characteristic components of this plant formation in the areas where it is better preserved: *Lavandula stoechas* L. subsp. *luisieri* (Rozeira) Rozeira, *Thymus mastichina* subsp. *donyanae* Morales, *Rosmarinus officinalis* L., *Helianthemum hirtum* (L.) Miller, *Cistus libanotis* L., *Ulex australis* Clemente, *Ulex erio-*

cladus C. Vicioso, *Cytisus grandiflorus* DC., *Scrophularia frutescens* L., *Helichrysum picardii* Boiss. & Reut., *Thymus mastichina* subsp. *donyanae* Morales, and the perennial herbs *Dianthus hinoxianus* Gallego, *Iberis contracta* subsp. *welwitschii* (Boiss.) Moreno and *Euphorbia baetica* Boiss.

The “Camarinal”

This is a scrubland dominated by the *Empetraceae Corema album* (L.) Don, endemic of the atlantic coast of the Iberian Peninsula (from La Coruña to Cádiz provinces) and the Azores Islands. In Doñana area this plant formation is related to the forests of *Juniperus phoenicea* subsp. *turbinata* and *J. oxycedrus* subsp. *macrocarpa* of which *Corema album* is one of the component species.

In Huelva province the “Camarinal” is formed by *Corema album* (L.) D. Don, *Halimium calycinum* (L.) K. Koch, *Rubia peregrina* subsp. *longifolia* (Poiret) O. Bolós, *Helichrysum picardii* Boiss. & Reut., *Asparagus aphyllus* L. and *Daphne gnidium* L. The “Camarinal” of “Monte Algaida” is represented only by *Corema album*. Its recognition is not clear and it could be consider as a mere component of the juniper forest.

The “Lentiscar”

This is a dense shrubby formation up to 4 m height dominated by *Pistacia lentiscus* L., which in Doñana area constitutes a phase of degradation of *Quercus suber* L. forests.

In “Monte Algaida” the “lentiscar” forms a band around the stabilized sands, which extends between the juniper woodland and the scrubland of *Halimium halimifolium* and the *Tamarix*, *Populus alba* and herbaceous communities which occupy the marginal area, in contact with the clay substrate. It is a rich community formed by *Pistacia lentiscus* L., *Phillyrea angustifolia* L., *Rhamnus lycioides* subsp. *oleoides* (L.) Jahandiez & Maire, *Rhamnus alaternus* L., *Myrtus communis* L., *Ruscus aculeatus* L., *Cistus salvifolius* L., *Chamaerops humilis* L., *Aristolochia baetica* L., *Clematis cirrhosa* L., *C. flammula* L., *Daphne gnidium* L., *Rubia peregrina* subsp. *longifolia* (Poiret) O. Bolòs, *Smilax aspera* L., *Tamus communis* L., and in some spots *Cytisus grandiflorus* L. Then, all woody taxa which characterize the “Lentiscar” of Doñana area except *Quercus coccifera* are present in “Monte Algaida”, where its plant composition is closer to those of “Coto del Rey” at the North of the Guadalquivir marshes, than to those at other parts of Doñana area (see Rivas Martínez & al. 1980).

Riparian formations

Riparian forest dominated by *Populus alba* L. are not widespread in Doñana area, where they occupy wet fresh-water area which are rarely over-flowed. Their floristic composition is rather rich and includes trees, shrubs, climber and herbaceous species.

In “Monte Algaida”, this plant formation is reduced to a short and narrow band between the “lentiscar” and the salty marshes and periferal wet areas covered by *Tamarix* formations and herbaceous communities dominated by *Juncaceae*. Consequently, *Populus alba* is accompanied by some species which are characteristic of riparian formations, together with species from the surrounding plant communities.

The main components, including perennial herbs are: *Populus alba*, *Tamarix africana* Poiret, *Rubus ulmifolius* Schott, *Pistacia lentiscus* L., *Myrtus communis* L., *Phillyrea*

angustifolia L., *Clematis cirrhosa* L., *Smilax aspera* L., *Aristolochia baetica*, *Lonicera periclymenum* L., *Arum italicum* Miller, *Iris pseudacorus* L. and *Bryonia cretica* subsp. *dioica* (Jacq.) Tutin. Four species which characterise these riparian forest in Doñana area are missing at "Monte Algaida": *Fraxinus angustifolia* Vahl, *Ranunculus ficaria*, *Crataegus monogyna* Jacq. and *Tamus communis* L. In a way, it seems as if the "Lentiscar" had invaded the area which should have been occupied by a riparian now most degraded forest.

The Tamarix formations

In Doñana area, *Tamarix* grow on temporary overflowed soils with high clay content and some salinity. In "Monte Algaida" this formation is much degraded, often overgrazed and formed in some places almost exclusively by old and depauperate specimens of *Tamarix africana* Poiret. It covers some marginal places mostly within the area covered by salty marshes. The most constant accompanying species is *Asparagus acutifolius* L., and close to the fresh-water herbaceous formations, *Phragmites australis* (Cav.) Trin.

A Cerinthe gymnandra community

A peculiarity of "Monte Algaida" pine forest is the widespread presence of a plant community dominated by the annual *Cerinthe gymnandra* Gasp. and the geophytes *Arum italicum* Miller and *Narcissus papyraceus* Ker-Gawler. While *Arum italicum* is a common component of riparian vegetation at Donaña area and is also present in the *Quercus suber* forests and often in the wet areas of the "lentiscar" (see Rivas Martínez & al. 1980), *Narcissus papyraceus* is very rare and had only been punctually indicated for some riparian areas, while *Cerinthe gymnandra* had not even been recorded for Doñana area.

At "Monte Algaida" *C. gymnandra* and *Narcissus papyraceus* occur in all open areas of the wide band of "lentiscar" with independence of the edaphic humidity. The associate populations of both species are, however, particularly dense when soil humidity increases, where the presence of *Arum italicum* is more frequent.

The position of this community, which is also formed by other herbaceous species, on soils with a higher or lower proportion of clay may explain the abundance of these three species, particularly *N. papyraceus*.

Phytosociologically, this community should be included in the class *Stellaretea mediae* R. Tx, Lohmeger & Preising in R. Tx. 1950, em. Rivas Martínez 1977 (Synonym: *Rudereto-Secalinetea* Br.-Bl. 1936), in spite of the fact that two of the characteristic species are perennial.

Discussion

Centuries of longstanding human intervention in Doñana area to exploit natural resources, has altered the plant communities to their present composition. Reduction of the original woodlands to profit timber and coal, periodical local clearing by fire to increase pastures, intense agriculture transformation of marshes and stabilized sands and planting of pines and eucalyptus, especially during part of the 20th century are the main factors which have modify native vegetation (Granados & al. 1987, 1988; García Novo 1997; García Murillo & Sousa 1999).

However, from 1964 the protective measures have been implemented in the area with the formation of the Doñana Biological Reserve first, followed by the declarations of Doñana National Park and Doñana Natural Park. Land management has favored natural vegetation recovering. Certainly, the resulting actual plant formations may greatly differ from the original in much of the area. But there are many, sometime extensive, spots where vegetation must represent more closely the original situation, on account of their floristic richness and the singularity of its components.

All woody plant formations of "Monte Algaida" pine forest but the "lentiscar", when compared with those more representative examples of the same formations at the main part of Doñana area, in Huelva province, show a poor and degraded floristic composition. Many of the most characteristic species are missing, which seems to indicate that plant communities at "Monte Algaida" pine forest are in clear regression owed, most probably, to the lack of new sand input by wind from the coast, as the stabilized sands are now completely separate from the coast by the orchards, farms and building which extend from the forest to the city of Sanlúcar de Barrameda, to the limited extend of the aeolian sands which do not allow a long term retention of rain water, and mainly to anthropic pressure.

Three anthropic actions have had higher incidence in the dynamics and actual composition of "Monte Algaida" woody plant communities: pine plantation, fire and nitrification. Most of the area was planted with *Pinus pinea* by previous clearing of the vegetation. The vegetation has recovered, but the floristic composition of resulting communities greatly differ from the original, if as original are understood the better preserve equivalent formations at the main part of Doñana area at the other side of Guadalquivir river (Huelva province). This may be the reason why the "lentiscar" is the best preserved plant formation, as most of its area is outside the pine forest.

The second factor must have been the fire. Last fire occurred in 1994, when a small area where the last old specimen of *Juniperus oxycedrus* subsp. *macrocarpa* still persisted, was burned. The fact that in this and other spots the "Monte blanco" is formed by only *Halimium halimifolium* indicates fire action, as this is the species of this community better adapted to fire (and also to cutting) by sprouting.

Besides, some spots of "Monte Algaida" are used as recreative areas by people from the neighboring city of Sanlúcar de Barrameda. The progressive nitrification, which is patent in many herbaceous communities not included in this note, must be the response to this land use, and may also be responsible for the wide presence in the area, more than 7 km away from the coast, of *Pancratium maritimum*, which at the coast of Doñana area is especially frequent in nitrified and ruderalized coastal areas, as near Matalascañas tourist resort and wide areas of the beach between Matalascañas and Mazagón intensely used by tourists. Maybe that the widespread presence of the plant community dominated by *Cerinthe gymnandra*, *Narcissus papyraceus* and *Arum italicum* is also a response to the nitrification.

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