Fundación Biodiversidad

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[Habitats in Danger]

Oceana´s proposal for protection

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Preface

A collaboration agreement that was establishment through the Research and Projects Department of the Fundación Biodiversidad has given Oceana the opportunity to demonstrate new criteria in support of the selection of marine habitats of interest to the European Community. The context of the project is included within our mission and exclusive dedication to researching, protecting and recuperating the oceans through investigation and scientific work, with a focus on biodiversity, the environment and sustainable marine development.

As part of a general diagnosis, the most environmentally important habitats have been identified in this report according to their unique qualities and biological and biogeographical interest. The following chapters detail research results and include proposals for representative types of natural habitats of interest to the European Community. Although the process of obtaining the data has been long and laborious, we have attempted to include extensive lists of taxonomic classifications that describe the communities associated with the identified habitats. Obviously, the lack of consistent data means priorities should be established, as a point of departure, for the development and implementation of action plans for the protection of these habitats.

It is necessary to promote a model for sustainable development that values and conserves natural resources, in order to promote the development and consolidation of a coherent network of special conservation areas within the European Union. In both aspects, the development of the proposal stems from the lack of a coherent representation of marine habitats of interest to the community, as well as from the need to urgently update this information. These points specifically refer to the Habitats Directive 92/43/CEE, which is the European Community's fundamental legislative instrument for halting the decline of biodiversity, specifically in the marine environment, with regards to its framework for application.

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Introduction

The objective of this proposal is to identify and subsequently evaluate habitats that show a representation of the geomorphological, hydromorphological and biogenic structures that contribute to elevated levels of biomass and specific biological richness. As such, they include a high level of biological diversity and an elevated number of endemic species.

Because the European Union has proposed to safeguard biodiversity, as well as wild fauna and flora within the territories of Member states, by means of natural habitat conservation, an ecological network of special areas of conservation (SACs) was created, known as "Natura 2000". The Natura 2000 network includes SACs, designated in accordance with the Habitats Directive, and also includes Special Protection Areas for birds (SPAs), established in accordance with the Birds Directive.

The Habitats Directive (92/43/CEE) and the Birds Directive (79/409/CEE) are key instruments for European Union policy in favour of biodiversity conservation. They are also fundamental tools to be used by the EU in meeting more general objectives in these areas, such as ending biodiversity loss by the year 2010.

The Habitats Directive was adopted on May 21, 1992, transmitted to member States on June 5, 1992, and finally put into effect two years later, in June, 1994. Currently, only nine marine and coastal habitats are designated (Annex 1) as types of habitats of interest to the European Community, the conservation of which requires them to be designated as SACs.

In March, 2003, a workgroup of marine environmental experts was created at the request of Member states´ governmental agencies´ Nature Conservation Directors and sponsored by the Habitats Committee. Their charge was to come to a common understanding on the agreements of the Natura 2000 network for marine environments, in order to identify and manage those areas designated by the Habitats Directive.

One of the objectives of this workgroup was to revise the definitions of some of the habitats already included in the Interpretation Manual of Habitats, so that these may be adapted and modified in order to create a coherent network of marine protected areas in the European Union. The results of this work have been periodically updated by Nature Conservation Directors, the Habitats Committee and its scientific workgroup.

During an initial review, the need to complete the definitions of some of the habitats included the Interpretation Manual of Habitats was considered. The three types of habitats referred to are: sand banks (Code: 1110), reefs (Code: 1170) and undersea structures formed by gas leeks (Code: 1180). Also, for habitat 1110, additional scientific advising was necessary and provided by an independent panel of experts sponsored by the European Environmental Agency (EEA). The process is not yet complete, a fact that was confirmed during the last Habitats Committee.

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Certain problems exist for the marine environment due to a lack of data, complex jurisdictional issues and overlapping responsibilities amongst different administrations. This problem is also being studied by a workgroup created by the European Commission in which various Member states are participating.

Various intergovernmental organisations, both regional (Barcelona Convention, OSPAR Commission, Helsinki Convention) and international (Convention on Biological Diversity), have acknowledged the need for the European Union to revise its principal legislation, and have pointed out the lack of marine species and habitats represented in its annexes.

Although anticipated activities such as surveillance, monitoring, research and education will promote coherence within the network, the main objective is to provide relevant information to be integrated into national and regional policies. This will include reconciling data from bibliographic reviews and

scientific inventories in order to propose types of habitats of interest to the European Community which can be included in Annex 1 of the Directive 92/43/CEE, and whose designation as SACs is necessary to achieve their conservation. Prompted by the need for greater representation of marine habitats in Europe, during its 2005 and 2006 campaigns, Oceana documented some of the elements necessary to consider and support a complete revision of the Habitats Directive.

The methodology used led to the creation of a unified report, made up of a series of chapters and organised by habitat groups, which presents a vision of the natural values inherent in the regional seas of Europe. This report reflects Oceana's mission and exclusive dedication to researching, protecting and recuperating the oceans through studies and work related to biodiversity, the environment and sustainable marine development.

The main objective of this document is to demonstrate the results of Oceana's work in identifying, locating, and documenting the susceptible marine habitats that should be included in national and regional legislation.

Given that various research centres, universities and foundations are working on projects to identify sites that should be prioritised by international policies for marine and coastal biodiversity conservation, it was important to combine efforts with these institutions in order to obtain consistent results.

The resulting research and documentation will be communicated to the general public with the hope that it will also be used as a tool at institutional levels, given the current gaps that exist in the docmentation, filming and research of the marine environment. Oceana also recommends that the research be made available to the academic community through publications in specialised scientific journals, symposiums, and congresses.

Oceana would like to contribute this document as a reference open to debate, both scientific and technical, regarding the state of marine conservation in order to guarantee benefits for wildlife and marine habitat protection.

These studies have been made possible thanks to the research campaigns carried out aboard the Oceana Ranger catamaran. Through the use of film equipment and at times a remotely-operated submarine vehicle (ROV), Oceana documented the habitats and key deep-sea species that must be protected and are proposed for inclusion in the lists of threatened species and habitats.

The data compiled during the campaigns provide a scientific contribution to the strategies that can be used to strengthen and ensure the conservation and sustainable development of natural resources, and to identify the threats to these ecosystems and evaluate their state of conservation.

As far as future actions are concerned, the information gathered will allow for knowledge regarding these marine ecosystems to be consolidated. A primary conclusion consists of the need to increase efforts to better understand these ecosystems.

Regarding the technical aspects of this project, Oceana would like to see an improved representation of the different marine species and habitats in the future, taking into account that some of these habitats are severely deteriorating due to the impact produced by human activities such as fishing, coastal defence constructions, pollution and tourism. Oceana's current lines of action are focused on the reduction of bottom trawling fisheries, the elimination of driftnets, bycatch and marine contamination.

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The projects and methods carried out during these campaigns create an invitation to Member states of the European Union to increase their participation in the conservation and sustainable use of these marine ecosystems, which are extremely vulne-rable to the impacts caused by human activities.

It should be pointed out that the lack of protection of certain types of seabeds is one of the most serious shortcomings of the Habitats Directive. As an example, it is important to note that the Directive does not include corals in its annexes of priority habitats, nor any of their characteristic Anthozoa species.

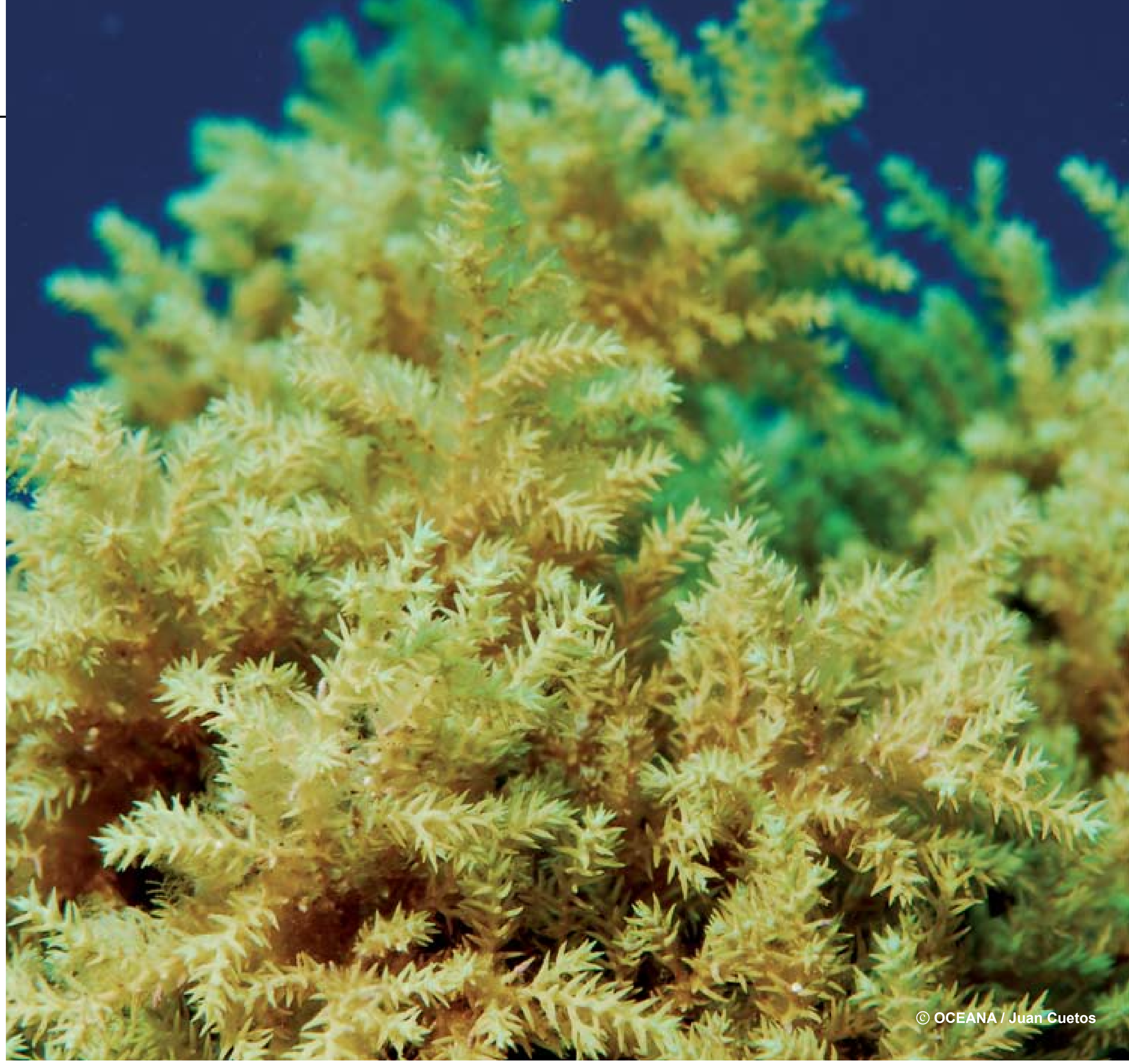
Other habitats that should be defined as priority habitats are deep-sea coral reefs, maërl beds, laminarian forests (also known as kelp forests), Cystoseira communities and seagrass meadows. The only marine habitats currently defined as priority habitats by the Habitats Directive are 1120, Posidonia oceanica, and 1150, coastal lagoons.

Throughout this document, the following types of habitats are proposed for consideration as those of interest to the community, amongst which the most important marine ecosystems can be found: seamounts, constructive gases, pelagic habitats, marine deserts, coral reefs (including deep-sea coral reefs, gorgonian gardens, sponge fields, biogenic reefs constructed by molluscs, polychaetes and crustaceans, green algae beds, red algal concretions (coralline, maërl beds) and laminaria forests.

Other habitats that should also be taken into consideration are the understories of brown algae beds, mixed meadows of photophilic algae and/or mixed algal beds, carpets of filamentous algae, rockpools, habitats with large species of colonial hydrozoans, bryozoans and tunicates, and colonial anthozoans

Habitats corresponding to caves, caverns and overhangs, as well as seagrass meadows and the different types of biogenic reefs described in this report were considered due to the necessity to harmonize and complete their definitions, and based on their characteristics, distribution, associated communities and degree of vulnerability, although these are already partially included in the Habitats Directive.

The habitats mentioned herein constitute veritable biodiversity hot spots, harbouring fragile ecosystems in need of urgent protection. In summary, Oceana has attempted to document a representative group of the geomorphological, hydromorphological and biogenic structures constituting a fundamental part of European natural heritage.



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List of identified habitats

Two fundamental types of habitats have been recognized the following list:

- **Physical habitats** ,including seamounts, volcanoes, caverns, sandy seabeds, etc.

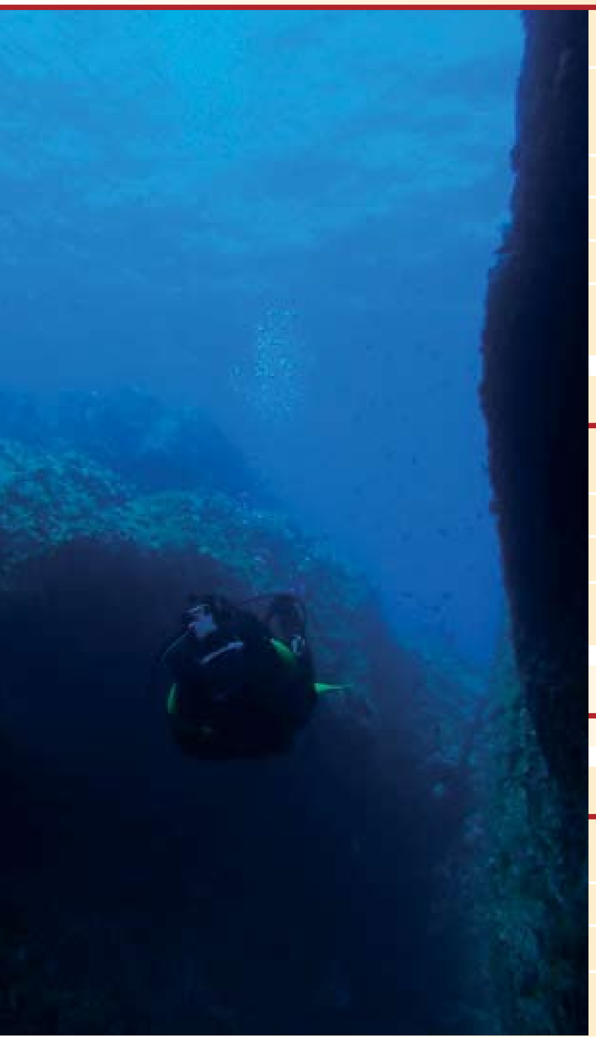
- **Biogenic habitats**, including coral reefs, kelp forests, sponge fields, etc.

We are aware that cataloguing these “habitats” is, perhaps, too restrictive for some of these environments, particularly the physical habitats, because a seamount or a marine desert may harbour a multitude of habitats. Equally, the same can be said of the biogenic habitats, where seagrass beds or coralline algae, for example, can harbour distinct communities, habitats, associations and characteristic facies.

Nevertheless, following the initiatives of other international agreements and conventions, such as the Oslo-Paris Convention for the protection of the North East Atlantic, the Barcelona Convention for protection of the Mediterranean or the United Nations Convention on Biological Diversity, we have decided to include them as such given their representative nature, importance, and vulnerability.

Physical habitats:

Geomorphological



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1- Raised features

- Seamounts
- Mounds
  - Carbonate mounds
- Hills
- Canyons
- Trenches
- Other submarine raised features

2- Constructive gases

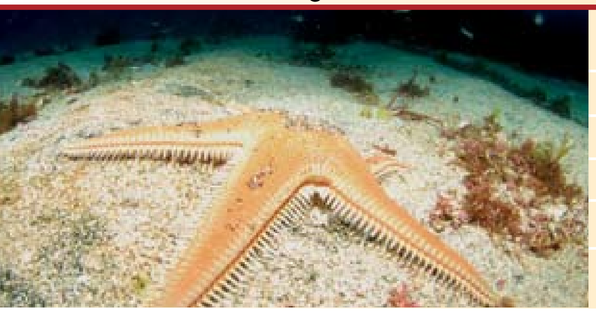
- Submarine volcanoes
- Hydrothermal vents
- Cold water seeps
- Other constructive gases

3- Caves, caverns and overhangs

4- Pelágics environments

- Convergence zones
- Divergence zones
- Marine currents
- Other marine deserts

Hidromorfológicos:



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5- Marine deserts

- Sandy seabeds
- Muddy seabeds
- Stone and gravel seabeds
- Mixed sediment seabeds
- Other marine deserts

Biogenic habitats:

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1- Coral reefs

- Coralliophila reefs
  - *Cladocora caespitosa* reef
- Oculinid reefs
  - *Oculina patagonica* reef
- Deep-sea soft coral reefs
- Other coral reefs

2- Mollusc reefs

- Mytilid reefs
  - *Mytilus edulis* reef
  - *Mytilus galloprovincialis* reef
  - *Modiolus modiotus* reef
  - *Bathymodiolus* sp. reef
  - *Musculus discors* reef
- Oyster reefs
  - *Ostrea edulis* reef
- Vermetid reef
  - *Dendropoma petraeum* reef
  - *Vermetus* sp. reef
- Limidae reefs
  - *Lima* sp. reef
  - Mixed mollusc reefs
  - Other mollusc reefs

3- Crustaceans reefs

- Lepadomorpha reefs
  - *Pollicipes pollicipes* reef
- Balanomorpha reefs
  - *Balanus* sp. reefs
  - *Semibalanus* sp. reefs
  - *Chtamalus* sp. reefs
  - *Megabalanus* sp. reefs
- Mixed crustacean reefs
- Other crustacean reefs

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4- Polychaete worm reefs

- Sabellid reefs
  - *Sabellaria alveolata* reef
  - *Sabellaria spinulosa* reef
- Mixed polychaete worm reefs
- Other polychaete worm reefs

5- Sponge fields and aggregations

- Calcareous sponge fields
- Hexactinellida sponge fields
- Desmospongia sponge fields
- Mixed sponge fields
- Sponge aggregations

6- Gorgonian gardens

- Circalittoral gorgonian gardens
- Deep-sea gorgonian gardens
- Other gorgonian gardens

7- Seagrass meadows

- Posidonia meadows
  - *Posidonia oceanica* meadow
- Cymodocea meadows
  - *Cymodocea nodosa* meadow
- Zostera meadows
  - *Zostera marina* meadow
  - *Zostera noltii* meadow
- Hydrocharitace meadows
  - *Halophila decipiens* meadow
- Mixed seagrass meadows

8- Green algae meadows

- Caulerpaceae meadows
  - *Caulerpa* sp. meadow
- Bryopsidace meadows
  - *Halimeda tuna* meadow
- Mixed green algae meadows
- Other green algae meadows

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9- Brown algae forests

- Fuciod forest
  - *Cystoseira* sp. forest
  - *Sargassum* sp. forest
  - *Fucus* sp. forest
  - Mixed fucoid forest
  - Floating sargassum
  - Other fucoid forest
- Laminaria forest
  - *Laminaria* sp. forest
  - *Saccorhiza* sp. forest
  - *Saccharina* sp. forest
  - *Alaria esculenta forest*
  - Mixed laminaria forests
  - Other laminaria forest

10- Red algal concretions

- Coralline algae
- Maérl beds
- *Mesophyllum* sp. reefs
- Laminar forest
- Trottoirs
- Corallinace seabeds
- Peyssonneliace seabeds
- Other red algal concretions

11- Other types of Habitats

- Understories of brown algae
- Mixed meadows of photophilic algae and/or carpets of mixed algae
- Beds of filamentous algae
- Rockpools
- Habitats formed by colonial species of hydrozoans, bryozoans and tunicates
- Colonial anthozoans or concentrations of cnidarians
- Other habitats yet to be defined

1 Seamounts

Characteristics

The undersea elevations referred to in this chapter include seamounts, knolls and banks. Seamounts are steep undersea mountains that rise above the surrounding sea floors and constitute unique habitats in the seas and oceans. They are dispersed throughout tectonically active areas. Due to its volcanic origin, faults, fissures and down-dropped blocks as well as other geomorphologic structures such as canyons, caves and hummocks interrupt the hard substrate.

Softer strata can also be found and may include biogenic sediments, such as arid sediments made up of foraminiferan sands and lithogenic sediments that have been transported from the continental margins.

Sometimes, the sediment is derived primarily from the precipitation of ferromanganese oxides.

The continental shelf is surrounded by abrupt undersea canyons that channel nutrient-rich organic material from superficial waters and the continental shelf towards the abyssal plains. Thus, undersea canyons are important geomorphological structures that play a key role in the balance of deep-sea ecosystems due to the richness of the waters in these areas compared to the adjoining bodies of water, due to the accumulation of organic material.

Seamounts constitute essential habitats for the life cycles of some species and present high levels of density as well as increased recruitment of macro and mega fauna. These areas also present high levels of endemism1 (i.e. hydrozoans), extending the length of the water column. As such, they are equally important for small pelagic species (i.e. the anchovy) as well as for marine birds and cetaceans.

Distribution

The distribution of these structures is centred around areas of significant tectonic activity. In the Mediterranean, the Alboran Sea (Spain), the Balearic Sea (Spain), the Gulf of Lyon (France) and the Ionian abyssal plain are especially important. As far as the Atlantic is concerned, seamounts can be found in the Mid-Atlantic Ridge including the European territories of Azores (Portugal), Madeira (Portugal) and Canary Islands (Spain). The first protected seamount is located in Azores (Portugal) and is an especially notable for its marine biodiversity, as are the Josephine and Gorringe Banks. Oceana carried out an expedition in this last location in 2005.

The distribution of species, the levels of endemism determined by tectonic characteristics, the biological importance of these ridges and seamount ranges may indicate that they provide linking areas serving as connections for both resident and migratory species. Because of this, they can be used as a basic methodological tool to assess and evaluate the potential ecological networks combined with reproductive strategies of larval dispersion. As such, they are true "*stepping stones*", acting as connections between the most important ecological habitats for various species, in the same way other biogenic habitats do, such as coral reefs.

Associated communities

The distribution of species in seamounts is distinctly different compared to the surrounding sea floors and the continental margins of similar depth. Due to a decrease in currents around the surface of the seamounts, the rocky substrata provide ideal conditions for emergent epifauna such as corals, crinoids and sponges. Some deep sea corals and sponge fields may be thousands of years old and can form complex structures.[2]

In the Mediterranean, the presence of scleractinian corals has been confirmed on coral patches at 355 to 410 meters depth in the Tyrrhenian Sea (Italy), northeast of the Tuscan Archipelago between the islands of Gorgona and Capraia. The largest bio constructing colonial coral is the species *Madrepora oculata* in association with the solitary coral *Desmophyllum dianthus* and the colonial coral *Lophelia pertusa*. Some of these bio formations date back to the end of the Pleistocene.[3] These deep-sea coral mounds, colonisers of muddy sediments in the continental slope, represent one of the few examples known in the Mediterranean.

Seamounts receive much attention mainly due to the collection of fish that take advantage of the benefits these areas offer for deep sea and semi-

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fishing technologies can be used, making these areas prone to exploitation. Due to this fact and based on historic data and the ecological characteristics of these habitats, various authors now consider the ichthyic communities to be extremely vulnerable.

Biological sampling reveals the presence of a unique biocenosis, in the sense that it is both representative and rare, including the presence of a variety of invertebrates amongst which interesting coral species can be found such as *Caryophyllia calveri* and *Desmophyllum cristagalli*. Cold water corals may be particularly abundant including the presence of gorgonian, scleractinian and antipatharian corals.

The Gorringe Bank[4] (Azores, Portugal) is especially important due to its high levels of endemism and provides the ideal conditions for the growth of suspension feeders. Gorgonian and scleractinian corals can be found in this location and Oceana, as already mentioned, had the opportunity to carry out research to document these

species during a segment of its transatlantic expedition. Another example is the Great Meteor Seamount located in the Mid-Atlantic Ridge that reveals the existence of different megafaunal taxa including sponges such as *Haliclonia* sp., species of gorgonian corals such as *Elisella flagellum* and the antipatharian and madreporarian corals, *Antipathes glabberima* and *Dendrophyllia cornigera.*

At the same time, the presence of *Dendrophyllia cornigera* has been identified amongst the antipatharian corals, located between 400 and 500 meters depth, as well as other coral species such as *Aulocyathus atlanticus* and *Balanophyllia thalassae*, inhabiting the Le Danois Bank in the Cantabrian Sea. Other species found on seamounts include sponges, hydroids and ascidians, crinoids, asteriods, ophiuroids, holothurians, molluscs and decapods[5].

The pelagic communities reveal quantitative and qualitative differences when compared to the surrounding waters. The larger part of the biomass of planktonic organisms constitutes the main diet for fish, squid and large predators such as sharks, rays, tuna and swordfish. Both large and small cetaceans, as well as sea turtles, participate in this highly productive food chain.

The main hypothesis that explains the increased concentration of plankton in these habitats is the localised upwellings of cold water that transport nutrients to the surface, increasing productivity and leading to veritable traps of advected plankton in circulation cells, known as Taylor columns.[6]

The ichthyic fauna presents a series of morphological, ecological and physiological[7] characteristics that allow it to successfully take advantage of an environment where currents and elevated concentrations of organic[8] material play a very meaningful role.

This fauna is essentially characterised by its longevity and slow growth rate. These species of teleosts include the orange roughy (*Hoplostethus atlanticus*),[9] the roundnose grenadier (*Coryphaenoides rupestres*),[10] *Sebastes* spp., *Pseudocyttus maculatus* and *Allocytus niger*.[11]

The most abundant species come from the *Macrouiridae, Berycidae, Alepocephalidae, Moridae, Gadidae, Trachichthydae, Squalidae, Scorpaenidae, and Lophiidae*[12] families, including more than 70 commercially[13] valuable species, amongst others: *Pseudopentaceros wheeleri, Beryx splendens, Sebastes rosaceus, S. variegatus, S. jordani, Thunnus albacares, Parathunus obesus; the crustaceans, Jasus tristani, Lithodes couesi*.

On the Galicia Bank, at depths over 900 meters, 70 species of teleosts have been found, as well as 11 species of sharks, three rays, two chimaeras, 11 crustaceans, six molluscs and three species of echinoderms. The most important species have already been mentioned for other locations, such as the teleosts, *Hoplostethus mediterraneus, Mora moro, Lepidion eques, Alepocephalus bairdii, Epigonus telecopus; the elasmobranchs,*[14] *Dalatias licha, Deania calceus, and the crustacean, Chaecon affinis.*

These locations have high concentrations of plankton or ichthyic biomass[15] and as such, are important fee ding areas for migratory species such as fish and marine mammals16 A wide variety of species has been found in other locations within the North-East Atlantic, for example in the Hatton Bank.[17] In the case of the Azores (Portugal), *Balaenoptera physalus, Physter macocephalus, Delphinus delphis, Tursiops truncatus* and various marine birds (*Puffinus gravis, Calonectris diomedea borealis*) can be found here.

The ecological significance of seamounts as far as large predators are concerned is emphasised by the fact that far-ranging pelagic species concentrate in these areas for mating and spawning. An example of this is the Formigas Bank in the Azores that attracts groups of small cetaceans such as the bottlenose dolphin (*Tursiops truncatus*), the common dolphin (*Delphis delphis*), the spotted dolphin *(Stenella frontalis*) and pilot whales (*Globicephala* sp.); and an especially high concentration of loggerhead turtles (*Caretta Caretta*) [18]

Other marine communities also concentrate in these areas for feeding. For example, in the Chella Bank area (Almeria, Spain),[19] certain species of cetaceans gather to feed due to its high concentration of nutrients.

Relation to other habitats of community interest

Seamounts constitute a type of habitat that should be valued by the community of the European Union given their scientific value and because they harbour unique ecosystems, often including a "disproportionate" quantity of biodiversity for their size/surface area.[20]

Although some publications point out that the Natura 2000 network will include seamounts in its Annex I denoted as reefs according to the Habitats Directive, it is once again evident that the specific ecological characteristics of this type of habitat should be taken into consideration independently.

Nevertheless, reefs are included within the habitats known as seamounts (Code: 1170), although other types of valuable habitats are also included, such as submarine structures made by leaking gases (Code: 1180) and submerged or partially submerged sea caves (Code: 8330).

According to EUNIS classification, seamounts correspond to the types of habitats included in code A6.7:

A6 Deep-sea bed
A6.7 – Raised features of the deep-sea bed
- **A6.71** – Permanently submerged flanks of oceanic islands
- **A6.72** – Seamounts, knolls and banks
- **A6.73** – Oceanic ridges
- **A6.74** – Abyssal hills
- **A6.75** – Carbonate mounds

Degree of vulnerability

These habitats are known not only as areas of high productivity, but also as areas in which fragile habitats are located that are especially vulnerable to fishing activities[21, 22] and other human activities.

The biological communities in some areas are also endangered, mainly due to fishing activities. Through investigations at approximately 100 meters depth, Oceana has seen the specific biological diversity in the ecosystems of the Chella Bank (Almeria, Spain), and the disturbance suffered here by the benthic communities. If certain activities would cease, such as trawling, these communities could regenerate.

The most significant threat in terms of geographic distribution is commercial fishing, which can lead to the destruction of both target and non-target species.[23] Because of these threats, changes occur in populations as well as alterations in the dynamics of populations and the structure of associated communities. Other physical damage observed includes changes in the type of substrate, including alteration of granulometry. The elimination of substrate and an increase in sedimentation has also been observed in certain areas.

The scale of impact on target species of long lining fisheries and bottom trawling fisheries[24] capable of carrying out activities at depths over 1,500 meters is quite high and affects species such as *Brosme brosme, Molva dypterigya, Mora moro, Hoplostethus atlanticus*[25] and *Deania calceus*.

More than 76 species of fish have been overexploited, including other species beyond those mentioned above, such as *Coryphaenoides rupestris, Sebastes* spp. and *Beryx splendens*. Many of the fisheries of these species have developed quickly and the fish populations have declined significantly in only one decade despite efforts made by the regional fishery commissions and the bilateral and multilateral agreements to improve fisheries management.

Furthermore, there is global concern regarding the irreversible damage to benthic communities caused by trawling. These fragile communities require urgent protection.

Cold water corals are located in especially productive areas and high levels of biodiversity can be found here. These habitats are targeted by conservation efforts in an attempt to avoid their destruction by bottom trawling fishing activities. Directly or indirectly, trawling constitutes a major threat to this habitat.

Some countries have begun to include the protection of these associated benthic communities, as well as this type of habitat,[26] in their national legislation, designating seamounts as marine protected areas or areas where fishing activities are restricted. These areas are established as marine reserves with valuable fishing resources. Current trends indicate the need to protect seamounts in international waters and extensive scientific awareness is necessary to support these proposals for protection.

Although not as impending as fishing activities, another threat is pollution from chemical spills, which is the main cause of the high level of contaminants found in large predatory species. Ballast waters, mining[27] and polymetallic sulphide spilling, along with noise pollution and bioprospecting, make this type of habitat and its associated species especially vulnerable.

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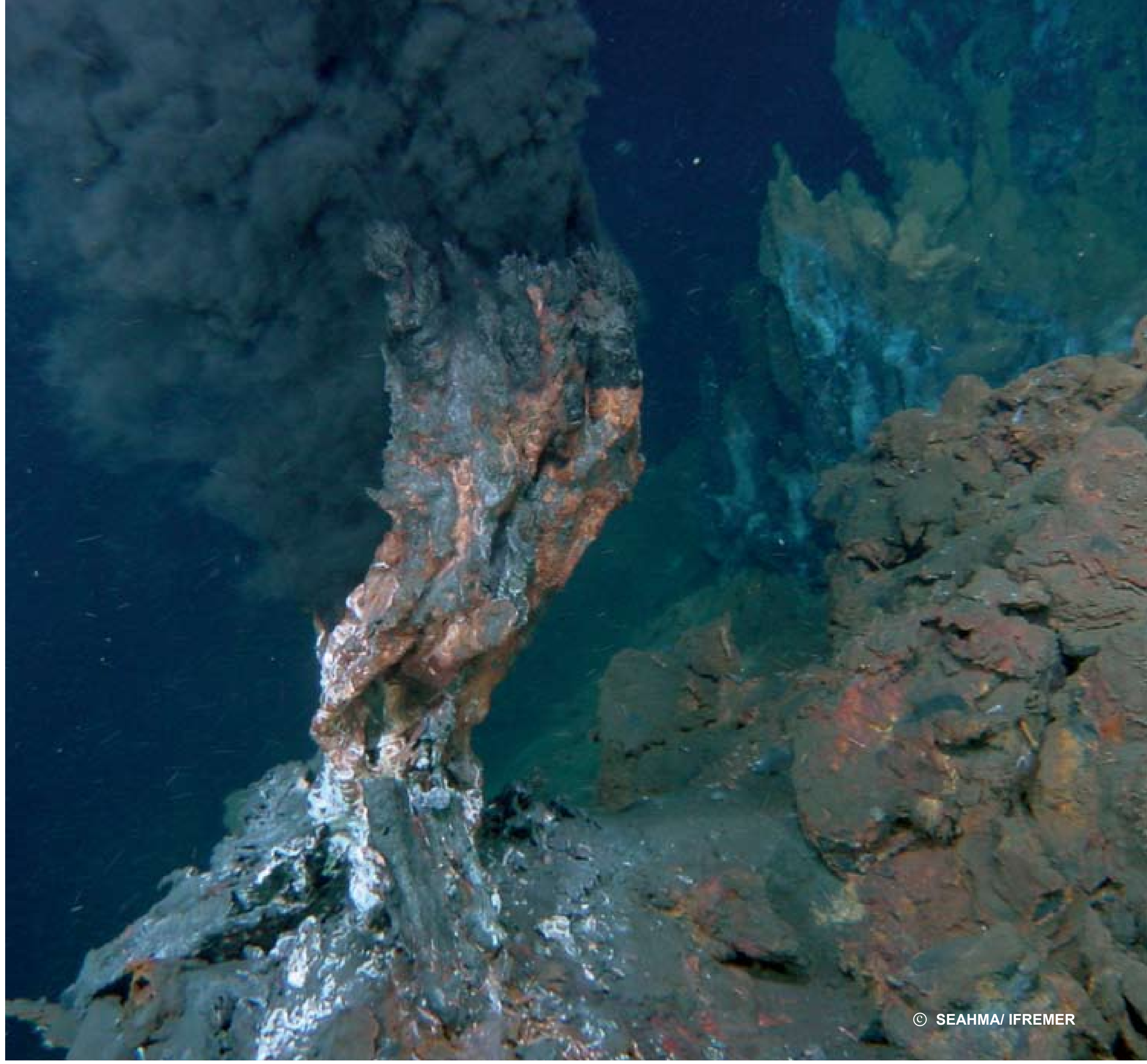
Other important aspects

The high levels of endemism and the considerable diversity of species make these types of habitats hotspots for biodiversity. This is mainly due to the retention of larvae in the surrounding areas and the subsequent attraction of predators that arrive to take advantage of the higher primary production in these areas compared to other parts of the abyssal plain or pelagic areas in the open seas.

The mechanisms for faunal dispersion in oceanic basins are still largely unknown and may present key aspects for a better understanding of deep-sea marine fauna biogeography. Seamounts may act as true "regional" centres for speciation, as well as valuable locations for



Constructive gases 2

Characteristics

Constructive gases are very complex structures comprised of blocks, slabs and columns originating from the addition of granules of sand to a carbonate matrix, which originates from microbial oxidation of gas emissions, mainly methane.

The gases emanate from the decomposed vegetable fossils and intermittently escape toward the surface by means of the many orifices in these structures. There is a type of undersea structure associated with gas emissions that is related to coral reefs. These are usually located in water shallower than the second type of associated structure, which corresponds to the hollows formed by gas seeps. These formations harbour diverse benthic communities comprised of algae and invertebrates, the latter of which is the most common inhabitant of the hard substrata found in this type of habitat. Ecologically, these benthic communities are completely different from the communities found in the surrounding areas. A number of topographical structures can be found in this type of habitat, such as overhangs, pillars and vertical walls. Numerous caves harbour a large part of the communities of both moving and sessile fauna. As such, this type of habitat contributes to increasing the rates of biodiversity.

The second type of carbonate structure corresponds to depressions in areas of sandy sediments, over 45 meters deep and a few hundred meters wide.

The methane hydrates stored in water molecules form clathrates. Today, the main part of the methane reserves in clathrates, located in the continental margins, are regarded as potential sources of hydrocarbon, although key environmental issues must be resolved regarding this point.

A gas hydrate is an association of water and methane at high pressure and low temperature and when these conditions are met, a crystalline structure is formed in which various water molecules surround a methane molecule. Macroscopically, these structures resemble ice and can be found at depths over 1,000 meters, located outside the continental shelf.

Coldwaterseeps,1aswellascarbonatehillsandmounds, are closely associated with tectonic activity. These are veritable natural laboratories used to understand the paleoecologyandtaphonomyofcarbonateecosystems.

Cold water carbonate seeps are geochemical archives of methane gas emanations and destabilisation of undersea gases.

Cold gas seeps, associated with tectonic structures such as mud volcanoes, constitute especially interesting deep-sea habitats.

They sustain unique ecosystems based on methane oxidation as the primary source of carbon and energy. They are dominated by microbes and communities of bivalves and highly specialised tube worms.[2]

Distribution

Examples of biologically active biocenoses in cold seeps associated with mud volcanoes have been located in the Levant Sea and also recently in the western Mediterranean around the Balearic Islands (Spain) and near the Rhone Delta (France).

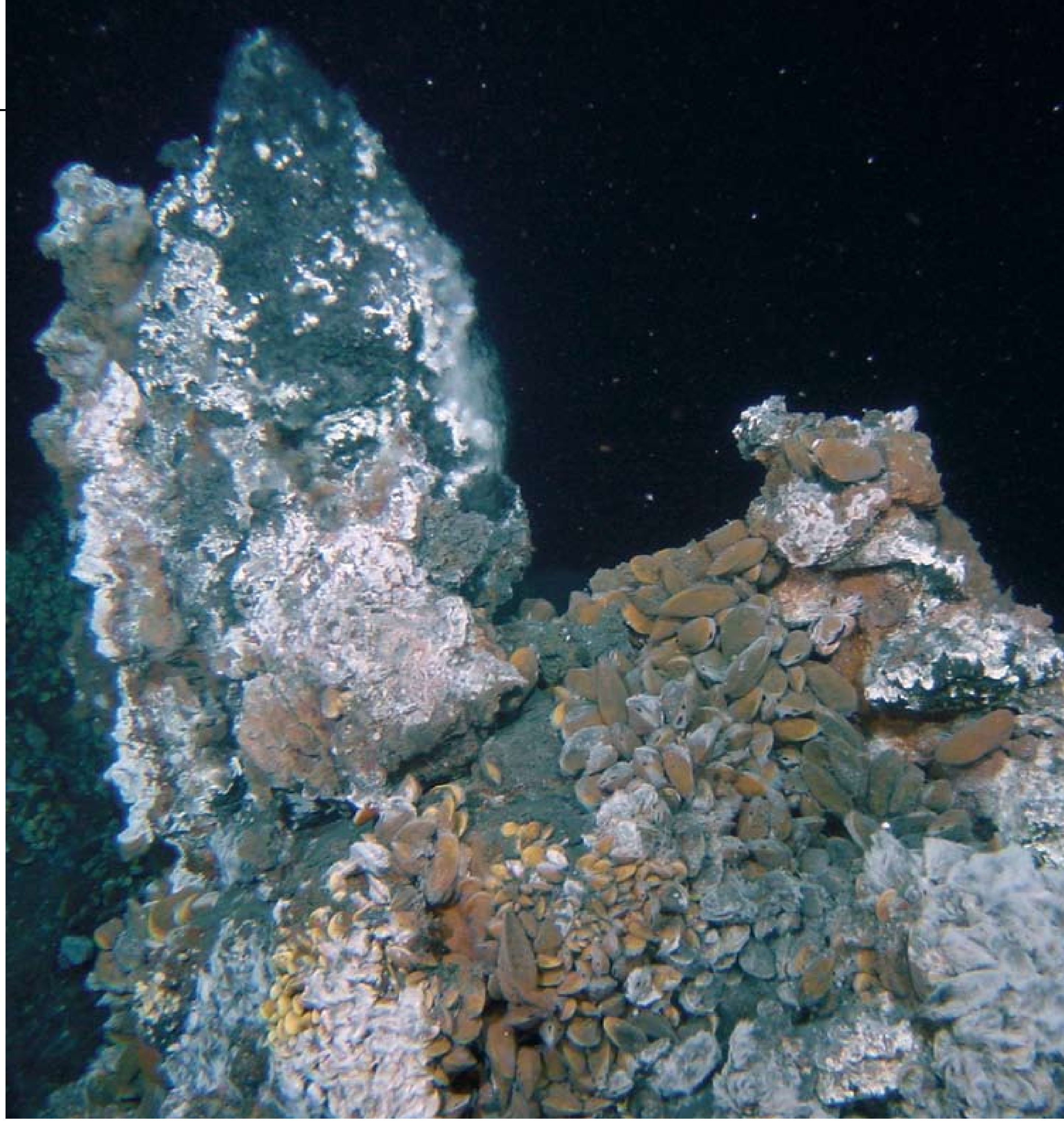
Active hydrothermal sediments can be found in locations where mounds and chimneys[3] are formed and where, at the same time, the earth's crust is formed. Vesteris, located in the Greenland Basin (Denmark), is an isolated undersea volcano that has recently shown hydrothermal activity.

João de Castro (Azores, Portugal) is one of the few known places where hydrothermal venting takes place at intermediate depths and Oceana documented these geomorphological formations during an expedition in 2005.

Examples of gas seeps in shallow waters,[4] colonised by macroalgae and invertebrates, have been observed at depths between zero and 30 meters (sublittoral areas), in northern Kattegat and in Skagerrak (Denmark, Norway and Sweden).

Aerobic methane oxidation within sediments is restricted to 4 centimetres in muddy sand and 13 centimetres in areas where the sand is thicker and more compact. Although gas seeps are usually found at greater depths,[5] they contribute significantly to the cycle of the elements within the sediment and in the water column.

Rocky seabeds harbour a wide range of diverse ecosystems formed by various organisms, from

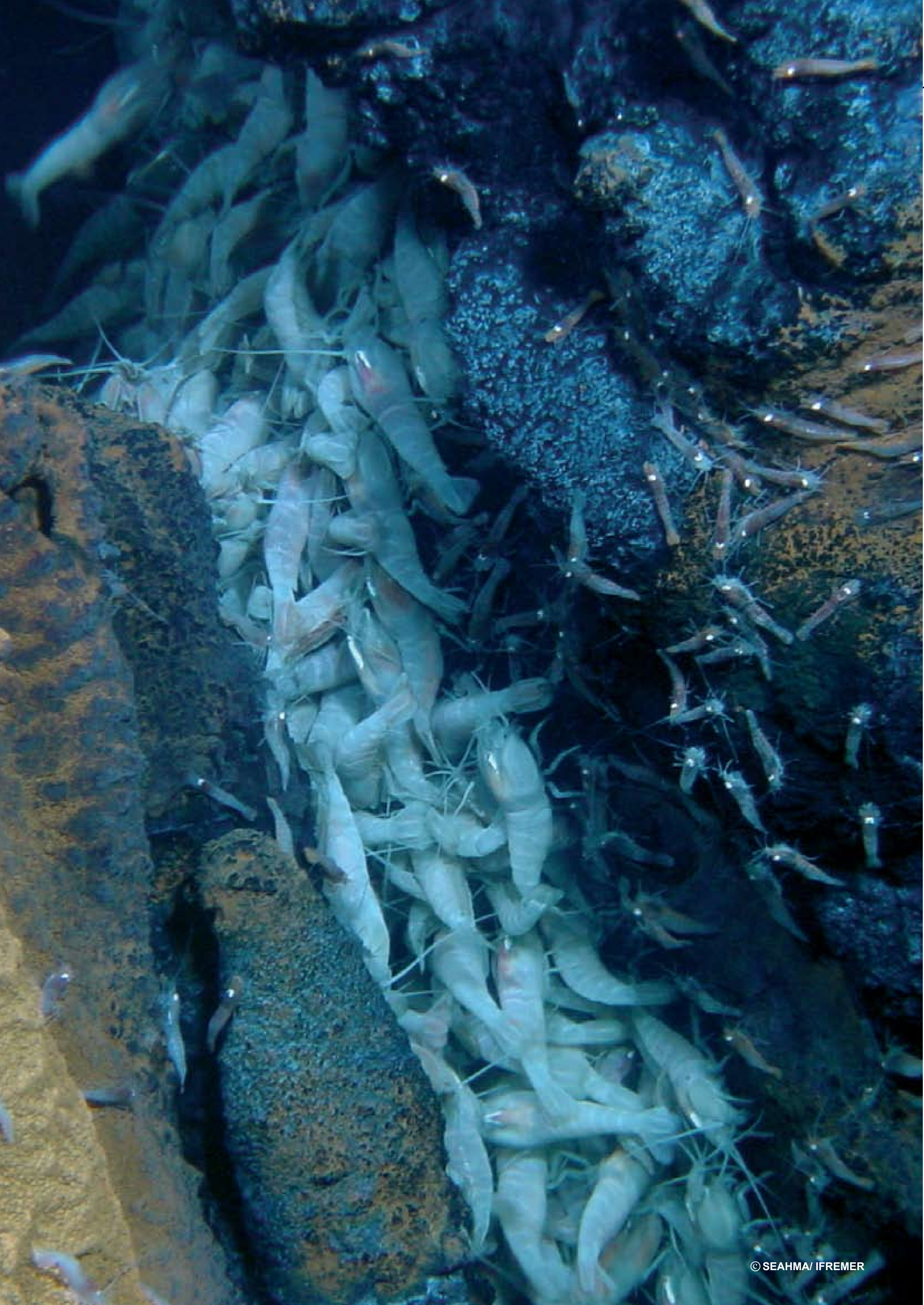


bacteria to macroalgae and Anthozoa. They are located within depressions on the seabed with soft substrata and can reach up to 45 meters in depth, with a variable width of over 100 meters typically.

Other types of structures are located in deeper waters and contain related benthic fauna which is highly specialised.[6] Depressions, with predominantly muddy sea floors, can be found at 100 meters depth in various marine ecoregions within European territory, such as in the waters of the North Sea (under jurisdiction of the United Kingdom).

Examples of extensive areas with these structures have been located on the Atlantic coast of Galicia (Spain)in shallower waters than the structures in the North Sea. They have also been found in the area surrounding the Straits of Gibraltar, in the Alboran Sea and the Gulf of Cadiz (Spain), in Fladen and Witch Grounds (North Sea) and in the Irish Sea.

The Lucky Strike and Menez Gwen hydrothermal vents (Azores, Portugal)[7] are the largest hydrothermally active areas known in the world.



Associated communities

Many organisms live within the rocks previously perforated by sponges, polychaete annelids and bivalves, directly contributing methane that feeds these biological communities.[8]

In terms of abundance, diversity and biomass, the sediments located around gas seeps are poor as a result of the toxicity produced by the release of hydrogen sulphide from methane emissions.[9]

The benthic communities are mainly comprised of invertebrate species specialised in the colonisation of hard substrates: hydrozoans, anthozoans, ophiuroids and gastropods.

These communities are different compared to the communities found on the muddy sea floors that surround these structures, where nematodes, polychaetes and crustaceans can be found.

There may also be high levels of diversity amongst the infauna, especially regarding communities of organisms found buried in the muddy sediments located on the slopes surrounding these structures.

The species associated to the structures located in more shallow regions such as Kattegat (Denmark)[10] include various fish: *Agonus cataphractus, Cyclopterus lumpus, Gadus morhua, Myoxocephalus scorpius, Syngnathus arus* and the most commercially valuable flat fish in Europe, *Pleuronectes plateas.*

As far as the invertebrates are concerned, the following crustaceans can be found: *Cancer pagurus, Carcinus maenas, Pagurus bernhardus*; the echinoderm, *Asterias rubens*; the anemone, *Metridium senile*; the scyphozoans: *Aurelia aurita, Cyanea capillata*; the anthozoan, *Alcyonium digitatum*,

If the structures formed by seeping gases are located in the euphotic zone, some macroalgae such as Laminaria (brown algae) and other green filamentous algae, such as some species of red algae, may be present.

As far as the faunal communities associated with these structures are concerned, a wide variety of invertebrates can be found such as poriferans, anthozoans, polychaetes (*Polycirrus norvegicus*), gastropods, bivalves (*Kellia suborbicularis*), decapods, echinoderms as well as numerous fish species.

The structures related to seeping gases located at greater depths[11] do not generally harbour vegetable communities. The fauna is comprised of specialised invertebrates that thrive on hard or rocky substrata, represented by some species of hydrozoans, anthozoans, ophiuroids and gastropods. Nematodes, polychaetes and crustaceans can be found on the soft or sandy sediments located around these structures.

An example found in Lucky Strike (Azores, Portugal) are the hydrothermal vents characterised by the formations of mollusc reefs, *Bathymodiolus azoricus*,[12] covering the surface of hydrothermally active hydrogen sulphide, as well as the cracks located on the seabed from where water seeps at high temperatures.

Relation to other habitats of community importance

This type of habitat is related to habitat 1180, which corresponds to submarine structures made by leaking gases (PAL.CLASS.: 11.24). It is necessary, however, to point out that some structures formed by leaking gases located in the sublittoral area and in deeper waters may also be associated with sandbanks which are slightly covered by sea water all the time (Code: 1110) and to reefs (Code: 1170).

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Not all of these structures are formed by leaking gases nor carbonates and these are the structures that are not included in Annex I of the Habitats Directive.

According to EUNIS classification, these types of habitats correspond to section A3.C:

A3.C Vents and seeps in sublittoral rock

-A3.C1 - Bubbling reefs in the sublittoral euphotic zone
- A3.C11 - Bubbling reefs in the sublittoral eupohtic zone with little or no macrophyte vegetation.

- A3.C12 - Bubbling reefs in the sublittoral eupho-tic zone dominated by macrophyte vegetation.

-A3.C2 - Bubbling reefs in the aphotic zone
-A3.C3 - Freshwater seeps in sublittoral rock
-A3.C4 - Oil seeps in sublittoral rock
-A3.C5 - Vents in sublittoral rock

A2 Littoral sediments.

A2.8 - Features of littoral sediments
-A2.81 - Methane seeps in littoral sediments

A3 Infralittoral rock and other hard substrata

A3.7 – Features of infralittoral rock
-A3.73 - Vents and seeps in infralittoral rock

- A3.C12 - Bubbling reefs in the sublittoral euphotic zone dominated by macrophyte vegetation

A4 Circalittoral rock and other hard substrata

A4.7 - Features of circalittoral rock

-A4.73 - Vents and seeps in circalittoral rock

A5 Sublittoral sediment

A5.7 - Features of sublittoral sediments
-A5.71 -Seeps and vents in sublittoral sediments

The habitats related to seeping gases in the deep-sea are included in section A6.9: vents, seeps, hypoxic and anoxic habitats of the deep sea.

A6 Deep-sea bed

A6.9 - Vents, seeps, hypoxic and anoxic habitats of the deep sea .

-A6.91 - Deep-sea reducing habitats
-A6.92 - Deep-sea bed influenced by hypoxic water column
-A6.93 - Isolated "oceanic" features influenced by hypoxic water column
-A6.94 - Vents in the deep sea

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Degree of vulnerability

Gas hydrates are an alternative source of energy with worldwide potential. The reserves of gas hydrates are estimated to be twice that of currently known renewable conventional natural gas resources and because of this, feasibility studies are taking place in these areas into the possibility of exploiting this resource. Irreparable damage to the environment may be caused by such exploitation because gas hydrates are not renewable.

Interest in bioprospecting these areas is beginning to increase due to the importance of these reserves to certain specialised faunal communities living around the hydrothermal vents. This may lead to excessive sampling and the subsequent destruction of the habitat.

Other important elements

The economic potential of these ecosystems leads to unsustainable extraction methods, altering the ecosystems that make up these structures, as mentioned in the paragraph above.

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3 Caves, caverns and overhangs

Characteristics

Caves exist on all floors with rocky substrata, although they are more frequently found in karst or volcanic (tube) areas rather than in areas presenting harder substrata (granites).

Both infralittoral and circalittoral permanently submerged caves have similar conditions to the circalittoral seabed. Essentially, the conditions are based on a gradual decrease in light at the entrance to the cave, total absence of light within the cave and low temperature.

Other factors, such as currents, dissolved oxygen and nutrients depend on the cave's shape and condition. This is because the supply of oxygen and nutrients depend on the movements of the water, the elimination of waste and the dispersion of larvae.

The representative marine faunal communities include some species of invertebrates, while algae constitute the flora present in these geomorphological habitats.

There is an absence of primary producers, except in the entrance to the caves, making the associated communities similar to those in deep-sea habitats. Due to the lack of primary producers, herbivores are non-existent and predators are scarce.

Nutrients are not usually abundant and the currents that supply them are usually irregular, so filter feeders[1] are plentiful, especially when the currents transport nutrients (plankton and detritus) to the interior of the cave. Detrivores are commonly found.

Distribution

Marine caves rarely develop in siliceous areas, where they are reduced to mere cavities caused by the movement of waves.

On rocky coasts, such as that of Gibraltar,[1] the portion of the coast that is subjected to marine and continental processes depends on the relative situation of the sea level. The evolution of the slopes and the karst system are also related to changes in sea level, corresponding to the base level.

On this type of isolated rocky coast, marine and phreatic levels define a reference morpho-genetic surface with the following sequence of structures: abrasion platform – cave/notch – cliff – slope. This sequence may temporarily repeat itself along the length of the mountain flanks, generating erosive superpositions or staircased structures.

The development of an abrasion platform on hard rocks and its accompanying cliff requires a series of lithological, climatic and dynamic marine conditions.

Their distribution[2] usually coincides with calcareous mountain massifs that frequently continue into the water and sporadically emerge in the shape of archipelagos.

This type of habitat is mainly found in calcareous coastal regions, as in the Iberian Peninsula (Portugal, Spain), the Balearic Islands (Spain), as well as in Ceuta (Spain) and the volcanic coasts of the Canary Islands (Spain).

Associated communities

The lack of light prevents the development of photosynthetic organisms, which are relegated to adjacent seabeds. This type of habitat, however, harbours rich and scientifically valuable fauna.

Many of the faunal species are nocturnal and use the caves as refuge during the day, while others are exclusively cave-dwelling.

The walls of the caves are covered by sessile epibenthic invertebrates such as sponges, cnidarians and tunicates. The following species can be found in these habitats: ophiuroids (*Ophiotrix fragilis, Ophioderma longicaudatum*), holothurians (*Holoturia tubulosa*) and decapod crustaceans such as lobsters (*Palinurus elephas*), slipper lobsters (*Scyllarus arctus*) or sponge crabs (*Dromia personata*).

A group of small cave-dwelling crustaceans are especially interesting from a biogeographical perspective, including coral shrimp (*Stenopus spinosus*), the crab (*Herbstia condyliata*) and various species of small mysids (*Hemimysis spelunicola, H. margalefi, Pyroleptomysis peresi*).[3]

The ichthyic community is represented by cardinal fish (*Apogon imberbis*), leopard-spotted gobies (*Thorogobius ephippiatus*), blackbelly rosefish (*Helicolenus dactyloterus*), forkbeards (*Phycis phycis*), conger eels (*Conger conger*) and brown meagre (*Sciaena umbra*).

The following section includes a reference classification organized by parameters such as depth and availability of light, which corresponds to the biocenoses present in these structures,[4] located in various biogeographical regions. Depth is a predominant factor in the composition of the communities.

Biocenosis of semi-dark caverns, overhangs, crevices and cave entrances and tunnels

This biocenosis is present in areas where algae are scarce or non-existent. It is comprised of many species that make up the intermediate stratum of the coralline community. It appears at any depth where the rock forms a cavity and there is enough darkness.

Some of the representative species of flora include algae,[5] *Palmophyllum crassum, Peyssonnelia rosamarina, P. rubra* and *Lithophyllum expansum.*

The faunal communities are represented by sponges: *Clathrina clathrus, Spirastrella cunctatrix, Acanthella acuta, Reniera mucosa, R. fulva, Ircinia dendroides, Oscarella lobularis, Chondrosia reniformes, Agelas oroides, Hexadella racovitzai, Diplastrella bistellata, Axinilla damicornis, Phorbas tenacior* and *Petrosia ficiformis.*

Some of the cnidarians include: *Sertularella crassicaulis, Parazoanthus axinellae, Caryophyllia inornata, Polycyathus muellereae, Cornularia cornucopiae, Leptosammia pruvoti, Caryophyllia smithii, Epizoanthus arenaceus, Madracis pharensis* and *Hoplangia durotrix.*

And the polychaetes: *Myxicola aesthetica, Filigrana implexa, Serpula vermicularis, Protula tubularia* and *P. intestinum.*

The molluscs are represented by Alvania montagui, *Hypselodoris elegans, Striarca lactea, Berthella aurantiaca, B. ocellata, Peltodoris atromaculata, Lithophaga lithophaga, Barbatia barbata* and *Lima lima.*

The crustaceans are represented by *Palinurus elephas, Dromia personata, Scyllarides latus* and *Scyllarus arctus.*

Some of the bryozoans include *Cellaria salicornioides, Smittina cervicornis, Sertella septentrionalis, Bugula calathus, Schizomavella auriculata, Margaretta cereoides, Adeonella calveti* and *Savigniella lafontii.*

The echinoderms are represented in this habitat by *Centrostephanus longispinus*[6] and *Holothuria sanctori.*

Amongst the ascidians, *Clavelina nana, Ascidia mentula* and *Halocynthia papillosa* can be found.

The ichthyic community[7] is represented by *Muraena helena, Anthias anthias, Apogon imberbes, Conger conger, Epinephelus marginatus, Scorpaena scrifa, Phycis phycis* and *Sciaena umbra.*

Many of the species found in caves are common to areas where the coralline community is located and are highly adapted to specific environmental conditions.

Biocenosis of semi-dark caves located in the entrance to deeper caves, overhangs, vertical walls, crevices, cornices or cave entrances and tunnels.

This presents a mat comprised of various facies. It is represented by cnidarians, anthozoans such as *Parazoanthus axinellae* in areas where sunlight is present; *Corallium rubrum* on the roof of the entrance, overhangs and dark crevices; *Leptosammia pruvoti, Agelas* sp. and *Spirastrella cunctatrix* in overhangs and cave entrances.

The madreporarians *Polycyathus muellerae, Caryophyllia inornata* and *Hoplangia durothrix* are located in the darkest areas. The bryozoan, *Sertella septentrionales*, can be found in the cave entrances. The hydrozoans are represented by species belonging to the *Sertularella* and *Eudendrium* families.

Biocenosis of caves in total darkness, located on vertical walls or in tunnels.

Certain species of algae are located at the entrance: *Lithophyllum frondosum, Peysonellia rubra, P. coriacea, P. rosamarina* and *Palmophyllum crassum.*

Sponges are commonly found, especially the following species: *Spirastrella cunctatrix, Oscarella lobularis, Agelas ovoides, Spongionella pulchella, Ircinia dendroides,*[8] *I. spinulosa, Chondrosis reniformes, Suberites carnosus* and *Acanthella acuta.*

As far as cnidarians are concerned, the anthozoans *Corallium rubrum Leptosammia pruvoti, Rolandia rosea, Hoplangia durothrix, Parazoanthus axinellae*[9] and *Cariophyllia inornata* are present.

The hydrozoans are not well adapted. The most common species are *Eudendrium racemosum* and *Campanularia bicuspidata.*

The tube polychaetes are represented by *Serpula vermicularis, Pomatoceros triqueter, Myxicola aesthetica, Spirobranchus polytrema.* Amongst the moving polychaetes, the detrivores or carnivores, the following species can be found: *Ceratonereis costae, Glycera tessellata, Lumbrinereis coccinea* and *Lisidice ninetta.*

Amongst the molluscs, the gastropods are represented by: *Calliostoma zizyphinum, Clanculus corallinus, Lurida lurida*; the bivalves are represented by the following species: *Lithophaga lithophaga, Acar pulchella* and *Barbatia barbata.*

Amongst the crustaceans, the following species are present: *Homola homola, Scyllarus arctus, Scyllarides latus, Palinurus elephas, Homarus gammarus, Maja verrucosa, M. crispata, Dromia vulgaris* and *Galathea strigosa.*

The amphipods and isopods live in association with sponges or other organisms.
The bryozoans are very diverse and abundant, as is the case with the following species: *Sertella septentrionalis, Crassimarginata maderensis, Cribillaria radiata, Prenantia inerme* and *Adenella calveti.*

The echinoderms are represented by families of starfish, *Marthasterias glacialis,*[10] *Coccinasterias tenuispina*;[11] the ophiuroids, *Ophiocomina nigra, Ophioderma longicaudum*; sea urchins, *Centrostephanus lonsgispinus*;[12] and holothurians, *Holothuria sanctori.*

The ascidians are represented by *Pyura vittata, P. dura, Cystodites dellechiajei, Didemnum maculosum, Clavelluna nana,* and representatives from the *Brotyllus* and *Diplosoma families.*

The ichthyic fauna[13] is represented by the following species: *Anthias anthias, Apogon imberbes, Scorpaena porcus, S. notata, Gobius niger*. Some species use these places as hideouts, as is the case with the conger eel (*Conger conger*), the dusky grouper (*Epinephelus marginatus*), the brown meagre (*Sciaena umbra*) and the Serranidae family of fish.

Biocenosis of caves in total darkness.

Two distinct communities can be identified: one is located at the entrance to the caves, where a small amount of light is present, and the other is located inside the caves, in total darkness. As such, there are no coralline algae here, only filter-feeding sessile invertebrates and some fish or crustaceans that use these places as refuge.

The composition of the faunal community of the caves in total darkness is similar, although the quantity of species varies. The cnidarians and bryozoans are small due to the lack of nutrients.


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Usually, the sponges do not have pigmentation and are laminar. In many cases, they have different shapes compared to the species that grow in the presence of sunlight. Some representative species include: *Penares helleri, Rhabderemia minutula, Verongia cavernicola, Reniera valliculata, R. sari, Diplastrella bistellata, Petrosia ficiformis, Anchinoe tenacior and species from the Haliclona family. Occasionally, Discodermia polydiscus appears, from the bath al region, Petrobiona massiliana* and *Pectoronimia hindei*.

The cnidarians may form characteristic facies and include *Guynia annulata, Conotrochus magananii, Polycyathus muellerae* and *Madracis pharensis*.

The sessile polychaetes are the most abundant and include *Omphalopoma aculeata, Vermiliopsis monodiscus, V. infundibulum,* and other *serpulids*.

The most characteristic gastropods include *Alvania reticulata, Homalopoma sanguinea, Bouvieria aurantiaca, Pleurobranchus testudinaria, Peltrodoris atromaculata* and *Discodoris cavernae*.

Crustaceans are rare, although the following species can sometimes be found: *Aristias tumidus, Herbstia condylata, Stenopsus spinosus, Palaemon serratus* as well as large quantities of mysidaceans that comprise the zooplankton.

The bryozoans are more common, especially the following species: *Celleporina lucida, Crassimarginatella crassimarginata, Setocellina cavernicola* and *Coronellina fagei*.

Amongst the echinoderms, *Ophiopsila aranea* and *Genocidaris maculata* can be found.

Within the ichthyic community, the *Oligopus ater* from the brotulidae family is present in this habitat.

Biocenosis of infralittoral caves

Red algae such as *Plocamium cartilagineum, Kallymenia* reniformes and *Pollyphora crispa* are usually located in the entrance to infralittoral caves, and in some cases laminar algae can also be found. Underneath these algae, coralline algae are fixed to the rocky substrata.

Currents are present in these areas of less sunlight and various sponges dominate here such as *Clathrina coriacea, Leucolenia brotyoides, Halichrondria panacea, Reniera rosea* and *Acanthella acuta*.

Amongst the hydrozoans, the *Nemertesia antennina* can be found. There is significant presence of the anemones, *Sagartia elegans* and *Metridium senile*.

Some representative anthozoans include *Parazoanthus axinellae, Epizoanthus arenaceus, Leptosammia pruvoti* and *Gerardia savaglia*.

Other species present in this habitat include the spirorbid polychaetes; the cirripod, *Balanus crenatus; the bryozoan, Pentapora fascialis; the crinoids,* and *Antedon bifida*.

Amongst the ascidians, *Polyclinum auarantium, Dendrodoa grossularia, Clavelina lepadiformis, Morchellium argus* are present as well as other species from the *Didemnidae* family.

Amongst the free moving animals, the European lobster (*Homarus gammarus*), *Scyllarides* latus and *S. arctus* can be found, as well as various species of fish, such as the greater forkbeard (*Phycis blennoides*).

Biocenosis of circalittoral caves.

Sponges such as *Dercitus bucklandi* and the following anthozoans can be found in circalittoral caves: *Caryophyllia inornatus, Hoplangia durothrix, Parazoanthus* spp.

The representative species of sponges present in caves in total darkness as well as deep-sea cave walls,14 roofs and tunnels include *Chondrosia reniformes, Spongionella pulchella, Petrosia ficiformis, Coralistes nolitangere, Lacazella* sp. and *Ircinia* spp.

Algae are scarce and the species present in this habitat is usually calcareous algae located in the entrance to the caves such as *Peyssonnelia* spp. and *Lithothamnium* sp.

The anemone *Telmatactis cricoides* is another representative species of this habitat, as well as the corals *Madracis asperula, Phyllangia mouchezii, Parazoanthus axinellae, Leptosammia pruvoti, Caryophillia inornata; the bivalve, Spondylus senegalensis; the bryozoan, Reptadeonella violacea; the ascidians, Ciona intestanilis* and *Halocynthia papillosa.*

Moving fauna is represented by the echiuran, *Bonellia viridis*, which usually lives amongst the crevices of the rocky seabed or detritus at ten to 100 meters depth, and only the trumpet can be seen peeking out of the crevices.

The presence of *Octopus vulgaris* must be mentioned, as well as the crustaceans *Enoplometopus callistus, Stenopsus spinosus, Plesionika narval*, the spider crab (*Sternorhynchus lanceolatus*), the lobster (*Palinurus elephas*), the spiny lobster (*Panulirus echinatus*), the slipper lobster (*Scyllarus arctus*), the locust lobster (*Scyllarus latus*) and the crinoid, *Antedon bifida* associated to the crustacean *Hyppolite hunti*.

The fish are represented by the cardinal fish (*Apogon imberbis*), the glasseye snapper (*Heteropriacanthus cruentatus*), the rockfish (*Scorpaena maderensis, S. canariensis*), forkbeards (*Phycis phycis*), various species of eels (Muraena helena, M. augusti), dusky grouper (*Epinephelus marginatus*), island grouper (*Mycteroperca fusca*), seabass (*Serranus cabrilla, S. stricauda*) and meagres (*Argyrosomus regius*).

In dark circalittoral caves or in conditions of scarce sunlight, species of sponges such as *Verongia aerophoba, Hexadella racovitzai, Geodia cydonium, Cacospongia scalaris, Axinilla damicornis, A. polypoides, Reniera cratera, Caminus vulcani, Corallistes nolitangere, Ircinia oros* and *Rhaphidostyla incisa* can be found.

The anthozoans are represented by species such as *Madracis pharensis* and *Gerardia savaglia*[15] that feed on the decapod *Balssia gasti*. Other anthozoans, also known as flower-animals, include the red gorgonian (*Lophogorgia ruberrina*) and the black coral (*Anti-pathes wollastoni*).[16]

The decapod (*Parapandalus narval*) and the swallowtail seaperch (*Anthias anthias*) are very common in this type of biocenosis.

Relation to other habitats of community interest

Submerged sea caves, as well as caves that are submerged only at high tide which are also considered partially submerged sea caves, are included in Annex I of the Habitats Directive as habitats of community interest and must be designated as SPC for their conservation.

These are referred to as submerged or partially submerged sea caves within the Natura 2000 code: 8330 PAL. CLASS.: 11.26.

This chapter has been included in the report because a large part of the associated communities17 are not listed or detailed, making their definition incomplete.

According to EUNIS classification, the structures that comprise this type of habitat are included in the following codes:

A1 Littoral rock and other hard substrata

A1.4 - Features of littoral rock

-**A1.44** - Communities of littoral caves and overhangs

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A3 Infralittoral rock and other hard substrata
A3.7 - Features of infralittoral rock
-**A3.71** - Robust faunal cushions and crusts in surge gullies and caves

A6 Deep-sea bed

A6.8 - Deep-sea trenches and canyons, channels, slope failures and slumps in the continental slope

-**A6.81** - Canyons, channels, slope failures and slumps on the continental slope
-**A6.82** - Deep-sea trenches

Degree of vulnerability

The deterioration caused by organic or industrial contamination leads to a pronounced loss of biodiversity, to the disappearance of the most sensitive species and to the permanence of resistant species and the subsequent appearance of other ecologically tolerant and highly variable species.[18]

This habitat is sensitive to the disturbances that affect communities inhabiting infralittoral and circalittoral waters, generally caused by coastal defence manoeuvres or contamination.[19]

It is also very sensitive to sedimentation due to the quantity of sessile filter feeders that comprise this habitat.

Other activities such as sport-diving produce negative effects due to the bubbles that accumulate within the cave, affecting all the organisms attached to the cave roof.

Relevant additional considerations

Halogenated (monoterpene) compounds have been isolated within the red alga, *Plocamium cartilagineous* and these compounds have an insecticide effect that could possibly be used to protect tomato and cereal crops from the borer moth.[20] This alga is usually located at the entrance to infralittoral caves.

Specific molecules and compounds[21] that block the human immunodeficiency type-I virus and have other pharmacological applications can be obtained from the colonising species represented by the anthozoan, *Gerardia savaglia*, located in infralittoral and circalittoral caves.

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4 Pelagic environments

Characteristics

The volume of the world's oceans is estimated to be approximately 1,338 cubic kilometres,[1] with an average depth of more than 3,500 meters and maximum depths of 11,034 meters (in the trench of the Mariana Islands) and 11,500 meters (in the Mindanao Trench). The pelagic habitat encompasses the largest surface area within the oceans and its marine life is associated to two very different ecological groups, distinguished mainly by their ability to swim. The first group is comprised of nekton: animals capable of swimming independently of the water's movement. The other group is comprised of planktonic organisms that float passively with the movements of the tides and currents.

Generally, the pelagic habitat is divided into these two regions, a small part of which is distributed along the continental shelf, called the neritic zone, located close to the coast. Due to this proximity to the coast, inflowing sediments contribute nutrients to the waters, making them nutrient-rich compared to oceanic waters.

The oceanic zone represents 92% of the total pelagic environment.[2] The proximity to the coast, with its contribution of sediments and nutrients, leads to a change in the physical and chemical properties of the water.

This is a highly dynamic habitat thanks to the influence of currents and tides; physical properties such as temperatures that can change rapidly; as well as productivity rates that can fluctuate daily and seasonally. Other influences include certain seasonal oceanographic phenomena related to the reversal of large current patterns, such as the El Niño phenomenon in the Pacific Ocean and the monsoon winds in the Indian Ocean.

The movement of pelagic fauna both vertically and across the water column adds to this dynamism and contributes to the heterogeneous nature of this environment. The physical parameters, productivity and other oceanographic characteristics vary seasonally and spatially. Atmospheric activity also plays an important role.

Some species live confined to specific areas during their entire life cycle, while others can live along the length of the water column depending on their habits (defence, feeding). Consequently, the food web within pelagic environments is linked to certain species that inhabit different regions in oceanic waters.

Distribution

The geographic distribution of pelagic organisms is generally very extensive. Numerous species are cosmopolitan and can be found in any of the world's oceans. The distribution of phytoplankton depends on the movements of water masses because, unlike nekton, these floating organisms are not capable of swimming.

Phytoplankton is comprised of microscopic algae that play a fundamental ecological role in the oceans because they transform solar energy into organic material. The phytoplankton's annual cycle depends on the mixing processes within the water column and the richness of nutrients. Alternatively, zooplankton is comprised of a community of animals, including both herbivores and carnivores, varying in size from one millimetre to two meters in length.

Scale is an important consideration when describing this environment. Mobility is another important consideration that helps to explain the structure of the pelagic environment in temporal and spatial terms, because some communities are relatively static while others are highly mobile.

The communities associated with the water column are classified according to depth ranges, characterised by the different degrees of sunlight present in the water column, temperature, pressure and the availability of nutrients.

The epipelagic zone, from 0 to 200 meters depth, is a relatively shallow area characterised by activities related to photosynthetic processes. The mesopelagic zone extends from 200 to 1,000 meters depth and its most relevant characteristic is that the availability of nutrients depends on vertical migratory processes. The bathypelagic zone, located between 1,000 and 2,700 meters depth, is characterised by the scant presence of species that steadily declines as depth increases and the abyssalpelagic zone is reached, beginning at 2,700 meters, continuing into a transition zone referred to as the benthopelagic zone that immediately turns into the abyssal plain.

Currents exist on the surface as well as in the depths of the oceans. The deep current that connects the world's oceans is known as thermohaline circulation. When the ocean currents mix the layers of warm and cold water, this allows the formation of a front that pushes the cold water to the depths of the ocean.

Surface waters become isolated by a thermocline at the mixed layer depth. In shallow waters, strongly influenced by the tides, the waters remain mixed throughout the year. The waters surrounding the Iberian Peninsula (Portugal and Spain) are a good example of this hydrodynamism.

It is possible to distinguish between the different water masses within the water column in the oceans and seas by differentiating them by varying levels of temperature, salinity and dissolved oxygen. There are also vertical stratification patterns where wind and wave action is not strong enough to mix the warm surface waters with the deeper cooler waters.

These differences, along with upwellings,[3] eddies, fronts[4] and currents can help to explain the structure of the pelagic environment on a temporal[5] and spatial scale.

In terms of biological diversity, this environment is linked to areas of high primary production and elevated presence of predators because there are high concentrations of nutrients due to the presence of fronts and mixing zones associated with reefs, canyons, seamounts and islands[6] that constitute physical obstacles for water masses. An example of these zones is the edge of the continental shelf along the Celtic Sea[7] (between southern Ireland and southwest England) and the effect of the northeast European current on it.

The areas within the pelagic environment correspond, for example, to the currents that are produced by the North Atlantic Drift. These habitats are characterised by hydrological aspects such as currents, water masses and fronts associated to changes in salinity and temperature.

The distribution of mating and breeding grounds as well as the presence of predators and concentrations of prey influence these regions and constitute the areas where migratory routes are established.

Upwellings, eddies and filaments, and fronts associated with changes in salinity and temperature are characterised by enhanced primary and secondary productivity and by the presence of highly migratory species. These areas present pronounced temperature, density and nutrient gradients, which in turn leads to increased production of phytoplankton.[8]

Examples of these areas include the Frisian, Flamborough and Ushant fronts (United Kingdom); the coastal upwellings in the Iberian Peninsula, Galicia (Spain) and Portugal, the coastal upwellings in the Alboran[9] Sea (Spain); the mesoscale eddies or "meddies" in the Mediterranean and the eddies in the Canary Island archipelago in the north-eastern area of Gran Canary Island (Spain).

The occidental and oriental sub-basins of the Alboran Sea (Spain) are located within the two semi-permanent anticyclonic gyres formed by the superficial Atlantic waters and upwelling processes take place on its edges.

Associated communities

Zooplankton[11] biomass and crustaceans, especially copepods, dominate this environment where approximately 2,500 species have been identified. The euphausiaceans comprise the other group of planktonic crustaceans important for their biomass. Although there are less than 100 species of these crustaceans, some of them can form significant concentrations.

The zooplankton is made up of important components such as ostracods, amphipods, cladocera, mysids, siphonophores, chaetognatha, jellyfish and larvae from invertebrates and fish. Approximately 70% of benthic species go through a planktonic larval stage.

Holoplankton refers to planktonic organisms that spend their entire life in the water column, whereas meroplankton spend only part of their life in the plankton. Ostracods belong in the latter group. In this sense, the seas and oceans are not made up of isolated compartments and there is a close interconnection between all processes.[13]

The other pelagic community, the nekton, is made up of free-swimming organisms, mainly vertebrates, fish, cetaceans and marine reptiles, where the cephalopods are the only representatives of invertebrate fauna. Approximately 80 species of pelagic cephalopods can be found in Spanish waters.[14]

There are many commercially valuable species amongst the fish community[15] such as the clupeiformes (sardines and anchovies), the perciformes including combers, seabass, mackerel, dolphinfish, Atlantic pomfrets, meagres, white seabreams, gilthead seabreams, red seabreams, parrotfish, skipjack tuna, bonito, bluefin tuna, white tuna, bigeye tuna, yellowfin tuna and swordfish;[16] and the elasmobranchs such as mako sharks, blue sharks and white sharks.

There is a wide variety of planktonic communities and these are classified according to their mobility. One group includes free-swimming organisms that can travel various kilometres in one week or less; the other group includes organisms that depend on physical transport processes within the water column[17]for their dispersion.

A recent study of the Irish Sea shows how both spatial and temporal data can be used to classify the characteristics of the water column by combining biological characterisation using five key features of the plankton community with stratification and salinity data sets to get an overview of pelagic regions in the Irish Sea.[18] Vertical stratification occurs when wind and wave action is not strong enough to mix the warm surface waters with the cooler deeper waters.[19]

The less mobile marine organisms, small invertebrates, fish eggs and larvae, and the species that comprise their food interact at a rate of one meter per day,[20] while free-swimming fish can explore kilometres in weeks or days.

The larger more migratory species are distributed throughout the oceans on temporal scales that can last for years. These species feed on "local" concentrations of nutrients, contribute or absorb energy or matter and transport or dissipate it long distances. There is a type of phytoplankton that is somewhat mobile (the flagellates) and even some bacteria that, theoretically, can resist dissipating turbulence or disruptions at low energy levels. All these species depend on physical transportation systems for their distribution, their physiological needs and their search for food in order to maintain their productivity.[21]

Zoogeographic discontinuities[22] can be described to define diverse pelagic environments and each one has characteristic local transport systems. When coastal transport systems dominate, most of the fish species do not spawn epipelagic eggs, however ovoviviparous species are abundant in these areas, for example Sebastes sp. and demersal eggs are predominantly produced. Close to the oceanic gyres, however, pelagic fish spawn epipelagic eggs and larvae. Furthermore, the most migratory pelagic species appear seasonally, penetrating the coastal system in search of appropriate nursery areas.[23]

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When they find these areas, they spawn and continue their journey.

Each organism's type of habitat and the transportation of energy and matter to and from each location depend on the organism's ability to move or the size of the habitat, for both a variety of predators and their prey.

The average length of trophic chains is shorter in areas where oceanic upwellings occur (this is directly related to low levels of diversity and the initial stages of the chain) than in the majority of the other more stable systems in other areas. In benthic food webs, the main part of the production is transported outside the upwelling area, horizontally to adjacent zones and vertically toward the ocean floor.[24]

In this way, inferior food webs in areas of upwellings frequently appear in other areas, moving further and further away from each other and from the upwelling centre. As such, on the northeastern coasts of Africa,[25] primary production is not as intense as in the littoral zone and the main part of zooplanktonic production is located near the continental shelf.

The fish and other large predators that comprise the food webs produced by seasonal upwellings require a certain level of seasonal mobility or migratory ability that facilitates transportation from the centre of production. The transportation can be passive; the cold water that has risen from the ocean depths may be transported at least 100 kilometres away from its source, forming a dissipation structure. The biological elements related to the food web are transferred from the centre of primary production by drifting or migration.[26]

As far as short food chains are concerned, the time spent on the surface is important because this is when the primary production cycle is completed and the food chain can be assimilated by the food web before the cold water sinks once again. Nevertheless, thanks to lateral advection, the impact of upwelling systems can extend far beyond its centre, due to both horizontal transference of nutrients and vertical precipitation of detritus.

This transference also takes place during seasonal migrations of many fish species that dissipate nutrients from the centres of primary production. Migrations also take place due to phenomena related with seasonal upwellings such as pycnoclines,[27] thermoclines[28] and oxygen stratification that can occur when deeper, cooler water masses that are low in oxygen levels rise to the surface.

Transference can also occur vertically towards the benthic systems, which may present anoxic conditions due to the decomposition of the abundant "shower" of detritus produced by primary production within the pelagic system.

In contrast to other highly diverse environments that are poor in nutrients, such as tropical coral reefs, the areas where upwellings take place are rich in nutrients[29] and support high levels of phytoplanktonic[30] production that leads to surface food webs dominated by a relatively low number of resident species.

Each component is characterised by its elevated biomass, which is highly variable in time. For the majority of the upwelling systems, however, this similarity is reinforced by the seasonality of production, which generally also contributes to the instability and diversity[31] within these systems.

In areas of the continental shelf, the larval stages of benthic organisms may be an important component of zooplankton during certain seasons. In epipelagic zones, copepods are the main source of nutrients for pelagic fish, as already mentioned.

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In temperate waters, the Cetorhinus maximus, a selective filter feeder located in areas with high concentrations of zooplankton, usually feeds on the surface layers according to investigations carried out in the British Isles,[32] the Hebrides (United Kingdom), the west coast of Ireland, the east of coast of the United Kingdom and the north coast of Britanny[33] (France), amongst other locations.

Although some sharks are usually found in the areas of the continental shelf characterised by the presence of tidal fronts, tracking studies[34] reveal how they move around the continental shelf, between centres of high productivity.

Their location on the edges of the shelf coincides with the highest levels of primary production.[35] Individuals tracked along the fronts located off the southwest coast of England moved to three main areas on the continental shelf: the Celtic Sea front (on the southwest coast of Great Britain and south of Ireland), the continental margin of the Goban Spur (southwest of Ireland)[36] and the Gulf of Biscay (northern Spain).

Despite widespread distribution,[37] it is important to consider these areas priority areas for certain species. Recent studies carried out in surface waters around Seco de Los Olivos (Almeria, Spain) have determined that this is a key distribution area for certain species of cetaceans.[38]

Operating at depths over 100 meters with a remote control vehicle, Oceana has verified that the Seco de los Olivos seamount constitutes an area of high productivity in spite of the fact that it is threatened by various human activities including bottom trawling.

Another example is the area of Princess Alice Bank (Azores, Portugal) where recent tracking studies have proven that seamounts may constitute vital feeding areas for certain species of sea turtles, especially for the loggerhead turtle (*Caretta caretta*). *Caretta caretta* has been observed during certain seasons in Azores[39] (Portugal) and the Canary Islands (Spain).

Relation to other habitats of community importance

There is a growing body of knowledge regarding the ecological significance of feeding areas, migratory routes and spawning and nursery areas. Taking into account their natural value and their interaction with other activities, the areas that have already been identified should be classified as habitats of interest.

It is obvious that these areas are representative proof of high concentrations of biological diversity, places that are critical for species' reproduction and growth, and can provide high levels of diversity to the surrounding areas.

Protecting the habitats within these areas with minimum impact from human activities may lead to the recuperation of this marine environment and would directly benefit the fauna present in these habitats.

Focusing on cetacean and ichthyic communities is the most well known method for applying conservation measures to the pelagic environment.

According to EUNIS classification, the pelagic habitats distributed throughout the water column correspond to A7:

A7.1 - Neuston

- **A7.11** – Temporary neuston layer
- **A7.12** – Permanent neuston layer

A7.2 - Completely mixed water column with reduced salinity

- **A7.21** – Completely mixed water column with reduced salinity and short residence time
- **A7.22** – Completely mixed water column with reduced salinity and medium residence time
- **A7.23** – Completely mixed water column with reduced salinity and long residence time

A7.3 – Completely mixed water column with full salinity

- **A7.31** – Completely mixed water column with full salinity and short residence time
- **A7.32** - Completely mixed water column with full salinity and medium residence time
- **A7.33** – Completely mixed water column with full salinity and long residence time

A7.4 – Partially mixed water column with reduced salinity and medium or long residence time

- **A7.41** – Partially mixed water column with reduced salinity and medium residence time
- **A7.42** - Partially mixed water column with reduced salinity and long residence time
- **A7.33** - Completely mixed water column with full salinity and long residence time

A7.5 – Unstratified water column with reduced salinity

- **A7.51** - Euphotic (epipelagic) zone in unstratified reduced salinity water
- **A7.52** – Mesopelagic zone in unstratified reduced salinity water
- **A7.53** – Bathypelagic zone in unstratified reduced salinity water
- **A7.54** – Abyssopelagic zone in unstratified re duced salinity water

A7.6 - Vertically stratified water column with reduced salinity

- **A7.61** – Water column with ephemeral thermal stratification and reduced salinity
- **A7.62** - Water column with seasonal thermal stratification and reduced salinity
- **A7.63** - Water column with permanent thermal stratification and reduced salinity
- **A7.64** - Water column with ephemeral halocline and reduced salinity
- **A7.65** - Water column with seasonal halocline and reduced salinity
- **A7.66** - Water column with permanent halocline and reduced salinity
- **A7.67** - Water column with ephemeral oxygen stratification and reduced salinity
- **A7.68** - Water column with seasonal oxygen stratification and reduced salinity
- **A7.69** - Water column with permanent oxygen stratification and reduced salinity

A7.7 – Fronts in reduced salinity water column

- **A7.71** – Ephemeral fronts in reduced salinity water column
- **A7.72** - Seasonal fronts in reduced salinity water column
- **A7.73** - Persistent fronts in reduced salinity water column

A7.8 – Unstratified water column with full salinity

- **A7.81** - Euphotic (epipelagic) zone in unstratified full salinity water
- **A7.82** – Mesopelagic zone in unstratified full salinity water
- **A7.83** – Bathypelagic zone in unstratified full salinity water
- **A7.84** – Abyssopelagic zone in unstratified full salinity water

A7.9 - Vertically stratified water column with full salinity

- **A7.91** – Water column with ephemeral thermal stratification and full salinity
- **A7.92** - Water column with seasonal thermal stratification and full salinity
- **A7.93** - Water column with permanent thermal stratification and full salinity
- **A7.94** - Water column with ephemeral halocline and full salinity
- **A7.95** - Water column with seasonal halocline and full salinity
- **A7.96** - Water column with permanent halocline and full salinity
- **A7.97** - Water column with ephemeral oxygen stratification and full salinity
- **A7.98** - Water column with seasonal oxygen stratification and full salinity
- **A7.99** - Water column with permanent oxygen stratification and full salinity

A7.A – Fronts in full salinity water column

- **A7.A1** – Ephemeral fronts in full salinity water column
- **A7.A2** - Seasonal fronts in full salinity water column
- **A7.A3** - Persistent fronts in full salinity water column

Degree of vulnerability

The evaluation of competition between human exploitation of these areas and the consumption of fish by predators such as marine mammals provides evidence of how a conflict of interest operates within these complex marine systems made up of feedback loops.

Human activities in the marine environment such as sailing and transportation may cause collisions with cetaceans, as well as diffuse contamination that is released into the pelagic environment. Together with military manoeuvres that affect cetaceans due to noise pollution, these activities produce strong negative impacts that must be remedied. The solutions should include corrective and preventive measures, supported by national and international legislation. Additionally, these should not only be applied to a group of species but to the biological components that make up the water column.

One example of what should be considered essential within these habitats are conservation measures for fisheries when these areas are designated as special marine protected areas. This is especially applicable to marine reserves with important fishing interests, taking into account that in order for conservation measures to be effective in these areas, they should include sufficient surface area[40] in order to ensure the viability of all ecological processes.

Conservation, management and planning measures established by conservation organisations suggest classification by creating various categories organised according to hydrodynamic conditions. Both bathymetry and hydrology are fundamental aspects to be taken into account when applying the basic tools for these processes.[41]

Other important elements

By using pelagic biogeography, the distribution of marine life in the world's oceans and seas can be explained from bacterioplankton to large cetaceans, as well as how species can aggregate and form characteristic ecosystems, maintaining optimum biomass for each component depending on conditions related to temperature, nutrients and the availability of sunlight. The actual areas where each characteristic ecosystem exists should be documented. The challenge is determining which of these ecosystems is characteristic.

A methodological example consists in a classification method made up of characteristic provinces or ecoregions.[42] Pelagic environments contribute to facilitating the classification of marine ecoregions based on aspects related to biomass in which physical, chemical, biological and ecological aspects are taken into account, such as temperature, salinity, the depth of the mixing layer and levels of productivity.

Oceanic productivity has profoundly influenced the composition of the atmosphere and the earth's climate.[43] Great efforts have been made in recent years to better understand carbon exchange between the ocean and the atmosphere, and to discover the role of oceanic productivity in the carbon cycle.

The recent increase in atmospheric carbon dioxide due to the burning of fossil fuels constitutes a new element to be taken into consideration.[45] For this reason, knowledge of the mechanisms that modify the amount of carbon dioxide in the ocean is fundamental in order to predict the evolution of the climate[46] in the future. Areas of coastal upwellings are especially interesting for the study of productivity given their role in the carbon cycle, acting as both emitters and absorbers of carbon dioxide.

The Alboran Sea is part of the most diverse and biologically productive[47] marine ecoregions in Europe. The pelagic and benthic communities it harbours are characteristic in both composition and distribution.[48] The determining factors for the bionomics of this sea, different from those of other Mediterranean ecoregions and the adjacent Atlantic region, include the mixing of Atlantic and Mediterranean waters as well as the deep-sea upwelling episodes that typically occur in this area.

5 Marine deserts

Characteristics

In general, the most important concentrations of organic material and the richest biocenoses are found at the continental shelf level, at any latitude. These areas are always close to river outlets that deposit nutrients and sediments in the ocean waters providing an important flow of phosphorus and nitrogen.

For this reason, it is not surprising that estuaries and swamps, together with the polar littoral area and coral reefs, are amongst the most productive oceanic regions in terms of biomass. In contrast, tropical waters are very poor in bioelements and are almost desert-like, harbouring weak levels of biomass in spite of the considerable diversity of their biocenosis.

In reality, concentrations of phosphates and nitrogen in ocean waters constitute the fundamental limiting factor for the development of oceanic biocenoses, more so than sunlight and temperature levels.

The apparently paradoxical fact that the Arctic and Antarctic seas have the highest levels of biomass in the hydrosphere, in spite of their incredibly low temperatures proves the essential role played by these mineral elements. Melting ice in the spring creates surface currents that indirectly promote the upwelling of deep, nutrient-rich waters.

As an immediate result, there is an incredible proliferation of phytoplankton during the first moments of the favourable season, and together with this, the appearance of numerous vertebrates and invertebrates attracted by these optimum feeding conditions.

The physico-chemical factors vary considerably because of the isotropic properties of the aquatic environment. Convection and diffusion of nutrients, along with marine currents, ensure a certain degree of heterogeneity of abiotic factors, limiting the number of possible habitats and making biomass distinction difficult.

Generally, in marine environments changes are more acute on the vertical axis than on the horizontal axis. This is because abiotic factors, such as temperature, levels of sunlight, pressure, density and availability of oxygen or nutrients, vary with depth.

In benthic environments, variations on the vertical axis can be accompanied by great heterogeneity on the horizontal axis produced by changes in the topography and nature of the substrata, by local variation of abiotic factors, or even by biotic factors caused by organisms' activities.

This vertical and horizontal heterogeneity leads to high levels of diversity in benthic communities compared to the pelagic environment. It is estimated that 95% of marine species are benthic, at least during their adult stages. It must be pointed out, however, that the benthic environment is functionally dependent on plankton because it is has especially low levels of primary production.

Due to variations in abiotic factors such as depth, benthic communities tend to be distributed in bands or horizons, at least in the most superficial layers. This phenomenon is known as zonation. Depending on this, benthic communities are grouped in bands or zones, usually referred to as floors, from supralittoral areas to the abyssal plains.

Apart from this vertical zonation, the main determining factor of the composition of benthic communities is the nature of the substrata: hard or soft, in other words, rocky or sedimentary.

The most heterogeneous and complex communities are those associated with hard substrata, while communities located on sedimentary substrata are usually much less diverse. The areas referred to as marine deserts are located on sedimentary substrata.

Distribution

In general, certain areas within the Mediterranean have been subjected to deeper analysis. In some areas, marine deserts are found on soft sediment floors that are a result of the mixing of terrestrially derived elements and biological elements.

Coastal detritic floors1 appear next to Posidonia meadows, pre-coralline or coralline, but may be also located on the borders between communities such as calm infralittoral biocenoses of photophilic algae and Cymodocea meadows, which are located at a certain depth, extending more than 100 meters.

Oceana has documented some marine desert areas on muddy floors in Burriana (Castellon, Spain). The sandy seabeds of the Northeast coast of Mallorca (Balearic Islands, Spain) and the muddy seabeds of the Island of Cabrera (Balearic Islands, Spain) are examples of the distribution of this type of habitat.

Sandy, detritic seabeds constituting clear examples of this type of habitat have also been documented in the Alboran Sea, in the seamount located in the Chella massif, also known as Seco de los Olivos (Almeria, Spain).

Another interesting place where marine deserts have been documented is in the Chafarinas Islands (Melilla, Spain), where the species *Alcyionum palmatum* was also identified.

Associated communities

Biocenosis of the coastal detritic bottom

Following are some of the species that make up the biocenosis of coastal detritic seabeds. As far as flora[2] is concerned, the following species of algae are present: *Valonia utricularis, Arthrocladia villosa, Cystoseira* sp., *Predata ollivieri, Phymatoliton calcareum, Peyssonnelia* spp., *Dasyopsis plana, Polysiphonia sebulifera, Zanardina prototyphus, Sporochnus pedunculatus, Galaxaura oblongata, Lithothamnium valens, Dudresnya verticillata, Cordylecladia erecta, Alsidium corallinum, Rytiphloea tinctoria, Aglaozonia melanoidea, Cystoseira spinosa, Phyllophora crispa, Mesophyllum lichenoides, Kallymenia reniformes, Rhodymenia ardissonei, Polysiphonia elongata, Vidalia volubilis.*

As far as associated faunal communities, the following sponges occur: *Grantia compressa, Suberites domuncula* and *Cliona viridis*; some species of cnidarians such as *Nemertesia antennina, Lophogorgia sarmentosa, Adamsia carcinopados, Aglaophenia spp., Pennatula phosphorea, Cribinopsis crassa, Alcyonium palmatum, Cerianthus membranaceus* and Alicia mirabilis.

The *polychaete Hyalinoecia* tubicola is also present, as well as the molluscs Acanthochitona communis, *Payraudeautia intricata, Chlamys varia, Venus verrucosa, Turritella mediterranea, T. triplicata, Fusinus rostratus, Lutraria lutraria, Venerupis decussatus, Cancellaria cancellata* and *Venus casina*. Crustaceans include *Dardanus calidus* and *Calappa granulata.*; and last, the bryozoan *Pentapora fascialis*; and the phoronid *Phoronis australis*.

Some of the echinoderm species identified include *Astropecten* spp., *Ophiocomina nigra, Spatangus purpureus, Luidia ciliaris, Echinus acutus, Holothuria polii, Chaetaster longipes, Echinocyamus pusillus* and *Holothuria tubulosa.*

The representative species of ascidian is the *Phalussia mammillata.*

As far as the ichthyic fauna is concerned, *Lophius piscatorius, Trachinus araneus, Dactylopterus volitans, Uranoscopus scaber, Xirichtys novacula* and *Triga* spp. are present.

Biocenosis of the muddy detritic bottom

This biocenosis is located in muddy areas of detritic seabeds due to the influence of terrestrial outflow of rivers or streams.

Sediments can range from muddy sand to compact mud. This community is much poorer than the communities found in coastal detritic seabeds.

The sandy mud, the muddy sand or the compact mud are rich in calcareous debris. These habitats can be found between 30 and 100 meters depth. The particles settle at a slow rate on the substrate comprised of fine sediment and some coarser remains or calcareous debris such as shells or carapaces.

The limits of the detritic community between the supralittoral and mediolittoral floors are generally difficult to distinguish on soft seabeds, it depends on the sediment particles; the species are mainly detrivorous.

The sedimentation processes are slow and promote the appearance of sessile epifauna. For example, the facies formed by the ophiurid, Ophiotrix quinquemaculata, is abundant in areas where the sediment is fine, feeding on suspended particles.

Some of the associated species include the sponge *Raspailia viminalis;* and *the cnidarians Aglaophenia acacia, Cerianthus membrabaceus, Alcyonum palmatum, Anemonactis mazeli, Lophogorgia sarmentosa* and *L. viminaklis.*

The sipunculans are represented by *Golfingia elongata*; and polychaetes, *Aphrodita acuelata Polyodontes maxillosus, Eupanthalis kimbergi, Nephtys hombergi, Liocapitella dollfusi* and *Euclymene palermitana.*

The molluscs are represented by gastropods such as *Turritella triplicata, T. turbona, Umbraculum mediterraneum, Glycymeris glycymeris, Naticarius millepunctatus, N. hebraeus, Scaphander lignarius, Semicassis saburon, S. undulatum, Nucula nucleus, Dentalium panornum, D. vulgare, Callista chione, Bolinas brandaris, Phalium undulatum, P. saburon;* the bivalves, *Tellina incarnata, T. serrata, Pecten jacobaeus; the scaphopods, Dentalium panormum, D. vulgare; the ascidians, Phallusia mamillata, Microcosmus sabatieri.*

Crustaceans may be represented by the isopod, *Cirolana neglecta*, the stomatopod, *Squilla mantis* and the commercially valuable decapod, *Nephrops norvegicus.*

The most frequently found echinoderms are the holothuria, *Pseudothyone raphanus*, and the starfish, *Luidia ciliaris, Chaestaster longipines.*

Biocenosis of mediolittoral detritic mud

This biocenosis is found in areas where stones and gravel3 are present. The fauna and flora are scarce due to the harsh conditions. Molluscs and crustaceans are the most well adapted species.

Amongst the molluscs, *Gibbula divaricata, G. rarilineata, Chiton olivaceus, Chiton cinereus* are present on the coasts of the United Kingdom and the crustaceans, *Gammarus* sp., *Sphaeroma serratus, Cymodoce truncata.*

Many of the species of fish found in these areas are commercially valuable, such as the small-spotted catshark (*Scyliorhinus canícula*), the anglerfish (*Lophius piscatorious*), the streaked gurnard (*Trigloporus lastoviza*), the greater weever (*Trachinus draco*) and the Atlantic stargazer (*Uranoscopus scaber*).

Biocenosis of detritic coastal terrigenous muds

The substrate of the circalittoral bottom is made up of fine and muddy sediment that also includes organic debris. This community is found at the same depth ranges as the coastal detritic and muddy detritic bottoms, in other words, between 30 and 100 meters depth.

As mentioned above, the sedimentation is fine and occurs quickly, thus easily burying organisms.

The Turritella communis gastropod facies are characteristic as well as the holothurians such as Labidoplax digitata. The anthozoans *Veretillum cynomorium, Virgularia mirabilis* and *Pennatula phosphorea*, are also representative.

When sedimentation rates are very low, the species Alcyonum palmatum is characteristically found, and other sessile organisms can also be found spread

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on the hard substrate. Examples are the sea urchin *Brissopsis lyrifera* and the polychaetes, *Lepidasthenia maculata, Phyllodoce lineada, Nereis longissima, Goniada maculata, Sternaspis scutata, Prionospio pinnata, Pectinaria belgica; the gastropods, Galeodea tyrrhena, Charonia lampas, Ranilla olearium* and the bivalves, *Thyasira croulensis, Mysella bidentata, Abra nitida, Thracia convexa*.

In the coastal detritic bottoms comprised of substrata made up of gravel, sands and muds located at depths between 90 and 150 meters on the continental shelf-edge, the characteristic facies includes the echinoderm Leptometra phalangium; crinoids are abundant in undersea canyons where currents are constant and large hydrozoans are numerous. Thecocarpus myriphyllum and Nemertesis antennina establish themselves on mud and silt making the sediment stable. Facies comprised of Neolampas rostellata, an echinoid that is present in areas of strong currents, are also typical; and the brachipod, *Gryphus viterus*, can be found on circalittoral and bathyal floors.

The most important species within this community are the scaphopod mollusc *Dentalium panormum*; the isopod crustacean *Cirolana borealis*; the amphipod Haploops dellavallei; the echinoderms already mentioned, *Leptometra phalangium, Thyone gadean*; the large hydrozoans from the *Lafoea genus*; the actinarian, *Gephyra*; the gastropod, *Capulus ungaricus*; the cirripod, *Scalpellum scalpellum*, amongst others.

Biocenosis of detritic coralline bottoms

Detritic bottoms are comprised of dead calcareous algae and debris made up of corals and shells, frequently sifted by terrigenous sediments. These biocenoses appear between 60 and 150 meters depth in places of slight hydrodynamic conditions or one-way currents. The coralline detritic component usually fixes itself to the hard substrata formed by communities of *Dendrophyllia ramea* and *D. cornigera*.

Dendrophyllia ramea appears between 45 and 100 meters deep forming tree-like colonies over one meter high and ten centimetres wide at the base, growing on the hard substrata to which they initially attach themselves. They surround themselves with detritic bottoms when growing so the inferior portion of the coral dies and can be colonised by a wide range of organisms.

Dendrophyllia cornigera appears at greater depths than *Dendrophyllia ramea*, at the bottom limits of the circalittoral region, although it may appear at bathyal levels occasionally. This coral forms small branching communities. At approximately 300 meters depth, this species is substituted by soft coral facies, considered a poor facies of the *D. cornigera* community.

The polychaete, *Ditrupa arietina* appears in the sediment; the decapods, *Paromola cuvieri, Cancer bellianus*; bryozoans from the genus *Cupuladria*; the ophiuran, *Astropartus mediterraneus*; the sea urchins, *Cidaris cidaris* and *Genocidaris maculata*.

Biocenosis of interstitial fauna

Apart from the species that live on or are buried within the sediments, the bottoms harbour interstitial fauna as well. These animals are adapted to living amongst the grains of sediment and are therefore very small, less than one millimetre in length.

Of the 33 phyla or large taxonomic categories of animals that exist, 20 have an interstitial representative, and five of them (Gastrotricha, Kinorhyncha, Loricifera, Tardigrada and Gnathostolmulida) are exclusively interstitial.

Other groups that are well represented in this faunal community include the crustaceans (Mystacocarida, Copepoda, Harpacticoda and Ostracoda), Rotifera and Nematoda, of which the most abundant are the turbellarians and the polychaetes.

Furthermore, some representatives of the following groups have adapted to interstitial life, such as the Hyrdozoa, Nemertina, Endoprocta, Mollusca (gastropods and aplacophores), Priapulida, Sipunculida, Oligochaeta, Brachiopoda, Holothuria and Tunicata.

As such, interstitial fauna contributes significantly to increasing the biodiversity within a medium that is apparently poor in species.

Relation to other habitats of community interest

This type of habitat is partially related to the sand banks permanently covered by seawater (Habitat: 1110), in the case that these sandy bottoms are barren and have little vegetation, although the main characteristic is the presence of some algae and a few invertebrates.

The habitat referred to by the Habitat Directives included in the Habitats Manual is currently being revised.

Degree of vulnerability

Generally, soft seabeds are unstable and susceptible to disturbances created by the currents that increase sedimentation over communities.[4]

Apart from this indirect threat, other types of habitat-altering threats exist such as those caused by destructive human activities. For example, bottom trawling poses a great threat to this habitat and obviously disturbs interstitial fauna.

The operations carried out in areas considered to be deserted, such as operations related to military manoeuvres, undersea explorations using certain technology is not as viable as some authors point out in relation to minimising certain impacts affecting populations of marine mammals.

Additional important information

Although these areas are relatively poor in biodiversity due to their location in the sublittoral zone, marine deserts are located close to economically important oceanic areas and harbour populations of organisms that act as emitters of biomass, as has been described in the paragraphs above.

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6 Coral reefs

Characteristics

Europe is not the most suitable place for the development of coral reefs, as shallow water reefs are characteristic of tropical waters. There are, however, some concentrations of reef-forming Anthozoa.

The most developed are the deep-sea reefs formed by soft, ahermatypical cold water corals (a solitary species, without zooxanthallae) although other shallow water reefs exist comprised of hermatypical corals (with presence of zooxanthellae algae).

Shallow water coral reefs exist only in the Mediterranean and surrounding waters and are remnants of the reefs that existed in the area when the climate, planet and conditions in this sea were more suitable for the development of these ecosystems. Cold water corals and the reefs formed by them, however, are widely documented and occur throughout European waters.

The Mediterranean madrepora (Cladocora caespitosa) usually forms semispherical or reniform “pillows” with a diameter of approximately 50 centimetres, although it may occupy various meters in width and height in some seabeds, growing atop dead coral and forming authentic reefs or other shapes, even tree-like structures, depending on depth, levels of sunlight and hydrodynamic conditions.

This scleractinian madreporarian coral can live in symbiosis with small dinophycean algae (zooxanthellae) of the *Symbiodiniuma*[1] genus, giving its polyps a characteristic blue-green colour. The cylindrical corallites can reach up to 10 centimetres in height and the colonies can be made up of hundreds or thousands of individuals.

It is the largest colonial madrepora in the Mediterranean and the only one that forms true reefs. It is also considered to be one of the communities that generates the highest levels of carbonates into this sea, with an annual production potential of between one and almost two kilograms of calcium carbonate per square meter.b

The second most important species of European madreporarian, as far as reef-building in the Mediterranean is concerned, is the *Oculina patagonia*. These reefs are typical of the Mediterranean area, but there is great debate about their indigenousness.

Initially, it was thought that its presence in Europe and the Mediterranean was man-induced, eventually leading to its invasion of Mediterranean waters because this species was identified in the fossil records of the South Atlantic, as its name indicates. Recently, however, some scientists have raised doubts regarding this species’ “exoticness” because the only live specimens found today are the species located in the Mediterranean Sea.

On the other hand, there exists the possibility that this species has benefited in recent years and turned into an invasive species within its own distribution range within the Mediterranean, especially in the eastern basin.c

Last, the two main white coral reef-forming species are the glass coral (*Lophelia pertusa*) and the white madrepora (*Madrepora oculata*). These are the most widely distributed coral reefs in Europe and, although the oldest specimens are found in Mediterranean waters, these species are more commonly found in the Atlantic and concentrations usually occur on slopes, canyons or vertical walls throughout the Atlantic, unlike true reefs.

Oceana has confirmed the existence of other colonial coral species forming dense aggregations that can also be considered reefs such as the species *Polycyanthus muellerae* or *Phyllangia mouchezii*. Special emphasis should be given to the orange coral (*Astroides calycularis*), endemic in the Mediterranean Sea and adjacent Atlantic waters and considered an endangered species included in Annex II of the Barcelona Convention and Annex II of the Bern Convention.d

Distribution

Cladocora caespitosa is an endemic species in the Mediterranean Sea, but some specimens can also be found in Atlantic waters near northern Africa and Portugale. This coral prefers well-lit seabeds in the infralittoral and circalittoral, usually between 15 and 40 meters depth, although some shallow water colonies have been found, as well as other colonies at over 600 meters depth. The shallow water colonies are photophilic, given their symbiotic relationship with *zooxanthellae algae*, lacking in the deep-sea colonies.

This occurs in all Mediterranean countries, both western and eastern, although the largest reefs have been found in the southwest Mediterranean.

Oculina patagonica was first recorded in 1966 in Savona (Gulf of Genoa, Italy).[6] Today, it can be found extensively distributed throughout the Mediterranean, especially in areas between Italy, France and Spain,[7]although a second centre exists in eastern Mediterranean waters, between Egypt, Israel, Lebanonh and recently, Turkey.[9]

Oceana's research work in recent years has confirmed that it is commonly present in southeastern Spanish waters.

Although the existence of deep-sea white corals was already known in ancient times, the presence of dense reefs has only recently been acknowledged. Studies carried out regarding this species have shed light on its distribution range and, although the largest concentrations can be found in European waters from the Arctic to Macaronesia, Lophelia pertusa has been found in all the oceans around the world, including the South Atlantic, the North and South Pacific and the Indian Oceans.[10]

White coral reefs usually occur in the deep sea, between 200 and 1,000 meters depth,[11] although they have also been found in less than 30 meters of water in Norwayl, and at more than 3,000 meters depth in the seamounts of New England.[13] They prefer temperatures between 4ºC and 12ºC[14], where the maximum acceptable temperature has been established at 13ºC for some formations in the Mediterranean.[15]

Some of the most important and representative concentrations of Cladocora caespitosa in Europe are located in Ses Salines, Ibiza and Es Grau, Menorca (Balearic Islands, Spain);[16] the island of Isabel II (Chafarinas Islands, Spain);[17] Portofino, Gulf of Atalanta, Santa Maria di Leuca and La Spezia (Italy);[18] Mljet (Croatia)[19];the Bay of Ramla (Gozo, Malta);[20] Chalkidiki and Northern Esporadas (Greece);[21] Port-Cros (France).[22]

As far as deep-sea corals are concerned, the Rockall Bank reefs, between Scotland and the Faroe Islands (Denmark) are especially important, as well as those located in the Wyville Thomson Ridge, also in Scotland; the Chapelle Bank in the Gulf of Biscay; the Galicia Bank in northwest Spain; the seamounts of the Gorringe Bank south of Portugal; etc.[23]

Associated species

Mediterranean madrepora reefs can harbour dependent communities comprised of more than 200 species[24] Amongst these, the polychaetesy[25] are abundant, as are the serpulids, isopodsz[26] such as *Gnathia inopinata, Paranthura costana, Paranthura nigropunctata, Carpias stebbingi, Joeropsis brevicornis,* foraminiferansaa[27] and a wide range of algae,[28] without forgetting the large quantities of bacteria concentrated in the mucus secreted by these animals[29].

Furthermore, many species feed off these animals' polyps, amongst them some molluscs from the Coralliophila genus such as *Coralliophila meyendorfii* or *Latiaxis babelis*, while others colonise structures they form by boring galleries in the rock, such as the date-mussel (*Lithophaga lithophaga*), species protected by the Habitats Directive and the Barcelona, Bern and Washington Conventions.

Since it was believed that *Oculina patagonica* was an allochthonous species, few studies have been carried out concerning their ecological importance and their associated biological community.

Oceana has confirmed its presence in shallow waters along with photophilic algae such as *Codium vermilara, Padina pavonica, Dictyota dichotoma, Laurencia obtusa, Amphiroa rigida*, etc., or even allochthonous alga such as *Asparagopsis taxiformis*. Endolithic algae (*Ostreobium* sp.) have also been found living in the calcareous structure[30].

Some fish also take advantage of the protection offered by these reefs, such as ringneck blennies (*Parablennius pilicornis*) and rainbow wrasse (*Coris julis*).

Some North-East Atlantic deep-sea coral reefs studied have shown extremely high levels of biodiversity, with over 800 species represented, including anthozoans, sponges, hydroids, bryozoans, echinoderms, tunicates, polychaetes, crustaceans, molluscs, echinoids, etc[31].Furthermore, these reefs are very important for commercially valuable species such as the roundnose grenadier (*Sebastes* spp.), the ling (*Molva molva*), the cusk (*Brosme brosme*) and the pollock (*Pollachius virens*), amongst others[32].

Amongst the Anthozoa that usually inhabit these reef formations, scleractinian corals can be found (*Desmophyllum cristagalli, Enallopsammia rostrata* and *Solenosmilia variabilisag*)[33] as well as gorgonian corals (*Paragorgia arborea, Primnoa resedaeformis*).

Relation to other habitats of community importance

The Mediterranean madrepora reefs are usually found on rocky seabeds in the infralittoral and circalittoral and even in areas close to or within seagrass meadows, especially those formed by *Posidonia oceanica*[34].

Oculina patagonica is usually found in rocky areas of the infralittoral, sharing or competing for space with other communities such as red algal concretions (*Lithophyllum, Mesophyllum, Peysonellia*, etc.) or prairies of green algae from the *Halimeda* genus.

It is frequently mentioned as part of the biocenosis of encrusting calcareous rhodophytes and urchins, as well as the biocenosis of photophilic infralittoral algae in calm waters.

Deep-sea coral reefs are usually found next to gorgonian gardens and are strongly related to carbonate mounds, seamounts and slopes.

According to EUNIS classification, coral reefs and other scleractinian colonising Anthozoa are included in the following codes:

A3.23 – Mediterranean communities of infralittoral algae moderately exposed to wave action
- **A3.238** - Facies with *Cladocora caespitosa.*

A4.71 – Communities of circalittoral caves and overhangs
- **A4.711** – Sponges, cup corals and anthozoans on shaded or overhanging circalittoral rock
- **A4.714 –** Caves and overhangs with *Leptopsammia pruvoti*

A5.63 – Circalittoral coral reefs
- **A5.631 –** Circalittoral *Lophelia petrusa* reefs

A6.22 – Deep-sea biogenic gravels (shells, coral debris)

A6.61 – Communities of deep-sea corals
- **A6.611 –** Deep-sea *Lophelia petrusa* reefs

The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Marine Habitats that is used for the selection and promotion of the conservation of natural sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

III.6 Hard and rocky bottoms (circalittoral)
- **III.6.1.14** Facies with *Cladocora caespitosa*

V.3 Hard and rocky bottoms (circalittoral)
- **V.3.1** Biocenosis of deep-sea corals

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Degree of vulnerability

Cladocora caespitosa is currently declining within the Mediterranean. Many fossil records exist of the reefs formed by this species during the Pleistocene and the Miocene. It is believed that changes in climate are causing this decline[35].

Many colonies documented during the 20th century have disappeared and the rate of decline in some areas within the Mediterranean can reach up to 50%.

Recently, these colonies have also suffered from bleaching processes similar to those that occur in tropical reefs, related to the high temperatures of the waters in the Mediterranean Sea[36].

Its annual growth rate is between one and five millimetres depending on the environmental conditions, especially the temperature of the water. The life span of these colonies is usually not longer than 50 or 60 years.

Other factors that affect these corals include the overgrowth of algae that compete for the same space and can destroy the colonies. This algal overgrowth may be due to the scarcity of herbivores and to the climate conditions that promote vegetable proliferation.

The collection these corals for aquarium or decorative use has also lead to the destruction of some colonies, as well as physical damage caused by bottom trawling, the anchoring of recreational boats or the illegal use of explosives for fishing.

In spite of its presumably rapid expansion throughout the Mediterranean, *Oculina patagonica* is not a typical opportunistic species because it does not have high rates of reproduction, although is can reproduce both sexually and asexually, it is predominantly gonochoric.

Some bleaching episodes have been identified amongst these hermatypical corals and bacterial infections have been found in different locations, growing various centimetres per day[37] .It is believed this is caused by the Vibrio shiloi bacteria, possibly transmitted by the bearded fire worm (*Hermodice carunculada*).[38] These bleaching episodes have also been associated with high temperatures in the Mediterranean during various years.am It is likely that these bleaching episodes have affected 80 to 90% of the *Oculina patagonica* colonies in the Mediterranean during the last 10 years.

Deep-sea coral reefs have proven to be very sensitive to anthropic disturbances. These ecosystems are especially fragile because some species need one year to grow between five and ten mm, while the reefs grow only between 1.3 and 2.5 mm during the same time span[40]. Some studies have proven that structures can reach a height of 35 meters[41].

In western Ireland, studies concluded that Lophelia pertusa formations were approximately 450 years old, while *Desmophyllum cristagalli* formations could be at least 4,550 years old[42]. The reefs located in the Sula Ridge (Norway) have been estimated to be 8,500 years old[43].

It is widely known that bottom trawling is one of the main causes of the destruction of these ecosystems in many regions around the world[44]. Scientists acknowledge the fact that "in general, serious damage can be caused to coral reefs wherever bottom trawling activities are carried out."[45] Various research projects have verified that the damage caused to coral reefs by these fishing practices in areas of the Atlantic takes place between 200 and 1,200 meters deep[46].

Bottom trawling has damaged between 30 and 50% of coral reefs in Norwegian waters[47]. Damage of this magnitude has also been confirmed in other areas of the North Atlantic such as the Darwin Mounds of north western Scotland, the southern areas of the Wyville Thomson Ridge and the Porcupine Seabright in Irish waters.

Other important elements

These reefs that have existed for thousands of years provide highly important live and fossil material that can be used as a chronological record to date environmental and climatic changes in the Mediterranean Sea.

It has been discovered that *Cladocora caespitosa* contains two sesterterpenes, cladocorans A 645 and B 646,[48] highly important for pharmacological use in the treatment of various diseases, for example in oncological treatments, because they have potential bactericide (inhibiting the growth of gram-positive bacteria) and antitubercular properties.

Concerning *Oculina patagonica*, if it were truly an autochthonous coral reef in Europe, it would be one of the most important habitats in this region because it constitutes a shallow water coral reef currently in expansion.

It can grow in both clean and contaminated waters. In fact, it is frequently found in protected areas such as the Cabo de Gataa[49] and in port areas such as Alicante and Almeria.

Furthermore, these species of corals usually include zooxanthellae colonies of the *Symbiodinium* genus, although they also occur as ahermatypical species.

Deep-sea coral reefs do not form just one habitat they form at least three. One of these habitats is generated by the calcareous structure of live Anthozoa, the second is formed by dead corals and the third, by the fragments of reef debris.

The EU has established some initiatives in order to protect some coral reefs, either by completely closing off the areas to fishing or by seasonally prohibiting fishing and trawling activities and/or other fishing methods that come into contact with the seabed and consequently cause damage to the coral reefs.

Similar measures have been put into practice in the Darwin Mounds (close to the Hebrides Islands, Scotland),[50] in Porcupine Seabright (in western Ireland),[51] or the banning of trawling, gill nets and other fishing gear within the waters of the archipelagoes of Azores, Madeira and the Canary Islands.[52]

Furthermore, some European countries, both within and without the European Community, have created special protected areas to conserve these ecosystems. For example, the Norwegian government has protected three of the most important concentrations of these species: the Sula Ridge, Iverryggen and the recently discovered Røst reef in the Lofoten islands. Two reef areas in Kosterfjord, Sweden, will also benefit from this protection.


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7 Gorgonian gardens

Characteristics

Gorgonian gardens are habitats created by species of octocoral Anthozoa that form significant concentrations in infralittoral, circalittoral and deep-sea bottoms.

These concentrations usually occur on hard substrata where they settle and form diverse communities.

In the Atlantic, these gardens are usually comprised of deep-sea gorgonian and can be found together with other species such as *Paragorgia arborea* and *Primnoa resedaeformis*, and sometimes with *Acanthogorgia armataa*[1] or with *Paramuricea placomus*[2].

One of the most characteristic species in North Atlantic gorgonian gardens is the Paragorgia arborea. These colonies can reach a height of more than 2.5 metersc and a life span of 180 years[4]. However, research concerning fossil records indicates they may live as long as 300 years[5]. and new research studies indicate colonies may even be close to 1,000 years old[6]. Primnoa resedaeformis may also have a long life span, living between 100 and 500 years[7].

The Portuguese Mediterranean area, however, is considered to harbour the most diverse colonies of octocorals in the North Atlantic[8].

In the Mediterranean, these gardens can be made up of a great variety of circalittoral octocorals. By means of a remotely controlled vehicle or underwater robot (ROV), Oceana was able to document the presence of gorgonian gardens, where the most common species found were Eunicella verrucosa, Paramuricea clavata, Elisella paraplexauroides, Viminella flagellum, Swiftia pallida or Callogorgia verticillata, along with other octocorals such as *Alcyonium palmatum* or *Paralcyonium spinulosum*, hexacorals such as *Dendrophylla cornigera, Dendrophylla ramea, Caryophyllia* sp. and antipatharians such as *Antipathes wollastoni*.

Dense gorgonian forests can also occur in this sea, on infralittoral and circalittoral seabeds strongly associated to coralline species, especially *Pamuricea clavata, Eunicella singularis, E. cavolini, E. verrucosa* and *Corallium rubrum*, although *Leptogorgia sarmentosa* may also be commonly found.

Paramuricea clava is an endemic species in the Mediterranean but it can also be found in adjacent Atlantic waters. It can reach a height of 1.3 meters[9] and form communities of up to 50 colonies per square meter[10].

Distribution

Gorgonian gardens are found in all European waters, although species can vary from one area to another. *P. arborea* and *P. primnoa* occur more frequently in the North Atlantic, on seafloors located at over 200 meters depth.[11] *P. arborea*, however, can also be found in other oceans around the world, such as the North Pacific,[12] the Indian Ocean[13] and even subantarctic waters[14].

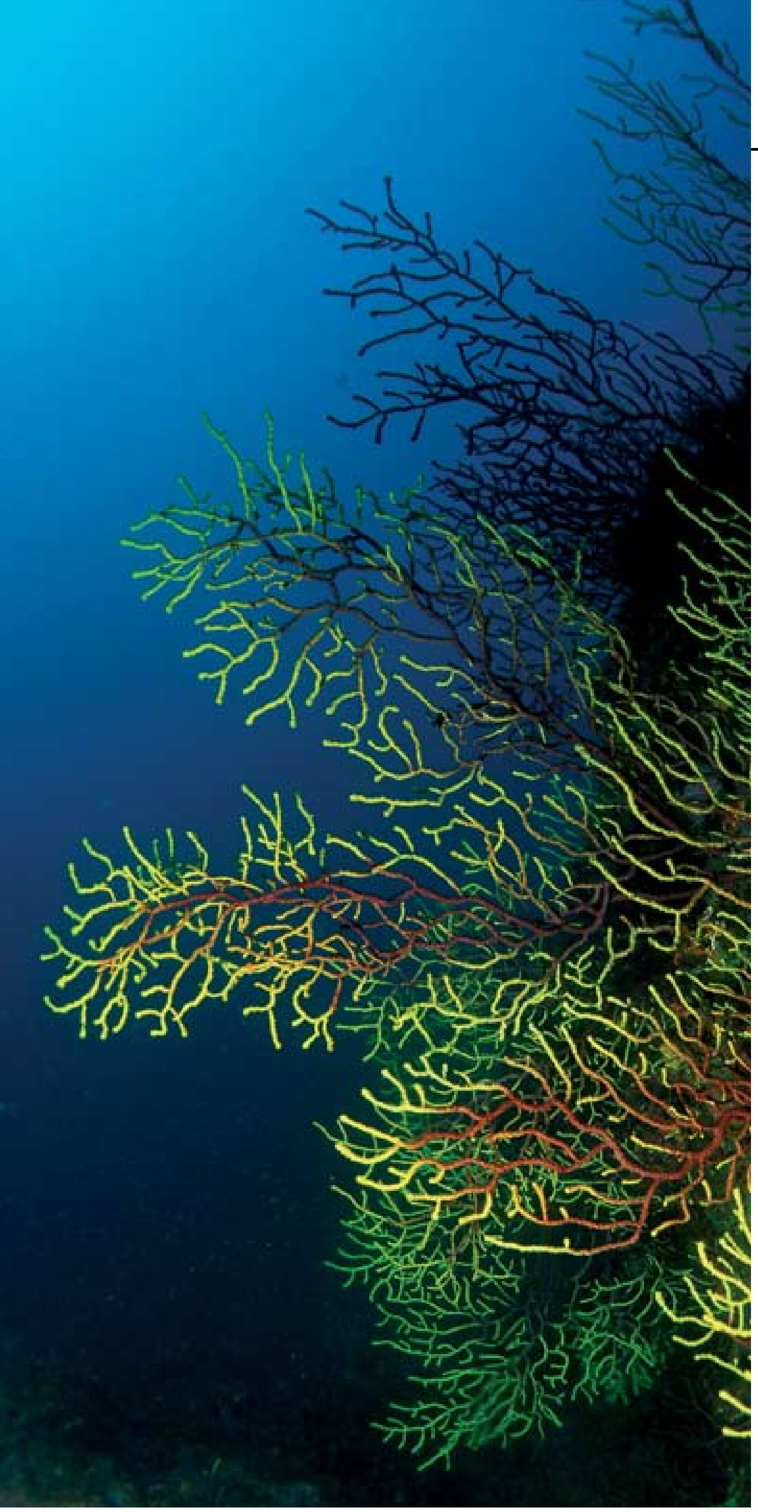
These concentrations of gorgonian can also occur in some areas of the Atlantic, where *Leptogorgia viminalis, Eunicella verrucosa* or *Swiftia pallida* can be found. Many of them have an Atlantico-Mediterranean distribution and *S. pallida*, for example can occur between very shallow waters and more than 2,000 meters depth[15]. Some gorgonian may occur abundantly in Macaronesia. For example, the following species can be found in the Canary Islands: *Acanthogorgia hirsuta, Callogorgia verticillata, Swiftia pallida, Leptogorgia viminalis, Elisella paraplexauroides* and *Eunicella verrucos.*[16]

The infralittoral and circalittoral species represented by individuals from the Paramuricea or Eunicella families are more characteristic of the temperate waters of southern Europe, between the southern British Isles,[17] the Gulf of Biscay[18] and the Mediterranean.[19]

Some important locations where these gardens are present include: *Paragorgia arborea* and *Primnoa resedaeformis* in the Faroe Islands[20] or Greenland;[21] *Swiftia pallida* and *Eunicella verrucosa* in Kenmare (Ireland)22 or Scotland;23 *Paramuricea clavata, Eunicella* sp., and *Corallium rubrum* in La Spezia and Portofino in the Sea of Liguria (Italy),24 in Port-Cross (France)25, in the Medas Islands (Catalonia)26 or the Bay of Kavala (Aegean Sea, Greece);[27] *Elisella paraplexauroides, Viminella flagellum* and *Eunicella verrucosa* in the Seco de los Olivos seamount and the Alboran Island (Andalusia, Spain);[28] *Eunicella verrucosa* and *E. cavollini*, in the Bay of Híguer (Basque region)29 and the Bay of Oleron (France).[30]

Associated species

Seventeen species of crustaceans were found associated with colonies of *Paragorgia arborea* and *Primnoa resedaeformis* in the Northeast Canal off Nova Scotia, with predominance of *P. arborea*. Amongst them, am



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phipods (*Metopa bruzelii, Stenopleustes malmgreni, Proboloides calcarata* and *Aeginella spinosa*), isopods (*Munna boecki*), and cirripeds (*Omatoscalpellum stroemii*), as well as parasitic copepods from the Poecilostomatidae family, pandalid decapods (*Pandalus propinquus*) and galatheids (*Eumunida picta*).[31] Other studies[32] have associated these gardens with other species including the anemones *Actinauge verrilli*, *Bolocera tudiae*, encrusting sponges such as *Ophiacantha abyssicola*, and echinoderms such as *Gorgonocephalus arcticus* or *Porania pulvillus*.

In circalittoral gorgonian gardens observed by Oceana in the Mediterranean, the most common associated fauna is comprised of anthozoans, such as the hexacorals *Dendrophyllia cornigera*, *D. ramea, Caryophillia* sp., and the octocorals *Alcyonium* sp., *Paralcyonium spinulosum, Parazoanthus* sp., fish including *Serranus cabrilla, Anthias anthias* or *Phycis phycis*, echinoderms including Astropartus mediterraneus or Echinus melo, tunicates such as *Halocynthia papillosa* or *Diazona violacea*, sponges such as *Aplysina aerophoba*, or polychaete worms including *Serpula vermicularis, Protula* sp., and different terebellids.

The gorgonian gardens occurring on coralline seabeds are described in a separate chapter dedicated to that habitat.

Relation to other habitats of community importance

Paragorgia arborea and Primnoa resedaeformis are usually found as a part of biogenic reefs along with deep-sea corals such as Lophelia pertusa, sponges (*Geodia* sp.) and molluscs (*Acesta excavata*)[33] where the ichthyic community includes roundnose grenadier (*Sebastes* sp.) or cusk (*Brosme brosme*).

Gorgonian gardens frequently occur in the Mediterranean and are considered part of certain infralittoral and circalittoral ecosystems, such as coralline ecosystems.

According to EUNIS classification, gorgonian can be found in the following communities:

A4.13 – Mixed faunal turf communities on circalittoral rock
- **A4.1311** - *Eunicella verrucosa* and *Pentapo rafoliacea* on wave-exposed circalittoral rock

A4.21 – Echinoderms and crustose communities on circalittoral rock
- **A4.211 -** *Caryophyllia smithii* and *Swiftia pallida* on circalittoral rock
  - **A4.2111** - *Caryophyllia smithii, Swiftia pallida* and *Alcyonium glomeratum* on waveshel tered circalittoral rock
  - **A4.2112** - *Caryophyllia smithii, Swiftia pallida* and large solitary ascidians on exposed or moderately exposed circalittoral rock

A4.26 – Mediterranean coralligenous communities moderately exposed to hydrodynamic action
- **A4.269** - Facies with *Eunicella cavolinii*
- **A4.26A** - Facies with *Eunicella singularis*
- **A4.26B** - Facies with *Paramuricea clavata*

A4.32 – Mediterranean coralligenous communities sheltered from hydrodynamic action
- **A4.322** - Facies with *Lophogorgia sarmentosa*

A4.71 – Communities of circalittoral caves and overhangs
- **A4.713** – Caves and overhangs with *Corallium rubrum*

A6.51 – Mediterranean communities of bathyal muds
- **A6.514** - Facies of compact muds with *Isidella elongata*

A6.61 – Communities of deep-sea corals

The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Habitats used for the selection of natural sites and promotion of the conservation of these sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

IV.3. 1 Biocenosis of coralline habitats
- **IV.3.1.10.** Facies with *Eunicella cavolinii*
- **IV.3.1.11.** Facies with *Eunicella singularis*
- **IV.3.1.12.** Facies with *Lophogorgia sarmentosa*

- **IV.3.1.13**. Facies with *Paramuricea clavata*

IV.3.2. Semi-dark caves
- **IV.3.2.2.** Facies with *Corallium rubrum*

V.1.1. Biocenosis of bathyal muds
- **V.1.1.4.** Facies of compact muds with *Isidella elongata*

Degree of vulnerability

In the majority of cases, gorgonian colonies have slow growth rates. Paragorgia arborea grows approximately one centimetre per year, while Primnoa resedaeformis grows approximately 1.7 centimetres.[34] Paramuricea clavata does not reproduce until it reaches between seven and 1335 years and can live longer than 50 years.[36]

Their longevity makes these species especially vulnerable to the destruction of physical surroundings that also adversely affect their recuperation. It is estimated that recovery time for Primnoa resedaeformis is at least 100 years.[37]

Important damage is also caused by certain fishing practices as well as the anchoring of recreational vessels atop gorgonian gardens, including within protected areas.[38]

Mass die-offs of gorgonian colonies occurred in the Mediterranean Sea during the decade of the nineties and have been associated to unusually high water temperatures.[39] The damage affected many colonies, especially the females.[40]

Climate changes can also potentially alter the composition of gorgonian gardens.[41]

Other important elements

Antibacterial diterpenoids that may be useful for the pharmaceutical industry have been isolated in *Paragorgia arborea*,[42] *Eunicella verrucosa*,[43] *E. cavolini and E. singularis*.[44]

Various species of gorgonian are highly valued and have been traditionally exploited. This exploitation has lead to the local decline of some species and the subsequent alteration of the communities. These species have long life spans, making their recuperation difficult and slow, as is the case with red coral (*Corallium rubrum*)[45] amongst others.

8 Sponge Fields

Characteristics

Sponge aggregations usually occur on the hard substrata of cliff walls, slopes, etc., inside caves, but also on seabeds with different types of substrata, including detritic or muddy areas[1].

Some aggregations are found in shallow waters on infralittoral and circalittoral seabeds attached to walls, reefs, slopes, cracks and caves, and crustose, encrusting sponges are commonly found settled on the substrata, creating dense mats. These aggregations usually harbour numerous species of desmosponges that support rich and diverse communities, mainly consisting of small epifauna. Oceana has documented these aggregations in many locations within the Mediterranean, including such diverse species as *Spirastrella cunctatrix, Phorbas tenacior, P. fictitius, Crambe* sp., *Oscarrela lobularis, Chondrosia reniformis, Clathrina* sp., *Petrosia ficiformis, Agelas oroides, Myxilla* sp., *Mycale* sp., *Ircinia* sp., *Dysidea* sp. and *Ircinia* sp.

These aggregations of crustose and encrusting sponges are not exclusive to the Mediterranean. They also occur in the North Atlantic, comprised of species such as *Myxilla incrustans, Leucosolenia complicata, Leuconia nivea, Pachymatisma johnstonia* or *Clathrina coriacea*[2].

Other colonies are also known to exist in deeper waters between the circalittoral and bathyal regions and are usually represented by cup sponges, glass sponges and/or tree sponges of various sizes. There are two classes of sponges that make up the majority of Atlantic aggregations: Desmospongia and especially Hexactinellida, known as glass sponges. In the Atlantic, they are found on seabeds between 250 and 1,300 meters depth in areas where water temperature ranges from 4ºC to 10ºC[3]. These aggregations can reach concentrations of up to five sponges per square meterd or represent up to 90% of the biomass of some seabedse and provide large quantities of silicon thanks to the dead sponge spicules that remain in or on the sediment, modifying the characteristics of the substrata[6].

Although these seabeds are dominated by glass sponges (i.e., *Pheronema carpenterig* or *Aphrocallistes bocagei*),h other sponges from the Desmospongia class can also be found (*Cladorhiza* sp., *Asbestopluma* sp., *Geodia barretti, G. macandrewi, Isops phlegraei*)[9]. Some of the sponge aggregations studied are those occurring in shallow waters and can be comprised of various dozens of species. Dense concentrations of crustose and encrusting sponges exist in the Mediterranean. Oceana has also confirmed the presence of important fields of tree sponges within the circalittoral Mediterranean, especially those from the *Haliclona, Axinella* and *Aplysina* classes along with other species such as the elephant ear sponge (*Spongia agaricina*) and others (*Suberites* sp., *Tethya* sp., *Thenea* sp.).

Other large sponges can also be found in well-lit circalittoral seabeds located between a depth range of 10 to 50 meters, both in the Atlantic[10] as well as in the Mediterranean, forming important habitats for many species. For example, species such as Cacospongia scalaris, Sarcotragus foetidus, Spongia officinalis, Hippospongia communis or Ircinia variabilis have been documented by Oceana during research studies carried out in 2005 and 2006.

Distribution

Sponge aggregations can be found throughout the Atlantic[11] and the European Mediterranean although many of the most studied and extensive sponge fields, formed by glass sponges, are located between the Arctic and Irish waters[12]. They can be frequently found near the shelf break. Sponge fields of these characteristics have also been located in Macaronesia and on the coasts of northern Africa[13], so it is possible that their distribution is much more extensive than was originally thought. OSPAR[14] defines the areas where sponge aggregations are located as regions I, III, IV and V (encompassing all of the North-East Atlantic, except the North Sea).

Some important sponge fields in Europe are located in Saint Kilda (Scotland)[15], Porcupine Seabright (Ireland)[16], the Faroe Islands (Denmark)[17], the Ba-learic Islands (Spain) or the Le Danois Bank (Spain)[18].

Associated species

The diversity and density of these sponge fields is often spectacular. Almost 250 associated species, mostly epibenthic[19], have been identified in the habitats formed by the sponge fields around the Faroe Islands. In Norway[20] one square meter yielded more than 1,000 specimens of sponges belonging to more than 200 species.

According to data obtained by Oceana during its 2005 and 2006 observation and documentation campaigns aboard the Ranger catamaran, species that feed off sponges are commonly found in areas where aggregations are located on walls, caves, cracks, etc, within the Mediterranean. These species include the nudibranch, *Discodoris atromaculata*, while other species that take advantage of the oscula and microhabitats including a worm from the *Terebellidae family*, *Eupolymnia nebulosa* and species competing for space, such as the anthozoans,

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Caryophyllia spp., *Hoplangia durotrix, Leptosamnia pruvoti* or *Polycyathus muellerae*. Bryozoans, hydrozoans, tunicates, crustaceans, molluscs, echinoderms, etc. are also usually found within these communities.

Some studies have identified up to 72 species within some of these sponge fields in Mediterranean waters[21]. The most frequently found species in circalittoral sponge fields located in depth ranges between 70 and 120 meters include seaman's hands coral (*Alcyonium* sp.), sea cucumbers (*Holothuria forskali*), tube anemones (*Cerianthus* sp.), echiuroids such as *Bonellia viridis* and tunicates such as *Halocynthia papillosa*, as well as brown and rhodophycean algae, and fish including the swallowtail seaperch (*Anthias anthias*) or the seabass (*Serranus cabrilla*).

Relation to other habitats of community importance

Many sponges are frequently related to deep-sea coral reefs[22]. For example, these associations have been identified in reefs around the Faroe Islands (Denmark)[23] or Rockhall (United Kingdom)[24] where dozens of different species have been identified, including the glass sponge Asconema setubalense.

Aggregations of Hexactinelliday[25] and Desmospongia sponges occur frequently around many seamounts[26]. In the Mediterranean, sponge fields can occur on soft or hard substrata, but are especially significant in relation to calcareous rhodophycean algae, where maërl or coralline habitats can be found.

According to EUNIS classification, sponge fields, aggregations and habitats comprised of poriferans are included in the following codes:

•**A1.15** – Fucoids in tide-swept conditions
-**A1.151** - *Ascophyllum nodosum*, sponges and ascidians on tide-swept mid eulittoral rock
-**A1.153** - *Fucus serratus* with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata
•**A1.44** – Communities of littoral caves and overhangs
-**A1.446** – Sponges and shade-tolerant red seaweeds on overhanging lower eulittoral bedrock and in cave entrances
A1.4461 – Sponges, shade-tolerant red seaweeds and *Dendrodoa grossularia* on wave-surged overhanging lower eulittoral bedrock and caves
-**A1.447** – Sponges, bryozoans and ascidians on deeply overhanging lower shore bedrock or caves
-**A1.448** – Faunal crusts on wave-surged littoral cave walls
•**A3.11** – Kelp with cushion fauna and/or foliose red seaweeds
-**A3.112** – Alaria esculenta forest with dense anemones and crustose sponges on extremely exposed infralittoral bedrock
- **A3.113** – *Laminaria hyperborea* forest with a faunal cushion (sponges and polyclinids) and foliose red seaweeds on very exposed infralittoral rock
•**A3.21** – Kelp and red seaweeds (moderate energy infralittoral rock)
-**A3.212** - *Laminaria hyperbore* on tide-swept, infralittoral rock
A3.2122 - *Laminaria hyperborea* park with hydroids, bryozoans and sponges on tide-swept infralittoral rock
•**A3.22** – Kelp and seaweed communities in tideswept sheltered conditions
-**A3.222** – Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
-**A3.225** – Filamentous red seaweeds, sponges and Balanus crenatus on tide-swept variable-salinity infralittoral rock
•**A3.34** – Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)
-**A3.342** - *Ascophyllum nodosum* and epiphytic sponges and ascidians on variable salinity intralittoral rock
•**A3.71** – Robust faunal cushions and crusts in surge gullies and caves
-**A3.712** – Anemones, including *Corynactis viridis*, crustose sponges and colonial ascidians on very exposed or wave surged vertical infralittoral rock
-**A3.713** – Crustose sponges and colonial ascidians with *Dendrodoa grossularia* or barnacles on wave-surged infralittoral rock
-**A3.714** - *Dendrodoa grossularia* and *Clathrina coriacea* on wave-surged infralittoral vertical rock
-**A3.715** – Crustose sponges on extremely wave-surged infralittoral cave or gully walls
•**A4.11** – Very tide-swept faunal communities on circalittoral rock
A4.1121 - *Tubularia indivisa* and cushion sponges on tide-swept turbid circalittoral bedrock
•**A4.12** – Sponge communities on deep circalittoral rock
-**A4.121** - *Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock
•**A4.13** – Mixed faunal turf communities on circalittoral rock
-**A4.131** – Bryozoan turf and erect sponges on tide-swept circalittoral rock
A4.1311 - *Eunicella verrucosa* and *Pentapora foliacea* on wave-exposed circalittoral rock
A4.1312 – Mixed turf of bryozoans and erect sponges with *Dysidia fragilis* and *Actinothoe sphyrodeta* on tide-swept wave-exposed circalittoral rock
A4.1313 – Mixed turf of bryozoans and erect sponges with *Sagartia elegans* on tide-swept circalittoral rock
-**A4.135** – Sparse sponges, *Nemertesia* spp., and Alcyonidium diaphanum on circalittoral mixed substrata
-**A4.136** - *Suberites* spp. with a mixed turf of crisiids and *Bugula* spp. on heavily silted moderately wave-exposed shallow circalittoral rock
-**A4.137** - *Flustra foliacea* and *Haliclona oculata* with a rich faunal turf on tide-swept circalittoral mixed substrata
-**A4.138** - *Molgula manhattensis* with a hydroid and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock
-**A4.139** – Sponges and anemones on vertical circalittoral bedrock
•**A4.21** – Echinoderms and crustose communities on circalittoral rock
-**A4.212** - *Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock
A4.2122 - *Caryophyllia smithii* and sponges with Pentapora foliacea, Porella compressa and crustose communities on wave-exposed circalittoral rock
•**A4.25** – Circalittoral faunal communities in variable salinity
-**A4.251** – Cushion sponges and hydroids on turbid tide-swept sheltered circalittoral rock
A4.2511 – Cushion sponges, hydroids and ascidians on turbid tide-swept sheltered circalittoral rock
A4.2512 – Cushion sponges and hydroids on turbid tide-swept variable salinity sheltered circalittoral rock
-**A4.252** - *Halichondria bowerbanki, Eudendrium arbusculum* and *Eucratea loricata* on reduced salinity tide-swept circalittoral mixed substrata

A4.31 – Brachipod and ascidian communities on circalittoral rock

-A4.312 – Large solitary ascidians and erect sponges on wave-sheltered circalittoral rock

A4.71 – Communities of circalittoral caves and overhangs

-A4.711 – Sponges, cup corals and anthozoans on shaded or overhanging circalittoral rock

A5.43 – Infralittoral mixed sediments

-A5.432 - *Sabella pavonina* with sponges and anemones on infralittoral mixed sediment

A5.52 – Kelp and seaweed communities on sublittoral sediment

-A5.525 - *Laminaria saccharina* and *Gracilaria gracilis* with sponges and ascidians on variable salinity infralittoral sediment

A5.62 – Sublittoral mussel beds on sediment

-A5.624 – *Modiolus modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata

A6.62 – Deep-sea sponge aggregations

-A6.621 - Facies with *Pheronema grayi*

The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Marine Habitats used for the selection of natural sites and promotion of the conservation of these sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

V.1. Biocenosis of bathyal mud

-V.1.1.1. Facies of sandy mud with *Thenea muricata*

-V.1.1.5. Facies with *Pheronema grayi*

Degree of vulnerability

Sponge fields and aggregations are especially sensitive to the physical impact caused by fishing practices. aa In general, it is believed that where demersal fisheries and sponge aggregations occur in the same locations, there is a high probability of impact and decline in sponge population.

In the Mediterranean, bottom trawling has had great impact on tree sponge communities such as *Axinella cannabina*.

Studies carried out in the Pacific have determined that the use of drift nets over sponge fields constitutes a severe impact, damaging between 55 and 67% of the trawled area, with evident signs of deteriorationad and no signs of recuperation in subsequent years.

Sponges are also sensitive to turbidity and contamination. Some studies carried out in contaminated areas indicate the existence of deformed spicules and adversely affected associated fauna.

A potential threat to some species of sponges is overexploitation for medicinal use,ag as happened in the past with European sponges collected for personal hygiene, contributing to the collapse of some populations.

Additional important information

The animal phylum Porifera is the source of the widest range of products used for pharmaceutical purposes.

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Mollusc reefs 9

Characteristics

Some species of sessile or encrusting molluscs create reef formations in European waters. Amongst them are species belonging to the Mytilidae and Vermetidae families.

Reef-forming mytilids belong to the *Mytilus* and *Modiolus* genera, while the vermetids are represented by some species from the *Dendropoma* and *Vermetus* genera.

Mussels from the *Mytilus* genus form dense concentrations on shallow infralittoral seabeds and also in temporarily dried out mediolittoral areas. The common or blue mussel (*Mytilus edulis*) is larger than the Mediterranean mussel (*M. galloprovincialis*). They may colonise different types of substrata and even artificial structures[1]. Normally, the concentrations are comprised of 20 to 40 species per square meter, although they can form dense beds and reefs over one meter thick[2].

The horse mussel (*Modiolus modiolus*) occurs in three physical forms including epifaunal, semi-infaunal and infaunal, although according to some researchersc only some formations within the last two types can be considered biogenic structures or reefs, especially the semi-infaunal forms.

The reef vermetid (*Dendropoma petraeum*) measures between two and five millimetres in diameter and lives in large colonies extending various meters with a thickness of 40 to 60 centimetres. They create reefs in a variety of different shapes. Normally, these occur in the shape of crests, ledges or platforms. Although thousand-year-old reefsd formed by this species do exist, normally these are fossil formations. Live animals, however, have been found in reefs that are between 450 and 650 years old[5].

Furthermore, the small vermetid (*Vermetus triquetus*) that lives within a four to six centimetre tube and can form dense colonies on hard substrata or even fixed to the shells of other molluscs, is also endemic in the Mediterranean and fossil reefs have been found dating back more than 1,800 years[6].

Some deep-sea molluscs, such as *Bathymodiolus* spp., also form dense concentrations considered biogenic reefs. Other reef-forming deep-sea molluscs include *Bathymodiolus azoricus*, found in hydrothermal vents around the Azores (Portugal)[7] or *B. puteoserpentis* in the Atlantic Ridge[8].

Other species of Mollusca also considered to be reef-builders include the common oyster (*Ostrea edulis*),[9] the green crenella mussel (*Musculus discors*)[10] or the gaping file-shell (*Limaria hians*)[11], amongst others.

Distribution

Mollusc reefs are usually found in mediolittoral and infralittoral regions, although some species form reefs at great depths.

These reefs are generally distributed throughout the European Atlantic, from Polar Regions to Macaronesia and the Mediterranean, especially the mytilids[12].

While Mytilidae reefs have a cosmopolitan distribution given their resistance to long periods of drying and their tolerance to a wide range of temperatures between -16°C[13] to almost 30º[14], the Vermetidae reefs prefer warmer waters between latitudes 44ºN and 44ºS in the Atlantic[15], although some formations have been found in Hawaiian waters within the Pacific[16].

The dominating species in these reefs comes from the *Dendropoma* genus and its distribution in Europe ranges from the Mediterranean to Macaronesia. *Dendropoma petraeum* is exclusively found in the Mediterranean and adjacent Atlantic waters, settling in areas of clear waters and strong hydrodynamic conditions, while the reefs formed by the other species within this genus in the Atlantic are conserved mainly as fossils[17].

As far as *Vermetus triqueter* is concerned, it can form reefs alone or together with *Dendropoma petraeum*. Sometimes this species takes advantage of microhabitats, such as rockpools[18], formed by *D. petraeum*.

Regarding the Mytilidae family, *Mytilus edulis* is distributed throughout colder waters (from British waters, the North Sea and the Baltic Sea to the Iberian Peninsula), while *M. galloprovincialis* is more likely to be found in the Mediterranean and the Black Sea, although it can reach the Gulf of Biscay and the southern British Isles[19].

Other European areas where mollusc reefs can be found include: *Dendropoma petraeum* and *Vermetus* sp. in Malta[20], in Cabo de Palos and Hormigas Islands (Murcia, Spain)[21], Sardinia, Capo Gallo and Isola delle Femmine (Italy)[22], etc.; *Modiolus modiolus* in Strangfort Lough (Northern Ireland)[23] or in Shetland Voes (Scotland)[24]; *Mytilus galloprovincialis* in Marseille (France)y and the Gulf of Thermaikos (Aegean Sea, Greece);z Mytilus edulis in Spiekeroog Island (East Frisia, Lower Saxony, Germany)[27], Lindisfarne and Bay of Budle (Berwickshire and North Northumberland, England)[28] ;and Bathymodiolus sp. in Azores (Portugal)[29].

Associated species

Dendropoma petraeum reefs are usually associated with rhodofycean algae and polychaete worms, as well as with other molluscs. Various studies indicate a significant presence of diverse species, amongst them more than 100 species of algae 30, 50 species of polychaetesae[31] and approximately 70 species of molluscs[32]. Species include *Mytilaster minimum, Cardia caliculata, Pissina glabrata, Lepidochitona caprearum, Patella ulyssiponensis, Onchidella celtica, Eatonina cossurae* or *Barleeia unifasciata*.

Various studies have proven that the reefs formed by *Mytilus edulis* are very important for other species[33]. For example, in the Wadden Sea approximately 70 to 80 epibenthic species have been identified[34], including brown algae (*Enteromorpha* spp., *Cladophora sericea, Fucus vesiculosus*), red algae (*Antithamnion plumula, Colaconema daviesii*), hydrozoans (*Coryne pusilla, Sarsia tubulosa*), bryozoans (*Bowerbankia* spp., *Alcyonidium mytili*) and a large quantity of balanids that serve as prey for starfish (*Asterias rubens*), common periwinkle (*Littorina littorea*) and crabs (*Carcinus maenas*)[35].

As far as *Mytilus galloprovincialis* is concerned, approximately one hundred species were identified in mussel concentrations in the Aegean Sea (within the Medite-rranean), predominantly consisting of polychaetes and crustaceans[36], while other studies emphasised the structural importance of different coastal communities[37].

The importance of bathyal mussels should also be stressed due to their relation to both symbiotic bacteria[38], and to other species that live amongst these reefs, such as crustaceans (*Rimicaris exoculata, Chorocaris* sp., *Mirocaris* sp., *Munidopsis crassa, Segonzacia mesatlantica*), echinoderms (*Ophioctenlla acies*), terebellid annelids (*Archinome rosacea*) or other molluscs (*Phymorhynchus moskalevi*)[39].

Relation to other habitats of community importance

Mollusc reefs are usually found on rocky substrata, although some mollusc reefs are also formed on soft substrata.

Vermetidae reefs, specifically those formed by *Dendropoma petraeum*, are usually formed and gain consistency by the use of calcareous red algae thalli such as *Spongites notarisii*[40]. Sometimes they border with another calcareous red algae, *Lithophyllum lichenoides*, contributing to the formation of ledges known as "trottoirs"[41].

As mentioned above, rockpools can lead to the formation of other mollusc reefs or they may form part of a larger community along with *Laurencia papillosa, Gastroclonium clavatum* and *Cystoseira amentacea*[42].

In the deep sea, *Bathymodiolus* sp. is closely associated to hydrothermal vents and cold water seeps[43].

Mytilus edulis can occur in other important habitats such as those formed by the fucoid brown algae *Fucus vesiculosus*[44], polychaete worm reefs formed by *Sabellaria* sp[45] or habitats formed by other molluscs such as *Modiolus modiolus.*[46]

According to EUNIS classification, reef-forming molluscs or those participating in other habitats are included in the following codes:

A1.11 – *Mytilus edulis* and/or barnacle communities
- **-A1.111** - *Mytilus edulis* and barnacles on very exposed eulittoral rock
- **-A1.22** – *Mytilus edulis* and fucoids and barnacles on moderately exposed shores
- **-A1.221** - *Mytilus edulis* and *Fucus vesiculosus* on moderately exposed mid eulittoral rock
- **-A1.222** - *Mytilus edulis, Fucus serratus* and red seaweeds on moderately exposed lower eulittoral rock

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- **A1.223** - *Mytilus edulis* and piddocks on eulittoral firm clay

A1.23 – Mediterranean communities of lower mediolittoral rock moderately exposed to wave action

- **A1.234** – Pools and lagoons sometimes as so-ciated with *Vermetus* spp. (infralittoral enclave)

A1.32 – Fucoids in variable salinity

- **A1.326** - *Fucus serratus* and large *Mytilus edulis* on variable salinity lower eulittoral rock

A1.49 – Hydrolittoral mussel beds

- **A1.491** – Hydrolittoral mussel beds: with little or no macrophyte vegetation
- **A1.492** – Hydrolittoral mussel beds: dominated by macrophyte vegetation

A2.21 – Strandline

- **A2.212** - *Mytilus edulis* and *Fabricia sabella* in littoral mixed sediment

A2.24 – Polychaete/bivalve-dominated muddy sand shores

- **A2.241** - Macoma balthica and Arenicola marina in muddy sand shores
- **A2.242** - *Cerastoderma edule* in littoral muddy sand
- **A2.243** - *Hediste diversicolor, Macoma balthica* and *Eteone longa* in littoral muddy sand

A2.31 – Polychaete/bivalve-dominated mid estuarine mud shores

- **A2.311** - *Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud
- **A2.312** - *Hediste diversicolor* and *Macoma balthica* in littoral sandy mud
- **A2.313** - *Hediste diversicolor, Macoma balthica* and *Scrobicularia plana* in littoral sandy mud

A2.72 – Littoral *Mytilus edulis* beds on sediment

- **A2.721** – *Mytilus edulis* beds on littoral sediments
  - **A2.7211** – *Mytilus edulis* beds on littoral mixed substrata
  - **A2.7212** – *Mytilus edulis* beds on littoral sand
  - **A2.7213** – *Mytilus edulis* beds on littoral mud

A3.11 – Kelp with cushion fauna and/or foliose red seaweeds

A3.1111 - *Alaria esculenta, Mytilus edulis* and coralline crusts on very exposed sublittoral fringe bedrock

A3.13 – Mediterranean communities of infralittoral algae very exposed to wave action

- **A3.133** - Facies with *Vermetus* spp.
- **A3.134** - Facies with *Mytilus galloprovincialis*

A3.36 – Faunal communities on variable or reduced salinity infralittoral rock

- **A3.361** - *Mytilus edulis* beds on reduced salinity infralittoral rock

A4.24 – Mussel beds on infralittoral rock

- **A4.241** - *Mytilus edulis* with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock
- **A4.242** – *Musculus discors* beds on moderately exposed circalittoral rock

A5.12 – Infralittoral coarse sediment

- **A5.123** - *Moerella* spp. with bivalves in infralittoral gravelly sand

A5.13 – Circalittoral coarse sediment

- **A5.132** - *Mediomastus fragilis, Lumbrineris* spp. with venerid bivalves in circalittoral coarse sand or gravel
- **A5.136** – Scallops on shell gravel and sand with some sand scour

A5.24 – Infralittoral muddy sand

- **A5.241** - *Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand
- **A5.242** - *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand
- **A5.245** – *Turritella* in muddy sand
- **A5.246** – *Ervillia castanea* beds in infralittoral sands

A5.25 – Circalittoral fine sand

- **A5.251** - *Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand
- **A5.252** - *Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand

A5.26 – Circalittoral muddy sand

- **A5.261** - *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment

A5.43 – Infralittoral mixed sediments

- **A5.433** - *Venerupis senegalensis, Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment
- **A5.434** – *Limaria hians* beds in tide-swept sublittoral muddy mixed sediment
- **A5.435** – *Ostrea edulis* beds on shallow sublittoral muddy mixed sediment

A5.44 – Circalittoral mixed sediments

- **A5.442** – Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment
- **A5.443** - *Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment

A5.52 – Kelp and seaweed communities on sublittoral sediment

- **A5.523** - *Laminaria saccharina* with *Psammechinus miliaris* and/or *Modiolus modiolus* on variable salinity infralittoral sediment

A5.62 – Sublittoral mussel beds on sediment

- **A5.621** – *Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata
- **A5.622** – *Modiolus modiolus* beds on open coast circalittoral mixed sediment
- **A5.623** - *Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata
- **A5.624** - *Modiolus modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata
- **A5.625** – *Mytilus edulis* beds on sublittoral sediment
- **A5.626** – *Hiatella arctica* beds on silty clay with small pebbles and shells
- **A5.627** – Baltic mussel beds in the infralittoral photic zone
  - **A5.6271** – Baltic mussel beds in the infralittoral photic zone with little or no macrophyte vegetation

The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Marine Habitats used for the selection of natural sites and promotion of the conservation of these sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

II.4.2. Biocenosis of lower mediolittoral rock

- **II.4.2.10.** Pools and lagoons associated with vermetids (infralittoral enclave)

III.6.1. Biocenosis of infralittoral algae

- **III.6.1.3.** Facies with vermetids
- **III.6.1.4.** Facies with *Mytilus galloprovincialis*

Degree of vulnerability

These reefs are threatened by many activities and given their location close to the coast, are especially affected by coastal destruction or occupation as well as contamination by black tides, coastal waste or eutrophication. As far as Vermitidae reefs are concerned, these are also subjected to deterioration caused by bathers and other visitors to coastal areas as they step on the ledges or terraces these molluscs form, as well as by the copper sulphate used by sports fishermen who use these molluscs as bait.

In certain locations, commercial exploitation or the destruction of seabeds by the use of destructive fishing methods have damaged important mollusc reefs. For example, this has happened to reefs formed by *Modiolus modiolus*, destroyed in various areas within the North Atlantic by the dredges used for harvesting scallops[48], Furthermore, the oyster reefs in the Wadden Sea are believed to have been damagedav by collateral effects of fishing, as well as by an increase in hypoxia[49].

As filter feeders, molluscs are also strongly affected by red tides and bacterial infections that can cause serious damage and even mass die-offs amongst these communities[50].

The deterioration of reefs formed by *Dendropoma petraeum* in the Mediterranean has lead to their inclusion in Annexes II and IV of the Barcelona Convention and Annex II of the Bern Convention. The following species are included as builders of threatened habitats in the Initial List of Threatened and/or Declining Species and Habitats of the OSPAR Convention for the protection of the North-East Atlantic: *Modiolus modioulus, Mytilus edulis* and *Ostrea edulis*.

Other important elements

Given their sensitivity, the reefs formed by *Dendropoma* sp. are considered significant environmental indicators and are used to calculate changes in sea level and sea surface temperature[51].

Many mollusc species are potentially invasive and are used commercially in aquiculture. As such, some European species have become invasive in other locations (Mytilus edulis[52], M. galloprovincialis[53]), while allochthonous molluscs have settled in European waters (i.e. *Crassostrea gigas*[54] or *Dreissena polymorpha*[55]), endangering the autochthonous reefs. This invasive versatility can also be seen in European waters. Furthermore, some mussel reefs can be considered invasive in the Wadden Sea,bd while oyster reefs have occupied extensive areas in the Mar Menor (Spain), increasing their density to ten oysters per square meter in less than ten years[57].

Worm reefs 10

Characteristics

Various species of polychaete worms from the *Serpulidae* and *Sabellidae* families are considered “bioconstructors” and, as such, biogenic reef builders. The majority of these species are found in the infralittoral and mediolittoral regions, although they may occur in the circalittoral and in deeper waters.

The most extensive and representative reefs in Europe are formed by the species belonging to the *Sabellaria* genus. *Sabellaria alveolata* and *S. spinulosa* are biologically similar. They usually form dense colonies sometimes comprised of more than 4,000 specimens per square meter,a although in some cases, up to 60,000 worms have been found per square meter[1]. They form their tubes using sand and shell particles, reaching a height of 20 centimetres. They have a rapid growth rate of almost ten to 12 centimetres per year and a high reproductive rate, reaching adulthood in only one year. Average life span is two to five years, although some specimens can reach up to nine years of age[3].

Although they normally form small reefs extending only a few meters, reefs have been found in some areas measuring 300 meters long and more than 50 centimetres thick[4].

The majority of the tube-forming polychaete worms are solitary or live in small groups (Sabella spalanzanii and S. pavonina), although some of them can be part of or form dense, highly populated aggregations. This is the case with species from the *Protula, Serpula* or *Bispira genera*.

Some serpulids form dense colonies that can be considered mini-reefs. In Europe, these species are represented by the *Filograna* and *Salmancina* genera. Some of these species, for example *Salmacina dysteri*, are considered important carbonate mound builders in association with the *bryozoan Pentapora fascialis* in the Adriatic Sea[5], This species is also highly important in Atlantic waters[6].

Furthermore, other polychaete worms such as the sand mason (*Lanice conchilega*) create structures that play an important role in sediment retention, mound formation and habitat configuration like any other tube-forming worm, although these structures are not considered reefs[7].

The majority of these worms reproduce by gametogenesis, sometimes synchronised, although some species (*Salmancina* sp., *Filograna* sp.) can do so asexually[8].

Oceana has confirmed the existence of various polychaete worms (*Serpula vermicullaris, Protula* sp., *Filograna implexa, Lanice conchilega*, etc.), in deep circalittoral waters between 100 and 250 meters depth.

Distribution

Polychaete reefs occur throughout European waters except in the Baltic Sea, Skagerrak and Kattegat[9]. Both Sabellaria spinulosa and S. alveolata occur more frequently in the western waters of the North-East Atlantic (around the United Kingdom and Ireland) where dense aggregations are formed comprised of millions of specimens. Some of these reefs can also be found in French Atlantic waters and the Wadden Sea.j Both species have also been found in various locations within the Mediterranean Sea, although less frequently[11].

While Sabellaria alveolata reefs usually occur in shallow waters including the infralittoral region, the *S. spinulosa* reefs occur between ten and 50 meters deep[12].

Sabellaria sp. reefs can be found in Morecambe Bay and the Solway Estuary (England), in Cardigan Bay and the Lleyn Peninsula (Wales), Glassdrumman (Northern Ireland)[13], Mont Saint-Michel Bay (Brittany, France)[15], Bernerie-en-Retz (Loire, France),o in Aguda (Portugal)[16], the Bay of Valencia (Spain)[17], the Gulf of Tigullio (Ligurian Sea, Italy)[18], the Gulf of Castellammare (Sicily, Italy)[19], and the Bay of Thessaloniki (Greece)[20].

Associated species

Sabellaria spinulosa reefs support characteristic epifauna and infauna, which is distinct from the habitats found in adjacent areas. The epifauna includes different species of sessile organisms such as hydrozoans, bryozoans (*Flustra foliacea, Alcyonidium diaphanum, Cellepora pumicosa*), sponges, tunicates and other polychaete worms, as well as vagile organisms comprised mainly of crustaceans (*pycnogonids, hermit crabs, amphipods*). Amongst the infauna, a wide variety of polychaetes can be found (*Protodorvillea kefersteini, Scoloplos armiger, Harmothoe* spp., *Mediomastus fragilis, Lanice conchilega, Pholoe synophthalmica*) and bivalves (*Abra alba, Nucula* spp., etc.)[21].

As far as Sabellaria alveolata is concerned, these reefs are settled by a variety of brown algae (*Fucus serratus, F. vesiculosus*), red algae (*Palmaria palmata, Polysiphonia* spp., *Ceramium* spp., *Laurencia* sp., *Corallina elongata, Lomentaria* sp.) and green algae (*Enteromorpha* spp., *Ulva lactuca*). Regarding fauna, balanomorph crustaceans can usually be found in these reefs (*Chthamalus montagui, C. stellatus, Semibalanus balanoides*) as well as a wide variety of molluscs (*Nucella lapillus, Nucula nucleus, Sphenia binghami, Musculus discors, Mytilus edulis, Patella vulgata, P. depressa, P. aspera*) and other polychaetes (*Fabricia stellaris, Golfingia* spp.). These formations harbour other species and serve as feeding areas for fish from the Blennidae family and crustaceans (*Carcinus maenas, Unicola crenatipalma*)[22].

Other studiesw have included other species in this list, such as new polychaetes (*Typosyllis armillaris, Eulalia tripunctata, Melinna cristata, Mediomastus fragilis, Harmothoe impar, Arenicola marina, Pygospio elegans, Autolytus prolifer, Exogone naidina*), oligochaetes (*Tubificoides brownae*), sipunculans (*Golfingia vulgaris*), molluscs (*Sphenia binghami*) or crustaceans (*Gammarus salinus, Harpinia pectinata*).

Relation to other habitats of community importance

As indicated above, polychaete reefs provide substrata for different species of algae that settle there and form habitats together. These algae include the fucoids such as *Fucus vesiculosus* y *Fucus serratus*[24].

Some polychaete reefs occur atop old mollusc reefs. In infralittoral areas, the platforms created by these reefs lead to the formation of rockpools[25].

EUNIS classification includes the following polychaetes:

A2.21 – Strandline
- **A2.212** - *Mytilus edulis* and *Fabricia sabella* in littoral mixed sediment

A2.23 – Polychaete/amphipod-dominated fine sand shores
- **A2.231** – Polychaetes in littoral fine sand
  - **A2.2311** – Polychaetes including *Paraonis fulgens*, in littoral fine sand
  - **A2.2312** – Polychaetes and *Angulus tenuis* in littoral fine sand
  - **A2.2313** – *Nephtys cirrosa*-dominated littoral fine sand

A2.24 – Polychaete/bivalve-dominated muddy sand shores
- **A2.241** - *Macoma balthica* and *Arenicola marina* in muddy sand shores
- **A2.242** - *Cerastoderma edule* and polychaetes in littoral muddy sand
- **A2.243** - Hediste diversicolor, *Macoma balthica* and *Eteone longa* in littoral muddy sand
- **A2.245** - Lanice conchilega in littoral sand

A2.31 – Polychaete/bivalve-dominated mid estuarine mud shores
- **A2.311** - *Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud
- **A2.312** - Hediste diversicolor and *Macoma balthica* in littoral sandy mud
- **A2.313** - Hediste diversicolor, *Macoma balthica* and *Scrobicularia plana* in littoral sandy mud

A2.32 – Polychaete/oligochaete-dominated upper estuarine mud shores
- **A2.321** - *Nephtys hombergii* and *Streblospio shrubsolii* in littoral mud
- **A2.322** - *Hediste diversicolor* in littoral mud
  - **A2.3221** - *Hediste diversicolor* and *Streblospio shrubsolii* in littoral sandy mud
  - **A2.3222** - *Hediste diversicolor* and *Corophium volutator* in littoral mud
  - **A2.3223** - *Hediste diversicolor* and *oligochaetes* in littoral mud

A2.42 – Species-rich mixed sediment shores
- **A2.421** - Cirratulids and *Cerastoderma edule* in littoral mixed sediment
- **A2.422** – Syllid and cirratulid polychaetes in poorly sorted mixed sediment shores
- **A2.423** – Syllid and cirratulid polychaetes in variable salinity muddy gravel shores

A2.71 – *Littoral Sabellaria* reefs
- **A2.711** – *Sabellaria alveolata* reef on sand-abraded eulittoral rock

A3.21 – Kelp and red seaweeds (moderate energy infralittoral rock)
- **A3.215** - *Sabellaria spinulosa* with kelp and red seaweeds on sand-influenced infralittoral rock

A4.22 – Sabellaria reefs on circalittoral rock
- **A4.221** - *Sabellaria spinulosa* encrusted circalittoral rock

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A4.2211 - *Sabellaria spinulosa* with a bryozoan turf and barnacles on silty turbid circalittoral rock

A4.2212 - *Sabellaria spinulosa*, didemnid and small ascidians on tide-swept moderately wave-exposed circalittoral rock

A5.12 – Infralittoral coarse sediment

- **A5.124** - *Hesionura elongata* and *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand
- **A5.127** – Dense Lanice conchilega and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand

A5.13 – Circalittoral coarse sediment

- **A5.131** - *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles
- **A5.133** - *Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand

A5.23 – Infralittoral fine sand

- **A5.234** – Semi-permanent tube-building amphipods and polychaetes in sublittoral sand

A5.24 – Infralittoral muddy sand

- **A5.243** - Arenicola marina in infralittoral fine sand or muddy sand
- **A5.244** - *Spisula subtruncata* and *Nephtys hombergii* in shallow muddy sand

A5.25 – Circalittoral fine sand

- **A5.252** - *Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand
- **A5.253** – Medium to very fine sand, 100-210 m, with polychaetes *Spiophanes kroyeri, Amphipectene auricoma, Myriochele* sp., *Aricidea wassi* and *amphipods Harpinia antennaria*

A5.27 – Deep circalittoral sand

- **A5.271** – Maldanid polychaetes and *Eudorellopsis deformis* in deep circalittoral sand or muddy sand

A5.33 – Infralittoral sandy mud

- **A5.335** - *Ampelisca* spp., *Photis longicaudata* and other tube-building amphipods and polychaetes in infralittoral sandy mud

A5.36 – Circalittoral fine mud

- **A5.364** – Silty sediments > 140 m with polychaetes *Lumbrineris fragilis, Levinsenia gracilis* and *amphipods Eriopisa elongata*
- **A5.365** – *Spiochaetopterus* beneath high salinity Atlantic water

A5.37 – Deep circalittoral mud

- **A5.377** - *Myrtea spinifera* and polychaetes in offshore circalittoral sandy mud

A5.43 – Infralittoral mixed sediments

- **A5.432** - *Sabella pavonina* with sponges and anemones on infralittoral mixed sediment

A5.45 – Deep mixed sediments

- **A5.451** – Polychaete-rich deep Venus community in offshore mixed sediments

A5.61 – Sublittoral polychaete worm reefs on sediment

- **A5.611** - *Sabellaria spinulosa* on stable circalittoral mixed sediment
- **A5.612** - *Sabellaria alveolata* on variable salinity sublittoral mixed sediment
- **A5.613** – *Serpula vermicularis* reefs on very sheltered circalittoral muddy sand

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II.2.1. Biocenosis of mediolittoral sands

II.2.1.1. Facies with *Ophelia bicornis*

Degree of vulnerability

Polychaetes from the *Sabellaria* genus appear to be quite tolerant of water quality, accepting various degrees of turbidity, a fact that favours its distribution throughout different Atlantic coasts[26].

One of the main threats to these reefs is physical damage caused by fishing activities such as trawling or the destruction of coasts. It is believed that the disappearance of *Sabellaria* sp. reefs in the Wadden Sea is due to bottom trawling for shrimp and to the construction of dikes and dams[27], as well as to aggregate dredging or the use of dredges to harvest molluscs[28].

In fact, *Sabellaria* sp. reefs have completely disappeared in the Wadden Sea and are currently on the Red List of Benthic Invertebrates of the Wadden Sea.[30] Regeneration of this habitat is difficult. Communities may take from 15 to 150 years to recover.

Nevertheless, deterioration of this habitat is not limited to the Wadden Sea. These reefs have also been damaged by bottom trawling documented in other places within the North Atlantic[31].

Other threats to these reefs have also been detected in the Mediterranean, including coastal engineering works that alter the dynamics of the coastline as well as the construction of breakwaters, artificial beaches and marinas[32].

Other elements to emphasise

There is a wide variety of polychaete worms. Many of them are reef-builders and contribute to the creation of habitats. Normally, they are used as indicators for biodiversity within different marine communities.

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11 Crustacean reefs

Characteristics

Only a few species of sessile crustaceans are capable of building biogenic reefs. These crustaceans are the cirripeds, divided into acorn barnacles or Balanomorpha and goose barnacles or Lepadomorpha.

While Balanomorpha fix themselves directly to the substrata by forming calcium plates, the Lepadomorpha do so by means of a neck, stalk or fleshy and flexible peduncle; a calcium plate or scale is found at the end of this stalk.

All of these species attach themselves to hard coastal substrata in infralittoral and mediolittoral regions, but can also be found fixed to floating objects or as epibiontic fauna attached to other animals, as is the case with sea turtles (i.e *Chelonibia patula, Balanus perforatus, Pachylasma giganteum, Stomatolepas sp., Conchoderma virgatum*, etc[1].), a or Norway lobsters (i.e. *Balanus crenatus*)[2].

Some barnacle species have nomadic tendencies. *Lepas anatifera* is usually found in temperate and tropical waters but may also occur in Antarctic waters[3]. Normally, it does not form part of coastal biota and usually lives pelagically, attached to the hulls of boats or to marine objects or animals.d It may have a rapid growth rate of one millimetre per day in the capitulum or calcareous plate[5].

One habitat-forming species in the circalittoral is Balanus crenatus, generally occurring with the hydrozoan *Tubularia indivisa*[6]. *Semibalanus balanoides* forms important communities in the mediolittoral, often occurring with other cirripeds such as *Balanus* sp.

Other important habitat-forming species belong to the Lepadomorpha family. The majority of cirripeds live in colonies and in the case of the goose neck barnacle (*Pollicipes pollicipes*), these can include up to 6,000 specimens per square meter. *Pollicipes* spp. prefers areas exposed to currents and wavesh[8] and reproduces by gametogenesis[9], capable of laying more than 30,000 eggs[10].

Distribution

The balanids from the *Chthamalus* genus are typically found in the Portuguese bioregion and are distributed from the Mediterranean to the Shetland Islands[11], including *Macaronesia*[12], *C. Stellatus* and *C. montagui* usually occur together on Mediterranean and Atlantic coasts. *C. montagui* is more frequent in the Atlantic, occupying coastal areas in the mediolittoral that often dry out, while *C. stellatus* prefers lower, constantly humid regions[13], but in the Mediterranean this distribution is not so evident[14]. Some studies indicate the frequent occurrence of *C. montagui* in protected coastal areas, such as bays, while *C. stellatus* is more often found in the open waters where wave action facilitates larval dispersion and subsequent establishment in new locations[15].

The species belonging to the *Balanus* genus are widely distributed. *Balanus balanus* is cosmopolitan and *Balanus perforatus* occurs frequently throughout the Atlantic, from the British Isles to the western coasts of Africa and the Mediterranean Sea. Although it shares some habitats with *Chthamalus*, *Semibalanus balanoides* occurs more frequently in the north[16].

Other species occur in reduced groups, such as Megabalanus azoricus, endemic to Macaronesia. This species was first discovered in the Azores and later in Madeira (and possibly on St. Helena Island)[17] and recently in the Canary Islands[18]. Pollicipes pollicipes occurs in the North-East Atlantic, from the British Isles to Senegalese waters[19], while Semibalanus balanoides is frequently found in the Pacific and Atlantic oceans, with the exception of some ecoregions such as the Gulf of Biscay[20].

Some important areas where communities of cirriped crustaceans can be found include: *Megabalanus azoricus* in João de Castro (Azores, Portugal)[21], Madeira (Portugal)[22] and Gando (Gran Canary, Canary Islands, Spain)[23];Pollicipes pollicipes in Gaztelugatxe (Basque Region, Spain)[24], in Brittany (France)[25], Castelejo and Zavial (Algarve, Portugal)[26]; Chthamalus montagui and C. stellatus in Cork (Ireland)[27], on Oliveirinha beach (Portugal)[28], on the Isle of Wight, Southampton and Torbay (England)[29]; Balanus perforatus in Abra de Bilbao (Spain)[30]; Balanus crenatus, on both sides of the English Channel (France and England)[31], *Semibalanus balanoides* in Loch Diabaig (Scotland)[32], Isle of Man and on the south eastern coasts of Ireland and Sweden[33].

Associated species

The majority of the communities formed by cirripeds have not been researched. One of the most studied communities is the one formed by *Balanus crenatus* in the Atlantic, which usually harbours a wide variety of species such as hydrozoans (*Tubularia indivisa, Sertularia argentea*), sponges (*Halichondria panicea*), anthozoans (*Sagartia elegans, Urticina felina, Metridium senile*), echinoderms (*Asterias rubens*), crustaceans (*Cancer pagurus*) and molluscs (*Nucella lapillus*), amongst others[34].

Different epibiontic species often settle in the structures formed by the cirripeds. As such, some have been related to a wide variety of species, such as *Chthamalus stellatus* with cyanophycean algae (*Brachytrichia quoyi, Nostoc entophytum, Hyella caespitosa, Mastigocoleus testorum, Calothrix parietina, Microcystis litoralis*)[35], Pollicipes pollicipes with red algae including *Aglaothamnion sepositum*[36], or diverse fauna atop *Balanus perforatus* such as the gastropod mollusc[37], the trematode Maritrema arenaria,al the hydrozoan Clava multicornis, the bryozoans *Valkeeria uva, Cryptosula pallasiana, Torbicellepora magnicostata*,[39] as well as rhodophycean algae such as Ceramium secundatum[40].

The habitats formed by *Chthalamus* sp. usually occur with other cirripeds such as *Semibalanus balanoides*, as well as with other species of molluscs typically found on mediolittoral rocks such as limpets (*Patella* spp.). Other species associated with these communities include bivalve molluscs (*Mytilus edulis, Melarhaphe neritoides, Littorina saxatilis*), anthozoans (*Actinia equina*) and lichens (*Verrucaria maura*) and a community similar to the one formed by *Semibalanus balanoides*, with which other red algae are associated, such as *Himanthalia elongata, Corallina officinalis, Mastocarpus stellatus or Osmundea pinnatifida*[41].

Relation to other habitats of community importance

Balanus perforatus is often associated with the photophilic biocenosis of upper infralittoral rock exposed by wave action[42], where *Cystoseira* spp., *Lithophyllum incrustans* and *Mytillus edulis* or *Patella* spp. are present.

Chthalamus spp. and *Semibalanus balanoides* are associated to various communities of fucoid and laminarian brown algae that form forests in coastal areas of the Mediterranean Sea and the Atlantic Ocean. In the Mediterranean, the association of barnacles and *Fucus vesiculosus* occurs in mediolittoral areas moderately exposed to wave action.

A1.1 – Littoral rock very exposed to wave action

- **A1.11 -** Mussels and/or barnacles communities
  - **A1.111** - *Mytilus edulis* and barnacles on very exposed eulittoral rock
  - **A1.112** - *Chthamalus* spp. on exposed upper eulittoral rock

A1.1121 - *Chthamalus montagui* and *Chthamalus stellatus* on exposed upper eulittoral rock

A1.1122 - *Chthamalus* spp. and Lichina pygmaea on steep exposed upper eulittoral rock

- **A1.113** - *Semibalanus balanoides* on exposed to moderately exposed or vertical sheltered eulittoral rock

A1.1131 - *Semibalanus balanoides, Patella vulgata* and *Littorina* spp. on exposed to moderately exposed or vertical sheltered eulittoral rock

A1.1132- *Semibalanus balanoides, Fucus vesiculosus* and red seaweeds on exposed to moderately exposed eulittoral rock

A1.1133 - *Semibalanus balanoides* and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles

- **A1.21** – Barnacles and fucoids on moderately exposed shores
  - **A1.211** - *Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock
  - **A1.213** - *Fucus vesiculosus* and barnacle mosaics on moderately exposed mid eulittoral rock
- **A1.44 –** Communities of littoral caves and overhangs
  - **A1.449** – Sparse fauna (barnacles and spirorbids) on sand/pebble-scoured rock in littoral caves
- **A2.43 –** Species-poor mixed sediment shores
  - **A2.431** – Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata
- **A3.22** – Kelp and seaweed communities in tide-swept sheltered conditions
  - **A3.225** – Red filamentous algae, sponges and Balanus crenatus on tide-swept variable-salinity infralittoral rock
- **A3.71** – Robust faunal cushions and crusts in surge gullies and caves
  - **A3.713** – Crustose sponges and colonial ascidians with *Dendrodoa grossularia* or barnacles on wave-surged infralittoral rock

A3.7161 - *Balanus crenatus* and/or *Pomatoceros triqueter* with spirorbid worms and coralline crusts on severely scoured vertical infralittoral rock

A3.7162 – Coralline crusts and crustaceans on mobile boulders or cobbles in surge gullies

- **A4.11** – Very tide-swept faunal communities on circalittoral rock
  - **A4.111** - *Balanus crenatus* and *Tubularia indivisa* on extremely tide-swept circalittoral rock
- **A4.22** – Sabellaria reefs on circalittoral rock

A4.2211 - *Sabellaria spinulosa* with a bryozoan turf and barnacles on silty turbid circalittoral rock

- **A5.13** – Circalittoral coarse sediment
  - **A5.131** - *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles

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II.4.2. Biocenosis of lower mediolittoral rock

- **II.4.2.5.** Facies with Pollicipes cornucopiae

Degree of vulnerability

Many of these communities are relatively resistant to contamination and occur frequently in anthropogenic areas including ports and artificial marine structures and oil platforms.aq They are, however, considered vulnerable to changes in water flow, salinity and turbidity[44].

Various researchers have related the distribution and reproductive success of diverse cirripeds to the climate changes occurring in European waters[45].

It has also been shown that some of the mass die-offs of these species are due to the extreme temperatures suffered for a certain a period of time[46].

Megabalanus azoricus has been found in some hydrothermal vents, such as the João de Castro undersea volcano in the Azores (Portugal)[47]

Other elements to emphasise

The commercial exploitation of some biogenic reef-forming crustaceans (*Pollicipes* sp.) is very important for certain European coastal communities, especially in Galicia (Spain)[48], Brittany (France)[49] and the Algarve (Portugal)[50], producing hundreds of tons annually.

In certain locations, species may be suffering overexploitation, such as *Pollicipes pollicipes* and *Megabalanus azoricus*, which is also commercially exploited[51].

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12 Praderas de fanerógamas marinas

Characteristics

Seagrass meadows are habitats comprised of superior photophilic plants. These plant species belong to the Magnoliophyta phylum, in other words they are flowering plants that also have a complex rhizome system.

Five species occur in Europe: *Posidonia oceanica, Cymodocea nodosa, Zostera marina, Z. noltii and Halophila decipiens*[1].

These plants are extremely important for marine communities because they harbour large quantities of habitats, biomass and oxygen while also protecting the coast from erosion, fixing carbon and sediments, etc[2].

Communities of seagrass meadows can concentrate large amounts of biomass and have a primary production[3] rate of approximately 1 kg/m^2. For example, primary production rates of Zostera marina in waters of the North Sea are approximately 160 to 400 grams (dry weight) per square meter[4], although this figure may vary between 500 and 1,000 grs(dw)/m^2/year[5]. In the Mediterranean, *C. nodosa* produces approximately 400 grs(dw)/m^2/year[6], but can reach over 750 grs(dw)/m^2/year[7] in the Atlanticg. More importantly, however, some *P. oceanica* meadows can produce more than three kilograms of biomass per square meter annually.Significant quantities of oxygen are also produced, reaching up to 20 litres per square meter[9].

Seagrass meadows can occur in different environments and on different substrata. For example, *Cymodocea nodosa* has been found in coastal lagoons, estuaries, open coasts, on sandy substratum, etc.; *Posidonia oceanica* on hard and soft substrata; *Zostera* sp. in intertidal and infralittoral areas.

Some of these meadows present very high densities. In some areas, Posidonia oceanica can reach densities of up to 1,000 specimens per square meter[10].

This seagrass produces the highest levels of leaf biomass and has the longest life span of all species, and also offers a large surface area for the settlement of epiphytes. Some can have up to 30 m^2 of leaf surface per square meter of meadow[11].

Seagrass meadows can form various habitats. Meadows comprised of dead leaves and plant debris are just as important as those made up of live plants because they constitute diverse biological ecosystems that are critical to coastal areas[12].

Furthermore, these meadows export a large part of their primary production to other marine ecosystems. m Oceana, for example, has found significant concentrations of dead leaves on detritic seabeds at more than 100 meters depth.

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Distribution

Posidonia oceanica is endemic to the Mediterranean Sea. This is the only representative species of this genus found in the northern hemisphere and is believed to be a relic, dating back to the Cretaceous Period[14].

The plants belonging to the *Zostera* genus are found off the coasts of all EU countries, extending from the Mediterranean Sea to the Black Sea, up to the Arctic.o Z. marina is the most widely distributed species, except in the Black Sea where Z. noltii is the representative species, as well as in the western Mediterranean and the meridional North Atlantic.

Within the European Union, Halophila decipiens is found only in waters around the Canary Island archipelago[16].

The bathymetric distribution of all these species is strongly limited by the quantity of light that penetrates the water, so it is quite rare to find these meadows at depths over 35 to 40 meters[17], although in exceptional cases, *H. decipiens* can be found at 80 meters depth[18].

Mixed meadows often occur where 2 or 3 different species participate, including, for example, Posidonia oceanica, *Cymodocea nodosa and Zostera marina*[19].

Seagrass meadows can be found off the island of Ischia (Gulf of Naples, Italy)[20], comprised of *Cymodocea nodosa* and *Zostera noltii*; in Calnegre (Murcia, Spain)[21], comprised of *C. nodosa*; in the Revellata Bay (Corsica)[22] or in Cabrera National Park (Balearic Islands)[23] and comprised of Posidonia oceanica; in Tvärminne, (Finland)[24];in the Tjärnö Archipelago (Sweden)[25]; in Hel (Poland)[26]; in the Isles of Scilly (England),aa comprised of *Zostera marina*; and off the southern and eastern coasts of Tenerife (Canary Islands, Spain)[28], comprised of Halophila decipiens.

Associated species

Seagrass meadows create a wide variety of environments that lead to the creation of the most diverse habitats, promoting the existence of a large variety of species. Similarly, the different strata within these prairies (rhizomes, bushes, leaves, etc.) each support a characteristic community as well as high levels of bacterial activity[29].

For decades, the importance of Posidonia oceanica meadows as a contributing factor to the biodiversity within the Mediterranean has been acknowledged internationally[30]. More than 1,400 different species of fauna and flora have been identified within *P. oceanica* meadows[31]. Amongst these, a large quantity of crustaceans can be found, such as amphipods (*Lysianassa caesarea, Ampelisca pseudospinimana, Hyale schmidtii*, etc.), and decapods (*Hyppolite inermis, Thoralus cranchii* or *Palaemon* sp.), or an abundance of epiphytes (*rhodophyceans, bryozoans, hydrozoans, tunicates*, etc.) that constitute the food supply for a multitude of species[32].

The majority of predators that feed off the *Posidonia oceanica* leaves are the epiphytes that grow on them. Some species, however, such as *Sarpa salpa, Paracentrotus lividus* and *Idotea hectica*[33], also feed off the plant's leaves.

Cymodocea nodosa meadows also harbour abundant biodiversity. The average epiphytic biomass of the *Cymodocea nodosa* meadows of the Canary Islands is 52.6 grams (dry weight) per square meter of leaves[34] and almost 70 different species of polychaetes alone have been identified[35], amongst them *Streptosyllis bidentata, Aricidea assimilis* and *Exogone parahomoseta*.

Certain coastal meadows are also immensely important for birds, sea turtles and other animals that feed and live in them[36] Furthermore, various commercial species, such as the flounder (*Platichtys flesus*), feed off the infauna harboured in these meadowsak while other species such as the Atlantic cod (*Gadus morhua*) use them as nursery areas[38].

Relation to other habitats of community importance

- **A2.13** – Mediterranean communities of mediolittoral coarse detritic bottoms
  - **A2.131** – Facies of banks of dead leaves of *Posidonia oceanica* and other phanerogams
- **A2.61** – Seagrass beds on littoral sediments
  - **A2.611** – Mainland Atlantic *Zostera noltii* or *Zostera angustifolia* meadows
    - **A2.6111** – *Zostera noltii* beds in littoral muddy sand
  - **-A2.612** – *Macaronesian Zostera* noltii meadows
  - **-A2.613** – *Pontic Zostera* marina and *Zostera noltii* meadows
  - **-A2.614** - *Ruppia maritima* on lower shore sediment
- **A5.53** – Sublittoral seagrass beds
  - **A5.531** – *Cymodocea* beds
    - **-A5.5311** – *Macaronesian Cymodocea* beds
    - **-A5.5312** – *Lusitanian Cymodocea* beds
    - **-A5.5313** – *Mediterranean Cymodocea* beds
  - **-A5.532** – *Halophila* beds
  - **-A5.5321** – Canary Island *Halophila* beds
  - **-A5.5322** – Mediterranean *Halophila* beds
    - **-A5.533** – Zostera beds in full salinity infralittoral sediments
    - **-A5.5331** – Zostera marina/angustifolia beds on lower shore or infralittoral clean or muddy sand
  - **-A5.5332** – Mediterranean *Zostera noltii* beds
  - **-A5.5333** – Association with *Zostera marina* in euryhaline and eurythermal environment
  - **-A5.5334** – Mediterranean *Zostera hornemanniana* beds
    - **-A5.534** – Ruppia and *Zannichellia* communities
  - **-A5.5341** – Middle European *Ruppia* and *Zannichellia* communities
  - **-A5.5342** – Tethyan marine Ruppia communities
  - **-A5.5343** - *Ruppia maritima* in reduced salinity infralittoral muddy sand
  - **-A5.535** – *Posidonia* beds
    - **-A5.5351** – *Ecomorphosis* of striped *Posidonia oceanica* meadows
    - **-A5.5352** – Ecomorphosis of "barrier-reef" *Posidonia oceanica* meadows
    - **-A5.5353** - Facies of dead "mattes" of Posidonia oceanica without much epiflora
    - **-A5.5354** – Association with *Caulerpa prolifera* on *Posidonia* beds
- **A5.54** – *Angiosperm* communities in reduced salinity
  - **-A5.545** – Zostera beds in reduced salinity infralittoral sediments

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The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Marine Habitats used for the selection of natural sites and promotion of the conservation of these sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

I.2.1. Biocenosis of supralittoral sands
- **I.2.1.5.** Facies of phanerogams which have been washed ashore (upper part)

II.3.1. Biocenosis of the detritic mediolittoral
- **II.3.1.1.** Facies of banks of dead leaves of *Posidonia oceanica* and other phanerogams

III.1.1. Biocenosis in euryhaline and eurythermal environment
- **III.1.1.4.** Association with *Zostera noltii* in euryhaline and eurythermal environment
- **III.1.1.5.** Association with *Zostera marina* in euryhaline and eurythermal environment

III.2.2. Biocenosis of well sorted fine sands
- **III.2.2.1.** Association with *Cymodocea nodosa* in well sorted fine sands
- **III.2.2.2.** Association with *Halophila stipulacea*

III.2.3. Biocenosis of superficial sands in sheltered waters
- **III.2.3.4.** Association with *Cymodocea nodosa* in superficial sands in sheltered waters
- **III.2.3.5.** Association with *Zostera noltii* in superficial sands in sheltered waters

III.5.1. *Posidonia oceanica* meadows (= Association with *Posidonia oceanica*)
- **III.5.1.1.** Ecomorphosis of striped meadows
- **III.5.1.2.** Ecomorphosis of barrier-reef meadows
- **III.5.1.3.** Facies of dead "mattes" of *Posidonia oceanica* without much epiflorao
- **III.5.1.4.** Association with *Caulerpa prolifera*.

Degree of vulnerability

Seagrasses reproduce asexually although they are flowering plants that produce seeds with variations amongst species. Reproduction rates for *Posidonia oceanica* are low and predators eat many of them, limiting their possibilities for reproduction and regeneration[41]. Reproduction and regeneration rates for *Cymodocea nodosa* are significantly higher than *P. oceanica*[42]. As far as Zostera spp. is concerned, its production of seeds is hundreds or thousands of times superior to that of the aforementioned species[43].

Various factors limit its growth rate, including light intensity[44] availability of nutrients[45], water temperature and salinity[46].

Some human activities can cause serious damage to these seagrass meadows, due to erosion and the dislodging of plants and leaves. Other important physical disturbances include anchoring of recreational vessels on the prairies[47] and, above all, mobile fishing gear such as bottom trawling.

Bottom trawling is considered the most important threat to these marine communities as well as other benthic communities due to its devastating effects. av This activity has damaged between 40 and 50% of the existing *Posidonia oceanica* meadows in the Mediterranean Sea[49]. A trawler can tear off between 100,000 and more than 350,000 leaves per hour, apart from seriously damaging the rhizomes[50], and altering the composition of the communities and species harboured within the meadows[51].

P. oceanica is clearly in decline due to both anthropogenic and natural causes (some of these are possibly also induced or aggravated by human activities). The following can be included amongst these causes[52]: destruction caused by mobile fishing gear, pollution, coastal development, climate changes, eutrophication, storms, infections caused by pathogens (such as protists from the Labyrinthula family), or even the amount of rainfall in the area[53].

During the 1930s, Zostera marina suffered a major die-off throughout the Atlantic caused by the "wasting disease"[54] which affected 90% of the prairies[55] in some areas of Europe and North America. The disease was believed to have been caused by the fungus *Labyrinthula zosterae*[56]. Unfortunately, the species has not yet recovered and other anthropogenic and natural factors are affecting the existing meadows[57].

Studies have proven the life span of *P. oceanica* meadows to be between 6,000 and 7,000 years for some plants[58], although some meadows may even date back more than 100,000 years[59], Long life spans have also been confirmed amongst *Zostera marina*, which can date back approximately 3,000 years[60].

Of all European seagrasses, *Posidonia oceanica* is considered the most vulnerable because the loss of a meadow may be irreversible. Even if its recuperation were viable, this process would take centuries[61].

All European seagrass species have suffered a serious decline in populations. For example, the dramatic changes that have occurred within the Wadden Sea during the last century have lead to the disappearance of *Zostera marina* in this area[62].

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The introduction of exotic seagrasses and algae and the subsequent competition with these seagrass meadows is also beginning to constitute a problem. This is the case of *Halophila stipulacea*[63], an Indian seagrass that is altering the dynamics, diversity and structure of benthic communities occupying extensive areas in the eastern Mediterranean and beginning to extend into western areas. Similarly, diverse species of green algae are causing problems such as *Caulerpa taxifolia* and *C. racemosa*, and other allochthonous organisms.

Currently, only Posidonia oceanica meadows are co sidered priority habitats in the EU Habitats Directive.

Other important aspects

The life plan of *Posidonia oceanica* and its assimilation of contaminants such as radionuclides[64] organochlorides or heavy metals[65] make it a good indicator of contamination levels in the marine environment[66].

13 Green algae meadows

Characteristics

Green algae are photophilic species that inhabit well-lit infralittoral areas, although some species occur in the circalittoral up to depths of approximately 80 to 90 meters.

The most common species are those from the *Caulerpa*[1] and *Halimeda* genera, forming beds in the more temperate regions within European waters.

Only eight of the 72 species belonging to the Caulerpa, a genus can be found in the Mediterranean[2] and of these, only two are autochthonous in European waters: *Caulerpa prolifera* and *C. ollivieri*. Furthermore, other species can be found in the Macaronesian islands: Caulerpa webbiana[3] *C. scalpelliformis*[4], C. sertularioides[5], C. Mexicana[6], C. cupressoides[7], as well as invasive species occurring in various areas within the *European benthos*, such as *C. taxifolia*[8] and *C. racemosa*[9].

Caulerpa prolifera is autochthonous but not exclusive to the Mediterranean and its foliage can reach a height of between 15 and 25 centimetres. They usually occur on fine sediments, including mud and sand[10], reaching densities of more than 350 grams (dry weight) per square meter[11].

In spite of preferring shallow areas, light intensity can affect *C. prolifera*[12], It has been proven that its growth rate and density increases when it is protected from direct sunlight by other algae and seagrasses[13].

Halimeda tuna is a sciaphilic species that can grow at more than 70 meters depth[14]. The fact that *H. tuna* grows well at greater depths may be due to the availability of nutrients at these depths and the possibility that a certain degree of photoinhibition may occur in shallower areas[15]. Some research indicates that other environmental factors, such as water temperature, can limit its growth[16].

The importance of chlorophycean species of the *Halimeda genus* is internationally acknowledged. These species contribute to marine ecosystems thanks to high levels of calcium carbonate production and also contribute to the formation of beaches[17] in the littoral areas. *Halimeda tuna* is the main carbonate producer amongst the green algae in the Mediterranean[18]. Some estimates regarding annual production rates for *H. tuna* in the Caribbean and the Mediterranean indicate quantities between 20 and 100 grams of calcium carbonate per square meter[19]. This data has also been confirmed by the fossil records (dated between the Jurassic and Holocene Periods), many of which are located in European waters, demonstrating the importance of this algae in the formation of coral reefs, carbonate mounds and the sedimentation of beaches[20].

Distribution

Caulerpa prolifera is distributed throughout the temperate waters of the Atlantic from Floridau and the Gulf of Mexico[21] to the Mediterranean Sea, forming mixed beds with the seagrasses *Halodule wrightii* or *Thalassia testudinum*[23].

This species has often been mistakenly identified as C. ollivieri, with which it sometimes forms mixed communities[24]. *Caulerpa ollivieri* also occurs in temperate waters of the Atlantic, from the western Mediterraneany to the coasts of Brazil[26]. As far as the *Halimeda genus* (Bryopsidales order) is concerned, it is widely distributed throughout tropical and temperate waters of the Atlantic and Pacific Oceans[27] *Halimeda tuna* is the only species of this genus that occurs in European waters and is distributed from the Mediterranean[28], where it forms important communities, to the warm waters of the Caribbean and Florida[29] where coral reefs occur (or even in the Atlantic waters of Brazil [30]), and in the Hawaiian Islands of the Pacific[31].

Caulerpa prolifera is related to various factors such as the nature of the seabed, the physico-chemical composition of the sediment, minimum temperatures, hydrodynamic conditions and depth[32]. Although it is widely distributed throughout the Mediterranean, it rarely occurs in the Adriatic[33]. It can become a predominant species in shallow water benthic ecosystems. For example, in a coastal area of approximately 250 kilometres, such as the region of Murcia, it is estimated that these beds occupy almost 2,250 hectares[34].

This species has also been found, although less frequently, as an epiphyte within infralittoral shade-tolerant algal communities where the dominating species are *Peyssonnelia polymorpha, Peyssonnelia rubra, Codium bursa, Flabellia petiolata, Halimeda tuna* or *Zanardinia protorypus*[35].

Caulerpa beds can occur in the Bay of Pollensa[36], the Mar Menor[37] or the Bay of Algeciras (Spain)[38], the Gulf of Tigallio (Italy)[39], the Bays of Luka Dubrovacka, Skrivena Luka and Stari Grad (Croatia)[40], Argolikos Bay (Greece)[41], etc. Halimeda tuna occurs in the Gulf of Trieste and Pantelleria Island (Sicily, Italy)[42], Pinya de Rosa in Blanes (Costa Brava, Spain)[43], Malta[44], Dramont (Saint Raphael, France),as amongst other places; and C. ollivieri in the Balearic Islands[46].

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Associated species

These communities can harbour a wide variety of species[47], as do other species of green algae such as *Acetabularia acetabulum, Codium vermi-liara* or *Codium bursa*. The fauna is represented by the bryozoan *Watersipora subovoidea*, the tunicate *Clavellina lepadiformis*, the crustaceans *Palaemon adspersus* and *Hippolyte* sp., or a variety of gastropods such as *Loripes lacteus*, *Parvicardium exiguum, Jujubinus striatus, Pusillina marginata, Rissoa membranacea, Bittium reticulatum, Corbula gibba, Pandora inequivalvis* or *Tricolia tenuis*. The amphipod *Caprella calerpensis* is another species commonly found within these communities, both in the Mediterranean and in the adjacent waters of the Atlantic[48].

They also serve as spawning areas for some species such as *Gobius niger*, *Pomatoschistus microps* and *Callionymus risso*[49].

Caulerpa prolifera frequently grows close to or within seagrass meadows[50]. The main predators of *C. prolifera* include some species of opisthobranchs, for example, *Oxinoe olivacea*[51], *Ascobulla fragilis* or *Lobiger serradifalci* [52].

Halimeda tuna usually occurs together with the chlorophycean alga *Flabellia petiolata*[53], Oceana has identified a wide variety of species within these beds, including fish such as seabass (*Serranus cabrilla*) and crustaceans such as hermit crabs (*Pagurus* sp., *Dardanus* sp.), as well as colonies of alcyonacean corals such as *Maasella edwardsii.*

Relation to other habitats of community importance

Some species of caulerpacean algae occur close to or within seagrass meadows, such as *Posidonia oceanica, Zostera* sp., or *Cymodocea nodosa*[54], but also amongst forests of *Cystoseira* such as *C. adriatica*, *C. schifneri* or *C. spinosa*. They also occur together with other algae including Rytiphloea tinctoria, Gracilaria verrucosa, Padina pavonica, Caulerpa ollivieri, Dasycladus vermicularis, Flabelia petiolata and Dictyopteris membranaceae*55*, or with other photophilic species such as *Amphiroa rigida, Padina pavonica* or *Halopteris scoparia*[56].

Mollusc reefs comprised of *Ostrea edulis*[57] can sometimes be found amongst the foliage.

Due to its sciaphilic characteristics, *Halimeda tuna* can also be found in vertical walls and sea caves[58]. *H. tuna* is frequently related to coralline or *precoralline algae*[59]. *Halimeda tuna* and *Flabellia petiolata* communities have also been found in shallow areas around hydrothermal vents[60].

Only a few green algae beds are included in EUNIS classification.

- **A5.28** – Mediterranean communities of superficial muddy sands in sheltered waters
  - **-A5.284** – Association with *Caulerpa prolifera* on superficial muddy sands in sheltered waters
- **A5.53** – Sublittoral seagrass beds
  - **-A5.535** – *Posidonia* beds
    - **- A5.5354** – Association with *Caulerpa prolifera* on *Posidonia* beds
- **A4.26** – Mediterranean coralligenous communities moderately exposed to hydrodynamic action
  - **- A4.267** – Algal bioconcretion with *Lithophyllum frondosum* and *Halimeda tuna*

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- **III.2.3.** Biocenosis of superficial muddy sands in sheltered waters
  - **- III.2.3.6.** Association with *Caulerpa prolifera* on superficial muddy sands in sheltered waters
- **III.5.1.** *Posidonia oceanica* beds (= Association with *Posidonia oceanica*)
  - **- III.5.1.4.** Association with *Caulerpa prolifera*
- **III.6.1.** Biocenosis of infralittoral algae
  - **- III.6.1.32.** Association with *Flabellia petiolata* and *Peyssonnelia squamaria*

Degree of vulnerability

Given its resistance to anthropogenic agents, *C. prolifera* has taken advantage of the disappearance of more vulnerable species in some areas in order to expand its own area of distribution[61]. Although it can also be adversely affected by coastal contamination, in some cases its presence can lead to the degradation of the existing ecosystem[62].

In the Mediterranean, this can sometimes occur inside ports and in coastal lagoons such as the Mar Menor (Murcia, Spain).

The introduction of allochthonous species from the Caulerpa genus into European waters, especially the Mediterranean, can cause alterations in the benthic communities and lead to the displacement of the autochthonous *Caulerpa prolifera*[63].

As far as *C. ollivieri* is concerned, this species has been considered severely endangered for decades[64].

Other important aspects

Caulerpa prolifera is rich in substances like carotenes[65], polypeptides[66] and sesquiterpenoidsbo used for nutritional and pharmaceutical products, as well as antibacterial substances[68].

Studies concerning Mediterranean macrophytes indicate that the chlorophycean *Caulerpa prolifera, Halimeda tuna* and *Flabelli* show the highest levels of activity concerning the production of bactericide, fungicide and antiviral substances as well as other compounds used for medicinal purposes[69].

Caulerpa prolifera can reproduce both sexually and asexually[70], and its proliferation can even occur because of fragmentation, as long as the fragments include part of the stem or rhizome[71], although it is not as successful as the invasive species *C. taxifolia*[72].

The caulerpacean algae introduced in European waters can compete with other invasive algae such as *Womersleyella setacea* causing both positive and negative effects[73].

14 Red algae concretions

Characteristics

Fossils of red algal concretions date back to the prehistoric periods and are conserved in various sites. These include the fossils in the Bay of Cadiz[1], a dating back to the Pliocene Period where maërl-forming rhodolithes are between three and five million years old. Red algal concretions can also be traced back to the Lower Cretaceous Period in various European locations[2].

The algae that participate in the formation of these beds belong to the Corallinaceae family (Corallines order), although algae from the Peyssonneliaceae family (Cryptonemiales order) are sometimes present as well. These algae are characterised by a rigid, calcium carbonate structure and are therefore referred to as calcareous algae.

The availability of light is a fundamental factor in the distribution of these communities[3], along with other factors including availability of nutrients[4], temperature[5] or hydrodynamic conditions[6].

Amongst the most characteristic habitats formed by these algae are coralline habitats, maërl beds, reefs or "trottoir" as well as other concretions that sometimes occur simultaneously with the aforementioned habitats, creating characteristic seabeds.

The coralline habitat is possibly the most complex and diverse ecosystem formed by the red algae in the European Union. This chapter may include all or the majority of the existing red algal concretions. In fact, maërl has sometimes been considered to be a plateau coralline[7].

Biogenic coralline beds are created by sciaphilic calcareous algae[8]. A general scientific consensus does not exist regarding the definition of this community, leading some authors to differentiate between types of coralline algae[9], depending on whether they occur on walls, plateaus, caves, etc. The complexity and great biological richness of these communities make them "multiple" habitats or a compendium of communities in which calcareous red algae is the principal builder but in which a wide variety of marine organisms participate as well.

The thickness of these concretions is highly variable and can reach over 2 meters in some areas[10]. The coralline algae that form these beds is mainly *Mesophyllum alternans* and *Litophyllum sticaeformis*[11], along with the participation of many other algae such as Neogoniolithon mamillosum or *Peyssonnelia* spp.[12],but also more than one hundred other animal species[13] including polychaetes, cnidarians, molluscs, sponges, bryozoans, foraminferans and crustaceans.

The amount of calcium carbonate generated annually by coralline algae is estimated to be between 100 and 465 grams per square metern[14] with an algal biomasso of 1,200 to 2,100 grams dry weight per square meter. The productivity of the other organisms that comprise this community must also be taken into account.

Some species of gorgonian have become typical representatives of this community thanks to their physical features and predominance in some areas. For example,the yellow gorgonian (*Eunicella cavolinii*) and the red gorgonian (*Paramuricea clavata*) can reach a biomass of 304 and 746 grams dry weight per square meter[16].

The red encrusting algae, *Mesophyllum alternans*, that belongs to the *Corallinaceae* family, is not only vitally important for coralline algae, but also forms small concretions occupying a volume of approximately 500 cm^3, although they can cover surfaces measuring various square meters. These reefs may occur together with seagrass meadows or other red algal concretions. Other algae belonging to this genus can also create pseudo-reef structures. There are, in fact, five species from the *Mesophylllum*[17] family in Europe: *M. expansum, M. lichenoides, M. alternans, M. macroblastum* and *M. macedonis.*

Maërl beds are comprised of unattached rhodolithes of coralline algae (they are not fixed to the substrata). The most important maërl-forming species are *Lithothamnion corallioides* and *Phymatolithon calcareum*. These species form complex communities that may cover various kilometres in length, with an annual calcium carbonate production rate estimated between 200 and more than 8,000 grams per square meter[18].

The trottoir is another mediolittoral coralline formation comprised of the alga *Lithophyllum byssoides*, frequently occurring with *Neogoniolithon notarisii.* This structure is also known as cornice or tenasse due to the wing shape it creates in areas exposed to wave action. They can create ledges measuring more than one meter wide[19].

Distribución

The coralline algae community occurs typically in the Mediterranean Seat preferring depths ranging between 40 and 120 meters[21], although some communities can be found in shallower waters of as little as 15 meters depth[22] Coralline communities, however, can also be found in Atlantic waters, such as the community identified by Oceana[23] in the Gettysburg and Ormonde peaks of the Gorringe Seamounts (southwest Portugal).

Mesophyllun alternans is an Atlantico-Mediterranean species distributed from the Cantabrian Sea to the northern coasts of Africa and some areas of the Macaronesia as well as the Mediterranean Sea[24]. Important reef-like concentrations, however, have only been found in certain areas of the Mediterranean, while it is usually referred to as part of the coralline habitat in the other areas. Although it is considered a *sciaphilic circalittoral* species, it can occur in shallow infralittoral waters at less than 20 meters depth in some areas.

The "trottoir" is a bioconstruction characteristically found in the Mediterranean where this species takes advantage of the small tides in order to form dense concretions at sea level. *Litophyllum byssoides* communities, however, can also occur in the Atlantic, from Ireland[25] y to Africa and the Macaronesian Islands[26].

As it is comprised of sciaphilic rhodophycean algae, maërl usually occurs below 40 meters depth, but not over depths of 85 to 90 meters[27]. Oceana, however, has identified *Lithothamnion coralloides* and *Phymatolithon calcareum* rhodolithes at less than 20 meters depth in some areas of the Mediterranean, such as the Alboran Sea. Maërl is one of the habitats comprised of calcified red seaweed that occurs throughout Europe, from the Arctic to the Mediterranean Seas and the Macaronesian Islands[28].

Significant coralline beds can be found in the Medas Islands (Cataluña, Spain)[29], in Port-Cros and Marseille (France)[30],in Portofino and Giannutri Island (Italy)[31], and in various islands of the Aegean such as Rhodes (Greece)[32], etc. *Mesophyllum alternans* reefs have been located in the Medas Islands[33], between Punta Entinas and Punta Sabinar (Almeria, Spain), Île Verte (La Ciotat, France)[34], etc. Concretions in the shape of trottoirs occur in Cerbere-Banyuls[35] (France), in Lititzia Cove (Scandola Marine Reserve, Corsica)[36], in cape Bagur and the Medas Islands (Catalonia, Spain)[37], in Mondragó Cove (Mallorca, Balearic Islands) and in the Egadi Islands (Sicily, Italy)[38], Important maërl beds can be found in the Bay of Brest (Brittany, France)[39], the coasts of Arosa and Vigo (Galicia, Spain)[40], in Galway Bay (Ireland)[41], etc., or those found by Oceana atop the seamounts of El Seco de los Olivos (Alboran Sea), Emile Baudot or Ausias March in the Balearic Islands.

Associated species

Coralline habitats harbour the most biologically rich communities in Europe. Thousands of species can be found living amongst these communities including algae, sponges, cnidarians, hydrozoans, molluscs, crustaceans, polychaetes, echinoderms, fish, etc. It is estimated that the number of invertebrate species found living amongst the coralline[42] is more than 1,200, the ichthyic community is represented by more than 100 species[43] and the algal communities are made up of more than 300 species[44].

These can include, among others,as red algae, such as *Mesophyllum alternans, Lithophyllum stictaeforme, Peyssonnelia* spp., *Kallymenia* spp., *Halymenia* spp., *Sebdenia* spp., *Osmundaria volubilis* or *Aglaothamnion tripinnatumlas*; green algae such as *Palmophyllum crassum, Flabellia petiolata, Halimeda tuna or Valonia macrophysa; brown algae Dictyota dichotoma, Dictyopteris membranacea, Zonaria tournefortii, Haloptеris filicina, Phyllariopsis brevipes, Zanardinia prototypus* or *Laminaria rodriguezii*; the sponges *Axinella damicornis, Acanthella acuta, Agelas oroides, Haliclona mediterranea, Cliona viridis, Clathrina clathrus, Oscarella lobularis, Chondrosia reniformis, Phorbas tenacior, Geodia cydonium, Dysidea avara, Spongia officinalis, Ircinia* spp.*, Axinella verrucosa, Petrosia ficiformis*, etc.; the hydrozoans *Eudendrium* spp., *Halecium tenellum, Campanularia everta, Sertularia distans, Sertularella polyzonias* and *Aglaophenia pluma*; the cnidarians *Parazoanthus axinellae, Leptopsammia pruvoti, Parerythropodium coralloides, Alcyonium acaule, Paramuricea clavata, Eunicella singularis, Eunicella cavolinii, Corallium rubrum, Maasella edwardsii, Hoplangia durotrix, Caryophyllia* spp., etc.; the polychaetes *Salmacina dysteri, Serpula* spp., *Sabella* spp.*, Myxicola aesthetica,* o *Protula* spp.*; Callochiton achatinus, Acmaea virginea, Calliostoma zizyphinum, Chauvetia mamillata, Bittium reticulatum, Hypselodoris fontandraui, Chromodoris luteorosea, Discodoris atromaculata, Flabellina affinis,* etc.; *the bivalves, Striarca lactea, Musculus costulatus, Lithophaga lithophaga, Pteria hirundo, Chlamys multistriata, Lima lima* or *Hiatella arctica; crustaceans including Maera* spp.*, Gitana sarsi, Galathea bolivari, Thoralus cranchii, Crania* spp.*, etc.; the bryozoans, Pentapora fascialis, Myriapora truncata, Turbicellepora avicularis, Tubulipora plumosa,* etc.*; tunicates, Ciona edwardsii, Halocynthia papillosa, Trididemnum spp. or Clavelina nana;* and the fish, *Anthias anthias, Gobius vittatus, Phycis phycis, Labrus bimaculatus, Diplodus puntazzo, Ctenolabrus rupestris, Spicara smaris, Scorpaena scrofa, Conger conger, Muraena helena, Zeus faber.*

The species found inhabiting Mesophyllum alternans reefs include red algae such as Jania rubens, Amphiroa rigida or different species belonging to the Peyssonelia family, but also a variety of crustaceans, both isopods (*Cymodoce truncata, Duynamene magnitorata, Janira maculosa*, etc.) and amphipods (*Caprella* spp.), tanaidaceans (*Tanais cavolinii, Leptochelia savignyi*) decapods (*Acanthonyx lunulatus, Pisa tetraodon, Alpheus dentipes*, etc.) as well as many molluscs. Sessile species include various sponges such as *Cliona viridis* or those belonging to the Tethya, Sycon, Leuconia genera or solitary vermetids such as *Serpulorbis arenariusat* or bioconstructing polychaetes including *Serpula concharum, Spirobranchus polutrema* or *Protula* sp[47].

Other species found in these reefs include echinoderms (*Arbacia lixula, Amphipholis squamata*, etc.) and some of these species feed off the algae such as sea urchins and the gastropod *Acmaea virginea* that consumes the stalks. *Lithophyllum incrustans* substitutes its competitors in areas where sea urchins feed off algae because it is more resistant to herbivores[48].

Work carried out by Oceana during 2005 and 2006 indicated that, apart from the aforementioned species, other species can also be found inhabiting these reefs such as the abalone (*Haliotis* sp.), the Noah's ark shell (*Arca noae*), the gold-headed goby (*Gobius xantocephalus*), the red-mouthed goby (*Gobius cruentatus*), the striped blenny (*Parablennius rouxi*), the polychaete *Serpula vermiformis*, the sea urchin *Paracentrotus lividus*, the crinoid *Antedon mediterraneus*, the ophiurid *Ophiothrix fragilis*, colonial ascidians (*Aplidium* sp.*, Diplosoma listerianum*, etc.), scorpionfish (*Scorpaena porcus*). Brown algae such as *Colpomenia sinuosa* or *Halopteris scoparia* can be found living atop these algae. They also serve as refuge and nurseries for young damselfish (*Chromis chromis*) as well as for females of the shrimp species *Thoralus cranchii* during spawning stages.

The "trottoir" generates different types of habitats and promotes the establishment of a variety of algae. As such, on surface waters exposed to sunlight, the following algae can be found: *Gelidium pusillum, Bryopsis rnuscosa, Sphacelaria cirrosa, Ralfsia verrucosa, Nemoderma tingitanum, Ceramiun rubrum, Callithamnion granulatum, Polysiphonia sertularioides, Chaetomorpha capillaris, Nemalion helmithoides*, etc., while other species establish themselves in hollows and underneath ledges, including *Coralina elongata, Rhodymenia ardissonei, Apoglossum ruscifolium, Schottera nicaeensis, Rhodophyllis divaricata*, etc[49].

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A wide variety of fauna can also be found here including cnidarians, bryozoans, hydrozoans, molluscs, crustaceans, echinoderms or fish.

Many algae can participate in the formation of maërl beds apart from *Lithothamnion corallioides* and *Phymatolithon calcareum*. These include *Lithothamnion lemoineae, L. glaciale y L. sonderi, Lithophyllum dentatum, L. fasciculatum, L. hibernicum, L. racemes, L. hibernicum, L. byssoides y L. expansum, Halcampa chrysanthellum, Neopentadactyla* mixta, *Edwardsia timida, Phymatolithon purpureum* or *Mesophyllum lichenoides*[50], as well as different algae belonging to the *Peyssonneliacea* family.

Maërl is considered to be a community with high rates of biodiversity, harbouring hundreds of species. In fact, more than one thousand species have been identified within this community. Hundreds of species have been identified of epiphytic algae and molluscs alone [51].

Relation to other habitats of community interest

Red algal concretions are possibly the most complex and diverse habitats in the EU. They are related to a wide variety of habitats of community interest in one way or another.

Coralline, in and of itself, is a group of habitats strongly associated with gorgonian gardens, sponge fields and aggregations, green algae beds, caves and caverns, etc. Furthermore, the trottoir can also lead to the formation of rockpools.

Mesophyllum alternans is fundamental for the formation of many of these habitats, forming small concretions in other habitats of community interest such as seagrass beds or kelp forests and participating in some coralline communities. Sometimes it can form veritable reefs amongst these communities, although concentrations are generally not very dense in the majority of the cases.

Oceana has documented how these reefs occupied part of the rhizomes and stalks of *Posidonia oceanica* meadows, and even formed linking communities between this meadow, maërl beds and other seagrass beds made up of *Cymodocea nodosa*.

The red algal concretions included in EUNIS classification are the following:

- **A1.13 –** Mediterranean communities of upper mediolittoral rock
  - **-A1.134 –** Association with *Lithophyllum papillosum* and *Polysiphonia* spp.
- **A1.14 –** Mediterranean communities of lower mediolittoral rock very exposed to wave action
  - **-A1.141** – Association with *Lithophyllum byssoides*
  - **-A1.143** – Association with *Titanoderma trochanter*
- **A1.23 –** Communities of the lower mediolittoral rock moderately exposed to wave action
  - **- A1.232 –** *Neogoniolithon brassica-florida* concretion
- **A1.41 –** Communities of littoral rockpools
  - **- A1.411 –** Coralline crust-dominated shallow eulittoral rockpools
    - **-A1.4111 –** Coralline crusts and *Corallina officinalis* in shallow eulittoral rockpools
    - **-A1.4112 –** Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools
- **A1.44 –** Communities of littoral caves and overhangs
  - **- A1.44B -** Association with *Phymatolithon lenormandii* and *Hildenbrandia rubra*
- **A3.11 –** Kelp with cushion fauna and/or foliose red seaweeds
  - **- A3.1111 -** *Alaria esculenta, Mytilus edulis* and coralline crusts on very exposed sublittoral fringe bedrock
- **A3.13 –** Mediterranean communities of infralittoral algae very exposed to wave action
  - **- A3.131 –** Overgrazing facies with incrustant algae and sea urchins
- **A3.14 –** Encrusting algal communities
- **A3.21 –** Kelp and red seaweeds (moderate energy infralittoral rock)
  - **- A3.2143 –** Grazed *Laminaria hyperborea* forest with coralline crusts on upper infralittoral rock
  - **- A3.2144 –** Grazed Laminaria hyperborea park with coralline crusts on lower infralittoral rock
- **A3.23 –** Mediterranean communities of infralittoral algae moderately exposed to wave action
  - **-A3.23J –** Association with Flabellia petiolata and Peyssonnelia squamaria
  - **-A3.23L –** Association with Peyssonnelia rubra and Peyssonnelia spp.
- **A3.24 –** Faunal communities on moderate energy infralittoral rock
  - **-A3.241 -** Halopteris filicina with coralline crusts on moderately exposed infralittoral rock
- **A3.31 –** Silted kelp on low energy infralittoral rock with full salinity
  - **-A3.3134 –** Grazed Laminaria saccharina with Echinus, brittlestars and coralline crusts on sheltered infralittoral rock
- **A3.35 –** Faunal communities on low energy infralittoral rock
  - **-A3.351 -** Codium elisabethae, Halopteris filicina and coralline crusts on sheltered infralittoral bedrock
- **A3.71 –** Robust faunal cushions and crusts in surge gullies and caves
  - **-A3.711 –** Foliose seaweeds and coralline crusts in surge gully entrances

- **A3.716 –** Coralline crusts in surge gullies and scoured infralittoral rock
  - **A3.7161 -** *Balanus crenatus* and/or *Pomatoceros triqueter* with spirorbid worms and coralline crusts on severely scoured vertical infralittoral rock
  - **-A3.7162 –** Coralline crusts and crustaceans on mobile boulders or cobbles in surge gullies

•A4.21 – Echinoderms and crustose communities on circalittoral rock

- **-A4.212 -** *Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock
- **-A4.2121 –** Brittlestars overlying coralline crusts, *Parasmittina trispinosa* and *Caryophyllia smithii* on wave-exposed circalittoral rock
  - **-A4.2122 -** *Caryophyllia smithii* and sponges with *Pentapora foliacea*, *Porella compressa* and crustose communities on wave-exposed circalittoral rock
- **-A4.214 –** Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock
  - **-A4.2142 -** *Alcyonium digitatum*, Pomatoceros triqueter, algal and bryozoan crusts on wave-exposed circalittoral rock
  - **-A4.2144 –** Brittlestars on faunal and algal encrusted exposed to moderately wave-exposed circalittoral rock
  - **- A4.2145 –** Faunal and algal crusts with Pomatoceros triqueter and sparse *Alcyonium digitatum* on exposed to moderately wave-exposed circalittoral rock
  - **- A4.2146 -** *Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock

• A4.26 – Mediterranean coralligenous communities moderately exposed to hydrodynamic action

- **-A4.261 –** Association with *Cystoseira zosteroides*
- **-A4.262 –** Association with *Cystoseira usneoides*
- **-A4.263 –** Association with *Cystoseira dubia*
- **-A4.264 –** Association with *Cystoseira corniculata*
- **-A4.265 –** Association with *Sargassum* spp.
- **-A4.266 –** Association with *Mesophyllum lichenoides*
- **- A4.267 –** Algal bioconcretion with Lithophyllum frondosum and *Halimeda tuna*
- **- A4.268 –** Association with *Laminaria ochroleuca*
- **- A4.269 -** Facies with *Eunicella cavolinii*
- **- A4.26A -** Facies with *Eunicella singularis*
- **- A4.26B -** Facies with *Paramuricea clavata*
- **- A4.26C -** Facies with *Parazoanthus axinellae*
- **- A4.26D –** Coralligenous platforms

•A4.32 – Mediterranean coralligenous communities sheltered from hydrodynamic action

- **- A4.321 –** Association with *Rodriguezella strafforelli*
- **- A4.322 -** Facies with *Lophogorgia sarmentosa*

•A5.46 – Mediterranean communities of coastal detritic bottoms

- **- A5.461 –** Association with rhodolithes on coastal detritic bottoms
- **- A5.462 –** Association with *Peyssonnelia rosa-marina*

•A5.51 – Maërl beds

- **- A5.511 –** *Phymatolithon calcareum* maërl beds in infralittoral clean gravel or coarse sand
  - **- A5.5111 –** *Phymatolithon calcareum* maërl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand
  - **- A5.5112 –** *Phymatolithon calcareum* maërl beds with *Neopentadactyla mixta* and other echinoderms in deeper infralittoral clean gravel or coarse sand
- **- A5.512 –** *Lithothamnion glaciale* maërl beds in tide-swept variable salinity infralittoral gravel
- **- A5.513 –** *Lithothamnion corallioides* maërl beds on infralittoral muddy gravel
- **- A5.514 –** *Lithophyllum fasciculatum* beds on infralittoral mud
- **- A5.515 –** Association with rhodolithes in coarse sands and fine gravels under the influence of bottom currents

The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Marine Habitats used for the selection of natural sites and promotion of the conservation of these sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

II.4.1. Biocenosis of upper mediolittoral rock

- **- II.4.1.4.** Association with *Lithophyllum papillosum* and *Polysiphonia* spp.

II.4.2. Biocenosis of lower mediolittoral rock

- **- II.4.2.1.** Association with *Lithophyllum lichenoides* (= entablature with *L. tortuosum*)
- **- II.4.2.2.** Association with *Lithophyllum byssoides*
- **- II.4.2.3.** Association with *Tenarea undulosa*
- **- II.4.2.8.** *Neogoniolithon brassica-florida* concretion

II.4.3. Mediolittoral caverns

-II.4.3.1. Association with *Phymatolithon lenormandii* and *Hildenbrandia rubra*

III.3.1. Biocenosis of coarse sands and fine gravels mixed by waves

- **- III.3.1.1.** Association with rhodolithes

III.3.2. Biocenosis of coarse sands and fine gravels under the influence of bottom currents (can also occur in the circalittoral)

- **- III.3.2.1**. Facies with maërl (=Association with *Lithothamnion corallioides* and *Phymatolithon calcareum*) (can also be found as facies with biocenosis of coastal detritic bottoms)
- **- III.3.2.2.** Association with rhodolithes

III.6.1. Biocenosis of infralittoral algae

- **- III.6.1.34.** Association with *Peyssonnelia rubra* and *Peyssonnelia* spp.
- **- III.6.1.35.** Facies and association with biocenosis of coralline (in enclave)

IV.2.2 Biocenosis of coastal detritic bottoms

- **- IV.2.2.1.** Association with rhodolithes
- **- IV.2.2.2.** Facies with maërl (*Lithothamnion corallioides* and *Phymatholithon calcareum*)
- **- IV.2.2.3.** Association with *Peyssonnelia rosa-marina*

Degree of vulnerability

Ecologically, red algal concretions constitute communities that are highly valuable and subjected to many threats. These communities are highly susceptible because the bioconstructing species have slow growth rates and long life spans.

Mesophyllum alternans annual growth rates in coralline are estimated to be between 0.1 and 0.3 mm[52], and as such, some coralline seabeds can take more than 5,000 years to form.

Like other red algal concretions, it can take centuries or even millennia for maërl to form. Some maërl beds can be 8,000 years old[53]. This is due to the slow growth rates of the algae, as slow as 0.10 to 0.96 mm each year[54], with rhodolithes that can be more than 100 years old[55]. Due to this, they are very vulnerable to anthropogenic disturbances. Irreparable damage can be caused by trawling nets or dredges used by fisheries. Some maërl communities destroyed by fishing activities have not shown signs of recovery in subsequent years[56].

The EU has included *Lithothamnion corallioides* and Phymatolithon calcareum in Annex V of the Habitats Directive, but this classification does not provide sufficient protection for maërl beds.

Furthermore, the alga *Lithophyllum byssoides* and its troittoirs are included in the Red Book of Mediterranean Flora[57].

Various species that are characteristically found in coralline, such as red and yellow gorgonian, are seriously damaged by recreational diving activities in certain areas[58]. Some species of cnidarians such as *Corallium rubrum* or *Gerardia savaglia* are included in the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean*59* and the Bern Convention, along with other organisms typically found within this community.

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The red algae *Lithophyllum byssoides, Ptilophora mediterranea* and *Schimmelmannia shousboei* are included in Annex II of the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean.

Some species living amongst the coralline are categorised as "in danger of extinction," amongst them the algae *Chondrymenia lobata, Halarachnion ligulatum, Halymenia trigona, Platoma cyclocolpa, Nemastoma dichotomum, Ptilophora mediterranea, Schizymenia dubyi* and *Laminaria rodriguezii*, and some species of molluscs such as the date mussel (*Lithophaga lithophaga*) and the pen shells (*Pinna nobilis* and *Pinna rudis*), echinoderms such as the long- spined sea urchin (*Centrostephanus longispinus*), or the fish, Sciaena umbra and *Umbrina cirrhosa*[60], although recent studies include many other organisms in this list[61].

Another serious threat to these ecosystems is climate change. This is because changes in water temperatures can affect the algae's calcification rate. Furthermore, various episodes[62] of mass mortality amongst suspension feeders within hundreds of kilometres of coralline in the Mediterranean have been associated with prolonged high temperatures reached in these waters[63].

The introduction of exotic species in European ecosystems is one of the most serious threats to many communities. One of the most dangerous species invading coralline is *Womersleyella* (*Polysiphonia*) setacea because it grows abundantly atop the coralline, making it impossible for the sunlight to reach the bioconstructing algae[64] and decreasing the biodiversity found within this community.[65] Other species that may affect the growth and development of this habitat include *Lophocladia lallemandii, Asparagopsis taxiformis* and *Caulerpa taxifolia*.

It has been confirmed that a wide variety of coralline species are seriously affected by pollution, which causes a loss of biological diversity.[66] Constructing species are especially affected by this because declines in water quality can lead to increases in the number of organisms that erode red algal concretions.[67]

Other important aspects

The biological diversity that exists amongst red algal concretions makes these communities both ecologically and commercially important. Various constructing species or species that inhabit the structures are commercially valuable. Apart from the pharmaceutical value of various tunicates, sponges or anthozoans, red coral (*Corallium rubrum*) has been commercially exploited for ornamental use and maërl rhodolithes are still being used in agriculture to make fertilisers or to control the acidity of substrates.

Furthermore, the long life spans of the concretions, including the coralline, maërl or the troittoirs, means these can be used as paleobathymetric indicators, providing records dating back thousands of years.[68]

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Kelp forest 15

Characteristics

Eleven kelp species exist in European waters[1], apart from those that have been introduced into these ecosystems (*Undaria pinnatifida* and *Laminaria japonica*). Just over half of these species, however, form what is referred to as kelp forests.

These algae vary in size but some species can grow more than four meters in length[2], making them the largest marine vegetable species in Europe.

These forests have high rates of productivity. It is estimated that *Laminaria ochroleuca* produces 17 metric tons of biomass per hectare annually and *Saccorhiza polyschides* can produce up to 39 metric tons[3].

Hybridisation of some genera is considered frequent[4], Moreover, hybridisation between species belonging to different genera is possible[5], such as *Laminaria digitata* with *L. saccharina* and *L. ochroleuca*, and these with *Saccorhiza polyschides*.

Laminaria usually has a life span of between one to 20 years and can be found in the mediolittoral and infralittoral areas. For example, *L. hyperborea* can be found at depths of 30 meters and can live as long as 25 years[6]. *L. ochroleuca* and *Saccorhiza polyschides* have been found at depths over 30 meters in some areas[7].

Kelp forests are the most biodiverse, productive and dynamic communities found in European waters[8].

It is estimated that kelp forests produce between 1,000 and 2,000 grams of carbon per square meter annually[9], although some authors estimate this production to be as high as 4,800 C/m^2 in some kelp forests[10], or between three and almost 20 kilograms of dry weight per square meter[11]. Recent work indicates that some kelp forests produce more than 4,000 grams of carbon per square meter annually, where more than one quarter of this production corresponds to dissolved organic carbon[12].

Distribution

Laminaria or kelp forests in Europe are typically found in the cold and temperate waters of the Atlantic, although they can also occur in the warmer waters of southern Europe and in the Mediterranean. Generally, however, they occur less frequently in southern Europe[13], because they prefer temperatures between ten and 15ºC, although they can resist a wider temperature range[14].

Saccorhiza dermatodea and *Laminaria solidungula* are arctic species while *Alaria esculenta* and *Laminaria digitata* are distributed from the Arctic to the coasts of the Bay of Biscay. *Laminaria hyperborea* and *Saccharina latissima* can occur on the southern coasts of the Iberian Peninsula. *Laminaria ochroleuca* is a more meridional species, distributed from the south of the British Isles to African waters, Macaronesia and the Mediterranean; *Saccorhiza polyschides* is extensively distributed throughout the Atlantic, from Norway to tropical Africa[15].

A few European laminarian species do not form forests although they are vitally important for the marine ecosystem. These species are represented by *Laminaria rodriguezii, Phyllariopsis purpurascens* and *P. brevipes*. These three laminarian species are more typically found in southern Europe and *L. rodriguezii* is exclusive to the Mediterranean[16].

By using a remotely operated vehicle or submarine robot (ROV) in waters of the Balearic Islands, Oceana has verified that these species can reach much greater depths than the larger forest-forming kelps, and can be found at depths over 100 meters.

Some European laminarian forests are formed by Saccorhiza polyschides in Cumbrae Island (Scotland)[17], in Port Erin (Isle of Man, United Kingdom)[18] or the San Raineri Peninsula (Sicily, Italy)[19] ;by *Saccorhiza polyschides* and *Laminaria ochroleuca* in Elantxove (Basque Region, Spain)[20], in Aguda (Portugal)[21], in Alboran Island[22], in the Strait of Messina (Sicily, Italy)[23] or in the seamounts of Gorringe (Portugal)[24]; by *Saccharina longicruris*, in southern Greenlandy[25] or in Northern Ireland[26]; by *Laminaria hyperborea* and *L. digitata* in Helgoland Island (Germany)[27]; by *Laminaria hyperborea* in Louch Ine (Cork, Ireland)[28]; by *Laminaria hyperborea, Saccorhiza polyschides* and *Saccharina latissima* in the Orkney Islands (Scotland)[29]; by *Laminaria agardhii* in the Gulf of Bothnia (Sweden)[30]; by *Laminaria digitata* in Skagerrak and the Kattegat (Denmark, Sweden and Norway)[31], in the Black Sea (Romania)[32] or in Bardsey Island (Wales, United Kingdom)[33]; by *Laminaria solindungula* in Greenlandah (Denmark); etc.

Associated species

Kelp forests harbour very rich communities of fauna and flora. More than 150 species of fauna and flora have been identified in mixed kelp forests formed by *Laminaria hyperborea* and *L. digitata* including polychaetes, bryozoans, crustaceans, molluscs, hydrozoans, tunicates, etc.ai Other studies carried out in these forests have identified more than 1,000 species[35].

The polychaetes can constitute more than ten percent of the species present in these habitats, amongst them the polychaetes belonging to the *Anaitides, Eulalia, Harmothoe, Hediste, Kefersteinia, Lagisca, Lepidonotus, Amblyosyllis, Brania, Pionosyllis, Trypanosyllis* genera. Crustaceans are also present, especially those belonging to the *Bodotria, Idotea, Apherusa, Jassa, Melita, Porcellan, Caprella, Pariambus, Ammothelia, Anoplodactylus genera*; the echinoderms from the *Amphipholis, Asterina, Ophiothrix, Asterias, Psammechinus, Pawsonia, Ocnus, Echinus, Psammechinus, Henrici* genera; or molluscs from the *Onoba, Tricolia, Elysia* genera. These kelp forest inhabitants have different preferences in regards to plant morphology, and can be found on stipes, fronds or holdfasts[37].

The epiphytic communities located on stipes can be very rich. More than 40 different species[38] have been found on *Laminaria hyperborean*, al including *Ulva* sp., *Corallina officinalis, Dictyota dichotoma, Ceramium* spp., *Delesseria sanguinea, Himanthalia elongata, Cryptopleura ramosa, Halurus siliquosa, Plocamium cartilagineum, Polysiphonia* spp., *Palmaria palmata, Gracilaria* spp., *Ptilota plumosa* or *Gymnogongrus crenulatus*[39]. The epiphytic community found exclusively or mostly on the holdfasts is also very diverse. Up to 77 species[40] have been identified in forests formed by *Saccorhiza polyschides*, an and specialised taxa were located in certain areas within the forest. For example, the gastropods *Patina pellucida* and *Lacuna vincta* are found on algae very exposed to water turbulence[41].

The sea urchin is the main predator of kelp forests and can be either friend of foe of the dynamic structure of the forest depending on their concentrations[42], although crustaceans from the Cancer and Hyas genera also consume the kelp.

Kelp forests are important areas for spawning and recruiting juveniles of commercially valuable species such as the Atlantic cod (*Gadus morhua*), the pollack (*Pollachius pollachius*) or the coalfish (*Pollachius virens*), and others including *Apletodon microcephalus*, Agonus cataphractus[43]. It is also an important feeding area for some species of marine birds such as the cormorant (*Phalacrocorax carbo*) or the common eider (*Somateria mollissima*)[44].

Relation to other habitats of community importance

Kelp forests may be related to a wide variety of habitats of community importance. These may include coralline or the forests formed by *Cystoseira* sp. amongst others.

According to EUNIS classification, these habitats are related to the following communities:

•A1.41 – Communities of littoral rockpools
- A1.412 – Fucoids and kelp in deep eulittoral rockpools
•A3.11 – Kelp with cushion fauna and/or foliose red seaweeds

- **A3.111** - Alaria esculenta on exposed sublittoral fringe bedrock
- **A3.1111** - *Alaria esculenta, Mytilus edulis* and coralline crusts on very exposed sublittoral fringe bedrock
- **A3.1112** - *Alaria esculenta* and *Laminaria digitata* on exposed sublittoral fringe bedrock
- **A3.112 –** *Alaria esculenta* forest with dense anemones and crustose sponges on extremely exposed infralittoral bedrock
- **A3.113 –** *Laminaria hyperborea* forest with a faunal cushion (sponges and polyclinids) and foliose red seaweeds on very exposed infralittoral rock
- **A3.114** - *Sparse Laminaria hyperborea* and dense *Paracentrotus lividus* on exposed infralittoral limestone
- **A3.115** - *Laminaria hyperborea* with dense foliose red seaweeds on exposed infralittoral rock
  - **A3.1151 –** *Laminaria hyperborea* forest with dense foliose red seaweeds on exposed upper infralittoral rock

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- **A3.1152** - *Laminaria hyperborea* park with dense foliose red seaweeds on exposed lower infralittoral rock
  - **A3.1153 –** Mixed *Laminaria hyperborea* and *Laminaria ochroleuca* forest on exposed infralittoral rock
- **A3.117** - *Laminaria hyperborea* and red seaweeds on exposed vertical rock

• **A3.12 –** Sediment-affected or disturbed kelp and seaweed communities

- **A3.121** - *Saccorhiza polyschides* and other opportunistic kelps on disturbed upper infralittoral rock
- **A3.122** - *Laminaria saccharina* and/or *Saccorhiza polyschides* on exposed infralittoral rock
- **A3.123** - *Laminaria saccharina, Chorda filum* and dense seaweeds on shallow unstable infralittoral boulders and cobbles
- **A3.125 –** Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock
- **A3.126** - *Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment

• **A3.21 –** Kelp and red seaweeds (moderately energy infralittoral rock)

- **A3.211** - *Laminaria digitata* on moderately exposed sublittoral fringe rock
  - **A3.2111** - *Laminaria digitata* on moderately exposed sublittoral fringe bedrock
  - **A3.2112** - *Laminaria digitata* and under-boulder fauna on sublittoral fringe boulders
  - **A3.2113** - *Laminaria digitata* and piddocks on sublittoral fringe soft rock
- **A3.212** - *Laminaria hyperborea* on tide-swept, infralittoral rock
- **A3.2121 –** *Laminaria hyperborea* forest, foliose red seaweeds and a diverse fauna on tide-swept upper infralittoral rock
- **A3.2122** - *Laminaria hyperborea* park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock
- **A3.213** - *Laminaria hyperborea* on tide-swept infralittoral mixed substrata
  - **A3.2131 –** *Laminaria hyperborea* forest and foliose red seaweeds on tide-swept upper infralittoral mixed substrata
  - **A3.2132** - *Laminaria hyperborea* park and foliose red seaweeds on tide-swept lower infralittoral mixed substrata
- **A3.214** - *Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock
  - **A3.2141 –** *Laminaria hyperborea* forest and foliose red seaweeds on moderately exposed upper infralittoral rock
  - **A3.2142** - *Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock
  - **A3.2143 –** Grazed *Laminaria hyperborea* forest with coralline crusts on upper infralittoral rock
  - **A3.2144 –** Grazed *Laminaria hyperborea* park with coralline crusts on lower infralittoral rock
- **A3.215** - *Sabellaria spinulosa* with kelp and red seaweeds on sand-influenced infralittoral rock
- **A3.217** - *Laminaria hyperborea* on moderately exposed vertical rock

• **A3.22 –** Kelp and seaweed communities in tide-swept sheltered conditions

- **A3.221** - *Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock
- **A3.222 –** Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
- **A3.223 –** Mixed kelp and red seaweeds on infralittoral boulders, cobbles and gravel in tidal rapids
- **A3.224** - *Laminaria saccharina* with foliose red seaweeds and ascidians on sheltered tide-swept infralittoral rock

• **A3.23 –** Mediterranean communities of infralittoral algae moderately exposed to wave action

- **A3.234 –** Association with *Cystoseira tamariscifolia* and *Saccorhiza polyschides*

• **A3.31 –** Silted kelp on low energy infralittoral rock with full salinity

- **A3.311 –** Mixed Laminaria hyperborea and *Laminaria ochroleuca* forest on moderately exposed or sheltered infralittoral rock
- **A3.312 –** Mixed *Laminaria hyperborea* and *Laminaria saccharina* forest on sheltered infralittoral rock
  - **A3.3121 –** Mixed *Laminaria hyperborea* and *Laminaria saccharina* forest on sheltered upper infralittoral rock
  - **A3.3122** - *Laminaria hyperborea* and *Laminaria saccharina* park on sheltered lower infralittoral rock
  - **A3.3123 –** Grazed, mixed *Laminaria hyperborea* and *Laminaria saccharina* on sheltered infralittoral rock
- **A3.313** - *Laminaria saccharina* on very sheltered infralittoral rock
  - **A3.3131** - *Laminaria saccharina* and *Laminaria digitata* on sheltered sublittoral fringe rock
  - **A3.3132 –** *Laminaria saccharina* forest on very sheltered upper infralittoral rock
  - **A3.3133** - *Laminaria saccharina* forest on very sheltered upper infralittoral rock

- **A3.3134 –** Grazed *Laminaria saccharina* with *Echinus*, brittlestars and coralline crusts on sheltered infralittoral rock
- **A3.314 –** Silted cape-form *Laminaria hyperborea* on very sheltered infralittoral rock

• **A3.32 –** Kelp in variable salinity on low energy infralittoral rock

- **A3.321 -** *Codium* spp. with red seaweeds and sparse *Laminaria saccharina* on shallow, heavily-silted, very sheltered infralittoral rock
- **A3.322 -** *Laminaria saccharina* and *Psammechinus miliaris* on variable or reduced salinity infralittoral rock
- **A3.323 -** *Laminaria saccharina* with *Phyllophora* spp. and filamentous green seaweeds on variable or reduced salinity infralittoral rock

• **A4.26 –** Mediterranean coralligenous communities moderately exposed to hydrodynamic action

- **A4.268 –** Association with *Laminaria ochroleuca*

• **A5.46 –** Mediterranean communities of coastal detritic bottoms

- **A5.466 -** Association with *Laminaria rodriguezii*

• **A5.52 –** Kelp and seaweed communities on sublittoral sediment

- **A5.521 -** *Laminaria saccharina* and red seaweeds on infralittoral sediments
- **A5.5211 –** Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles
- **A5.5212 -** *Laminaria saccharina* and robust red algae on infralittoral gravel and pebble
- **A5.5213 -** *Laminaria saccharina* and filamentous red algae on infralittoral sand
- **A5.5214 -** *Laminaria saccharina* with red and brown seaweeds on lower infralittoral muddy mixed sediment
- **A5.522 -** *Laminaria saccharina* and Chorda filum on sheltered upper infralittoral muddy sediment
- **A5.523 -** *Laminaria saccharina* with *Psammechinus miliaris* and/or *Modiolus modiolus* on variable salinity infralittoral sediment
- **A5.524 -** *Laminaria saccharina, Gracilaria gracilis* and brown seaweeds on full salinity infralittoral sediment
- **A5.525 -** *Laminaria saccharina* and *Gracilaria gracilis* with sponges and ascidians on variable salinity infralittoral sediment
- **A5.529 -** Facies with *Ficopomatus enigmaticus*
- **A5.52A –** Association with *Gracilaria* spp.
- **A5.52B –** Association with *Chaetomorpha linum* and *Valonia aegagropila*
- **A5.52C –** Association with *Halopitys incurva*
- **A5.52D –** Association with *Ulva laetevirens* and *Enteromorpha linza*
- **A5.52E –** Association with *Cystoseira barbata*
- **A5.52F –** Association with *Lamprothamnium papulosum*
- **A5.52G-**Association with *Cladophora echinus* and *Rytiphloea tinctoria*

The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Marine Habitats used for the selection of natural sites and promotion of the conservation of these sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

• **III.6.1.** Biocenosis of infralittoral algae

- **III.6.1.10.** Association with *Cystoseira tamariscifolia and Saccorhiza polyschides*

• **IV.3.1.** Biocenosis of coralline

- **IV.3.1.8.** Association with *Laminaria ochroleuca*

Degree of vulnerability

European kelp can be threatened by other allochthonous laminarians introduced in the habitat for commercial exploitation that compete with the autochthonous species, such as Undaria pinnatifida[45]. Other fucoid invaders such as *Sargassum muticum* also compete with laminarians for this habitat[46].

These species are also vulnerable to pollution. Some heavy metals,au as well as water turbidity[48] can affect the reproductive success of laminarians.

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Rising water temperatures caused by climate change are also detrimental to and can affect the distribution of laminarians in European waters. The species, typically found in the meridional areas such as *Laminaria ochroleuc*, could occupy spaces usually inhabited by other more northern species such as *L. digitata* or *L. hyperborean*[49].

Some of these communities are also affected by fishing practices, such as bottom trawling[50].

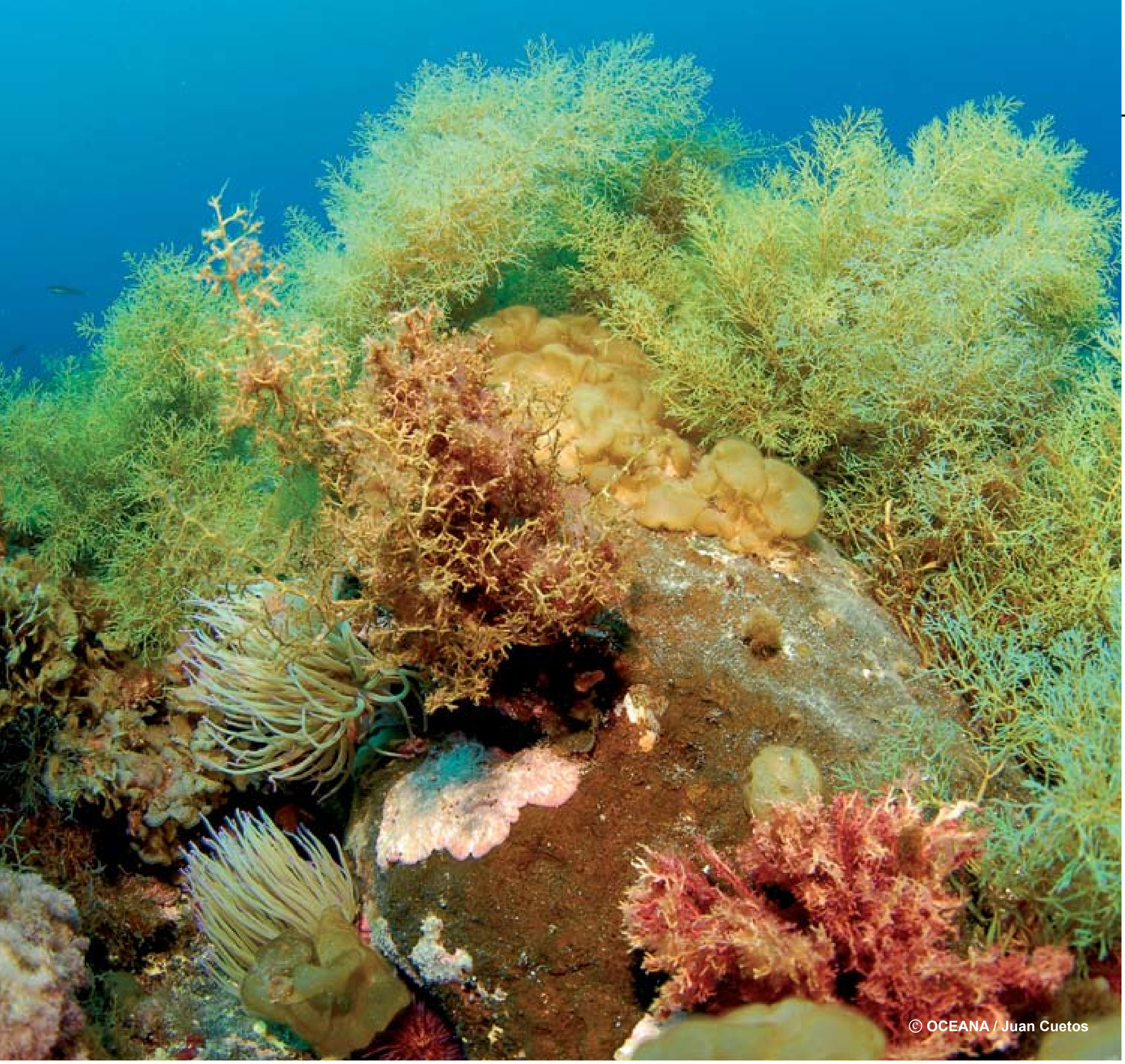
Furthermore, commercial exploitation of these species can lead to the decline of the forests and, in some cases, may promote the development of some species of algae while threatening other more vulnerable species[51] (i.e., *L. digitata* instead of *L. hyperborea*).

Laminaria rodriguezii is a protected species within the Mediterranean and is included in Annex I of the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean[52]. This species, along with Mediterranean communities of *Laminaria ochroleuca*, is included in Annex I of the Bern Convention[53].

Other important aspects

Since ancient times, laminarians have been used for fertilisation and nutrition[54]. Currently, they are an important source of alginates[55] They are also being studied for medicinal purposes, thanks to their potential anti-cancer effects[56].

Kelp forests also absorb a large part of wave energy and are therefore play a key role in protecting coastlines[57].



16 Fucoid beds

Characteristics

Various brown fucoid algae can occupy large extensions within the marine ecosystem forming highly productive communities including associations with a wide and rich variety of fauna and flora. These algae include those belonging to the *Cystoseira, Sargassum* and *Fucus genera*.

The *Cystoseira genus* has the longest life span amongst brown algae. Many species can live up to 20 years[1], although others can live up to 40 years[2]. This is especially true of deep-sea species such as *C. zosteroides* or *C. spinosa*[3].

These species are very dynamic and are in the process of speciation, which leads to a wide range of varieties within each species[4]. Furthermore, these algae present significant morphological variability depending on the time of year and the habitat[5].

The dynamic properties of fucoid algae populations can also be seen amongst the Fucus genus, which is currently undergoing hybridisation processesf. Additionally, the genetic similarities between species su-ggest a recent radiation of this genus, supporting the widely accepted view that the fucoids are amongst the most evolutionary advanced of the brown algae[7].

Some specimens can be very large. *Cystoseria spinosa* reaches approximately 44 centimetres in height[8]. *C. tamariscifolia* can reach up to 60 centimetres, although this species normally measures between 30 and 45 centimetres[9], and *C. foeniculacea* can measure over 80 centimetres[10].

Although *Cystoseira* forests can be considerably dense, what is truly important about these algae are the communities they create. The *C. spinosa* or *C. zosteroides* communities can produce a biomass of approximately 1,400 grams of dry weight per square meter. Communities formed by C. mediterranea have produced up to 4,000 grams of biomass dry weight per square meter, making them one of the most productive communities in the Mediterranean[11], However, due to this alga's seasonal variation[12] autumn production is usually only 700 grams[13].

These communities also produce significant quantities of oxygen. Species such as *C. mediterranea* or *C. balearica* can produce between 13 and 18 mg of O2/h dw [14].

Algae from the *Sargassum* genus occur mainly in temperate European waters and usually form forests along with other fucoids from the Cystoseira genus because they have similar preferences, settling on infralittoral and upper circalittoral seabeds. However, algae from the Fucus genus live in shallower waters; many of them occupy mediolittoral areas and rockpools such as *F. vesiculosus, F. distichus, F. spiralis or F. serratus*[15], and they are rarely found at depths over five meters[16].

Distribution

Most *Cystoseira* forests develop on the upper infralittoral areas, in well-lit biotopes with strong to moderate hydrodynamic conditions, forming one of the most important vegetable communities in this area[17]. Some species, however, can be found in the circalittoral at depths up to 100 meters.

It is known that they have been present since the existence of the Tethys Sea during the Mesozoic Era[18]. It is estimated that more than 50 different species exist around the world[19], of which 80% are present in the Mediterranean and Atlantic waters of the Lusitano-Macaronesian biogeographical regions. In Europe, they can also be found in the Cantabrian Sea, the British Isles and the North Sea[20].

An estimated 37 species occur in waters of the European Union; 23 species occur in the Mediterranean and four in the Atlantic, apart from another ten species that can occur in both areas[21]. Furthermore, the Mediterranean also shares another three species with the Black Sea: *C. crinita, C. barbata* and *C. bosphorica*.

Given the great variations displayed by this genus, the definition of the species is still under debate and some authors have identified more than 50 species in the Mediterranean alone[22].

Some species are widely distributed[23] For example, *C. compressa* occupies the largest expanses within the Atlantic, from the Mediterranean to the Caribbean, including Macaronesia. *C. humilis* and *C. tamariscifolia* also occur in many areas within the North East Atlantic, from the Hebrides Islands to the Canary Islands, Mauritania and Cape Verde, as well as the Mediterranean. *C. barbata* is distributed from the Black Sea to the Atlantic waters of the Iberian Peninsula. Other species, however, are found only in specific areas. *C. bachycarpa* and *C. hyblaea* have been found only in Sicily (Italy).

Another important European alga is *Cystoseira foeniculacea*, occurring from Ireland[24] and the United Kingdom[25] to Holland[26], reaching the North African coasts of Senegal and all the archipelagoes of Macaronesia[27] as well as both the western[28] and eastern[29] coasts of the Mediterranean.

Algae belonging to the *Cystoseira genus* create a wide range of communities depending on the depths and the hydrodynamic properties of the waters where they occur, amongst other factors. For example:[30] *C. amentacea occurs* in the mixed waters of the upper infralittoral; *C. tamariscifolia* and *C. foeniculacea* also occur in shallow waters but they prefer moderate to calm waters; species such as *C. nodicaulis, C. mauritanica* and *C. balearica* frequently occur in deeper waters of the infralittoral, as well as shallow waters from 15 to 20 meters depth; while *C. spinosa* and especially *C. zosteroides* occur in calm waters with scant presence of sunlight.

Furthermore, many sargasso species, such as *Sargassum vulgare*, are widely distributed and occur in the Indian Ocean[31], in the Atlantic and in the Mediterranean[32] *Sargassum acinarium* is found in temperate waters of the Atlantic[33] and Mediterrane[34], but can also occur in the Indian[35] and Pacific Oceans[36] .Other species, including *Sargassum flavifolium*, are distributed from the Cantabrian Sea and the Atlantic coasts of the Iberian Peninsula[37] to the Mediterrane[38]. Some species are found only in specific areas, such as Sargassum orotavicum, which is endemic to the Canary Islands[39].

As far as the *Fucus* algae are concerned, their distribution is very widespread throughout the Atlantic and they occur in all European waters, from Macaronesiaan to the Arctic[41], including the North Sea[42] and the Baltic Sea[43]. They sometimes occur together with other fucoids, such as *Ascophyllum nodosum*[44]. In the Mediterranean, the North Atlantic Fucus species are rare and are normally found only in the Alboran Sea and the Straits of Gibraltar,as present as the endemic *F. virsoides*[46].

Some important fucoid algae beds can be found in Punta de Galdar (Gran Canaria, Canary Islands, Spain)[47] comprised of *C. tamariscifolia*; in Las Rotes (Denia, Alicante, Spain)[48], Cap Mitjá and Cap d'en Roig (Costa Brava, Spain)[49] formed by *C. mediterranea*; in Harri Bolas (Vizcaya, Spain)[50] with *C. baccatta* and *C. tamariscifolia*; in Tuzla-Vama (Romania)[51] with *C. barbata*; in the Black Sea[52] comprised of *C. crinita*; in Port-Cross National Park (France)[53] formed by C. zosteroides; in Porto Cesareo (Ionic Sea, Italy)[54] formed by *C. amentacea, C. barbata* and *C. compressa*; in the Jason Islands (Madeira, Portugal)[55], Zakynthos (Greece)[56] and both sides of the English Channel (France and England)[57] formed by *C. foeniculacea*; in Clare Island (Mayo, Ireland)[58] with *C. foeniculacea* and *C. nodicaulis*; in Alboran Island (Spain), formed by *C. amentacea, C tamariscifolia, C. mauritanica, C. foeniculacea* or *C. usneoides*[59]; in I'ile Verte (Buches du Rhone, France)[60] with *C. foeniculacea* and *C sauvageauanae*; in Evoikos Gulf (Greece)[61] formed by C. amentacea; in waters of the Gulf of Biscay[62] (Spain) formed by *C. baccatta, C. humilis, C. tamariscifolia* and *C. usneoides*; in Torre del Serpe (Apulia, Italy) with *C. squarrosa*[63] ; in Corsica (France) formed by C. *spinosa, C. amentacea and Sargassum vulgare*[64]; in Linosa Island (Sicily, Italy)[65] formed by *Cystoseira brachycarpa, C. sauvageauana, C. spinosa, C. zosteroides, Sargassum acinarium* and *S. trichocarpum*; in Granadilla (Tenerife, Canary Islands, Spain)[66] formed by *C. abies-marina, C. compressa, Sargassum vulgare, S. filipendula* and *S. desfontainesii*; in Ramla Bay (Gozo, Malta)[67] formed by *Sargassum vulgare*; in Tvaerminne (Finland)[68,] in Donegal[69] (Ireland) or the Vigo estuary[70] (Spain) formed by *Fucus vesiculosus*, in the Gulf of Trieste (Slovenia and Italy) formed by F. virsoides[71].

Other species of fucoids occurring in European waters include *Cystoseira algeriensis, C. barbatula, C. compressa, C corniculata, C. crinitophylla, C. dubia, C. elegans, C. jabukae, C. montagnei, C. pelagosae, C. planiramea, C. platyclada, C. schiffneri, C. sedoides, C. funkii, C. adriatica, C. wildprettii, Sargassum cymosum, S. furcatum, S. hornschuchii, S. polycystum, S. racentaceum, S. thunbergi, S. trichocarpu, Bifurcaria bifurcata, Halidrys siliquosa, Himanthalia elongate* and *Pelvetia canaliculata*, amongst others.

Associated species

More than 70 epiphytes have been identified on *Cystoseira tamariscifolia* in the Canary Islands alone, including a wide variety of red algae belonging to the *Ceramiun* and *Cladophora genera*[72].

The presence of epiphytes is also considerable on other Fucales species. Approximately 30 species of epiphytes have been identified on communities of *Fucus serratus* including bryozoans such as *Flustre-llidra hispida* and *Electra pilosa* and hydrozoans including *Dynamena pumila*[73]. These communities are also important for vagile species. *F. vesiculosus* harbours rich faunal communities including species that feed off these algae such as the isopod *Dynamene bidentata*, the amphipod *Hyale nilssoni* or the mollusc *Littorina littoralis*[74].

Cystoseira mediterranea communities harbour a great variety of red algae[75], such as *Corallina elongata, Ceramium rubrum, Polysiphonia deludens, Polysiphonia mottei, Jania rubens, Callithamnion granulatum, Lithophyllum incrustans, Hildenbrandia canariensis, Mesophyllum lichenoides*. Many of these are epiphytic[76], including Corallina elongata, Corallina granifera, *Gelidium pusillum, Ceramium rubrum, Laurencia obtusa, Rytiphloea tintoria, Hypnea muscijorinis*, *Pseudocorodesmis furcellata* or *Amphiroa cryptarthrodia* and more than 70 species can be found in different locations[77],

As far as faunal communities are concerned, high concentrations of sessile species have been identified, including hydrozoans[78]. Nineteen species of hydroids have been identified in communities formed by C. compressa; 21 species in *C. amentacea* and up to 27 species have been identified in habitats formed by *C. barbata* including dense communities of *Halecium pusillum, Aglaophenia tubiformis, Ventromma halecioides, Orthopyxis integra* or *Clytia* sp.

More than 60 species of polychaetes have been collected in *Cystoseira amentacea* forests as well as some 20 species of hydrozoans[79], and up to 56 different species of crustaceans have been identified in *C. crinata* forests[80].

In the waters of the Alboran Sea, other algae along with *C. amentacea, C tamariscifolia, C. mauritanica and C. foeniculacea* can be found. This includes *Sargassum vulgare* or *Litophyllum lichenoides*, as well as various sea urchins such as *Paracentratus lividus* and *Arbacia lixula* and anthozoans including *Anemonia sulcata*. Brown algae including *Zonaria tourneforti* and *Colpomenia sinuosa* occur in communities found under these algae, such as *C. usneoides*, along with sponges (*Cliona viridis, Ircinia* sp.), anthozoans (*Alicia mirabilis* and *Aiptasia mutabilis*), echinoderms (*Echinaster sepositum*) and tunicates (*Pseudodistoma obscurum*)[81].

Rich ichthyic fauna gather within the deep-sea communities formed by *Cystoseira* sp. (*C. zosteroides* and *C. spinosa*) including species such as *Coris julis, Serranus scriba, Serranus cabrilla, Labrus viridis, Symphodus* spp., *Sparus aurata, Diplodus* spp., *Epinephelus costae* or *Muraena helena*, as well as a wide variety of algae, bryozoans, hydrozoans, anthozoans, poriferans, tunicates, etcetera[82].

Relation to other habitats of community interest

In the Alboran Sea and the Atlantic regions, some *Cystoseira* species function as "underforests" within laminarian forests[83].

Mollusc colonies and beds formed by *Mytilus galloprovincialis*, or crustaceans such as the balanid *Balanus* perforatus, occur in some communities formed by *C. mediterranea*[84].

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Some *Cystoseira* species, such as *C. amentacea*, can also occur together with red algal concretions in the shape of "trottoirs" formed by *Lithophyllum byssoides*[85] or coralline.

Communities of fucoid algae have sometimes been found near shallow areas with hydrothermal vents[86] and *Fucus* spp. can occur near mollusc beds in the Atlantic[87].

The following communities are included in EUNIS habitats classification:

- **A1.12** – Robust fucoid and/or red seaweed communities
  - **A1.121** - *Fucus distichus* and *Fucus spiralis*, f. nana on extremely exposed upper eulittoral rock
- **A1.15 –** Fucoids in tide-swept conditions
  - **A1.151** - *Ascophyllum nodosum*, sponges and ascidians on tide-swept mid eulittoral rock
  - **A1.152** - *Fucus serratus*, sponges and ascidians on tide-swept lower eulittoral rock
  - **A1.153** - *Fucus serratus* with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata
- **A1.21 –** Barnacles and fucoids on moderately exposed shores
  - **A1.211** - *Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock
  - **A1.212** - *Fucus spiralis* on full salinity exposed to moderately exposed upper eulittoral rock
  - **A1.213** - *Fucus vesiculosus* and barnacle mosaics on moderately exposed mid eulittoral rock
  - **A1.214** - *Fucus serratus* on moderately exposed lower eulittoral rock
    - **A1.2141** - *Fucus serratus* and red seaweeds on moderately exposed lower eulittoral rock
    - **A1.2142** - *Fucus serratus* and under-boulder fauna on exposed to moderately exposed lower eulittoral boulders
    - **A1.2143** - *Fucus serratus* and piddocks on lower eulittoral soft rock
  - **A1.215** - *Rhodothamniella floridula* on sand-scoured lower eulittoral rock
- **A1.22** - *Mytilus edulis* and fucoids on moderately exposed shores
    - **A1.221** - *Mytilus edulis* and *Fucus vesiculosus* on moderately exposed mid eulittoral rock
    - **A1.222** - *Mytilus edulis, Fucus serratus* and red seaweeds on moderately exposed lower eulittoral rock
    - **A1.223** - *Mytilus edulis* and piddocks on eulittoral firm clay
- **A1.31 –** Fucoids on sheltered marine shores
    - **A1.311** - *Pelvetia canaliculata* on sheltered littoral fringe rock
    - **A1.312** - *Fucus spiralis* on sheltered upper eulittoral rock
    - **A1.3121** - *Fucus spiralis* on full salinity sheltered upper eulittoral rock
    - **A1.3122** - *Fucus spiralis* on full salinity upper eulittoral mixed substrata
  - **A1.313** - *Fucus vesiculosus* on moderately exposed to sheltered mid eulittoral rock
    - **A1.3131** - *Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock
    - **A1.3132** - *Fucus vesiculosus* on mid eulittoral mixed substrata
  - **A1.314** - *Ascophyllum nodosum* on very sheltered mid eulittoral rock
    - **A1.3141** - *Ascophyllum nodosum* on full salinity mid eulittoral rock
    - **A1.3142** - *Ascophyllum nodosum* on full salinity mid eulittoral mixed substrata
  - **A1.315** - *Fucus serratus* on sheltered lower eulittoral rock
    - **A1.3151** - *Fucus serratus* on full salinity sheltered lower eulittoral rock
    - **A1.3152** - *Fucus serratus* on full salinity lower eulittoral mixed substrata
  - **A1.316 –** Association with *Fucus virsoides*
- **A1.32 –** Fucoids in variable salinity
  - **A1.321** - *Pelvetia canaliculata* on sheltered variable salinity littoral fringe rock
  - **A1.322** - *Fucus spiralis* on sheltered variable salinity upper eulittoral rock
  - **A1.323** - *Fucus vesiculosus* on variable salinity mid eulittoral boulders and stable mixed substrata
  - **A1.324** - *Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock
  - **A1.325** - *Ascophyllum nodosum* ecad. Mackaii beds on extremely sheltered mid eulittoral mixed substrata
  - **A1.326** - *Fucus serratus* and large *Mytilus edulis* on variable salinity lower eulittoral rock
  - **A1.327** - *Fucus ceranoides* on reduced salinity eulittoral rock
- **A1.41 –** Communities of littoral rockpools
  - **A1.412 –** Fucoids and kelp in deep eulittoral rockpools
    - **A1.4121** - *Sargassum muticum* in eulittoral rockpools
    - **A1.4114** - *Cystoseira* spp. in eulittoral rockpools
- **A3.13 –** Mediterranean communities of infralittoral algae very exposed to wave action
  - **A3.132 –** Association with *Cystoseira amentacea var. amentacea, var. stricta, var. spicata*
  - **A3.151** - Cystoseira spp. on exposed infralittoral bedrock and boulders
- **A3.23 –** Mediterranean communities of infralittoral algae moderately exposed to wave action
  - **A3.234 –** Association with *Cystoseira tamariscifolia* and *Saccorhiza polyschides*
  - **A3.239 –** Association with *Cystoseira brachycarpa*

- **A3.23A –** Association with *Cystoseira crinita*
- **A3.23B –** Association with *Cystoseira crinitophylla*
- **A3.23C –** Association with *Cystoseira sauvageauana*
- **A3.23D –** Association with *Cystoseira spinosa*
- **A3.23E –** Association with *Sargassum vulgaris*

• A3.31 – Silted kelp on low energy infralittoral rock with full salinity

- **A3.315 -** *Sargassum muticum* on shallow slightly tide-swept infralittoral mixed substrata

• A3.33 – Mediterranean submerged fucoids, green or red seaweeds on full salinity infralittoral rock

- **A3.331 –** Association with *Stypocaulon scoparium = Halopteris scoparia*
- **A3.332 -** Association with *Trichosolen myura* and *Liagora farinosa*
- **A3.333 –** Association with *Cystoseira compressa*
- **A3.334 –** Association with *Pterocladiella capillacea* and *Ulva laetevirens*
- **A3.335 -** Facies with large *Hydrozoa*
- **A3.336 –** Association with *Pterothamnion crispum* and *Compsothamnion thuyoides*

• A3.34 – Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)

- **A3.341 –** Mixed fucoids, *Chorda filum* and green seaweeds on reduced salinity infralittoral rock
- **A3.342 -** *Ascophyllum nodosum* and epiphytic sponges and ascidians on variable salinity infralittoral rock
- **A3.343 -** *Polyides rotundus* and/or *Furcellaria lumbricalis* on reduced salinity infralittoral rock
- **A3.344 -** *Fucus ceranoides* and *Enteromorpha* spp. on low salinity infralittoral rock

•A4.26 – Mediterranean coralligenous communities moderately exposed to hydrodynamic action

- **A4.261 –** Association with *Cystoseira zosteroides*
- **A4.262 –** Association with *Cystoseira usneoides*
- **A4.263 –** Association with *Cystoseira dubia*
- **A4.264 –** Association with *Cystoseira corniculata*
- **A4.265 –** Association with *Sargassum* spp.

•A5.52 – Kelp and seaweed communities on sublittoral sediment

- **A5.52E –** Association with *Cystoseira barbata*

The Regional Activity Centre for Specially Protected Areas created a list of the main biocenosis organised according to bathymetric position (zonation) and type of substrata. This was done according to the Interpretation Manual of European Marine Habitats used for the selection of natural sites and promotion of the conservation of these sites within the United Nations Environment Programme and according to the Mediterranean Action Plan.

II.4.2. Biocenosis of lower mediolittoral rock

- **II.4.2.7.** Association with Fucus virsoides

III.1.1. Biocenosis of euryhaline and eurythermal environment

- **III.1.1.10**. Association with *Cystoseira barbata*

III.6.1. Biocenosis of infralittoral algae

- **III.6.1.2.** Association with *Cystoseira amentacea* (*var. amentacea, var. stricta, var. spicata*)
- **III.6.1.10.** Association with *Cystoseira tamariscifolia* and *Saccorhiza polyschides*
- **III.6.1.15.** Association with *Cystoseira brachycarpa*
- **III.6.1.16.** Association with *Cystoseira crinita*
- **III.6.1.17.** Association with *Cystoseira crinitophylla*
- **III.6.1.18.** Association with *Cystoseira sauvageauana*
- **III.6.1.19.** Association with *Cystoseira spinosa*
- **III.6.1.20.** Association with *Sargassum vulgare*
- III.6.1.25. Association with *Cystoseira compressa*

IV.3.1. Biocenosis of coralline

- **IV.3.1.1.** Association with *Cystoseira zosteroides*
- **IV.3.1.2.** Association with *Cystoseira usneoides*
- **IV.3.1.3.** Association with *Cystoseira dubia*
- **IV.3.1.4.** Association with Cystoseira corniculata
- **IV.3.1.5.** Association with *Sargassum* spp. (*autochthonous*)

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Degree of vulnerability

For more than 20 years, different studies have indicated that *Cystoseira* sp. forests are suffering a decline[88]. In fact, the forests made up of algae belonging to the *Cystoseira genus* are considered one of the vegetable habitats with the highest rates of decline in recent years, as well as being communities with slow recovery rates of between 10 and 100 years[89].Many species are included in the “red books” or lists of endangered species[90]. Consequently, *C. crinita* and *C. barbata* are considered severely threatened in the Black Sea; while the Red Book of Flora in the Mediterra-nean includes *C. caespitosa, C. elegans, C. ercegovicii, C. mediterranea, C. sauvageanica, C. spinosa and C. zosteroides*[91].

Cystoseira species are especially vulnerable due to their long life spans. The cauloids of some deep-sea species grow only 1.5 centimetres per year[92].

Cystoseira forests are very sensitive to pollution and are consequently used as indicators of water quality[93], because it has been proven that many fucoid species, especially those belonging to the C*ystoseira* and *Sargassum genera*, are very demanding as far as water quality is concerned[94].

C. tamariscifolia has disappeared in some areas of the Cantabrian coasts due to pollution[95]. *Cystoseira* sp. forests affected by organic and inorganic pollution have been studied both in the Atlantic and the Mediterranean[96]. This includes the effects of hydrocarbon pollution within these communities[97]. Other factors that affect them are turbidity[98] and eutrophication[99].

According to the Mediterranean Action Plan[100], species such as *Cystoseira amentacea, C. mediterranea, C. sedoides, C. spinosa* and *C. zosteroides* are considered priorities due to their high rates of decline. Furthermore, the development of national plans has been requested for the conservation of *Cystoseira* sp. belts. All these species are also included in Annex II, under maximum protection, of the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean[101] and in Annex I of the Bern Convention[102].

A recent study concerning fucoid brown algae undertaken in the Alberes coast (France) indicates that only 5 of the 14 taxa that existed in the 19th century still exist today in that area[103].

Some allochthonous fucoid species, such as *Sargassum muticum*, have strongly established themselves in the Mediterranean[104] and the Atlantic[105], endangering autochthonous populations.

It has been verified that sedimentation and eutrophication are also factors that can lead to the decline of species belonging to the *Fucus genus*[106]. This deterioration in water quality along with changes in salinity and levels of nutrients may also have caused a series of synergies that have led to the decline of fucoid algae beds by favouring the expansion of other epiphytic algae that compete for space and food[107], while also favouring the reproduction of the principal predators such as the isopod *Idotea baltica*[108].

The decline of *Fucus* species in some areas of the Baltic Sea, such as the Gulf of Kiel during the 1980's, has lead to a reduction in biomass of up to 95%[109].

In some cases, species from the *Mucus genus* compete for space. In Northern Spain, *Fucus serratus* is occupying the space traditionally populated by *Fucus vesiculosus* because it seems the latter species is less resistant to pollution and has lower rates of reproduction, giving the advantage to the former species[110] A similar case occurs in the Baltic Sea, where *F. evanescens* is colonising new areas where *F. vesiculosus* and *F. serratus* are also currently in decline[111].

Other important aspects

Fucoid algae are also a source of protein and substances used in the pharmaceutical industry. For example, steroids and volatile acids have been found in *Cystoseira barbata* and *C. crinita* [112]; sulphated polysaccarrides in *C. canariensis*[113] or meroditerpenes in various Mediterranean species [114]; alginates in *Sargassum* spp[115].; carotenoids and bactericides in Fucus spp[116].

Fucoid brown algae are also excellent indicators of water quality and have been used to verify levels of pollution caused both by hydrocarbons[117], and heavy metals[118], as well by as radioactive isotopes[119].

Other identified habitats 17

In the preceding pages, a variety of natural habitats of European Community interest have been grouped together under different chapters. A wealth of scientific information exists about these communities and they are often mentioned mainly due to their high ecological value.

Nevertheless, there are other habitats in European waters that are no less important. Either there is a lack of information about them and they require a more precise definition or they were not included in the first analysis.

All of these marine habitats should be subjected to subsequent revisions in order to evaluate the possibility of them being included in the lists and current action plans for their protection.

In general, any sessile organism has the ability to form a critical habitat (especially if they occur in large numbers).

Amongst these, it is necessary to include the following communities:

Understories of brown algae

As mentioned before, some species of fucoids form an understory level within other habitats, such as kelp forests. Although other brown algae species belon ging to the *Dictyota genus* form dense communities in infralittoral and circalittoral waters, such as *Dictyopteris membranacea* or *Zonaria tournefortii*.

Oceana has found these algae occurring together with kelp and *Cystoseira* sp. beds in various areas within the Mediterranean Sea and the Atlantic Ocean, such as the Gorringe seamounts (Portugal),a with sargassum in Placer de la Barra Alta, in the Columbretes Islands, or with seagrass meadows also in the Columbretes Islands (Castellon, Spain). These understories can occur together with a wide variety of red, green and brown algae.

In *Dictyopetris membranacea* understories, accompanying flora such as *Padina pavonica, Halopteris filicina, Dictyota dichotoma, Corallina granifera, Halimeda tuna, Falbellia petiolata* is commonly found as well as different species from the *Peyssonnelia genus*[2].

In Zonaria tournefortii understories, accompanying species can include *Halopteris filicina, Sporochnus pedunculatus, Acrosorium uncinatum, Aglaothamnion sepositum, Cryptoleura ramosa, Plocamniun cartilagineum, Porphyra leucosticta*, etc[3].

Mixed meadows of photophilic algae and/or carpets of mixed algae

A variety of algal species form dense meadows or carpets in well-lit infralittoral waters, such as the communities formed by photophilic algae on hard substrata in the Mediterranean represented by *Padina pavonica, Lobophora variegata, Codium* spp., *Halopteris scoparia, Laurencia* sp., *Dictyota dichotoma, Dilophus fasciola, Taonia atomaria*, amongst others.

Although these habitats are commonly found on rocky seabeds in the Mediterranean, not enough attention has been paid to them in spite of the rich variety of associated species they harbour. Recently, it was proposed that these seabeds be taken into account when marine protected areas are being designated[4]. Dense beds of photophilic algae occur in Cabo de Gata (Almeria, Spain)[5], in Cabrera Archipelago (Balearic Islands, Spain)[6], and in Santa Croce Bank (Gulf of Naples, Italy)[7].

Beds of filamentous algae

Dense beds of filamentous algae frequently form in mediolittoral and infralittoral areas. The filamentous algae are frequently associated with other habitats of community interest such as crustacean or mollusc beds, fucoid algae beds, etc., but they also create habitats or microhabitats that are very important for a wide variety of species, some of which feed off the algae[8].

Amongst the algae that participate in these beds are those from the following genera: *Ceramium, Chaetomorpha, Cladophora, Ectocarpus, Pilayella, Polysiphonia*, etc. Some important areas with beds of filamentous algae occur in the Öregrund Archipelago (Bothnia Sea, Sweden)[9] and in the Gulf of Finland[10].

Rockpools

Rockpools pools have been mentioned a number of times in the chapters within this document related to other types of habitats of community interest. These pools form characteristic habitats.

Organisms that are strongly tied to these habitats or that use them opportunistically can be found in these pools[11]. These habitats are important for faunal communities on land as well[12]. Furthermore, rockpools occur in all coastal countries within the European Union.

Habitats with colonial species of hydrozoans, bryozoans and tunicates

The hydrozoans, especially the colonial species, can generate or participate in biologically rich communities. Species such as *Eudendrium* sp., *Tubularia indivisa, Nemertesia* sp., *Halocordile* sp., *Aglaophenia* sp., *Sertularia* sp., *Errina aspera*, etcetera, are distributed throughout most European waters. Although many hydrozoans are part of a more complex biocenosis made up of suspension feeding species, their presence is fundamentally important for the existence of other species, such as nudibranchs, which usually feed off the hydrozoans[13].

The case of the bryozoans is similar to the hydrozoans, although the volume, quantity and capacity of calcium carbonate production makes them extremely important for a wide variety of habitats including coralline, biocenosis of caves, as well as being important epiphytes within gorgonian gardens. Species such as *Pentapora fascialis, Smittina cervicornis, Flustra foliacea, Miriapora truncata, Sertella septentrionalis, Hornera lichenpoides*, amongst others, are very important for the configuration of habitats and sustain a large part of carbon fixing and biomass production of the communities in which they participate[14].

Different species of tunicates such as *Polyclinum aurantium, Molgula manhattensis, Dendrodoa grossularia, Ascidiella aspersa, Diazona violacea, Clavellina* sp., amongst others, are also widely distributed both geographically and bathymetrically.

Colonial anthozoans or concentrations of cnidarians

Some colonial anthozoans form important habitats or microhabitats with high concentrations of species, such as the colonial species *Maasella edwardsii, Parazoanthus axinellae, Corynactis viridis* or *Epizoanthus* sp. Aggregations of branching colonial species of anthozoans on different types of substrata are also important, such as *Virgularis mirabilis, Funiculina cuadrangularis* or *Pennatula* spp. on soft seabeds, sometimes forming dense forests. Or similarly, colonies of *Parerythropodium coralloides, Paralcyonium spinulosum* or *Alcyonium* sp.[15], found on various substrata.

The dense communities formed by other species of solitary cnidarians are also important in the formation of these types of habitats. The following species are especially important: *Anemonia sulfata*, identified by Oceana and other researchers during expeditions carried out in waters of the Alboran Sea and Columbretes Island[16] (Spain); *Urticina felina* in Galway Bay[17] (Ireland); *Metridium senil* in Limfjorden (Denmark)[18] and *Aiptasia mutabilis* in El Calón (Almeria, Spain), amongst others.

Other habitats yet to be defined

Many other marine habitats of European Community interest are included within the EUNIS classification system that should be taken into account when developing management and conservation plans for the seas and oceans that surround European coasts.

Nevertheless, this classification system is incomplete because research into the European marine environment is constantly being updated and new habitats and species are being discovered. Therefore, the protection of biological diversity will depend on our capacity to assimilate new data and understand the importance of these immensely dynamic ecosystems, as well as their inherent value.

Conclusions

To understand the ecological and geomorphological processes that occur within habitats, as well as to understand the degree of alteration from impacts caused by human activities, it is necessary to obtain data concerning the locations, extensions and distribution of the habitats. The European Commission admits that there is a general lack of both the scientific data and resources needed to carry out the required scientific work, and the Habitats Directive (92/43/CEE) is problematic, for example in regards to the definitions of some types of habitats.

Given that it is necessary to study how to more effectively apply the Habitats Directive (92/43/CEE), and although the development of its approach may be complex, specific problems for marine areas commonly stem from a lack of data, complex jurisdictional issues and overlapping responsibilities amongst different administrations. These problems are being studied by a workgroup created by the European Commission in which various Member states are participating.

According to the European Environmental Agency, there are studies which demonstrate a severe decline in some species that were previously widely distributed, but which now consist of very unstable populations located within reduced areas of distribution. Member states must avoid the deterioration and alterations of habitats which may have a significant effect on species. The selection process for marine and coastal protected areas has been hindered due to the lack of data on habitats and species.

In the months before the 1992 Earth Summit in Rio de Janeiro, the European Union adopted a fundamental legislative tool for the application of the United Nations Convention on Biological Diversity in EU territories: the Habitats Directive. This Directive establishes a common framework for the conservation of fauna, flora, natural and semi-natural habitats. Its purpose was to create the Natura 2000 network, and to maintain or restore the species and natural habitats of inte-rest to the European Community at a favourable conservation status. As conservation and the sustainable use of biodiversity has gained political ground during the last few years within the community, the VI Environment Action Programme of the EU, adopted in 2002, establishes European Union's environmental priorities. One of the four priorities concerns nature and biodiversity policy, and its objective is to end biodiversity loss in the European Union by the year 2010.

Furthermore, in 1998, the European Union approved a biodiversity strategy in which it acknowledged its leading role in promoting the objectives of the Convention on Biological Diversity, and established the framework in which Member states should contribute through European Community policies and instruments. Various political objectives are established in the strategy, the first of which is the conservation of natural resources. Two key objectives regarding this issue are the full application of the Habitats Directive and the Birds Directive (92/43/CEE and 79/409/CEE), and the support for creating networks of designated areas, in particular the Natura 2000 network.

The future tendencies on a global and community scale, along with the application of the EU Biodiversity Strategy and its action plans established by the European Council to achieve an increased integration of biodiversity in designated areas, need not be questioned. The conservation of the marine environment and its biological diversity makes it necessary to urgently protect and designate the identified areas.

As mentioned above, during the European Council held in Gothenburg in June, 2001, the European Union Heads of State set the goal of ending biodiversity loss by 2010. The means to achieve this goal are included in the VI Environment Action Programme decided on by the Council and Parliament in July, 2002.

The Plan of Implementation for the Decisions made at the World Summit on Sustainable Development ("Johannesburg Plan of Implementation") calls for a significant reduction in the current rate of biodiversity loss by the year 2010. In collaboration with the European Environmental Agency, the EU is developing a series of indicators that will be used to track the advances made toward achieving this goal. The effective application of the Habitats and Birds Directives and the establishment of the Natura network are fundamental tools for reaching the goals that have been established for the international community and the EU by 2010.

Annex I (natural habitat types of community interest) and Annex II (animal and vegetable species of co-mmunity interest) of the Habitats Directive offer information concerning the types of habitats and species that require designation as Special Areas of Conservation (SACs). Some of them are defined as "priority" habitats or species, which means they are in danger of disappearing. The only marine habitats currently defined as priority habitats in the Habitats Directive are 1120, *Posidonia oceanica* and 1150, coastal lagoons.

Annex I of the Habitats Directive is not representative of the marine environment because it does not include all habitat types, and the definitions of the habitat types that are included are incomplete. In conclusion, taking into account that Member states must work with the current annexes in order to designate SACs, the interpretation of these habitat types turns out to be insufficient. Currently, only nine habitat types are included in Annex I of the Habitats Directive as habitats of interest to the European Community whose conservation requires them to be designated as SACs.

The decisions made concerning the management of these sites should take into account ecological processes, including population dynamics, food webs interactions between species. This evaluation will provide valuable information on how management plans can be focused on strategic objectives, emphasising action plans in certain areas that will allow for integrated management and planning in each sector, maintaining an adequate level, and basing itself on an ecosystem focus.

Given the technical complexity concerning the identification, evaluation and selection of certain species and areas, protection measures should be urgently established through the designation of sites of community interest for certain threatened and extremely important benthic communities, such as coralline beds, deep-sea corals, maërl beds, seagrass meadows, and kelp forests, amongst others.

Annex I of the Habitats Directive (92/43/CEE)

- **1110** **Sandbanks which are slightly covered by sea water all the time**
- **1120** **Posidonia meadows (Posidonion oceanicae) (*)**
- **1130** **Estuaries**
- **1140** **Mudflats and sandflats not covered by seawater at low tide**
- **1150** **Coastal lagoons(*)**
- **1160** **Large shallow inlets and bays**
- **1170** **Reefs**
- **1180** **Submarine structures made by leaking gases**
- **8330** **Submerged or partially submerged sea caves**

(*) Priority Habitat

Once an area is adopted by the European Commission as a site of community importance, Member states must take the appropriate measures to avoid the deterioration of the natural habitats and the habitats of species, as well as any disturbances that could affect the species which prompted the selection of the area in the first place (article 6, section 2).

Certain habitats should be mentioned, amongst others, as examples that currently exist in the marine environment and which are included in this report: cold water coral beds that extend out to the end of the slope from 400 down to 1,000 meters deep, as exemplified by the species Lophelia pertusa, occurring in the North East Atlantic. The presence of the species *Madrepora oculata* should also be highlighted, which suffers from the impacts of fishing activities. Also of importance are: the coralline bioconstructions, located on the circalittoral seafloor and dominated by encrusting coralline algae; the species *Cladocora caespitosa*, which is the madrepora forming the largest colonies in the Mediterranean; the maërl beds on the continental shelf with the associated species *Mesophyllum, Lithophyllum* and *Spongites*; the "trottoir" formed by red calcareous algae atop rocks that form micro-reefs endemic to the Mediterranean, with species such as *Cryptonemia tunaefortis*, *Fauchea repens, Osmundaria volubilis, Phyllopora crispa, Polysiphonia subulifera*; the laminaria or kelp forests represented in subtidal rocky beds on the European Atlantic coasts with species such as *Laminaria, Saccorhiza* and *Phyllariopsis*; the brown fucoid algae forests occurring in the Atlantic, where the Mediterranean shares the following species with the Black Sea, *Cystoseira crinita, C. barbata* and *C. bosphorica*; and sublittoral muddy floors of the photic zone formed by the seagrass Zostera noltii occurring in the Baltic Sea.

These types of habitats are veritable indicators of changes suffered in recent times and should not be ignored when evaluating and analysing the current state of European waters. One example of this is the severe decline of seagrass meadows due to an alarming increase in pollution, turbidity and a general deterioration of the coastline.

The declines in biodiversity due to the effects of human activities, such as the eutrophication caused by industrial, urban and other types of pollution (hydrocarbons, ballast waters, maritime transport, noise pollution), the construction of coastal infrastructure, the excessive development of coastal areas and the overexploitation of marine resources considerably impact biological communities and cause alterations in the types of habitat that have been described in this report. Legislative measures must be adopted to promote their protection and halt the declines suffered by these communities.

Seagrass meadows (*Posidonia oceanica, Cymodocea nodosa, Zostera marina, Z. noltii*), kelp forests, calcareous bioconstructions, "trottoirs" formed by red algae, coralline beds, maërl beds, and deep-sea corals, amongst others, constitute some of the biological components necessary to ensure ecological stability in a system that is currently vulnerable.

In order to conserve the unique qualities and strengthen the biological diversity of marine ecosystems, it is necessary to establish the following conservation standards:

- Functional conservation sites geared specifically towards protecting biodiversity to ensure the long-term survival of wild species and biological communities, which present biodiversity patterns and ecological processes not altered by the impact of human activities.

- Ecological networks that preserve the functional connectivity between conservation sites, ensuring the conservation of natural habitats and improving their interrelations.

Lastly, the factors that produce ecological imbalances in some populations are a result of increasing declines in various pelagic and benthic communities. This requires that adequate protection measures be established for the biological communities associated with the habitat types described in this report, and which themselves form a habitat type of interest to the European Community, thanks to their own unique biological characteristics and important environmental values.

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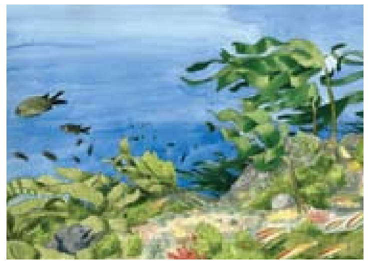
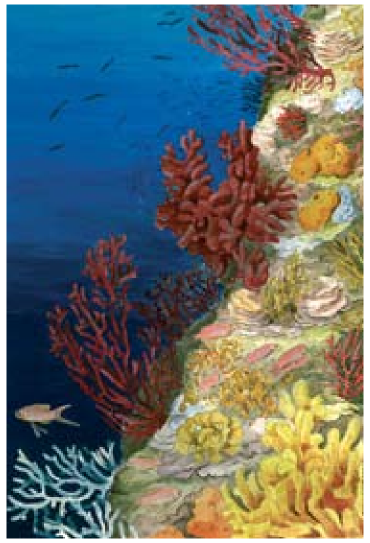
Illustrated habitats

1 Reefs formed by polychaetes, bivalves and crustaceans

2 Seagrass meadows



3 Kelp forests



4 Coralline algae community

5 Maërl beds

6 Deep-sea corals

Oceana has illustrations of the following habitat types available.

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