# Chapter 8
# Coastal Vegetation

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**Abstract** The coastal vegetation of the Iberian Peninsula (including the Balearic Islands) is represented by a set of plant communities that colonize biotopes as diverse as sea cliffs, beaches, dunes, marshes and estuaries. From a geographical point of view, we have differentiated the following sections: in the north, the coastal strip extending from the mouth of the Bidasoa River, the political border with France, up to Ría de Aveiro in Portugal integrates into the Atlantic-European biogeographic Province (covering the sectors Cantabrian-Basque, Galician-Asturian and Galician-Portuguese) and exhibits a great diversity in the vegetation of coastal cliffs. Dune vegetation is well represented in Corrubedo, Liencres, Somo, Zarautz and other places; communities of marshes and estuaries also show strong contrasts (Galician Rías Bajas, Santoña, Urdaibai) and constitute biogeographic boundaries of species and plant communities with the rest of the Iberian coasts.

From the Ría de Aveiro southwards up to Gibraltar, the diverse coastal landscape includes beaches and dunes alternating with estuaries and rugged coasts; we highlight some important and well preserved areas such as the Sintra-Cascais Natural Park, the Tagus and Sado estuaries, the Portuguese southwestern coast, Ría Formosa, Doñana (Huelva), that are home to a wide range of species and plant communities.

The Mediterranean coast of the Iberian Peninsula runs from Gibraltar to the border with France. This stretch comprises the following biogeographical provinces: Baetic, Murcian-Almerian and Balearic-Catalan-Provençal. The coastline between Gibraltar and Cape Sacratif (Granada) reflects the orogeny of the Baetic Ranges, where cliffs alternate with small pebble beaches. The semiarid and arid ombrotypes that dominate the coastline between Cape Sacratif and the foothills of Sierra de Bernia (Alicante) are determining factors in the composition of the plant communities there. This section presents interesting coastal ecosystems, such as Punta Entinas-Sabinar and the volcanic cliffs of Cabo de Gata (Almería), Mar Menor (Murcia), Albufera de Valencia, Delta del Ebro, Es Trenc and Ses Covetes (Mallorca), Albufera des Grau Natural Park (Minorca), Las Salinas Natural Park (Ibiza and Formentera), as well as numerous cliffs that harbour a wide range of species and plant communities.

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## 8.1 Introduction

The littoral or coastal zone has its own characteristics resulting from the interaction between the terrestrial and marine environments. Interactions between rocks, inland and marine water, living beings and other factors, are the reason for a strong specialization. Coastal plant ecosystems are subject to special conditions and severe stress (wave action, tides, wind, type of substrate, salinity) which have favoured the selection of ecotopes related to ecological gradients. They are home to a large variety of plant species and plant communities with a high degree of adaptation. The coastline is very dynamic and it constantly varies throughout geological time (regressions and progressions), due to tectonic movements of the continental plate, oscillations of water level, amount of sediments and sedimentation response.

The Iberian Peninsula has about 7200 km of coastline, of which nearly 3700 correspond to the Atlantic coast and the rest to the Mediterranean. The Atlantic coast has a high tidal variation that favours the development of extensive saltmarshes. Moreover, the direction of marine currents affects water temperature and is an important factor in the composition of plant communities. A special feature of the Mediterranean coast is the practical absence of tides, and therefore of extensive saltmarshes; however, there are frequent estuaries and coastal lagoons where fresh and marine waters mix.

To understand the diversity of the Iberian coast, we have separated the different environments: first, rocky coasts with abundant cliffs; second, sedimentary coasts where beaches, dunes, as well as estuaries and coastal lagoons are frequent. The coastline has been divided into three main sections, according to biogeographic and bioclimatic features (Fig. 8.1):

1. **Cantabrian coasts and Northwestern Iberia**
   This extends from the Bidasoa River (Basque Country) up to Ría de Aveiro (Portugal) forming the border between the Eurosiberian and Mediterranean regions. It comprises three biogeographical sectors included in the Atlantic European Province: Galician-Portuguese, Galician-Asturian and Cantabrian-Basque.
2. **Iberian Atlantic coast**
   This is made up of the coastal stretch between Ría de Aveiro (Portugal) and Punta de Tarifa (Spain) at the Strait of Gibraltar. It is integrated in the Coastal Lusitano-Andalusian Province of the Mediterranean Region and includes four biogeographical sectors: Divisorio-Portugues, Ribatagano-Sadense, Algarviense and Gaditano-Onubense Litoral p.p. (Fig. 8.1)
3. **Iberian Mediterranean coast**
   This section extends from Punta de Tarifa to the border with France in Gerona, including the Balearic Islands. From west to east we distinguish the following biogeographical provinces: Coastal Lusitano-Andalusian, Baetic, Murcian-Almerian and Balearic-Catalan-Provençal are included.


**Fig. 8.1** Map of the Iberian Peninsula coastline with the locations of the main sites mentioned in the text. *1*: Bidasoa River; *2*: Cape Peñas (Asturias); *3*: Ría de Foz (Lugo); *4*: Rías Altas; *5*: Rías Bajas; *6*: Ría de Aveiro; *7*: Cape Mondego; *8*: Peniche Peninsula; *9*: Cape Roca; *10*: Cape Espichel; *11*: Troia Peninsula; *12*: Cape Sines; *13*: Cape San Vicente; *14*: Ría Formosa; *15*: Doñana National Park; *16*: Cape Trafalgar; *17*: Tarifa; *18*: Cape Sacratif (Granada); *19*: Punta Entinas-Sabinar; *20*: Cape of Gata; *21*: Santa Pola (Alicante); *22*: Altea (Alicante); *23*: Cape San Antonio; *24*: Albufera de Valencia; *25*: Delta del Ebro; *26*: Cape Creus; *27*: Balearic Islands

## 8.2 Cantabrian Coasts and Northwestern Iberia

The Cantabrian coast, from the mouth of the Bidasoa River in Guipúzcoa to Ría de Foz (Lugo), has an almost straight layout with dominance of cliffs and "rasas" (erosional surfaces affected by tectonic uplift) alternating with small "rías" (fluvial valleys flooded by risen sea level) and estuaries with some beaches, dunes and marshes. In contrast, the Galician coastline is irregular and jagged with wide valleys, also called "rías". The northern rías or "Rías Altas" are short and narrow along the Cantabrian coast and very open in the Atlantic stretch, while those of the south called "Rías Bajas" are funnel-shaped; some of them are very profound and penetrate more than 30 km inland. From the mouth of the Miño River to the south a sandy low coast extends up to Ría de Aveiro (Portugal), which is a shallow coastal lagoon of nearly 45 km in length.

The western stretch is dominated by materials of Paleozoic and Precambrian origin, such as granites of the Galician Atlantic coast, or the slates, quartzites and sandstones of northern Galicia and western areas of Asturias, while the eastern

zone, from Cape Peñas (Asturias) to the Bidasoa River, is characterized by Mesozoic and Cenozoic materials, especially limestones, dolomites and conglomerates.

## *8.2.1 Climatic Features*

The Northern Iberian Peninsula is affected by prevailing westerly winds and polar front disturbances flowing from west to east across the North Atlantic. They are the source of abundant rainfall.

The average annual temperature ranges between 13–15 °C and, in summer, between 18–20 °C. Precipitation generally exceeds 1000 mm, except in northern Galicia which has slightly lower values, and the eastern coast of the Basque Country (Guipúzcoa) which receives more than 1500 mm of rainfall, mainly in summer, and also has colder temperatures.

This coastal area has a temperate macrobioclimate with rainy summers and a thermo-tempered thermotype that penetrates several kilometres inland on the west coast (Cantabria and Galicia) and only a few hundred metres in the Bay of Biscay. The ombrotype varies between sub-humid and humid.

## *8.2.2 Vegetation Description*

### 8.2.2.1 Cliffs

A characteristic feature of this coastal stretch is the abundance of rocky cliffs, highly variable in shape, altitude, inclination or degree of alteration and fracturing of rocks, characteristics related to the nature of the substrate and its structure. These characteristics as well as climatic variables determine the existence of different plant communities. On the Atlantic cliffs, three bands or belts are distinguished (Fernández Prieto and Loidi 1984):

### 8.2.2.2 Lower Level

Crevices and ledges of rocks that receive splashing waves are inhospitable places in which only very specialized plant types (chasmophytes) that are salt-tolerant (halophytes) grow, predominantly hemicryptophytes and chamaephytes. They form communities with few species, some of them with a wide distribution area, such as *Crithmum maritimum*; others are common along the European Atlantic coast, e.g. *Limonium ovalifolium, Plantago maritima* and *Spergularia rupicola*; or have a restricted area of distribution, such as *Armeria pubigera* subsp. *pubigera* of the Iberian northwestern, or *Armeria euscadiensis* on the Basque coast.

Several communities whose floral composition varies depending on the nature of the rocks, their structure, hardness or slope, occur in this coastal stretch, of which we mention:

The Crithmo maritimi-Armerietum pubigerae of granite cliffs located between Oporto and Rías Altas with *Armeria pubigera* subsp. *pubigera* as the dominant taxon, accompanied by *Spergularia rupicola* and *Crithmum maritimum* (Rivas-Martínez 1978).

The Spergulario rupicolae-Armerietum depilatae replacing the previous association in the rocky headlands between Lugo coast and Cape Peñas (Asturias). It is characterized by *Armeria pubigera* subsp. *depilata* and occurs on metamorphic rocks (slates, quartzite).

The Crithmo maritimi-Limonietum binervosi is located on the Cape Peñas-Biarritz. The main species are *Limonium binervosum*, *Armeria pubigera* subsp. *depilata, Plantago maritima* and *Silene uniflora,* growing on hard limestone.

The Armerio depilatae-Limonietum ovalifolii. Cretaceous limestones of the central stretch on the Santander coast (between Suances and Castro Urdiales) present a stepped arrangement that allows the occurrence of diverse environments colonized by different communities. The more exposed positions are occupied by this association.

The Crithmo maritimi-Plantaginetum maritimae. This association occurs at some biotopes of the eastern Cantabrian coast formed by soft substrata, and where wave action eliminates many species, thus leaving only those with a strong root system like *Crithmum maritimum* and *Plantago maritima.*

#### 8.2.2.3 Middle Level

This band, away from the strong waves, allows the colonization of many species which form dense grasslands with *Festuca pruinosa* as the main taxon, together with other species such as *Angelica pachycarpa, Anthyllis vulneraria* subsp. *iberica*, *Dactylis marina*, *Daucus carota* subsp. *gummifer, Leucanthemum crassifolium, Leucanthemum pluriflorum, Lotus corniculatus* var. *crassifolius*, *Rumex acetosa* subsp. *biformis, Silene uniflora* and *Trifolium occidentale.* Most of these taxa are also common in the lower band, so that, consequently, communities of both levels are included in the same alliance, Crithmo maritimi-Armerion maritimae*,* whose optimum lies at the Cantabrian-Atlantic coast and reaches the Divisorio Portugues Sector (Rivas-Martínez 1978).

The furthest extending association in the western stretch is the Dauco gummiferi-Festucetum pruinosae, located on coastal cliffs of the Galician-Portuguese and Galician-Asturian sectors. On the eastern Cantabrian cliffs, that association is replaced by the Leucanthemo crassifolii-Festucetum pruinosae, whose floristic composition is similar to the the Dauco gummiferi-Festucetum pruinosae, but it lacks the most western taxa, such as *Angelica pachycarpa* and *Jasione maritima* subsp. *gallaecica*. It fringes another community, mainly characterized by

*Brachypodium rupestre* and *Festuca pruinosa* (Festuco pruinosae-Brachypodietum rupestris), that occupies deep soils in protected zones of the Cantabrian littoral cliffs. The easternmost community on the Basque coast is the Festuco pruinosae-Armerietum euscadiensis with the endemic species *Armeria euscadiensis* (Fernández-Prieto and Loidi 1984).

Within the complex of cliff vegetation, there are other communities developed at nitrified places, such as those in small crevices of siliceous rocks formed almost exclusively by *Asplenium marinum*. Other communities are located in areas where there are abundant bird droppings, e.g. the Cochleario danicae-Matricarietum maritimae (siliceous rocks, Galician-Portuguese and Galician-Asturian sectors), and the Crithmo maritimi-Brassicetum oleraceae (limestone substrata, Cantabrian-Basque Sector).

#### 8.2.2.4 Higher Level

At the uppermost level of capes and promontories, highly exposed to strong sea winds, small, cushion-shaped shrubs of heather and gorse grow. The floristic composition of these stands includes plants of the Calluno-Ulicetea class, such as *Calluna vulgaris*, *Cirsium filipendulum*, *Erica cinerea*, *Erica vagans*, *Halimium alyssoides*, *Glandora prostrata* and several aerohaline ecotypes of the genus *Ulex* (*Ulex europaeus* f. *maritimus*, *Ulex gallii* f. *humilis, Ulex latebracteatus* f. *humilis, Ulex latebracteatus* subsp. *izcoi* f. *pulvinatus*) that behave as differential taxa between different communities (Izco 1993).

The Sileno maritimae-Ulicetum pulvinati, with *Ulex latebracteatus* subsp. *izcoi* f. *pulvinatus,* is an association of rocky cliffs of the northernmost sector of the Galician coast splashed by the Cantabrian Sea. From the Gulf of Ártabro (A Coruña harbour) to the south until Aveiro, the whole west-facing coastal area corresponds to the Galician-Portuguese sector and the aforementioned association is replaced by the Cisto salviifolii-Ulicetum humilis, with *Ulex latebracteatus* f. *humilis* as the dominant taxon.

The Angelico pachycarpae-Ulicetum maritimi supersedes the previous associations on the western Asturian coast with *Ulex europaeus* f. *maritimus* and *Angelica pachycarpa.*

The Ulici humilis-Ericetum vagantis is characterized by *Ulex gallii* f. *humilis, Erica vagans* and *Genista occidentalis* and grows on limestone cliffs of the eastern Cantabrian coast.

Another association, the Genisto occidentalis-Ulicetum maritimi, can be found adjacent to the previous one, on easily eroded substrates of the Basque coast, where a second band of hard limestone cliffs constitutes, but it also occurs as the sole association in this level. Such formations are considered priority habitats (dry Atlantic coastal heaths with *Erica vagans*) of the Habitat Directive (European Commission 2013). A summary of cliff communities is shown in Table 8.1.

Due to their exceptional nature, we here highlight shrub communities in which wild olives or laurels dominate, occupying small areas near the coastline in the

**Table 8.1** Cantabrian and Northwestern Iberian cliff communities

| Association | Biogeographical Sector | Main species |
|---|---|---|
| **Lower level** | | |
| *Crithmo maritimi-Armerietum pubigerae* | Galician-Portuguese<br>Galician-Asturian | *Armeria pubigera* subsp. *pubigera* |
| *Spergulario rupicolae-Armerietum depilatae* | Galician-Asturian | *Armeria pubigera* subsp. *depilata*<br>*Spergularia rupicola* |
| *Crithmo maritimi-Limonietum binervosi* | Galician-Asturian<br>Cantabrian-Basque | *Limonium binervosum*<br>*Armeria pubigera* subsp. *depilata* |
| *Armerio depilatae-Limonietum ovalifolii* | Cantabrian-Basque | *Limonium ovalifolium*<br>*Armeria pubigera* subsp. *depilata* |
| *Crithmo maritimi-Plantaginetum maritimae* | Cantabrian-Basque | *Crithmum maritimum*<br>*Plantago maritima* |
| **Middle level** | | |
| *Dauco gummiferi-Festucetum pruinosae* | Galician-Portuguese<br>Galician-Asturian | *Festuca pruinosa*<br>*Angelica pachycarpa*<br>*Jasione maritima* subsp. *gallaecica* |
| *Leucanthemo crassifoliae-Festucetum pruinosae* | Cantabrian-Basque | *Festuca pruinosa*<br>*Leucanthemum crassifolium* |
| *Festuco pruinosae-Armerietum euscadiensis* | Cantabrian-Basque | *Armeria euscadiensis* |
| *Festuco pruinosae-Brachypodietum rupestris* | Cantabrian-Basque | *Festuca pruinosa*<br>*Brachypodium rupestre* |
| *Leucanthemo crassifolii-Helichrysetum stoechadis* | Cantabrian-Basque | *Leucanthemum crassifolium*<br>*Helichrysum stoechas* |
| **Higher level** | | |
| *Cisto salviifolii-Ulicetum humilis* | Galician-Portuguese | *Ulex latebracteatus* f. *humilis*<br>*Cistus salviifolius* |
| *Sileno maritimae-Ulicetum pulvinati* | Galician-Portuguese<br>Galician-Asturian | *Ulex latebracteatus* subsp. *izcoi* f. *pulvinatus, Angelica pachycarpa, Rumex acetosa* subsp. *biformis* |
| *Angelico pachycarpae-Ulicetum maritimi* | Galician-Asturian | *Ulex europaeus* f. *maritimus*<br>*Angelica pachycarpa, Armeria pubigera* subsp. *depilata* |
| *Ulici humilis-Ulicetum vagantis* | Cantabrian-Basque | *Ulex gallii* f. *humilis, Erica vagans, Cirsium filipendulum* |
| *Genisto occidentalis-Ulicetum maritimi* | Cantabrian-Basque | *Ulex europaeus* f. *maritimus*<br>*Genista occidentalis* |

middle of the Cantabrian coast. The association Lithodoro diffusae-Oleetum europaeae is a permanent relict community, in which microphanerophytes such as *Olea europaea* subsp. *sylvestris, Laurus nobilis, Rhamnus alaternus* and *Quercus ilex* predominate, together with some climbing shrubs like *Smilax aspera, Rubia peregrina* subsp. *longifolia* and *Hedera helix.* There is a sparse herbaceous layer, including some plants of the nearby thermophilous forests (*Tamus communis, Iris foetidissima*) and the coastal cliffs (e.g.*Crithmum maritimum* and *Leucanthemum crassifolium*). It occurs on steep hillsides and limestone cliffs with a southern orientation. Another type of shrubby community is constituted of *Laurus nobilis* accompanied by some shrubs and climbing plants like *Hedera helix, Smilax aspera, Rubia peregrina* and *Tamus communis*. The association Hedero helicis-Lauretum nobilis is a dense community adapted to the abrupt relief of north-facing limestone cliffs and exposed to strong sea winds (Bueno and Fernández Prieto 1991). This community is also a priority habitat of the Habitat Directive (European Commission 2013).

More information about these communities can be found in Rivas-Martínez (1979); Fernández-Prieto and Loidi (1984); Bueno and Fernández-Prieto (1991); Izco (1993); Díaz-González (1998).

#### 8.2.2.5 Dunes

The structure of the Atlantic coastal dunes follows the general scheme of dune vegetation in which communities are replaced from sea level to inland according to ecological gradients like sand mobility, influence of sea wind or increasing organic matter.

The zone nearest the sea, where marine organic deposits are accumulated, is colonized by annual halo-nitrophilous plants such as *Beta maritima, Cakile maritima* or *Salsola kali* together with others like *Chamaesyce peplis, Chamaesyce polygonifolia, Honckenia peploides* and *Polygonum maritimum*. These species form irregular and discontinuous communities on mobile wet sands with high salinity. The most widespread association in this territory is the Honckenyo-Euphorbietum peplis that also can colonize other places in the innermost mobile dunes, when the usual communities occurring there have become destroyed.

Another halo-nitrophilous community (Polygono maritimi-Elytrigietum athericae) can also develop in contact with the mobile dunes. The association is formed by dense grasslands of *Elytrigia atherica* together with biennial and perennial plants such as *Beta maritima, Matricaria maritima, Raphanus maritimus* subsp. *landra, Polygonum maritimum* or annual species like *Cakile maritima* and *Atriplex prostrata* (Díaz-González and Fernández-Prieto 1994).

Embryonic dunes are low, discontinuous and highly mobile sand mounds on which the dominant plant is *Elytrigia juncea* subsp. *boreoatlantica*, a tetraploid taxon (2n = 28) of the Atlantic coast, which is usually accompanied by other dune plants like *Calystegia soldanella, Eryngium maritimum, Euphorbia paralias* or *Honckenya peploides.* The association Euphorbio paraliae-Elytrigietum boreoatlanticae extends along the Atlantic coast, from southern Brittany to Figueira da Foz in Portugal.

Mobile dunes or white dunes are usually located land inward behind the previous formations. The herbaceous community is formed by *Ammophila arenaria* subsp. *australis*, a hemicryptophyte with long rhizomes that contributes to fixing the sands, allowing other specialized dune plants to grow, such as *Calystegia soldanella*, *Eryngium maritimum*, *Euphorbia paralias*, *Medicago marina*, *Otanthus maritimus, Pancratium maritimum*. The association Otantho maritimi-Ammophiletum australis is common along the Cantabrian and Portuguese coasts up to the Peniche Peninsula, Portugal (Fig. 8.2).

Inland from the coast, behind the mobile dunes, some factors like the decrease of wind strength, the low salinity of sands, as well as the increase in organic matter, lead to an increasing diversity of plants, mainly chamaephytes, such as *Crucianella maritima, Euphorbia portlandica, Helichrysum picardii, Iberis procumbens, Scrophularia frutescens*, etc. (Fig. 8.3). The main association, Iberidetum procum-

**Fig. 8.2** Mobile dunes (Otantho-Ammophiletum australis). São Jacinto, Portugal (Photo C. Neto)

**Fig. 8.3** Grey dunes of Corrubedo, La Coruña, Spain. Iberidetum procumbenti*s* and moss communities (Photo M. Herrera)

bentis, colonizes the grey dunes in coastal areas of northern Portugal and Galicia and coexists with the Linario polygalifoliae-Corynephoretum canescentis, a community of medium coverage formed by chamaephytes, hemicryptophytes and geophytes, like *Corynephorus canescens, Linaria polygalifolia, Euphorbia portlandica, Sedum album, Sedum acre* and *Romulea clusiana*. The gaps between the perennial plants are occupied by therophytes such as *Viola kitaibeliana* var. *henriquesii, Pseudorlaya pumila* subsp. *microcarpa, Silene littorea, Silene scabriflora* subsp. *gallaecica* and *Omphalodes littoralis* subsp. *gallaecica,* whose association, the Violo henriquesii-Silenetum littoreae, has its optimum in spring (Izco et al. 1988). Moss communities with *Pleurochaete squarrosa* and *Syntrichia ruralis* var. *ruraliformis* grow on shady areas, facing north and with a higher humidity (Rodríguez-Oubiña et al. 1998).

Other associations of the Cantabrian-Atlantic grey dunes are the Helichryso maritimi-Koelerietum albescentis in which chamaephytes and hemicryptophytes like *Asperula occidentalis, Carex arenaria, Galium arenarium, Dianthus hyssopifolius* subsp. *gallicus, Helichrysum stoechas* subsp. *maritimum* and *Koeleria albescens* predominate (Loriente 1974) and the Carici arenariae-Festucetum juncifoliae with a dune-endemic species, *Festuca juncifolia,* and located in the Galician-Asturian Sector (Rivas-Martínez and Izco 2011). The open spaces are occupied by moss and lichen communities that coexist with annual plants (Tuberarietea guttatae class) and grow on oligotrophic soils (nitrogen-poor sands). All these communities of the Atlantic grey dunes are considered priority habitats in the Habitats Directive (European Commission 2013).

#### 8.2.2.6 Estuaries and Saltmarshes

Communities of estuaries and saltmarshes of more or less flooded areas have a plant composition that varies according to factors such as substrate type, intensity of flooding, level of the water table and degree of salinity. The different biotopes have a specialized flora which is threatened by proliferation of invasive species, urban development and industrial discharges. Zonation from the seashore (at low tide) to inland is as follows:

Seagrass communities are represented mainly by meadows of *Zostera* that colonize muddy or sandy bottoms only exposed at low tide. *Zostera marina* generally occupies muddy estuaries where fresh and marine waters mix, favouring the deposition of fine sediments, and forming monospecific communities (Zosteretum marinae). The association has disappeared from many estuaries of the Basque coast due to industrialization which led to contamination and turbidity of water (Silván and Campos 2002).

*Zostera noltii* most often develops in the loose substrates of the intertidal zone where it can form vast meadows (Zosteretum noltii) in contact with *Zostera marina* or *Spartina maritima* populations. Like the previous species, their populations have disappeared or decreased significantly in many estuaries of this stretch of the coast. Another community that can be found in estuaries is the Enteromorpho intestinalis-

Ruppietum maritimae, whose main species, *Ruppia maritima*, has a wide salinity tolerance. It colonizes channels and pools of brackish waters in contact with communities of rushes and reeds (Díaz-González 2006/2009).

The perennial pioneer community of the intertidal zone is formed by dense meadows of *Spartina maritima* growing on muddy soils, often accompanied by *Fucus vesiculosus* and *Bostrychia scorpioides*. The association Spartinetum maritimae is common along the European Atlantic coast and reaches southern Spain (Cádiz). Some neophytes of American origin, like *Spartina alterniflora* and *S. patens*, also grow in many estuaries of this coastal area. These compete with native communities when they form very dense populations (Silván and Campos 2002).

A type of vegetation formed by pioneer annual species usually develops on periodically flooded mud flats, in contact with communities of *Spartina* sp. pl. and *Sarcocornia perennis*. The dominant plants are species of *Salicornia*, a taxonomically very difficult genus, especially with herbarium material (Rivas-Martínez and Herrera 1996). There are two types of communities on the Atlantic coast, a group with tetraploid species such as *Salicornia dolichostachya*, *Salicornia lutescens* and *Salicornia obscura* included in the alliance Salicornion dolichostachyae-fragilis, occupying the lowest level of saltmarshes; and another group with diploid species (*Salicornia ramosissima*) growing on less flooded soils corresponding to the medium and high levels of saltmarshes (Salicornion europaeo-ramosissimae).

On more stable soils, only flooded during high tide, the association Puccinellio maritimae-Sarcocornietum perennis is formed by dense populations of *Sarcocornia perennis* together with some halophilous species such as *Halimione portulacoides, Puccinellia maritima, Spartina maritima* or *Sarcocornia pruinosa.* In sandy and degraded areas, some species like *Halimione portulacoides* may dominate, elsewhere there is a predominance of herbaceous elements (e.g. *Puccinellia maritima*) as a result of grazing pressure (Herrera 1995). Behind this community, at a higher level only flooded at high tides, another shrubby community can be found, in which *Sarcocornia pruinosa* (*Sarcocornia fruticosa* auct.) and *Halimione portulacoides* are the main species, together with others such as *Tripolium linneanum*, *Plantago maritima, Limbarda crithmoide*s and *Puccinellia maritima* (Puccinellio maritimae-Sarcocornietum pruinosae).

The saltmarsh vegetation complex includes other types of communities, such as those growing in channels draining the estuaries or on the higher levels of marshes, in which *Elytrigia atherica* is the main species together with other plants such as *Atriplex prostrata, Beta maritima, Halimione portulacoides, Limbarda crithmoides* and others. The most widespread association is the Inulo crithmoidis-Elytrigietum athericae that forms dense populations on soils with organic matter left by tides. Another shrubby community is the Elytrigio athericae-Suaedetum verae, which is formed by nanophanerophytes like *Suaeda vera* and *Halimione portulacoides* that may be found on dry sandy soils at the border of saltmarsh.

In less saline marsh areas, several communities formed mainly by *Juncus maritimus* populations can be found: the Puccinellio maritimae-Juncetum maritimi with some halophilous plants such as *Puccinellia maritima, Triglochin maritima* and *Sarcocornia perennis* growing on muddy saline areas near the mouth of estuaries.

The latter is replaced by the Junco maritimi-Caricetum extensae with *Juncus maritimus* and *J. gerardii* as dominant species, on clayey-sandy soils with brackish waters. Soils with lower salinity are colonized by the association Agrostio stoloniferae-Juncetum maritimi, whose composition includes typical plants of wet meadows such as *Galium palustre, Lythrum salicaria, Lotus pedunculatus* and *Mentha aquatica,* together with halophilous or subhalophilous species like *Tripolium linneanum, Apium graveolens, Glaux maritima, Plantago maritima*, and others (Díaz-González 2006/2009).

More information about these communities can be found in Izco et al. (1992), Díaz-González and Fernández-Prieto (1994); Rivas-Martínez and Herrera (1996); Bueno (1997); Díaz-González (2006/2009).

## 8.3 Iberian Atlantic Coast

The Iberian Atlantic Coast comprises the coastal stretch between south Ría de Aveiro (Portugal) and Punta de Tarifa at the Strait of Gibraltar. It corresponds to a large part of the Coastal Lusitano-Andalusian Province, extending from southern Ría de Aveiro up to Marbella (Málaga). It is a transition territory where plant migratory pathways converge, especially in the littoral zone, one in a north-south direction for Atlantic taxa (e.g. *Angelica pachycarpa, Cochlearia danica, Elytrigia juncea* subsp. *boreoatlantica, Limonium vulgare, Silene uniflora*), another in the opposite direction for Mediterranean species like *Cymodocea nodosa, Limonium ferulaceum, Sarcocornia alpini* and *Suaeda splendens,* etc. (Costa et al. 2009).

The coastal landscape between Aveiro and Lisbon includes low sandy coasts alternating with cliffs (e.g. Capes Mondego, Carvoeiro, Roca), estuaries like the Mondego River, and coastal lagoons (Óbidos). On the Portuguese southwestern and southern coast, there are the large estuaries of the Tagus and Sado, the dunes of Troia Peninsula, the coastal lagoons of Ría de Alvor and Ría Formosa, as well as the rugged coastline with small beaches at its base, between Cape Sines and Cape San Vicente. The Spanish coast between the Guadiana River and Punta de Tarifa (Gaditano-Onubense Litoral Sector) has extensive saltmarshes at the mouth of the rivers Tinto, Odiel, Guadalquivir, Guadalete and Barbate, as well as remarkable dune ecosystems (e.g. Doñana National Park, Cape Trafalgar) and some sandstone cliffs in Cádiz.

### *8.3.1 Climatic Features*

The climate is Mediterranean with a strong influence of moist air masses coming in from the Atlantic Ocean. Temperatures increase from north to south; the annual average is 15–16 °C (e.g. Aveiro, Mira, São Martinho do Porto) and 16–18 °C in Lisbon, Faro, Huelva and Algeciras. Annual rainfall is more abundant in the north,

around 900 mm (e.g. Aveiro, Figueira da Foz) decreasing towards the south, 450–500 mm (southern Algarve, Huelva coast). The geographical position of the Strait of Gibraltar, under the influence of different air masses (Azores anticyclone, disturbances from west) determines the highest rainfall, around 700–900 mm (e.g. Algeciras, Tarifa). The most common thermotype is the thermomediterranean that extends along the coastline, except for the Portuguese northern section (e.g. Leiria, Mira, Quiaios) which is mesomediterranean. The ombrotype varies from dry to subhumid.

## *8.3.2 Vegetation Description*

### 8.3.2.1 Cliffs

The most exposed zones, splashed with salt spray, have a specialized flora, due to environmental conditions and geographic isolation, in which *Armeria* and *Limonium* play important roles in vegetation composition. The taxa *Armeria pseudarmeria, Daucus hispanicus* subsp. *halophilus, Dianthus cintranus* subsp. *cintranus, Limonium multiflorum, Limonium ovalifolium, Limonium plurisquamatum, Limonium virgatum, Spergularia australis* and other species, are the characteristics of the associations between Capes Mondego and Espichel, such as the Dactylido marinae-Limonietum plurisquamati, the Limonietum multifloro-virgatii and the Diantho cintrani-Daucetum halophili, included in the Crithmo maritimi-Daucion halophili, an alliance of the Coastal Lusitano-Andalusian Province.

In the Berlengas archipelago, a few km from Peniche Peninsula, grows a local endemic, *Armeria berlengensis*, accompanied by Atlantic species, such as *Angelica pachycarpa, Silene uniflora* and *Spergularia rupicola.* The association Spergulario rupicolae-Armerietum berlengensis, developed on granite rocks, has affinities with the Cantabrian-Atlantic communities of the previous stretch. In the crevices of rocks where gull droppings are abundant, this community is in contact with stands of halo-nitrophilous plants like *Suaeda vera, Beta maritima, Frankenia laevis, Scrophularia sublyrata* and *Lavatera maritima* that characterize the association Scrophulario sublyratae-Suaedetum verae (Costa et al. 1998).

The southwestern coast (Costa Vicentina) is characterized by high cliff faces, formed by unstable sandstones or hard substrates (schists), of 40–120 m high, which are crowned by fossil dunes (Neto et al. 2001). The cliff communities, less diverse than the previous ones, have among others, the following species: *Crithmum maritimum, Limonium ferulaceum, Limonium virgatum, Limonium ovalifolium, Daucus hispanicus* subsp. *halophilus, Dittrichia maritima, Pallenis maritima* and *Spergularia australis* (Fig. 8.4). The Spanish stretch (Huelva-Cádiz) is characterized by low coasts with large areas with extensive dune ecosystems, while only some sandstone cliffs emerge on the Cádiz coast with *Limonium emarginatum* (Asensi 1984).

**Fig. 8.4** Dunes on cliffs. Almograve, Alentejo coast, Portugal (Photo C. Neto)

The higher levels of the cliff faces, exposed to strong sea winds, have a vegetation type whose physiognomy is similar to that mentioned for the Cantabrian coast, formed by small, thorny, cushion-shaped shrubs in which some ecotypes adapted to this environment stand out, such as *Ulex jussiaei* subsp. *congestus*, *Ulex latebracteatus* f. *humilis* and *Astragalus tragacantha* subsp. *vicentinus.* On the Portuguese coastline the following associations can be found:

The Cisto salvifolii-Ulicetum humilis that extends from the Divisorio Portugues to the Galician-Portuguese Sector.

The Daphno maritimae-Ulicetum congesti with the Portuguese endemic *Ulex jussiaei* subsp. *congestus* found between Capes Mondego and Roca.

The Dauco halophili-Astragaletum vicentini with two local endemics: *Astragalus tragacantha* subsp. *vicentinus* and *Silene rothmaleri,* growing at the Sagres Peninsula. A summary of these communities is shown in Table 8.2.

The permanent vegetation of the Portuguese limestone cliffs is a low forest with *Juniperus turbinata* of the association Querco cocciferae-Juniperetum turbinatae with species like *Asparagus aphyllus, Osyris lanceolata, Quercus coccifera, Phillyrea angustifolia, Pistacia lentiscus, Rhamnus alaternus, Rhamnus oleoides, Rubia peregrina, Olea europaea* subsp. *sylvestris, Smilax aspera*.

Information concerning these communities can be found in Rivas-Martínez et al. (1990); Costa et al. (1998, 2000); Arsénio et al. (2009); Neto et al. (2009).

**Table 8.2** Iberian-Atlantic cliff communities

| Association | Location | Main species |
|---|---|---|
| **Lower level** | | |
| *Dactylo marinae-Limonietum plurisquamati* | Cape Mondego- Peniche Peninsula | *Limonium plurisquamatum* |
| *Limonietum multifloro-virgatii* | Tagus Estuary- Peniche Peninsula | *Limonium multiflorum* |
| *Diantho cintrani-Daucetum halophili* | Cape Roca | *Dianthus cintranus*<br>*Armeria pseudarmeria* |
| *Spergulario rupicolae-Armerietum berlengensis* | Berlengas Islands | *Armeria berlengensis*<br>*Spergularia rupicola* |
| *Helianthemo-Limonietum virgati* | Cape Espichel | *Limonium virgatum* |
| *Dittrichietum maritimi* | Capes San Vicente-Sines | *Dittrichia maritima* |
| *Limonietum ferulacei* | Southwest Algarve | *Limonium ovalifolium* |
| *Limonietum emarginati* | Cádiz coast | *Limonium emarginatum* |
| **Higher level** | | |
| *Cisto salviifolii-Ulicetum humilis* | Divisorio Portugues and Galician-Portuguese sectors | *Ulex latebracteatus* f. *humilis* |
| *Daphno maritimae-Ulicetum congesti* | Capes Mondego-Roca | *Ulex jussiaei* subsp. *congestus* |
| *Dauco halophili-Astragaletum vicentini* | Cape San Vicente | *Astragalus tragacantha* subsp. *vicentinus, Silene rothmaleri* |

### 8.3.2.2 Dunes

On the Portuguese coast, the nearest sea community growing on marine debris is constituted by annual plants such as *Cakile maritima, Chamaesyce peplis* and *Salsola kali* that characterize the association Salsolo kali-Cakiletum maritimae which has a Mediterranean distribution and is being replaced north of the Peniche Peninsula by the Atlantic association Honckenyo-Euphorbietum peplis. Another perennial community with *Sporobolus virginicus* subsp. *arenarius* (Sporoboletum arenariae) is usually developed in the first line of the flat coastal dunes with coarse sand particles (Rivas-Martínez and Cantó 2002b).

The embryonic dunes from Figueira da Foz up to Aveiro have the same association as the Galician-Portuguese sector: the Euphorbio paraliae-Elytrigietum boreoatlanticae, which is replaced in the southern section to Cape Trafalgar (Cádiz) by the Elytrigietum junceo-boreoatlanticae, whose dominant taxa are *Elytrigia juncea* subsp. *juncea* of Mediterranean distribution and *Elytrigia juncea* subsp. *boreatlantica* of the Atlantic coast.

Mobile dunes or white dunes with *Ammophila arenaria* subsp. *australis* are also represented by two communities: the Otantho-Ammophiletum australis which stretches from the Cantabrian-Atlantic coast to Peniche (Portugal) and the Loto cretici-Ammophiletum australis, an association on the southern Iberian coast that differs from the former by the abundance of *Lotus creticus* (Fig. 8.5).

Semi-fixed dunes or grey dunes typically are floristically rich and contain several chamaephytes: *Armeria pungens, Artemisia crithmifolia, Crucianella maritima, Lotus creticus, Scrophularia frutescens*, and some endemics, e.g. *Armeria welwitschii, Herniaria maritima, Linaria lamarckii* and *Thymus carnosus*. The association Artemisio crithmifoliae-Armerietum pungentis has a wide distribution area ranging from Tarifa to the Tagus Estuary, being replaced in further north up to Cape

**Fig. 8.5** Mobile dunes (Loto cretici-Ammophiletum australis) Troia Peninsula, Portugal (Photo C. Neto)

Mondego by the Armerio welwitschii-Crucianelletum maritimae (Costa et al. 2000). The gaps in these communities are occupied by numerous annual plants that appear in spring, such as *Catapodium hemipoa*, *Cutandia maritima*, *Erodium laciniatum*, *Ononis variegata*, *Hedypnois arenaria, Herniaria algarvica, Linaria ficalhoana, Linaria munbyana* subsp. *pygmaea*, *Linaria pedunculata, Silene littorea*. The widespread associations are the Ononido variegatae-Linarietum pedunculatae of the southern Iberian Peninsula and the Herniario algarvicae-Linarietum ficalhoanae of southwestern Portugal, both included in the alliance Linarion pedunculatae which stretches from the Galician to the Almerian coasts and reaches North Africa (Díez-Garretas et al. 2003).

The mature stage of the dune ecosystem is a *Juniperus turbinata* forest that occupies stable dunes, paleodunes or fossil dunes on sea cliffs. The association Osyrio quadripartitae-Juniperetum turbinatae occurs along the Atlantic coast from Cape Mondego to Tarifa. Together with *Juniperus turbinata,* there are shrubs and trees such as *Olea europaea* subsp. *sylvestris, Osyris lanceolata, Phillyrea angustifolia, Pistacia lentiscus, Rhamnus alaternus, Rhamnus oleoides, Quercus coccifera* and climbing plants like *Lonicera implexa, Smilax aspera* and *Rubia peregrina* subsp. *longifolia.* These *Juniperus* forests are generally accompanied by a shrubby community with *Corema album,* a relict species from the Iberian western coasts. The association Rubio longifoliae-Corematetum albi contains also other species, e.g. *Antirrhinum cirrhigerum*, *Asparagus aphyllus, Daphne gnidium* and *Rubia peregrina* subsp. *longifolia*.

**Fig. 8.6** *Juniperus navicularis* and a community of *Cladonia* spp. Tróia Peninsula, Portugal

In the inner paleodunes of the Sado Basin, the mature stage corresponds to the association Daphno gnidii-Juniperetum navicularis, basically formed by *Juniperus navicularis* together with *Daphne gnidium, Osyris alba, Osyris lanceolata, Phillyrea angustifolia, Pistacia lentiscus, Rubia peregrina* subsp. *angustifolia* and others. In this environment there are fragile communities dominated by species of *Cladonia* (*C. mediterranea, C. portentosa*, among others), that are very sensitive to trampling (Fig. 8.6). The Santolinetum impressae, a community with the endemic *Santolina impressa* is common on disturbed soils.

*Juniperus navicularis* is an endemic species of the Iberian southwestern coast that reaches some coastal areas of Huelva and Cádiz. It grows on dry sandy substrata, sometimes associated with podzol soils, conditions that prevent the development of the *Quercus suber* forests which normally occupy soils with shallower and wetter sands. Human activity in the Sado Estuary, due to agriculture and forestry (plantations of *Eucalyptus camaldulensis, Pinus pinea* and *Pinus pinaster*), has encouraged the development of scrub rich in endemic species such as *Armeria pinifolia, Armeria rouyana, Stauracanthus genistoides, Thymus capitellatus* and *Ulex australis* subsp. *welwitschianus*. The association Thymo capitellati-Stauracanthetum genistoidis covers large areas in this territory (Neto 2002). Other communities with *Stauracanthus spectabilis* replace that association in the Portuguese southwestern stretch. In these biotopes, without influence of salt spray, annual plant communities of the alliance Hymenocarpo hamosi-Malcolmion trilobae are developed. They are rich in species, including *Arenaria algarbiensis, Arenaria emarginata, Corynephorus macrantherus, Linaria algarviana*, *Loeflingia baetica*, *Malcolmia triloba, Malcolmia triloba* subsp. *gracillima, Omphalodes kuzinskyanae, Ononis baetica, Ononis broteriana, Trisetum dufourei*, *Vulpia fontquerana,* etc. (Costa et al. 2011).

**Fig. 8.7** Grey dunes (Artemisio crithmifoliae-Armerietum pungentis) with the alien species *Carpobrotus edulis*. Troia Peninsula, Portugal

A serious problem in the dune ecosystems of Portugal is the presence of invasive alien plants, like *Acacia longifolia, Acacia melanoxylon, Arctotheca calendula, Carpobrotus edulis, Oenothera stricta* which cover large areas preventing the development of natural communities (Fig. 8.7).

The coastal stretch between the mouth of the Guadiana River (Huelva) and Tarifa is a low coast that corresponds to the sunken part of the Guadalquivir Depression where extensive dune systems are located, the Doñana National Park being the most significant. The structure of the vegetation, typical of the mobile and semi-fixed dunes, is similar to that indicated for the Portuguese section. The halo-nitrophilous community with *Cakile maritima* and *Salsola kali* is scarcely represented as well as the embryonic dunes association with *Elytrigia juncea*, but, in contrast, the white dunes form long strings parallel to the coastline.

On the outer fixed dunes within reach of the sea winds, a coastal juniper community is established, forming a discontinuous band in contact with the semi-fixed dunes (Fig. 8.8). The association Rhamno oleoidis-Juniperetum macrocarpae, with *Daphne gnidium, Juniperus turbinata, Pistacia lentiscus, Rhamnus oleoides, Rubia peregrina* subsp. *longifolia* and *Phillyrea angustifolia,* is endemic on the Huelva and Cádiz coast (Rivas-Martínez et al. 1980).

The mature stage of the dune ecosystem corresponds to the association *Osyrio quadripartitae-Juniperetum turbinatae* already mentioned for the Portuguese stretch.

**Fig. 8.8** Coastal juniper community (Rhamno oleoidis-Juniperetum macrocarpae). Trafalgar Cape, Spain

The open spaces of the fossil dunes are occupied by oligotrophic grassland in which annual plants such as *Arenaria algarbiensis, Linaria tursica, Loeflingia baetica, Malcolmia triloba, Vulpia fontquerana* and others grow (Linario donyanae-Loeflingietum baeticae).

Disturbances in these forests promote the development of scrub dominated by chamaephytes and nanophanerophytes. The association Halimio halimifolii-Stauracanthetum genistoides, locally called "monte blanco", is characterized by *Stauracanthus genistoides, Halimium halimifolium, Halimium calycinum* and *Lavandula sampaioana* subsp. *lusitanica,* with some endemic species such as *Armeria velutina, Cistus libanotis* and *Thymus albicans.* The association is found on stable sands and paleodunes with a low organic matter content and a water table at over 2 m deep. A variant with *Ulex australis* and *Erica scoparia,* indicating the links with heathlands, develops on soils with a water table at less than 1 m deep. The association Erico scopariae-Ulicetum australis, called "monte negro", in contrast with the previous community, represents a substitution stage of *Quercus suber* forests (Rivas-Martínez et al. 1980).

*Juniperus* woodlands form slow-growing ecosystems which have been catalogued as priority habitats (coastal dunes with *Juniperus* spp.) of the Habitat Directive (European Commission 2013). They have been replaced, in many cases, by *Pinus pinea* plantations, which form quick-growing and extensive forests along the southwestern Spanish coast.

More information about these communities can be found in Rivas-Martínez et al. (1980, 1990); Asensi et al. (1993, 2007, 2014); García Novo and Merino (1993); Neto (2002);. Díez-Garretas (2007); Díez-Garretas and Asensi (2014).

#### 8.3.2.3 Estuaries and Saltmarshes

Saltmarsh systems are located at the mouth of rivers, among which we highlight the Tagus and Sado estuaries, Ría de Alvor and Ría Formosa in Portugal. The Guadalquivir marshes are the most extensive ones on the Andalusian Atlantic coast, followed by those of the mouths of the Guadiana, Tinto-Odiel, Barbate and Bay of Cádiz. The zonation of communities from the sea to inland is as follows:

The main seagrass species growing in intertidal areas are *Zostera noltii, Zostera marina* and *Cymodocea nodosa*, occupying sandy or muddy substrates. The first, *Zostera noltii*, is the most widely distributed species and forms extensive meadows in the Sado Estuary, Ría Formosa and Bay of Cádiz. Ría de Aveiro is the northern limit for this species on the Atlantic coast. *Zostera marina* meadows are scarce and many of its populations have disappeared or declined significantly, especially on the Portuguese coast (Cunha et al. 2013). *Cymodocea nodosa* is a Mediterranean species, the Sado Estuary being its northern limit. It is common on the southern coasts of Portugal where it grows on sandy or sandy-muddy substrates, more rarely on rocks of shallow coastal areas, estuaries and protected bays.

The dominant community on the muddy bottoms of the intertidal zone is formed by *Spartina maritima* populations, sometimes accompanied by *Sarcocornia perennis*. The South American neophyte *Spartina densiflora* occupies a more elevated level than the previous community and covers large areas at Ría Formosa and the Odiel Estuary. It has a sufficiently strong invasive ability to displace native vegetation.

In the same biotopes, two groups of annual *Salicornia* communities can be found: one with tetraploid species and an Atlantic distribution such as the Salicornietum fragilis occupying the lower level of estuaries; another one with diploid and tetraploid species that extend along the Mediterranean coast, like the Suaedo splendentis-Salicornietum patulae which grows at higher elevations in estuaries (Costa et al. 1996).

The next band of vegetation, developed on soils subjected to tidal flow, is occupied by the chamaephyte *Sarcocornia perennis* together with other species and grasses that differentiate the two associations of this coastal stretch: the Puccinellio maritimae-Sarcocornietum perennis extending from the Cantabrian coast to the mouth of the Tagus, and the Puccinellio ibericae-Sarcocornietum perennis from the south of this river to the Cádiz coast (Fig. 8.9). These communities are replaced, in the inner band, somewhat higher, by the Halimiono portulacoidis-Sarcocornietum alpini, whose dominant species is *Sarcocornia alpini*, common in the SW Iberian coasts and NW Morocco. It extends throughout the southwest of the Iberian Peninsula up to south of the Tagus River and is replaced by the Triglochino

**Fig. 8.9** Barbate saltmarsh, Cádiz, Spain (Puccinellio ibericae-Sarcocornietum perennis)

maritimae-Sarcocornietum alpini in the saltmarshes north of this river (Costa et al. 2009).

The *Sarcocornia pruinosa* communities are located on soils that are subject to flooding, slightly above the mean tide level. The Cistancho phelypaeae-Sarcocornietum pruinosae is a southern Iberian association that is formed by dense populations of *Sarcocornia pruinosa*, accompanied by species like *Halimione portulacoides* and the parasite *Cistanche phelypaea.* Although Ría de Aveiro has been considered the boundary between the Eurosiberian and Mediterranean Regions, several saltmarsh communities find their limit at the Tagus River, which can be considered the true border for this vegetation type (Costa et al. 2009).

The highest level of the saltmarsh is covered by a perennial vegetation adapted to increased concentrations of salts in the soil, especially in summer. The association Inulo crithmoidis-Arthrocnemetum macrostachyi grows on highly saline soils that are subject to prolonged drought and occurs from the Cádiz saltmarsh up to the mouth of the Tagus River. The disturbed sandy soils are occupied by the Cistancho phelypaeae-Suaedetum verae and the sandy-loamy soils by the Polygono equisetiformis-Limoniastretum monopetali. Other communities associated with saltmarsh vegetation complex are:

The Polygono equisetiformis-Juncetum maritimi. Rushes that occupy sandy or sandy-loamy soils with a low salinity on the banks of rivers and estuaries. The association, frequent in estuaries between the rivers Tagus and Guadalquivir, is composed by dense populations of *Juncus maritimus* and *Juncus acutus* together with

other species, such as *Limbarda crithmoides, Spergularia marina, Polygonum equisetiforme, Limonium algarvense, Triglochin barrelieri,* etc. (Costa et al. 1996).

The Polygono equisetiformis-Tamaricetum africanae. A shrubby community dominated by *Tamarix africana* which grows on river banks and coastal lagoons with a long period of drought. It is common in the estuaries between the rivers Tagus and Guadalquivir, where it occupies sandy or clayey soils, in areas where stronger currents cause the mobilization of sediments and loss of shrubby and herbaceous elements.

The Bolboschoeno compacti-Schoenoplectetum litoralis. Saltmarsh areas subjected to prolonged flooding have communities of helophytes such as *Schoenoplectus littoralis* and *Bolboschoenus maritimus* subsp. *compactus* that colonize loamy and clayey soils covered temporarily by fresh and salt waters (Rivas-Martínez et al. 1980).

Information concerning these communities can be found in Costa et al. (1996, 2009); Neto et al. (2009); Rivas-Martínez et al. (1980, 1990).

## 8.4 Iberian Mediterranean Coast

The Mediterranean coast, with about 3500 km, includes the peninsular coastline (more than 2000 km) and the coasts of the Balearic Islands (1428 km) and includes sedimentary coasts (almost 25%), which are related to the mouths of large rivers (Ebro, Turia, Segura and Júcar), and rocky shores associated with coastal mountainous reliefs (Catalonian Coastal Ranges, Iberian System and Baetic Ranges). An important difference between the Atlantic coasts and those of the Mediterranean lies in the virtual absence of tides and a lack of large marshes in this stretch, but there are semi-enclosed coastal lagoons (albuferas). On the other hand, the Mediterranean river mouths have also estuaries and delta areas associated with high sediment transport of some Mediterranean rivers (e.g. Ebro and Llobregat).

### *8.4.1 Climatic Features*

The characteristic climate is Mediterranean with a dry period covering at least the summer months. Temperatures are cooler on the Catalonian coast (annual average of 15 °C in Gerona) and gradually increase towards the south (18–19 °C, from Murcia down to Málaga). The lowest annual precipitation occurs in the southeast (e.g. 157 mm, the lighthouse of Cape of Gata, Almería; 199 mm, Águilas, Murcia), while the highest corresponds to the Gerona coast, with more than 600 mm. The general thermotype is the thermomediterranean, except in the northern section that corresponds to the mesomediterranean. The dry ombrotype is the most widespread, except in the north (subhumid) and the southeast (semiarid – arid).

The Balearic coast has an average temperature of 16–18.5 °C and rainfall decreases from east to west, about 650 mm in Mahón (Minorca) and Alcudia (Majorca) and

400 mm in Ibiza and Formentera. North winds have a drying effect on coastal vegetation, especially on the northern coast of Minorca, but this is more attenuated in southern areas. The thermotype corresponds to the thermomediterranean and the ombrotype is dry or subhumid in the northern part of the larger islands.

## *8.4.2 Vegetation Description*

### 8.4.2.1 Cliffs

Vegetation occupying the first band of cliffs subjected to sea winds and splashing waves are included in the alliance Crithmo maritimi-Limonion whose optimum is found in the western Mediterranean. Over twenty associations have been described, in which *Crithmum maritimum* and *Limonium* sp. pl. are common, together with taxa belonging to the group *Daucus hispanicus* (subsp. *commutatus*, subsp. *hispanicus* and subsp. *majoricus*). Several sections can be distinguished:

1. Málaga-Altea (Alicante). The proximity of the Baetic Ranges to the sea has led to a coastline with rocky outcrops alternating with small beaches at their base. Sedimentation processes in large sectors of this coast have created accumulations of powerful torrential cones and a narrow coastal plain. Despite the rugged coast, cliff communities are scarce, but include: the Crithmo maritimi-Limonietum malacitani with *Limonium malacitanum* on the Málaga coast and the Limonio cossonianae-Lycietum intricati, a community composed of *Crithmum maritimum* accompanied by less specialized species like *Limonium cossonianum*, *Lycium intricatum* and *Salsola papillosa* (Fig. 8.10). This vegetation extends into semiarid and arid zones of the Murcian-Almerian Province. It also occupies volcanic cliffs at Cape of Gata.
2. Altea-Blanes (Gerona). It is characterized by the dominance of limestone cliffs inhabited by endemic species of *Limonium*, as is shown in the following table:

| Limonium taxa | Area | Association |
|---|---|---|
| *Limonium rigualii*, *Limonium scopulorum* | Cape San Antonio | Crithmo maritimi-Limonietum rigualii |
| *Limonium perplexum*, *Limonium girardianum, Limonium virgatum* | Sierra de Irta (Northern Castellón) | Crithmo maritimi-Limonietum girardiani |
| *Limonium gibertii, Limonium virgatum* | Tarragona | Crithmo maritimi-Limonietum gibertii |
| *Limonium revolutum*, *Limonium minutum* subsp. *pericotii* | Bay of Rosas and the Medes Islands | Dauco hispanici-Crithmetum maritimi |

3. Costa Brava. This coastal region in northeastern Spain stretches between Blanes (Gerona) and the Franco-Spanish border. The northernmost section between the Albera Massif and Cape Creus is characterized by the dominance of metamorphic

**Fig. 8.10** Limestone cliffs of Málaga. Crithmo maritimi-Limonietum malacitani

rocks (schists, quartzites, amphibolites) on which the association Armerietum ruscinonensis occurs with some endemic species, e.g. *Armeria ruscinonensis, Limonium geronense* and *Limonium tremolsii,* and accompanied by *Dianthus pyrenaicus* subsp. *attenuatus* and *Polycarpon polycarpoides* subsp. *catalaunicum*. Elevated above the level of this vegetation, a second vegetation band is developed, in which cushion-shaped communities with *Astragalus tragacantha* subsp. *tragacantha* dominate, similar to those of Cape San Vicente (Portugal). Another feature of this territory is the *Juniperus macrocarpa* community developed on granite and limestone rocks exposed to sea wind. The association Astragalo tragacanthae-Juniperetum macrocarpae has several territorial species, e.g. *Astragalus tragacantha, Festuca ruscinonensis* and *Polycarpon polycarpoides* subsp. *catalaunicum* (Rivas-Martínez and Cantó 2002a).

4. Balearic Islands. The Balearic archipelago consists of two groups of islands and about one hundred islets: in the north Majorca, Minorca, Cabrera (Gimnesias); in the south Ibiza and Formentera (Pitiusas). Most coastal cliffs consist of limestone, except for some areas with siliceous rocks in the north and east of Minorca.

The Balearic Islands have a great diversity of cliff communities, especially in the Gimnesias Islands, where nine of the ten associations described from the area are located. The special characteristics of the local biotopes, together with the isolation of the populations, have favoured a rich speciation in these islands, especially in the genus *Limonium*, that possess 17 endemic species in these environments, 8 of which are exclusive to Majorca (*Limonium balearicum, Limonium caprariense, Limonium carregadorense, Limonium dragonericum, Limonium gymnesicum, Limonium majoricum, Limonium muradense, Limonium portopretanum, Limonium pseudodictyocladum*) (Fig. 8.11).

**Fig. 8.11** Limestone cliffs of Majorca. Limonietum caprariensis (Photo L. Llorens)

On some rocky coasts of Majorca and Minorca a second band of vegetation is found, occupying positions near the sea. These communities comprise thorny, cushion-shaped species, many of them endemic, e.g. *Anthyllis hystrix, Carthamus balearicus, Dorycnium fulgurans, Euphorbia maresii, Launaea cervicornis* and *Santolina magonica.* The most frequent association is Launaeetum cervicornis which occurs adjacent to the *Limonium* communities of the lower band. A summary of these communities is shown in Table 8.3.

Information about these communities can be found in Rivas-Martínez et al. (1992a, b); Gil and Llorens (1995); Crespo et al. (2003).

### 8.4.2.2 Dunes

The Mediterranean coastal dunes have been subjected to a marked disturbance in the last sixty years, mainly due to tourism and urban pressure with the construction of marinas, promenades and housing developments and that has led to the deterioration and disappearance of many of these ecosystems. However, there still are some Mediterranean dune ecosystems in a good state of preservation, including Punta Entinas-Sabinar (Almería), Dehesa del Saler (Valencia), Cala Mesquida and Es Trenc (Majorca).

**Table 8.3** Balearic Islands cliff communities

| Association | Location | Species |
|---|---|---|
| **Lower level** | | |
| *Limonietum pseudebusitani* | Ibiza, Cabrera | *Limonium pseudebusitanum*<br>*L. ebusitanum, L. scorpioides* |
| *Limonietum caprariensis* | Cabrera, South Majorca | *Limonium caprariense, L.pseudebusitanum*<br>*Daucus hispanicus* subsp. *majoricus* |
| *Limonietum pseudodictyoclado-carregadorensis* | West Majorca | *Limonium pseudodictyocladum, L. carregadorense, L. pseudarticulatum, Silene sedoides* |
| *Limonietum majorico-gymnesici* | Northeast Majorca | *Limonium majoricum, L. gymnesicum* |
| *Dauco majorici-Limonietum marisolii* | Southern Majorca | *Limonium pseudebusitanum Limonium marisolii, Daucus hispanicus* subsp. *majoricus* |
| *Crithmo maritimi-Limonietum balearici* | Northern Majorca | *Limonium balearicum, L. tenuicaule, Daucus hispanicus* subsp. *majoricus* |
| *Dauco hispanici-Limonietum biflori* | Northeast Majorca | *Limonium biflorum, L. xbolosii, L. balearicum* |
| *Santolino magonicae-Limonietum biflori* | North and east Minorca | *Limonium biflorum, L. companyonis, L. virgatum, Santolina magonica* |
| *Limonietum minuto-fontqueri* | North and east Minorca | *Limonium minutum, L. fontqueri, L. tenuicaule, Senecio rodriguezii* |
| *Limonietum artruchio-minuti* | South and west Minorca | *Limonium artruchium, L. minutum, L. minoricense, L. saxicola* |
| **Higher level** | | |
| *Euphorbio pithyusae-Anthemidetum maritimae* | Majorca, Minorca | *Anthemis maritima, Euphorbia pithyusa* |
| *Helichryso microphylli-Dorycnietum fulgurantis* | Southwest Majorca | *Dorycnium fulgurans*, *Helichrysum italicum* subsp. *microphyllum* |
| *Launaeetum cervicornis* | Majorca, Minorca | *Launaea cervicornis* |
| *Santolino magonicae-Anthyllidetum hystricis* | Minorca | *Anthyllis hystrix, Carthamus balearicus, Santolina magonica* |

**Mobile Dunes** The first vegetation band of dunes and beaches forms a more or less continuous strip where marine debris is deposited. Here annual communities are represented by two associations: the Salsolo kali-Cakiletum aegyptiacae, common on sandy beaches, and the Hypochoerido radicatae-Glaucietum flavi on beaches of boulders and pebbles. Another perennial community formed basically by *Sporobolus virginicus* subsp. *arenarius* (Eryngio maritimi-Sporoboletum arenariae) is usually developed in first band on flat coastal dunes with coarse sand particles (Rivas-Martínez and Cantó 2002b).

The dominant species of embrionic dunes is the diploid taxon *Elytrigia juncea* subsp. *juncea* which characterizes the association Cypero mucronati-Elytrigietum junceae that occurs widely along the Mediterranean Iberian coast.

White dunes are colonized by two associations: the Loto cretici-Ammophiletum australis on the southern Iberian coasts, already mentioned in the Iberian-Atlantic stretch, and the Medicagini marinae-Ammophiletum australis on the western Mediterranean coast with *Calystegia soldanella, Crucianella maritima, Eryngium maritimum, Ononis ramosissima, Pancratium maritimum* and *Echinophora spinosa*. The latter species is a good differential species against the other communities.

**Stable Dunes** Behind the mobile dunes sands are consolidated and wind action has decreased, and the plant cover is dominated by chamaephytes on semi-fixed dunes and phanerophytes on more stable dunes. The main association on semi-fixed dunes is the Crucianelletum maritimae with *Crucianella maritima*, *Helichrysum stoechas* subsp. *maritimum, Malcolmia littorea, Ononis ramosissima* and *Teucrium dunense*, among others. It occurs along the Mediterranean coast from Gerona to Alicante and is replaced by the Loto cretici-Crucianelletum maritimae on the southeastern Iberian Peninsula and the Balearic Islands. Minorca has an endemic association, the Ononido crispae-Scrophularietum minoricensis, with *Scrophularia ramosissima* subsp. *minoricensis* and *Ononis crispa*.

*Juniperus* communities and other phanerophytes play an important role on stable dunes and represent the mature stage of these ecosystems. Taking into account both *Juniperus* species, the maritime juniper (*Juniperus macrocarpa*) has a very restricted distribution area on the Iberian Mediterranean coast with some scattered populations at Alicante, Valencia, Castellón, Gerona, Majorca and Ibiza (Diez-Garretas and Asensi 2014). Among these, we highlight those found in dunes on the cliffs of the Sierra Helada (Alicante). They contain some shrubs like *Osyris lanceolata, Ephedra fragilis, Corema album, Chamaerops humilis* and *Rhamnus lycioides* (Coremato albi-Juniperetum macrocarpae). Another example is found in the Bay of Alcudia (Majorca), one of the few places in the Balearic Islands where *Juniperus macrocarpa* occurs. That association, Rubio longifoliae-Juniperetum macrocarpae, is formed of pines (*Pinus halepensis*), shrubs (*Pistacia lentiscus, Myrtus communis*) and some climbing plants (*Rubia peregrina* subsp. *longifolia, Lonicera implexa* and *Smilax aspera*).

*Juniperus turbinata* forests, which grow in the innermost dunes, are scarce on the Mediterranean coast, but do occur at Almería and Murcia. The Rhamno angustifoliae-Juniperetum turbinatae is well represented in Punta Entinas-Sabinar (Almería) where a dense forest is formed with *Juniperus turbinata* and *Pistacia lentiscus* as dominant species, accompanied by, e.g., *Rhamnus oleoides* var. *angustifolia, Maytenus europaeus* and *Lycium intricatum* (Fig. 8.12).

Nearby, in the coastal areas of the Cape Gata-Níjar Natural Park, the fixed dunes are colonized by open populations of *Ziziphus lotus,* a species that inhabits semiarid and arid sites in the southeast Iberian Peninsula (Fig. 8.13). The physiognomy of this peculiar community (Ziziphetum loti) consists of separate specimens of *Ziziphus* which retain sand in mounds of more than 1 m high and about 25 $m^2$ surface area, on which other plants, like *Asparagus albus, Lycium intricatum, Withania frutescens, Rubia peregrina, Thymelaea hirsuta* and *Arisarum simorrhinum,* grow (Peinado et al. 1992). A substitution stage of the Ziziphetum loti and also of *Juniperus turbinata* forests, on sandy soils, is a low scrub (tomillar) mainly formed by chamaephytes such as *Teucrium dunense, Helianthemum almeriense* subsp. *scopulorum* and *Thymus hyemalis* corresponding to the association Teucrio dunensis-Helianthemetum scopulorum. A community of annual plants

**Fig. 8.12** *Juniperus turbinata* forests (Rhamno angustifoliae-Juniperetum turbinatae) and "tomillares" (Teucrio dunense-Helianthemetum scopulori). Punta Entinas-Sabinar, Almería

**Fig. 8.13** *Ziziphus lotus* community. Cape of Gata-Níjar Natural Park, Almería, Spain

(Wahlenbergio nutabundae-Loeflingietum pentandrae) is developed on sandy soils after the rainy period. The vegetation of the arborescent scrub *Ziziphus lotus* is considered a priority habitat in the Habitats Directive (European Commission 2013).

The *Juniperus turbinata* woodlands are also frequent in the Balearic Islands. The most widespread association is Clematido balearicae-Juniperetum turbinatae that is occurs throughout the islands on dunes and paleodunes. It is a dense forest with shrubs (*Pistacia lentiscus, Ephedra fragilis, Phillyrea angustifolia* var. *rodriguezii, Ruscus aculeatus, Asparagus acutifolius*), climbing plants (*Clematis cirrhosa* var. *balearica*, *Clematis flammula, Rubia peregrina* subsp. *longifolia*) and sometimes pines (*Pinus halepensis*). A dynamic stage of *Juniperus* forests in Majorca is a low scrub that grows on stable dunes, corresponding to the association Teucrio dunensis-Thymelaeetum velutinae with psammophilous species (*Halimium halimifolium, Teucrium dunense, Crucianella maritima*) and the endemic *Thymelaea velutina.* The annual grassland which covers the gaps of this forest is formed of numerous species such as *Chaenorhinum formenterae*, *Loeflingia hispanica, Maresia nana, Medicago littoralis, Ononis reclinata, Silene cambessedesii*, *Vulpiella stipoides, Triplachne nitens, Wahlenbergia nutabunda* and others, belonging to the alliance Alkanno-Maresion nanae (Rivas-Martínez et al. 1992a).

Stable dunes in other areas, such as the Dehesa del Saler (Valencia), are occupied by a dense forest (Phillyreo angustifoliae-Rhamnetum angustifoliae) in which phanerophytes like *Phillyrea angustifolia, Rhamnus oleoides* var. *angustifolia, Quercus coccifera, Pistacia lentiscus* and *Juniperus macrocarpa* together with *Pinus halepensis* grow (Costa and Mansanet 1981). Another dynamic stage of this dune ecosystem is a scrub with *Halimium halimifolium* and *Teucrium dunense* as dominant species (Teucrio belionis-Halimietum halimifolii).

More information about these communities is given in Costa and Mansanet (1981); Peinado et al. (1992); Asensi and Díez-Garretas (1993); Rivas-Martínez et al. (1992a, b).

#### 8.4.2.3 Salt Marshes and Coastal Lagoons (Albuferas)

These ecosystems are very rare on the south Mediterranean coast. An example is the Albufera de Adra (Granada), a zone of faunistic interest whose vegetation has been significantly reduced in recent decades due to the development of crops under plastic. In Almería, the saltmarshes of Punta Entinas-Sabinar and Cape of Gata are well preserved.

The Iberian eastern coast from Cape Gata to the Bay of Rosas (Gerona) has many areas with saltmarshes and salt pans, especially on the coast of Murcia and Alicante (Cartagena, San Javier, Torrevieja, Santa Pola, Calpe). Coastal lagoons (albuferas) with brackish or salt water, separated from the sea by a sand bar that is not completely closed, are also frequent. A good example is the Albufera de Valencia, a large lagoon where the water table is regulated by river inputs and groundwater aquifers, and where salinity is generally low except in areas close to the channels of communication with the sea areas (Costa et al. 1986). In the Balearic Islands, the

Albufera de Majorca, an old lagoon separated from the sea by a dune ridge, and the Salinas Natural Park (Ibiza and Formentera) are the most representative natural areas.

The tidal range on the Mediterranean coasts is negligible or almost non-existent compared to the Atlantic coast and therefore some communities, such as those with *Spartina maritima* are lacking, but in general the Mediterranean coastal communities follow a similar pattern as on the Atlantic coasts.

The seagrass meadows, located below sea level, play an important role in the coastal dynamics, protecting the shore from erosion and contributing to the maintenance of coastal ecosystems (Pergent et al. 2012). Of the four species found in the Mediterranean, only one, *Posidonia oceanica*, is endemic, the other three are also found in the Atlantic Ocean. *Zostera noltii* occupies muddy bottoms in estuaries and coastal lagoons along the Mediterranean coast, where it forms monospecific meadows. It also is often associated with *Zostera marina*, scarce on the Mediterranean coast, or *Cymodocea nodosa* with which it can form mixed communities.

*Posidonia oceanica* occurs along the Iberian Mediterranean coast from the Bay of Estepona (Málaga) to Cape Creus, where it forms extensive meadows, sometimes fragmented or in decline due to the presence of toxic waste, sewage or trawling fleets. It grows in shallow or deep water, depending on the water transparency, on sandy or rocky substrates. The best meadows are found in the Cape Gata-Níjar Natural Park (Almería), Tabarca Island (Alicante), Las Salinas (Ibiza and Formentera) and Medes Islands (Gerona). *Posidonia* beds are considered priority habitat in the Habitats Directive (European Commission 2013).

The first band of shrubby vegetation in flooded areas is dominated almost exclusively by *Sarcocornia alpini,* a characteristic species of Sarcocornietum alpini with its optimum in the western Mediterranean. This community is not frequent in the Iberian Mediterranean saltmarshes but is well represented at Punta Entinas-Sabinar (Almería) and Santa Pola (Alicante).

The biotopes that are periodically flooded with saline waters and dry up during summer are colonized by *Sarcocornia lagascae* communities that form monospecific populations, or are sometimes accompanied by plants of adjacent associations. The Limonio cossoniani-Sarcocornietum lagascae, with *Limonium cossonianum, Frankenia corymbosa* and *Halimione portulacoides*, among others, has its optimum in coastal and inland saltmarshes of the Murcian-Almerian Province (Alonso and De la Torre 2002a); it is replaced by the Limonio bellidifolii-Sarcocornietum lagascae along the Catalonian-Levantine and Balearic coasts.

The gaps between the *Sarcocornia lagascae* plants are occupied by annual species of the genera *Salicornia* (*Salicornia patula, Salicornia emerici*) and *Suaeda* (*Suaeda spicata, Suaeda splendens*) that grow on highly saline soils of clayey texture. The Suaedo spicatae-Salicornietum patulae is a widespread association inhabiting small depressions or marsh borders on the Mediterranean coast. The Salicornietum emerici is another association in which *Salicornia emerici* is the dominant species and has a similar ecology.

On higher and less flooded soils with a high concentration of salts in the dry season, communities of *Arthrocnemum macrostachyum* are preponderant. Two associations can be found in the Murcian-Almerian Province: on clayey soils the Frankenio corymbosae-Arthrocnemetum macrostachyi with *Frankenia corymbosa, Halimione portulacoides, Suaeda vera* and some *Limonium* species; and on stony and sandy soils the Frankenio corymbosae-Halocnemetum strobilacei with *Halocnemum strobilaceum* as the dominant species (Peinado et al. 1992). These communities are replaced by the Sphenopo divaricati-Arthrocnemetum macrostachyi on the Catalonian-Valencian coast and Balearic Islands. In the gaps of these formations small creeping plants such as *Frankenia pulverulenta*, *Spergularia marina, Mesembryanthemum nodiflorum* can grow, together with some grasses (*Parapholis incurva, Sphenopus divaricatus*) that are characteristic of the annual vegetation on halophilous habitats.

The drier areas of saltmarshes, whose surface is covered with a salt crusts during the dry season, have a particular type of vegetation in which rosette plants are typical (*Limonium* spp.). Two alliances integrate the numerous associations which have been described from this coastal stretch: the Limonion confusi with a Tyrrhenian-Mediterranean distribution and with numerous endemic species of *Limonium*, particularly in the Balearic Islands, e.g. *Limonium antonii-llorensii*, *Limonium boirae*, *Limonium companyonis*, *Limonium grosii*, *Limonium heterospicatum*, *Limonium magallufianum*, *Limonium marisolii*, *Limonium migjornense*, etc. (Gil et al. 1998); and the Lygeo sparti-Limonion furfuracei of the coastal and inland saltmarshes of the Murcian-Almerian Province, in which *Lygeum spartum* is common together with the *Limonium* species: *Limonium angustebracteatum, Limonium caesium, Limonium cossonianum, Limonium delicatulum, Limonium santapolense* and *Limonium supinum* (Peinado et al. 1992). These communities are considered priority habitat in the Habitats Directive (European Commission 2013).

On disturbed soils communities characterized by the succulent nanophanerophyte *Suaeda vera* occur accompanied by plants of neighbouring associations. The association Lavatero davaei-Suaedetum verae with *Lobularia maritima* subsp. *columbretensis*, an endemic species of the Columbretes Islands off Cape Oropesa in Castellón, is noteworthy (Alonso and De la Torre 2002b).

The borders of saltmarshes in Southeast Iberia is formed by a *Tamarix boveana* forest with *Tamarix canariensis* and some halophilous plants like *Halimione portulacoides, Limonium cossonianum, Suaeda vera* and *Arthrocnemum macrostachyum.* The Inulo crithmoidis-Tamaricetum boveanae is the association here and it represents the potential natural vegetation of highly saline clay soils on coastal marshes and endorreic depressions with a semiarid ombroclimate (Peinado et al. 1992).

The vegetation complex growing in these environments with a variable range of flooding and salinity, includes patches of other communities such as reeds and grasslands occupying clay or sandy soils associated with saltmarshes, salt pans, coastal lagoons and delta areas with more or less influence of seawater.

The most saline areas may be colonized by *Juncus subulatus*, usually accompanied by *Arthrocnemum macrostachyum*. The Juncetum maritimo-subulati is a frequent association in temporary water courses (ramblas), but it also grows at the margin of some coastal saltmarshes (north of Valencia, Salinas de Calpe in Alicante).

The less saline areas are dominated by communities of *Juncus maritimus* or *Juncus gerardi*. The Elymo elongati-Juncetum maritimi is an association of dense rushes occupying the border of saltmarshes on muddy soils. It occurs across the Iberian southeast, the Levantine coast and the Balearic Islands. It is replaced by the Spartino-Juncetum maritimi on the coasts of Catalonia and Provence where *Juncus maritimus* is usually accompanied by *Spartina patens* (de Bolòs 1967). The association that colonizes some Catalonian coastal areas with brackish waters is the Junco gerardii-Triglochinetum maritimae, a reedbed that develops on slightly saline, wet soils where hygrophilous plants grow, including *Phragmites australis, Polypogon monspeliensis, Bolboschoenus maritimus, Paspalum distichum* (Perich and Vilar 2002).

Another moderately halophilous community is the Schoeno nigricantis-Plantaginetum crassifoliae and, depending on the soil texture, it appears as a meadow of *Plantago crassifolia* on clayey soils, or is accompanied by *Schoenus nigricans* on sandy soils (Perich and Vilar 2002). It occurs along the Mediterranean coast, usually in deep depressions among dunes.

Grasslands with helophytes like *Bolboschoenus maritimus* subsp. *compactus* and *Schoenoplectus litoralis* are common in loamy and slightly brackish soils. The Bolboschoeno compacti-Schoenoplectetum litoralis is the association that colonizes saltmarsh and borders of lagoons all along the western Mediterranean.

Finally, we want to mention some communities of coastal wetlands in contact with the previous vegetation. These wetlands, common in the Gulf of Valencia, have been reduced significantly since the nineteenth century, as a result of soil recovery for agriculture, urban development and, especially, tourism (Costa et al. 1986).

The borders of ponds and lagoons are occupied by reeds and cattails that develop in freshwater, although they tolerate a slight salinity. The Typho-Schoenoplectetum tabernaemontani is the association that inhabits this environment with *Schoenoplectus tabernaemontani, Typha latifolia* and *Typha angustifolia* as the dominant species. Near it, another helophytic community of greater height, up to 3 m, is developed. The Typho domingensis-Phragmitetum maximi with *Typha domingensis* and *Phragmites australis* subsp. *altissimus* is the association that grows on small peat islets subjected to waterlogging (Fig. 8.14). The formation of these peat islets, locally called “mates”, is favoured by the accumulation of dense clumps of *Cladium mariscus,* whose association (Hydrocotylo-Mariscetum serrati) represents a serial stage of vegetation with reeds and cattails.

The floating aquatic vegetation (Lemnetea minoris) is relatively common on both eutrophic waters (Lemnetum gibbae) as well as oligotrophic waters (Ricciocarpetum natantis). In brackish pools of marine origin *Ruppia drepanensis* (Ruppietum drepanensis) develops.

**Fig. 8.14** Community of reeds (Typho domingensis-Phragmitetum maximi) in Albufera de Valencia (Photo M. Costa)

More information about these communities is given in de Bolòs (1967, 1997); Costa et al. (1986); Llorens (1985); Peinado et al. (1992); Rivas-Martínez et al. (1992a, b); Gil et al. (1998); Alonso and De la Torre (2002a, b); Rufo et al. (2016).

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