Chapter 10: Benthic fauna of littoral and deep-sea habitats of the Alboran Sea: A hotspot of biodiversity

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Abstract

Benthic habitats as well as their associated biota have been studied in the Alboran Sea since the nineteenth century, with a very significant increase of knowledge in the last five decades. The geographical location of the Alboran Sea between 3 different biogeographical regions, the complex oceanography and the heterogeneous seafloor promote the coexistence of a wide diversity of habitat-forming species and, therefore of habitat types. Some of these habitats host very complex communities in comparison to similar ones that are located northwards in the Atlantic Ocean or eastwards in the Mediterranean Sea. Moreover, some of those habitats are considered to be threatened or are experiencing very strong declines during this last decade and are probably extinct nowadays (e.g. *Zostera marina* beds). General knowledge of the associated biota is larger for those habitats of shallow waters in comparisson to those of the deep-sea, and for those located in the northern sector in relation to those of the southern sector of the Alboran Sea. In most habitats, only some components of the associated biota have been studied and there is a general lack of information for specific groups (e.g. meiofauna, Platyhelminthes, etc.).

Keywords: Macrobenthos, biodiversity, habitat, intertidal, infralittoral, circalittoral, bathyal, Mediterranean Sea

1. Historical exploration of habitats and their associated benthic communities in the Alboran Sea

The Alboran Sea and the Strait of Gibraltar represents an area of strategic and scientific interest from many points of view and have been the subject of numerous geological, hydrological and fishery resources studies. A detailed knowledge of their benthic marine biota came rather late, mostly starting in the late XXth century. Early reports include the decapod list for the coasts of Málaga by de Buen (1887), a short note on Alboran Island by Richard and Neuville (1897), recording there for the first time the occurrence of the North Atlantic gastropod *Littorina saxatilis* or the first record of the limpet *Patella ferruginea* in Chafarinas Islands by Pallary (1920).

At present, a large amount of information has been secured on the marine biota of extraordinary biogeographical interest, but it is scattered in many publications, reports or Doctoral thesis, almost always focused on specific taxonomic groups or particular areas. It would be tedious to detail all of them, but hereafter we provide some hints on the major efforts and sources.

1.1. Ship-based exploration

The great deep-sea explorations of the XIXth century completely ignored the Alboran Sea. Closest came H.M.S. "Porcupine" (1870) that sampled in detail western Portugal and the Ibero-Moroccan Gulf, then sailed East to explore the Sicily straits, and the French research vessel "Talisman" (1883) that maked a very thorough survey along the Atlantic coasts of Portugal, Spain and Morocco but did not enter the Mediterranean.

In the mid XXth century, Jacques Cousteau's celebrated ship "Calypso" was repeatedly chartered by the French government for scientific cruises, one of them in the Ibero-Moroccan Gulf and the Alboran Sea in 1958. Few results were published (e.g. Pérès 1959 for Tunicates and Bellan 1959 for Polychaetes) but this was the occasion for divers to make the first encounter with the *Laminaria* forests (Cousteau and Dugan 1963).

The French cruise "Polymede II" (April-May 1972) collected 15 benthic samples along the Alboran Sea, at depths between 80 and 1000 m, and some of this material was studied (e.g. amphipods, Bellan-Santini 1983; 1985; caudofoveates, Salvini-Plawen 1977; bryozoans, d'Hondt 1977; cephalopods, Mangold-Wirz 1973; echinoderms, Sibuet 1974).

The starting point for our knowledge of the deep-sea benthos on each side of the strait of Gibraltar is really the BALGIM expedition, organized in May-June 1984 by the Muséum National d'Histoire Naturelle of Paris. Samples were taken with beam trawl, epibenthic sled and rock dredge at depths between 160 and 1700 m and an impressive set of results was published for almost all important taxonomic groups except gastropods and polychaetes: sponges (Boury-Esnault et al. 1994), octocorals and antipatharians (Grasshoff 1989), hydrozoans (Ramil and Vervoort 1993), bryozoans (Harmelin and d'Hondt 1992a,b; 1993), decapods (García Raso 1996), barnacles (Foster and Buckeridge 1995), cumaceans (Ledoyer 1987; López-González et al. 1996), pycnogonids (Stock 1987), bivalves (Salas 1996), echinoids (David 1989), chaetognaths (Casanova 1987) and tunicates (Monniot and Monniot 1988, 1990; Turón 1988).

In 1985 and 1986, the Instituto Español de Oceanografía assessed the bottoms exploited for red coral (*Corallium rubrum*), between 75 and 130 m depth, mostly on the platform surrounding the Alboran Island. Templado et al. (1986) summarized general data and preliminary results regarding the fauna, and later some reports were published on particular taxonomic groups, such as sponges (Maldonado 1992, 1993) and decapods (García Raso et al. 1989).

The impressive 1000 m high cliff on the south face of the Alboran Ridge was filmed from the French submersible "Cyana" during the "CyanAlboran" cruise in September-October 1994. Sadly, the underwater images were never made available to biologists and virtually no results have been published.

Another major breakthrough came with the research project "Fauna Ibérica" coordinated by the Museo Nacional de Ciencias Naturales (CSIC, Spain), aimed to updating taxonomy and distribution data for all faunal groups and to issue authoritative monographs in due course. In this context, the FAUNA I cruise (Fig. 1.1) sampled the Ibero-Moroccan Gulf and the Alboran Sea in July 1989, followed years later by Fauna IV (July 1996) where particular attention was given to sampling around the Alboran platform by diving in 0-60 m and trawling down to 450 m. Preliminary results of the first cruise were published by Templado et al. (1993). Study of the material collected in both cruises resulted in numerous publications on particular taxonomic groups, and the description of species new to science. A general monograph on the benthic fauna and flora surrounding the island was issued by Templado et al. (2006).

Since 1994, the MEDITS annual surveys provide information on demersal and epibenthic species of trawlable grounds of the northern part of the Alboran Sea. Although the main objective of these surveys is to carry out the assessment of exploited demersal resources by direct methods, information on presence, abundance and biomass of epibenthic species and habitat-forming species caught with the otter trawl have been recorded during the last decades, published in papers for specific groups (e.g. molluscs, decapods) and used in the initial evaluation of the Marine Strategy Framework Directive (DIR 2008/56/EC) (Abelló et al. 2002; IEO-MAGRAMA 2012; Ciércoles et al. 2018).

In 2008, a Training-through Research Cruise funded by the UNESCO, under the framework of the EU project HERMES, explored coral mounds and cold seeps in the West Alboran Sea. These investigations confirmed the presence of large coral buildups comparable by their dimensions to carbonate mud mounds of the NE Atlantic Ocean. This was the first and very important documentation of large-scale cold-water coral reefs in the Alboran basin. Detailed investigations of mud volcanoes revealed strong gas emissions (mainly in Carmen mud volcano), which fuelled abundant chemosymbiotic organisms, including frenulate polychaetes and bivalves (Comas and Suzyumov 2009).

Further exploration was carried out on the little known Djibouti Banks, located in international waters of the northern part of Alboran Sea, on board R/V "Cornide de

Saavedra" of the Instituto Español de Oceanografía, in March-April 2009. Sampling consisted of 13 rock dredge hauls, 35 shipek grabs, 7 beam trawl hauls and 4 otter trawl hauls over the three banks of the Djibouti group; molluscs from the Algarrobo seamount were reported on by Gofas et al. (2014b).

At the same time, the German cruise POSEIDON POS 385 in May-June 2009 investigated the distribution and faunal composition of cold-water coral ecosystems in the Alboran Sea (Hebbeln et al. 2009). By means of a 'remotely operated vehicle' (ROV), they targeted the Málaga mounds, Al Idrissi Bank in the Djibouti group, the East Melilla area including Banc des Provençaux, the Alboran and Adra ridges and the Seco de los Olivos (also known as Chella Bank). The video-based investigations were completed by fauna and sediment sampling from the ROV or by standard sampling methods (gravity corer, box corer). A remarkable finding was the occurrence of some living deep-sea oysters (*Neopycnodonte zibrowii*) that colonised a steep cliff at 490 m water depth.

As part of the INDEMARES "Inventory and designation of the Natura 2000 network in marine areas of the Spanish state" project, a LIFE+ project aimed at documenting by identifying areas of value to the Natura 2000 network in Spanish offshore areas, research was carried out around the Alboran Island with R/V "Isla de Alborán" in 2011 and 2012, and around Seco de los Olivos by OCEANA on board their catamaran "OCEANA Ranger". Results were summarized in two INDEMARES monographs (Gofas et al. 2014b; De la Torriente et al. 2014, 2018). OCEANA also explored other parts of the Alboran Sea using ROV-mediated imaging, in places such as Banc des Cabliers, the Djibouti banks (El Algarrobo/Avempace), and Banco Sabinar (Avenzoar) (Pardo et al. 2011). The images obtained during those cruises have notably contributed to our understanding of the *in situ* composition and aspect of benthic communities on these bottoms.

1.2. Shore-based studies

Data on the coastal biodiversity of the Alboran Sea started to be collected when the Biological-Marine Station of Málaga, now a centre of Instituto Español de Oceanografía, was created in 1911 by Odón de Buen, but his work and that of his sons Fernando and Rafael were mainly focused on the ichtyofauna (O. de Buen 1912; F. de Buen 1926). With the outbreak of the Spanish civil war, de Buen was on the losing side and was exiled; any progress was hardly made during the following decades.

The spectacular renaissance of taxonomy and natural history in Spain in the last decades of the twentieth century featured, among others, the beginning of significant shore-based studies in the Alboran Sea and the Strait of Gibraltar. Early work includes several Doctoral thesis on some taxonomic groups in an area which was then very poorly known: J. Enrique García Raso on decapods (1981), Carmen Salas Casanova on Bivalves (1984), José Carlos García Gómez on opisthobranch molluscs (1984), Ángel A. Luque on shelled gastropods (1984) and Manuel Maldonado (1993) on sponges.

Starting in 1982, a group of researchers from the universities Autónoma de Madrid and Barcelona and the Museo Nacional de Ciencias Naturales of Madrid studied the marine gastropods of the Almería coast, publishing a first inventory in 1986 (Ballesteros et al. 1986). In 1983, the University of Málaga (UMA) explored the Alboran Island, resulting in a general description of the marine habitats and biota (García Raso and Salas 1984), and lists of decapod crustaceans (García Raso 1984) and marine molluscs (Salas and Luque 1986).

Further research involving the universities of Málaga and Autónoma de Madrid, and the Museo Nacional de Ciencias Naturales studied between 1985 and 1990 the marine biota around Cabo de Gata with institutional funding from the Consejería de Medio Ambiente of the Andalusian Government. These projects led to the declaration of the “Parque Natural Cabo de Gata-Níjar” in January 1988, to the first conservation measures of its Marine Reserve and to the publication of a monograph on its marine biota (García Raso et al. 1992). Later on (1995-1996), the same authority funded a project that produced the first detailed maps of seagrass meadows in Almería and a further project (2001-2003) on the Andalusian marine macrophytes grounds that resulted in a collective monograph on the seagrass meadows and other marine vegetation of the Andalusian coasts (southern Spain) (Luque and Templado 2004).

The exploration of the Strait of Gibraltar also started in the 1980s. In May, 1986, an intensive sampling around Ceuta, at the eastern entrance of the Strait, was organized as a joint venture of the Muséum National d’Histoire Naturelle of Paris and the University of Sevilla. This was mainly targeted to molluscs and, although no synthetic report was ever published, the material collected there was the basis for the description or revision of many species (Gofas 1987, 1992, 1993; García Gómez and Ortea 1988; García Gómez et al. 1989; Salvini-Plawen 2003). Mostly based on this material, Gofas (1998) stated the enormous interest of the Strait because of the presence of several short-range endemics, unusual on a mainland shoreline. In the strait of Gibraltar and surroundings, intensive studies of the fauna and the benthic communities followed under the impulse of José Carlos García Gómez, at University of Seville. He created there the Marine Biology Laboratory, supervised many Doctoral thesis on the benthos of the area (J. Lucas Cervera Currado on opisthobranch gastropods, 1988; Carlos M. López Fé de la Cuadra on bryozoans, 1990; Pablo López-González on anthozoans, 1993; José Luis Carballo on sponges, 1994; Santiago A. Naranjo Lozano on tunicates, 1995; Mª Dolores Medel Soteras on hydrozoans, 1996; Juan E. Sánchez Moyano on the epifauna of photophilous algae, 1996; among others) and carried on many projects which eventually culminated with mapping the nearshore communities and with the creation of the·"Parque Natural del Estrecho" in January 2003 (see García-Gómez 1995; García Gómez et al., 2003).

For the purpose of conservation and sustainable development, the regional authority launched in 2004 the Sustainable Management of the Andalusian Marine Environment Program (Junta de Andalucía 2008-2018). The annual surveys are supported by a highly specialized technical team, distributed throughout the Andalusian coast, with the intention of gathering homogeneous information. Through this program, more than 2500 records of the 87 threatened species of marine invertebrates were collected in the

Red Book of the invertebrates of Andalusia (Barea-Azcón et al. 2008); hundreds of hectares of seagrass meadows of the 4 species of marine angiosperms present in the Andalusian coast were mapped, and more than 1000 sightings of cetaceans were made. In total, the biodiversity inventory comprises more than 900 species on the coasts and the Andalusian marine environment.

The Museo del Mar Ceuta Foundation, established in 2006, opened a further basis of operation where bionomic studies were carried out, particularly on the extraordinarily diverse sea bottoms surrounding Ceuta's Monte Hacho and Benzú, which were declared as Sites of Community Importance in July 2006. The results of this series of surveys are summarized in a book by Ocaña et al. (2009).

Somewhat later, at the beginning of this century, exploration of the coast of Granada was initiated by the late Amelia Ocaña, of University of Granada. The results, mainly obtained by SCUBA diving, are presented in a profusely illustrated guide (Sánchez Tocino and Ocaña 2003). After her premature death in 2007, work was continued there by Luis Sánchez Tocino who also set up a web site dedicated to the benthic fauna of the Granada coast, and co-supervised the Doctoral thesis of Carlos Navarro-Barranco (2015) on benthic fauna of marine caves from Granada and Málaga coasts. In parallel, data on the benthic communities of the Granada coast were also provided by Cebrián et al. (2000) and Cebrián and Ballesteros (2004).

The marine zoology group at University of Málaga extended research to other areas, including the outstanding site of Calahonda (Málaga) which was surveyed in 2006 and declared as a Special Area of Conservation in the Natura 2000 network in August 2015 (Figure 1.2). This research again involved several Doctoral thesis: José Luis Rueda on the molluscs associated with seagrasses (2007), Javier Urra on the molluscs of different habitats of the Calahonda Special Area of Conservation (2012), J. Enrique García Muñoz and Ángel Mateo Ramírez (both in 2016) on the decapods of the same area. A summary of the investigations in Calahonda is given in García Raso et al. (2010) and other data are also included in the abovementioned monograph on seagrass and other vegetated bottoms of Andalusia (Luque and Templado 2004).

Much less is known of the southern part of the Alboran Sea. The fauna and flora of the Spanish city of Melilla have been mostly ignored in the scientific literature, but some general features were presented by Bueno del Campo and González García (1996). One exception is the Chafarinas Island, which have staged numerous scientific projects dedicated to their marine biota, mostly involving scientists from the universities of Málaga, Valencia, Autónoma de Madrid and, more recently, of Granada and Centro de Estudios Avanzados de Blanes (CSIC), resulting in several Doctoral thesis: Eduardo López and Francisco J. Torres Gavilá on annelids (1995 and 2007 respectively), Álvaro L. Peña Cantero on hydrozoans (1995), Jordi Silvestre on decapod crustaceans (2000), Santiago Villora-Moreno on meiofauna (1993), Amparo Martí-Gil on amphipods (1997), and many articles on different animal groups such as sponges and molluscs (e.g. Maldonado et al. 2013; Oliver et al. 2016). An overview was provided by Guallart and Afán (2013) and Maldonado et al. (2013). A prominent feature of this insular setting is the survey over many years of the endangered limpet *Patella ferruginea*, which has there its most important populations (Guallart and Templado 2016). Another exception is the Mar Chica near Nador, the sole coastal lagoon of the Alboran Sea and a very important element in the socio-economic context of Northern Morocco (Guelorget et al. 1984; Dakki 2003; Zine 2003). In the proximity of Nador, the Doctoral thesis by Mohamed Menioui (1988) provided interesting information on the benthic communities associated with macroalgae. Important bionomic research is going on in the Moroccan and Algerian parts, involving in many cases the Regional Activity Center for Specially Protected Areas in the Mediterranean, and some results have been published (Ben Haj et al. 2009; Bazairi et al. 2013; Dauvin et al. 2013 among others). It is expected that the gap will be filled in due course.

2. Supralittoral and intertidal communities

Along the sea-land interface, animal and vegetal communities are subject to high stress, therefore it is the home of few, highly specialized species. This is a very hostile environment, where the substrate is subject to strong insolation, sudden changes in temperature and splashing, intense evaporation and rainfall (Templado et al. 2012). In the Alboran Sea, contrarily to the Atlantic where the tidal range can span several metres, the intertidal zone is a very narrow strip due to a tidal range usually less than 1 m. In addition, it is very exposed to human impacts due to the intense tourist pressure and high coastal population density.

Very few studies have tackled the intertidal communities, and they basically regard the western area (e.g. Conradi and López-González 1999; Krapp-Schickel et al. 2011 on peracarid crustaceans) or are contained in more general accounts (García Raso et al. 1992; 2010), in addition to a few of diverse nature (such as Fischer-Piette 1959; Kensler 1964; 1965; Castellanos et al. 2003; Shemesh et al. 2009; Guerra-García et al. 2011).

2.1. Supralittoral rocky shore

The supralittoral stage corresponds to the “splash zone”, i.e. rock surfaces permanently emerged but receiving moisture from wave action. Its vertical extension varies between a few centimetres in calm areas, to a few meters, depending on the topography of the coast, its inclination and exposure to surf. The extension of this habitat in the Alboran Sea coincides with that of rocky shores, including artificial substrates such as piers and groins.

The community of the supralittoral rock is mainly characterized by various lichens, especially those of the genus *Verrucaria* (*V. amphibia* and *V. maura*). The most characteristic animal species are the periwinkles *Melarhaphe neritoides* and *Echinolittorina punctata* (a thermophilous species found in West Africa and only in the warmer parts of the Mediterranean which feed on cyanophyceae)(Figure 2.1), and the detritivorous isopod *Ligia italica*. Otherwise, the rock surface is usually barren.

2.2. Supralittoral boulders

This is an intermediate habitat between sedimentary and hard substrates. Technically it would belong to the former if the diameter of the boulders is less than 64 cm. It usually occurs in certain coves exposed to wave action (Templado et al. 2012). Although the boulders are heavily exposed to sunlight, the underpart of those that remain half-buried keeps permanent moisture, and retains organic matter of plant debris. This habitat is rarely found in the Alboran Sea, being mostly developed in the Strait of Gibraltar and, within the city of Málaga, at the site of Baños del Carmen (Gofas et al. 2011).

This peculiar environment (Fig. 2.2) hosts gastropods, such as *Paludinella globularis*, *Leucophytia bidentata*, *Pseudomelampus exiguus* and *Pedipes dohrni* (the latter, a thermophilous species), collembolans such as *Anurida maritima* and other arthropods (pseudoscorpions, centipedes) which require further study.

2.3. Midlittoral rocky shore

The midlittoral stage corresponds to the intertidal zone, which is constantly exposed to wave action. In most of the Mediterranean Sea the slight oscillations of sea level (which do not exceed 40 cm) are not cyclical and are due mainly to changes in atmospheric pressure. In the Alboran Sea the influence of the tides is still conspicuous, but it fades as we move away from the Strait of Gibraltar. The communities of the midlittoral stage are definitely organized as belts or horizons (Fig. 2.3), usually well delimited and structured by sessile organisms, mainly algae and barnacles, whose composition and extent depends largely on the degree of wave action.

The upper belt of the midlittoral is characterized by the abundance of chthamalid barnacles (*Microeuraphia depressa*, *Chthamalus montagui* and *C. stellatus*) which can cover a large part of the substrate, and the presence of the highly mobile crab *Pachygrapsus marmoratus.* Among other algae, the rhodophyte *Rissoella verruculosa* may appear in the upper levels in some well-preserved areas such as the Chafarinas Islands. The limpets *Patella rustica* and *P. ferruginea*, the latter an endangered species restricted to the Alboran Sea, North Africa, Sardinia and Corsica, are noteworthy elements at this level and compete for space with the barnacles, which usually also settle on their shells. The trochids *Phorcus articulatus* (in sheltered sites) and *P. turbinatus* (in sited exposed to wave action) retreat to sheltered crevices at the time of low tide.

Below the horizon of barnacles, there is an algal turf in which the coralline alga *Ellisolandia elongata* is prominent. In the most sheltered areas and in those with high levels of eutrophication, the red algae are replaced by green algae such as *Ulva* spp. As it happens in the supralittoral and infralittoral levels, the extension of these communities is constrained by the extension of a rocky shoreline.

Species richness increases drastically in the middle and lower parts of the midlittoral, where an algal turf usually develops (Guerra-García et al. 2011). There is also a clear species turnover, where the abovementioned barnacles are replaced by larger species (such as *Perforatus perforatus* and *Amphibalanus amphitrite*) and the genus *Pachygrapsus* is represented instead by *P. transversus*, and *P. maurus* (more rare) in fissures of rocks. The most characteristic molluscs are the limpets *Patella caerulea* (also *P. depressa* in the western part of Málaga coast and in the Straits) and *Cymbula safiana* (a prevalently West African species) which replace *P. rustica* and *P. ferruginea* in the lower horizon of the midlittoral, many species of trochids, and the false limpet *Siphonaria pectinata*, a pulmonate mollusc convergent in shape with the true limpets; the polyplacophoran *Lepidochitona caprearum* is also frequent. The mussels (*Mytilus galloprovincialis* and *Perna perna*) form mixed aggregations where wave action is sufficient, and the sea anemone *Actinia equina* is also a conspicuous element in shaded areas of exposed sites. At the lower levels among the algal turf, the fauna is very diverse and there are many other small species of different groups. Molluscs are quite thoroughly studied (Gofas et al. 2011) and the most characteristic species in the midlittoral algal turf are *Skeneopsis planorbis*, *Nodulus spiralis*, *Pisinna glabrata*, *Tricolia miniata* and *Cassiella abylensis*, the latter in the Strait of Gibraltar where this species is endemic. Other groups (pycnogonids, amphipods, copepods, isopods, polychaetes, tanaids, insect larvae, ostracods, mites, nematodes, ophiuroids, echinoids, sponges, bryozoans and foraminifera) are also diverse but not studied in detail yet. A study about gammarid amphipods inhabiting intertidal seaweed of Tarifa found a distinct vertical segregation of the species (Krapp-Schickel et al. 2011). Some isopods also occur under stones in this level such as *Sphaeroma serratum* and species of the genera *Cymodoce* and *Dynamene*. The hermit crab *Clibanarius erythropus* characteristically forms dense aggregations among intertidal rocks and protects itself in shells of the local gastropods (e.g. *Cerithium lividulum*). In the intertidal zone, the gap under loose rock slabs and the fissures of the bedrock constitute a refuge from desiccation and predation, and is the home of many species such as decapods (e.g. *Porcellana platycheles*, the crabs *Xantho poressa*, *Eriphia verrucosa* and *Pilumnus hirtellus*, the prawn *Athanas nitescens*), many molluscs (e.g. *Gibbula racketti*, *Ocinebrina edwardsii*, *Columbella rustica*, *Striarca lactea*, *Cardita calyculata*), polychaetes (mainly serpulids), and sessile invertebrates such as colonial tunicates or sponges. Occasionally conditions are met for some species of the infralittoral, like the urchin *Paracentrotus lividus* and the sea anemone *Anemonia viridis*, forming “enclaves” in rock pools on under large slabs (Templado et al. 2012).

In some areas, the so-called “vermetid reefs” (Fig. 2.4.) are formed by the sessile gastropod *Dendropoma lebeche* (formerly known as *D. petraeum*) whose dense aggregates are being filled and cemented by the encrusting calcareous alga *Neogoniolithon brassica-florida*. These are found in the Strait of Gibraltar and reach their maximum development in the coasts of Alicante, Murcia and Almería, and in the Chafarinas Islands (Guallart and Calvo 2006; Guallart and Afán 2013) but surprisingly show a large gap in the coast of Málaga, even in rocky areas. The crevices and hollows inside the vermetid reef provide shelter to numerous organisms, such as polychaetes, the gastropod *Fossarus ambiguus*, the bivalves *Lasaea adansoni* and *Liosolenus aristatus*, the sipunculid *Phascolosoma stephensoni* or the intertidal fish *Coryphoblennius galerita*, the latter using the cavities to harbour its spawn (Moreno 2006).

All rocky shores can theoretically fit the loose concept of Habitat 1170 “Reefs” as defined in the EU Habitats Directive (92/43/EEC), but intertidal rocky shores are seldom claimed as such in Nature 2000 reports. Nevertheless, much of the intertidal rocky shore is comprised in several of the existing marine protected areas. The main driver for protection of intertidal sites remains in the occurrence of species catalogued as endangered, such as *P. ferruginea* and *D. lebeche*, whose presence triggers restrictions to any intervention affecting their habitat. Threats and pressures are many because of the accessibility of this habitat, and include illegal harvesting as well as trampling and oil spills.

2.4. Supra- and midlittoral sedimentary substrates

On the supralittoral part of sandy beaches, amphipods of the family Talitridae (such as *Talitrus saltator*) are very characteristic intertidal crustaceans in the Alboran Sea and elsewhere; these are known as “sea fleas”, which remain buried during the day, being more active at dusk and at night in search of organic detritus that constitute their food. In the intertidal strip of sandy beaches, isopods of the genus *Eurydice* and amphipods of the genera *Haustorius*, *Bathyporeia*, *Urothoe* and *Leucothoe* are found; these species show a zonation in their distribution, but due to the small tidal range and steep slope of the beaches, this zonation is not well defined in the Alboran Sea and species broadly overlap.

In the lowermost part of coarse sand beaches, the bivalve *Donacilla cornea* usually occurs. Intertidal areas with muddy sands are suitable for the construction of galleries, which favours the presence of burrowing decapods such as *Upogebia pusilla* and *Pestarella tyrrhena* as well as of amphipods belonging to the genera *Corophium* and *Monocorophium*.

In some areas, mainly in the Almería province and in the Chafarinas Islands, the characteristic leaf-litter accumulations of *Posidonia oceanica* harbour a good number of species, mostly detritivores, such as the amphipods of the genus *Orchestia*, various isopods, insects, and the oligochaete *Pontodrilus littoralis*, among others (García Raso et al. 1992).

3. Coastal lagoons

The coastline of the Alboran Sea currently has extensive sandy beaches, cliff areas and some large bays (Algeciras, Almería), leaving only very few inlets that can be considered coastal lagoons (Ojeda Zújar 2004). The evolution of the coast in the Quaternary, with the Flandrian transgression (about 6000 years ago), allowed some valleys of Andalusia (Guadiaro, Guadalhorce and Andarax) to be flooded, forming inlets and making navigable the final sections where the Phoenicians and Romans constructed their ports. Those are now filled with sediment and very limited areas with a favourable topography allowed the formation of sand bars that delimited coastal lagoons.

The most extensive coastal lagoon of the Alboran Sea is undoubtedly the Mar Chica or Sebkha Bou Areg, located in Morocco east of Melilla (Zine 2003; Ruiz et al. 2006). It is a large lagoon of 11500 ha with a semi-circular shape and a maximum depth of 8 m. The Mar Chica is separated from the Alboran Sea by two sandy strips, Boukana (10 km long) to the north west, and Aljazeera (12.5 km) to the south east, separated by a mouth 120 m wide, where it connects with the Mediterranean. Several cities are settled on its banks, being the most important Nador, located on the inner shore and representing a source of urban and agricultural spills.

The Mar Chica mostly comprises soft bottoms, sandy or mud, historically with dense meadows of seagrass and of the alga *Caulerpa prolifera*. The seagrasses *Zostera marina*, *Cymodocea nodosa* and *Zostera noltei* were reported by González García and Conde Poyales (1994) but only the latter two are mentioned in recent reports.

A less extensive area of coastal lagoons is located in Rio Martil near the city of Tetuan, on the Moroccan coast, in which Pallary (1920) mentioned several species of hydrobiids found also on the Atlantic coasts.

On the north coast of the Alboran Sea the most important coastal lagoons are those of Adra (Albufera Honda of 13 ha and Albufera Nueva of 29 ha). Some coastal lagoons have been transformed into saline ponds by man. There were several of these “salinas” on the north coast of the Alboran Sea in the provinces of Granada (Motril) and Almería (Guardias Viejas, Cerrillos, Roquetas and Cabo de Gata). Among them, only those of Cabo de Gata Natural Park (400 h.) are still yielding annual harvests of salt. The salt process involves the entry of marine water through a long channel in which there is marine fauna (Ojeda Zújar 2004).

Due to the scarcity of coastal lagoons, the Alboran Sea acts as a major biogeographic barrier between the numerous lagoons of the European and Moroccan Atlantic coast, and those of the Western Mediterranean starting from Cabo de Gata eastwards.

In Sebkha Bou Areg, frequent species are the gastropods *Bulla striata* and *Bittium reticulatum*, the bivalves *Polititapes aureus, Cerastoderma* sp., *Abra* sp. and *Gastrana fragilis*, the polychaete *Sabella pavonina*, the decapods *Palaemon serratus* and *Carcinus maenas*, the echinoderm *Holothuria tubulosa* and the tunicates *Clavellina lepadiformis* and *Botrylloides leachii* (Bueno del Campo and González-García 1996). The seagrass meadows are also reported as the habitat of the bivalve *Pinna nobilis* and the cephalopod *Sepia officinalis*, among others. In the last third of the 20th century, in areas of freshwater outcrop within the lagoon, the native shrimp *Penaeus kerathurus* was still fished in great quantity, but at present it is very scarce due to contamination of the south shore and by the installation of aquaculture companies dedicated to Japanese shrimp *Penaeus japonicus* (Bueno del Campo and González-García 1996).

In Cabo de Gata, the channels leading to the salt pans harbour species such as the gastropods *Aplysia punctata*, *Philine quadripartita* and *Haminoea orteai* (Ballesteros et al 1986; Talavera et al. 1987), the decapod crustacean *Palaemon serratus* and several fish (López Carrique et al. 2004). In areas of lower salinity in the interior of the saline lagoon, the silt-dwelling bivalves *Abra segmentum*, *Scrobicularia plana* and

Cerastoderma glaucum are abundant, as well as the gastropod *Hydrobia acuta*, among the filamentous algae (Gofas et al. 2011). In the ponds with higher salinity the branchiopod crustaceans *Artemia* spp. (*Artemia salina, A. parthenogenetica* and the introduced *A. franciscana*) are dominant and represent the basis of the food of the pink flamingo *Phoenicopterus roseus* (García Rodríguez et al. 1982; López Carrique et al. 2004).

The Albufera de Adra lagoons are peculiar because they are currently secluded from the sea and their fauna is mainly freshwater, with some species of euryhaline fish such as *Aphanius iberus, Anguilla anguilla, Atherina boyeri* and *Chelon labrosus* (Vidal and Castro 1990).

In Spain, the lagoons such as those of Adra and Cabo de Gata are included in Special Areas of Conservation under the Nature 2000 network but the occurrence of priority habitat 1150 "Coastal lagoons" of the Annex I of the EU Habitats Directive was never claimed in the official registrations as Site of Community Importance. In Morocco, Sebkha Bou Areg is declared as "Site d'Interêt Biologique et Ecologique". All three sites are listed as Ramsar wetlands of international importance. Coastal lagoons that are permanently connected to the sea are also listed as "Essential Marine Habitats (EMH) of relevance for the management of priority species" by the Scientific Advisory Committee of the General Fisheries Commission for the Mediterranean (General Fisheries Commission for the Mediterranean 2009). Despite all these classifications, coastal lagoons in the Alboran Sea are under heavy pressure, mainly because of urban and agricultural discharges (Zine 2003; Ruiz et al. 2006).

4. Hard bottom communities of the continental shelf

The infralittoral hard bottoms are very heterogeneous, depending on the exposure to wave action, the slope and orientation of the substrate, and the intensity of light which decreases progressively as the depth increases (Templado et al. 2012). The photophilous communities are dominated, both physiognomically and in biomass, by macrophytes, whereas in sciaphilous communities the animal component tends to predominate and the substratum is occupied by sessile species.

4.1. Communities of photophilous macroalgae

The community of photophilous algae is characteristic of shallow areas, although, with adequate conditions of transparency of the water, it can reach 30 m depth or more. In the Western Mediterranean, the infralittoral rocky bottoms with moderate to high exposure to wave action are dominated by species of Fucales mainly belonging to the genus *Cystoseira*. These are usually erect with a medium or large size (usually between 20 cm and more than 1 m, in the case of *C. usneoides*), and provide a habitat which can be compared to a miniature forest (Luque and Templado 2004; Templado et al. 2012). Below this, there is a turf stratum formed by small algae, and a basal layer formed by encrusting calcareous algae and by sediment deposited in small depressions of the substrate. In the Alboran Sea, well structured communities dominated by *Cystoseira* spp. only appear in the Eastern part (e.g. Cabo de Gata, Almería, Alboran Island, Chafarinas Islands). In shallow, calmed environments of the infralittoral of the western part, the brown alga *Halopteris scoparia* (Fig. 4.1.) tends to replace *Cystoseira* in large areas (Sánchez Moyano et al. 2001a, 2002; Urra et al. 2013a). Several species of conspicuous invasive macroalgae (e.g. *Asparagopsis taxiformis, Asparagopsis armata, Rugulopteryx okamurae*, *Caulerpa cylindracea*) are nowadays common on these shallow environments, displacing numerous indigenous species.

Two different strata (sediment and frond) form the habitat of macroalgal communities, and the associated species use these microhabitats selectively. For example, the molluscs inhabiting the algal fronds are dominated by microalgae or periphyton grazers, whereas depositivores, plankton and seston feeders and carnivores dominate the sediment in the underlying stratum (Urra et al. 2013a). Among the most characteristic animal species in these algal communities of calm environments are the sea urchins *Paracentrotus lividus* and *Arbacia lixula*, which graze on the algae, allowing the installation of some sessile animals such as *A. sulcata* or *Aiptasia mutabilis*, or even generate barren rock surfaces known locally as "blanquizales", where crustose coralline algae of the genus *Lithophyllum* dominate the substrate.

In the Alboran Sea, invertebrate communities associated with infralittoral macroalgal beds are dominated by crustaceans and molluscs, followed by echinoderms and polychaetes. Most published works on macroalgal communities of the Alboran Sea were focused on communities associated with *Halopteris scoparia* and *Ellisolandia elongata* beds of the northwestern part. *Halopteris scoparia* provides shelter to an astoundingly diverse array of small animals, mostly molluscs (ca. 200 species), crustaceans (ca. 100 peracarid species, mainly amphipods; 35 decapod species) and polychaetes (over 80 species) (Sánchez-Moyano and García-Gómez 1998; Conradi and López-González 1999; López and Viéitez 1999; Sánchez-Moyano et al. 2002; Castellanos et al. 2003; López and Gallego 2006; Urra et al. 2013a; Mateo-Ramírez et al. 2018). Gastropods such as *Rissoa guerinii*, *Bittium reticulatum*, *Nodulus contortus* and *Eatonina fulgida* or bivalves such as *Musculus costulatus* were the most abundant species on these *H. scoparia* beds (Urra et al. 2013a). Regarding crustaceans, Conradi and López-González (1999) found 116 benthic gammarid amphipod species inhabiting different habitats of Algeciras Bay, of which 41 occurred in *H. scoparia*. In relation with other peracarid taxa, the tanaidaceans *Leptochelia dubia* and *Tanais dulongii*, the cumaceans *Cumella limicola* and *Nannastacus unguiculatus* as well as the isopods *Paranthura nigropunctata* and *Stenosoma capito* were the most abundant species on *H. scoparia* beds of the Strait of Gibraltar (Guerra-García et al. 2009b). Regarding decapods, *Hippolyte leptocerus*, *Pilumnus hirtellus*, *Sirpus zariquieyi*, *Acanthonyx lunulatus*, *Athanas nitescens* and *Achaeus gracilis* were the dominant species in shallow algal communities from Málaga coast (Mateo-Ramírez et al. 2018). López and Viéitez (1999) studied the polychaete assemblages associated with different algae beds from Chafarinas Islands. They reported ca. 37 species inhabiting the community of algae exposed to wave action (*Ellisolandia elongata*, *Asparagopsis armata*, *Cystoseira tamariscifolia* and *Laurencia obtusa* facies), with *Syllis prolifera*, *Salvatoria vieitezi*, *Exogone naidina*, *Sphaerosyllis hystrix* or *Amphiglena mediterranea* among the main species. The high abundance of *Sphaerosyllis hystrix* and *S. austriaca* in this habitat seems to be related to the relatively simple structure of the fronds that did not allow larger predatory species to settle (López and Gallego 2006). Sánchez-Moyano et al. (2002) cited the polychaetes *Platynereis dumerilii*, *S. hystrix*, *S. prolifera*, and *A. mediterranea* as abundant species among *Halopteris* in the Strait of Gibraltar.

Ellisolandia elongata is a calcifying macroalga that occur in both the lower horizons of the intertidal zone and the upper infralittoral. Its fronds are smaller compared to those of *H. scoparia* and consequently the invertebrate assemblage is less diverse (Guerra-García et al. 2009a). Crustaceans of this community were studied in detail and are characterized by the caprellids *Caprella hirsuta*, *C. penantis* and *C. grandimana*, the amphipods *Hyale schmidti*, *H. stebbingi*, *Jassa marmorata*, *Stenothoe monoculoides* and *Ampithoe* spp., as well as the isopod *Ischyromene lacazei* and the tanaid *Tanais dulongi* (Guerra-García and Izquierdo 2010; Izquierdo and Guerra-García 2011). The peracarid communities around the Gibraltar Strait (including European and African locations), show similar values of abundance and species richness (Guerra-García et al. 2009a).

There are some studies about the invertebrate fauna associated with invasive algae such as *Asparagopsis armata*. The crustacean communities associated with this species are dominated in terms of species richness and abundance by amphipods, being the most abundant species *C. penantis* and *H. schmidti*, *Podocerus variegatus* and *A. mediterranea* (Pacios et al. 2011; Soler-Hurtado and Guerra-García 2011). Other groups such as isopods (*Paranthura costana* and *Stenosoma acuminatum*), tanaids (*Tanais dulongii*) and decapods (4 species, with *Pilumnus hirtellus* and *Acanthonyx lunulatus* as dominant species) are poorly represented (Pacios et al. 2011; Soler-Hurtado and Guerra-García 2011) compared to brown algae. In the Strait of Gibraltar, Pacios et al. (2011) found 41 crustacean species (18 gammarids, 7 caprellids, 10 isopods, 3 tanaidaceans and 3 decapods). These studies suggest that species richness of crustaceans associated with *A. armata* is comparable with that of the native intertidal algae species, but changes on the abundance of some species occur. Nevertheless, another studied conducted in the coast of Málaga and Granada highlighted that the invasive macroalgae *Asparagopsis taxiformis* hosted an impoverished peracarid assemblage (both in terms of abundance and species richness) in comparison to that associated with the sympatric native *H. scoparia* (Navarro-Barranco et al. 2018).

Most of the species found among photophilous algae in the Alboran Sea display an Atlanto-Mediterranean distribution, but in the western part, thermophilous West African elements such as *Modiolus lulat* and *Natica vittata* can occur (García Raso et al. 2010). The composition of the assemblages may vary according to hydrodynamic conditions, sedimentation rate and algal morphology (Sánchez-Moyano and García-Gómez 1998; Sánchez-Moyano et al. 2001a, 2002).

Some components of the community, such as molluscs, present a marked seasonal relationship with the vegetative cycle of the algae (Urra et al. 2013a). Others, such as decapods, move between adjacent habitats (e.g. *C. nodosa*) inducing seasonal variations (Mateo Ramírez and García Raso 2012; Mateo-Ramírez et al. 2018).

Like the midlittoral rocky shore, infralittoral hard bottoms including the community of photophilous algae can theoretically enter the loose concept of Habitat 1170 “Reefs” from the EU Habitats Directive. Because it is so extensive, this habitat is well represented in most of the existing marine protected areas. Threats and pressures are many because of the accessibility of this habitat, and include illegal harvesting as well as trampling and oil spills.

4.2. Posidonia oceanica

The Mediterranean angiosperm *Posidonia oceanica* is the largest of the marine phanerogams found in the Alboran Sea, and the most outstanding as for habitat engineering. It is very demanding in terms of ecological requirements and does not tolerate large variations of salinity, therefore it is not found in brackish or hyperhaline lagoons, neither in the vicinity of river mouths. It is also very sensitive to eutrophication, to most of the pollutants and also does not tolerate high sedimentation rates (Boudouresque et al. 2006; Templado et al. 2012 and references therein). It can be considered, therefore, an indicator of clean waters, well oxygenated and free of contamination. *Posidonia* meadows occupy a wide bathymetric range (from 0 to more than 30 m deep), which implies that it occurs through a gradient in various biological aspects and hydrological parameters, such as wave action, light and temperature.

Posidonia meadows are a complex ecosystem, in which the leaf stratum and the lattice of rhizomes have very different characteristics and associated fauna. The leaf stratum is a relatively unstable habitat in which the leaves are continually renewed, are subjected to wave action and to the grazing action of some species, such as the salema (*Sarpa salpa*). The stratum of rhizomes is more stable albeit illumination may vary according to leaf growth, and presents greater complexity.

Posidonia may grow both on sedimentary and rocky substrates but when installed on soft bottoms, the rhizome stratum forms a rigid structure which provides the features of a hard bottom. When the meadow is installed on sandy bottoms, the rhizomes may be mostly buried and leave little space for animals; otherwise the rhizomes leave an intricate network of cavities, populated by the sciaphilous species characteristic of hard substrates. The rhizome stratum grows at very slow rates (10 cm to 1 m per century) and may build up to several metres in thickness in some parts of the Mediterranean (Boudouresque et al. 2006).

Whereas extensive *Posidonia* beds are found in most of the Mediterranean Sea (see Giakoumi et al. 2013 and Telesca et al. 2015), the occurrences in the Alboran Sea are patchy (Junta de Andalucía 2008-2017; Aranda and Otero 2014). On the northern shore, the most extensive meadows are found along the coast of Almería, in the Cabo de Gata-Níjar Natural Park (Figure 4.2.) and in several Special Areas of Conservation (SACs) nearby, like those of Fondos Marinos de Punta Entinas-Sabinar and that of Fondos Marinos del Levante Almeriense. A small meadow is reported in the Acantilados de Maro Cerro-Gordo SAC, at the limit between Granada and Málaga provinces, and the westernmost stands are found in the SACs of Calahonda (Málaga), El Saladillo-Punta de Baños and Bahía de Estepona. All those have been mapped in detail during the

LIFE+ project for the conservation of *P. oceanica* meadows in the Andalusian Mediterranean (LIFE09 NAT/E/000534) starting in 2011 (Aranda and Otero 2014). The westernmost meadows around Calahonda are patchy and are unique in their architecture, differing from most Mediterranean meadows by their shallow occurrence (0-5 m), a phenology with short leaves (29 - 45 cm in spring) and a sediment-filled rhizome stratum (García Raso et al. 2010; Urra et al. 2013b). On the southern shore, *Posidonia* meadows are reported around Beni Saf and Cap Blanc, west of Oran, Algeria (Khodja 2013), then there is an isolated occurrence in the Chafarinas Islands (Guallart and Afán 2013), but the species is missing in the large area under the influence of the mouth of the Moulouya river and has not been reported further west along the Moroccan coast even in apparently appropriate areas such as Al Hoceima National Park (Guallart and Afán 2013).

Luque and Templado (2004) coordinated one of the most exhaustive bibliographic compilations on the composition and, in some cases, the structure of these communities based on the information obtained by researchers from different institutions (Universidad Autónoma de Madrid, and universities of Málaga, Cádiz, Granada, Sevilla; Museo de Ciencias Naturales de Madrid-CSIC and the Environment Agency of the Junta de Andalucía). The community associated with the *P. oceanica* meadows has been intensively studied, both in the north-western and north-eastern Alboran Sea, although attention was biased to certain faunistic groups (e.g., polychaetes, molluscs, decapods, echinoderms or fish) (San Martín et al. 1990, García Raso 1990, García Raso et al. 1992, 2010; Luque and Templado 2004; Urra et al. 2013b; Mateo Ramírez et al. 2015). In general terms, the community associated with *Posidonia* is more complex and diverse than those associated with *Z. marina* or *C. nodosa* due to the simpler structure of the leaf and rhizome strata and usually shallower occurrence of those small seagrasses associated with soft bottoms (Luque and Templado 2004). As an example of this structural complexity, more than 800 species have been identified in the *Posidonia* meadows of the Almería coast (García Raso et al. 1992). The polychaetes stand out for their high species richness (240 species, San Martín et al. 1990; Luque and Templado 2004; Torres Gávila 2008) together with molluscs (over 200 species, García Raso et al. 1992; Luque and Templado 2004; Urra et al. 2013b), amphipods (over 70 species, Luque and Templado 2004), decapods (over 50 species, García Raso 1990; García Raso et al. 1992; Luque and Templado 2004; Mateo Ramírez et al. 2015) and echinoderms (25 species, Luque and Templado 2004). Studies on other groups (e.g. foraminiferans, nemerteans, turbelarians) inhabiting the *Posidonia* meadows of the Alboran Sea are very scarce.

Posidonia leaves, which can reach more than one meter in length in the Western Mediterranean, including Chafarinas Islands, Cabo de Gata and other places in the Almería province, constitute a very particular habitat. It is a dense, permanently moving stratum, with illuminated and shaded areas (upper and lower of the leaves) and which considerably increases the available surface of colonisable substrate. The most common epiphytic organisms in this substrate are calcareous algae, which dominate especially in the illuminated area of the leaves, followed by encrusting bryozoans (*Electra* *posidoniae*, *Patinella radiata*), hydroids (*Sertularia*, *Campanularia* and *Aglaophenia*), colonial tunicates, serpulid polychaetes (*Spirorbis*) and sea anemones (*Parastephanauge paxi*, better known under the incorrect name *Paractinia striata*) (Junta de Andalucía 2008-2017). Among the mobile fauna, the most abundant are gastropods (such as *Tricolia speciosa*, *Jujubinus* spp., *Gibbula ardens*, *Steromphala umbilicaris*, juveniles of *Crepidula unguiformis*, several rissoids such as *Rissoa auriscalpium* and *R. ventricosa*, and the emerald neritid *Smaragdia viridis*. Among the crustaceans, there are characteristic isopods such as *Synischia hectica*, numerous amphipods and some characteristic decapods, such as *Hippolyte inermis*. The planarian *Planocera graffi* and the echinoderm *Asterina phylactica* (previously identified as *Asterina pancerii* in Andalusian coasts and reconsidered by López-Márquez et al. (2018) are also recorded, at least in the eastern part around Cabo de Gata. Some species of very small and cryptic fish, such as *Opeatogenys gracilis* and *Apletodon incognitus* occur among the *Posidonia* leaves. In the westernmost part of the Alboran Sea, the "fundamental stock" of molluscan species described by Russo et al. (1984) as associated to the leaf stratum of *Posidonia* is either missing (e.g. *Tricolia speciosa*, *Rissoa ventricosa*, *Rissoa violacea*, *Gibbula ardens*, *Petalifera petalifera*, *Flexopecten hyalinus*), or present in very low numbers (e.g. *Steromphala umbilicaris*, *Rissoa auriscalpium*), a possible explanation being that the meadows are too patchy to sustain viable populations of these species (Gofas et al. 2011) or because they are strict Mediterranean species that become rarer towards the Strait of Gibraltar

The *Posidonia oceanica* rhizome stratum is very complex, with distinct micro-habitats (García Raso et al. 1992, Luque and Templado 2004). While the leaf stratum has characteristic species adapted with small and flattened forms, the stratum formed by the rhizomes has no exclusive fauna since it is composed of species that are also found in other adjacent hard substrates. Nevertheless, this stratum of rhizomes deserves special attention, since it is densely populated by organisms. For example, 50 different decapod species and more than 900 specimens have been recorded in a 30×30 cm frame (0.09 m^2) in *P. oceanica* meadows from Almería (García Raso 1990). Small specimens and juveniles dominate in this stratum, due to its role as protection and nursery for many species, as observed in a much lesser extent in the small seagrasses *Z. marina* and *C. nodosa*. Frequent macrofauna which inhabits the rhizomes are the sponges *Chondrosia reniformis*, *Phorbas fictitius* and *Crambe crambe*, the cnidarians *Pachycerianthus* sp. and *Aiptasia mutabilis*, the annelids *Salmacina* spp., *Protula intestinum*, *Bispira volutacornis* and *Sabella spallanzanii*, the bivalves *Striarca lactea* and *Barbatia barbata*, the chiton *Lepidopleurus cajetanus*, the gastropod *Chauvetia mamillata*, the bryozoans *Schizobrachiella sanguinea*, *Schizoporella errata*, *Reteporella grimaldii* and *Schizomavella mamillata.* The echinoderms *Holothuria tubulosa*, *Paracentrotus lividus*, *Sphaerechinus granularis*, *Echinaster sepositus*, *Ophioderma longicauda* and *Antedon mediterranea*, the tunicates *Didemnum fulgens*, *Pseudodistoma obscurum*, *Phallusia mammillata* and *Pycnoclavella communis*, and fish such as *Gobius* spp. are also common in *Posidonia* meadows. In the rhizomes two species of hermit crabs are dominant, *Cestopagurus timidus* (in shallow water, especially in 3-4.5 m) and *Calcinus tubularis* (in deeper water, ca. 9 m), and also show (especially the first one) day-night movements from the rhizomes to the leaves (García Raso 1990; Manjón-Cabeza and García Raso 1994, 1995). Other dominant decapods of this stratum are also common in sciaphilous enclaves of rocky bottoms, and include *Athanas nitescens*, *Alpheus dentipes*, *Pisidia longimana* (also mentioned as *P. longicornis*) and *Pilumnus hirtellus* among others.

In the westernmost part, *Posidonia* meadows in Calahonda (Málaga) usually have a sediment-filled rhizome stratum, and the molluscan species found there as dominant e.g. *Tritia incrassata*, *Bittium reticulatum*, *Gibbula racketti*, *Nodulus contortus*, *Tricolia pullus* and *Gibberula miliaria* (Urra et al. 2013b) are not specific to the *Posidonia* habitat but shared with neighbouring hard substrates with photophilous algae. In this area, some tropical Atlantic species such as the bivalve *Ungulina rubra* inhabit the rhizome stratum, having there the only known populations for the Mediterranean and the European coasts (Urra et al. 2013b).

Possibly one of the most characteristic species in *Posidonia* meadows is the mollusc *Pinna nobilis*, one of the largest bivalves in the world. Unfortunately, since 2016 this species suffered a massive mortality that has affected almost 100 % of the Spanish populations south of the Ebro Delta, including the Alboran Sea (see chapter 11 of this book). *Pinna rudis*, a similar but smaller species that usually lives in hard substrates, is also frequently observed over *Posidonia* rhizomes, particularly in the western part, and has been not affected by this massive mortality event.

In addition to the communities associated with leaves and rhizomes, there are a number of mobile species that move through the meadow in search of shelter or forage for food. These are mostly fish (e.g. *Gobius* spp., *Symphodus* spp., *Serranus scriba*, *S. cabrilla*, *Coris julis*, *Sarpa salpa*), but also crustaceans and cephalopods, such as the cuttlefish *Sepia officinalis* (García Raso et al. 1992; Luque and Templado 2004).

There is definitely an interaction and connectivity between the *Posidonia* community and surrounding habitats, although the rhizome (due to its morphological characteristics, complexity and protection capacity) seems more stable. This exchange may minimize the negative effect that the fragmentation of *Posidonia* meadows (which is frequent in a large part of the Alboran Sea, near the western limit of its distribution) could cause on the animal community (Luque and Templado 2004; Urra et al. 2013b; Mateo Ramírez et al. 2015). The seasonal dynamics of the associated fauna is driven by the annual variability of the dominant species, with greater abundance and specific richness observed in the spring and summer months in the case of molluscs (Urra et al. 2013b), and in autumn for the decapod crustaceans (Mateo-Ramírez et al. 2015), due to reproductive events.

Mesophyllum alternans is a coralline alga which takes the form of rather large (up to 20 cm) rosettes, and is mostly associated with the rhizomes of *Posidonia oceanica*. This alga encloses a complex network of cavities, which provides shelter to a rich and varied animal community and therefore enhances the biodiversity and the value of the *Posidonia* meadow in the Alboran Sea (Hergueta and Salas 1986, García Raso and Fernández Muñoz 1987, Fernández Muñoz and García Raso 1987, López de la Rosa and García Raso 1992, García Raso et al. 1996). The enclosed fauna is typically composed by gastropods, such as *Alvania nestaresi* and *Chauvetia mamillata*, bivalves such as *Hiatella arctica* and *Striarca lactea*, decapods such as *Alpheus dentipes*, *Pilumnus hirtellus*, *Pisidia longimana*, *Athanas nitescens* and *Cestopagurus timidus* (Luque and Templado 2004). Sponges such as *Sycon* spp and *Leuconia* sp., the polychaetes *Platynereis dumerilii*, *Ceratonereis costae* and *Syllis gracilis* (Luque and Templado 2004), the pycnogonids *Achelia langi* and *Tanystylum conirostre* (Munilla 1991), and the echinoderms *Amphipholis squamata* and *Arbaciella elegans*, among many others, are also common (Luque and Templado 2004). In addition, many juveniles of larger species find refuge in these structures, such as the sea urchins *Paracentrotus lividus* and *Arbacia lixula*. Some species, such as the excavating sponge *Cliona viridis*, perforate the concretions, while others such as the vermetid *Thylacodes arenarius* contribute to the growth of these structures. The mobile species, in any case, move between the rhizomes and the *Mesophyllum* concretions so that both communities are quite similar.

Posidonia beds are the only accurately defined marine habitat in the EU Habitats Directive and, fortunately, are treated therein as priority habitat "1120* Posidonia beds (*Posidonion oceanicae*)" (Díaz Almela and Marbà 2009) which requires that at least 60% of the surface occupied by this habitat must be included in Nature 2000 Special Areas of Conservation in order to consider their protection as sufficient (European Commission 2007: 43).

Some species inhabiting *Posidonia* meadows such as *Pinna nobilis* and *Pinna rudis*, are included in lists of threatened and endangered species. The former, included in the Spanish and Andalusian Catalogues of Threatened/Endangered Species (LESRPE and LAESRPE) as well as in Annex II of the Barcelona Convention, is in a serious decline as mentioned above (100% of mortality in 2018), due to a protozoan infection, so it has recently been declared in a "critical situation". The second species of *Pinna*, included in Annex II of the Barcelona Convention, and in the Spanish List of Wildlife Species in Special Protection Regime although with no particular mention of threat (Barea-Azcón et al. 2008), is a thermophilous species and still a frequent component of the *Posidonia* meadows of the Alboran Sea, particularly in those near the Strait of Gibraltar (García Raso et al. 2010). The small starfish *Asterina pancerii* (currently attributed to *A. phylactica* in the Andalusian coasts by López-Márquez et al. 2018) is included in Annex II of the Barcelona Convention, and in the Spanish List of Wildlife Species in Special Protection Regime although with no particular mention of threat (Barea-Azcón et al. 2008). These lists should be now updated in order to consider the inclusion of *A. phylactica* for the Alboran Sea sector.

There are scanty nineteenth and twentieth century reports of *Posidonia* as far West as the bay of Algeciras, particularly from the Gibraltar harbour (Bull et al. 2010), and that could explain old records in that area of molluscs commonly linked to *Posidonia* meadows and nowadays absent from the area (e. g. *Tricolia speciosa, Cardites antiquatus*). Surveys in the Calahonda SAC (Málaga) show an alarming extension of dead *Posidonia* rhizomes now overgrown by macroalgal communities or covered by sand, pointing to ongoing decline of this emblematic species in the westernmost part of its distribution range (García Raso et al. 2010).

4.3. Kelp forests

Large brown algae such as *Laminaria ochroleuca*, *Saccorhiza polyschides* and *Phyllariopsis* spp., widely distributed along the Atlantic coasts, reach some parts of the Alboran Sea. Surprisingly, despite the great animal diversity that lives in this complex habitat, the fauna that inhabits the kelp forest of the Strait of Gibraltar and Alboran Island has not been studied in detail. The only available data comes from the observations made during the Fauna IV campaign in the *Laminaria/Saccorhiza* forests surrounding the Alboran Island between 25 and 50 m in depth. These data were included in a chapter within the book on the marine vegetal communities of Andalucía (Luque and Templado 2004) and later in the monograph of the fauna and flora of Alboran (Templado et al. 2006).

Few animal species can be found on the smooth blades of these large algae, possibly because they segregate antifouling substances and for being very beaten by the strong currents, which may difficult the larvae settlement. Among these few species, the most outstanding is the bryozoan *Membranipora membranacea* (exclusive of the blades of laminariales), the anemone *Alicia mirabilis*, the gastropod *Calliostoma zizyphinum* and the colonial ascidians of the genus *Botryllus*. Sometimes the sea urchin *Sphaerechinus granularis* can be found eating these blades, although their preferred food are encrusting red algae of the basal layer of the kelp forests. The limpet *Patella pellucida*, which is an obligate associate of the kelp, has extremely scanty records in the Alboran Sea, being reported only from Tangiers (Gofas et al. 2011).

The basal stratum of these forests is often composed of encrusting red algae and is inhabited by a rich community dominated by sponges and ascidians, often with a coverage close to 100%. Among the most conspicuous species are several gorgonians (*Eunicella verrucosa*, *Eunicella gazella*, *Eunicella labiata*, *Leptogorgia sarmentosa*) intermingled with the kelp. The white gorgonian *Eunicella verrucosa* may reach a high density (up to 20 colonies/m^2), although the size of their colonies is relatively small. Other frequent species are the serpulid worms *Serpula vermicularis* and *Protula intestinum*, the octocorals *Alcyonium acaule* and *Parerythropodium coralloides* (the latter usually on the gorgonians), the hydroids *Nemertesia antennina* (whose colonies can reach up to 30 cm in height), and some species of the genus *Aglaophenia*, several erect bryozoans of branched colonies (*Myriapora truncata*, *Frondipora verrucosa*, *Pentapora fascialis*, *Bugula spiralis*), ascidians (*Rhopalaea neapolitana*, *Phallusia mammillata*, *Aplidium elegans*, *Polycarpa mamillaris*, among others; Ramos-Esplá 1991), and a large number of sponges, such as *Crambe crambe*, *Oscarella lobularis*, *Dysidea* spp., *Axinella damicornis* or *Aplysina aerophoba* (Maldonado 1993).

Through this complex and shaded habitat, there are also a multitude of mobile animals, mainly polychaetes, gastropod molluscs, crustaceans and echinoderms. Many species of fish also find refuge in these kelp forests, like many wrasses (e.g. *Coris julis* and *Cichlasoma bimaculatum*) and serranids (mainly *Serranus scriba*), and the so-called “three tails” (*Anthias anthias*). Another common fish among the recesses of the undergrowth is the so-called “torillo” (*Blennius ocellaris*). Large schools of the sparid *Pagellus acarne* are frequent above the forest.

Despite representing a unique benthic community in the Mediterranean, kelp beds do not receive any other protection than their eligibility as "1170 Reefs" (Templado et al. 2009) of the EU Habitats Directive. Nevertheless, the kelp *Laminaria ochroleuca* is included in Annex I of the Berne Convention (strictly protected flora species) only for its Mediterranean populations. The status of kelp forests is not better in the Atlantic, where they are more widespread but where Norway, Iceland, Denmark, Ireland and the European Commission have strongly opposed at OSPAR's Biodiversity Committee, Berlin, March 6-10, 2017, the inclusion of kelp forests in the List of Threatened and or Declining Species and Habitats.

4.4. Infralittoral hard bottoms dominated by sessile invertebrates

Calcareous bio-concretions structures are often developed under dim light conditions by coralligenous species and other habitat-forming invertebrates, providing highly structured environments which, in turn, support a wide range of other sessile and mobile species (Ballesteros 2006). These biotic assemblages are more extensive at circalittoral depths of the Alboran Sea (Giakoumi et al. 2013), although they can be found as enclaves in the infralittoral zone under crevices, overhangs or at the entrance of marine caves.

Dominant sessile invertebrates constituting this so-called pre-coralligenous community have been described both in the southern and northern areas of the Alboran Sea (e.g. Chafarinas Islands, Cap des Trois Fourches, Al Hoceima, Alboran Island, coast of Granada, the "Laja del Almirante" in the Calahonda Special Area of Conservation, Málaga). This habitat harbours sciaphilous coralline algae (e.g. species of the genera *Mesophyllum*, *Lithophyllum*), bryozoans (e.g. *Pentapora fascialis*, *Myriapora truncata*), polychaetes (e.g. *Salmacina dysteri*), sponges (*Oscarella lobularis*, *Reniera* spp., *Crambe crambe*, *Clathrina* spp., *Axinella* spp., *Ircinia* spp., *Aplysina cavernicola*, etc.), cnidarians (*Astroides calycularis*, *Eudendrium racemosum*, *Alcyonium* spp., *Eunicella* spp.), echinoderms or ascidians (*Aplidium conicum*, *Didemnum* spp., *Halocynthia papillosa*), among others (Pérez-Ruzafa and López-Ibor 1988; Cebrián and Ballesteros 2004; Franzosini and Limam 2004; Sánchez-Tocino et al. 2009; García Raso et al. 2010; Bazairi et al. 2013). Exceptionally shallow occurrences of the gorgonian *Ellisella paraplexauroides* were recorded around the Chafarinas Islands by Maldonado et al. (2013) (see chapter 11).

Along the coast of Granada, in the northern part of the Alboran Sea, these communities are characterized by a dominance of suspension feeders and higher biomass of calcium carbonate than in other temperate and Mediterranean sites (Cebrián et al. 2000; Cebrián & Ballesteros 2004). This pattern, together with its high diversity of species, seems influenced by the particular hydrodynamic conditions within this area (mixing of Atlantic and Mediterranean waters and the occurrence of upwelling events). Although they were not exclusive of coralligenous communities, many mobile species (some of them protected) are commonly associated with these sciaphilous environments. Among them there are molluscs (*Luria lurida*, *Naria spurca*), decapods (*Scyllarides latus*, *Scyllarus arctus*, *Palinurus elephas*), echinoderms (*Echinaster* *sepositus*, *Ophidiaster ophidianus*, crinoids and brittle stars) and fish species (e.g. *Sciaena umbra*, *Scorpaena* spp., *Apogon imberbis*) (Templado et al. 2004).

Distribution of coralligenous communities in the infralittoral zone is not only limited by topographic features. For example, a highly diverse coralligenous community dominated by gorgonians, bryozoans, molluscs and decapods has been reported at shallow depths of the Calahonda SAC due to the high turbidity levels in the water column (García Raso et al. 2010; Urra et al. 2012).

One of the most conspicuous and emblematic sciaphilous habitats in the shallow hard bottoms of the Alboran sea is dominated and structured by the threatened orange coral *Astroides calycularis* (Fig. 4.3.). The biological characteristics and relevance of this colonial scleractinian, as well as its geographical distribution, will be further detailed in Chapter 11.

Like the other benthic habitats of hard bottoms, the precoralligenous may fit the Habitat 1170 "Reefs" (Templado et al. 2009) as defined in the EU Habitats Directive. A particular consideration must be given to *Astroides calycularis*, which is included in the Spanish and Andalusian Catalogues of Threatened/Endangered Species (LESRPE and LAESRPE) with the category "vulnerable", which entails effective protection of habitats where the species occurs. Besides its role as biodiversity reservoir, the precoralligenous habitat is also valuable from an aesthetic point of view, being focal points for recreational diving. Together with other main sources of human perturbation (e.g. coastal pollution, climate change), physical impacts due to scuba diving activities and fishing gear are noticeable due to the high fragility and low growth rate of calcareous organisms (Ballesteros 2006).

4.5. Circalittoral hard bottoms with coralligenous communities

Coralligenous communities represent complex bioconstructions developed over a basal layer of calcareous algal species, and secondarily by different sessile and filter feeding macroinvertebrates with calcareous skeletons (e.g. anthozoans, sponges, serpulid annelids, bryozoans), that thrive under dim light conditions on rocky crests, walls, overhangs and crevices, supporting high levels of biodiversity and a complex trophic net (Ballesteros 2006). This is an emblematic habitat in the Mediterranean Sea, locally starting in the infralittoral zone below 20 m (precoralligenous, see above) and widely developed in the circalittoral zone, where conditions of temperature, currents and salinity are relatively constant (Laborel 1987; Ballesteros 2006). Overall, the composition of the coralligenous community is highly determined by depth and the relief of rocky outcrops, becoming considerably different from one place to another separated horizontally or vertically by few meters, which promotes high species richness.

Coralligenous communities at circalittoral depths have been recently studied in detail in areas included within the Natura 2000 network (EU Habitat Directive) such as the Alboran Island (Gofas et al. 2014a; Sitjà and Maldonado 2014) and the Seco de los

Olivos (hereafter "Seco") (de la Torriente et al. 2014), in the framework of the EU LIFE+ INDEMARES project. Coralligenous communities develop on rocky substrates that occupy large areas of the Alboran Island platform (30-100 m depth), mainly in the southern flank and in the south-western outcrop, and on the shallowest areas of the Seco (ca. 100 m depth), where light conditions still allow the growth of calcareous red algal species. The calcareous basal layer is mainly composed of *Lithophyllum stictaeforme* and *Neogoniolithon mamillosum* in the Alboran Island platform, plus *Mesophyllum alternans* in the Seco, and represents a hard substratum that is colonized by sessile large-size animals with bioconstruction potential.

Overall, gorgonians are the most characteristic taxa in this community, with *Eunicella verrucosa*, *Paramuricea clavata* and *Leptogorgia sarmentosa* (Figure 4.4) dominating between 30 and 90 m depth. Secondary typifying species at this depth range include other anthozoans such as the zoantharian *Savalia savaglia*, the black coral *Antipathella subpinnata*, the soft octocoral *Alcyonium acaule*, and the coral *Dendrophyllia ramea* (de la Torriente et al. 2014; Gofas et al. 2014a). Moreover, colonies of the subtropical large gorgonian *Ellisella paraplexauroides*, one of the largest colonial invertebrates in the Mediterranean, were observed in the Chafarinas and Alboran Island (Maldonado et al. 2013; Gofas et al. 2014a).

The sponge fauna also represents an important component of the coralligenous community, with a great amount of encrusting, branching and massive sponges sharing habitat with the octocorals. This faunal component has been deeply studied in the case of the Alboran Island platform, where common sponges include *Dysidea fragilis*, *Sarcotragus pipetta*, *Hexadella racovitzai*, *Penares helleri*, *Crambe tailliezi*, *Caminus vulcani*, *Dercitus plicatus*, *Craniella cranium*, as well as several species of the genera *Axinella*, *Suberites*, *Calthropella*, *Erylus*, *Haliclona*, *Spongosorites* and *Phorbas* (Maldonado 1992, 1993; Sitjà and Maldonado 2014). Other common organisms include the polychaete *Sabella pavonina*, which can develop dense aggregations in some areas of the Alboran platform, becoming a typifying species of the community; the bryozoans *Myriapora truncata*, *Pentapora fascialis* and *Reteporella grimaldi*; the ascidians *Diazona violacea*, *Ascidia mentula*, *Botryllus schlosseri*, *Polycarpa mamillaris*, *Polycarpa pomaria*, *Styela canopus* and *Microcosmus vulgaris*, among others; and the brachiopods *Megathiris detruncata*, *Terebratulina retusa*, *Novocrania anomala* and *Megerlia truncata*. Furthermore, a great diversity of mobile organisms swarms around these complex bioconstructions, including a large number of small-size polychaetes, molluscs, crustaceans and echinoderms. Echinoderms are among the best represented large-size organisms and include the sea-urchins *Sphaerechinus granularis*, *Gracilechinus acutus* and *Centrostephanus longispinus*, and especially the basket sea star *Astrospartus mediterraneus*, which is observed on several gorgonians with their branched arms totally extended. Besides, threatened and/or protected species are frequently observed in the coralligenous community including several species with high commercial value such as the spiny lobster *Palinurus elephas*, the European lobster *Homarus gammarus*, the Mediterranean slipper lobster *Scyllarides latus*, the spider crab

Maja squinado, the sea snail *Charonia lampas*, or the date mussel *Lithophaga lithophaga*. Among fishes, *Anthias anthias* is among the commonest species and forms swarms next to some overhangs of the rocky bottom. Groupers such as *Epinephelus marginatus* and the wrass *Cichlasoma bimaculatum* are also characteristic of this habitat.

At deeper areas and down to 200 m depth or more, coralligenous communities turn to a “Roche du Large” community (*sensu* Pérès and Picard 1964) with a different faunal composition. The community on the Alboran platform is dominated by the gorgonians *Viminella flagellum*, *Acanthogorgia hirsuta*, *Acanthogorgia armata* and specially *Callogorgia verticillata*, a typical species of the bathyal level that can develop dense “gorgonian gardens” (Gofas et al. 2014a). Other typical species include small-size gorgonians (e.g. *Bebryce mollis*) and scleractinians (*Dendrophyllia cornigera*). The red coral *Corallium rubrum*, although occasionally occurring in caves as shallow as 20 m, is a typical component of the deeper part of the circalittoral and reaches its maximum densities under rocky overhangs below 100 m depth (Fig. 4.5). The sponge fauna is also very characteristic, being represented on the Alboran platform and the Seco by large specimens of the predominantly Atlantic *Asconema setubalense*, *Phakellia robusta*, *Phakellia ventilabrum* and *Poecillastra compressa*, together with a great variety of small erect sponges with stalked “lollipop” morphologies (e.g. *Podospongia lovenii*, *Rhizaxinella elongata*, *Rhizaxinella gracilis*, *Crella pyrula*), and branching morphologies (e.g. *Axinella vellerea*, *Axinella pumila*, *Stelligera stuposa* and *Stelligera rigida*) (Maldonado 1992, 1993; Sitjà and Maldonado 2014) (see also chapter 11 regarding “animal forests”).

At Seco, gorgonians and sponges are also important faunal components, especially in the rocky pinnacles that surround the main edifice. Characteristic gorgonians include *Swiftia dubia*, *Bebryce mollis*, *Acanthogorgia hirsuta*, *Acanthogorgia armata*, *Placogorgia coronata*, *Dendrobrachia fallax*, *Callogorgia verticillata* and *Viminella flagellum*, sometimes intermixed with large hexactinellid sponges (e.g. *Asconema setubalense*) which form important aggregations in bathyal rocky bottoms. On the summit of these pinnacles, mainly in areas exposed to strong currents, black coral communities composed of *Leiopathes glaberrima*, *Antipathes dichotoma*, and less frequently *Antipathes subpinnata* are usually observed. Regarding sponge communities, they can vary spatially, with small boring sponges (e.g. *Hymedesmia paupertas*, *Antho* sp.) dominating rocky bottoms with scarce sessile organisms; large sponges (e.g. *Pachastrella monilifera*, *Poecillastra compressa* and *Phakellia* spp.) dominating deep rocky bottoms, or isolated large sponges (e.g. *Spongosorites flavens*, *Haliclona perlucida* and *Geodia* sp.) found in sites with large boulder deposits (de la Torriente et al. 2014).

Additionally, several submarine canyons have been studied within the Alboran basin in the last decade, providing some information of the coralligenous communities inhabiting these systems. Regarding this, the La Línea de la Concepción and Guadiaro submarine canyon heads in the north-western part of the Alboran shelf (60-100 m depth) display mixed bottoms composed of rocky boulders, gravels and biogenic remains that are colonized by the abundant *Eunicella verrucosa*, together with *Leptogorgia sarmentosa* in the case of La Línea canyon, with individuals of *Astrospartus mediterraneus* laying on branched gorgonian colonies (Vázquez et al. 2015). Secondary typifying species of these communities include dispersed small colonies of the cold-water coral *Dendrophyllia cornigera*, as well as echinoderms such as *Centrostephanus longispinus* and *Cidaris cidaris* or the echiurian *Bonellia viridis*. In deeper settings (140-200 m), colonies of *Callogorgia verticillata*, *Dendrophyllia cornigera* and *Caryophyllia* solitary corals were observed in high density in coralligenous communities of the Guadiaro canyon (Vázquez et al. 2015).

All coralligenous (and precoralligenous) bottoms can easily be encompassed in the broadly defined habitat of "1170 Reefs" (Templado et al. 2009) of the EU Habitats Directive. Furthermore, the use of towed dredges and trawl nets fisheries over coralligenous bottoms is forbidden under Art. 4 of the Council Regulation (EC) No 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea (Council of the European Union 2006). "Coralligenous beds" are also listed as "Essential Marine Habitats (EMH) of relevance for the management of priority species" by the Scientific Advisory Committee of the General Fisheries Commission for the Mediterranean (General Fisheries Commission for the Mediterranean 2009). A few of the characteristic species, e.g. the sea-urchin *Centrostephanus longispinus* and more recently several species of gorgonians have been included in Annex 2 of the Barcelona convention, but this is of limited consequence unless national bylaws enforce protection in practice. The red coral *Corallium rubrum*, the most sought after species in this environment, is of particular concern and information on its conservation status and exploitation is thoroughly discussed in chapter 11.

5. Caves

Despite being considered as unique and sensitive habitats requiring protection under EU Habitats Directive, the number of studies dealing with marine caves and their biota in the Alboran Sea are scarce and, as a consequence, this is the Mediterranean region with the lowest number of marine caves reported (Giakoumi et al. 2013). To date, all ecological studies have been conducted in the northern part of the Alboran Sea (mainly in the coast of Granada) (Navarro-Barranco 2015), while the biota of Moroccan caves remain almost unexplored. Nevertheless, long stretches of the coastline along the southern margin of the Alboran Sea are composed by limestone cliffs which likely contain marine caves, some of them already reported at the Cap de Trois Fourches, Al-Hoceima National Park or Chafarinas Islands (Maldonado et al. 2011; Espinosa et al. 2015). Most of the marine caves studied in the area are small and shallow, although deeper (below 30 meters deep) and longer (approximately 100 metres long) caves have been also described (Navarro-Barranco et al. 2015).

A common biological feature is the so-called “biocoenosis of semi-dark caves”, where dim light favours the dominance of sessile invertebrates, such as the sponges *Dysidea avara*, *Sarcotragus* spp., *Petrosia ficiformis* and *Chondrosia reniformis*, the anthozoans *Astroides calycularis, Parazoanthus axinellae* and different species of gorgonians, the bryozoans *Aldeonella calveti*, *Pentapora fascialis*, and the fishes *Phycis phycis* and *Conger conger*, among others. Those species are not exclusive of cave habitats, being also found in other sciaphilous environments (crevices, overhangs, coralligenous assemblages) or photic habitats but with less coverage by sessile organisms.

The Cerro-Gordo marine cave, located in the coast of La Herradura (Granada), is the most interesting and studied cave in this area. Due to their extensive length, inner areas within this cave are characterized by constant conditions of darkness and by water confinement. Benthic taxa occurring in the innermost part of the cave are highly specialized species, mainly encrusting sponges and bryozoans, brachiopods (*Novocrania anomala*, *Megathyris detruncata*) or serpulid polychaetes (Navarro-Barranco et al. 2015).

Unlike sessile communities, other elements of Alboran cave fauna (mainly crustaceans) are relatively well known in comparison with other Mediterranean areas. The singularity of mobile epifaunal assemblages inhabiting cave sediments and hard substrates have been highlighted (Navarro-Barranco et al. 2013, 2014). The spatial distribution, trophic ecology and colonization patterns of the Amphipoda, which constitute the best-known cave-dwelling macrofaunal group in this area (forty-nine species reported until know), has been also explored (Navarro-Barranco 2015; Navarro-Barranco et al. 2015). Dense swarms of the Mediterranean endemic mysid *Hemimysis margalefi* can be found inside some of the caves (Rastorgueff et al. 2014); as well as the sponge-feeding molluscs *Naria spurca*, *Luria lurida*, *Peltodoria atromaculata* and *Berthella ocellata*; or the decapods *Stenopus spinosus*, *Palaemon serratus*, *Lysmata seticaudata* and *Dromia personata*. Regarding fishes, the cardinal fish *Apogon imberbis* or the leopard-spotted goby (*Thorogobius ephippiatus*) are frequent in caves.

Ecological studies conducted in caves in the Alboran Sea have pointed out the slow rate of colonization, the uniqueness of their species composition and the high stability of the environmental conditions, supporting the current consideration of marine caves as highly valuable and sensitive habitats to human perturbation. Although recent studies conducted within the Cerro-Gordo cave have highlighted its good environmental status, significant temporal variations of the sessile assemblage structure have occurred during the last decade (both at internal and external cave sectors) (Navarro-Barranco et al. 2015).

Submarine caves are adequately defined in the EU Habitats Directive as “8330 Submerged or partially submerged sea caves” (López-Bedoya and Pérez-Alberti 2009), and are therefore eligible for inclusion in a marine Special Area of Conservation. The major human source of impacts suggested for marine caves are due to scuba diving, coastal infrastructures and global change, but specific studies have not been conducted in this area so far.

6. Soft bottom communities of the continental shelf

Like in most marine environments, sedimentary bottoms are predominant in the Alboran Sea, where fine and medium sand generally extend down to 20-30 m depth, with more muddy patches in front of the river mouths, harbours and deeper zones (MAPAMA 2019). Exceptions are the Strait of Gibraltar and some sectors of the littoral of Granada, characterized by the presence of many cliffs in the coastal line, where the shelf is very narrow and most of the infralittoral soft bottom consists of patches of coarse bioclastic sand (Rueda and Salas 2003). Nevertheless, at both sides of the Strait, there are long sandy beaches such as Caños de Meca on the Atlantic side or La Línea de la Concepción on the Mediterranean one.

Most of the studies on communities from sublittoral soft bottoms have been carried out in the northern margin of this basin, such as the Gibraltar area (Rueda et al. 2000; Rueda and Salas 2003), the littoral of Málaga province (García Raso 1982, 1983, 1984, 1987; Salas et al. 1984; Salas 1987; Urra et al. 2011, 2013c), the littoral of Granada province (Rueda et al. 2009a, b; Marina et al. 2015) or the bay of Almería (Rodríguez and Ibáñez 1974). The African part of the Alboran Sea has been less sampled and studied. In Morocco there are some data from few areas, such as the National Park of Al Hoceima (UICN 2012), Cap des Trois Fourches (Bazairi et al. 2013) and Jbel Moussa (Bazairi et al. 2016). The infralittoral soft bottom in these areas is represented by fine sand in the sheltered bays, from 3 to 20-30 m depth, some of them bordered by *Cymodocea nodosa* meadows, while in the capes the bottom is mainly coarse bioclastic sand. In Algeria the data from the Alboran margin are from the littoral of Oran (Hussein 2015) and Rachgoun Island (Ramos-Esplá et al. 2016). In the latter most of the infralittoral zone is occupied by rock with photophilous algae, with *Posidonia* beds in the southern littoral of the island. The infralittoral soft bottom of the Oran area is mainly represented by coarse bioclastic sand with meadows of *Posidonia oceanica* and *Cymodocea nodosa* (Hussein 2015).

In general, the most extensively represented infralittoral biosedimentary units in the Alboran Sea are the shallower well sorted fine sands, coastal bioclastic sand and gravel, and coastal terrigenous muds, the latter in areas with less current and usually under influence of rivers or aquaculture facilities which supply the mud.

6.1. Well sorted fine sand

This assemblage is located in the shallower part of the infralittoral zone, usually between 1 and about 25 m, but there are substantial differences between the surf zone and the deeper parts (Pérès and Picard, 1964; Dauvin et al. 2017). The surf zone (1 to 3 m) is characterized by high instability due to the strong hydrodynamic environment, and the bottom is medium-grained sand. The faunistic assemblages show low species richness and high dominances. Below, where the waves no longer have a direct effect, there are very homogenous sands of terrigenous origin with a low mud content, the so-called “well sorted fine sands”. These bottoms are usually devoid of macrophytes (except for seagrasses, see below). Most of their fauna belongs to the infauna and their surface is apparently barren. Altogether, this is probably the most extensive infralittoral habitat.

In the surf zone, the bivalve *Donax trunculus* (locally known in Spain as “coquina”) is the most characteristic mollusc, together with the Mediterranean *Donax semistriatus* and the Atlantic *Donax vittatus* (Salas 1987) and the Mediterranean nassarid *Tritia grana* as well as the tropical West African naticid *Sinum bifasciatum* (only in the coast of Málaga) (Gofas et al. 2011). Among the decapod crustaceans the characteristic species are *Philocheras trispinosus*, *Philocheras monacanthus* and the crabs *Liocarcinus vernalis* and *Portumnus latipes* (Salas et al. 1994; García Muñoz et al. 2008). These two latter species prey on the foot of *Donax* species (Salas et al. 2001). From 5 m downwards, the faunal assemblage shows higher species richness than the surf zone (Urra et al. 2011), but still with dominance of few species, such as the commercially exploited bivalve *Chamelea gallina* (locally known as “chirla”), the most characteristic species of this assemblage at 5-10 m depth, together with *Acanthocardia tuberculata*, *Spisula subtruncata*, *Donax venustus* and *Tellina tenuis*. The bivalves *Callista chione* and *Glycymeris nummaria* are abundant between 15-25 m depth. Most of the gastropods are scavengers (*Tritia reticulata*, *Tritia pygmaea*) or carnivorous (*Bela zonata*, *Euspira* spp.). The hermit crab *Diogenes pugilator* is the dominant decapod in this bottom (García Muñoz et al. 2008), with maximum abundance between 5 and 15 metres. Other common decapods are the crabs *Atelecyclus undecimdentatus* and *Liocarcinus depurator*. The burrowing echinoderms *Echinocardium cordatum* and *Echinocardium mediterraneum* coexist in this geographic area and type of bottom, together with dense populations of the epibenthic *Ophiura ophiura* and different species of *Astropecten*. The polychaete *Ophelia neglecta* is also common in this bottom, together with different species of nereids. Many species of fish, such as the sparids *Lithognathus mormyrus* and *Diplodus* spp. make incursions on these bottom when foraging, but most characteristic and permanently living in this habitat are flatfish such as *Bothus podas*, and the weeverfish *Trachinus draco* and *Echiichthys vipera* (García Raso et al. 1992, 2010). A number of tropical West African species, such as the gastropods *Mesalia varia*, *Tritia vaucheri* and *Gibberula epigrus* (Urra et al. 2011) also characterizes this habitat in the westernmost part, mostly along the western coast of Málaga province. The African sea star, *Luidia atlantidea* has been recently found in the littoral of Málaga (Gallardo-Roldán et al. 2015) (see chapter 11).

Some seasonality has been observed for the assemblage of molluscs in the littoral of Málaga, with maximum of species richness, abundance and diversity in autumn (Urra et al. 2013). The latter was related with the dynamics of some bivalves, such as *Donax trunculus*, *Acanthocardia tuberculata* or *Callista chione*, probably due to the high fishery activity during the summer, the tourist season and the settlement of larvae in September and October.

All shallow soft bottoms could fall under the loose definition of Habitat 1110 "Sandbanks permanently covered by sea water" of the EU Habitats Directive. Taking into account the extension of this kind of habitats, this has only been claimed in the case where seagrasses are settled on the sandy bottom. Nevertheless most, if not all, marine protected areas of the Alboran Sea harbour a more or less extensive representation of soft bottom habitats. In practical terms, the main impacts and the protection status of infralittoral sandy bottoms are mostly related to fisheries of shellfish species, such as *Donax trunculus*, *Chamelea gallina*, *Callista chione* and *Acanthocardia tuberculata* (Tirado and Salas 1999; Tirado et al. 2002, 2003, 2017; Urra et al. 2018), and to beach replenishments that results in the smothering of the infaunal communities.

6.2. Vegetated infralittoral soft bottoms

The communities associated with the small seagrasses *Zostera marina* and *Cymodocea nodosa* have been studied in to a lesser extent, compared to *Posidonia*, and only certain faunistic groups have been the subject of detailed studies (e.g. molluscs, decapods, caprellids or fishes) in relation to other phyla (e.g. polychaetes, echinoderms) (Luque and Templado 2004; González et al. 2007, 2008; Rueda et al. 2009a; Marina et al. 2012; Mateo-Ramírez and García Raso 2012). There are hardly any studies on the community associated with *Zostera noltei* present in both estuarine and marine locations (e.g. Bay of Algeciras, Mar Chica lagoon, Smir lagoon) and these studies would be necessary to understand the ecological role and importance of this seagrass for fauna. The faunistic diversity associated with these seagrass meadows of the Alboran Sea is greater than in other places of their area of distribution, due to the biogeographical confluence of species from northern Europe, the Mediterranean Sea, the western coasts of Africa or endemic species from southern Spain (Luque and Templado 2004; Rueda et al. 2009a; García Raso et al. 2010; Rueda et al. 2010).

6.2.1. *Zostera marina* meadows

The *Zostera marina* meadows were common in the Andalusian coasts of the Alboran Sea until a decade ago, in Marine Protected Areas (e.g. Acantilados de Maro-Cerro Gordo Special Area of Conservation), but they suffered a strong decline, being currently reduced to small patches in very specific areas of the coast of Granada and Almería and can be considered almost disappeared (Urra et al. 2008, Rueda et al. 2009b, Junta de Andalucía 2008-2017, Arroyo et al. 2015). Since *Z. marina* is an Atlantic species, the progressive warming of the water seems to be not favourable in the Alboran Sea. In the Moroccan coasts these meadows have been very little studied, but they do seem to be still present (Hocein 2015).

The most studied eelgrass meadows are those that occurred between the coast of Málaga and Granada. They were located in soft bottoms but at greater depths (5-17 meters) than those of other areas of the Iberian Peninsula (1-10 meters), therefore their biological communities presented certain differences with respect to other shallower *Z.*

marina meadows of the European Atlantic coasts (Luque and Templado 2004; Rueda et al. 2009a). More than 200 species have been recorded at the time when these meadows were thriving (Luque and Templado 2004; González et al. 2007, 2008; Rueda et al. 2009a).

In the leaf stratum, the dominant organisms were benthic foraminifera, colonies of hydrozoans (*Coryne* spp.), the gastropods *Jujubinus striatus* (due to their high and constant reproductive activity), *Smaragdia viridis*, *Mitrella minor* (feeding on egg masses of different species), *Rissoa membranacea* or *R. monodonta* (both obligate associates with smaller seagrasses), small microherbivorous shrimps of the genus *Hippolyte* (*H. holthuisi*, *H. niezabitowskii* and *H. inermis*), and *Periclimenes* (*P. scriptus*), the bryozoan *Electra pilosa*, the ascidian *Diplosoma spongiforme* and the crinoid *Antedon mediterranea* (Rodríguez and Cabrera 2002; Luque and Templado 2004; Rueda et al. 2009a). Some of these species, such as the hippolytids or the gastropods *S. viridis* are perfectly adapted to live in and between the leaves, because their shape and colour (or transparency) that gives them an amazing ability to camouflage. In addition, some species, as hippolytid shrimps, are able to modify their coloration according to the colour scheme of the leaves and that of the epiphytes that cover them. Generally, these species are not dominant but they characterize these habitats and show an interesting biology (Cobos et al. 2005, 2011, Manjón-Cabeza et al. 2009, 2011). For example, *Smaragdia viridis* shows a strong association with this plant, feeding on the younger epidermal tissues and preferring this species against other small seagrasses (e.g. *Cymodocea nodosa*) (Rueda and Salas 2007; Rueda et al. 2011). Among the fishes, *Opeatogenys gracilis*, endemic to the Mediterranean Sea and south of Portugal, is linked to the leaf stratum of this and other seagrasses, and currently represents the smallest teleost of the Mediterranean Sea (Luque and Templado 2004: 152). The demersal community is mainly composed of cephalopods (e.g. *Sepia elegans*, *Sepietta oweniana*, *Sepiola affinis*) and about 70 fish species (dominating the syngnathids *Nerophis ophidion* and *Syngnathus* spp.) (Luque and Templado 2004). In general the demersal and epibenthic fauna show increases in the specific richness and abundance during the summer and autumn, and especially during the night, as well as strong positive correlations with the leaf biomass (García Raso et al. 2006; Rueda and Salas 2008; Rueda et al. 2008).

The sediment colonized by *Z. marina* commonly harbours infaunal anthozoans, such as *Cereus pedunculatus*, *Condylactis aurantiaca* and *Cerianthus membranaceus*, the sedentary polychaetes *Sabella spallanzanii*, *Spiochaetopterus* sp., *Myxicola infundibulum* or *Lanice conchilega*, the scavenger gastropods *Tritia pygmaea* and *T. reticulata* and the bivalves *Moerella distorta*, *Tellina fabula*, *Lucinella divaricata* or *Solemya togata*, the latter in partially anoxic sediments with a high content of organic matter from certain areas of the seagrass meadow (Luque and Templado 2004; González et al. 2007; Rueda and Salas 2008). The infaunal species presents maximums of abundance in autumn, with bivalve species (e.g. *Moerella distorta* and *Tellina fabula*) that reach high densities (~ 2000 ind/m^2) and display a strong correlation with the organic matter content of the sediment (Rueda and Salas 2008). Among the decapods, the dominant species are *Philocheras echinulatus* and pagurids such as *Diogenes pugilator*. Echinoderms (e.g. *Astropecten aranciacus*, *Coscinasterias tenuispina*, *Sphaerechinus granularis*, *Holothuria tubulosa*) are similar to those present in *C. nodosa* meadows, including species that are also common in the adjacent soft bottoms (Luque and Templado 2004).

In fact, the specific composition and structure of these communities associated with *Zostera marina* or *Cymodocea nodosa* are quite influenced by that of the surroundings habitats. Therefore, there is much connectivity between vegetated and unvegetated soft bottoms, therefore the structure of the communities varies significantly depending on the seagrass phenology and diel or seasonal movements of the mobile species (Rueda et al. 2008, Mateo Ramírez et al. 2015, 2018).

After the regression and loss of *Zostera marina* meadows in the northern Alboran Sea, a concurrent regression of the epifauna was detected, as well as changes in the structure of the infauna, with an increase in the densities of some species of bivalves (e.g. *Moerella distorta*, *Chamelea gallina*) (Rueda et al. 2009b).

6.2.2. *Cymodocea nodosa* meadows

Apart from lagoon environments, *Cymodocea meadows* are most developed in the eastern part of the Alboran Sea, particularly in the Cabo de Gata-Níjar Natural Park (García Raso et al. 1992; Luque and Templado 2004). In the western part, *Cymodocea* is patchier and may even settle on hard bottoms, like it does in the Calahonda (Málaga) Special Area of Conservation (García Raso et al. 2010; Mateo-Ramírez and García Raso 2012).

About 200 species have been documented in *Cymodocea nodosa* of the northern Alboran Sea (Luque and Templado 2004). Some studies of deep meadows of *C. nodosa* from the coasts of Almería (10-15 m) have documented 59 fish species, dominated by *Symphodus cinereus*, *Bothus podas* and *Syngnathus abaster*, 54 species of molluscs, dominating *Rissoa monodonta*, *R. membranacea*, *Gibbula leucophaea*, *Smaragdia viridis* and *Tricolia tenuis* (Marina et al. 2012), and 48 species of decapods, dominating *Hippolyte niezabitowskii*, *H holthuisi* and *H. inermis* (García Raso et al. 2006). In shallow *Cymodocea* meadows, the specific richness is lower, with dominant species such as the decapods *Hippolyte leptocerus* or *Hippolyte garciarasoi* (Mateo-Ramírez and García Raso 2012) or the molluscs *Tritia donovani*, *Tritia cuvierii* and *S. viridis*. Echinoderms can be abundant in these meadows, but the species present are often those typical of soft bottoms (*Ophiura texturata*, *Astropecten* spp., *Echinocardium mediterraneum*) (Luque and Templado 2004) or of neighbouring hard bottoms (*Holothuria* spp.). During the night there is a flux of species from the adjacent unvegetated sedimentary bottom (García Raso et al. 2006), such as *Processa modica*, *P. macrophthalma* and *P. edulis*, crabs of the genus *Liocarcinus* (*L. navigator*, and especially juveniles of *L. vernalis*), *Portunus hastatus*, the armoured shrimp *Sicyonia carinata* and species of the genus *Philocheras*, such as *P. bispinosus* or from the nearby macroalgal bottoms, such as the prawn *Eualus cranchii* and juveniles of the spider crabs *Macropodia rostrata* and *Maja* spp.

Therefore, an increase in the number of species associated with the leaf stratum of *C. nodosa* occur during the night from adjacent bottoms, with the presence of different species of sparids or the decapods *Processa modica* and *Palaemon xiphias*, as well to the sedimentary stratum (*Tritia cuvierii*) (García Raso et al. 2006; Marina et al. 2012). On the other hand, a positive relationship between the abundance and the specific richness of different groups of crustaceans has been documented with the biomass or complexity of the seagrass (number of leaves and density of shots) (González et al. 2008; Mateo-Ramírez and García Raso 2012).

Information on other groups such as peracarid crustaceans, polychaetes or echinoderms is very scarce for *Cymodocea nodosa* meadows of the Alboran Sea (Luque and Templado 2004). Nevertheless, some recent studies have shown the presence of the caprellids *Phthisica marina*, *Pseudoprotella phasma*, *Pariambus typicus* (González et al. 2008), the irregular sea urchin *Brissus unicolor* (García Raso et al. 2010), the isopod *Cymodoce robusta* (Castelló and Carballo 2001), as well as epiphytic brown algae of the order Ectocarpales (*Acinetospora crinita* and *Ectocarpus siliculosus*), whose proliferations in summer can change the structure of the mollusc and decapod assemblages (García Raso et al. 2006; Marina et al. 2012).

6.2.3. *Caulerpa prolifera* meadows

Caulerpa prolifera meadows settle preferently on more muddy and sheltered bottoms than *Cymodocea* or *Zostera*, and sometimes form compound meadows with the latter. The best known occurrence in the Alboran Sea is in Algeciras Bay (Sánchez Moyano et al. 2001b; 2007, Sánchez-Moyano and García-Asencio 2009) where it may have replaced former seagrass meadows when environmental conditions were downgraded. There are also reports in sheltered inlets or harbours around Cabo de Gata (Luque and Templado 2004).

In the *Caulerpa prolifera* beds from Algeciras Bay, Sánchez-Moyano et al. (2001b) reported a total of 140 taxa, among which 50 molluscs, 41 polychaetes, 35 crustaceans and 5 echinoderms. The dominant molluscs on the fronds were the bivalve *Anomia ephippium*, the gastropods *Pusillina radiata* and *Jujubinus striatus*, whereas the infauna included bivalves such as *Loripes orbiculatus* and *Abra alba*. At least three species of molluscs, the sacoglossans *Oxynoe olivacea*, *Lobiger serradifalci* and *Ascobulla fragilis* are obligate associates of *Caulerpa prolifera*, the former two on the fronds and the latter on the rhizoids (Gofas et al. 2011). The crustacean community was further analysed by Sanchez-Moyano et al. (2007), who reported 45 species (17 amphipods, 8 cumaceans, 9 decapods, 6 isopods, 4 tanaidaceans and 1 leptostracan) belonging to epifauna and infauna. Amphipods and tanaidaceans were the most abundant groups. A total of 51 species of polychaetes and 1 oligochaete were reported by Sánchez-Moyano and García-Asencio (2009), of which a few species (the oligochaete *Aktedrilus* cf. *monospermathecus*, the capitellids *Notomastus latericeus* and *Capitella capitata*, the syllid *Exogone verugera*, the nereid *Neanthes acuminata* and the cirratulid *Aphelochaeta filiformis*) represented more than 80% of the total. The annelid and molluscan assemblages in *Caulerpa prolifera* meadows is similar that of smaller seagrass meadows and may have been inherited from the latter, thanks to the morphological similarity between *Caulerpa* fronds and seagrass leaves.

Seagrass meadows and *Caulerpa prolifera* meadows on sedimentary bottoms are comprised in the currently accepted definition of Habitat 1110 "Sandbanks permanently covered by sea water" of the EU Habitats Directive, and described as such when included in proposals for the Natura 2000 network. All the seagrass species, including *Zostera marina* and *Cymodocea nodosa*, are listed in Annex 2 of the Barcelona Convention and in the Spanish List of Wildlife Species in Special Protection Regime, although with no particular mention of threat. The causes of the demise of *Zostera* beds in the Alboran sea are not precisely known, but illegal trawling or dredging, global warming and disease may have contributed.

6.3. Bioclastic sands and gravels

This kind of habitat is found generally below 20 m depth and the sediment is formed by medium to coarse sand with abundant bioclasts and a higher content of mud and organic matter than the well-sorted fine sand. Most of the sediment originates from the degradation of shells or other skeletal remains (Pérès and Picard 1964; Pérès, 1982). In the shallower settings, this is the so-called "détritique côtier" which normally grades offshore to more muddy sediments. At greater depths, typically below 95-100 m and down to the shelf edge, is found the "détritique du large" where the bioclasts are commonly remnants of Quaternary thanatocenosis. When the mud input is low, both may form a continuum. In fact, "detritic" is a misnomer because, in geological vocabulary, it should refer to products of erosion of pre-existing rocks whereas here the elements result from bioconstruction and should properly be referred to as bioclasts.

Coastal bioclastic sands and gravels are quite extensive in the Strait of Gibraltar area, e.g. near Barbate (Manjón-Cabeza and García Raso 1998; Rueda et al. 2000; García Raso and Manjón Cabeza 2002) and Punta Cires (Bazairi et al. 2016) in a setting where strong currents winnow the finer sediment particles. They are also well represented in some parts of the coast of Málaga (Urra et al. 2013) and Granada (Marina et al. 2015). The extension of this habitat along the Moroccan coast is not precisely known, but taking into account the scarcity of sediment input from rivers, it should be considerable.

Coastal bioclastic sands and gravels generally show high species richness and low dominance values, thanks to the heterogeneity generated by the larger bioclasts. Among the molluscs, the gastropods are dominant in number of species but the bivalves show, in general, higher abundances (Rueda et al. 2000, Rueda and Salas 2003; Urra et al. 2011). Characteristic species are the bivalves *Digitaria digitaria, Gouldia minima, Nucula hanleyi, Lembulus pella, Laevicardium crassum, Parvicardium scabrum, Pitar rudis, Timoclea ovata*. Among the gastropods, *Calyptraea chinensis*, which lives inside large empty valves lying on the sediment, is one of dominant species. Other characteristic gastropods are the carnivorous *Euspira nitida, Crassopleura maravignae, Fusinus pulchellus* and *Bolinus brandaris*. Among the crustaceans, the pagurids are dominant in the littoral of Málaga, mainly *Paguristes eremita* and *Anapagurus* *hyndmanni*, but *Diogenes pugilator, Anapagurus alboranensis, Dardanus arrosor, Pagurus forbesii* and *P. peudosculptimanus* are also abundant (García-Muñoz et al. 2008; 2014). Other characteristic crustaceans of this bottom are *Ebalia tumefacta, E. deshayesi, Pisidia longicornis* and *Galathea intermedia.* In the littoral of Granada, *Anapagurus alboranensis* is also a dominant species in the assemblage (Marina et al. 2015). Different species of sea stars can be present, most of them from the genus *Astropecten*, such as *A. irregularis, A. aranciacus, A. johnstoni* or *A. platyacanthus.* The nemertean *Cerebratulus marginatus* is also common. In the littoral of Granada, the echinoderms *Ophiocten affinis*, *Amphiura* spp. and *Astropecten bispinosus* were frequent (Marina et al. 2015). This assemblage did no show a significant seasonal dynamic, probably due to the existence of low dominances, high species richness and high complexity (Urra et al. 2013c).

In the last decade of the twentieth century, large banks of the bivalve *Ervilia castanea* were located in coarse sand bottoms of Granada (Punta Negra) and Almería (Cabo de Gata Natural Park and other zones) between 10 and 23 m depth. The extension of these banks (tens of meters wide) and their density with up to 90000 individuals/m^2 were really impressive. In the community were abundant, in addition to *Ervilia castanea*, the polychaete *Nereiphylla rubiginosa*, the gastropod *Bittium submammillatum, Calyptraea chinensis, Aglaja tricolorata* and *Embletonia pulchra*, the bivalves *Digitaria digitaria*, *Goodallia triangularis* and *Corbula gibba* and the echinoderm *Echinocyamus pusillus*, among others (Moreno 1998). It is interesting to note that these banks detected in 1995 and 1996 have no longer been observed (Diego Moreno, personal observation). It is possible that the progressive warming of the waters by the global change is adverse for the settlement in the Alboran Sea of *Ervilia castanea*, an Atlantic species that finds its best populations in the Azores Islands.

Deeper bioclastic bottoms have been less studied than coastal ones, and most of the available information deals with specific shelf areas of the northern Alboran Sea (Templado et al. 1993; de la Torriente et al. 2014; Gofas et al. 2014a; Marina et al. 2015; Moya-Urbano et al. 2015). Most of these studies have given some information on the spatial distribution of some faunistic groups, mainly of molluscs, decapods and echinoderms, and in some cases in relation to environmental variables (Marina et al. 2015; Moya-Urbano et al. 2015).

Shelf-edge bioclastic bottoms were studied in detail on the Alboran platform and on Seco de los Olivos (also known as Chella Bank) through the recent LIFE + project INDEMARES and they probably represent the best known of their kind in the Alboran Sea, in terms of benthic composition and structure (de la Torriente et al. 2014; Gofas et al. 2014a; Moya-Urbano and Rueda, comm. pers.). In general, the associated fauna is very diverse and includes the large benthic foraminifera *Miniacina miniacea* on bioclasts (especially in the outer shelf at depths of more than 100 m), the rare sponges *Axinella spatula*, *A. salicina*, *A. alborana* and *Rhizaxinella elongata* (Sitjà and Maldonado 2014), and many cnidarians. Among the latter, the gorgonian *Eunicella filiformis* lies loose on the bottom, the hydroids *Modeeria rotunda* and *Aglaophenia* *tubulifera*, the solitary coral *Caryophyllia* spp. and the gorgonian *Leptogorgia sarmentosa* settle on large bioclasts, and some sea-pens (*Veretillum cynomorium, Pennatula rubra*) may also occur. The annelid *Hyalinoecia tubicola* crawls over the sediment, *Lanice conchilega* builds a semi-buried tube and serpulids settle on the bioclasts. Among molluscs, the most frequent species are the gastropods *Anatoma aspera*, *Clelandella miliaris, Calyptraea chinensis, Fusinus pulchellus, Orania fusulus, Xenophora crispa* as well as the rare and protected cowry *Schilderia achatidea*, the bivalves *Bathyarca pectunculoides, Parvamussium fenestratum, Neopycnodonte cochlear, Arca tetragona* and *Parvicardium minimum*. The most common decapods are *Inachus dorsettensis, Munida rutllanti, Galathea intermedia, Anapagurus breviaculeatus, Pagurus prideaux, Eurynome aspera*, and *Ebalia granulosa*. The crinoid *Antedon mediterranea*, the starfishes *Anseropoda placenta* and *Chaetaster longipes*, the holothurian *Parastichopus regalis* and different ophiuroids (*Ophiothrix quinquemaculata*) are representative of the echinoderms. The bryozoans *Cellaria salicornoides* and *Reteporella* spp. and the ascidian *Molgula appendiculata* grow commonly on medium-sized bioclasts. Interestingly, a part of Alboran Island shelf bioclasts is composed of subfossil shells of *Modiolus modiolus* and other boreal species that inhabited during these bottoms (then close to the coast due to a lower sea level) during the last ice-age.

Despite their unquestionable species richness, bioclastic gravels do not benefit from any kind of formal protection otherwise than being encompassed in marine protected areas designated for other components. Perspectives for specific protection are scant because these bottoms are a major target for trawling and because they can be very extensive. A fair representation of coastal bioclastic gravels is found in Parque Natural del Estrecho, in the Calahonda Special Area of Conservation, and in the "Site d'Intérêt Biologique et Ecologique" of Jbel Moussa, among others. The deeper "shelf edge" gravels are included in the offshore Special Areas of Conservation planned on the Alboran Platform and Seco de los Olivos (Gofas et al. 2014a; de la Torriente et al. 2014).

6.4. "Maërl"/rhodolith beds

"Maërl" or rhodolith beds are defined by the presence of free-living calcareous red algae over an underlying sediment. The Breton word "maërl" was used since 1867 for Atlantic bottoms of this kind off the NW coast of France, mainly formed by the branched calcareous algae *Phymatolithon calcareum* and *Lithothamnion corallioides* (Cabioch 1969). The term "rhodolith" (Ginsburg and Bosellini 1973), meaning red stone, was subsequently coined to designate unattached nodules formed by coralline algae, spanning a large array of forms (branched or not) and sizes (from a few millimetres to over 10 cm), and this term became used worldwide (Bosence 1983a, b; Foster 2001). Both "maërl" and "rhodolith" are often used indifferently (e.g. in EUNIS (2018), A5.51) but Basso et al. (2016) pointed out that "maërl" in a strict sense refers only to branched rhodoliths.

Mediterranean “maërl” beds were considered to be a facies of the “coastal detritic bottoms” by Pérès and Picard (1964), a criterion followed in the classification of benthic marine habitat types for the Mediterranean region (UNEP/MAP/RAC-SPA 2006). That is because the calcareous algae grow and accumulate on a variety of soft bottoms mainly composed by bioclastic gravels or coarse sands (calcareous detritus of coralline algae, molluscs, echinoderms, anthozoans, etc.) originated locally or from the neighbouring biocoenoses. “Maërl” beds are usually composed of varying proportions of living and dead rhodoliths, with or without additional sediment (Bosence 1983a, b). Fine sand or mud may fill interstices, with mud content below 20% (Picard 1965), since these bottoms are under moderate to high hydrodynamism. The nature of the underlying sediment is crucial because suitably sized grains for spore settlement must be present. Once established, the rhodoliths themselves provide this suitable substrate.

The best and most extensive representation of this habitat in the Alboran sea is found on the Alboran insular platform between 25 and at least 100 m. The INDEMARES Alboran project (Gofas et al. 2014a) mapped 76 km^2, covering more than one-third of the Alboran platform. The summit platform of Seco de los Olivos, situated off Almería in the north-eastern part of the Alboran Sea, is covered by rhodoliths between 76 and about 100 m depth (de la Torriente et al. 2014). Occurrences along the mainland coast are extremely limited and patchy along the Andalusian coast. This is consistent with expectations since the buildup of “maërl” beds requires flat, current swept bottoms in the 20-100 m depth range, a substrate of sand or gravel without too much mud, and clear, transparent waters away from the input of rivers. The strait of Gibraltar meets some of these conditions but lacks flat sedimentary bottoms, and the bay of Málaga is too muddy in the appropriate depth interval. The sole significant occurrence documented so far is off Punta de la Polacra in the Cabo de Gata-Níjar Natural Park (Luque and Templado 2004). The continental platform of the Moroccan and Algerian parts of the Alboran Sea could meet the requirements in more extensive areas but much exploration is still needed to assess the actual extension of “maërl”/rhodolith beds, documented so far off Cap des Trois Fourches (Bazairi et al. 2013).

Rhodolith beds are remarkable as bioconstructions, and contribute to elaborate a complex and heterogeneous habitats which supports high species richness and diversity supported by their three-dimensional structure (Foster et al. 2013; Gofas et al. 2014a; de la Torriente et al. 2014). The main species that make up the rhodoliths in the Alboran platform are *Lithophyllum racemus*, *Lithothamnion corallioides*, *Lithothamnion philippi* and *Phymatolithon calcareum*, although up to 21 different species of coralline algae have been identified using molecular tools, of which 11 are still under study (Gofas et al. 2014a). At shallower depths (25-50 m), some fleshy algae attached to rhodoliths, like *Ulva rigida* or some laminarians (mainly *Laminaria ochroleuca*). Samples yielded a total of 415 benthic species (algae other than those forming maërl and fish excluded). These bottoms harbour an interesting fauna of sponges and anthozoans, including some rare or new species. Most common sponges are *Bubaris vermiculata* of a striking red colour, *Diplastrella bistellata* of orange colour, and several species of the genera *Eurypon* and *Axinella*. Small encrusting sponges are pervasive on the rhodoliths, especially on the large ones. The species *Crambe tailliezi*, considered rare in the

Mediterranean, appears usually in the rhodolith bottoms surrounding the island of Alboran. Anthozoans are mainly represented by different octocorals (*Alcyonium coralloides*, *Alcyonium* sp., *Paralcyonium spinulosum*, *Eunicella filiformis* and *Eunicella* spp.) attached to rhodoliths. Among the most frequent mobile animals are some echinoderms, among which the brittle star *Ophiactis balli*, which occupies the crevices of the rhodoliths, is one of the most abundant. Other common echinoderms in this habitat, and usually rare, are the starfish *Chaetaster longipes* and *Hacelia attenuata*, and the sea urchin *Genocidaris maculata*. The most characteristic molluscs are epifaunal bivalves such as *Hiatella arctica*, *Gregariella semigranata* and *Modiolula phaseolina*, some polyplacophorans (chitons), among which *Callochiton septemvalvis* takes the colour of the red algae, and the gastropod *Bolma rugosa*. Among decapod crustaceans are abundant the small slipper lobster *Scyllarus pygmaeus*, several hermit crabs, such as *Paguristes eremita* and *Dardanus arrosor*, and numerous species of crabs, among them *Ebalia* spp. and *Parthenopoides massena*. To summarize, rhodoliths are a real microcosm which houses a great diversity of small invertebrates which thrive through the labyrinth of crevices, and are still poorly studied (Gofas et al. 2014a). In the Seco de los Olivos rhodoliths are covered in some areas by small sessile invertebrates (sponges, hydrozoans, bryozoans), whereas in other areas they show a dense covering of alcyonaceans (*Alcyonium palmatum* and *Paralcyonium spinulosum*), large sponges (*Chondrosia reniformis*, *Aplysina aerophoba*, *Axinella polypoides*, *Tedania* sp.), and gorgonians (*Paramuricea clavata*, *Eunicella verrucosa*) and even black corals (*Antipathella subpinnata*), or bryozoans (*Reteporella grimaldii*, *Omalosecosa ramosa*). Echinoderms like *Echinus melo*, *Holothuria forskali* and *Chaetaster longipes* are common (de la Torriente et al. 2014). Demersal fish associated with “maërl” beds around Cabo de Gata-Níjar and on the Alboran insular platform are *Scorpaena notata*, *S. scrofa* and *Chelidonichthys lastoviza* (Luque and Templado 2004; Ramos Esplá and Luque 2008; Gofas et al. 2014a).

The importance of “maërl” beds has been acknowledged by several national or international agreements, binding or not. The OSPAR commission has included “Maërl beds” habitat on the OSPAR List of threatened and/or declining species and habitats (OSPAR agreement 2008-6; see OSPAR Commission 2010). Regarding the Mediterranean Sea, the Council Regulation (EC) 1967/2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea (Council of the European Union 2006), prohibited the fishing with trawl nets, dredges, shore seines or similar nets above coralligenous habitats and “mäerl”/rhodolith beds. In addition to this legally binding regulation, the European Commission’s “Scientific, Technical and Economic Committee for Fisheries Opinion on Sensitive and Essential Fish Habitats in the Mediterranean Sea” has recognized “maërl” beds as a priority item among “sensitive fish habitats in the Mediterranean Sea” defined as “fragile habitats that are recognized internationally as ecologically important and which support important assemblages of commercial and non-commercial fish species and which may require special protection” (European Commission 2006). Following this, “Association with rhodoliths (including all of its facies)” is listed as “Essential Marine Habitat

(EMH) of relevance for the management of priority species" by the Scientific Advisory Committee of the General Fisheries Commission for the Mediterranean (General Fisheries Commission for the Mediterranean. 2009). Despite this and the clamour of the scientific community (Barberá et al. 2003; Otero and Basso 2015) "maërl"/rhodolith beds have no recognition at all in Annex I of the EU Habitats Directive.

The Spanish Law 5/2007 of 3 April 2007, of the National Parks network includes "maërl" beds as a marine natural system required to be represented in the network. Finally, the Order APA/767/2018, of June 19, 2018, modifies the Order of 8 September 1998 and expands the prohibition of trawling in the Marine Reserve of Alboran Island in depths lower than 100 m (70 m in the former 1998 Order), specifically targeted to protect the rhodolith beds, which extend down to 100-110 m in this area. A major - anthropogenic impact on Mediterranean rhodolith beds is due to otter trawling (Barberá et al. 2003, and references therein; Bordehore et al. 2003). "Maërl"/rhodolith beds constitute a very vulnerable habitat, due to the slow growth rate of their components, low reproductive potential and the long time of regeneration.

6.5. Coastal Terrigenous Mud

This kind of bottom can be found already in the infralittoral zone, particularly in bays or inlets under the influence of rivers, which supply terrigenous fine sediments, and covers extensive areas of the continental shelf (Pérès and Picard 1964). The percentage of mud is high, and most of it is of inorganic origin, therefore the percentage of organic matter is moderate.

Characteristic species of shallow muddy bottoms of the littoral of Málaga are molluscs such as the tropical West African gastropod *Tritia elata* and the bivalve *Spisula subtruncata*. *Chamelea striatula* can reach high densities and replaces *Chamelea gallina* where the mud content increases. Some species are associated with cnidarians, such as the rare architectonicid *Basisulcata lepida*. Regarding crustaceans, the pagurids are also dominant, such as *Anapagurus breviaculeatus*, *A. petiti*, *Pagurus excavatus*, *P. cuanensis* and *P. prideaux* (García Raso et al. 2010). Sea pens such as *Veretillum cynomorium*, *Pteroides spinosum* and *Cavernularia pusilla* may occur, although more commonly found in deeper parts of the continental shelf. Among the echinoderms, the brittle star *Acrocnida brachiata* is common in this type of bottom. Besides, the aquaculture of the mussel *Mytilus galloprovincialis* in the infralittoral of southern Spain has been a great expansion in the last decades (Tirado et al. 2011) and suspended mussel cultures generate large amounts of mud under the rafts, promoting the onset of this type of assemblage.

Benthic communities of circalittoral muddy sand bottoms are generally dominated by different cnidarians (*Epizoanthus arenaceus*), molluscs (the gastropods *Alvania testae*, *Sorgenfreispira brachystoma*, *Turritella communis*, *T. mediterranea*, *Bivetiella similis*, and the bivalves *Saccella commutata*, *Chamelea striatula*, *Timoclea ovata*), annelids

(*Hyalinoecia tubicola*, *Ditrupa arietina*), decapods (*Plesionika heterocarpus*, *Philocheras bispinosus*, *Anapagurus alboranensis*, *Processa canaliculata* and *P. nouveli*, *Galathea* spp.) and echinoderms (*Astropecten irregularis*, *Leptopentacta tergestina*, *Ophiocten affinis*) (Marina et al. 2015; Moya-Urbano et al. 2015).

Some of these species can also occur on more fully muddy bottoms. In these bottoms the community is composed by the cnidarians *Veretillum cynomorium*, *Cavernularia pusilla*, *Pennatula rubra*, *Alcyonium palmatum* and *Cerianthus membranaceus*, the annelids *Spiochaetopterus* cf. *costarum* and *Sternaspis scutata*, the gastropods *Tritia ovoidea* and *Turritella communis*, the bivalves *Tellina compressa*, *Nucula sulcata*, *Abra alba*, *A. nitida*, *Chamelea striatula* and *Venus nux*, the decapods *Philocheras bispinosus*, *Goneplax rhomboides*, *Alpheus glaber* and *Inachus dorsettensis*, as well as some echinoderms (*Astropecten irregularis*, *Amphiura* spp., *Oestergrenia digitata*, *Ocnus planci*) (Cano and García et al. 1982; Moya-Urbano et al. 2015). Muddy sediments generally occur at higher depths and their high organic content promotes higher abundances of deposit feeders, representing an important variable explaining the distribution of the benthic communities (Marina et al. 2015¸ Díaz et al. 2017).

In these types of circalittoral soft bottoms, some habitat-forming species such as sea pens (*Veretillum*, *Pennatula*) and gorgonians (*Spinimuricea* cf. *atlantica*) provide hard substrate and food for other invertebrates (e.g. *Armina maculata* feeding on *V. cynomorium*) (Gofas et al. 2011). Nevertheless, the sessile habitat-forming species are suffering impacts from trawlers and have declined during decades. They sometimes display higher abundances close to rocky bottoms where they are protected from trawling (Gofas et al. 2014a).

Although temporal changes have been poorly studied in circalittoral bottoms and thought to be less acute than in infralittoral bottoms, Díaz et al. (2017) detected a higher abundance of benthic and demersal cephalopods (e.g. *Octopus vulgaris*, *Sepia* spp.) in autumn and winter in the circalittoral bottoms of the bay of Málaga.

The circalittoral muddy bottoms of the Alboran Sea are not encompassed by any specific regulation for their protection. They are in general exposed to a higher trawling activity than the bathyal ones due to their proximity to the fishing ports, and this may have produced continued impacts on the habitat-forming species such as the sea-pens. The OSPAR Convention recognizes “Sea-pen and burrowing megafauna communities” among the list of threatened and declining habitats, and although outside the scope of this Convention, this should be taken into account to promote some kind of status within the Mediterranean Sea.

7. Deep-sea communities

In the Alboran Sea, the bathyal level, ranging from the edge of the continental shelf to the continental slope, features a broad diversity of benthic communities. The deep-sea benthic communities of the region are strongly influenced by the peculiar oceanographic setting in which the superficial Atlantic Water (AW) within the first 200 m, with a high level of primary productivity, flows above the outgoing Levantine Intermediate Water (LIW). They are also influenced by their geographical location, resulting in the overlap of Mediterranean fauna and typical "Atlantic" species (Gofas et al. 2014b).

7.1. Bathyal hard bottoms

Bathyal hard bottom communities are patchily distributed over the heterogeneous and complex topography of the basin, and are restricted to prominent geomorphological features, such as seamounts, coral mounds, canyons and ridges (Muñoz et al. 2008; Würtz 2012, Rovere and Würtz 2015). Information is still scanty and regards mostly Seco de los Olivos (Chella Bank), the Cabliers and Djibouti seamounts, and the edge of the Alboran platform (Hebbeln et al. 2009; Pardo et al. 2011; Lo Iacono et al. 2012; de la Torriente et al. 2014, 2018, Gofas et al. 2014a, b). From the few acquired information it emerges that the seamounts of the Alboran Sea harbour vulnerable marine ecosystems, including cold-water coral communities, gorgonian, black coral and sponge aggregations (see chapter 11). This diverse group of habitat forming taxa provides a three-dimensional structure for refuge and food for many more benthic species and offers attachment substrates for different faunal groups (Sebens 1991; Buhl-Mortensen et al. 2010).

Cold-water coral communities (see also chapter 11) are one of the most emblematic and diverse in the northeast Atlantic and the Mediterranean, including Alboran. They are mainly structured by the scleractinian corals *Madrepora oculata* and *Desmophyllum pertusum* (commonly known as *Lophelia pertusa*), which are suspension-feeders and require hard substrates to settle and develop. Their occurrence on areas exposed to constant current regimes is functional to a delicate interplay between the delivery of nutrient particles and avoidance of excess sedimentary input, which could hinder their development. However, cold-water corals are also sensitive to the physical characteristics of the water masses, such as temperature, salinity, pH and oxygen concentration (Gori et al. 2013).

Other scleractinians such as *Dendrophyllia cornigera* typically occur on the outer part of the continental shelf, were recorded on rocky bottoms between 40 and 160 m depth around the Alboran Island (Gofas et al. 2014) and are still found on the slope. The scleractinian *Anomocora fecunda* also settles on bathyal hard substrates, as well as other species such as *Caryophyllia calveri, C. smithii*, *Desmophyllum dianthus* which because of their small size and low density are not considered as habitat forming taxa, but appear as part of the corals, gorgonian and sponges communities (de la Torriente et al. 2014).

Although the corals are the most conspicuous elements, the deep-water rocky bottom harbours more concealed associated species which are poorly documented due to the difficulty of sampling this kind of bottoms. Among other species, the small bivalve *Limopsis angusta* has been reported as abundant on Xauen bank (Salas 1996).

Gorgonians and antipatharians ("black corals", e.g. *Leiopathes glaberrima*, *Antipathes dichotoma*, *Antipathella subpinnata* and *Parantipathes larix*) often form dense and extensive assemblages in the deep sea, with a great variety of morphologies (fan-like structure, whips, branched forms, etc.) (see chapter 11). Each species develops in those areas where particular environmental conditions are met: *Viminella flagellum* which alternate dense meadows with sparse colonies, usually associated to other soft corals forming mixed gardens. These species are gradually replaced by other species such as *Callogorgia verticillata* and *Acanthogorgia hirsuta* as depth increase. Dense and conspicuous forests of *C. verticillata* have been found between 70 and 240 m depth in rocky outcrops around the Alboran Island, being rather unusual the occurrence of this bathyal species at these shallower bottoms (Gofas et al. 2014a). Other smaller species such as *Bebryce mollis*, *Dendrobrachia bonsai*, *Muriceides lepida*, *Paramuricea macrospina*, *Placogorgia coronata*, *P. massiliensis*, *Swiftia dubia* and *Villogorgia bebrycoides* are also typical of these communities (de la Torriente et al. 2014, 2018).

The Alboran Sea shelters a remarkable diversity of sponges, and is the only part of the Mediterranean where aggregations of large hexactinellids, such as those of *Asconema setubalense*, have been reported usually close to steep escarpments. On the Seco de los Olivos, areas dominated by this large sponge have been recorded throughout the two main ridges surrounding the main central guyot (Pardo et al. 2011; de la Torriente et al. 2018). Another hexactinellid sponge, the small and stalked *Sympagella delauezei*, was recently described from several seamounts of the Alboran Sea, growing on rocks but also on coral rubble (Boury-Esnault et al. 2015).

Other species forming part of the bathyal sponge communities are *Geodia* sp., *Phakellia robusta*, *P. ventilabrum* and the "lollipop" sponges of the genera *Podospongia*, *Crella* and *Stylocordyla* (de la Torriente et al. 2014, 2018; Gofas et al. 2014a). The latter small sponges may be abundant on the substrate forming a dense undergrowth beneath larger sponges and gorgonians. *Poecillastra compressa* and *Pachastrella monilifera* are also key structuring sponges from the circalittoral to the bathyal in the Alboran Sea (Sitjà and Maldonado 2014).

Dense aggregations of the giant deep-sea oyster *Neopycnodonte zibrowii* colonizing vertical walls and overhangs have been found on the Djibouti Banks (Hebbeln et al. 2009) and Seco de los Olivos (de la Torriente et al. 2014), whereas aggregations of the smaller *N. cochlear* can be found almost everywhere at shallower depths (80-200 m) in the Alboran sea.

Additionally, other species which may be found on bathyal hard bottoms of the Alboran Sea are mobile species such as sea urchins (*Cidaris cidaris*, *Gracilechinus acutus*), sea cucumbers (*Holothuria* sp.), brittle stars (*Ophiothrix* sp.) and crinoids (*Leptometra phalangium*) but they are not restricted to hard bottoms and can also be found on deep bioclastic gravels. Particularly, dense aggregations of *Cidaris cidaris* and *Leptometra phalangium* were recorded on the Seco de los Olivos (de la Torriente et al. 2014) and Djibouti banks (Gofas et al. 2014a), respectively. There is also a wide representation of crustaceans such as crayfish (*Palinurus mauritanicus*), squat lobsters (*Munida* sp.) and species of the genera *Plesionika* (*P. edwardsii*, *P. gigliolii*, *P. narval*) (Aguilar et al. 2008).

The hard bottoms of the bathyal zone are included in the broad concept of "1170 Reefs" (Templado et al. 2009) of the EU Habitats Directive. In addition, the use of towed dredges and trawl nets fisheries at depths beyond 1000 m is forbidden under Art. 4 of the Council Regulation (EC) No 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea prohibited (Council of the European Union 2006). "Sub marine canyons", "Seamounts", and "Deep sea corals (*Lophelia pertusa* and *Madrepora oculata* beds)" are listed as "Essential Marine Habitats (EMH) of relevance for the management of priority species" by the Scientific Advisory Committee of the General Fisheries Commission for the Mediterranean (General Fisheries Commission for the Mediterranean 2009). Although the Alboran Sea is not within the scope of OSPAR convention, it is worth taking note that "Carbonate mounds", "Coral gardens", "Deep-sea sponge aggregations", "*Lophelia pertusa* reefs" are placed on the OSPAR list of threatened and/or declining species and habitats. Recently in 2013, some progress has been made in including several species of cold-water corals (*M. oculata* and *L. pertusa*) and antipatharians (e.g. *Leiopathes glaberrima*) in Annex 2 of the Barcelona Convention and they have been incorporated into the Spanish List of Wildlife Species in Special Protection Regime.

7.2 Bathyal soft bottoms

Soft bottoms are the most widespread habitats in the bathyal stage of the Alboran Sea and elsewhere, the sediments originating either from deposition of planktonic organisms or from sediment mobilization from the shelf to the slope or along the slope due to the contouritic transport (Emig 1997; Muñoz et al. 2008; Cartes et al. 2004; Templado et al. 2012). These sediments can be of different textures (from bioclastic gravel to clay) and they generally display a higher mud content in deep areas with low hydrodynamism (Muñoz et al. 2008; Ciércoles et al. 2018). Although these bathyal soft bottom communities occur from the shelf break to the base of the slope, most information is available from the upper and middle slope (between 200 and 600 m depth) compared to the lower slope (Sibuet 1974; Salas 1996; García Raso 1996; Abad et al. 2007; Hebbeln et al. 2009; Gofas et al. 2011, 2014b; Pardo et al. 2011; de la Torriente et al. 2014, 2018; Ciércoles et al. 2018).

A prominent feature of the upper bathyal slope, often continued from the shelf edge, is the local occurrence of coarse bioclastic sands and gravels in areas with moderate to strong bottom currents that winnow the fine sediments (e.g. cold-water coral rubble) (de la Torriente et al. 2014). The benthic fauna of these type of bottoms include some small solitary corals (*Caryophyllia* spp.) and actiniarians (*Actinauge richardi*), small gorgonians (*Bebryce mollis, Swiftia dubia*), both sedentary (*Serpula vermicularis* on bioclasts) and mobile polychaetes *Hyalinoecia tubicola*, the molluscs *Limopsis aurita, Xenophora crispa, Fusiturris similis, Antalis panorma, Bathyarca philippiana, B. pectunculoides, Astarte sulcata, Neomenia carinata*, the decapods *Ebalia nux, Cymonomus granulatus*, the crinoid *Leptometra phalangium* and the echinoid *Cidaris cidaris*, both of them also dominating sometimes hard bottoms (Salas 1996; García Raso 1996; Abad et al. 2007; Hebbeln et al. 2009; Gofas et al. 2011, 2014b; de la Torriente et al. 2014, 2018; Ciércoles et al. 2018; Moya-Urbano and Rueda pers.

comm.). In some areas with dense aggregations of *Leptometra phalangium* (e.g. Djibouti Bank), a high diversity of molluscs has been registered with more than 150 species, including new records for the Mediterranean Sea (e.g. *Turbonilla vaillanti*) and new species for science (e.g. *Melanella scarifata, Graphis pruinosa, Alexandromenia avempacensis*) (Gofas et al. 2014b; Pedrouzo et al. 2014). Suspension feeders seem to be dominant in this type of community as result of the moderate bottom currents that occur in graves and coarse sand bottoms (Gofas et al. 2014b). Because of its exceptional richness, both in numbers and in the quality of the species, this type of bathyal community with *Leptometra* and *Limopsis* should be considered a high priority for habitat conservation in the Mediterranean deep sea.

In bathyal sand bottoms, the associated fauna shares many components with the abovementioned offshore gravels and with the more fully muddy bottoms and often constitute a transition between both. The sponge *Thenea muricata*, the molluscs *Callumbonella suturale*, *Euspira fusca*, *Parvicardium minimum*, the crustaceans *Parapenaeus longirostris, Solenocera membranacea, Plesionika edwardsi, Philocheras echinulatus*, *Processa nouveli*, and *Ergasticus clouei* as well as the echinoderms *Ophiura ophiura*, *Ophiocten abyssicolum*, *Luidia sarsii*, *Parastichopus regalis* and *P. tremulus* are found in this context (Salas 1996; García Raso 1996; Abad et al. 2007; Gofas et al. 2011; Hebbeln et al. 2009; de la Torriente et al. 2014, 2018; Ciércoles et al. 2018; Moya-Urbano and Rueda pers. comm.).

Bathyal muddy bottoms are probably the most widespread bottom type in the Alboran Sea and are generally colonized by different cerianthids (*Cerianthus* spp., *Arachnanthus oligopodus*), bamboo coral (*Isidella elongata*) and sea-pens (*Virgularia mirabilis, Kophobelemnon stelliferum, K.* cf. *leuckarti*, *Funiculina quadrangularis*), polychaetes (*Sabella* sp., *Spiochaetopterus* sp.), molluscs (*Abra longicallus, Kelliella abyssicola*, *Nucula sulcata, Cuspidaria* spp., *Aporrhais serresianus, Buccinum humphreysianum*, *Galeodea rugosa*), decapods (*Nephrops norvegicus, Monadaeus couchii, Goneplax rhomboides, Pagurus alatus, Plesionika* spp., *Calocaris macandrae*), the holothurian *Mesothuria intestinalis*, the fragile starfish *Hymenodiscus coronatus*, the echinoid *Brissopsis lyrifera*, and the small ophiuroid *Ophiocten abyssicolum* that sometimes can be the dominant macrobenthic component (Salas 1996; García Raso 1996; Abad et al. 2007; Hebbeln et al. 2009; Gofas et al. 2011; Pardo et al. 2011; Ciércoles et al. 2018; Moya-Urbano and Rueda, pers. comm.).

Sea-pen communities have also been detected in coarser sandy bottoms of the Djibouti Banks, the Alboran Ridge and Seco de los Olivos, mainly on areas characterized by low-medium slopes (Hebbeln et al. 2009; Pardo et al. 2011, de la Torriente et al. 2018).

The bamboo coral *Isidella elongata* is known to occur in the Alboran Sea, and has been documented in several places, such as Seco de los Olivos seamount and Cabliers and Djibouti banks (Pardo et al. 2011; de la Torriente et al. 2018), with scattered colonies on muddy bottoms, probably due to trawling activity (see chapter 11).

Another group that can be abundant in some deep soft bottoms of Alboran Sea are bryozoans, although with only a few species. Among them, the most common are the stalked bryozoans *Kinetoskias* sp., which were thought to have entered from the

Atlantic via the Gibraltar Strait (Harmelin and d'Hondt 1993), but has later been found further inside the Mediterranean Sea, in the Balearic Islands (Aguilar et al. 2013).

The soft bottoms of the bathyal zone do not fit, even approximately any of the habitats listed in the EU Habitats Directive. However, the use of towed dredges and trawl nets fisheries at depths beyond 1 000 m is prohibited under Art. 4 of the Council Regulation (EC) No 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea prohibited (Council of the European Union 2006).

The bathyal soft bottoms are not considered in the EU Habitat Directive and their sole legal protection derives from the prohibition of trawling and dredging deeper than 1000 m under Art. 4 of the Council Regulation (EC) No 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea (Council of the European Union 2006).

The bamboo coral *Isidella elongata* is a critically endangered species, following IUCN Red List category (Mastrototaro et al. 2017; Otero et al. 2017), and habitats such as *Leptometra phalangium* beds, *Funiculina quadrangularis* beds, *Isidella elongata* beds and more generally the deep sea below 1000 m depth are listed as "Essential Marine Habitats (EMH) of relevance for the management of priority species" by the Scientific Advisory Committee of the General Fisheries Commission for the Mediterranean (General Fisheries Commission for the Mediterranean. 2009).

7.3. Cold seeps

Cold seeps are outstanding components of some slope areas of the Alboran Sea and even more so in the adjacent Gulf of Cádiz, where they are more widespread and diverse due to the geological past and wide availability of fluid enriched sediments (Vanreusel et al. 2009). In the Alboran Sea, cold seeps are mainly represented by mud volcanoes (seafloor edifices formed by mud and fluid extrusion) and pockmarks (seafloor depressions formed by fluid extrusion and further seafloor collapse) (Comas et al. 2003; Sautkin et al. 2003). These cold seeps are mostly located in the West Alboran Basin between 350 and 1600 m depth. Most studies have been performed on specific mud volcanoes (e.g. Perejil, Kalinin) and pockmarks (e.g. Crow´s foot pockmark field) of the southern field on the Moroccan margin (Comas et al. 2003; Hilário et al. 2011; Rodrigues et al. 2011; López-Rodríguez et al. 2014). Cold seep communities of the Alboran Sea have been poorly studied in comparison to those of the Gulf of Cádiz or the western Mediterranean Sea, and the available information is only based on the presence of some chemosymbiotic species. Initially, Comas et al. (2003) detected chemosynthetic communities with pogonophorans in Kalinin mud volcano, beneath few centimetres of pelagic drape. Later on, Hilário et al. (2011) collected four fragments of stiff-walled tubeworms in a cluster of NE–SW pockmarks, named "Crow's foot'' pockmarks. One of them contained the anterior part of a vestimentiferan or sibloginid tubeworm that was assigned to the genus *Lamellibrachia*. This represented the first record of a vestimentiferan polychaete in the western Mediterranean and indicated some fluid venting activity in these pockmarks because *Lamellibrachia* is typically associated with the presence of carbonates and sulphide at the sediment surface. Furthermore, Rodrigues et al. (2011) indicated the occurrence of two chemosymbiotic bivalves (*Myrtea* sp., *Lucinoma* sp.) and two siboglinids (*Lamellibrachia* sp., *Siboglinum* sp.) in cold seeps of the Alboran Sea. López-Rodríguez et al. (2014) also found bivalves of the genus *Acharax* at ca. 10 cm depth in the mud breccia of the flank of Perejil mud volcano, where methane bubbles were also detected as well as abundant vestimentiferan tubeworms at the top. Together with the preliminary characterization of the chemosymbiotic communities, different studies on the micro-paleontological communities (mainly foraminifera) of these mud volcanoes have been done for characterizing and dating the mud breccia sediments (Sautkin et al. 2003; Gennari et al. 2013). The presence of chemosymbiotic fauna on some mud volcanoes (e.g. Perejil, Kalinin) indicates that current methane/hydrocarbon seeping in some of them still occurs (Hilário et al. 2011). Nevertheless, the majority of the Alboran Sea mud volcanoes seem to be inactive or maybe just dormant, so it is very unlikely that chemosynthesis-based communities will develop on them (Comas et al. 2010).

Cold seeps are encompassed in the EU Habitats Directive as "1180 Submarine structures made by leaking gases", but the most noteworthy occurrences in the Alboran Sea are not within EU jurisdictional waters. Cold hydrocarbon seeps are listed as "Essential Marine Habitats (EMH) of relevance for the management of priority species" by the Scientific Advisory Committee of the General Fisheries Commission for the Mediterranean (General Fisheries Commission for the Mediterranean. 2009).

8. Gaps of knowledge and further steps

Benthic habitats as well as their associated biota have been studied in the Alboran Sea since the nineteenth century, with a significant increase of knowledge in the last decades. Nevertheless, there are still important gaps of information on different aspects such as the presence and mapping of some of these habitats, the characterization of the associated biota of specific habitats or the absence of information on some faunistic groups that compose the benthic communities.

In relation to the presence of habitats and their spatial distribution, this information is mainly available for the ones located in the intertidal and infralitoral zones, because these have been traditionally more accessible and the focal point of different projects from both Universities and Research Institutes (e.g. IEO) as commented in the introduction. Most of the information is available for the northern sector of the Alboran Sea and there is a need of carrying out similar exploration on the southern part of the basin. In the circalittoral and bathyal zones, the habitat mapping has been mostly done developed in some marine protected areas under the framework of the INDEMARES project, but it is still missing in different areas. Habitat mapping has mainly been performed within MPAs and therefore information outside MPAs is nearly absent, and sometimes not accurate at a small scale (meters, 10s meters). This information is sometimes restricted to reports of the Andalusian regional authority or the Instituto Español de Oceanografia as well as papers for specific habitats (seagrass beds) or available online at the EMODNET Seabed Habitats. The information on the presence and mapping for some deep-sea habitats is very scarce and mostly limited to recently created MPAs. Regarding this, even some large seafloor geomorphological features surely containing different types have not been explored so far such as some seamounts (e.g. El Segoviano, Maimonides 1 and 2, Al Mansour, Yussu) and submarine canyons (e.g. Almería canyon, Ceuta canyon, Motril and Carchuna canyons, etc..). Although habitat maps of some areas are available and, some of those areas have been designed as priorities for conservation (current MPAs), similar works should be done in other ecologically important areas, especially in the deep-sea, in order to develop a proper spatial management for the whole Alboran Sea in relation to habitats, habitat-forming species and the remaining species.

The information on the associated biota is not equal for the different habitat types, and of course, the shallower habitats have been studied in more detail than the deep-sea ones as commented previously. But, there is still not enough information on the composition and structure of the communities associated with intertidal rocky shores, some infralittoral and circalittoral macroalgal beds (e.g. *Cystoseira*, kelps), coralligenous bottoms in general, rhodolith/maerl bottoms as well as with sedimentary and hard bottom habitats of the circalittoral and bathyal zones. In some habitats, the information is adequate for some parts (e.g. *Posidonia oceanica* beds of northeastern Alboran Sea) but scarce for other parts (e.g. *P. oceanica* beds of southern Alboran Sea). The information on the associated biota is still scarce for some key deep-sea habitats of the Alboran Sea such as the cold-water coral banks, the sponge aggregations and those sedimentary habitats colonized by octocorals (e.g. bamboo coral beds, sea-pen communities, etc.).

Knowledge on some faunistic groups is generally scarcer than for others, and some groups have been studied in more detail in some habitats but not in others (e.g. molluscs in seagrass beds vs. molluscs in cold-water coral banks). The presence of experts on different faunistic groups in some institutions that are developing projects in the Alboran Sea represents a key factor for improving the knowledge on those groups. In general, there is still scarce knowledge on small cnidarians (e.g. hydrozoans), annelids, nemerteans, platyhelminths, some echinoderms (e.g. holothurians, brittle-stars), bryozoans, some small crustaceans (e.g. ostracods, tanaids, balanids, isopods) in most habitats, and groups of minute organisms of the interstitial environment (e.g. Nematoda, Loricifera, Kinorhyncha or Gasrrotricha). The best studied groups accross habitats are molluscs, decapods, fishes and large echinoderms, but there are even gaps of knowledge for those groups on specific habitats (e.g. cold-water coral banks). It is important to highlight the complexity and exceptional richness of the biota (or of some of their components) in already studied habitats of the Alboran Sea, when compared to similar ones of the European Margin. This surely reduces the effectiveness of developing complete biodiversity studies, especially for complex faunistic groups with large number of species (e.g. annelids), because a combination of species from different biogeographical regions (Lusitanian, Mediterranean, Mauritanian) may occur as already detected in faunistic groups that have been studied in more detail so far such as the molluscs or decapods. In this sense is important to have a good knowledge and information on the fauna from the different biogeographical regions that merge in the

Alboran Sea, and this knowledge is still scarce for the Mauritanian region (northwestern Africa).

Information on the temporal variation of the associated community of different habitats is extremely scarce and only available for specific groups (e.g. molluscs, crustaceans, fishes) and for infralittoral soft bottoms or some vegetated habitats (e.g. seagrass beds, inflalittoral macroalgal beds). This information is even absent for habitats that are known to display significant seasonal and intrannual changes in other parts of the Mediterranean Sea (e.g. intertidal habitats on rocky shores). Annual monitoring of habitats and benthic communities in the Alboran Sea is mostly available for the littoral areas of the northern Alboran Sea in relation to the Water Framework Directive and also to the Andalusian regional authority through the Sustainable Management of the Andalusian Marine Environment Program. Some MPAs also develop some annual monitoring in threatened habitats but there is a lack of a standardized methodology that could be useful for contrasting results between MPAs, especially between the northern and southern sectors of the Alboran Sea. The Medits expeditions have also developed a monitoring sampling scheme but, in this case, the information is only available for large macrobenthic species of trawlable grounds which can generally be collected with an otter trawl. Studies on the interannual changes are generally just available for some faunistic components of circalittoral and sedimentary habitats (results of Medits expeditions) or for threatened species (e.g. *Patella ferruginea*). Day and night variation of the associated community has only been studied in some seagrass beds and this represents an important factor to take into account for further studies in other vegetated habitats (e.g. macroalgal beds). Moreover, studies on growth and development of habitat-forming species are null, even for those species that are endemic of the Mediterranean Sea and have their distribution limits in this basin (e.g. *Posidonia oceanica*) and may display significant differences due to the stressing conditions of being at the distribution limit (e.g. lower growth rate, lower reproductive output). The role of environmental variables in the distribution or temporal patterns of the fauna has been mostly analyzed in macroalgal beds, seagrass beds and some sedimentary habitats. Finally, there is almost null information on the effects of the human activities in the communities associated with the majority of habitats of the Alboran Sea.

Acknowledgements

To be completed once the reviewing process has finished

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