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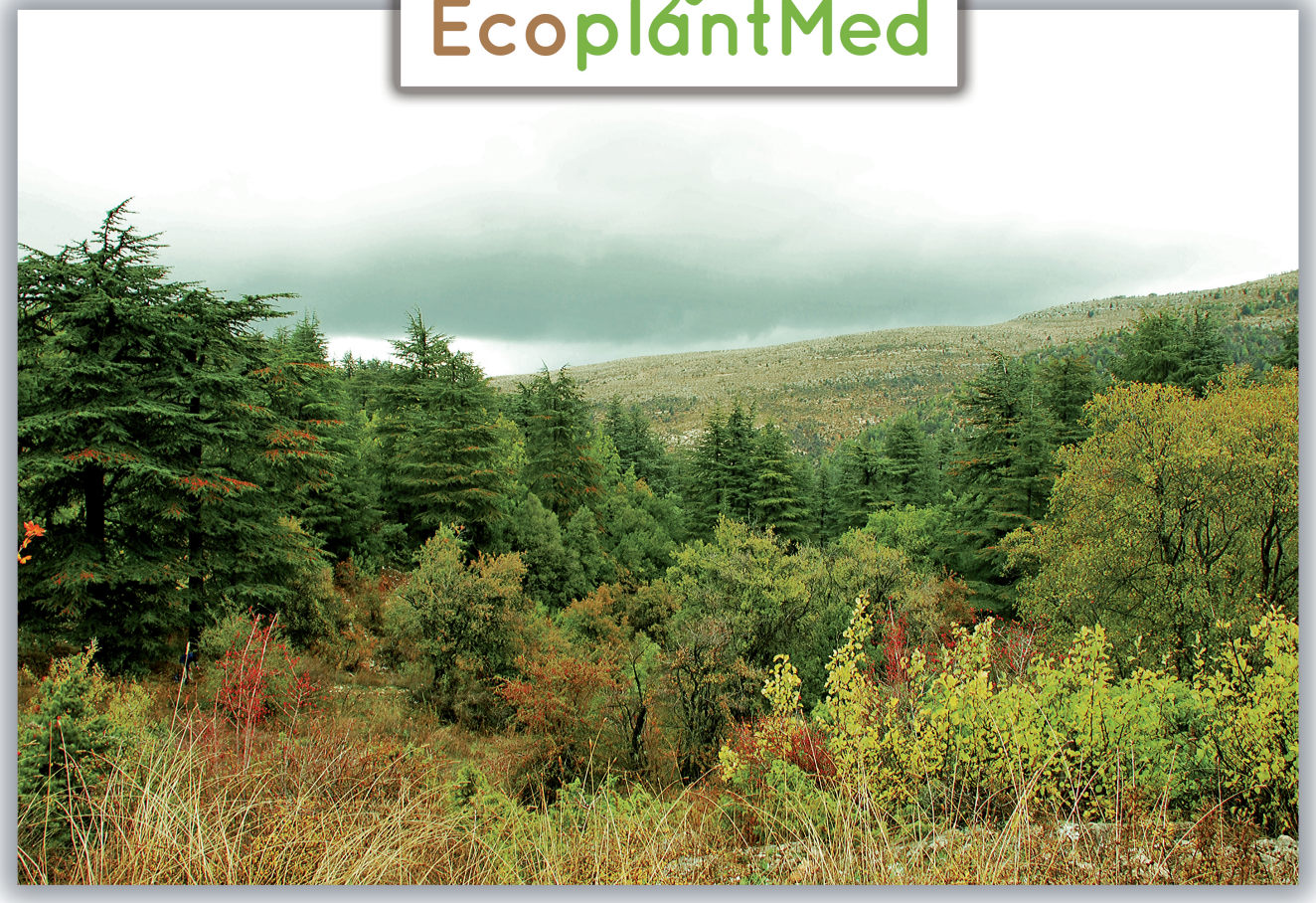

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The impact rehabilitation of coastal ecosystems on floristic diversity: the case of the dunes of Korba (Tunisia)

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Abstract
The coastal ecosystems in the Nabeul area (Cap Bon), eastern part of Tunisia, are subject for several decades to a permanent and anarchic operation that generated a sharp deterioration resulting in the reduction of the biological potential and failure of ecological and socio-economic balances. Faced with this critical situation, the services of "APAL" in Tunisia (Coastal Protection and Planning Agency of Tunisia) opted for the rehabilitation of hundreds of hectares of sand dunes to reduce the magnitude of this scourge. The rehabilitation of the dunes cords was made by utilizing the multiple technique of protection (Implanting a wooden fence to protect the dune ecosystem, using *ganivelles* techniques for mechanical dune stabilization, installing of pipelines flows (roads) for the passage of summer visitors and the creation of ecological tours). The aim of the present work was to evaluate the impact of using these rehabilitation techniques on floristic diversity in the dunes of Korba (Cap Bon, Tunisia). The methodological approach adopted is that of evaluating floristic biodiversity on protected dunes and other neighboring areas located outside the protected area. The phytosociological plots were sampled basing on the methods of Braun-Blanquet, including the original cover-abundance scale. Data analysis shows the beneficial effect of rehabilitation on the structure, the composition and functioning of these coastal dunes and psammophile vegetation. Indeed, the protection increased floristic richness, species diversity (as indicated by Shannon-Weaver index) and the floristic composition, particularly palatable species: *Ammophila arenaria*, *Cynodon dactylon*, *Retama raetam*, *Thymelaea hirsuta* and *Euphorbia paralias*. This rehabilitation technique allowed the maintenance of several species reflecting the value of these coastal dunes in terms of biodiversity.

Key words: anthropogenic activities, diversity index, floristic richness, protected area.

Introduction

Mediterranean coastal ecosystems are characterized by strong climatic constraints and pedological salinity, wind, drought and shallow soils or mobile. While moving of the beach to the interior, we find a succession of landscape elements of dunes whose character and morphological vegetal is linked to the progressive modification of ambience salinity, wind power and sandy motions. The coastal of Tunisia are under big pressure from urbanization and implantation by tourist associations and agencies. More than 70% of economic activities are based on the coastline, 90% of which is accounted by tourist activities which have induce several problems owing to the uncontrolled development that threatens the ecological wealth and inshore natural landscape sites in Tunisia (Ramade, 1997). Tunisia has a great variety of coastal landscapes that reflect differences in biophysical conditions, and cultural heritage. The northern coast has an undulating coastline while the immediate hinterland consists of a wooded range of hills and mountains. Agricultural coastal plains can be found in the area of Cap Bon. Some of the most characteristic landscapes of Tunisia comprise coastal wetlands and semi-mobile landscapes of dunes. Some of the towns have exerted more their influence on the surrounding landscapes than others. The major threats to the coastal landscapes of Tunisia, are common along the Mediterranean coastal zone, and related to uncontrolled development, urbanization, increasing national and international tourism, land-based pollution, and unplanned or over-exploitation of natural resources, in particular freshwater. The strongest among these pressures, following the general trends in the South Mediterranean coast, are population increase and animal husbandry. As in the majority of Mediterranean countries an assessment of landscape character and associated pressures on specific landscape types has never being realised in Tunisia. The Cap Bon peninsula, located at the north-eastern tip of Tunisia was selected for a more detailed landscape study. Coastal ecosystems in peninsula of Cap Bon are subject for several decades to a permanent and uncontrolled exploitation which led to a sharp deterioration resulting in the reduction of the biological potential and disruption of ecological and socioeconomic balance. Faced with this critical situation, the service of Coastal Protection and Planning Agency of Tunisia (APAL Tunisia) has chosen the re-

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habilitation of hundred hectares of dunes to mitigate the magnitude of this damage. The rehabilitation of the dunes strip was made by installing multiple protection methods; the establishment of wooden fence to protect the dune ecosystem, the use of ganivelles techniques for mechanical dune stabilization, installing flow pipes to facilitate the access for summer visitors and to create ecological circuits and allowing finally a biological fixation in some dunes. This study aims to evaluate the impact and effect of the use of techniques and methods of protection and restoration of coastal dunes on the floristic diversity of the coastal dunes of Korba region (Cap bon, Tunisia).

Material and Methods

Study area

The study area is located in the North-East of Nabeul prefecture in Tunisia (Fig. 1). The dunes are located between Korba lagoon which is a RAMSAR site and the beach of Korba (Mediterranean Sea). The dunes of Korba constitute a unique ecosystem that spans nearly 9 km. The width varies between 400-500 m. The height varies between 1.5 m and 3 m. The dunes are fixed by herbaceous vegetation and woody plants. The protection and rehabilitation of the coastal dunes of Korba was decided since 2005. The methodological approach is based on a comparative analysis of floristic biodiversity indicator parameters of protected and non protected dunes and the assessment of the anthropogenic factors effect on these two types of dunes.

Sampling

The phytosociological plots were sampled basing on the methods of Braun-Blanquet (1964) including the original cover-abundance scale. 30 plots were included in the present analysis; among them, 20 plots are established in protected dunes and the 10 others in unprotected dunes (Tab.1). The plots has an area of 20 m^2 located along each transect and distributed at regular intervals. A total of 49 species were found on the 30 plots. In order to compare the effect of anthropogenic factors (trampling of vegetation and overgrazing) on protected and unprotected dunes, we have implemented the following classification: the degree of protection, pasture and human pressure (vacationers). Plant species and their nomenclature were identified with flora books (Cuénod *et al*., 1954; Ozenda, 1977; Pottier-Alapetite, 1979, 1981; Quézel & Santa, 1962, 1963).

Data analysis

The ordinations were performed using Past software (version 2.1) and R software package. (R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL

http://www.R-project.org/.) Accordingly, the chosen methods were Correspondence analysis (CA) and Canonical Correspondence analysis (CCA). Biodiversity indices for these classes are calculated in the present work, ten diversity indices and species richness were calculated for 30 plots to describe the diversity of the

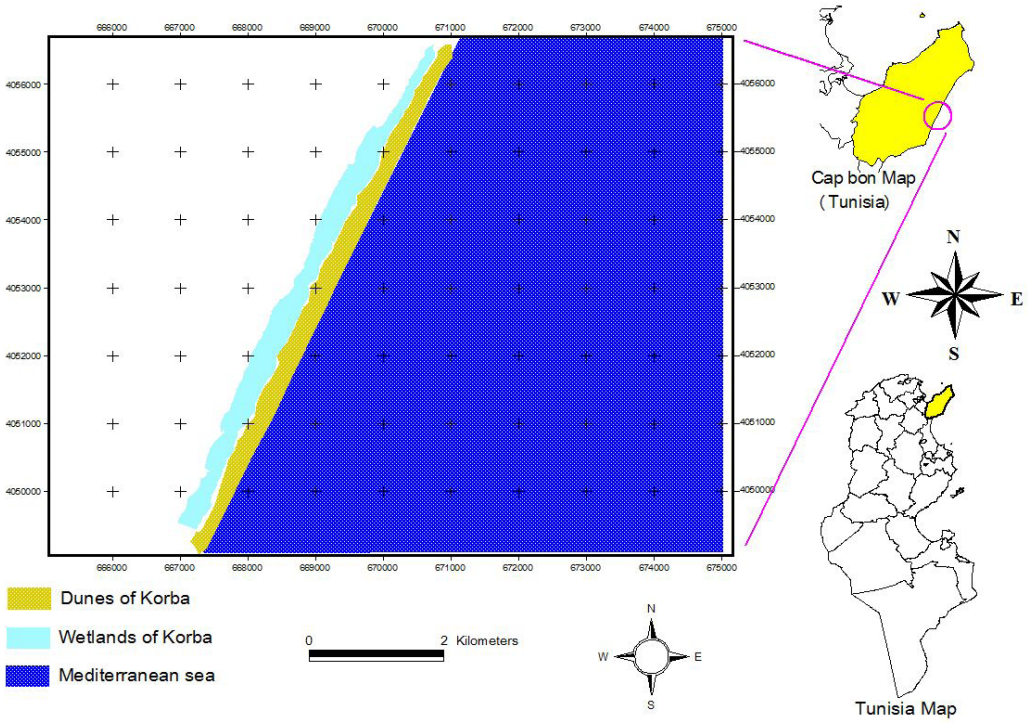

Fig. 1 - Map of Tunisia showing the sites in the study area.

Tab. 1 - Characteristics of 30 vegetation site in study area.

Site	Number of Taxa (species)	Site in protected area	Site out protected area
S1	6	x	
S2	5	x	
S3	15	x	
S4	14	x	
S5	8	x	
S6	4	x	
S7	5	x	
S8	4	x	
S9	10	x	
S10	3	x	
S11	10	x	
S12	3	x	
S13	14	x	
S14	4	x	
S15	12	x	
S16	5	x	
S17	6	x	
S18	3	x	
S19	5	x	
S20	2	x	
S21	6		x
S22	5		x
S23	4		x
S24	4		x
S25	7		x
S26	3		x
S27	6		x
S28	4		x
S29	6		x
S30	4		x

ground vegetation in the data. Delineation of the study area was made with GIS ArcView 3.2 software after the georeferencing of the topographic map. All statistical analyses were carried out using SPSS for windows v. 11.5.

Results

The final list of 49 species that were recorded in sites in the study area, represent 10 families of flowering plants (*Poaceae*, *Arecaceae*, *Asteraceae*, *Tamaricaceae*, *Lilaceae*, *Fabaceae*, *Chenopodiacae*, *Amaryllideae*, *Typhaceae* and *Joncaceae*). The large family is represented by *Poaceae* and *Chenopodiaceae* family. The vegetation was dominated by psammophiles vegetation by followed hydrophilic vegetation. The signficant psammophiles and hydrophilic components reflected the generalized features of the vegetation of the dunes to near wetlands. The biodiversity index of study site is given in Tab. 2; this table also includes the Simpson index is from 0.48 to 0.92, Shannon index is from 0.67 to 2.60, Evenness index is from 0.74 to 1, Brillouin index is from 0.46 to 1.96, Menhinick index is from 0.89 to 3.20, Margalef index is from 0.62 to 4.53 and Equitability index is from 0.81 to 1. Using multivariate analysis (CA), three plant communities of flora are distinguished (Fig. 2); psammophiles, nitratophiles and hydrophiles. Rich and varied, the psammophiles group (G1) is dominated by *Ammophila arenaria*, *Retama raetam*, *Euphorbia paralias* and *Eryginum maritimum*. The hydrophiles Vegetation groups (G2) dominated by *Sarcocornia fruticosa*, *Suaeda fruticosa*, *Juncus maritimus*, *Juncus acutus* and *Salsola kali*. The nitratophiles Vegetation groups (G3) dominated by *Daucus carotta* and *Beta vulgaris*. The dendrogram illustrating the presence of 03 vegetation groups using analysis of 30 sampled stands in the stu-

Tab. 2 - Characteristics of vegetation diversity index derived after the application of analysis on the 30 sites in study area.

Diversity index	N	Minimum	Maximum	Mean	SD	Variance
Simpson	30	0,48	0,92	0,76	0,1	0,011
Shannon	30	0,67	2,6	1,61	0,48	0,23
Evenness	30	0,74	1	0,91	0,05	0,003
Brillouin	30	0,46	1,96	1,13	0,43	0,187
Menhinick	30	0,89	3,2	1,86	0,52	0,27
Margalef	30	0,62	4,53	2,18	0,91	0,83
Equitability	30	0,81	1	0,95	0,03	0,001

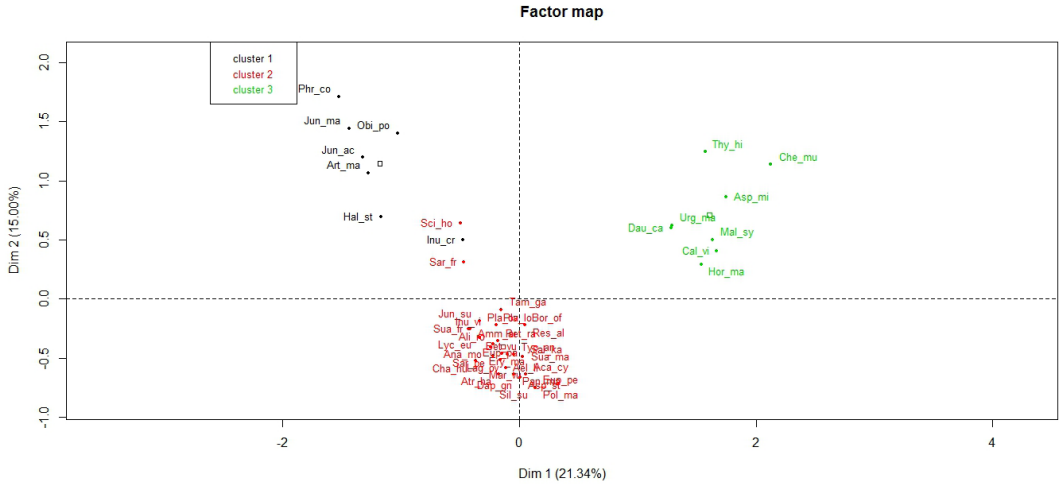

Fig. 2 - Correspondence analysis map (49 plant species x 30 sites).

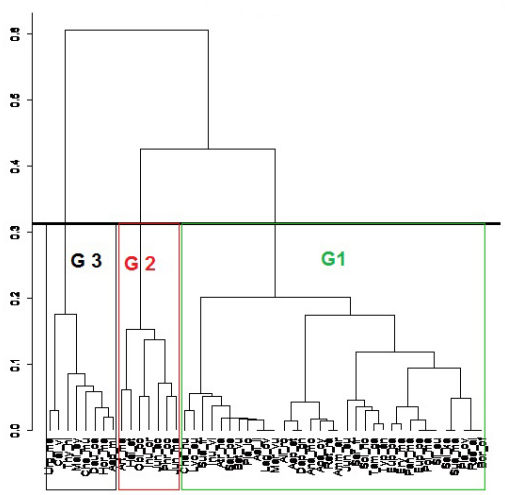

Fig. 3 - Dendrogram of 30 sites and 49 species after Cluster Analysis.

dy area (Fig. 3). Cluster Analyses broadly divided the plant community in to three assemblies which could be clearly seen in two main branches of the dendrogram; (i) vegetation of dunes (ii) vegetation of wetlands (iii) vegetation of degraded areas (outside the protected areas: dominated by *Asphodelus microcarpa*, *Urginea maritima* and *Beta vulgaris*). The vegetal rug is analyzed by 03 principal factors wich are the level of protection, level of pasture and the anthropic action. The impact of these three factors is widely expressed by index of species diversity. The application of CCA Ordination (Fig. 4) on the cover and presence estimates of the 49 species recorded in the 30 samples indicated the recognition of three vegetation groups. This study shows the recolonization of dunes by psammophiles species. This multidimensional treatment accentuates the importance of anthropic and protection factors that govern this dynamic. Finding of this research was conducted during the spring clearly indicate that the dunes ecosystem type of floristic element gradually change on the protection and degree of perturbation (anthropic action). The state of the vegetation cover has been followed before, during and after the rehabilitation work (Fig. 5). The rehabilitation of the dunes improved vegetation cover and stabilizing the ecosystem.

Discussion

Monitoring of plant density in particular of perennials gives a good picture of the trends of spread or disappearance of plant species and permits an assessment of the ecosystem ability to regenerate (Floret, 1988). A large number of individuals promote the accumulation and fixation of soil particles, improves the water balance and facilitates the establishment of new plant species (Floret & Pontanier, 1982; Jauffret, 2001). Under animal activity, the palatable plant species progressively disappear giving way to the spread of unpalatable and very palatable annual species in protected dune. The humans pressures have a negatively affect the site, because plant regeneration is not possible during the spring. Around the relevets R 21 to R 30 investigated here, the grazing intensity and human pressure alongside the gradient affected plant species composition and decreased their regeneration capacity. The present study can contribute valid hypotheses for future work which must extend the focus on dune and coastal ecosystems. Further it will be important, the pasture affect the distribution of plants on dune, functioning as determinant keys of the animal load for a particular well (Thébaut & Batterbury, 2001). Such studies will be particularly useful with

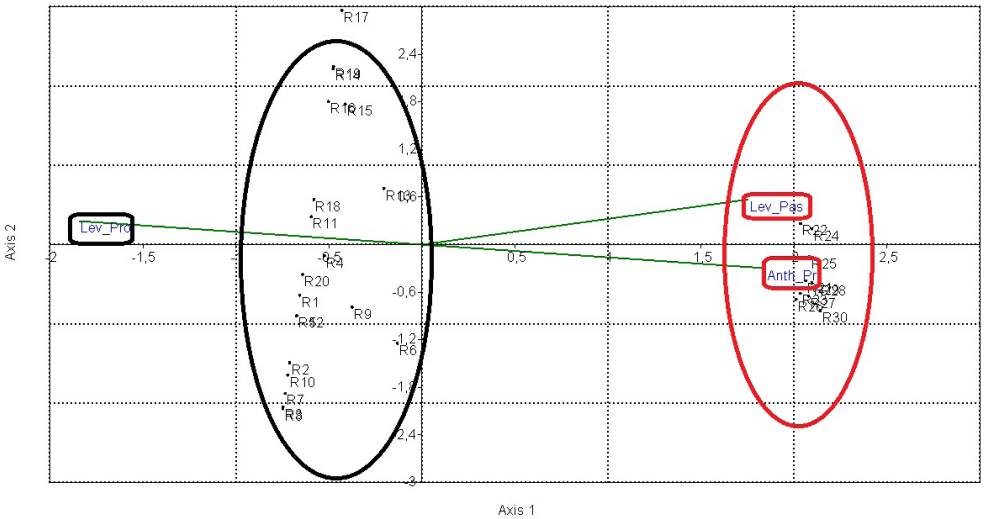

Fig. 4 - Ordination Biplot Diagram of Sites and Environmental Variables identified using Canonical Correspondence Analysis (CCA) of the 30 sampled stands in the study area. (Lev_Pas : degree of pasture; Lev_Pro: degree of protection; Anth_Pr: anthropic pressure.

Fig. 5 - The evolution of the dune ecosystem (The state of coastal dunes before rehabilitation / the state of coastal dunes being rehabilitation / the state of coastal dunes after rehabilitation).

concern to ecosystem maintenance and consolidation, by this way contributing also to the floristic heritage management and to nature conservation measures. The sustainable use of natural vegetation and the reduction of land degradation processes will be most important to ensure the rural population subsistence and the economic productivity (Dembélé *et al*., 2006; Jauffret & Lavorel, 2003).

Conclusions

Data analysis shows the beneficial effect of rehabilitation on the structure, composition and functioning of these coastal dunes and psammophiles vegetation. Indeed, the protection increases floristic richness, species diversity and improves the floristic composition, especially with sand-fixing species extinct outside the protected dunes: Ammophila arenaria, Retama raetam, Thymelaea hirsuta, Euphorbia paralias and Eryginum maritimum. This rehabilitation technique allowed the maintenance of several species reflecting the heritage value of these coastal dunes in terms of biodiversity. Finally, species diversity was optimum at the protected dunes as compared to the lower dunes which are not protected and where direct anthropogenic activities and the high grazing pressure are continuous. Such kind of species distributional phenomenon has also been observed in other dunes ecosystem. Moreover increase in herbaceous vegetation is positively correlated to the increase in protection.

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Appendix I: List of vegetation in study area

Plant Species	Family	Found in dunes	Found in wetlands
Acacia cyclopis	*Leguminosae*	*x*	
Aeluropus littoralis	*Gramineae*	*x*	
Allium roseum	*Liliaceae*	*x*	
Ammophila arenaria	*Gramineae*	*x*	
Anagallis monelli	*Primulaceae*	*x*	
Arthrocnemum macrostachyum	*Chenopodiaceae*		*x*
Asparagus stipularis	*Liliaceae*	*x*	
Asphodelus microcarpus	*Liliaceae*	*x*	
Atriplex halimus	*Chenopodiaceae*		*x*
Calycotome villosa	*Leguminosae*	*x*	
Chamaerops humilis	*Palmae*	*x*	
Chenopodium murale	*Chenopodiaceae*	*x*	
Crucianella maritima	*Rubiaceae*	*x*	
Daphne gnidium	*Thymelaeaceae*	*x*	
Daucus carotta	*Umbelliferae*	*x*	
Ecballium elaterium	*Cucurbitaceae*	*x*	
Eryngium maritimum	*Umbelliferae*	*x*	
Euphorbia paralias	*Euphorbiaceae*	*x*	
Euphorbia peplis	*Euphorbiaceae*	*x*	
Halocnemum strobilaceum	*Chenopodiaceae*		*x*
Inula crithmoides	*Compositae*		*x*
Inula viscosa	*Compositae*		*x*
Juncus acutus	*Juncaceae*		*x*
Juncus maritimus	*Juncaceae*		*x*
Juncus subulatus	*Juncaceae*		*x*
Lagurus ovatus	*Gramineae*	*x*	
Lycium europaeum	*Solanaceae*		*x*
Malva sylvestris	*Malvaceae*	*x*	
Marrubium vulgare	*Labiatae*	*x*	
Obione portulacoides	*Chenopodiaceae*		*x*
Pancratium maritimum	*Amaryllidaceae*	*x*	
Phragmites communis	*Gramineae*		*x*
Plantago logopus	*Plantaginaceae*	*x*	
Plantago ovata	*Plantaginaceae*	*x*	
Polygonum maritimum	*Polygonaceae*	*x*	
Reseda alba	*Resedaceae*	*x*	
Retama raetam subsp. bovei	*Leguminosae*	*x*	
Salsola kali	*Chenopodiaceae*		*x*
Sarcocornia fruticosa	*Chenopodiaceae*		*x*
Sarcocornia perennis	*Chenopodiaceae*		*x*
Scirpus holoschoenus	*Cyperaceae*		*x*
Silene succulenta	*Caryophyllaceae*	*x*	
Solanum nigrum	*Solanaceae*		*x*
Suaeda fruticosa	*Chenopodiaceae*		*x*
Suaeda maritima	*Chenopodiaceae*		*x*
Tamarix gallica	*Tamaricaceae*		*x*
Thymelaea hirsuta	*Thymelaeaceae*	*x*	
Typha angustifolia	*Typhaceae*		*x*
Urginea maritima	*Liliaceae*		*x*