

# Chapter 10

## Invertebrates: The Realm of Diversity



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### 10.1 Emblematic Species

There is a body of literature about the terminology related to “focal species” (flagship, keystone, umbrella or charismatic species) from an ecological or conservation point of view (e.g. Caro et al. 2004; Ducarme et al. 2013). Without going into this debate, we prefer to use simply here the term “emblematic species” for those representatives of the Alboran Sea which have successful populations and serve as a symbol to draw attention and stimulate conservation awareness and action. The term emblematic species overlaps in part with flagship or charismatic species (see

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Ducarme et al. 2013). Although normally large vertebrates monopolized these species, we selected here as examples three invertebrates: the limpet *Patella ferruginea*, the gorgonian *Ellisella paraplexauroides* and the stony coral *Astroides calycularis*.

### 10.1.1 *Patella ferruginea*

One of the most emblematic species of the Alboran Sea is the large limpet *Patella ferruginea* (Fig. 10.1), which can exceed 100 mm of maximum shell diameter. It lives in the upper midlittoral part of rocky coasts, mainly at the *Chthamalus* spp. level. Like other limpets, it is a broadcast spawner and a sequential protandrous hermaphrodite showing alternating sex reversal. All specimens reach adulthood as males, and later most of them change into females, having the capacity to reverse back to males (Guallart et al. 2013). The youngest specimens are found within the *Dendropoma lebeche* belt (which coincides with the mean sea level), and they move to higher levels when reaching a larger size (Guallart et al. 2017).

*Patella ferruginea* is a western Mediterranean endemic species, and it is considered one of the most endangered marine invertebrates of this sea. It was widely



**Fig. 10.1** The large limpet *Patella ferruginea* is one of the most endangered marine invertebrates in the Mediterranean. Here it is close to *Patella depressa*, in the *Chthamalus stellatus* level (Ceuta, Strait of Gibraltar). [José Templado]

distributed all along the western Mediterranean coasts during the Pleistocene and was still quite common until the end of the nineteenth century. Since then, its populations have drastically decreased (Templado et al. 2004). Currently, it is considered extinct on the European continental coasts except for some localities of southern Spain (see Luque et al. 2018 for an updated review). Nowadays the main populations are restricted to the North African coasts, from the Strait of Gibraltar to Tunisia. Otherwise, some relict populations persist in certain island enclaves around Corsica, Sardinia and Sicily.

According to data compiled by Luque et al. (2018), more than 90% of specimens of *P. ferruginea* are concentrated along the coasts of the Alboran Sea, mainly on the African side, where its populations are quite scattered and fragmented. The main populations (with several thousands of adult limpets) are located in Ceuta (Strait of Gibraltar), Melilla, Chafarinas Islands, Habibas, Rachgoun and Plana islands (western coast of Algeria) and Zembra Island (Tunisia). Conversely, along the more than 700 kilometres of Andalusian coastline between the Strait of Gibraltar and Cabo de Gata, estimated numbers do not reach 8000 specimens (CMA 2014).

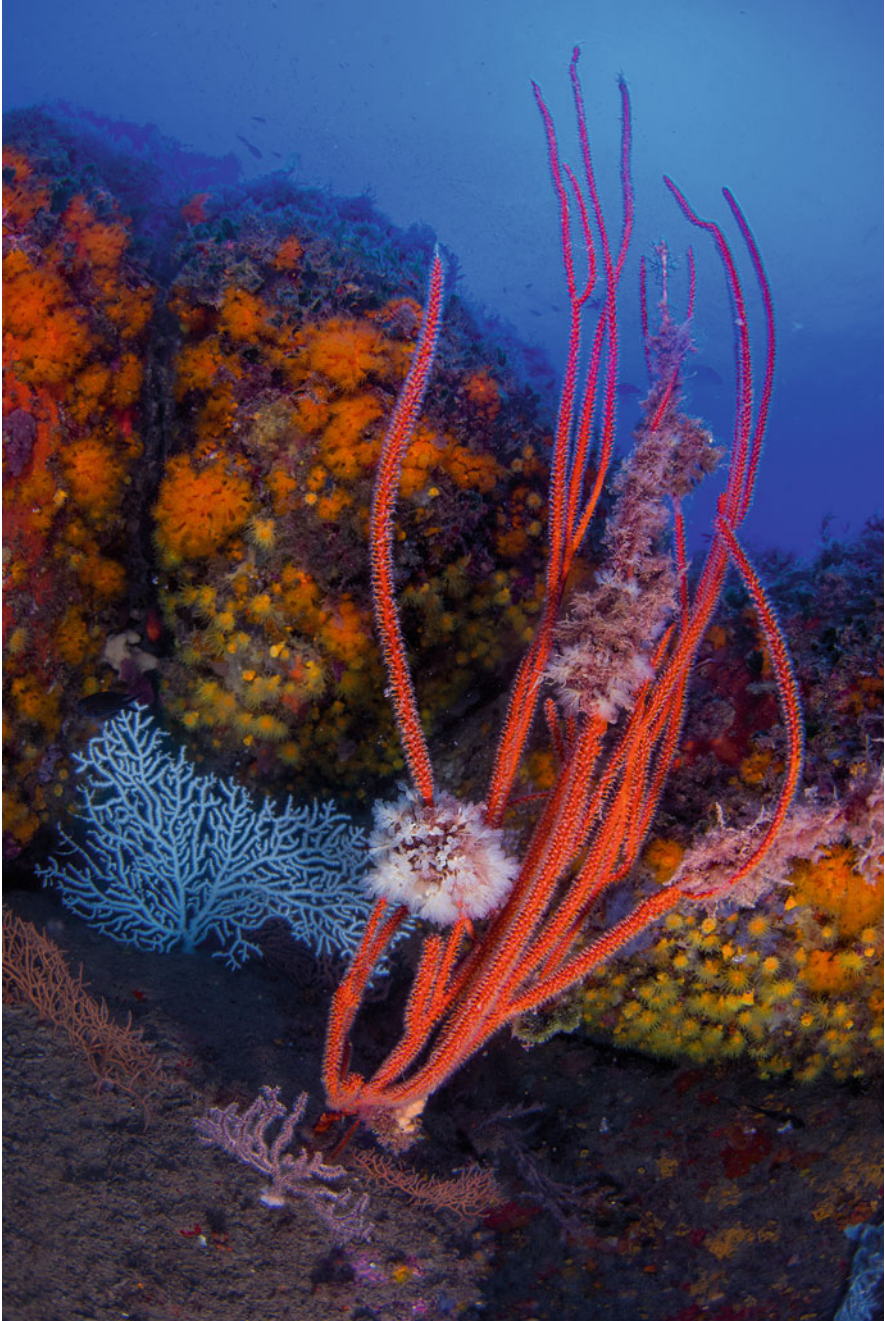
The decline of this limpet is attributed to human impact, such as overharvesting, development of coastal infrastructures (and the consequent degradation and fragmentation of the habitat) and marine pollution (Templado et al. 2004; Moreno and Arroyo 2008; Luque et al. 2018). *Patella ferruginea* is currently considered in danger of extinction and was included in 1992 as a “species in need of strict protection” in Annex IV of the Habitats Directive (92/43/CEE), in 1996 as an “endangered or threatened species” within Annex II of the Barcelona Convention, as “strictly protected” in 1996 in Annex II of the Bern Convention and as “in danger of extinction” in the Spanish Catalogue of Endangered Species (see Sect. 10.5).

### 10.1.2 *Ellisella paraplexauroides*

The gorgonian *Ellisella paraplexauroides* (Fig. 10.2) is one of the largest colonial invertebrates in the Mediterranean Sea and the only member of the genus *Ellisella* (Anthozoa, Alcyonacea, Ellisellidae) recorded in European waters (Grasshoff 1992). It forms brick-red candlestick like colonies, to just over 2 m high with ramifications arising from a common short stem and heading parallel upwards.

*Ellisella paraplexauroides* is an Atlantic-Mediterranean species rarely found in the Mediterranean (Templado et al. 2006; Arroyo et al. 2008; Angiolillo et al. 2012). In the Atlantic, the species occurs along the west coast of Africa (from Angola to Morocco) and off the Canary islands (Brito and Ocaña 2004), while in the Mediterranean, most of the records (reviewed by Angiolillo et al. 2012) are restricted to the Gibraltar Strait (Arroyo et al. 2008; Ocaña et al. 2009) and Alboran Sea (Templado et al. 2006; Arroyo et al. 2008). Inward into the Mediterranean, only isolated colonies have been reported off Algeria and Tunisia, Naples (doubtful record) and Pantelleria Island (data compiled by Angiolillo et al. 2012).





**Fig. 10.2** The gorgonian *Ellisella paraplexauroides* is one of the largest colonial invertebrates in the Mediterranean Sea and dominates the rocky bottoms mainly between 20 and 25 m in the Special Area of Conservation of the Chafarinas Islands. Here it is close to other smaller gorgonians (from top to bottom, *Eunicella verrucosa*, *Leptogorgia sarmentosa* and *Eunicella labiata*), the orange

Despite being a large charismatic species, very little is known about its basic biology and ecology. In most of its distribution area, this gorgonian seems to be located on shelf bottoms mainly in the depth range of 50–200 m. Nevertheless, in the Canary Islands has been recorded at the extreme depths of 690 m (Brito and Ocaña 2004), while in the Strait of Gibraltar area and around the Chafarinas Islands can be found as shallow as 15–20 m depth (Ocaña et al. 2009; Maldonado et al. 2013). Scattered colonies have been found in the deep shelf around the Alboran Island (Templado et al. 2006; Gofas et al. 2014) between 70 and 200 m depth and in the Seco de los Olivos (also known as Chella Bank) below 80 m depth (Aguilar et al. 2008; de la Torre et al. 2014). Likewise, some colonies were photographed and sampled from 80 to 94 m depth on the northeast coasts of Pantelleria Island (Angiolillo et al. 2012).

The occurrence of *Ellisella paraplexauroides* around the Chafarinas Islands is noteworthy. This species dominates the underwater rocky landscape from about 17–20 m deep with an average density of 0.5 colonies  $\text{m}^{-2}$  (maximum, 5 colonies  $\text{m}^{-2}$ ) (Maldonado et al. 2013). These authors pointed out that this unique population requires serious conservation attention owing to considerable damage caused by small-scale fishing operations. Likewise, Otero et al. (2017) highlight that this gorgonian should be considered “vulnerable” in the Mediterranean basin, since its populations are concentrated around the few sites mentioned and have suffered a drastic decline over recent decades. This decline is mainly related to the impact of unregulated and illegal fisheries, particularly the use of benthic gillnets, trawling gear and longlines. These authors also draw attention to the exceptional value of the population of *E. paraplexauroides* of Chafarinas Islands. In fact, this species was included in 2013 in Annex II of the Barcelona Convention, among other gorgonians and corals (see Sect. 10.5), and listed as “vulnerable” in the IUCN Red List.

### 10.1.3 *Astroides calycularis*

Another conspicuous and emblematic species of the Alboran Sea is the scleractinian coral *Astroides calycularis* (Figs. 10.2 and 10.3), known as “Mediterranean orange coral” because of the deep orange colour of its coenosarc and polyps (Zibrowius 1995). This species is also well represented in few sectors of the Tyrrhenian Sea, Sicily and Malta and on the Zembra Island in Tunisia, but the greatest concentration and distribution of colonies occurs in the Strait of Gibraltar and Alboran Sea. It barely extends into Atlantic waters beyond the Strait of Gibraltar, and its known western limit of distribution is located at La Caleta, Cadiz City (Moreno et al. 2008a).



**Fig. 10.2** (continued) coral *Astroides calycularis* and the yellow coral *Leptopsammia pruvoti* (22 m depth) [Luis Sánchez Tocino]



**Fig. 10.3** A colony of the orange coral *Astroides calycularis* in the Special Area of Conservation Acantilados de Maro-Cerro Gordo (Granada), 3 m depth. This species adorns the shady rocky surfaces of the Alboran Sea from surface levels down to about 30 m [Luis Sánchez Tocino]

The orange coral lives in shaded habitats, such as vertical walls, overhangs and cave entrances, prefers areas with high wave action and can be found from the water surface down to a depth of just over 50 m, although it is mainly found in shallower waters. In some places, this coral is the dominant species covering up to 80–90% of wall surface (Ocaña et al. 2009). In exposed places, it typically forms massive colonies with polygonal corallites. In sheltered or deeper places, colonies tend to have a bush-shaped morphology with nearly circular corallites.

Based on fossil evidence, we know that this coral was widely distributed throughout the Western Mediterranean Sea during certain periods of the Pleistocene (Zibrowius 1995) but disappeared from the Northern Mediterranean areas during colder periods. Currently, the range distribution of *A. calycularis* is mainly restricted to rocky coastal areas of the southwestern basin of the Mediterranean, and it is considered a key species in the Alboran Sea (Cebrián and Ballesteros 2004).

Moreno et al. (2008a) and Terrón-Sigler et al. (2015) detailed its distribution in the north side of the Alboran Sea and pointed out that the species is especially abundant on the coasts of Cadiz and Granada. North of Cabo de Gata, *A. calycularis* is only found up to Cabo de Palos (Murcia) as very isolated and dispersed colonies. Conversely, there are scanty data of this coral in the southern side of the Alboran Sea. It is very abundant in Ceuta (Strait of Gibraltar), where it can reach high coverage (Ocaña et al. 2009) and has been also recorded in the Alboran Island,

Melilla and Chafarinas Islands (Templado et al. 2004, 2006), where it is common but with relatively low densities. *Astroides calycularis* is also widely distributed along the coasts of Morocco with spectacular occurrences around Cape Tres Forcas (Bazairi et al. 2013) and in the Al Hoceima National Park (Franzosini and Limam 2004) and Algeria. Its southeastern limit seems to be located in Cap Bon and Zembra Island (Tunisia), where Boudouresque et al. (1986) pointed out that this coral covers extensive surfaces of shallow rocky bottoms down to 15 m depth.

Further north, Musco et al. (2016) recorded well-developed populations in the Sorrento Peninsula and the islands of Ischia and Capri along the coast of Campania; the Cilento Coast; the area between Calabria and Sicily, including the Straits of Messina and the Aeolian Islands; the northwestern coast of Sicily, including Ustica and the Egadi Islands; and the islands in the Strait of Sicily. Some colonies were found along the coast of Croatia (Grubelić et al. 2004) which suggests that the geographical range of *A. calycularis* is expanding northwards.

The strictly coastal habitat of *A. calycularis* and its preference for shaded enclaves in the upper infralittoral belt expose this coral to the impact of human activities. This, coupled with its narrow range of tolerance for temperature, seems to be causing its decline. On the other hand, its planula larvae show negative buoyancy and demersal behaviour, crawling along the rocky wall to find a suitable place on which to settle (Goffredo et al. 2010). Hence, the species' larvae have low dispersal capabilities, which leads to a restricted gene flow and connectivity, increasing differentiation among populations because of isolation by distance (Casado-Amezúa et al. 2012). All the above has determined that the orange coral is nowadays protected under Appendix II of the Bern Convention, Annex II of Barcelona Convention and Appendix II of CITES (with all scleractinian corals). It is also catalogued as “vulnerable” in the Spanish and Andalusian Catalogues of Endangered Species (see Sect. 10.5) but considered as of “least concern” in the IUCN Red List.

## 10.2 Rare Species

The vast majority of species are rare, having a low number of individuals or a restricted spatial occurrence. A particular species may be rare for several reasons, namely: small absolute population size, small geographic range, highly specialized mode of life in conditions that are themselves uncommon, low population density, incidental occurrence in environments not normally occupied by the species, successful breeding at only a few sites (Vermeij and Grosberg 2018) or simply be an artefact due to scarce knowledge linked to the availability of the relevant taxonomic specialists (Bianchi et al. 2014). Species which are represented anywhere by few, scattered individuals implies good dispersal abilities, while species which are restricted to a very peculiar habitat and are abundant there, but that habitat in itself is rare and/or inaccessible, are rather characterized by direct development and low dispersal potential, and their rarity may be an artefact due to our access limitation (Gaston 1994). It has long been recognized that populations below a critical density



or number of individuals face a high risk of extinction, because of demographic fluctuations or reproductive failure due to different impacts (Vermeij and Grosberg 2018). Nevertheless, rarity may also hold the key to survival during crises (e.g., Bianchi et al. 2014), and many species persist chronically rare.

Most communities are composed of a few dominant species and a high number of rare species. Indeed, the bulk of biodiversity at species level consists of a host of small, inconspicuous and little-known species. Nevertheless, rare species are the neglected component of biodiversity, and they are often considered as “noise” and ignored in ecological studies (Piraino et al. 2002). Likewise, biodiversity conservation focuses mainly on a few charismatic species (generally either vertebrates or large and conspicuous invertebrates) and disregards what represents the most of the biodiversity. Conversely, the importance of rare species could be crucial as a reservoir of potential diversity and provide information for the possible future composition of a community after changes in environmental conditions. Highly distinct combinations of traits are supported predominantly by rare species. It is thus not only the quantity but also the quality of biodiversity that matters (Mouillot et al. 2013).

A broad array of species may allow ecosystems to maintain their functioning, and a high number of species serves as a buffer against the effects of environmental impacts and enhances the recovery potential of communities. Therefore, rare species are particularly important from the point of view of conservation, ecology and evolutionary biology (Lim et al. 2012). Furthermore, since rare species are represented by only a few individuals or small populations often restricted to particular habitats, they are vulnerable to being lost. To summarize, although still incomplete, there is growing scientific evidence that many rare or little-known species may play key ecological roles in the function, structure and composition of some ecological communities and could be important as a genetic reservoir and for long-term evolutionary potential. Nevertheless, rare or little-known species are, by their nature of being scarce, often not explicitly included in conservation and natural resource planning (Raphael and Molina 2007).

We consider here as rare species those that are very restricted in number of individuals or spatial occurrence but also those of unusual morphological or biological characteristics. Sometimes the supposed rare species are not so much but belong to groups of tiny animals very poorly studied. Indeed, the number of rare species in the Alboran Sea is very high, and here we will mention only a few of them as examples.

### ***10.2.1 Porifera***

The bottoms of the Alboran Sea are characterized by a high richness and diversity of sponges. Among this fauna, there are a significant number of Mediterranean endemisms and rare species, along with numerous “Atlantic” species found in this westernmost Mediterranean area where may reach notable abundances (Sitjà and



Maldonado 2014). As examples can be mentioned *Jaspis eudermis* and *Axinella vellerea*, previously only known from Azores and a Norwegian fiord, or *Hemiassterella elongata*, previously known only from its holotype collected in the Cape Verde Islands.

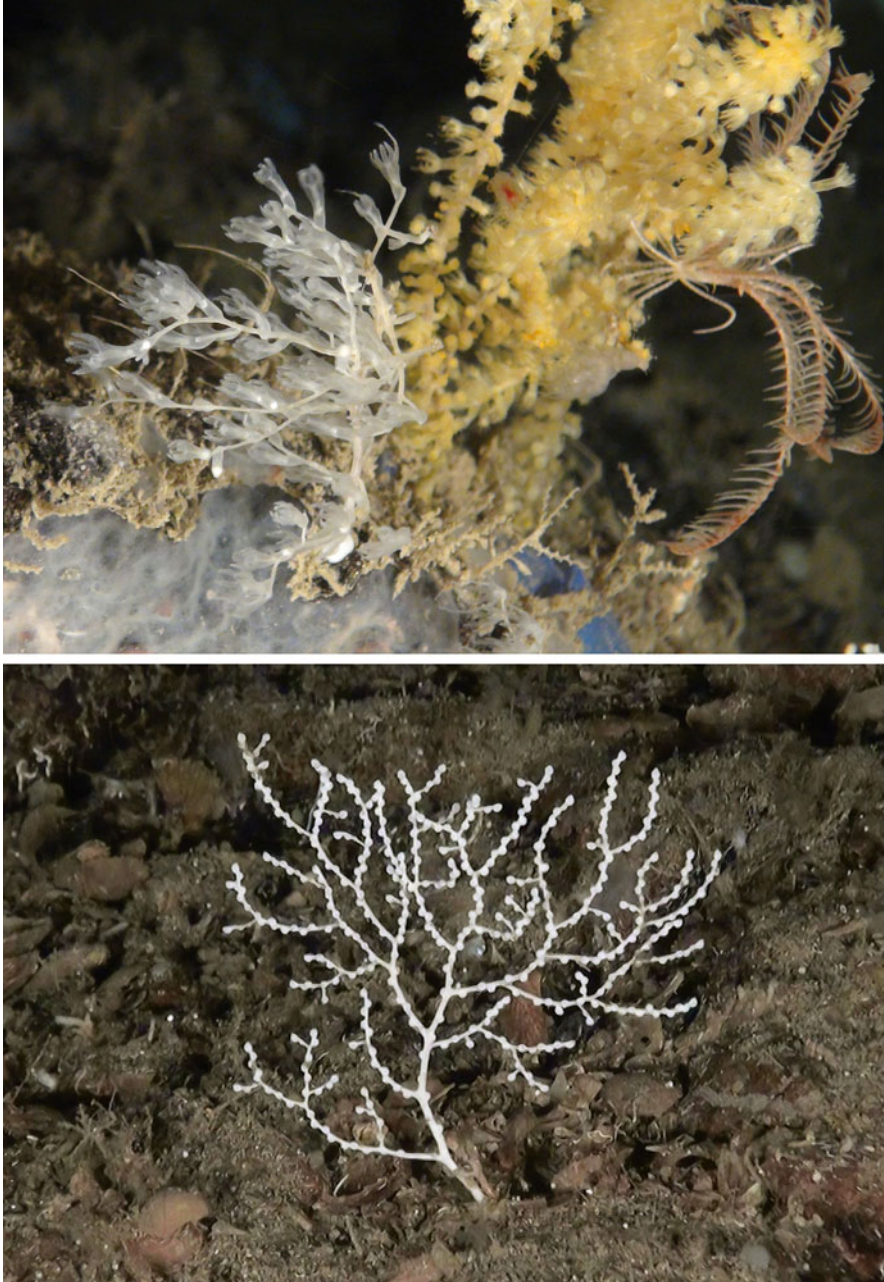
On the other hand, one of the most peculiar groups within the phylum Porifera is that formed by carnivorous sponges, all belonging to the family Cladorhizidae (Hestetun et al. 2016). Contrary to the aquiferous system used to filter water for particulate matter characteristic of this primitive phylum, the carnivorous sponges have developed the ability to trap prey items coupled with the complete or partial reduction of the aquiferous system. In the Mediterranean, these peculiar sponges are represented by two species: *Cladorhiza abyssicola* and *Lycopodina hypogea*. The former is a bathyal sponge widely distributed in the NE Atlantic that has been found in deeper waters of a few locations of the NW Mediterranean (Vacelet 1969) and one specimen in the Alboran Sea (Boury-Esnault et al. 1994). Meanwhile, *L. hypogea* was originally described (as *Asbestopluma hypogea*) from shallow submarine caves (15–25 m depth) in the Western Mediterranean Sea and the Adriatic (Vacelet and Boury-Esnault 1996; Bakran-Petricioli et al. 2007). Nonetheless this species has subsequently been observed in some deep Mediterranean and Atlantic locations (in the depth range 100–500 m), among them in the Seco de los Olivos (Aguilar et al. 2011b, at 167 m) and Cabliers Seamount (Chevaldonné et al. 2015, between 370 and 400 m) on the north and south margins, respectively, of the Alboran Sea.

### 10.2.2 Cnidaria

The small and semitransparent anemone *Sideractis glacialis* is mainly known in northern latitudes of the East Atlantic, usually in deep white coral banks. It was recorded in the NW Mediterranean by den Hartog et al. (1993) and more recently by Aguilar and Marín (2013) in some seamounts near the Balearic Islands and in the Seco de los Olivos. Due to its small size and inconspicuous colour, this species may often have been overlooked. The Mediterranean records reveals that it is more widely distributed than has previously been assumed, and its distributional range possibly coincides to a large extent with that of white coral banks formed by *Desmophyllum pertusum* and *Madrepora oculata*.

The large scyphozoan jellyfish *Drymonema dalmatinum* was described from the Dalmatian coast in the Adriatic Sea. Despite its conspicuous size, this medusa has been very rarely observed. Malej et al. (2014) reported an increased frequency of sightings in the last 15 years from the Adriatic and eastern Mediterranean Sea, and recently Kienberger and Prieto (2016) reported a single specimen observed and photographed by scuba divers near La Herradura (S Spain) at a depth of 12 m, with a bell diameter of approximately 70 cm.

*Dendrobrachia bonsai* (Fig. 10.4) is a delicate and small gorgonian whose whitish and inconspicuous colonies usually do not exceed 10 cm in height. This species was recorded by Zibrowius and Taviani (Zibrowius and Taviani 2005) as



**Fig. 10.4** Two delicate gorgonians, *Dendrobrachia bonsai* (above) that does not exceed 10 cm in height (Seco de los Olivos, 440 m depth) and the Atlantic *Nicella granifera* (below), recently found in the Seco de los Olivos (430 m depth) [Ricardo Aguilar, Oceana]



**Fig. 10.5** Aggregations of dead colonies of the deep-water scleractinian coral *Anomocora fecunda*, previously only known from the Caribbean and Macaronesian Seas, have been found in Cabliers and Seco de los Olivivos Banks (here in a detritic bottom dominated by *Cidaris cidaris* in the Seco de los Olivivos around 400 m depth) [Ricardo Aguilar, Oceana]

*D. fallax* in bathyal bottoms south of Malta (Strait of Sicily) and in the Seco de los Olivivos. Later, López-González and Cunha (2010) described these specimens together with others obtained in the Gulf of Cadiz and in Al Idrisi Seamount (Djibouti Plateau) as a new species (*D. bonsai*). More recently, Sartoretto (2012) noted the presence of this species in five submarine canyons between 200 and 500 m depth on the western coast of Corsica, mainly along the rocky walls and overhangs of high cliffs. Likewise de la Torriente et al. (2014, 2018) and Ocaña et al. (2017) found some colonies of *D. bonsai* in Catifas Bank and Seco de los Olivivos between 380 and 450 m. Another small Atlantic gorgonian, *Nicella granifera* (Fig. 10.4), has been recently found for the first time in the Mediterranean in the Seco de los Olivivos at 430 m depth (Ocaña et al. 2017) and then in the Emile Baudot Seamount in the Balearic Promontory (Ricardo Aguilar, pers. obs.).

Species belonging to the genus *Anthomastus* were recently recorded in the Cabliers and the Seco de los Olivivos Banks (Pardo et al. 2011; de la Torriente et al. 2014, respectively). These deep-sea mushroom corals were previously known from the Indo-Pacific, Atlantic and Antarctic waters (Molodtsova 2013), mainly associated to seamounts and knolls, and are very easily distinguished by their external appearance with reddish tones and huge expanded autozooids, which are specialized in feeding. The records of species of this genus in the Alboran Sea expand its distribution to the Mediterranean Sea. In both Cabliers and Seco de los Olivivos Banks, aggregations of dead colonies of the scleractinian *Anomocora fecunda*



(Fig. 10.5) were also found between 200 and 400 m depth (Pardo et al. 2011; de la Torriente et al. 2014; Ocaña et al. 2017). This species was previously known only from tropical waters of the western and eastern Atlantic (Caribbean and Macaronesian Seas).

### 10.2.3 *Nemertea*

The heteronemerteans *Micrura dellechiaiei* (Fig. 10.6) and *Cerebratulus aerugatus*, previously known only from their type locality in the Gulf of Naples, had not been recorded again in 120 years until recently. Several specimens of the former were collected during two oceanographic surveys conducted in Spanish Mediterranean waters, in the Menorca Channel (Balearic Islands) and near the Alboran Island (Herrera-Bachiller et al. 2015), between 48 and 101 m depth. The second species was recently recorded in Ceuta (Strait of Gibraltar) by Junoy et al. (2018), along with other rare nemerteans, such as *Tetrastemma coronatum*, only known previously from the Azores and Madeira Islands, or *Prosorhochmus chafarinensis*, originally described from the Chafarinas Islands by Frutos et al. (1998).



**Fig. 10.6** The nemertean *Micrura dellechiaiei*, previously only known from the Gulf of Naples, has been recently found near the Alboran Island between 48 and 101 m depth [Juan Junoy]



### 10.2.4 Meiofauna (*Gastrotricha*, *Kinorhyncha*, *Tardigrada*)

The term “meiofauna” (or “meiobenthos”) include microscopic benthic invertebrates (size mainly between 0.5 and 1 mm) that live in both marine and freshwater environments. Most of the recognized animal phyla have representatives in meiofauna, but only five of them are exclusively meiofaunal. These tiny animals are a common component of the interstitial environment (between sand grains) where they reach a high abundance and are ubiquitous and ecologically important in sedimentary bottoms recycling detritus and dead organic matter. Nematodes are the dominant group of the marine interstitial environment, but this group has not been documented in the Alboran Sea. Other common components of marine meiofauna are Gastrotricha, Kinorhyncha or Tardigrada. These are very little studied groups (also in the Alboran Sea), and their rarity is due to limited knowledge rather than to real scarcity.

Gastrotricha is a clade of aquatic microscopic animals that are among the smallest metazoans, mainly living in the marine and freshwater interstitial environment and on the surface of aquatic plants. Only one species of this group, *Pleurodasys helgolandicus*, widespread along the North Sea and the Atlantic European coasts, is known to form stable populations along the Spanish coast of the Alboran Sea (Todaro et al. 2006).

Kinorhyncha is a phylum of meiobenthic organisms less than 1 mm in length and found exclusively in marine or estuarine sediments, from coarse sand or shell gravel to very fine mud. Sánchez et al. (2012) recorded about 12 kinorhynch species in south Spain (Algeciras Bay and Granada coast). Among them, *Echinoderes dujardinii* (Fig. 10.7) was collected by Sánchez-Tocino et al. (2011) in shallow waters near Almuñécar (Granada, Spain). Subsequently, two new species, *Dracoderes gallaicus* and *Pycnophyes almansae*, were described from specimens collected in Algeciras and Almuñécar (Sørensen et al. 2012; Sánchez et al. 2014).

Tardigrada are micrometazoans that occupy a diversity of niches in freshwater, marine and terrestrial habitats. In the Alboran Sea, this group has only been studied in the Chafarinas Islands by Villora Moreno and de Zio Grimaldi (1996) who recorded 14 species, 5 of which were new records for the Mediterranean Sea. Three of them were the first record after its original description: *Florarctus acer*, *F. asper* and *F. stellatus*. Further, *Halechiniscus chafarinensis* was described as a new species by de Zio Grimaldi and Villora-Moreno (1995).

### 10.2.5 *Cycliophora*

Cycliophora is one of the most recently described animal phyla whose members live commensally on the mouthparts of lobsters of the family Nephropidae (Obst et al. 2005). Up to date, two species have been described, *Symbion pandora*, from the Norway lobster (*Nephrops norvegicus*), and *S. americanus*, from the American

**Fig. 10.7** The meiobenthic kinorhynch *Echinoderes dujardinii* has been recorded in shallow water near Almuñécar (Granada coast, S Spain) [Luis Sánchez Tocino]



lobster (*Homarus americanus*). Nevertheless, molecular studies show that more cryptic species can exist (Obst et al. 2005; Baker and Giribet 2007). *Symbion pandora* is widely distributed in the eastern Atlantic and has been also recorded in NE Spain (Catalonian coast), in the Tyrrhenian Sea and in the Alboran Sea (Granada coast, Sánchez-Tocino and Tierno de Figueroa 2008) living on the mouthpieces of the lobster *Nephrops norvegicus*.

### 10.2.6 Entoprocta

Only very few, small and poorly known species of the phylum Entoprocta are known in the Mediterranean Sea, all of them belonging to the family Loxosomatidae. Recently two new species of this small animal group have been described from the shores of Granada: *Loxosomella ameliae* and *Loxosomella almugnecarensis* (by Sánchez-Tocino and Tierno de Figueroa 2009a and Tierno de Figueroa and Sánchez-Tocino 2009a, respectively). Furthermore, three other species of *Loxosomella* have been recorded by these authors in the same area: *L. crassicauda* (Tierno de Figueroa and Sánchez-Tocino 2008), *L. pes* (Sánchez-Tocino and Tierno de Figueroa 2009a) and *L. tethyae* (Tierno de Figueroa and Sánchez-Tocino 2009b). All of them are tiny (<5 mm), sessile stalked animals, commensal mainly on sponges. Three of these species have been also found in the Chafarinas Islands,

and this makes the Alboran Sea one of the better known areas for this group, together with the Gulf of Naples (Sánchez-Tocino and Tierno de Figueroa 2009b, c).

### 10.2.7 *Polychaeta*

Vestimentiferan tubeworms (Annelida, Siboglinidae) represent one of the most intriguing clades within polychaetes from both a phylogenetic and an ecological point of view and are typically associated with reducing habitats such as hydrothermal vents and cold seeps. They depend on organic compounds supplied by endosymbiotic chemoautotrophic bacteria and lack a mouth and gut in the adult phase. *Lamellibrachia anaximandri* is the only known representative of siboglinids in the Mediterranean Sea (Southward et al. 2011). This vestimentiferan tubeworm has recently been described at various deep locations of the Eastern Basin and Southern Tyrrhenian Sea (at the Palinuro volcanic complex) (Rubin-Blum et al. 2014) and has also been observed in a mud volcano field in the West Alboran Basin at 570 m depth (Hilário et al. 2011). Vestimentiferan tubes appeared grouped in dense bush-like aggregates, and they can exceed 1 m in length.

### 10.2.8 *Crustacea*

The isopod *Astacilla carlosoteroi* was previously only known from a single, incomplete female from the Ferrol estuary (Galicia, NW Spain, Atlantic), but recently some specimens (including males) have been found near the Alboran Islands (Rincón et al. 2018). This is the first report of the species from the Mediterranean Sea and the second worldwide record of the species.

### 10.2.9 *Bryozoa*

The pedunculate bryozoans of the genus *Kinetoskias* are typically abyssal and are characterized by an erect colony and an elongate peduncle supporting a cup-shaped crown of slender, unilaminar branches. The north Atlantic species *Kinetoskias smitti* Danielssen, 1868, was recorded in the Alboran Sea at a much shallower depth (428 m) than in the Atlantic (Harmelin and d'Hondt 1992), and this is the only record of this genus in the Mediterranean.

### 10.2.10 *Echinodermata*

The sea star *Coronaster briareus* is mainly known from the western Atlantic, where it extends from New Jersey to Venezuela and possibly South Brazil (Clark and Downey 1992). In the eastern Atlantic, it was recorded from the Cape Verde Islands and some seamounts (Clark and Downey 1992). Recently, several individuals of this starfish were reported for the first time from the Mediterranean Sea near the Maltese Islands between 240 and 562 m (Evans et al. 2018). Notwithstanding, one orange-red specimen was photographed in the southern flank of El Idrissi Bank, at 365 m depth (Hebbeln et al. 2009, Fig. 5.8c as *Coronaster* sp.).

The large starfish *Luidia atlantidea*, known hitherto in the Atlantic coasts of northwestern Africa, has been recently reported for the first time in the European margin of the Alboran Sea (Gallardo-Roldán et al. 2015). Most individuals were collected close to La Caleta de Vélez and Fuengirola. It was mainly found in shallow bottoms of fine sand with pebbles and/or bioclasts, where this starfish generally occurs together with the dominant molluscs *Chamelea gallina* and *Donax trunculus*.

## 10.3 Habitat-Forming Species

The term “animal forests” has been introduced to describe megabenthic communities dominated by sessile suspension feeder invertebrates (such as sponges, cnidarians or bivalves among others). These communities are complex three-dimensional environments that support a high biodiversity, by providing structure and shelter to many other organisms (Rossi et al. 2017). Animal forests are distributed worldwide, ranging from tropical to polar latitudes and from shallow to deep-sea bottoms. Some of the most characteristic underwater animal forest seascapes of the Alboran Sea are composed of anthozoans, such as the gorgonians and red and black coral forests, the fields of sea pens or the scleractinians forming the cold-water coral reefs. Some bivalves and sponges can also form highly complex and diverse three-dimensional structures.

### 10.3.1 *Sponges*

Sponges are an important component of the deep-shelf benthos, particularly on rocky bottoms, where they make peculiar assemblages characterized by a wide diversity of small, erect species forming a dense “undergrowth” among a scatter of large sponges and gorgonians (Sitjà and Maldonado 2014). Some of them are key bioengineer species forming three-dimensional structures during their long lifespans that provide suitable habitats for a wide variety of other marine species. A high diversity and abundance of small erect species growing among the large astrophorids



and axinellids typically build in the Mediterranean the so-called “sponge gardens” or “sponge grounds” in depth ranges which are similar to those reported on North-Atlantic margins (Maldonado et al. 2016).

Sponges are one of the best studied and more diverse groups in the Alboran Sea and offer many novelties, as previously noted in Sect. 10.2.1. Specifically, about 200 species have been recorded around the Alboran Island (Sitjà and Maldonado 2014). Here we will focus only on highlighting the most dominant species that make up sponge gardens.

Among demosponges, the astrophorids *Poecillastra compressa* and *Pachastrella monilifera* appear to have the most extensive geographical distribution within the Mediterranean and give rise to dense aggregations (reaching densities of up to 10 individuals m<sup>-2</sup>), sometimes as dominant species and others mixed with corals and gorgonians (Aguilar et al. 2017). Both species show an Atlantic-Mediterranean overlapped distribution and share a great morphological and dimensional plasticity, which allow them to grow into a variety of different environments, on several types of substrate and within a wide bathymetric range (Bo et al. 2012). They can be massive, plate-like or cup-like in shape, being *P. monilifera* generally white, while *P. compressa* exhibits orange colour when observed alive. Both species are common in the deep circalittoral hard bottoms of the Alboran Ridge (Sitjà and Maldonado 2014).

The demosponges of the genus *Phakellia*, with mostly Atlantic distribution, are also common in the Western Mediterranean (de la Torriente et al. 2014; Aguilar et al. 2017), becoming abundant in the deep circalittoral and upper bathyal zones, especially on slopy rocky plains and seamounts. Both chalice-shaped or fan-shaped sponges *Phakellia ventilabrum* and *P. robusta* are widespread in the Strait of Gibraltar and Alboran Sea (Maldonado 1992; Boury-Esnault et al. 1994; Carballo and García-Gómez 1994; Lo Iacono et al. 2012; Gofas et al. 2014; de la Torriente et al. 2018). In the Alboran Ridge, *Phakellia* species have been observed in mixed assemblages dominated by cnidarians and sponges on the deep circalittoral hard bottoms (Gofas et al. 2014) and rhodolith beds (Sitjà and Maldonado 2014).

On soft bottoms, the presence of sponge aggregations is limited to a few species, such as the northwestern Atlantic *Thenea muricata*, which is also common in muddy bottoms of the bathyal zone throughout the Mediterranean, including the Alboran Sea (Boury-Esnault et al. 1994). The *T. muricata* assemblage is usually monospecific, reaching a high biomass. It is affected by bottom trawling (Pansini and Musso 1991), since it is a common by-catch species.

The northeastern Atlantic large (up to 1 m tall) and vase-shaped hexactinellid sponge *Asconema setubalense* is the most important species forming aggregations in the Western Mediterranean (Boury-Esnault et al. 2015), mainly on seamount rocky bottoms at depths below 200 m, but has not been found beyond the Alboran Sea. Another widespread Atlantic glass sponge is *Phoronema carpenteri*, which can also give rise to important communities but in this case on muddy bottoms. In the Mediterranean, it has been found from the Alboran to the Tyrrhenian Sea at depths between 350 m and more than 2000 m (Boury-Esnault et al. 2015).



**Fig. 10.8** The rare stalked sponge *Sympagella delauzei* has been recorded in several seamounts of the Alboran Sea (Avempace Bank at 388 m depth) [Ricardo Aguilar, Oceana]

The new recently described white urn-shaped and stalked hexactinellid *Sympagella delauzei* (Fig. 10.8) has been recorded on several seamounts of the Alboran Sea (Avempace, Seco de los Olivos, Catifas, Cabliers and Tofiño) between 320 and 480 m depth (Boury-Esnault et al. 2015). Out of the Alboran Sea, this species has been only found off West Corsica and the Gorringer Bank (NE Atlantic). Another recently described hexactinellid is *Tetrodictyum reisiwigi*, but it is more widely distributed in the Mediterranean, reaching the eastern basin. This small species is formed by several tubes more or less coalescent, expanding from a narrower base of attachment to the substrate (Boury-Esnault et al. 2017), and can form aggregations on hard bottoms of seamounts, escarpments and canyons within the depth range of 200–2500 m. It was collected in two stations of the Alboran Sea during the BALGIM Cruise (1984) between 390 and 560 m depth and was previously identified as *T. tubulosum* by Boury-Esnault et al. (1994).

As mentioned before, numerous smaller sponges may form dense “undergrowths” among larger sponges and gorgonians, mainly in three major habitats of the deep shelf: “maërl” or rhodolith beds, rocky plains moderately sloping and isolated rocky outcrops surrounded by soft sediments (Sitjà and Maldonado 2014). Among them are frequent some submassive species of the genera *Suberites* (*S. compressa*), *Sarcotragus* (*S. pipetta*) or *Spongia* (*S. agaricina*), others with branching morphology such as those of the genera *Axinella* (e.g. *A. vellerea*, *A. pumila*) and *Stelligera* (e.g. *S. rigida*, *S. stuposa*) and a variety of small digitate

and stalked sponges such as *Crella pyrula*, *Podospongia lovenii*, *Rhizaxinella elongata*, *R. gracilis* or *Stylocordyla* sp.

### 10.3.2 Gorgonians

The so-called gorgonian forests are one of the most emblematic Mediterranean marine communities, showing a high diversity and great structural complexity. The nearly 30 species forming these forests have different morphologies, with sizes varying between a few centimetres and more than 2–3 m high and inhabit a wide range of environments (Gori et al. 2017). They are typical on hard bottoms, but some of them are also able to tolerate high levels of sedimentation or to anchor themselves on soft bottoms and form dense monospecific or multispecific assemblages that can extend over large areas.

Most of the Mediterranean species of gorgonians are present in the Alboran Sea, as well as some Atlantic species such as *Eunicella gazella*, *E. labiata*, *E. filiformis*, *Filigorgia guineensis*, *Spinimuricea atlantica* or *Ellisella paraplexauroides*, some of them coming from northwestern Africa. This fact determines that the bottoms of the Strait of Gibraltar and the Alboran Sea harbour more species than other Mediterranean or nearby Atlantic areas. Specifically, up to 19 species have been recorded in the bottoms surrounding the Alboran Island down to 500 m depth (Templado et al. 2006). In contrast, for example, only eight species were found in Tunisian waters within the depth range of 7–120 m (Ghanem et al. 2018), nine were observed between 40 and 360 m depth in the Menorca Channel (Grinyó et al. 2016), and five species were observed in the Algarve coast down to 30 m depth (Cúrdia et al. 2013).

Four gorgonian species are commonly present in shallow areas of the Mediterranean (Gori et al. 2012), namely, *Eunicella singularis*, *E. cavolinii*, *Paramuricea clavata* and *Leptogorgia sarmentosa*. In the Alboran Sea, *E. cavolinii* becomes very rare, being replaced by another species such as *Eunicella labiata* (Fig. 10.2). Furthermore, in the Strait of Gibraltar and Chafarinas Islands, the abovementioned *Ellisella paraplexauroides* (Fig. 10.2) can be found as shallow as about 20 m.

*Eunicella singularis* can be considered the most common and abundant gorgonian species and the only one known to host symbiotic algae. It is abundant throughout the western Mediterranean and Adriatic Sea, is occasionally present in the eastern Mediterranean and reaches the coasts of the Algarve in the near Atlantic. This species is common on rocky bottoms in shallow waters, as well as on deeper coralligenous formations. The extensive distribution of *E. singularis* on a regional scale may be related to its tolerance to a wide range of irradiance and abiotic factors, and it is found commonly on horizontal or sloping bottoms (Linares et al. 2008a; Gori et al. 2011). In contrast, the emblematic Mediterranean red gorgonian *Paramuricea clavata* show a more patchy distribution mainly in the western basin of the Mediterranean and the Adriatic Sea. It is associated with vertical rocky walls and occupied a narrow range of light and environmental conditions from about 20 m

to at least 110 m. Both species are widely distributed in the Alboran Sea and Strait of Gibraltar (Templado et al. 2006; Ocaña et al. 2009).

*Leptogorgia sarmentosa* (Figs. 10.2 and 10.20) shows a patchy distribution (Templado et al. 2006; Ocaña et al. 2009). It is a quite resistant species, able to thrive in very shallow waters and harsh environmental conditions, such as those typical of harbour habitats (Betti et al. 2018) and possess the ability to tolerate high silting levels and turbid waters.

*Eunicella gazella* and *E. labiata* are West African gorgonians distributed from Portugal to Angola, entering the Alboran Sea where they show a patchy and dispersed distribution (Abou Oualid et al. 2016). These species are usually found as isolated colonies in shady rocky enclaves between 5 and 20 m. *Eunicella labiata* is the most frequent gorgonian on the coastal bottoms of the Algarve (Cúrdia et al. 2013), but in the Alboran Sea, it has been only recorded from the Granada coast and the Chafarinas Islands (Sánchez-Tocino et al. 2009), while *E. gazella* reaches the Columbretes Islands in the Balearic Sea (Templado et al. 2002).

With a tree-like morphology often moulded on that of gorgonians, the so-called gold coral *Savalia savaglia* (Fig. 10.9) (an epizoic zoanthid species) may form a facies together with gorgonians, with a significant role in benthic assemblages due to their relatively long life span. It is the sole zoanthid able to produce a rigid and thick-layered proteinaceous skeleton, which grows on the stem of gorgonians for several hundreds of years and can reach up to 2 m high, with a main trunk diameter up to 15 cm (Cerrano et al. 2010). This species has been recorded sporadically in the Mediterranean Sea, mainly in circalittoral coralligenous bottoms, but recent discoveries have extended its bathymetric range down to 900 m in the deep coral communities (Giusti et al. 2015).

Monospecific facies with high density of colonies of *S. savaglia* have been found in some circalittoral bottoms of the Canary Islands, where it can be confused with *Antipathozoanthus macaronesicus* (Ocaña et al. 2007). Further, some colonies have recently been found in northeastern Spain at a depth of 26–29 m (Altuna et al. 2010). In the area of the Strait of Gibraltar and Alboran Sea, sparse colonies of *S. savaglia* have been recorded within gorgonian forests, between 20 and 40 m in depth in Ceuta (Ocaña et al. 2009), Cape Tres Forcas and Chafarinas Islands (González García et al. 2005), between 40 and 90 m in rocky outcrops around the Alboran Island (Templado et al. 2006) and in bathyal rocky bottoms down to 900 m in Avempace and Seco de los Olivos Banks (Pardo et al. 2011; de la Torriente et al. 2018).

Several species of gorgonians can be found on the deeper part of the continental shelf (at about 110–200 m depth), often occurring in multispecific assemblages, which are more frequent in the rocky outcrops that occur toward the shelf edge. Among other species, *Paramuricea macrospina*, *Swiftia pallida*, *S. dubia*, *Acanthogorgia hirsuta*, *Viminella flagellum*, *Bebrice mollis*, *Eunicella filiformis*, *E. verrucosa* and *Callogorgia verticillata* are typical gorgonians of these bottoms (Gori et al. 2017) and sometimes extend their distribution deeper onto the upper slope. Coexistence is observed at low and intermediate densities among large- (e.g. *C. verticillata*), medium- (e.g. *E. verrucosa*) and small-sized species (*Swiftia*





**Fig. 10.9** The zoanthid *Savalia savaglia* (called “gold coral”) starts growing on the stem of a gorgonian or antipatharian and then produce its own proteinaceous skeleton (Chafarinas Islands, 27 m depth) [Luis Sánchez Tocino]

spp.). This could indicate that differences in size may reduce interspecific competition for space and food (Grinyó et al. 2016).

*Eunicella verrucosa* (Fig. 10.2) has been described as an Atlantic species with a wide bathymetric range and seems to replace the Mediterranean *E. cavolinii* in the Alboran Sea. In the Strait of Gibraltar and Atlantic locations, this species may be found from shallow waters (6–8 m) down to about 80 m, but in the Alboran Sea, it is mainly found at deeper waters (35–200 m). Around the Alborán Island, it is quite abundant in the undergrowth of the *Laminaria* and *Saccorhiza* forests between 25 and 60 m (small colonies), but it can extend to deeper waters (down to about 200 m), where colonies are larger (Templado et al. 2006; Gofas et al. 2014). In the Seco de los Olivos, de la Torriente et al. (2018) found this gorgonian in the depth range of 75–450 m (more frequently in the range of 75–150 m).

The whip-like gorgonian *Viminella flagellum* is mainly an Atlantic species living in temperate and subtropical waters. Its occurrence in the Mediterranean Sea seems to be limited to its westernmost part (Alboran and Balearic Seas), with the exception of a record on the western coast of Corsica (Giusti et al. 2012, 2017). This gorgonian is characterized by monopodial colonies up to 3 m high with only one or few side branches. It may form dense meadows, especially over seamount summit plateaux, and may reach great depths (down to about 1000 m). In Alboran and Balearic Seas, the species has been recorded at a depth range of 90–400 m, generally on rocky substrata arising from detritic bottoms, where it achieves high densities over large areas (Aguilar et al. 2006; Grinyó et al. 2016). Nevertheless, *V. flagellum* is considered a near threatened species by IUCN Red List (García et al. 2015). Another whip-like gorgonian is the West African species *Eunicella filiformis*, only recorded in the Mediterranean from the Strait of Gibraltar (Carpine and Grasshoff 1975) and some areas of the Alboran Sea, such as Xauen Bank and Alboran Ridge (Templado et al. 2006; Gofas et al. 2014), and off the coast of Malaga and Granada (Templado et al. 1993; Ocaña et al. 2000), in the depth range of 60–300 m.

Small aggregations of the alcyonacean *Chironophthya mediterranea* (Fig. 10.10), recently described by López-González et al. (2015) in the Balearic Islands at a depth range of 115–200 m, have been recorded in some places accompanying *V. flagellum*. This alcyonacean was later found along the south Sardinian continental margin (Cau et al. 2017), in the Seco de los Olivos between 90 and 180 m (de la Torriente et al. 2018) and in the Cabliers Coral Mound between 300 and 400 m (Corbera et al. 2019).

The large Atlanto-Mediterranean gorgonian *Callogorgia verticillata* forms dense forests that can begin in the deep shelf and extend to a depth of more than 1000 m. This species generally dominates on gently sloping silted rocky bottoms in areas characterized by high sedimentation rates, often forming mixed gardens with other gorgonians and sponges. In the Alboran Sea, *C. verticillata* is very common in bottoms between 70 and 400 m (Templado et al. 2006; Gofas et al. 2014; de la Torriente et al. 2018).

*Acanthogorgia hirsuta* has been recorded in some areas of the northeast Atlantic and in some scattered western Mediterranean locations. This species is frequent in some areas of the Alboran Sea, such as the Alboran Ridge (Templado et al. 2006), El



**Fig. 10.10** The recently described alcyonacean *Chironephthya mediterranea* has been found in the Seco de los Olivos in the depth range of 90–180 m [Ricardo Aguilar, Oceana]

Idrissi Bank and the so-called Melilla Mounds (Hebbeln et al. 2009), Seco de los Olivos (de la Torre et al. 2018) and Cabliers Bank (Ocaña et al. 2017), usually on lightly silted rocky substrates of the shelf edge and upper slope between 150 and 400 m depth.

*Paramuricea macrospina* is an endemic Mediterranean gorgonian found mainly on rocky bottoms between 50 and 200 m depth and has recently been reported as one of the most abundant species in shelf and shelf edge environments, mainly in northwestern Mediterranean (Grinyó et al. 2016; Pica et al. 2018). In the Menorca Channel (western Mediterranean), *P. macrospina* is the dominant gorgonian species at 65–90 m depth, but it is also commonly found on the shelf-edge associated with other gorgonians at 110–160 m depth (Grinyó et al. 2016). Recently, the species has been found in the Seco de los Olivos around 120–130 m depth. This gorgonian has been included in the IUCN Red List of Threatened Species (Aguilar et al. 2015).

Some small-sized gorgonians are also widespread along the shelf edge and upper slope, being *Swiftia pallida*, *Bebryce mollis* and *Villogorgia bebrycoides* the most frequent species. They can create a sort of “underbrush” together with sponges living at the base of larger species, although they may form important monospecific thickets in the upper bathyal zone, usually between 200 and 700 m (Aguilar and Marín 2013). All these small gorgonians are well represented in several locations of the Alboran Sea (Templado et al. 2004; de la Torre et al. 2014).

*Isidella elongata*, known as bamboo coral, is the main tree-like species on deep bathyal compact muds (it characterizes a facies together with the sea pen *Funiculina quadrangularis*) between about 500 and 1200 m depth (occasionally shallower) on relatively flat bottoms with a gentle slope (Cartes et al. 2013; Mastrototaro et al. 2017). The bamboo coral (with colonies up to 70 cm height) is almost exclusively restricted to the Mediterranean Sea, but it can extend to the adjacent Gulf of Cadiz and North Morocco. Maynou and Cartes (2012) pointed out that some fish and decapod crustaceans reach maximum abundance in bottoms where *I. elongata* reaches a high density, such as the deep-water shrimps *Aristeus antennatus* and *Plesionika martia*, both of high commercial interest. In fact, this deep-water coral is increasingly rare in the Mediterranean due to intense fishing pressure from trawlers targeting the red shrimp (*Aristeus antennatus*) at continental slope depths, so nowadays the species is considered Critically Endangered (Otero et al. 2017; Pierdomenico et al. 2018). In the Alboran Sea has been recorded in the Djibouti, Cabliers and Chella Banks, with a maximum density in the depth range of 400–500 m (de la Torriente et al. 2014).

All gorgonian species mentioned above are considered to be the most frequent in the Strait of Gibraltar and Alboran Sea, but there are also a number of other gorgonian species that have been recorded sporadically in this area, such as *Filigorgia guineensis* (Ocaña et al. 2000), *Paramuricea grayi* (Ocaña et al. 2009), *Dendrobrachia bonsai*, *Placogorgia coronata* (de la Torriente et al. 2014), *Placogorgia massiliensis*, *Spinimuricea atlantica* or *Nicella granifera* (Ocaña et al. 2017).

Regarding species conservation, three gorgonians (*Savalia savaglia*, *Callogorgia verticillata* and *Ellisella paraplexauroides*) have been recently included in Annex II of the Barcelona Convention.

### 10.3.3 Red Coral

The emblematic Mediterranean red coral *Corallium rubrum* belongs to the same group as gorgonians (order Alcyonacea, formerly Gorgonacea), but unlike the gorgonians (suborder Holaxonia), which have a flexible skeleton of a corneous nature, in *C. rubrum* (suborder Scleraxonia), the skeleton is hard calcified. It is a typical Mediterranean species widely distributed throughout the basin and into the neighbouring Atlantic Ocean from Portugal to Moroccan coasts (Boavida et al. 2016), and there are some scattered records in Canary Islands and Cape Verde Islands (Brito and Ocaña 2004).

The red coral is a sciaphilous long-lived species (a colony can live for more than 100 years) with low growth and reproductive rates and a very restricted dispersion ability (Cau et al. 2013). It inhabits a wide depth range from shallow-water caves in the infralittoral zone to depths greater than 1000 m in the bathyal zone (Rossi et al. 2008; Costantini et al. 2010; Taviani et al. 2010; Knittweis et al. 2016) although more commonly at 30–200 m. Although it may form single-species forests on rocky



bottoms or be the predominant species on escarpments and in caves, it has also been found as part of mixed forests associated with large gorgonians as an important component of Mediterranean “coralligenous” assemblages. Furthermore, in the deepest bathymetric levels, it may appear associated with the white coral communities (Freiwald et al. 2009; Taviani et al. 2010). In shallow waters (between about 15 and 70 m), *C. rubrum* colonies (most of them less than 5 cm tall) grow in caves, crevices, overhangs and other protected interstices in crowded patches. In deeper waters, between about 70 and 130 m, coral colonies tend to be larger and more dispersed and typically settle on open surfaces. Below 130 m, colonies tend to be even larger and less dense.

In the Alboran Sea, *Corallium rubrum* is a typical component of the deeper part of the circalittoral rocky bottoms, and it is widespread in seamounts and rocky outcrops, where reaches its maximum densities below 100 m depth. In the Alboran Ridge, the red coral has been found mainly between 60 and 300 m (Templado et al. 2006; Gofas et al. 2014), and in the Seco de los Olivos, it has been found below 100 m (de la Torriente et al. 2014). In this area, shallow populations (15–50 m) of the red coral are only known in the Strait of Gibraltar (López-González 1993; Ocaña et al. 2009), while the presence of this species has not been detected in the Chafarinas Islands.

Because of their high economic value, the precious red coral has been heavily exploited in the Mediterranean Sea since ancient times. Its long history of intensive commercial harvesting has resulted in a well-documented decline of its stocks throughout the Mediterranean Sea, becoming especially apparent during the last decades with clear evidence of overexploitation (Santangelo et al. 2010; Tsounis et al. 2010). Due to this, several Mediterranean countries have developed national legislation to regulate red coral fishing in their territorial waters or adopted the regulations by the General Fisheries Commission for the Mediterranean (GFCM). According to these recommendations, the populations (down to 50 m depth) should be fully protected from exploitation, allowing their extremely slow recovery, and a minimum harvest colony size (7 mm of colony basal diameter) corresponding to an age of 30–35 years (Priori et al. 2013) should be established.

Regarding the Alboran Sea, the discovery in the mid-1980s of rich red coral banks led to their uncontrolled harvesting and to a consequent rapid depletion by fishermen from Sicily. Red coral was decimated by the usage of the so-called “Italian bar”, a device formed by a heavy cross and tangle nets dragged over the bottom (Santangelo et al. 2010). This prompted the Instituto Español de Oceanografía to target cruises around the Alboran Island and Seco de los Olivos for evaluation of the resource and the impact on it. The results of these researches were gathered in a monographic volume of the Boletín Español de Oceanografía (1986) dedicated to different topics on the red coral. In 1984, the Spanish government authorized four fishing boats from Almería to extract coral on the Alboran Ridge using an “Italian bar” modified under the control of researchers from IEO. This type of fishing proved to be equally harmful to the environment and was banned in 1986. Since this date, and for some years, the extraction of coral by divers was allowed down to 100 m. On the other hand, at that time, the French-made submarine Nerée 201 was authorized to

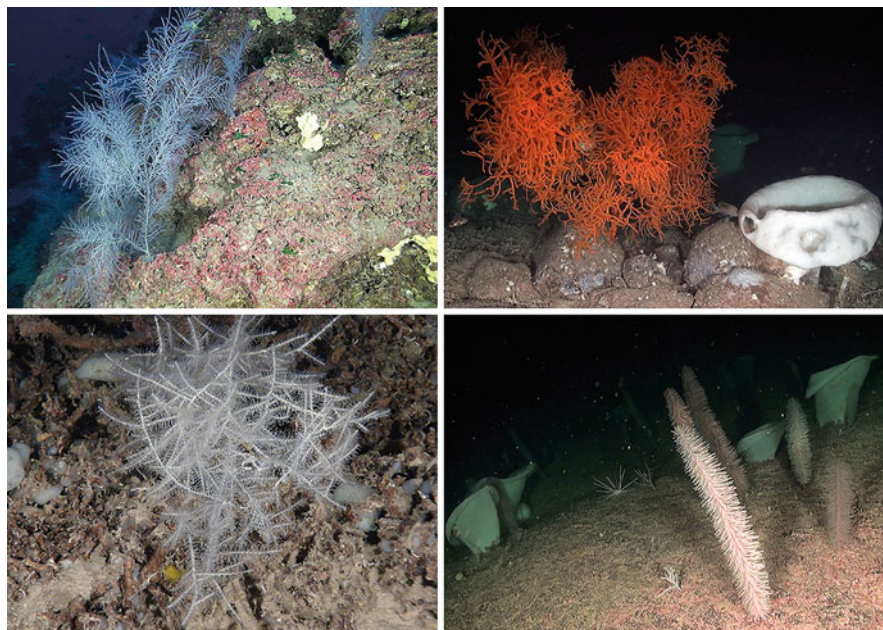
collect coral. Finally, the fishing of red coral was totally forbidden in this area. Exploitation of new areas is believed to occur in the short term off Morocco and Algeria (Cau et al. 2013).

In the Mediterranean, the protection of the red coral is strategic and should be more strictly protected not only by regional and national laws but also by international conventions. Recently, *Corallium rubrum* has been included in the IUCN Red List as an “Endangered” species (Garrabou et al. 2015; Otero et al. 2017), and it is also listed in Appendix III (protected fauna species) of Bern Convention. Nonetheless, it is still only included in Annex III (species whose exploitation is regulated) of Barcelona Convention and in Appendix V (species whose exploitation may be subject to management measures) of the EU Habitats Directive. Proposals for the inclusion of *Corallium rubrum* in the CITES Appendix II (species not necessarily threatened with extinction but that may become so unless trade is closely controlled) were started in 1987. Successive proposals in 2007 and 2010 for including in that Appendix all the *Corallium* species and the whole family Coralliidae were rejected by CITES Parties, after the FAO Expert Advisory Panel concluded that the available evidence did not support such proposals (Tsounis et al. 2010; Cannas et al. 2019). Up to now, all these efforts have resulted in only four species of *Corallium* currently listed under Appendix III (that regulates trade in the included species and needs the cooperation of other countries to prevent unsustainable or illegal exploitation) by China (CITES 2019) and adaptive management plans for red coral fisheries in the Mediterranean (Bruckner 2016). Apparently, Coralliidae in general and *Corallium rubrum* in particular remain excluded from CITES because the currently available data are still insufficient to quantify the decline of populations (Bruckner 2009; Santangelo and Bramanti 2010; Santangelo et al. 2010; Cannas et al. 2019). However, one may also wonder if this is really justified by insufficient knowledge (and the non-application of the precautionary principle in this case) to manage a resource which is just as unnecessary for human well-being as black corals, hawksbill turtle shells or sperm whale ivory, or if it is influenced by the red coral industry lobby.

#### 10.3.4 Black Corals

Antipatharians, commonly known as black corals, have been recognized in the last decade as important components of Mediterranean deep coral gardens (Bo et al. 2009) and are frequently found associated to deep gorgonian assemblages, where quite often they are the dominant species, mainly on the deeper rocky shoals located on the upper continental slope (Bo et al. 2014, 2015). Black corals are extremely long-lived and slow-growing organisms; therefore, the presence of large colonies is an indicative of well-preserved environments (Bo et al. 2015).

Four species are the primary components of the Mediterranean antipatharian fauna: *Antipathes dichotoma*, *Parantipathes larix*, *Leiopathes glaberrima* and *Antipathella subpinnata* (Bo et al. 2018). A fifth species typical of the Macaronesian islands, *Antipathella wollastoni*, has been reported in the Gibraltar Strait (Ocaña



**Fig. 10.11** Four black corals found in the Alboran Sea. From left to right and from top to bottom, *Antipathella subpinnata* (Seco de los Olivos, about 100 m depth), *Leiopathes glaberrima* (Seco de los Olivos, 290 m depth, next to the sponge *Asconema setubalense*), *Phanopathes rigida* (Cabliers Coral Mound, around 400 m depth) and *Parantipathes larix* (Cabliers Coral Mound, 470 m depth, next to *A. setubalense*) [Ricardo Aguilar, Oceana]

et al. 2006b) and is likely to be present in the Alboran Sea. Furthermore, the West Atlantic species *Phanopathes rigida* (Fig. 10.11) has been recently observed in the Cabliers Coral Mound, where it is abundant and dominates in its northern sector mainly in the depth range of 300–440 m (Corbera et al. 2019).

Antipatharians were rarely found shallower than 50 m, while the majority occurs in the depth range between 100 and 300 m, only on rocky slopes and isolated shoals. The large (up to 1.5 m tall), white, branched *Antipathella subpinnata* (Fig. 10.11) is a common component of the lower fringe of the circalittoral (60–150 m) and is the most widespread species with an Atlanto-Mediterranean distribution (Bo et al. 2008). It is able to form dense meadows starting at 60 m, sometimes mixed with *Paramuricea clavata*, and has been occasionally recorded down to 500 m associated with white coral mounds, but records of *A. subpinnata* below 100 m are sporadic. In the Alboran Sea, this species has been observed on steep rocky bottoms (Gofas et al. 2014) and seamount summits (de la Torre et al. 2014). In Chafarinas Islands, *A. subpinnata* has been detected at a very shallow depth (26–32 m) compared with what is usual in all the distribution area of this species (Sánchez-Tocino et al. 2014; Sánchez-Tocino pers. obs.).

The large arborescent *Leiopathes glaberrima* (Fig. 10.11) forms bright orange colonies up to 2 m tall. It is widespread, known from the Pacific and the northeastern Atlantic Oceans (Macaronesian Archipelago and Bay of Biscay) and in the Mediterranean Sea, mainly in its central part (Massi et al. 2018). This species occurs in a broad bathymetric range (known depth range between 70 and 790 m) on rocky shoals, moderately silted, under low to moderate currents. It has proved to be an optimal indicator of the stability of the deep marine environments found at such depths (Deidun et al. 2015), being one of the most long-lived organisms known, reaching an age of up to 4000 years (Roark et al. 2006). In the Alboran Sea has been recorded in the Cabliers (Pardo et al. 2011; Corbera et al. 2019) and Seco de los Olivos Banks (de la Torriente et al. 2018) between 200 and 400 m depth.

*Antipathes dichotoma* is an Atlanto-Mediterranean species characterized by tall arborescent colonies with loose, long, flexible branches and large polyps. This species has a wide bathymetric distribution range and typically occurs on isolated rocky habitats surrounded by detritic or muddy seafloors under moderate currents and high sedimentation rates (Bo et al. 2011). In the Alboran Sea, there are records from the Cabliers and Algarrobo Banks (350–400 m) (Pardo et al. 2011; Corbera et al. 2019) and Seco de los Olivos (70–250 m) (de la Torriente et al. 2018).

*Parantipathes larix* (Fig. 10.11) is a monopodial or sparsely branched black coral up to 2 m tall showing a characteristic bottle-brush pinnulation pattern. This Atlanto-Mediterranean species lives on rocky bottoms both along the continental shelf and in deeper waters, usually between 200 and 700 m in isolate banks, often very sparsely distributed (Angiolillo and Canese 2018). Exceptional forests dominated by dense monospecific populations of *P. larix* were recorded only off the Island of Montecristo (Tuscan Archipelago, Tyrrhenian Sea) (Bo et al. 2014). In the Alboran Sea, it has been recorded in the Cabliers Bank at about 400 m depth (Pardo et al. 2011; Corbera et al. 2019) and in the Seco de los Olivos between 200 and 500 m (de la Torriente et al. 2018).

Unlike what occurs with red and pink corals (Coralliidae), all species of black corals (Antipatharia) are already included in CITES Appendix II (CITES 2019), and five Mediterranean species are listed in Annex II of Barcelona Convention.

### 10.3.5 Sea Pens

The anthozoans of the order Pennatulacea are commonly known as sea pens and are typical representatives of soft bottoms, where they bury part of the colony in the substrate. About a dozen species are known to occur in the Mediterranean Sea. Pennatulaceans, together with the alcyonaceans of the family Isididae (commonly known as bamboo corals), are the main components of forest-like habitats on soft bottoms. These habitats are considered key sites of aggregation for biodiversity and sustain a high abundance of species of commercial interest. The sea pen fields have been listed as vulnerable marine ecosystems worldwide (Otero et al. 2017). Despite their ecological value, pennatulacean habitats have been overlooked compared with

cold-water coral ecosystems (order Scleractinia), or those characterized by sea fans or soft corals (order Alcyonacea) (Ruiz-Pico et al. 2017).

*Veretillum cynomorium* is a very common Atlanto-Mediterranean species found on muddy, sandy and detritic beds in shallow bottoms, but it can extend to greater depths throughout the continental shelf. Another Atlanto-Mediterranean species is *Cavernularia pusilla*, recorded from the Bay of Biscay to Senegal and sparsely distributed throughout the Mediterranean. It inhabits coarse detritic bottoms and “maërl” beds, reaching highest densities between 30 and 60 m depth and decreasing in density below this range (Altuna et al. 2006). López-González (1993) recorded this species in the Strait of Gibraltar between 14 (shallower known record) and 74 m, with abundances of 4–5 ind. m<sup>-2</sup>, and it has been also found in the Alboran Sea in the Sabinar Bank (also named “Avenzoar Bank”) (Pardo et al. 2011) and near the Alboran Island (IUCN 2012).

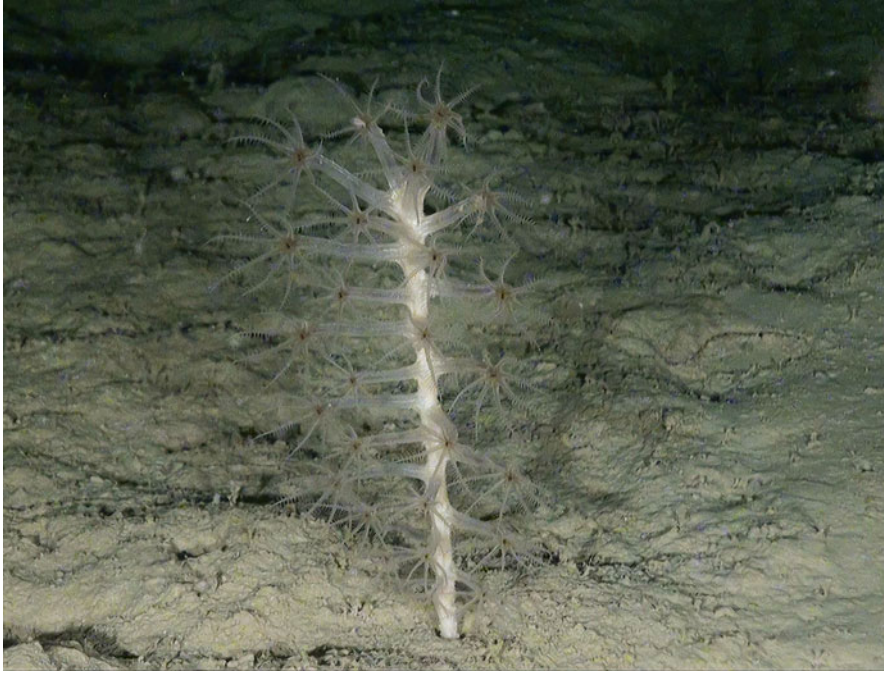
*Virgularia mirabilis* have also a wide bathymetric and geographical distribution. It inhabits muddy-sandy bottoms, from the infralittoral to the bathyal zones, sometimes also mixing with other pennatulaceans or forming monospecific communities (Aguilar et al. 2017).

The sea pens of the genera *Pteroeides* and *Pennatula* are widely distributed and can form mixed communities on the shelf edges and the beginning of the slope. *Pennatula rubra* and *Pteroeides griseum* are more abundant from 30 to 160 m on sandy-muddy bottoms, reaching densities of  $\leq 10$  specimens m<sup>-2</sup> (Porporato et al. 2014), while *Pennatula aculeata* and especially *Pennatula phosphorea* prefer deeper, muddy bottoms. All these species are widely distributed throughout the whole Mediterranean Sea, except *P. aculeata*, a North Atlantic species with only a few records in the western Mediterranean, including the Granada coast in the Alboran Sea (Ocaña et al. 2000).

*Funiculina quadrangularis* has a worldwide range, being common throughout the North Atlantic and the Mediterranean Sea. It inhabits both sandy and muddy bottoms over a wide depth range, although it is more common on compact bathyal muds, where it can reach high densities and may appear in mixed communities with other pennatulaceans, bamboo corals or other soft-bottom species (de la Torre et al. 2014). These assemblages provide an essential habitat for some commercial crustaceans, such as *Parapenaeus longirostris* and *Nephrops norvegicus* (Mastrototaro et al. 2017).

*Kophobelemnon stelliferum* (Fig. 10.12) normally lives on muddy bottoms below 400 metres, where it can occur in large aggregations, and also appears mixed with *Isidella elongata* or, in some cases, with *Funiculina quadrangularis* and *Pennatula phosphorea* (Mastrototaro et al. 2013). It has been found on some seamounts of the Alboran Sea, such as Avempace, Cabliers or Seco de los Olivos Banks (Pardo et al. 2011; de la Torre et al. 2018).





**Fig. 10.12** The sea pen *Kophobelemnion stelliferum* on a muddy bottom of the Cabliers Bank (about 450 m depth) [Ricardo Aguilar, Oceana]

### 10.3.6 Deep Reef-Building Corals

Biogenic reefs are any durable hard structure built by living organisms that rises from the bottom, can increase in volume or thickness through the progressive stratification of successive generations of organisms and generate special habitats. Deep reefs in the Alboran Sea are mainly formed by stony corals or deep-sea oysters.

The so-called white coral or cold-water coral community (CWC) is dominated in the Mediterranean Sea by the azooxanthellate colonial species *Desmophyllum pertusum* (formerly known as *Lophelia pertusa*) and *Madrepora oculata* and the solitary coral *Desmophyllum dianthus*. A recent study (Adamo et al. 2016) shows a surprising genetic identity between *Desmophyllum pertusum* and *D. dianthus* and suggests the potential conspecificity of both species. This consequently leads, in any case, to ascribe both taxa under the generic name *Desmophyllum* (which has priority over *Lophelia* by date of publication). These corals are usually found below the photic zone at upper bathyal depths between 180 and 1000 m, where they can build large three-dimensional structures (Freiwald et al. 2009).

Until recent times, these deep-water corals were mostly recorded in the Mediterranean as Pleistocene fossils, with just a few records of living specimens, and it has been suggested that the postglacial conditions could cause their sharp decline

(Zibrowius 1980; Taviani et al. 2005). However, the advent of the new deep-sea exploration technologies has highlighted the richness of the Mediterranean deep-sea environments (Angiolillo and Canese 2018). As a result, large and highly structured CWC communities characterized by a significant coral growth and colonies density have been found in specific areas, such as the northern Ionian Sea, the Southwestern Adriatic Sea, the Strait of Sicily, the Sardinia Channel, the most westerly part of the Gulf of Lions submarine canyon system and the Alboran Sea (Orejas et al. 2009; Chimienti et al. 2018).

Radiocarbon ages of these reef-forming coral species revealed that they proliferated in the Alboran Sea during the last glacial-interglacial transition and the Early Holocene (ca.13–10 ka BP) with pronounced growth periods (Fink et al. 2013). After a subsequent period of coral absence, cold-water corals recolonized this basin during the Mid-Holocene (about 5.4 ka BP). According to Fink et al. (2013), that period of sustained cold-water coral growth in this area was closely linked to phases of high marine productivity. In more recent times, changes in hydrodynamic conditions have produced a shift from a CWC community dominated by *Desmophyllum pertusum* to other dominated by *Madrepora oculata* and dendrophylliid corals (Stalder et al. 2015). These authors pointed that their data suggest that *M. oculata*, and in particular dendrophylliids, show a higher tolerance to environmental changes than *D. pertusum*, whose upper limit of thermal tolerance is near 15 °C (Gori et al. 2014).

According to Pardo et al. (2011), nowadays white cold-water corals generate three distinct habitats widespread along the Alboran Sea: reefs and colonies of live corals, dead coral reefs and extensive bottoms covered with coral debris (rubbles), allowing the existence and settlement of different species and biocenosis. Dead corals predominate, while small reef patches of living colonies appear scattered in seamounts and escarpments, mainly observed from ca. 200–600 m depth, with the dominance of *Madrepora oculata* on most of the locations. Specifically, up to date, living CWC have been observed in the following sites of the Alboran Sea:

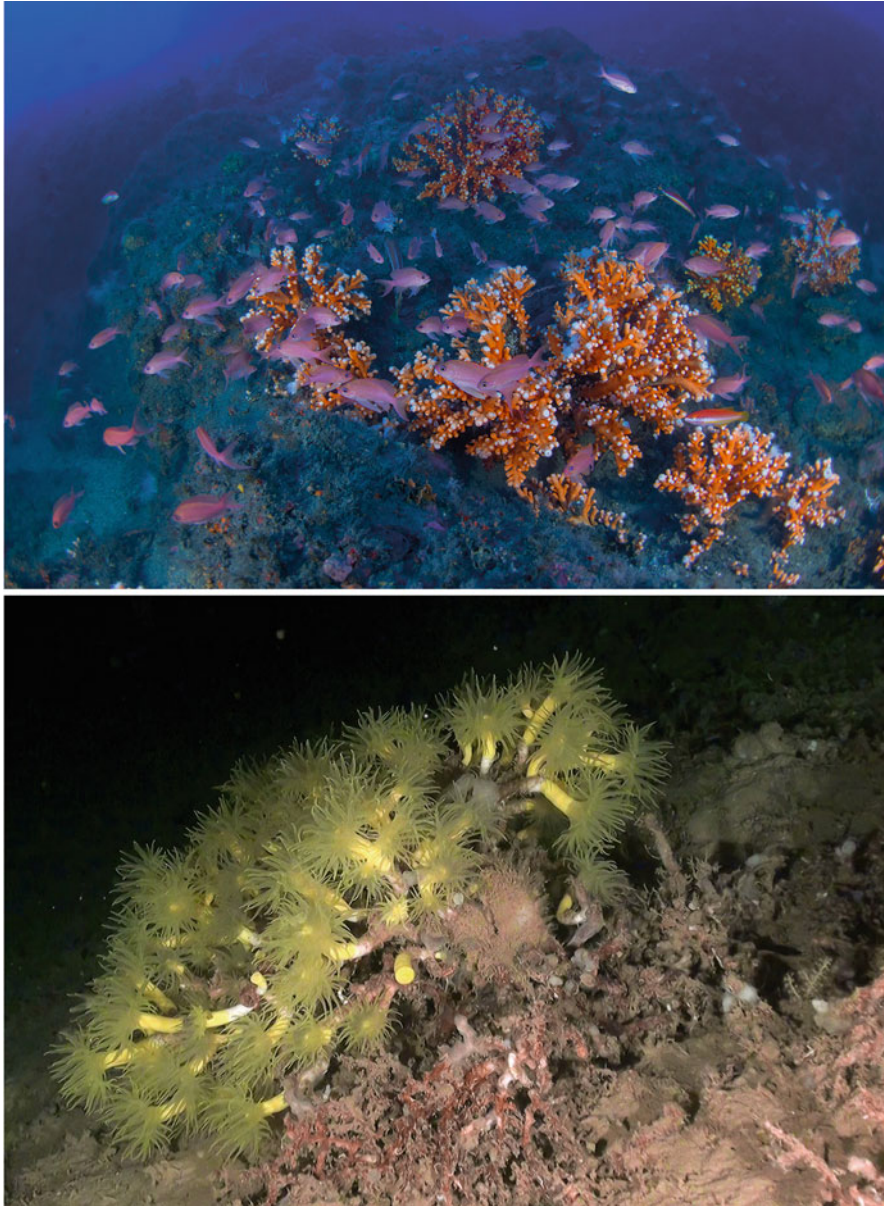
- Avempace Bank: isolated, living colonies of *M. oculata* at 350–360 m depth (Pardo et al. 2011).
- El Idrissi Bank: isolated colonies of *M. oculata* at about 400 m depth (Hebbeln et al. 2009).
- Alboran Ridge: living colonies of *M. oculata* deeper than 400 m (Templado et al. 2006).
- Seco de los Olivos: living colonies of *Desmophyllum pertusum*, *M. oculata* and specimens of *D. dianthus* below 220 m depth (Pardo et al. 2011). The highest densities were found between 300 and 500 m on rocky walls with steep slopes, but they extend down to 650 m (de la Torriente et al. 2018). These cold-water corals appeared intermixed with diverse communities where occur other scleractinians as *Dendrophyllia cornigera*, *Caryophyllia calveri* or the Atlantic species *Anomocora fecunda*.
- Catifas Bank (W Cabliers): living colonies of *M. oculata* and *D. pertusum* at about 360–460 m in depth (Pardo et al. 2011).

- Cabliers Bank: abundant dead reefs with living colonies up to 1 m tall at about 320 m depth (Pardo et al. 2011). These authors highlighted a reef south of the bank that extends over an area of about 10 ha. Likewise Lo Iacono et al. (2014a) and Corbera et al. (2019) pointed out an extremely dense and constant reef with large colonies of *D. pertusum* and *M. oculata* over a considerable extension about 300 m depth in its northern sector.
- Banc de Provençaux: individual living colonies of *M. oculata* and *D. pertusum* growing on the dead coral framework in the southerly ridges of the bank at 310 m depth (Hebbeln et al. 2009).
- West Melilla Mounds Field: frequent *D. pertusum* and *M. oculata*, below 350 m, with the latter species dominating the shallower areas (Lo Iacono et al. 2014a, b).
- Strait of Gibraltar: remarkable quantities of living *Desmophyllum pertusum* and to a lesser extent *Madrepora oculata* associated with large dead coral fragments at the depth range of 150–330 m (Álvarez-Pérez et al. 2005).

Other stony corals that form important marine habitats are the so-called “yellow tree corals” of the genus *Dendrophyllia*, represented in the Mediterranean by two species: *D. cornigera* and *D. ramea* (Fig. 10.13). Both are also present in the northeastern Atlantic and form large branched colonies but differ significantly in morphology, geographical distribution and ecology (Salomidi et al. 2010). *Dendrophyllia cornigera* extends further north than *D. ramea*, and its northern limit is the Celtic Sea, whereas *D. ramea* does not range further north than the Iberian Peninsula. Both species are common along the Atlantic coast of Morocco and occur further south along the African coast. A third smaller species of this genus, *D. laboreli*, is distributed along the Atlantic coasts of northwest Africa, reaching the Strait of Gibraltar (López-González et al. 2010), and isolated colonies have been found at Cabo Negro, on the Moroccan coast of the Alboran Sea (Ocaña et al. 2011).

The tree-like colonies of *D. ramea* reach up to 1 m high and 20 cm in diameter at the trunk base. In the Mediterranean, it was considered to be limited to the southwestern part of the Mediterranean Sea, but recently it has been found in the southern Croatian islands, Adriatic Sea (Kružić et al. 2002), from Greek waters in the southwest Korinthiakos Gulf (Salomidi et al. 2010) and off Cyprus in the Levantine Sea (Orejas et al. 2017). This coral is distributed in circalittoral rocky bottoms and can be observed within scuba diving depths, as shallow as 30–40 m in the Strait of Gibraltar (Ocaña et al. 2009) and in some localities of the Alboran Sea, such as the coast of Granada (Ocaña et al. 2000) or Chafarinas Islands (Maldonado et al. 2011). In the Alboran Ridge, Templado et al. (2006) and Gofas et al. (2014) found this coral deeper, between 90 and 115 m. Likewise, huge populations of *D. ramea* were recently discovered in the northern coast of Sicily between 80 and 120 m depth (Aguilar et al. 2017), around 130 depth off Cyprus (Orejas et al. 2017) and in submarine canyons off Lebanon (Ricardo Aguilar pers. obs.). This coral is common in the Canary Islands, forming banks between 60 and 150 m (Brito and Ocaña 2004).

The tree-like colonies of *Dendrophyllia cornigera* reach up to 60 cm high (normally it does not exceed 30–40 cm) and 10 cm in diameter at the trunk base (Brito and Ocaña 2004). This coral typically occurs deeper than *D. ramea*, at deep



**Fig. 10.13** Colonies of *Dendrophyllia ramea* (above, Punta de la Mona, Granada, 35 m depth) and *Dendrophyllia cornigera* (below, Catifas Bank, 390 m depth) [Luis Sánchez Tocino and Ricardo Aguilar, Oceana, respectively]



circalittoral and bathyal rocky bottoms, mainly in the slope habitats where it may co-occur with *Madrepora oculata* and *Desmophyllum pertusum*. In the Bay of Biscay, *D. cornigera* can be found shallower and locally forms dense monospecific aggregations between 50 and 620 m (Reveillaud et al. 2008; Sánchez et al. 2009). Around the Canary Islands and nearby seamounts, it is the dominant coral between 200 and 600 m depth (Brito and Ocaña 2004; Almón et al. 2014a, b). In the Alboran Sea, *D. cornigera* is widespread on different seamounts mainly in the 150–600 m bathymetric range (Templado et al. 2006; Hebbeln et al. 2009; Pardo et al. 2011), but places with dense populations are rare.

The hydrocorals belonging to the family Stylasteridae are important components of deep coral communities, and they are worldwide distributed from shallow to deep waters. *Errina aspera* is the only stylasterid known from the Mediterranean, and its current occurrence has been confirmed only in the Straits of Messina and Gibraltar and the Atlantic coast of Morocco (Zibrowius and Cairns 1992). The colonies of this species reach up to 20 cm, generally show a bidimensional, fan-shaped morphology (more rarely as bush-like colonies) and growth on rocky bottoms exposed to strong currents (Salvati et al. 2010).

According to Salvati et al. (2010), the abundant population of *E. aspera* in the Messina Strait is located between 110 and 230 m depth. In the Gibraltar Strait, this hydrocoral has been found in a wide bathymetric range (61–443 m), but it is particularly abundant between 150 and 330 m (Álvarez-Pérez et al. 2005). *Errina aspera* has been frequently recorded in association with the giant barnacle *Pachylasma giganteum*, and the gastropod *Pedicularia sicula* is always associated with this hydrocoral (Zibrowius and Cairns 1992).

The scleractinians *Desmophyllum pertusum* and *Madrepora oculata* and the stylasterid *Errina aspera* are currently included in Annex II of the Barcelona Convention. The latter species is also included in Appendix II of Bern Convention.

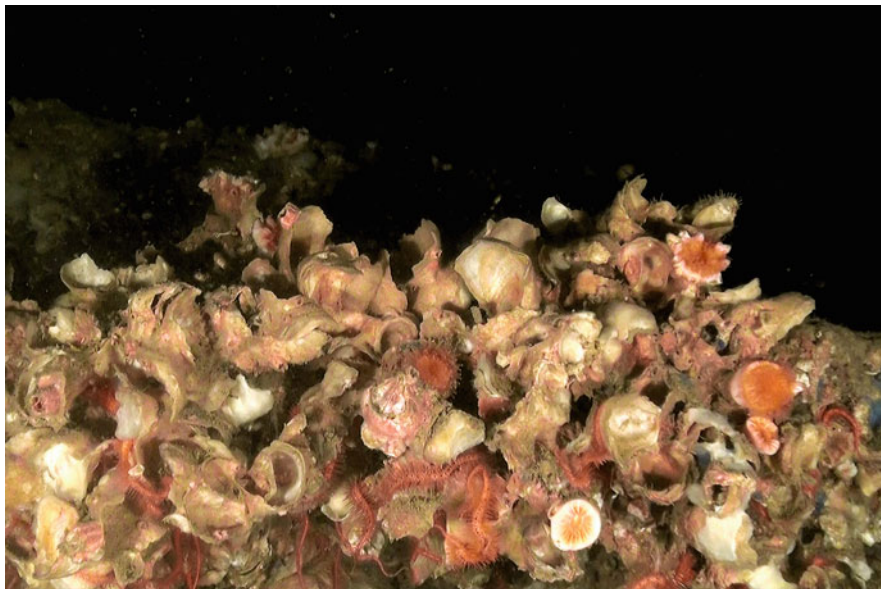
### 10.3.7 Deep-Sea Oysters

Two species of the genus *Neopycnodonte* (family Gryphaeidae), *N. cochlear* (Fig. 10.14) and *N. zibrowii*, form dense aggregations along the European shelf and slope.

*Neopycnodonte cochlear* is distributed worldwide, both in ancient and modern environments (Van Rooij et al. 2010). In the Mediterranean, this oyster characterizes some areas of the continental shelf in rock outcrops and deep bioclastic gravels. Conglomerates of *N. cochlear* are widespread throughout the continental shelf of the Alboran Sea and in the Alboran Ridge between 50–300 m depth (Templado et al. 1993, 2006; Gofas et al. 2011).

The giant deep-sea oyster *Neopycnodonte zibrowii* was recently described from deep water in the Azores and Bay of Biscay between 420 and 450 m depth (Wisshak et al. 2009), but its geographical range extends from the Celtic Sea to Anna Ridge off Angola (Beuck et al. 2016). This oyster was found thriving concealed under





**Fig. 10.14** Conglomerates of *Neopyncnodonte cochlear* are widespread throughout the continental shelf of the Alboran Sea (off Punta de Calaburras, Malaga, 130 m depth) [Ricardo Aguilar, Oceana]

overhangs in high densities. Van Rooij et al. (2010) observed living *N. zibrowii* in the Bay of Biscay in depths from 540 to 846 m, colonizing overhanging banks or escarpments protruding from steep canyon flanks. Further, Johnson et al. (2013) described a biotope of vertical surfaces and overhangs at depths between 633 and 762 m covered by the bivalves *Acesta excavata* and *N. zibrowii* in one of the major submarine canyons along the Celtic margin. Likewise, Gofas et al. (2010) reported the occurrence of living *Neopyncnodonte zibrowii* between 680 and 730 m, on the slope of the Hespérides Mud Volcano Complex located in the central part of the Gulf of Cadiz.

This “living fossil” oyster has an extensive lifespan that may exceed 500 years (placing it among the longest-lived molluscs known to date) and grows to more than fourfold the size of large *N. cochlear*, up to 30 cm (Wisshak et al. 2009; Beuck et al. 2016). Its occurrence, either living or subfossil, has been noted in scattered locations in the eastern Atlantic (living) and the Mediterranean (mainly as subfossil) (Taviani et al. 2007; Gofas et al. 2010). By that time, Hebbeln et al. (2009) also reported the presence of living specimens of *N. zibrowii* in steep cliffs of El Idrissi Bank, southeast of the Djibouti complex (Alboran Sea) at 490 m among abundant fossil oysters. Further, de la Torre et al. (2014, 2018) found dense clusters of this species at the base of rocky walls down to 462 m depth in the Seco de los Olivos. Zibrowius (pers. comm.) observed dense aggregates on the south wall of Alboran platform, on video footages by submersible “Cyana” taken in 1993 and never released.

## 10.4 The Invertebrates of the Water Column

### 10.4.1 Planktonic Invertebrates

The peculiar and contrasting hydrological characteristics of the Alboran Sea are reflected in the structure and dynamics of plankton communities, which have been the object of many researches and publications. Several articles concern the specific composition and population assemblages of zooplankton in the Alboran Sea (e.g. Vives et al. 1975; Rodríguez 1983; Greze et al. 1985; Champalbert 1996; Youssara and Gaudy 2001; Andersen et al. 2004; Siokou-Frangou et al. 2010). In fact, nearly 30 years ago, a literature review and field guide of zooplankton of this area was already published by the Woods Hole Oceanographic Institution (Madin 1991).

While microzooplankton is mainly composed by protists (flagellates, dinoflagellates, ciliates, radiolarians, foraminiferans, among others), the invertebrates are the main component of mesozooplankton (size range of 0.2–2 mm) and macroplankton (organisms visible to the naked eye). Epipelagic mesozooplankton is highly diversified in terms of taxonomic composition. In addition to the strictly planktonic groups (holozooplankton), the pelagic larval phases of many invertebrates which are benthic in their adult phase are also incorporated to the plankton (merozooplankton). As elsewhere, copepods represent the largest group in the Alboran Sea both in terms of abundance and biomass (about 60% of the biomass), followed by cladocerans (near 20%) and larvae of various groups (about 12%, mainly crustaceans and molluscs).

More than 250 species of copepods have been recorded in the Alboran Sea. A few small-sized and species-rich genera of calanoids (*Clausocalanus*, *Calocalanus*, *Pleuromamma* and *Temora*, together with *Ctenocalanus vanus*) and cyclopoids (*Oithona*, *Oncaea*) account for the bulk of copepod abundance and biomass in epipelagic layers (Seguin et al. 1994; Youssara and Gaudy 2001; Siokou-Frangou et al. 2010). According to Rodríguez (1983), the most abundant copepods reported in spring in the upper layer were *Paracalanus parvus*, *Clausocalanus arcuicornis*, *Centropages chierchiae*, *Acartia clausi*, *Temora stylifera*, *Oithona similis*, *O. nana* and *Oncaea* spp. Some species seem particularly linked to Atlantic waters, such as *Pleuromamma borealis*, *Subeucalanus crassus*, *Eucalanus elongatus* or *Triconia dentipes* (Youssara and Gaudy 2001). Otherwise, two copepod species were described from the Alboran Sea by Shmeleva (1979): *Oncaea alboranica* and *Calocalanus alboranus*.

In the neuston layer, pontellids often constitute the major diurnal biomass. Among the most abundant species, *Anomalocera patersoni*, *Pontella lobiancoi*, *P. atlantica* and *Pontellopsis regalis* have an Atlantic origin and are abundant in oceanic waters, whereas *Pontella mediterranea* and *Labidocera wollastoni* are rather neritic species (Champalbert 1996).

Across the Almería-Oran Front area, three species of *Pleuromamma* were found in large numbers: *P. borealis*, the most abundant, followed by *P. abdominalis* and to

a lower extent by *P. gracilis* (Andersen et al. 2004). Other abundant copepods recorded by these authors around this front are *Subeucalanus monachus*, *Eucalanus hyalinus*, *Clausocalanus furcatus* and *Centropages typicus*.

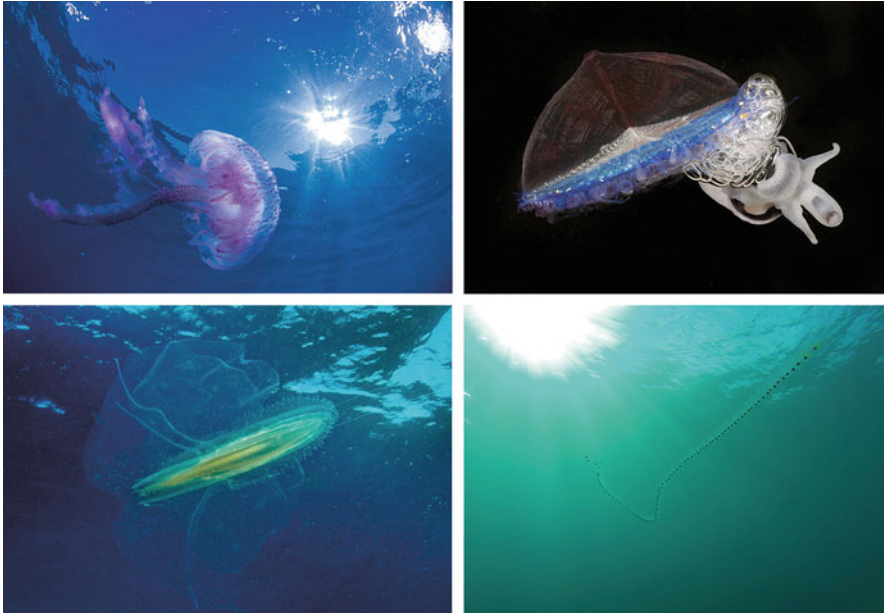
Cladocerans, which exhibit a seasonal and/or aggregative distribution, are represented by few species, but they can be very abundant in coastal waters, such as *Penilia avirostris*, *Pseudevadne tergestina*, *Evadne spinifera* and *E. nordmanni* (Rodríguez 1983). On the other hand, ostracods, which are not numerous in the mesozooplankton communities at temperate latitudes, are more abundant in deep waters than in the epipelagic zone (Siokou-Frangou et al. 2010).

The macroplankton of the Alboran Sea consists essentially of euphausiids, chaetognaths and gelatinous zooplankton. According to Madin (1991), the dominant euphausiid species occurring were *Euphausia krohnii*, *Nematoscelis megalops*, *Stylocheiron abbreviatum* and *S. suhmi*, with maximum abundances in summer.

Chaetognaths are active predators and an important component of zooplankton. They are well represented in the Alboran Sea by more than a dozen species (Camiñas 1985) that become very abundant in areas of higher biomass, such as in the vicinity of the Almería-Oran Front. According to this author, the most abundant chaetognaths in the area are *Parasagitta friderici*, *Serratosagitta tasmanica*, *Pterosagitta draco*, *Flacisagitta enflata* and *Decipisagitta decipiens*.

Three main phyla, the carnivorous Cnidaria and Ctenophora and the filter-feeding Tunicata, dominate the gelatinous macroplankton (Fig. 10.15). These holoplanktonic organisms exhibit important seasonal and interannual variations, both in biomass and specific composition. As evidence of the species richness of gelatinous plankton in the Alboran Sea, 58 species of planktonic Cnidaria and Ctenophora were observed during a cruise in April 1991 off the North Moroccan coast: 12 hydromedusae, 18 siphonophores, 6 scyphomedusae and 22 ctenophores (Mills et al. 1996). The most abundant species in surface waters were *Pandea conica* and *Solmaris leucostyla* (hydromedusae); *Nanomia bijuga*, *Lensia conoidea* and *Abylopsis tetragona* (siphonophores); and *Haeckelia beehleri*, *Pleurobrachia rhodopsis*, *Bolinopsis vitrea*, *Ocyropsis maculata* and *Beroe ovata* (ctenophores). The mesopelagic *Solmissus albescens* (Narcomedusae) was the most numerous jellyfish in a wide bathymetric range capable of migrating to the surface at night. A few species, such as the coronate scyphozoans *Periphylla periphylla* and *Paraphyllina ransoni* and the siphonophore *Rhizophysa filiformis*, seemed to occur mainly near the bottom (Mills et al. 1996). These authors have also noted a very rich mesopelagic ctenophore fauna. Among them, *Bathocyroe fosteri* and *Thalassocalyce inconstans*, originally known from the Atlantic, have been reported in this westernmost area of the Mediterranean (Madin 1991).

The ubiquitous and troublesome scyphozoan *Pelagia noctiluca* (Fig. 10.15), which appears to be blooming with increased frequency (Brotz and Pauly 2012), deserves special mention. This holoplanktonic jellyfish inhabits oceanic as well as coastal areas, being responsible for the majority of the stings suffered by bathers (Canepa et al. 2014). Blooms of this medusa have been persistent in recent years in the Andalusian coast, resulting in a large number of stings and in the temporary closure of many beaches.



**Fig. 10.15** Some common representatives of gelatinous macroplankton in the Alboran Sea. From left to right and from top to bottom, the scyphozoan *Pelagia noctiluca* (Punta de la Mona, Granada, 3 m depth), the siphonophoran *Velevella velevella* with the gastropod *Janthina pallida* attached (Playazo de Rodalquilar, Almería, 0 m depth), the ctenophoran *Leucothea multicornis* (Villaricos, Almería, 2 m depth) and a salp chain probably of *Thalia democratica* (Carboneras Island, Almería, 3 m depth) [Luis Sánchez Tocino, upper left, and Diego Moreno]

Pelagic filter-feeding tunicates are also an important component of gelatinous plankton and comprise four groups: appendicularians (class Appendicularia) and salps, pyrosomes and doliolids (class Thaliacea), all represented in the Alboran Sea. They often form large swarms after the upwelling of cool, nutrient-rich water promoting blooms of phytoplankton. The appendicularians are the predominant pelagic tunicates, mainly the genera *Oikopleura* during summer and *Fritillaria* during winter (Champalbert 1996). In turn, the species of salps, pyrosomes and doliolids that occur sporadically in swarms are mostly *Thalia democratica*, *Pyrosoma atlanticum* and *Doliolum nationalis*.

#### 10.4.2 Nektonic Invertebrates

Most nektonic animals are vertebrates, mainly fish, whereas invertebrates are only represented by cephalopods (squids) and some crustaceans (larger euphausiids, shrimps, prawns and swimming crabs), many of them being commercially important marine species.

The cephalopods are the largest nektonic invertebrates. Some common species in the Alboran Sea are *Loligo vulgaris*, *L. forbesii*, *Alloteuthis media*, *Abralia veranyi*, *Illex coindetii*, *Todarodes sagittatus*, *Ommastrephes bartramii*, *Sthenoteuthis pteropus*, *Brachioteuthis riisei* and *Ancistroteuthis lichtensteinii* (Guerra 1992; Templado et al. 1993; González and Sánchez 2002; Quetglas et al. 2013). They are important predators and are also agents for the transfer of nutrients from the pelagic community to higher trophic levels.

Among the decapod crustaceans, a good number of caridean (suborder Dendrobranchiata) and penaeoidean species (suborder Pleocyemata) form a characteristic trophic guild of macroplankton-epibenthic feeders that mainly dwell near the bottom (nektobenthic species) but have sharp diel vertical migrations into upper water layers during the night (Judkins 2014). These migrations behaviour have an important role in the transfer of matter and energy from the upper primary productive layers of the sea, where these species come up to feed during the night, down to the epibenthic community of the continental slope, where they dwell during the day (Simão et al. 2015).

The Alboran Sea is characterized by the dominance of caridean pandalid shrimps, which reach in this area the highest values of abundance and show a trend to have a shallower distribution compared with other areas (Carbonell and Abelló 1998; Fanelli and Cartes 2004). The most common Alboran pandalids are *Chlorotocus crassicornis*, *Plesionika acanthonotus*, *P. heterocarpus* and *P. martia*. Two very common shrimps of the suborder Pleocyemata are the pasiphaeids *Pasiphaea sivado* and *P. multidentata* (Simão et al. 2015). Both species also show a shallower bathymetric range in the westernmost region of the Algerian shore than in other sectors, linked to the occurrence of upwelling areas on the northwestern edges of the Alboran Sea.

The other important group of benthopelagic shrimps is that formed by species of Sergestoidea and Penaeoidea, also well represented in the Alboran Sea. The most common are the penaeoideans *Gennadas elegans* and *Funchalia villosa* and the sergestoideans *Robustosergia robusta*, *Sergia japonica*, *Allosergestes sargassi*, *Parasergestes vigilax* and *Eusergestes arcticus* (García Raso 1982; García Raso et al. 2018).

Among the swimming crabs, the portunid *Polybius henslowii* deserves special mention by its uncommon behaviour. It is a benthopelagic species distributed along the eastern Atlantic coasts from the British Islands to the Alboran Sea and southern Morocco. Usually of benthic habits, this crab moves periodically to surface waters, forming large pelagic swarms mainly composed of females, which excludes a reproductive migration and might be related to feeding. During this pelagic period, this species feeds on fish, squids or other crustaceans (Signa et al. 2008). Some of these surface swarms have been observed off the Moroccan coast near the Strait of Gibraltar from May to August (Ocaña et al. 2006a). These authors pointed out that the large concentrations of *P. henslowii* are the main source for the diet of the loggerhead turtles in this area and for a number of other species including gulls and pelagic and benthopelagic fishes.



## 10.5 Threatened Species

The protocol concerning Specially Protected Areas (SPA) and Biological Diversity in the Mediterranean (Barcelona Convention) established lists of endangered or threatened marine species (Annex II) and of species whose exploitation is regulated (Annex III) (Templado et al. 2004). Many of them were previously included in the Annexes of the Bern Convention. In addition, only a handful of marine invertebrates appear in other international conventions (Habitat Directive 92/43/CEE; CITES) (Ramos et al. 2001) or international Red Lists (IUCN) (Otero et al. 2017). The majority of the marine invertebrates included in these conventions and lists of the Mediterranean Sea are present in the Alboran Sea (66 species, see Table 10.1).

The SPA and Biodiversity Protocol was signed in 1995 by most of the Mediterranean countries and entered into force in 1999 in Spain and in 2009 in Morocco. The last Amendments to Annexes II and III entered into force in both countries in 2015. The initial list of Annex II was mainly composed of molluscs, with some sponges and a few cnidarians, crustaceans and echinoderms. That is why the modification of Annexes was proposed in 2013 during the SPA Focal Points meeting in order to improve the representativeness of deep-sea corals (Aguilar and Marín 2013). As a result, the last amendment of 2015 incorporated 11 cnidarians, among which there are several species of black corals; the gorgonians *Ellisella pareplexauroides*, *Callogorgia verticillata* and *Eunicella verrucosa*; and the scleractinians *Cladocora caespitosa*, *C. debilis*, *Madrepora oculata* and *Desmophyllum pertusum*. At the same time, the IUCN promoted a regional workshop on Mediterranean anthozoans Red List (September–October 2014), as a result of which new species of cnidarians were included in the IUCN Red List (Otero et al. 2017). Among the species not included in previous agreements stands out the bamboo coral *Isidella elongata*, listed as “critically endangered”. Further, the scleractinian corals *Desmophyllum dianthus* and *Dendrophyllia cornigera* were listed as “endangered”, and the gorgonian *Paramuricea clavata*, the coral *Dendrophyllia ramea* and the sea pens *Funiculina quadrangularis*, *Pennatula rubra*, *P. phosphorea* and *Pteroeides griseum* as “vulnerable”. Consequently, the cnidarians is the group with the highest number of protected or regulated species in the Alboran Sea, with 24 species (23 anthozoans and 1 hydrozoan), followed by molluscs with 20 species (14 gastropods and 6 bivalves), sponges (9 species), crustaceans (8 species) and echinoderms (5 species) (see Table 10.1).

Few of the threatened species live in the intertidal fringe, such as the gastropods *Patella ferruginea*, a critically endangered limpet with its best populations in the Alboran Sea, and the vermetid *Dendropoma lebeche*, which builds singular reefs in association with calcareous algae. Most of the protected species are subtidal and can live in different habitats and substrates, such as rocks or caves (as the coral *Astroides calycularis*) or seagrass meadows (*Pinna nobilis*). For these four species, included in the Spanish Catalogue of Endangered Species, the Alboran Sea constitutes the western limit of distribution since they do not extend to the Atlantic Ocean or are only found in areas close to the Strait of Gibraltar. *Pinna nobilis* has been declared as

**Table 10.1** Marine invertebrates present in the Alboran Sea and included in International Conventions and Lists of endangered species or whose exploitation is regulated (nomenclature according to WoRMS 2019). The name of the taxonomic group and the number of species by group of each Convention or List are shown. Bern Convention (1986) included the Annexes II (strictly protected fauna species; status in force since 2018) and III (protected fauna species; status in force since 2002). Barcelona Convention (1995) included the last amendments of 2015 of Annexes II (endangered or threatened species) and III (species whose exploitation is regulated). The Habitat Directive (92/43/CEE) included the Annexes IV (species in need of strict protection) and V (species whose catch from the wild can be restricted by European law). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) included all the species of scleractinians or hard corals (cnidarians), but here only those that are present in other Conventions and Lists are cited. The IUCN Red List includes the categories CR (Critically Endangered), EN (Endangered), VU (Vulnerable), NT (Near Threatened), LC (Least Concern), DD (Data Deficient) and LR/nt (Lower Risk/near threatened). In Spain the current Catalogue of Endangered Species and the List of Wild Species with Special Protection was published in 2011, with successive modifications in 2012, 2015, 2016, 2019 and 2020, and the equivalent of Andalusia in 2012. The categories in the Catalogue are EN (in danger of extinction) and VU (vulnerable). In 2018, the Spanish government declared critically endangered (CR) the bivalve *Pinna nobilis*, inside the EN category. This species has been subsequently included in 2019 as critically endangered in the IUCN Red List. Other abbreviations: Med, Mediterranean populations

Group/species	Bern Convention 1986 Annex	Barcelona Convention 1999 Annex	Habitat Directive 1992 Annex	CITES Annex	IUCN Red List	Spanish catalogue and list 2011+added (category or population)	Andalusian catalogue and list 2012 (category or population)	Observations
<b>PORIFERA</b>	<b>5</b>	<b>10</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>6</b>	<b>3</b>	
<i>Aplysina</i> spp.	II	II				Med		Only <i>Aplysina cavernicola</i> included in Bern Convention
<i>Axinella polypoides</i>	II	II				Med	Yes	
<i>Spongia agaricina</i>		III						
<i>Tethya</i> spp.		II				Med		There are still no species of the genus included in Bern Convention
<i>Geodia cydonium</i>		II				Med	Yes	
<i>Sarcotragus foetidus</i>		II				Med		<i>Ircinia foetida</i> is a synonym
<i>Sarcotragus pipetta</i>		II				Med	Yes	<i>Ircinia pipetta</i> is a synonym
<i>Hippospongia communis</i>	III	III						
<i>Spongia lamella</i>	III	III						<i>Spongia agaricina</i> is a synonym

(continued)

Table 10.1 (continued)

Group/species	Bern Convention 1986 Annex	Barcelona Convention 1999 Annex	Habitat Directive 1992 Annex	CITES Annex	IUCN Red List	Spanish catalogue and list 2011+added (category or population)	Andalusian catalogue and list 2012 (category or population)	Observations
<i>Spongia officinalis</i>	III	III						
<b>CNIDARIA</b>	<b>3</b>	<b>13</b>	<b>1</b>	<b>5</b>	<b>23</b>	<b>11</b>	<b>2</b>	
<b>Anthozoa</b>								
<i>Antipathella subpinnata</i>		II			NT	Med		Recently (2019) included in the Spanish List
<i>Antipathes dichotoma</i>		II			NT	Med		Recently (2019) included in the Spanish List
<i>Leiopathes glaberrima</i>		II			EN	Med		Recently (2019) included in the Spanish List
<i>Parantipathes larix</i>		II			NT	Med		Recently (2019) included in the Spanish List
<i>Callogorgia verticillata</i>		II			NT	Med		Recently (2019) included in the Spanish List
<i>Eunicella verrucosa</i>					VU			
<i>Paramuricea clavata</i>					VU			
<i>Ellisella paraplexauroides</i>		II			VU	Med		Recently (2019) included in the Spanish List
<i>Isidella elongata</i>					CR			
<i>Corallium rubrum</i>	III	III	V		EN			
<i>Funiculina quadrangularis</i>					VU			
<i>Pennatula phosphorea</i>					VU			
<i>Pennatula rubra</i>					VU			
<i>Pteroeides griseum</i>					VU			<i>Pteroeides spinosum</i> is a synonym

	II	II	II	II	II	II	II	II	II	NT	Med	Yes	Recently (2019) included in the Spanish List
<i>Savalia savaglia</i>										EN	All areas		
<i>Cladocora caespitosa</i>										EN			
<i>Cladocora debilis</i>										DD			
<i>Desmophyllum dianthus</i>										EN			
<i>Desmophyllum pertusum</i>										EN	Med		Recently (2019) included (as <i>Lophelia pertusa</i> ) in the Spanish List
<i>Madrepora oculata</i>										EN	Med		Recently (2019) included in the Spanish List
<i>Dendrophyllia cornigera</i>										EN			
<i>Dendrophyllia ramea</i>										VU			
<i>Astroides calycularis</i>	II	II	II	II	II	II	II	II	II	LC	VU	VU	
<b>CNIDARIA</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>1</b>	
<b>Hydrozoa</b>													
<i>Errina aspera</i>	II	II	II	II	II	II	II	II	II		Med	Yes	
<b>MOLLUSCA</b>	<b>12</b>	<b>12</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>3</b>	<b>13</b>	<b>13</b>	
<b>Gastropoda</b>													
<i>Patella ferruginea</i>	II	II	IV	IV	IV	IV	IV	IV	IV	EN	EN	EN	
<i>Cymbula saftiana</i>	II	II								Med	Med	Yes	Included as <i>Patella nigra</i> in Bern and Barcelona Conventions
<i>Dendropoma lebeche</i>	II	II								VU	VU	VU	Included as <i>Dendropoma petraeum</i> in Bern and Barcelona Conventions
<i>Naria spurca</i>	II	II								Med	Med	Yes	Included as <i>Erosaria spurca</i> in Barcelona Convention

(continued)

Table 10.1 (continued)

Group/species	Bern Convention 1986 Annex	Barcelona Convention 1999 Annex	Habitat Directive 1992 Annex	CITES Annex	IUCN Red List	Spanish catalogue and list 2011+added (category or population)	Andalusian catalogue and list 2012 (category or population)	Observations
<i>Lurida lurida</i>	II	II				Med	Yes	
<i>Schilderia achatidea</i>	II	II				Med	Yes	
<i>Zonaria pyrum</i>	II	II				Med	Yes	
<i>Tonna galea</i>	II	II				Med	Yes	
<i>Ranella olearia</i>	II	II			LR/nt	Med	Yes	
<i>Monoplex parthenopeus</i>					LR/nt			Included as <i>Ranella parthenopeum</i> in IUCN Red List
<i>Charonia lampas</i>	II	II				VU	VU	
<i>Charonia variegata</i>	II	II				Med	Yes	Included as <i>Charonia tritonis variegata</i> in Barcelona Convention
<i>Babelomurex cariniferus</i>								Included as <i>Lattaxis babelis</i> in IUCN Red List
<i>Tritia tingitana</i>						VU	VU	Recently (2020) included in the Catalogues from the Red Book (2008, as <i>Nassarius tingitanus</i> )
<i>Mitra zonata</i>	II	II				Med	Yes	
<b>MOLLUSCA</b>	<b>4</b>	<b>4</b>	<b>2</b>	<b>0</b>	<b>1</b>	<b>4</b>	<b>6</b>	
<b>Bivalvia</b>			IV			Med	Yes	
<i>Lithophaga lithophaga</i>	II	II					Yes	Included in the Andalusian List from the Red Book (2008)
<i>Modiolus lulat</i>								Critically endangered (Spanish Catalogue) since 2018 and IUCN Red List since 2019
<i>Pinna nobilis</i>	II	II	IV		CR	CR	VU	



<i>Pinna rudis</i>	II	II							Med	Yes	Included as <i>Pinna pernula</i> in Bern Convention
<i>Pholas dactylus</i>	II	II							Med	Yes	
<i>Barnea candida</i>										Yes	Included in the List of Andalusia from the Red Book (2008)
<b>ARTHROPODA</b>	<b>6</b>	<b>6</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	
<b>Crustacea</b>											
<i>Pachylasma giganteum</i>		II							Med	Yes	
<i>Palinurus elephas</i>	III	III									
<i>Sylliarides latus</i>	III	III	V								
<i>Sylliarides pygmaeus</i>	III	III									
<i>Sylliarus arctus</i>	III	III									
<i>Homarus gammarus</i>	III	III									
<i>Maja squinado</i>	III	III									
<b>ECHINODERMATA</b>	<b>3</b>	<b>3</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>4</b>	<b>3</b>	<b>4</b>	
<i>Ophidiaster ophidianus</i>	II	II							Med	Yes	
<i>Hacelia attenuata</i>										Yes	Included in the List of Andalusia from the Red Book (2008)
<i>Asterina pancerii</i>	II	II							Med	Yes	The species living in Andalusia is <i>A. phylactica</i> (López-Márquez et al., 2018)
<i>Centrostephanus longispinus</i>	II	II	IV						Med	Yes	
<i>Paracentrotus lividus</i>		III									
<b>Total taxa:</b>	<b>34</b>	<b>49</b>	<b>6</b>	<b>5</b>	<b>27</b>	<b>39</b>	<b>30</b>	<b>30</b>			



**Fig. 10.16** A female of the threatened gastropod *Zonaria pyrum* on its egg cluster. This is the rarest of the four Mediterranean cowries, all of them included in annex II of Bern and Barcelona Conventions (Calahonda, Granada, 14 m depth) [Antonio Rodríguez-Medel]

critically endangered (CR) in 2018 by the Spanish government and then included in 2019 in the same category in the IUCN Red List, after the massive mortality event of recent years (see Sect. 10.7). Recently, some deep-water species have been included in the Annex II of the Barcelona Convention, such as the corals *Madrepora oculata*, *Desmophyllum pertusum* and *Callogorgia verticillata*, or in the IUCN Red List, such as *Desmophyllum dianthus* and *Dendrophyllia cornigera*.

Some species present in the Alboran Sea are of West African origin and present their only European populations in this area. Examples are the limpet *Cymbula safiana* and the bivalve *Modiolus lulat*, the latter species included in the Andalusian Red List of endangered species. Other Mediterranean protected molluscs, such as the four species of cowries (Fig. 10.16), have a wider distribution that includes the West African coast but become increasingly rare in the Mediterranean.

The set of protected species is in any case scarce relative to the invertebrate diversity and richness of the Alboran Sea. For example, some endemic species or with restricted distribution are still not protected, such as some molluscs living in the Strait of Gibraltar (Gofas 1998; Gofas et al. 2011), except for the recently protected (2020) gastropod *Tritia tingitana*, as well as other invertebrates that are suffering an alarming decline in their populations. Among the additional species that should be protected in the Alboran Sea, we consider at least the following taxa: the sponges



**Fig. 10.17** Four of the species here proposed to be protected. From left to right and from top to bottom, the sponge *Petrosia ficiformis* with two specimens of the nudibranch gastropod *Peltodoris atromaculata* (Cerro Gordo, Malaga, 8 m depth), the anthozoan *Phyllangia americana mouchezii* (Calahonda, Granada, 16 m depth), the bivalve *Donacilla cornea* (Torregarcía, Almería, 0 m depth) and a couple of the decapod crustacean *Stenopus spinosus* in a crevice together with a conger (*Conger conger*) and the holothurian *Holothuria arguinensis* (Calahonda, Granada, 21 m depth) [Luis Sánchez Tocino, upper left; Antonio Rodríguez-Medel, upper and bottom right; Diego Moreno, bottom left]

*Calyx nicaeensis* and *Petrosia ficiformis* (that has suffered some events of mortality, Garrabou et al. 2009; Fig. 10.17); the gorgonians *Eunicella gazella* and *E. labiata*; the scleractinians *Phyllangia americana mouchezii* (Fig. 10.17), *Pourtalosmilia anthophyllites* and *Dendrophyllia laboreli*; the gastropods *Monoplex corrugatus*, *Bursa scrobilator* and *Tarantinaea lignaria*; the bivalves *Spondylus gaederopus* (that has suffered some events of mortality, see Sect. 10.7 and Fig. 10.19), *Donacilla cornea* (Fig. 10.17) and *Ungulina rubra*; the crustaceans *Pollicipes pollicipes* and *Stenopus spinosus* (Fig. 10.17); and the echinoderms *Asterina gibbosa* and *Astrospartus mediterraneus*. In addition, some invertebrates of groups that have not traditionally been included in threatened species lists should be protected, such as the sipunculans *Sipunculus nudus*, the polychaete *Sabellaria alveolata*, the bryozoans *Pentapora fascialis* and *Reteporella* spp., and the tunicate *Halocynthia papillosa*. Most of them were included and evaluated in the *Red Book of Invertebrates of Andalusia* (Barea-Azcón et al. 2008). Protective measures should also be considered for large holothurians of the genus *Holothuria* and for *Parastichopus regalis*, which are now heavily harvested in the Mediterranean for the export to Asia (González-Wangüemert et al. 2018).

On the other hand, some of the species traditionally considered of interest for fisheries and included in Annex III (species whose exploitation is regulated) of the Barcelona Convention should be moved to Annex II and be considered as threatened. This should apply especially for large exploited crustaceans that are increasingly scarce in the Alboran Sea, such as *Palinurus elephas* and *Homarus gammarus*, or those that have practically disappeared from this Mediterranean area, such as *Scyllarides latus* and *Scyllarus arctus*.

## 10.6 Species Originally Described from the Alboran Sea

The overview on the Mediterranean Sea biodiversity compiled by Coll et al. (2010) pointed out that the Alboran Sea displays the highest values of species richness of the basin. This was also suggested by Templado et al. (2006), García Raso et al. (2010) or Aguilar et al. (2011a) and makes this area a biodiversity hotspot, within the wider hotspot that the Mediterranean Sea represents globally. The Alboran Sea represents a transition zone between the Atlantic Ocean and the Mediterranean Sea where co-exist warm-water (from Atlantic North Africa), cold- and temperate-water (from the northeast Atlantic) and Mediterranean species, plus some endemic species restricted to this zone. Only the insular shelf of Alborán Island hosts more than a quarter (26.87%, 1636 species) of the total Mediterranean species richness of 11 benthic groups (Gofas et al. 2014). As another example, the megadiverse Mollusca, a good proxy indicator for total marine species richness, comprises in Spanish waters of the Alboran Sea and Gibraltar Strait 1245 species, about 52.5% of the total diversity of this phylum in the entire Spanish waters, including the Canary Islands (Gofas et al. 2017).

All said above is reflected in the sustained description of new species from the Alboran Sea during the past four decades. According to the non-exhaustive review listed in Table 10.2, no less than 154 new species have been described since 1980 in the Alboran Sea and the Strait of Gibraltar (18 Porifera, 6 Cnidaria, 5 Platyhelminthes, 1 Kinorhyncha, 2 Entoprocta, 8 Polychaeta, 1 Nemertea, 1 Tardigrada, 25 Crustacea, 1 Pycnogonida, 75 Mollusca, and 11 Bryozoa) (Fig. 10.18). The highest number of new species were described from the Strait of Gibraltar (89) on both African and European sides, followed by the Alboran Island (28) and other localities within the Alboran Sea (28) and the Chafarinas Islands (9).

## 10.7 Mass Mortality Events

Events of mass mortality related to climatic anomalies (storms, high water temperature or oxygen deficiency episodes) and mainly affecting filter-feeding benthic invertebrates (sponges, corals, gorgonians, bivalves, ascidians, etc.) have become

**Table 10.2** Species originally described in the Strait of Gibraltar and Alboran Sea since 1980 (SG, Strait of Gibraltar; AI, Alboran Island, CH, Chafarinas Islands; OT, other localities within the Alboran Sea). Those species that have fallen into synonymy have been excluded (nomenclature according to WoRMS 2019)

Species	SG	AI	CH	OT
<b>Porifera</b>				
<i>Axinella alborana</i> Sitjà and Maldonado 2014		+		
<i>Axinella estacioi</i> Carballo and García-Gómez, 1995	+			
<i>Axinella spatula</i> Sitjà and Maldonado 2014		+		
<i>Axinyssa diversicolor</i> (Carballo, 2000)	+			
<i>Cerbaris alborani</i> (Boury-Esnault et al. 1994)				+
<i>Coelosphaera cryosi</i> (Boury-Esnault et al. 1994)				+
<i>Crambe tuberosa</i> Maldonado and Benito, 1991		+		
<i>Delectona alboranensis</i> Rosell, 1996		+		
<i>Dotona mediterranea</i> Rosell and Uriz, 2002		+		
<i>Endectyon filiformis</i> Sitjà and Maldonado 2014		+		
<i>Forcepia megachela</i> (Maldonado 1992)		+		
<i>Haliclona palmonensis</i> Carballo and García-Gómez, 1995	+			
<i>Halichondria almae</i> (Carballo, Uriz and García-Gómez, 1996)	+			
<i>Plakinastrella mixta</i> Maldonado 1992		+		
<i>Pleraplysilla reticulata</i> Maldonado and Uriz, 1999		+		
<i>Scleranthelia microsclera</i> López-González, Ocaña and García-Gómez, 1995	+			
<i>Scopalina ceutensis</i> Blanquer and Uriz, 2008	+			
<i>Vulcanella aberrans</i> (Maldonado and Uriz, 1996)		+		
<b>Cnidaria</b>				
<i>Antennella ansini</i> Peña-Cantero and García-Carrascosa, 2002			+	
<i>Cordagalma bimaculatum</i> Pugh, 2016				+
<i>Eudendrium moulouyensis</i> Marques, Peña-Cantero and Vervoort, 2000			+	
<i>Filellum disaggregatum</i> Peña Cantero, García-Carrascosa and Vervoort, 1998			+	
<i>Merona ibera</i> Medel, García-Gómez and Bouillon, 1993	+			
<i>Scleranthelia microsclera</i> López-González, Ocaña and García-Gómez, 1995	+			
<b>Platyhelminthes</b>				
<i>Parotoplana cucullata</i> Delogu, Casu and Curini-Galletti, 2008	+			
<i>Parotoplana fretigaditani</i> Delogu, Casu and Curini-Galletti, 2008	+			
<i>Parotoplana mastigophora</i> Delogu, Casu and Curini-Galletti, 2008				+
<i>Parotoplana varispinosa</i> Delogu, Casu and Curini-Galletti, 2008				+
<i>Phaenoplana caetaria</i> Pérez-García, Noreña and Cervera, 2018	+			
<b>Kinorhyncha</b>				
<i>Pycnophyes almansae</i> Sánchez, Herranz, Benito and Pardos, 2014				+
<b>Entoprocta</b>				
<i>Loxosomella almugnecarensis</i> Tierno de Figueroa and Sánchez-Tocino, 2009				+

(continued)



**Table 10.2** (continued)

Species	SG	AI	CH	OT
<i>Loxosomella ameliae</i> Sánchez-Tocino and Tierno de Figueroa, 2009				+
<b>Polychaeta</b>				
<i>Amphicorina triangulata</i> López and Tena, 1999			+	
<i>Bispira primaoculata</i> Cepeda and Lattig, 2017				+
<i>Exogone acerata</i> San Martín and Parapar, 1990	+			
<i>Myrianida longoprimitirratu</i> s (López, San Martín and Jiménez, 1996)			+	
<i>Ophryotrocha alborana</i> Paxton and Åkesson, 2011	+			
<i>Ophryotrocha rubra</i> Paxton and Åkesson, 2010	+			
<i>Opisthodonta serratisetosa</i> (López, San Martín and Jiménez, 1996)			+	
<i>Salvatoria celiae</i> (Parapar and San Martín, 1992)	+			
<b>Nemertea</b>				
<i>Prosorhochmus chafarinensis</i> Frutos et al. 1998			+	
<b>Tardigrada</b>				
<i>Halechiniscus chafarinensis</i> de Zio Grimaldi and Villora-Moreno 1995			+	
<b>Crustacea</b>				
<i>Anapagurus alboranensis</i> García-Gómez, 1994				+
<i>Anthessius arcuatus</i> López-González, Conradi, Naranjo and García-Gómez, 1992	+			
<i>Astacilla cingulata</i> Castelló and Carballo, 2000	+			
<i>Astacilla pauciseta</i> Castelló and Carballo, 2000	+			
<i>Botryllophilus conicus</i> Conradi, López-González and García-Gómez, 1994	+			
<i>Caprella caulerpensis</i> Guerra-García, Sánchez-Moyano and García-Gómez, 2002	+			
<i>Caprella ceutae</i> Guerra-García and Takeuchi, 2002	+			
<i>Caprella monai</i> Guerra-García, Sánchez-Moyano and García-Gómez, 2001	+			
<i>Caprella paramitis</i> Guerra-García, Sánchez-Moyano and García-Gómez, 2001	+			
<i>Caprella pseudorapax</i> Guerra-García, Sánchez-Moyano and García-Gómez, 2001	+			
<i>Caprella sabulensis</i> Guerra-García, Sánchez-Moyano and García-Gómez, 2001	+			
<i>Caprella santosrosai</i> Sánchez-Moyano, Jiménez-Martín and García-Gómez, 1995	+			
<i>Caprella takeuchii</i> Guerra-García, Sánchez-Moyano and García-Gómez, 2001	+			
<i>Doridicola comai</i> Conradi, Megina and López-González, 2004	+			
<i>Enterocola africanus</i> López-González, Conradi and García-Gómez, 1993	+			
<i>Eriopisella ruffoi</i> Martí and Villora-Moreno, 1996			+	
<i>Heteranthessius hoi</i> López-González and Conradi, 1995	+			
<i>Leptocheirus alboranensis</i> Ortiz and Jimeno, 2006		+		
<i>Limnoria turae</i> Castelló, 2011		+		

(continued)

**Table 10.2** (continued)

Species	SG	AI	CH	OT
<i>Mychophilus palmatus</i> López-González and Conradi, 1996	+			
<i>Pagurus pseudosculptimanus</i> García Muñoz, Cuesta and García Raso, 2014				+
<i>Pedoculina garciagomezi</i> Sánchez-Moyano, Carballo and Estacio, 1995	+			
<i>Stenosoma albertoi</i> (Castellanos and Junoy, 2005)	+			
<i>Stenosoma raquelae</i> (Hedo and Junoy, 1999)	+			
<i>Urothoe hesperiae</i> Conradi, López-González and Bellan-Santini, 1995	+			
<b>Pycnogonida</b>				
<i>Hannonia stocki</i> Munilla, 1993	+			
<b>Mollusca</b>				
<i>Alexandromenia avempacensis</i> Pedrouzo and Cobo, 2014				+
<i>Alvania alboranensis</i> Peñas and Rolán, 2006		+		
<i>Alvania nestaresi</i> Oliverio and Amati, 1990				+
<i>Alvania vermaasi</i> Aartsen, Menkhorst and Gittenberger, 1984	+			
<i>Aphanitoma mariottinii</i> Smriglio, Rufini and Martín Pérez, 2001		+		
<i>Baenopsis baetica</i> (García-Gómez, 1984)	+			
<i>Bittium circa</i> Moreno, 2006		+		
<i>Calliostoma gubbiolii</i> Nofroni, 1984				+
<i>Cassiella abylenis</i> Gofas, 1987	+			
<i>Cerithiopsis tarruellasi</i> Peñas and Rolán, 2006		+		
<i>Chauvetia dentifera</i> Gofas and Oliver, 2010	+			
<i>Chauvetia taeniata</i> Gofas and Oliver, 2010	+			
<i>Crisilla aartseni</i> Verduin, 1984	+			
<i>Curveulima beneittoi</i> Peñas and Rolán, 2006		+		
<i>Dikoleps marianae</i> Rubio, Dantart and Luque, 1998				+
<i>Dikoleps templadoi</i> Rubio, Dantart and Luque, 2004	+			
<i>Dizoniopsis abylenis</i> Bouchet et al. 2010	+			
<i>Dizoniopsis aspicienda</i> Bouchet et al. 2010	+			
<i>Doto alidrisi</i> Ortea, Moro and Ocaña, 2010	+			
<i>Doto caballa</i> Ortea, Moro and Bacallado, 2010	+			
<i>Doto furva</i> García-Gómez and Ortea, 1984	+			
<i>Doto unguis</i> Ortea and Rodríguez, 1989				+
<i>Eatonina matildae</i> Rubio and Rodríguez Babio, 1996	+			
<i>Eubranchus linensis</i> García-Gómez, Cervera and García, 1990	+			
<i>Eulimella carminae</i> Peñas and Micali, 1999				+
<i>Eulimella oliveri</i> Peñas and Rolán, 2006		+		
<i>Facelinopsis pacodelucia</i> Ortea, Moro and Caballer, 2014	+			
<i>Fjordia insolita</i> (García-Gómez and Cervera, 1990)	+			
<i>Gibberula jansseni</i> van Aartsen, Menkhorst and Gittenberger, 1984	+			
<i>Granulina gubbiolii</i> Smriglio and Mariottini, 1999				+
<i>Granulina torosa</i> Gofas, 1992	+			
<i>Granulina vanhareni</i> (van Aartsen, Menkhorst and Gittenberger, 1984)	+			
<i>Graphis pruinosa</i> Gofas and Rueda, 2014				+

(continued)

**Table 10.2** (continued)

Species	SG	AI	CH	OT
<i>Jujubinus alboranensis</i> Smriglio, Mariottini and Oliverio, 2015		+		
<i>Jujubinus dispar</i> Curini-Galletti, 1982	+			
<i>Lepidochitona severiano</i> Carmona Zalvide and García García, 2000	+			
<i>Leptochiton xanthus</i> Kaas and van Belle, 1985	+			
<i>Macellomenia adenota</i> Salvini-Plawen, 2003	+			
<i>Macromphalus abylenis</i> Warén and Bouchet, 1988	+			
<i>Melanella scarifata</i> Gofas and Rueda, 2014				+
<i>Mitrella bruggeni</i> van Aartsen, Menkhorst and Gittenberger, 1984	+			
<i>Mitrella templadoi</i> Gofas, Luque and Urrea, 2019	+			
<i>Mitromorpha wilhelminae</i> (van Aartsen, Menkhorst and Gittenberger, 1984)	+			
<i>Monophorus alboranensis</i> Rolán and Peñas, 2001		+		
<i>Odostomia kromi</i> Aartsen, Menkhorst and Gittenberger, 1984	+			
<i>Odostomia soriano</i> Peñas and Rolán, 2006		+		
<i>Okenia hispanica</i> Valdés and Ortea, 1995				+
<i>Onchodia valeriae</i> (Giusti Fr., 1987)				+
<i>Onoba guzmani</i> Hoenselaar and Moolenbeek, 1987	+			
<i>Onoba josae</i> Moolenbeek and Hoenselaar, 1987	+			
<i>Onoba tarifensis</i> Hoenselaar and Moolenbeek, 1987	+			
<i>Parvicardium vroomi</i> van Aartsen, Menkhorst and Gittenberger, 1984	+			
<i>Parviturbo alboranensis</i> Peñas and Rolán, 2006		+		
<i>Pogonodon pseudocanaricus</i> (Bouchet, 1995)				+
<i>Pseudosimnia angusta</i> Celzard, 2017	+			
<i>Rugulina monterosatoi</i> (van Aartsen and Bogi, 1987)				+
<i>Runcina bahiensis</i> Cervera, García-Gómez and García, 1991	+			
<i>Runcina macrodenticulata</i> García-Gómez and López de la Cuadra, 1990	+			
<i>Setia alboranensis</i> Peñas and Rolán, 2006		+		
<i>Setia anselmoi</i> (van Aartsen and Engl, 1999)	+			
<i>Setia bruggeni</i> (Verduin, 1984)	+			
<i>Setia lacourti</i> (Verduin, 1984)	+			
<i>Setia slikorum</i> (Verduin, 1984)	+			
<i>Similiphora tricolorata</i> Bouchet, 1997	+			
<i>Simnia jacintoi</i> Fehse and Trigo, 2015	+			
<i>Tambja ceutae</i> García-Gómez and Ortea, 1985	+			
<i>Tambja marbellensis</i> Schick and Cervera, 1998				+
<i>Trapania hispalensis</i> Cervera and García-Gómez, 1990	+			
<i>Trenchia anselmoi</i> Rubio and Rolán, 2013		+		
<i>Tricolia deschampsii</i> Gofas, 1993	+			
<i>Tricolia entomocheila</i> Gofas, 1993	+			
<i>Tricolia tingitana</i> Gofas, 1993	+			
<i>Trophonopsis alboranensis</i> (Smriglio, Mariottini and Bonfitto, 1997)		+		
<i>Tyrannodoris europaea</i> (García-Gómez, 1988)	+			

(continued)

**Table 10.2** (continued)

Species	SG	AI	CH	OT
<b>Bryozoa</b>				
<i>Bicrisia gibraltarensis</i> Harmelin, 1990	+			
<i>Crepis harmelini</i> Reverter-Gil, Souto and Fernández-Pulpeiro, 2011	+			
<i>Disporella alboranensis</i> Álvarez, 1992		+		
<i>Disporella pyramidata</i> Álvarez, 1992				+
<i>Disporella robusta</i> Álvarez, 1992		+		
<i>Fenestrulina barrosoi</i> Álvarez, 1993		+		
<i>Hemicyclopora dentata</i> López de la Cuadra and García Gómez, 1991	+			
<i>Patinella distincta</i> (Álvarez, 1993)	+			
<i>Puellina pseudoradiata</i> Harmelin and Arístegui, 1988				+
<i>Schizomavella rectangularis</i> Reverter-Gil, Berning and Souto, 2015	+			
<i>Sessibugula barrosoi</i> López de la Cuadra and García-Gómez, 1994	+			



**Fig. 10.18** Two species originally described from the Alboran Sea, the shelled gastropod *Alvania nestaresi* (left, Los Escullos, Almería, 5 m depth) and the nudibranch *Tyrannodoris europaea* (right, Almería Port, 14 m depth) [Diego Moreno]

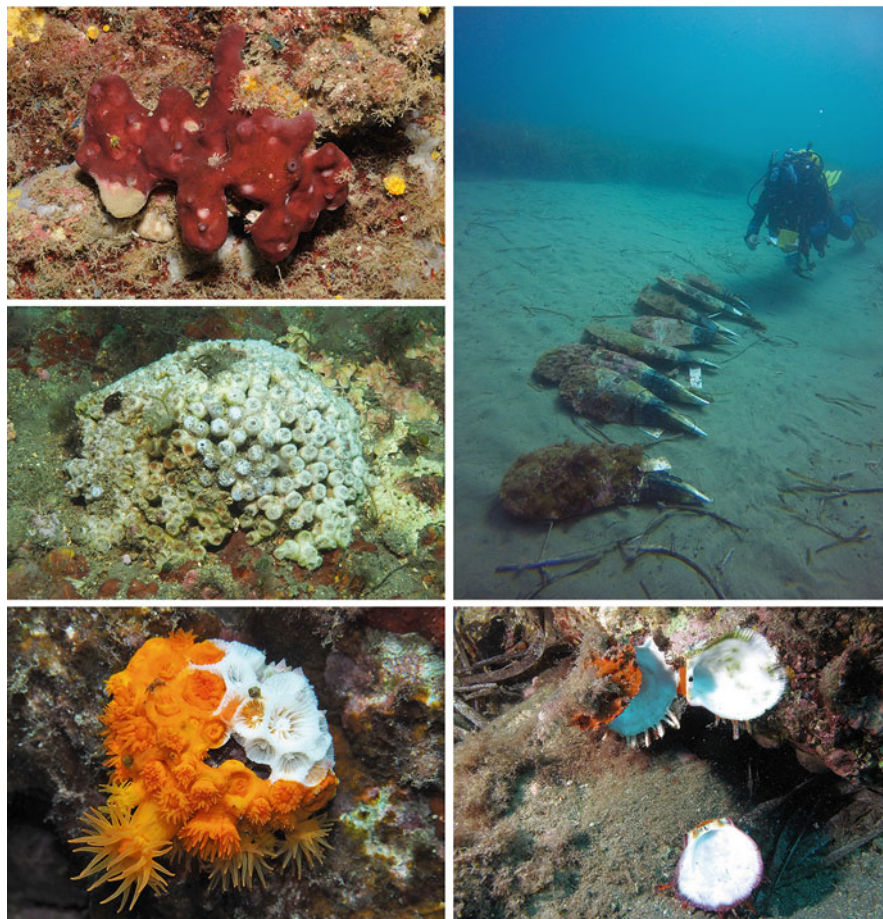
frequent in the last three decades across the Mediterranean Sea (e.g. Stachowitsch 1984; Cerrano et al. 2000; Perez et al. 2000; Garrabou et al. 2009; Bensoussan et al. 2010; Lejeusne et al. 2010; Crisci et al. 2011; Rivetti et al. 2014; Di Camillo and Cerrano 2015; Rubio-Portillo et al. 2016). These events can cause massive damage or death to those species by (i) thermal stress (that makes them more susceptible to infections and diseases); (ii) decrease in the efficacy of defence mechanisms; (iii) damages by hypoxia; (iv) increasing populations of pathogenic organisms as fungi, bacteria or protists (or increasing their virulence); (v) favouring the arrival and settlement of thermophilic species to the detriment of the most sensitive to high temperatures; and (vi) inducing coral bleaching or the breakdown of the cyanobacteria-sponge symbiosis (Stachowitsch 1984; Kushmaro et al. 1998; Cerrano et al. 2000; Perez et al. 2000; Coma et al. 2009; Lejeusne et al. 2010; Maldonado et al. 2010; Cebrián et al. 2011; Sánchez-Tocino and Tierno de Figueroa 2016). In fact, as referred by Lejeusne et al. (2010), the Mediterranean Sea is one of

the most affected seas by the global warming and by the extreme events derived from the current climate change. Moreover, the increases of temperatures act synergistically with other anthropogenic disturbances, which also cause mass mortalities. Different types of professional and recreational fishing impact mainly invertebrates on rocky bottoms (corals, bryozoans, sponges and gorgonians), whereas trawling on soft bottoms affect sea pens, echinoderms and many other benthic animals. Coastal degradation, biological invasions and pollution added to high temperatures and pathogens cause serious conservation problems for marine species in the Mediterranean Sea and hamper the recovery of their populations (Lejeune et al. 2010; Templado 2014).

Several events of mass mortality have been detected in the Alboran Sea in recent years, affecting different invertebrates, such as sponges, cnidarians, molluscs and echinoderms. Maldonado et al. (2010) found disease outbreak in sponge populations of the genus *Ircinia* from the Granada coast and the Chafarinas Islands and pointed that epidemic outbreaks could recur periodically at the end of summer and early autumn probably favoured by short periods of abnormally high water temperatures in August. Their study in 2008 and 2009 showed that, although 27% of the sponges died, the sponge immune system could successfully resist the disease in many cases. More recently, in 2016 late summer, a new mass mortality event was reported for the sponges *Ircinia variabilis* and *Sarcotragus fasciculatus* in the Granada coast coinciding with abnormally high seawater temperatures (Sánchez-Tocino and Tierno de Figueroa 2016). In this study, diseased sponges ranged from 7.2% to 81%, and dead ones ranged from 0% to 92.8%. Authors detected an effect of the coast topography and thermocline position on the degree of mortality or disease, as had been previously reported for the anthozoan *Corallium rubrum* in the Mediterranean Sea (Garrabou et al. 2001). Necrosis in *Petrosia ficiformis* related with environmental stress was recorded in Liguria (Cerrano et al. 2001) and recently observed in Almería (Moreno pers. obs., Fig. 10.19).

Sánchez-Tocino et al. (2017) pointed out that the moderate to low recruitment (previously reported by Maldonado et al. 2013) of the anthozoan *Ellisella paraplexauroides* populations in the Chafarinas Islands, the impacts of fishing and the particular shallow distribution of this species in this archipelago could have an important negative effect in its conservation. These authors also highlighted that mass mortality events caused by high temperatures, such as those affecting other species of gorgonians in the Mediterranean (e.g., Cerrano et al. 2000; Linares et al. 2008b; Cupido et al. 2009), could also have contributed to the preoccupying conservation status of this population. In relation to this, de la Linde Rubio et al. (2018) reported a mortality episode of the gorgonians *Eunicella singularis* and *Paramuricea clavata* in Chafarinas Islands also after a high temperature event in summer 2014. On average, 43% of the colonies of *E. singularis* were found dead and 21% damaged, while in *P. clavata* none of the studied colonies was dead but only half of them were completely healthy. Unlike other mass mortality events in the Mediterranean (Crisci et al. 2011), *P. clavata* was apparently not so affected in the Chafarinas Islands. Nevertheless, recent observations showed mortality in the colonies of *P. clavata* from the shallower areas of these islands (Sánchez-Tocino et al.





**Fig. 10.19** Mortality events. From top to bottom and from left to right, necrosis (white patches) in the sponge *Petrosia ficiformis* (Carboneras Island, Almería, 17 m depth), partially dead colonies of the scleractinian corals *Cladocora caespitosa* (Balanegra, Almería, 15 m depth) and *Astroides calycularis* (San José, Almería, 3 m depth), cemetery of marked specimens of *Pinna nobilis* (Carboneras Island, Almería, 10 m depth, 2016) and two dead specimens of *Spondylus gaederopus* (Carboneras Island, Almería, 8 m depth) [Diego Moreno/Sustainable Marine Environment Management Program/Junta Andalusia, three photos on the left; Agustín Barrajón Domenech/Sustainable Marine Environment Management Program/Junta Andalusia, two photos on the right]

2019). Furthermore, punctual episodes of mass mortality of the anthozoan *Parazoanthus axinellae* have been observed in the Granada coast at the end of particularly warm summers (personal observations), coinciding with that detected in the Ligurian Sea (Cerrano et al. 2006).

Other anthozoans, such as the Mediterranean endemic scleractinians *Cladocora caespitosa* and *Astroides calycularis* (Fig. 10.19), may suffer massive mortalities.

The first species is the sole zooxanthellate scleractinian reef-builder of the Mediterranean and has been affected by bleaching events in the last years due to seawater warming (Kersting et al. 2013). Gambi et al. (2010) reported local mass mortality events of the thermophilic azooxanthellate orange coral *Astroides calycularis* also related to high water surface temperatures. Both species support a high biodiversity (Pitacco et al. 2017; Terrón-Sigler et al. 2014).

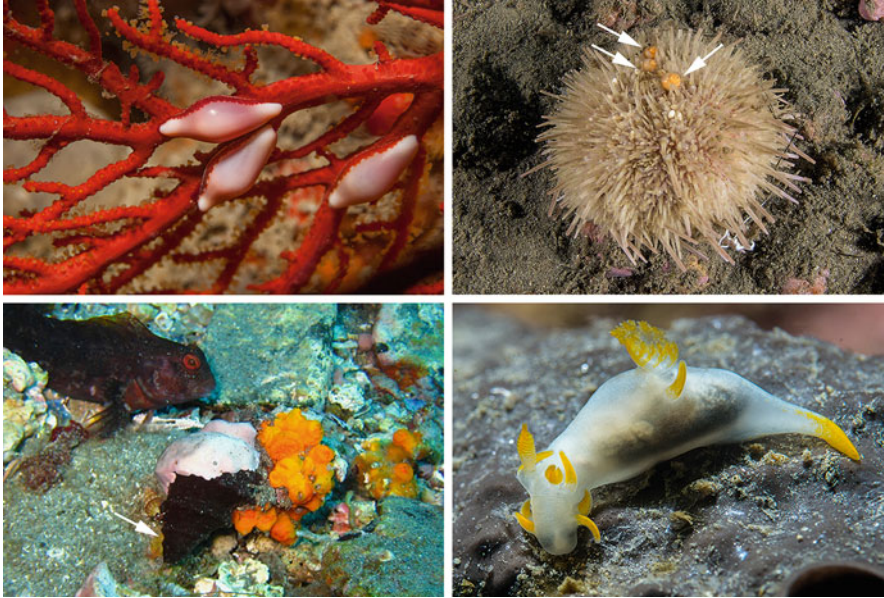
Among molluscs, the better known cases of mass mortalities are the recurrent events suffered by the bivalve *Spondylus gaederopus* since the 1980s and the more recent mortality that have severely affected *Pinna nobilis* populations in the western Mediterranean. The European thorny oyster (*S. gaederopus*), which lives attached by the lower (right) valve to more or less vertical rock walls and other hard substrates, suffered the first known case of mass mortality in 1981 in France for causes yet unknown (Meinesz and Mercier 1983). Similar mortality events were observed in this species in the Alboran Sea since 1990, and subsequently there have been mortalities in 2005 and later years, detected in the Granada coast (personal observations) and, particularly, in the Chafarinas Islands (Sánchez-Tocino et al. 2009). Mass mortalities of *S. gaederopus* are easy to detect since this species loses the flat upper (left) valve when it die and the white inside of the convex lower valve that remains attached to the rock can be seen by divers from a distance of several meters (Fig. 10.19). Observed mortalities of *S. gaederopus* often coincide with a number higher than usual of empty shells of other bivalves that live attached with the byssus to rocky bottoms, such as *Arca noae* and *Barbatia barbata* (personal observations). For the former species, a massive mortality has been recently reported in the Strait of Messina (Bottari et al. 2017). Currently, *Spondylus gaederopus* is still present in many localities in the Alboran Sea, but it is uncommon, and its abundance has never been the same since the recorded mortalities (Moreno et al. 2008b).

Nevertheless, the most drastic and surprising mass mortality event that has affected any invertebrate species in the Alboran Sea and the whole Mediterranean is that first detected in October 2016 in southeastern Spain (Fig. 10.19) affecting the Mediterranean endemic and threatened fan mussel *Pinna nobilis*, one of the world's largest bivalves, which lives associated to seagrass meadows. By the end of 2016, between 70% and 90% of the specimens died, and in the spring of 2017, practically 100% of the population died in most of the southern Spanish coasts including the Alboran Sea. Vázquez-Luis et al. (2017) found in the Spanish Mediterranean Sea mortality values of 100% in the North part of the Alboran Sea and of 90–99% in the Chafarinas Islands. These authors and Darriba (2017) pointed out a haplosporidian-like parasite detected in dying individuals as the very likely cause of this mortality. The parasite associated to this mortality (the protist *Haplosporidium pinnae*) was subsequently described in 2018 (Catanese et al. 2018) and infects the vital organs of the bivalve causing its death. It seems to be a very specific pathogen because it does not affect the closely related species *Pinna rudis*, somewhat smaller and that prefers rocky substrates, although it is also found in *Posidonia* meadows. By 2019, the mortality of *Pinna nobilis* affects populations of other Mediterranean countries (France, Italy, Malta, Greece, Croatia, Turkey, Cyprus, Tunisia and Morocco), according to IUCN (2019). According to Cabanellas-Reboredo et al. (2019), the

haplosporidian has probably dispersed regionally by surface currents, and the disease expression seems to be closely related to temperatures above 13.5 °C and to a salinity range between 36.5 and 39.7 psu. *Pinna nobilis* has been recently included in the IUCN Red List as a critically endangered species (Kersting et al. 2019).

Finally, a mass mortality episode of echinoderms was detected in August 2009 affecting to the starfish *Astropecten aranciacus* and the sea urchins *Spatangus purpureus*, *Paracentrotus lividus* and *Sphaerechinus granularis* in Almuñécar, Granada coast (Tierno de Figueroa and Sánchez-Tocino 2010). This event coincided with a sudden increase in sea temperature, reaching values higher than those ever registered in the previous 25 years.

Effects of mass mortalities may extend from the directly affected species to other invertebrates linked by trophic or symbiotic relationships. *Pinna nobilis*, for example, may host three symbiotic, commensal or mutualistic, decapod crustaceans: the shrimp *Pontonia pinnophylax* and the crabs *Nepinnotheres pinnotheres* and *Pinnotheres pisum* (Rabaoui et al. 2008; Trigos and Vicente 2018). *Pontonia pinnophylax* is a Mediterranean species that could also live in association with sponges and ascidians (Trigos and Vicente 2018), *Nepinnotheres pinnotheres* may live also in ascidians, and *Pinnotheres pisum* lives also in mussels, oysters and other bivalves (Rabaoui et al. 2008; Becker and Türkay 2017). Local extinction of the fan mussel predictably carries at least a population decline of these decapod species or even their local extinction (co-extinction). This is especially so for *Pontonia pinnophylax*, since Calafiore et al. (1991) revealed that the larval development of this shrimp is stopped in the zoea phase in the absence of *Pinna nobilis* (Trigos and Vicente 2018). Similar effects are predictable for specialized gastropods preying on sponges. For example, the doridoidean nudibranch *Peltodoris atromaculata* (Fig. 10.17) feeds on *Petrosia ficiformis* (Ros 1978) and *Paradoris indecora* on *Ircinia variabilis* (Marín et al. 1997), whereas *Trapania maculata* and *T. hispalensis* (Fig. 10.20) are common on *I. variabilis* and *Sarcotragus spinosulus* but feed on Entoprocta of the genus *Loxosomella* living on the sponges (Sánchez Tocino and Cervera 2006). Many other doridoideans feed on sponges (e.g., Megina et al. 2002; Gemballa and Schermtuzki 2004), as also do gastropods belonging to the families Triphoridae or Cerithiopsidae (Wells 1998; Bouchet et al. 2010). Similarly, other gastropods are more or less specific predators of anthozoans, such as Ovulidae (Fig. 10.20), which feed on several species of octocorals (Fehse et al. 2010; Priori et al. 2014); Coralliophilinae (Muricidae, Fig. 10.20), which prey on stony corals, sea anemones, antipatharians or octocorals (Richter and Luque 2002, 2004); or Epitoniidae that only feed on stony corals or sea anemones (Richter and Luque 2004). Some nudibranchs also feed on diverse anthozoans including gorgonians (McDonald and Nybakken 1997, 1999; Goodheart et al. 2017). Finally, echinoderm mass mortalities may affect, among others, to the specialized parasitic gastropods of the family Eulimidae (Fig. 10.20) that feed on many species of this group (Warén 1983).



**Fig. 10.20** Four examples of gastropods linked by trophic relationships to species that may suffer mass mortalities. From left to right and from top to bottom: the ovulid *Simnia spelta* on the gorgonian *Leptogorgia sarmentosa* (Cantarriján, Granada, 13 m depth), may also feed on species of the genera *Eunicella* and *Paramuricea*; the eulimid *Pelseneeria minor* (arrows), on the sea urchin *Psammechinus microtuberculatus* (La Rábita, Granada, 150 m depth), may also feed on other sea urchins; the coralliophiline muricid *Babelomurex cariniferus* (arrow), here feeding on the orange coral *Astroides calycularis* (Almuñécar, Granada, 15 m depth), may also feed on *Cladocora caespitosa*; and the doridacean nudibranch *Trapania hispalensis*, which feeds on entoprocts of the genus *Loxosomella*, on the sponge *Sarcotragus spinosulus* (Punta de la Mona, Granada, 14 m depth) [Luis Sánchez Tocino]

## 10.8 Some Aims for Present and Future Research

At least from the taxonomic point of view, the main groups of marine invertebrates of the Alboran Sea (e.g. sponges, anthozoans, molluscs, decapod crustaceans, echinoderms) are reasonably well known, but knowledge on most of minor groups, and also on polychaetes and non-decapod crustaceans, is much scarcer and needs to be improved. However, research work on basic scientific issues, such as taxonomy, systematics or biogeography, seems to be currently unfashionable for funding agencies. Qualified and constantly updated systematic inventories of all the components of biodiversity are necessary since they provide a permanent scientific record for documenting patterns of diversity, endemism and alien species. Small cryptic invertebrates are numerically dominant in most marine ecosystems, but the inventory of these species requires the participation of trained taxonomists (those experts able to identify, describe and classify species). Regrettably, expertise in biodiversity



is being lost and needs to be urgently reinforced. Moreover, the available information is unbalanced between the north and south shores of the Alboran Sea, with the latter much less known. Thus, it would be necessary to increase research efforts in Moroccan and Algerian waters to have a more complete and updated overview of the biodiversity of this Mediterranean basin.

On the other hand, the biological traits and the role of the species in the maintenance of biodiversity, functionality and resilience of ecosystems remain poorly understood, particularly for the vast majority of rare species. Thus, besides the necessary basic research on taxonomy, investigations must be also focused on the species ecological features (mainly on trophic interactions) and on its reproductive biology, larval development, settlement and recruitment. Moreover, and especially for the threatened species, it is also essential to understand the environmental factors that modulate their distribution and, in the current context of global change, their thermal tolerance limits, acclimatization capacities and resilience under other human impacts and diseases. Finally, genetic data (such as population genetic variability and the extent of connectivity), associated with ecological studies, are of primary importance to detect when a population is threatened and to predict the influence of environmental changes on individual species. All these issues will determine “winners” and “losers”, and such knowledge is necessary for successful management and effective protection.

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