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Agricultural development vs biodiversity conservation: the Mediterranean semiarid vegetation in El Ejido (Almería, southeastern Spain)

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The development of a greenhouse agriculture in the traditionally impoverished region of Poniente de Almería, on the Mediterranean coast of Spain, has caused an enormous rise in living standards. However, the environmental impact of this badly-planned growth threatens the very dynamics of the exploitation system. A special examination must be made of the use of the three major resources responsible for the functioning of greenhouse production and its impact on the ecosystems and particularly on the vegetation. These resources are: clayey soils, sand from fossil dunes and ground water. While the use of the clayey soils and sand have negative effects on the conservation of ecologically valuable communities found nowhere else in Europe, ground water overexploitation has produced an increase in salinity in most of the aquifers. Of these, sand has been by far the best monitored resource and restoration programmes have been implemented in the extraction zones. This survey deals with the recent evolution of areas where the arto (*Maytenus senegalensis* subsp. *europaeus*) and the sabina (*Juniperus phoenicea* subsp. *turbinata*) have long been the dominant species, although the presence of the former is nowadays notoriously diminished. The study is based on aerial photographs taken in 1957, 1977 and 1985, together with our own field work. Curiously enough, all this man-made process of degradation has stimulated ornithological diversity. Finally, we propose here some measures which aim to preserve the most important enclaves of these Mediterranean shrub formations, specially those of the arto, since sabina-dominated communities already belong to existing conservation areas.

Keywords: environmental impact; *Maytenus europaeus*; dunes vegetation; birds diversity; restoration of degraded areas.

Introduction and area under study

The region of Poniente de Almería encompasses Llanos de El Ejido and Campos de Dalías. Located in the southwest of the province of Almería, in semiarid southeastern Spain, it comprises a large, mildly undulating plain of 30 000 ha that extends from the slopes of Sierra de Gádor to the sea (Fig. 1). Lying on the Alpujárride basement complex, this mainly flat area descends to sea level in stages which have their origin in ancient Quarternary sea cliffs. Its connection with Sierra de Gádor is provided by a system of

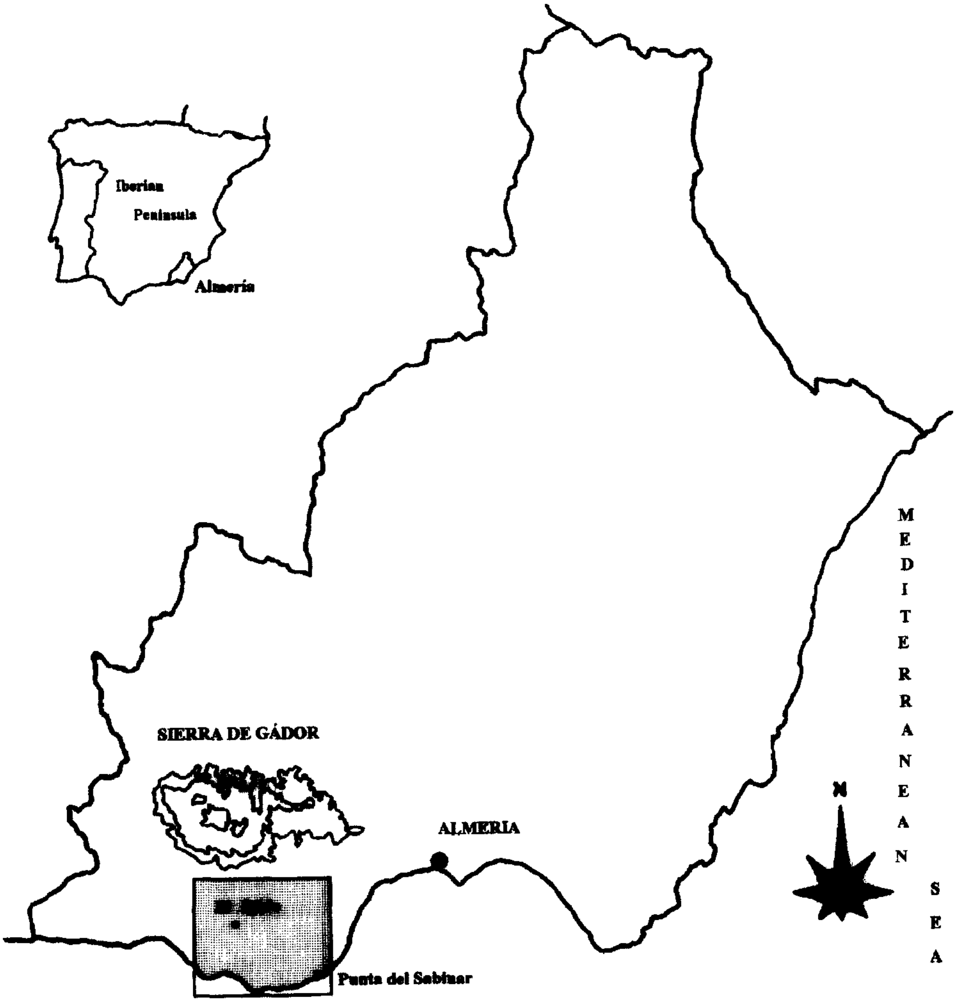


Figure 1. The location of study area in southeastern Spain.

alluvial fans (Goy and Zazo, 1986a). All over the area there are layers of sandy limestones and marine Pliocene calcarenites covered by Quaternary sand and conglomerates (Dabrio *et al.* 1985; Goy and Zazo, 1986b). During the Quarternary, this abrasion platform underwent marine transgressions and regressions together with fractures nowadays concealed by fluvial deposition.

The area, an internal drainage basin, consists of an irregular net of gullies and ravines which originate in Sierra de Gádor and descend to supralittoral altitude but do not reach the sea. Although karstic springs may occasionally nurture these gullies, water is mainly provided in the form of torrential rain, which accounts for the high risk of flooding in the area.

The southern part of this plain, an ancient marine terrace, presents immature soils (lithosols and regosols), of high salinity, covered, for the most part, by a calcareous crust which makes them unsuitable for agriculture. Between this area and the Sierra piedmont glacis, there exists a slightly depressed corridor with soils of a better quality (calcareous regosols). This corridor, developed on Quaternary *terrae rosae* (Pérez Pujalte and Oyonarte, 1987), extends from west to east. In the Holocene epoch a series of sedimentary alluvia and facies give rise to deposition beaches, wind drifts, dunes and salt marshes along the coastline.

Annual rainfall ranges from over 200 mm in Almería, the capital city of the province, to almost 300 mm on the west side of the area under study. Peak values occur in winter (December and January), and the second-highest in spring. Temperatures are moderate. The lowest values are recorded in December or January, although even during this period the average temperature is never below 6 °C. The proximity of the sea explains the narrow temperature fluctuation, some 13 °C. A rainfall distribution and temperature data are typical of a Mediterranean climate (Archibold, 1995).

Human presence in the area can be traced back to Neolithic times, since Argar pottery and tools have been found in El Ejido. There also exist traces of livestock-raising and esparto-harvesting (*Stipa tenacissima*) during the Roman period. Later, Moorish stockbreeders from Sierra Nevada used the region as winter pastureland, a practice in use until recently. At that time, both irrigation and dry farming (olive groves and white mulberry) were also found. Land communications with the region were always extremely difficult. Until 1870, the major road entering the area was nothing more than a dirt track for local use. The current transformation of the landscape began with extensive irrigation plans and active measures against soil salinity. The addition of sand to the soil began in 1957, and the first greenhouses built in the 1960s were only a prelude to their enormous expansion during the 1970s (Table 1).

Favourable relief and climate conditions explain the recent agricultural development of this coastal area. Mountain ranges form an orographic barrier which protects the Mediterranean littoral from cold north winds, producing a moderate winterless bioclimate. In addition, the high peaks concentrate sufficient moisture in winter to recharge the ground water network and compensate the meagre rainfall of the low-lying land.

These extraordinarily favourable conditions for early harvesting have been further stimulated by three technological innovations which have caused a dramatic increase in production. Firstly, the arrangement of successive layers of clayey soil, organic fertilizer and sand on the uncultivated land has extended crop acreage and improved farming areas. Secondly, the use of plastic film to fit greenhouses has, as its most notable effect, the early

Table 1. Socioeconomic development of the area between 1963 and 1991. (Source: Agencia de Medio Ambiente)

Year	Cultivated surface area (ha)	Cultivated area with greenhouses (ha)	Number of inhabitants	Production (t)	Turnover sales ($)
1963	1000	0	55 000		
1971	4000	1.14	69 059		
1979	1590	5864	92 882		
1984	960	10 000	100 000	1150	350×10^6
1987	700	11 600	108 858	1120	415×10^6
1991	600	14 400	125 000	1155	650×10^6

harvesting of crops, at a time when there is a severe shortage on European markets. Thirdly, the use of drip-irrigation systems has so far alleviated the water deficit.

It is not surprising that this area has been quoted as an outstanding example of spectacular economic growth in a region ill-provided with natural resources and, until recently, farmed by traditional methods (García-Dory, 1991). Politicians and economists use this process as an example of a magnificent combination of human imagination, use of unexploited resources and the extensive application of state-of-the-art agricultural techniques. The 'Almeriense economic miracle' well justifies its name, since the living standards have risen so dramatically in the region that the isolated and hand-to-mouth economy of the 1950s has given way to one of the highest incomes *per capita* in the country. What we have here is a huge economic development based upon the remarkable transformation of traditional farming patterns into a new and highly profitable agriculture which uses industrial production methods.

Such tremendous growth and massive exploitation of the resources have given rise to many environmental problems. Since the Western model of efficiency is usually measured in terms of production rates (McNeely, 1994), a further consideration of the vulnerability of those resources is rarely made. Nature is seen as something operating on its own (Hoerr, 1993) and man's action is always justified it if leads to a greater control of nature and larger profits. The changes taking place in El Campo de Dalías exhibit all the features of the Western way of life. A former semidesert landscape, as regards its vegetation and climate conditions, is now devoted to extensive farm production with some sizable urban settlements.

The attitude of society and public agencies has been of little help, since they have always considered most of the current farming areas as former wastelands of no ecological value. This encouraged indiscriminate exploitation and gave rise to a huge influx of population in search of work which showed no regard for the natural resources.

Among the main ecologically negative impacts affecting the region, special mention must be made of:

(1) the reduction of natural habitats,
(2) the tremendous increase in population,
(3) an increase in the destructive effects of cattle-breeding, since pasturelands have been reduced in extension, and finally,
(4) the disposal of solid and chemical pollutants which may seriously damage the nutrient cycle.

In this last respect, it is clear that all this intensive farming encourages the incidence of crop pests. The subsequent use of highly toxic pesticides ultimately destroys useful insects such as pollinators, predators of other harmful species or simply vital links in the ecosystem.

Our aim in this work is to examine the use being made of the three major natural resources for greenhouse production (Table 2): (1) the clayey soil (natural habitat of the arto, *Maytenus europaeus*, communities), (2) sand from fossil dunes (where the sabina, *Juniperus phoenicea* subsp. *turbinata*, communities prosper) and (3) ground water. It is important to note that these last two resources are supplied well below market prices (Muñoz and Requejo, 1991).

The indiscriminate exploitation of these natural resources, together with the fragmentation of plant habitats, have harmed several vegetation communities to the extent of destroying them partially or totally. However, the new man-made habitats have caused

Table 2. Consumption of inputs and environmental impact

Resources	Annual consumption of inputs	Related environmental impact
Soil	300 ha	• Illegal construction of greenhouses • Destruction of arto communities
Water	110×10^6 m^3	• Net contribution of reserves of 22×10^6 m^3/year • Marine intrusion: 4×10^6 m^3/year
Sand	300 000–400 000 m^2	• Change in the coastline • Destruction of lentisco-sabina communities on stable dunes
Clayey soil	1650 000 m^3	• Opencast quarries which have not been relandscaped • Destruction of arto communities • Pollution of the aquifer
Organic fertilizers	436 000 t	• Ever-increasing eutrophication of the aquifer (over 100 mg^{-1}/1 nitrates) • Water of some of the wells no longer suitable for drinking
Mineral fertilizers	27 000 t	• As for organic fertilizers
Plastic	15 000 t	• 40% is not recycled • Some uncontrolled burning of the plastic: pollution of the atmosphere • Illegal rubbish dumps: deterioration of the landscape
Pest control products	1060 $ per ha	• High levels of heavy metals in water • Metabolites of pesticides in concentrations below 10 PPB
Seeds	18 000 Kg	• Ever-increasing incidence of seed-transmitted plant diseases

richer bird communities to appear and this leads to a paradox in the policy of biodiversity conservation.

Maytenus senegalensis subsp. *europaeus* has been, among other valuable species, the most seriously harmed by the agricultural development, which has also affected, to a lesser extent, the formations of *Juniperus phoenicea* subsp. *turbinata*.

Maytenus senegalensis belongs, along with the cornical (*Periploca laevigata* subsp. *angustifolia*), azufaifo (*Ziziphus lotus*) and sabino (*Tetraclinis articulata*) communities to the Iberian group of the *Periplocion angustifoliae* phytosociological alliance (Peinado *et al.*, 1992). All these taxa are restricted to coastal zones of the Iberian Peninsula and only extend into the interior along the valleys of the Andarax, Almanzora and Guadalentín rivers (Fig. 2). Their ecological value arises from the fact that they are found nowhere else in Europe. Only in Morocco have other related formations been observed (Benabid and Fennane, 1994). The 92/43 EEC Bill (31. 17 *Ziziphus Shrubs*) paid particular attention to these plant assemblages declaring them of interest to the Community and recommended

Figure 2. Distribution of communities where junipers and sabina are the dominant species. Spread of phytosociological alliance *Periplocion angustifoliae* in the Iberian Peninsula and North Africa.
= Distribution of Juniperus turbinata associations. ■ Spread of alliance Periplocion angustifoliae.

Phytosociological names for Iberian, Balearic and Moroccan associations of *Juniperus phoenicea* subsp. *turbinata* (= *Juniperus phoeniceae* subsp. *lyciae* auct.): (1) *Osyro quadripartitae–Juniperetum turbinatae*; (2) *Rhamno oleoidis-Juniperetum macrocarpae*; (3) *Rhamno angustifoliae-Juniperetum turbinatae*; (4) *Ephedro distachyae-Juniperetum macrocarpae*; (5) *Clematido balearicae-Juniperetum turbinatae*; (6) *Clematido cirrhosae-Juniperetum lyciae (turbinatae)*; (7) *Rhamno rotundifoliae-Juniperetum lyciae (turbinatae)*.

the creation of special conservation areas (European Communities (EEC Bill), 1992). As Fernández Casas and Sánchez (1972: 24) noted, the arto communities of *Maytenus senegalensis* subsp. *europaeus* of Campos de Dalías, in the local district of El Ejido (Almería), are the best preserved and they give rise to a unique semiarid ecosystem.

Maytenus senegalensis (Lam.) Exell is a species of wide distribution. It occurs frequently in the tropical zones of Asia and Africa and enters the Mediterranean area via Morocco. Some botanists who have worked in the Iberian Peninsula and North Africa recognize a new taxon in this region. However, the classification of Güemes and Crespo (1990), which describes it as a subspecies, is now widely accepted. This indigenous taxon is found quite commonly along the North-African and Iberian coasts (always in areas with rainfall below 400 mm), but it is only in the area under study where, due to climatic and biogeographic conditions, that it is the climax vegetation.

Up to now these communities had not been mapped in detail, and some recent surveys (Ruiz de la Torre, 1990) had even omitted them, either because of their limited dimension or because the overwhelming presence of esparto (*Stipa tenacissima*) and thyme (*Thymus hyemalis*) stands concealed them.

The lentisco-sabina assemblage (*Pistacia lentiscus* and *Juniperus phoenicea* subsp. *turbinata*) is present on the dunes which limit the area near the sea to the south. There is only one other place along the Mediterranean coast of Spain where formations of this sort can be found: Dehesa del Saler, in the province of Valencia. Closely-related communities, where junipers and sabina are the dominant species, are also present in the Balearic Islands, Sicily, Morocco and the Atlantic south coast of Spain (Fig. 2). These communities, like those of arto, are also mentioned in the 92/43 EEC Bill (see Maritime dunes on the shores of the Mediterranean) (European Communities (EEC Bill), 1992).

Materials and methods

Our research on the *Maytenus senegalensis* subsp. *europaeus* and sabina communities was carried out only within the local district of El Ejido, in the province of Almería, because in no other region do these communities flourish so vigorously. Therefore, our study is based on those localities which in 1957 had more or less continuous and sizable spots of arto.

Aerial photographs taken in 1957, 1977 and 1985 have provided considerable information in our research. The peculiar physiognomy of these plant communities, formed by hedge-like gregarious taxa, provides easy visual identification as tiny dark spots. These spots present a more or less circular profile and their distribution is scattered and never forms a solid mass. This fact explains the extensive presence of other taxa, such as esparto and thyme among others, within the mapped stands. Field work data have served to complete aerial information, particularly with regard to arto communities. This survey also includes useful field observations from our previous study in 1983 on these communities and their state of conservation. A good deal of the data shown in Table 3, constructed according to the method of Braun-Blanquet (1928), were recorded at that time.

A brief description of the state of *Maytenus senegalensis* subsp. *europaeus*, in notorious regression nowadays, is given. This includes a scale of 1 to 3 applied to naturalness, the percentage cover of the arto communities within the mapped stands, associates, environmental impact, etc. We also studied the succession of the lentisco-sabina assemblage from the period of the removal of the presumed original vegetation cover, and the changes affecting the bird communities.

Results

The impact on arto communities

Due to the apparent gregarious character of arto communities, they occur closely packed and tangled with other associates. The final result is a badly-structured, almost circular bulk of thorny shrubs, climbers, scrub and bushes (Table 3) which reaches up to 4 m in height. These semispherical natural hedges are found some meters apart one from the other.

The communities studied can be divided into two major groups. Those to the north, on the calcareous soils of Sierra de Gádor and the large alluvial fans at the foot of the mountains, appear in association with *Genista retamoides* and *Sideritis foetens*. To the south, the plant communities extend on an internal drainage basin made up of conglomerates at the foot of the sierra. In this case, *Caralluma europaea*, *Androcymbium europaeum* and other interesting flora are sometimes to be found.

The area already colonized by these communities in 1957 is made up of seven large sites (Fig. 3): Llano del Aguila, Llano de la Maleza, Loma de Onayar, Loma de la Mezquita, Loma Blanca and Soto Tablas-Loma del Hornillo. A diachronic examination reveals that

Table 3. Phytosociological factors in stands of *Maytenus senegalensis* subsp. *europeus* communities (*Mayteno-Ziziphetum loti* Fernández Casas, 1970) in the area under study

Stand number[a]	1	2	3	4	5	6	7
Altitude (m × 10)	5	5	4	6	5	5	14
Cover (%)	100	80	90	95	95	85	80
Orientation	–	–	SE	W	–	–	S
Slope (°)	–	–	10	5	–	–	5
Area (m^2)	90	300	120	260	270	150	90
Characteristic taxa of ass. and higher unities							
Maytenus europaeus	4	3	4	4	4	3	3
Ziziphus lotus	.	3	+	.	.	.	1
Asparagus albus	2	1	2	1	2	1	2
Rhamnus angustifolia	2	1	2	1	2	3	3
Asparagus horridus	.	.	+	+	+	+	1
Phlomis almeriensis	.	.	.	.	.	.	+
Rubia longifolia	1	2	.	1	2	1	1
Olea sylvestris	1	.	1	1	.	1	+
Whitania frutescens	2	2	2	3	2	2	+
Ephedra fragilis	.	.	.	1	.	.	.
Accompanying[b]							
Salsola genistoides	+	+	.	.	.	.	.
Lycium intricatum	+	1	+	+	+	1	.
Ballota hirsuta	+	+	+	1	1	+	.
Fagonia cretica	+	1	1	1	+	1	.
Helianthemun scopulorum	+	1	.	1	.	.	.
Helianthemun almeriense	.	.	1	.	.	.	.
Thymus hyemalis	+	1	+	.	.	.	2
Ruta chalepensis	+	.	+	+	+	+	.
Piptatherum miliaceum	+	.	1	1	1	.	1
Phagnalon rupestre	+	+	+	.	.	.	.
Artemisia barrelieri	+	.	.	.	.	.	+
Teucrium eriocephalum	+	+	+	+	+	+	.
Plantago albicans	+	.	.	.	.	.	.
Teucrium bellium	+	1	+	+	.	+	.
Caralluma europaea	.	.	1	.	.	.	.
Satureja obovata	.	.	+	.	+	.	+
Thymelaea hirsuta	.	.	.	+	.	+	.
Lavandula multifida	.	.	.	+	.	.	1
Phagnalon saxatile	.	.	.	.	+	+	+

[a]Localities: (1) Proximity to Sto. Domingo; (2) Road Sto. Domingo-Almerimar; (3) Loma de Onayar; (4) and (5) Loma de la Mezquita; (6) Cuevas del Mojón; (7) Llano del Aguila.

[b]In addition: in 3: *Polygala rupestris* +; in 4: *Lapiedra martinezii* +; in 5: *Salsola oppositifolia* 1, *Sedum sediforme* +, *Suaeda pruinosa* +; in 7: *Fumana laevipes* 1, *Paronychia suffruticosa* +, *Dactylis glomerata* +, *Teucrium capitatum* +.

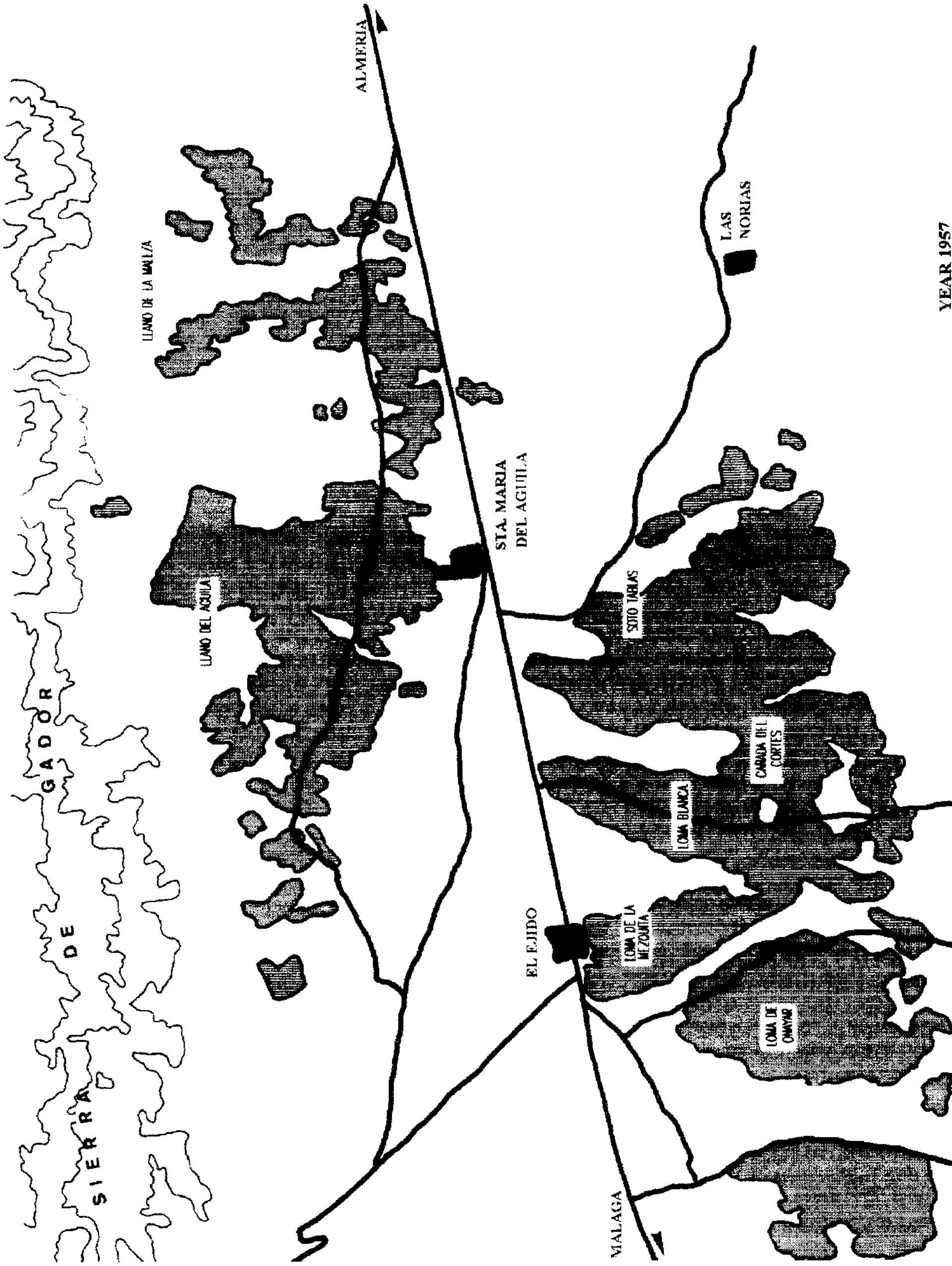


Figure 3a. Areas occupied by *Maytenus senegalensis* subsp. *europaeus* communities within the local district of El Ejido (southeastern Spain) in 1957.

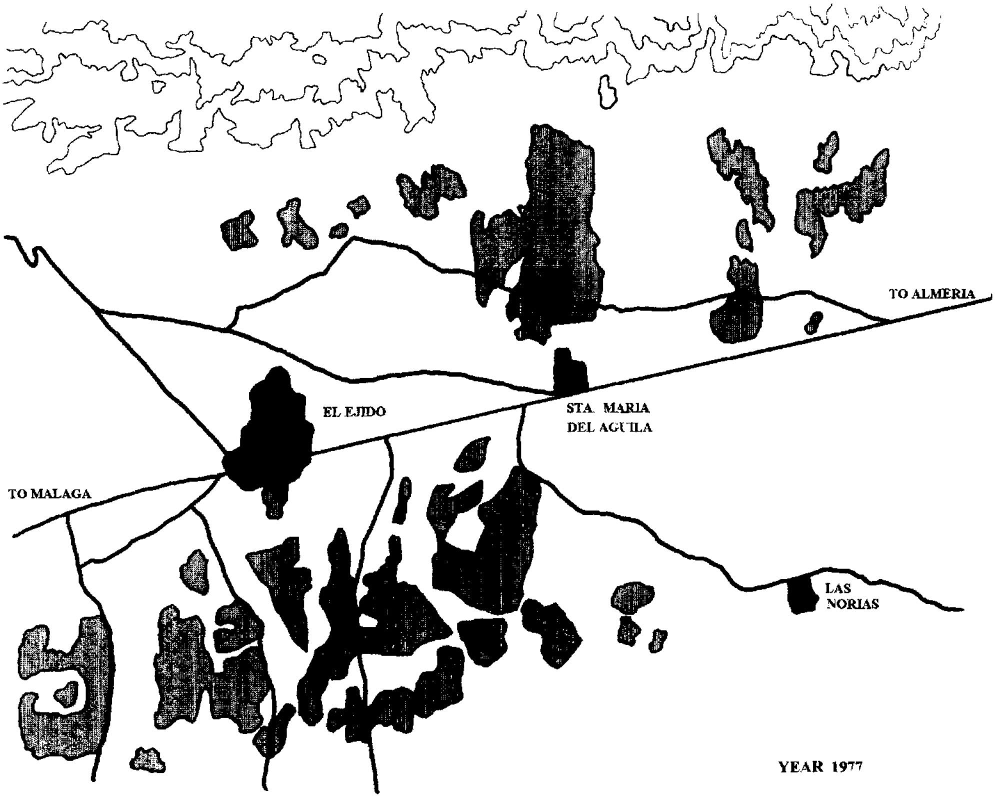


Figure 3b. Areas occupied by *Maytenus senegalensis* subsp. *europaeus* communities in 1977.

the size of each spot has diminished dramatically and today they present a very fractured distribution. Table 4 shows how dramatic this regression has been.

This situation can be likened to that already described by Wilcove *et al.* (1986), where fragments of the original habitats are often isolated from one another by agricultural fields. When dealing with similar cases, Primack (1993) depicts them as, 'habitat-islands in an unhospitable agricultural sea'. Habitat fragmentation dramatically increases the ratio of edge to interior habitat. The most important edge effects are microclimatic changes in

Table 4. Change in the size of the area covered by *Maytenus senegalensis* subsp. *europaeus* over almost 40 years in the region under study

Year	Area occupied by arto communities (ha)	Area no longer colonized by arto communities (ha)	Percentage of deteriorated area
1957	2370	?	?
1977	1450	920	38.8
1984	530	920	77.6
1994	202	328	91.5

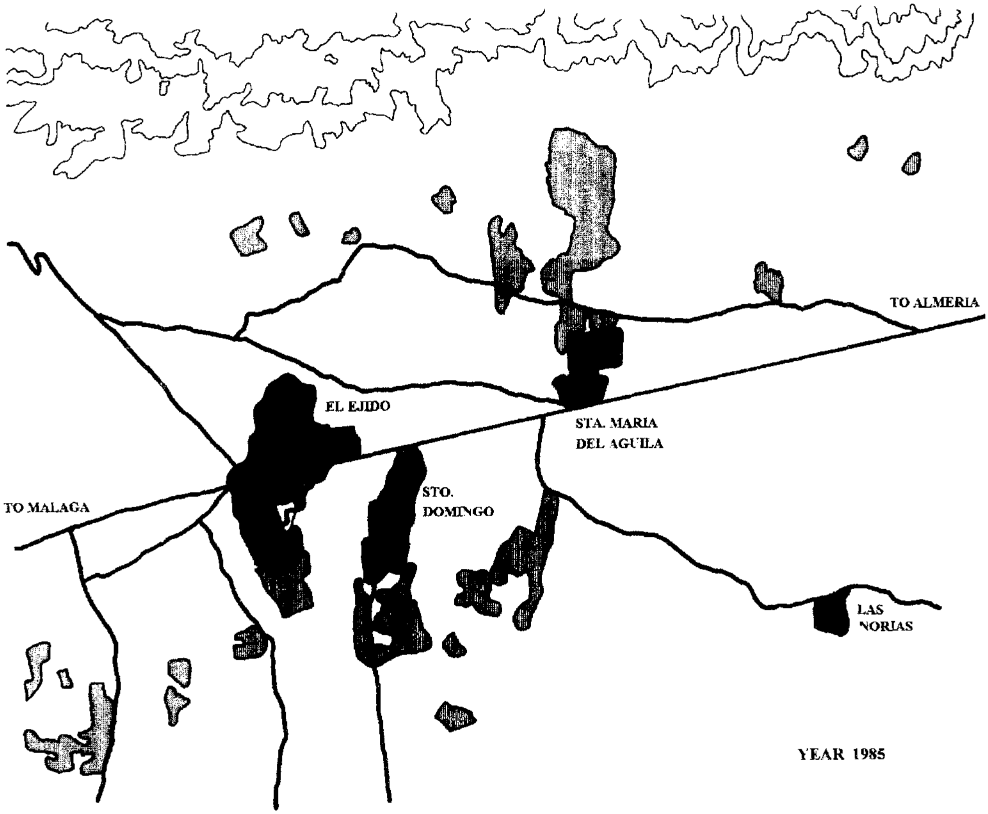


Figure 3c. Areas occupied by *Maytenus senegalensis* subsp. *europaeus* communities in 1985.

light, temperature, specific richness, etc. (Simberloff and Gotelli, 1984; Laurence, 1991; Bierregaard *et al.*, 1992).

Habitat fragmentation can also affect animal communities (Terborgh, 1992). The importance of conservation corridors to reduce these effects has been already stressed by some authors (Simberloff and Abele, 1982; Simbeloff and Cox, 1987).

Table 5 gives a precise idea of the current state of the vegetation spots dominated by the arto. Numbers correspond to those shown in Fig. 3d. Other species have also been dramatically reduced by the environmental changes. Of these, more than 12 are mentioned in a recent bill of the Andalusian Autonomous Government which includes an inventory of endangered wild flora (BOJA, 1994). No doubt, the most seriously affected species are the above mentioned *Caralluma europaea* and *Androcymbium europaeum*, described according to IUCN categories as 'vulnerable' (V) and as 'endangered' (E), respectively. Until recently, Campos de Dalías and El Ejido comprised some of the best examples of these two taxa. Other species listed in the inventory are: *Salsola genistoides* (nt), *Salsola webbi* (nt), *Helianthemum almeriense* (R), *Phlomis purpurea* subsp. *almeriensis* (nt), *Sideritis foetens* (nt), *Sideritis pusilla* (nt), *Teucrium eriocephalum* subsp. *almeriense* (nt), *Thymus hyemalis* (nt) and *Linaria oligantha* (R).

The tremendous reduction of the areas previously occupied by arto communities is mainly due to the demand for clayey soil for the preparation of greenhouses (1650 000 m^3

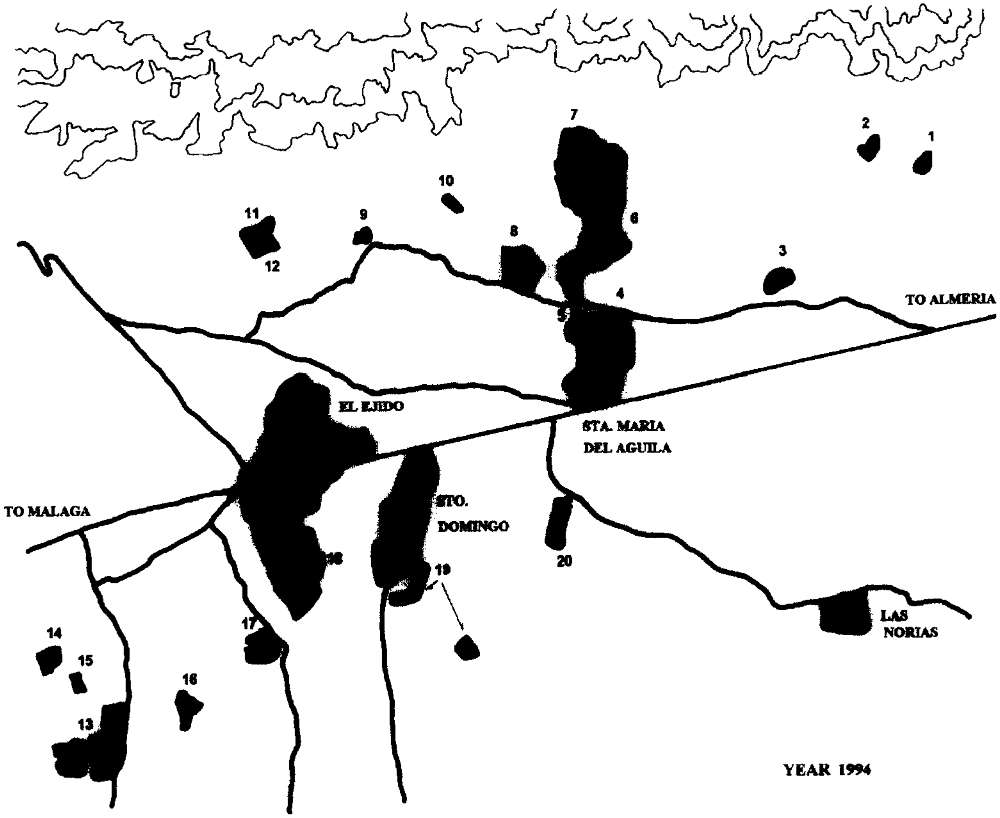
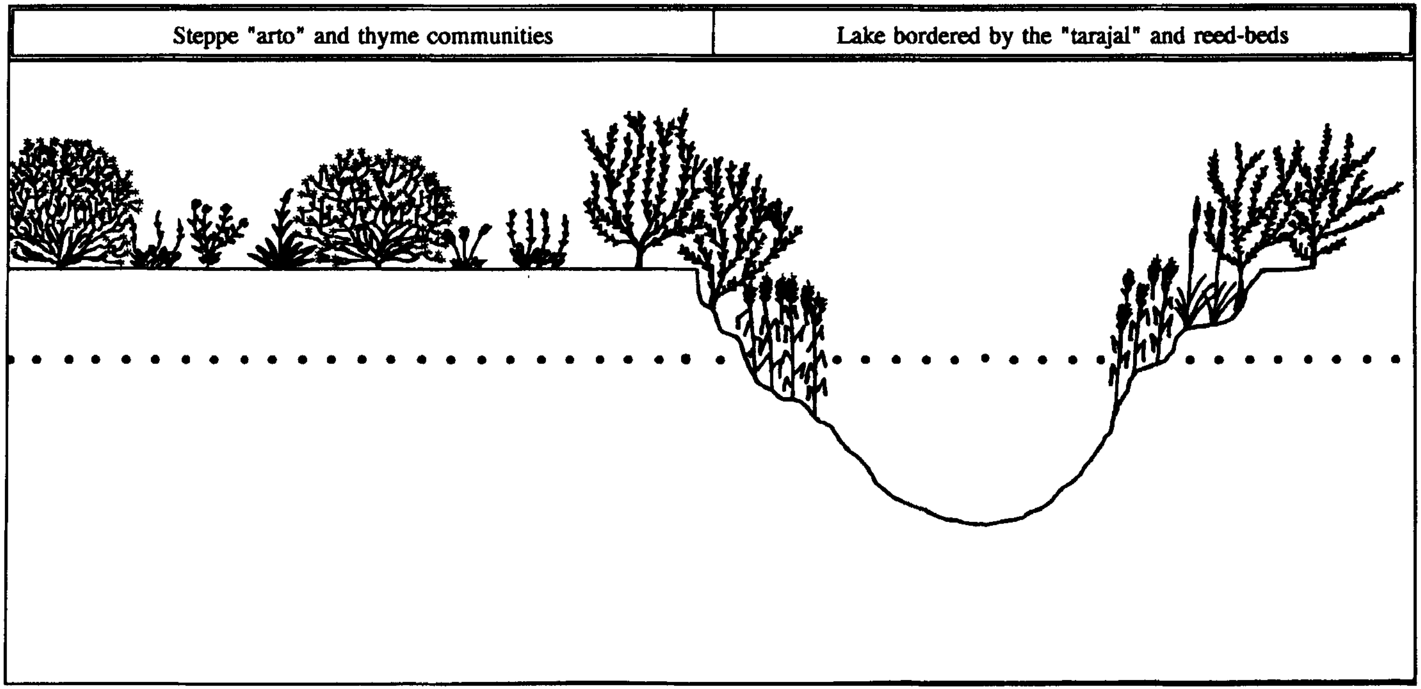


Figure 3d. Areas occupied by *Maytenus senegalensis* subsp. *europaeus* communities in year 1994.

per year), since from the early 1980s many open-case quarries have appeared on the sedimentary corridor crossing the region. These quarries, with a mean depth of 10 m, are abandoned as soon as the water table of the central superior aquifer of Balanegras-Las Marinas is reached (Fig. 4). This aquifer has undergone marine intrusion and nowadays the ground water recharge supplied by the irrigated lands exceeds the amount of water extracted (Alonso-Cobos, 1989). As a result, the abandoned quarries have been replaced by a lake of 130 ha. known as Laguna de las Norias, the fourth in size in the province of Almería.

Two nesting species of extraordinary interest, the marbled teal (*Marmaronetta angustirostris*) and white-headed duck (*Oxyura leucocephala*) are present in the bird communities of the Laguna de las Norias. The population of marbled teal in Europe is found mainly in Spain and its number has decreased by 90% in this century (Navarro and Robledano, 1992). In the last few years, the total population in Spain ranged from 50 to 200 couples, 90% of them nesting in Andalusia (Mañez, 1991; Green, 1993). Laguna de las Norias is of vital importance for the preservation of this species.

The European population of white-headed duck is mainly found in Turkey, Spain and Russia. The Spanish population reached the lowest records in the 1970s with 22 individuals (Torres *et al.*, 1986). The protection policy implemented in the nesting enclaves in Andalusia caused this number to increase by 786 in 1992 (Tucker and Heath, 1994). In 1994



Bird communities	Bird communities
Galerida theklae, *Burhinus oedicnemus*, *Calendrella cinerea*, *Sylvia melanocephala*, *Emberiza calandra*, *Caprimulgus ruficollis*, *Alectoris rufa*, *Lanius excubitor*.	*Fulica atra*, *Aythya ferina*, *Tachybaptus ruficollis*, *Podiceps nigricollis*, *Ixobrychus minutus*, *Anas platyrhynchos*, *Marmaronetta angustirostris*, *Oxyura leucocephala*, *Himantopus himantopus*, *Burhinus oedicnemus*, *Charadrius alexandrinus*, *Recurvirostra avosetta*, *Charadius dubius*, *Larus ridibundus*.

Figure 4. Vegetation and bird communities before and after the open-cast extraction of clayey soil down to the water table.

Table 5. Current state of *Maytenus senegalensis* subsp. *europaeus* spots in the area under study.

Locality UTM (USO: 30S)	Area (ha)	Cover (%)	NI	X(cm)	Presence of *Ziziphus lotus*	Associated communities	Environmental impact and observations
1. Llano de la Maleza WF2473	4.2	1–5	1	120	Occasional	Espartal Nitrophilus thyme *S. foetens* and *Ph. almeriensis* bushes	Greenhouses Pasturage
2. Llano de la Maleza WF2373	4.5	5–10	2	160	Frequent	Nitrophilus thyme *G. retamoides*	Preparation for new greenhouses Pasturage
3. Llano del Águila WF2272	7.5	1–5	1	100	Frequent	Thyme	Building tip Neighbouring greenhouses Pasturage
4. Sta. Mª del Águila WF2071	8.1	20–25	2	180	Occasional	Thyme	Future built-up area Agricultural waste material Plastic films
5. Sta. Mª del Águila WF2071	11	1–5	1	150	Frequent	Nitrophilus thyme	Proximity to town Rubbish dump Building tip
6. Llano del Águila WF2072	9.9	1–5	1	150	Rare	Thyme	Land no longer under cultivation Agricultural waste material Plastic films
7. Llano de las Mercedes WF2073	114	15	2	190	Occasional	Thyme	Land cleared for dirt roads Pasturage
8. Sta. Mª del Águila WF1972	23	5–10	1	160	Frequent	Nitrophilus thyme	Agricultural waste material Plastic films Dirt tract for entry Neighbouring greenhouses Pasturage
9. Cortijo Los Galones WF1772	3	10–15	2	160	Rare	Thyme Prickly pear	Collection point for agricultural waste (closed at present) Pasturage
10. Cueva de las Palomas WF1873	3.3	< 1	1	120	Rare	Olive trees	Land no longer under cultivation Growing number of greenhouses

11. Loma de Cueva Redonda WF1673	5.4	5–10	2	150	Occasional	*G. retamoides*	Small buildings Pasturage Protected by the rugged nature of terrain
12. Loma de Cueva Redonda WF1672	8.1	1–5	1	150	Frequent	Nitrophilus thyme	Neighbouring greenhouses Pasturage
13. Toril WF1366	46.3	10–15	2	200	Occasional	Thyme Esparto	Agricultural waste material Plastic films New greenhouses Pasturage
14. Loma de Onayar WF1367	6.9	5	1	160	Rare	No associates observed	Agricultural waste material
15. Cortijo Los Toribios WF1367	3	1–5	1	160	Frequent	No associates observed	Agricultural waste material Building tip Neighbouring greenhouses In danger of extinction
16. Las Hoyuelas WF1567	7.5	< 1	1	100	Frequent	Nitrophilus thyme	Agricultural waste material Neighbouring quarry in use
17. Loma Blanca WF1667	11.6	10–15	1	150	Frequent	Nitrophilus thyme	Agricultural waste material
18. Loma de la Mezquita WF1668	28.7	15–20	2	180	Occasional	Nitrophilus thyme	Agricultural waste material Building tip Rubbish heap Road construction Pasturage
19. Sto. Domingo WF1768	9.9	20	2	200	Occasional	Nitrophilus thyme	Agricultural waste material New built-up area Rubbish heap Road construction Pasturage
20. El Rinconcillo WF1969	12.5	5	1	160	Rare	Nitrophilus thyme	Rubbish heap New greenhouses Road construction

N.I.: Naturalness index

the Laguna de las Norias has been the most important nesting enclave for white-headed duck in Spain (López Martos *et al.*, 1993).

The impact on the lentisco-sabina communities

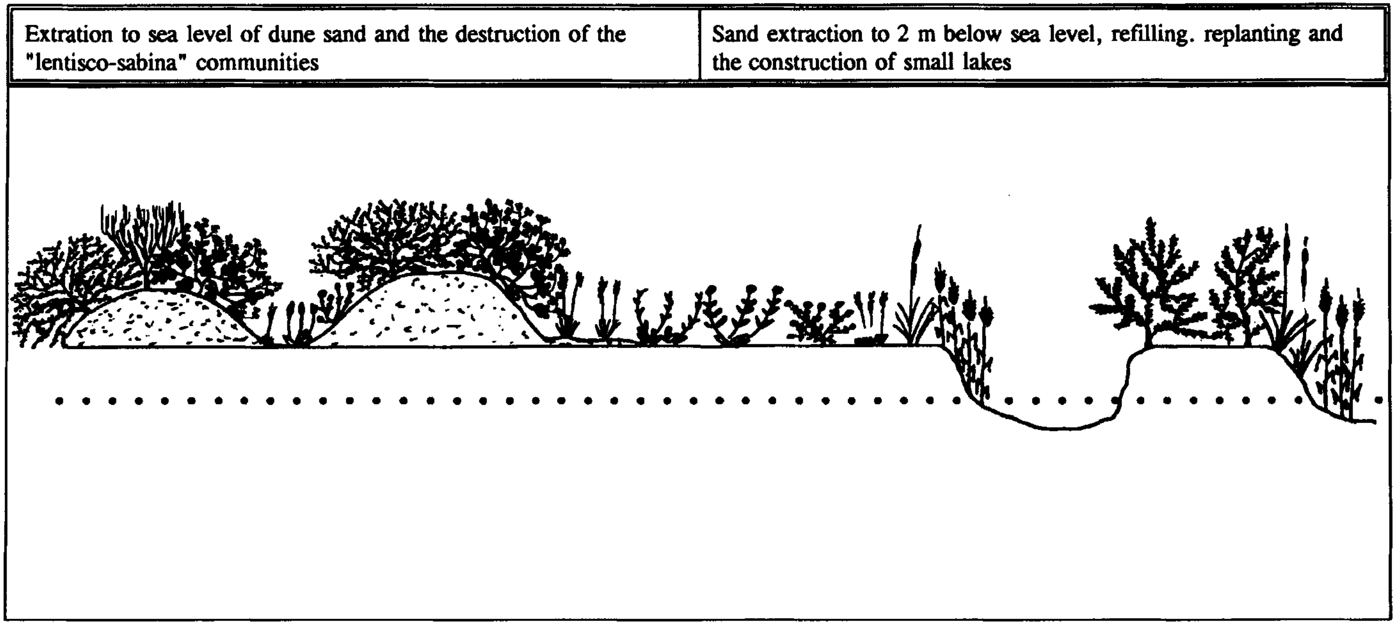
In recent years the annual demand for sand to provide the soil for new greenhouses or renew the existing ones (COPT, 1989) has decreased and is now stabilized at some 300000 m^3 per year (Table 2). In the late 1970s the farming acreage grew so enormously that sand was indiscriminately extracted from beaches. As a result, the coastline was affected and the tourist industry was so seriously damaged that the *Servicio de Costas* had to ban these activities (COPT, 1987). In the 1980s sand extraction was carried out in private properties bordering on public land and the removal of the scrub vegetation fixing the soil led to the destruction of many ecosystems. Total denudation in the early 1980s of the vegetation cover on the eastern side of the area dominated by lentisco-sabina communities is an example of this. Here, the quarries reached sea level and were later recolonized by salt-loving chenopodiaceae.

In 1986, farmers asked for more sand to be extracted and the environmental authorities and the *Servicio de Costas* accepted their demands, implementing a programme to monitor sand extraction and restoration of areas already exploited. The crucial guidelines of the programme were as follows.

- Division and demarcation of the area already exploited to sea level.
- Complete ban on sand extraction outside that area in order to avoid new incursions on the sabina-lentisco communities.
- Extraction was to be carried out in plots of 2 ha. and never more than two adjoining plots at one time.
- The extraction procedure is as follows: (1) removal of 30 cm of surface soil, (2) sand extraction to a limit of 2 m below sea level, (3) filling-in of exhausted pits by means of calcarenites from a neighbouring quarry, (4) replacement of the surface soil previously removed.
- The replanting of certain areas with tamarisk (*Tamarix* spp.).
- The construction of a network of ponds on the north boundary of the area to make good use of the spring of water that, due to irrigation recharge, emerges from the superior aquifer.

Calcarenite filling has acted as an underground barrier which prevents ground water from leaking into the sea. Thus, this water from the superior aquifer has given rise to permanent springs on the north edge of the area which have been used to fill artificial lakes. The current landscape is the result of replanting *Tamarix africana* and *Tamarix canariensis* and the spontaneous appearance of marsh vegetation such as *Phragmites australis*, *Juncus acutus* and *Juncus maritimus*. The selective extraction of sand has also played a role in the configuration of the landscape. Since the sand extracted tends to be coarse, littoral dune communities, which prosper on fine sand, have colonized the rest of the area under exploitation. Finally, it is also worthy of note that salt-loving frutescent communities, characterized by the presence of *Atriplex halimus*, *Salsola oppositifolia*, and *Suaeda pruinosa* among others, occur with a distribution proportional to the time passed since the quarry was abandoned.

Figure 5 shows the mosaic of new habitats in the area, a brief summary of the emergent plant communities and the changes in the bird communities.



"Lentisco-sabina" communities established on the stable dunes **Bird communities**	Sand-loving grassland **Bird communities**	Lakes and reed-beds **Bird communities**
Galerida theklae, Emberiza calandra, Sylvia melanocephala, Caprimulgus ruficollis, Alectoris rufa, Burhinus oedicnemus, Muscicapa striata, Sylvia undata, Turdus merula, Lanius excubitor, Lanius senator, Acanthis cannabina.	*Galerida theklae, Burhinus oedicnemus, Calandrella rufescens, Otis tetrax, Glareola pratincola.*	*Galerida theklae, Burhinus oedicnemus, Calandrella rufescens, Otis tetrax, Glareola pratincola, Fulica atra, Tachybaptus ruficollis, Gallinula chloropus, Anas platyrhynchos.*

Figure 5. Vegetation before and after the sand extraction, in one case after the quarry has been filled in and in the other after the construction of small lakes.

Discussion and conclusions

Arto communities

Most of the spots formerly occupied by *Maytenus senegalensis* subsp. *europaeus* have disappeared as a result of greenhouse farming and the agricultural residues it generates. Urban development has also contributed to this transformation. El Ejido and Santo Domingo are prominent examples of this, since they have extended their built-up area by 61.2 and 77.3 ha, respectively (Fig. 3). Likewise, the construction of roads has caused serious damage to the vegetation, covering leaves and branches with dust. The strong winds combined with the quarries, land clearing, greenhouse soil preparation and sand from abandoned farmland originate frequent dust clouds in the region. In addition, plastic film remnants get caught on thorns and branches, producing a partial covering that can seriously injure plant metabolism. Finally, the areas where the arto communities prosper are frequently chosen to store urban waste material.

Of all these man-made negative impacts, pasturage is the least harmful because it is concentrated in ever smaller areas due to the pressure of greenhouse expansion. There is no standard impact of grazing on arto communities. Much depends on the particular species. While no effects of herbivores have been observed on *Maytenus europaeus*, the acebuche bushes (*Olea europaea* subsp. *sylvestris*) are stunted through browsing.

Table 5 illustrates another negative effect on the arto communities. These areas are often used for the construction of public buildings (Hospital de Santo Domingo), highways or roads, big shopping centers, or for dumping agricultural waste. Paradoxically, there is an area of similar monospecific formations of *Ziziphus lotus* in the Parque Natural de Cabo de Gata-Níjar in the strictest preservation category under Spanish environmental laws: *Reserva Integral*. Much of the blame is to be put on the botanists themselves, since they have not been capable of arousing the interest of ecologists in these valuable communities. Knowledge is always prior to real esteem, a consideration which should lead to the assessment of the scientist's role in modern society.

Ten years ago, the largest and most densely populated spots of arto were those of Loma de Onáyar, Loma de la Mezquita, Loma Blanca, Cañada de Cortés and Soto Tablas. Today they are so considerably changed and reduced as to be close to extinction. Generally speaking, the most aggressive man-induced changes have taken place south of the Málaga-Almería road. Although the spots of arto communities at the foot of Sierra de Gádor have undergone changes, they are currently the most extensive and uniformly-covered of all (Llano de las Mercedes has an area of 114.03 ha.). However, density rates are lower than in Santa María del Aguila and Loma de la Mezquita. Undoubtedly,

Table 6. Suggested protective measures for the communities of *Maytenus senegalensis* subsp. *europaeus*

Communities	Acceptable state of conservation	Very deteriorated
Very near urban settlement	Park near the town	Park near the town or greenbelt area
Far from urban settlement	Nature reserve	Restoration of the area of Nature reserve

geomorphological conditions are responsible for this asymmetrical north-south distribution.

In the present situation it is vital to adopt measures to preserve, at least to a certain extent, these communities. In this respect, the two major criteria should be: current rates of naturalness and density, etc., and proximity to urban settlements. At all events, the disposal of urban and agricultural waste affecting these communities should be banned as soon as possible and their conservation should be given due attention in building or environmental programmes. It is of prime importance to protect, at least, the large and particularly well-preserved sites. At present the inventory of the Andalusian Conservation Areas is being revised. It would be wise to add these sites to it. Taking into account the current environmental degradation rate, this measure should no longer be postponed.

The province of Almería comprises over 400000 ha of steppes. The creation of the Laguna de las Norias as a consequence of clay extraction caused the disappearance of several ha. of thyme communities and a little area of arto communities. These new man-made wetlands, surrounded by a green belt of marshy vegetation, lie on the route of migrant birds following the coastline of Almeria. Today, the lake serves as a shelter for one of the most important bird communities of gulls, terns, waders and ducks in Andalucía (López Martos *et al.*, 1993). A co-operation agreement has been signed by the El Ejido Town Council and the SEO (*Sociedad Española de Ornitología*, Spanish Ornithological Society) to manage this bird sanctuary, being the second Andalusian wetland which is privately run. At present, the Spanish government is taking the necessary steps before the EU to declare it a ZEPA (*Zonas de Especial Protección para las Aves*, Bird Zones under Special Protection). For this, the EU environmental policy demands that the area reach a value of 29 or over according to the Bezzel Index. The application of this criterion to the area gives a total value of 80 (López Martos *et al.*, 1993), since the nesting of white-headed duck (*Oxyura leucocephala*), marbled teal (*Marmaronetta angustirostris*) and black-winged stilt (*Himantopus himantopus*) are estimated to have valves of 33, 30 and 17, respectively. The planned management programme gives major importance to monitoring both the quality and quantity of the water (salinity and eutrophication rates).

Lentisco-sabina communities

Since the Parlamento Regional de Andalucía passed the 2/89 Bill of Protected Wild Areas, activities such as those of the late 1970s and early 1980s resulting in the loss of 60 ha of sabina communities have ceased. This bill declared almost 3000 ha of marshlands and the entire littoral dune system a conservation area. Although some sand extraction zones were also included, the category of *Paraje Natural* given to this conservation area only allows scientific and educational activities. In the 5 years since the passing of the bill, a programme for the management of the resources of the *Paraje Natural* has been drawn up. This programme contemplates some changes in the sand extraction zones. As long as the superior aquifer has a surplus of water, it is vital to maintain the network of ponds on the north boundary, the tamarisk (*Tamarix* spp.) formations and the dune grasslands. As a result of this programme, there has been a considerable increase in the diversity and ornithological importance of the nesting and wintering bird communities.

Alternatives to the current land-use must be promoted. Firstly, the population should become environmentally conscious and programmes aiming at this goal must be implemented. Secondly, ecotourism might be attracted by the environmental conditions if the necessary information and infrastructures were available. Thirdly, due attention should be paid to ecologically valuable vegetation communities in any forthcoming development programmes. In this last respect, there should always be corridors of uncultivated land between large farming areas.

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