The corals of the Mediterranean
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01. Introduction
There are corals which live as solitary animals or in colonies, composed of rigid, semi-rigid or soft structures, and which protect themselves under rock formations or grow erect like trees; there are those which prefer exposure to the sun or which live in zones of darkness; those which generate light or which have medicinal properties, existing in shallow waters or at depths of more than 5,000 meters; those with polyps that grow anew each year, or in colonies as old as 50 to 1,000 years on reefs which have taken more than 8,000 years to develop. Although the number of coral species found in the Mediterranean represents less than 5% of those extant throughout the world today, the diversity of the types and forms of life serve as an example to us, demonstrating the full importance of these animals in relation to the global marine ecosystem.

Corals are simple animals and as such, are capable of forming very complex and diverse communities. Contrary to popular belief, simple organisms show the highest capacity for adaptation and mutation, since complex organisms are more specialized and therefore less likely to undergo genetic and physical modifications over a short period of time. Many people believe that corals are plants. This is because the great majority of these creatures are species which live fixed to the substrate, and with a quick glimpse they do not seem to be very active. Because we are terrestrial animals, we are used to drawing a distinction between plants and animals according to their respective ability to move. Yet, what is an obvious observation as far as land creatures are concerned, does not apply to the sea. Appearances to the contrary, there are other animals which also spend all or part of their life anchored to rocks or other substrates, or even to other organisms. This is seen in porifers (sponges), bryozoans, hydrozoans and a great number of worms, mollusks and crustaceans. The fact that some species look like tree branches only serves to increase the confusion.

Corals are animals whose cells are organized in tissues. They have a nervous system, grow and reproduce, form colonies and can feed directly from the organisms which surround them in the water.

All of them are uniquely marine species which exist in all of the ocean habitats known to us, from shallow water and tide pools to the greatest depths known to support marine life.
Corals belong to one of the oldest extant classes of animals in the world. Their fossil remains can be traced back to the pre-Cambrian era,¹ when there was a great surge in oceanic life over 500 million years ago.

Occupying 1.1% of the surface of the world’s oceans and 0.3% of all salt water, the Mediterranean no longer shelters the great coral reefs that thrived 60 million years ago. This is due to millennia of climactic and oceanographic changes. However, even today this sea harbors a spectacular array of corals, including some which are not found anywhere else.

The very term “coral” is ambiguous in itself, since it can be a common term for a few species with rigid skeletons or, specific anthozoan groups. Sometimes, it is used to describe species which belong to other classes of marine life, such as hydrozoans and bryozoans. This occurs with fire, or stinging, coral (*Millepora* sp.) and with false coral (*Myriapora truncata*).

We have selected to use “corals” as the name to group together all anthozoans species, including true corals, black coral, sea fans (or, gorgonians), sea feathers, and anemones. We do not include here the other species commonly referred to as corals, such as fire coral. These are hydrozoans, a class of animals with distinct differences.

The anthozoans, or “flower animals” from the original Greek translation, are a class within the Cnidaria phylum. They are a group of of animals which spend their whole life in the polyp phase.

The cnidarians, or coelenterates, derive their name from their cnidocytes or stinging cells - cnidocyte means stinging or itching needle, derived from the Greek word knidé (nettle). The other older name they are known by, coelenterates means vacuous intestine - from the Greek koilos (vacuous) and enteron (intestine).

The Cnidarian phylum is divided into four classes of species: hydrozoans, cubozoans, scyphozoans and anthozoans.

The hydrozoans and cubozoans spend part of their life as medusas and part as polyps. The scyphozoans only exist as medusas and never enter the polyp stage. Anthozoans only exist as polyps and do not go through a medusoid phase. The cnidarians once included a fifth class, conulata, which went extinct in the Triassic period.

As for the anthozoans, which we have decided to treat as corals and to which this writing is dedicated, they have traditionally been subdivided into two subclasses: Octocorallia and Hexacorallia.

The Octocorallia (or Alcyonacea) derive their name from the 8-fold tentacular symmetry of their polyps, and an equal number of septa or complete, but unpaired, mesentery (the layers of the gastrovascular cavity which reaches from the mouth to the anus). They divide into five orders: Stolonifera (organ-pipe coral; tree fern coral), Alcyonacea (soft corals), Gorgonacea (gorgonians, or sea fans; sea feathers), Helioporacea or Coenothecalia (Indo-Pacific blue coral) and Pennatulacea (sea pens).

Hexacorallia (or Zoantharia) is not only the name for the species with six tentacles, but also signifies the species with more than eight tentacles (many times they are found in multiples of six), with six complete and paired
mesenteries. They divide into seven orders: Actinaria (sea anemones), Scleractinia or Madreporaria (stony corals), Ceriantharia (tube-dwelling anemones), Antipatharia (black corals), Corallimorpharia (coral anemones), Zoanthidea or Zoantharia (colonial anemones) and Ptychodactiaria. Other orders that used to belong to this class are now extinct, such as the Rugosa, Tabulata, Heterocorallia, etc. Two-thirds of all anthozoans in the world belong to this subclass.

In the second half of the 20th century, some authors proposed a third subclass to unite Ceriantharia and Antipatharia under a common order, Ceriantipatharis, given their similarities during the larval stage as well as their unpaired mesenteries, among other common traits. This in turn was a subclass that could be divided into two very distinct orders: the Ceriantharia, or tube-dwelling anemones, which can retract entirely into their tubes, and the Antipatharians, or black corals, which have retractable tentacles. In contrast to all other anthozoans, the latter do not form a ring around their mouths.

There is no scientific consensus as to the classification of these animals. Anthozoa is an animal phylum which has yet to be adequately defined. This can be expected, as the taxonomic classifications and the subsequent identification of their related species can be very divergent.

The taxonomic classification which we have decided to use in this report is the one used in Sistema Naturae 2000² (excluding the Scleractinia, which follow the definition of Vaughan T.W. & J.W. Wells, 1943³, updating certain types and species based on the MAR-BEF,⁴ ITIS⁵ and Hexacorallia of the World⁶ databases). On the other hand, we have kept the names Octocorallia and Hexacorallia instead of Alcyonacea and Zoantharia to avoid confusing, respectively, the two subclasses and two orders.
02. Physical characteristics of corals

White gorgonia (Eunicella singularis) © OCEANA/ Juan Cuetos
A coral is a polyp which can live alone or in colonies and cover itself with a hard or soft exoskeleton, but its overall constitution is rather simple.

The polyps are sac-like with radial symmetry and two layers of tissue: an external one called the ectoderm or epidermis, and an internal one known as the gastrodermis. There is also a third gelatinous layer in between called the mesoglea.

The polyp produces calcium carbonate from within the ectoderm for the purpose of building the firm skeleton of many corals.

On their bottom side they have an anchoring or basal disk which is used to anchor the polyp to the substrate or other structure securing a large colony, while the disk-shaped tentacular mouth is found on the upper side, facing away from the substrate.

Corals only have one orifice serving as both mouth and anus, leading to the pharynx, a short tube connecting the mouth with the gastrovascular cavity. This is separated by the wall of the septa or mesentery, forming the chambers in which the digestive cells are located.

One particularly characteristic trait of anthozoans and other cnidarians are the “cnidos” (greek), stinging needles known as cnidocytes. There are three different types: 1) nematocysts, shaped like small harpoons, which can shoot out and penetrate the tissue of prey, inoculating it with the toxin they contain. They are found in the tentacles and gastrovascular cavity of all anthozoans; 2) spirocysts, only found among hexacorallias, which use adhesion with their victims instead of needles; and 3) ptychocysts, also adhesive, and used by ceriantharias (tube-dwelling anemones) to construct their tubes.

**Configuration**

Corals can be found living in isolation or in immense colonies; they may display only their soft bodies live inside a tube or create erect structures that are rigid, semi-rigid or soft and on which they anchor their polyps. They may rise into branch formations, with many or few dendrites, or carpet vertical walls on the sea-floor, making it look like a carpet of grass; they may take on the aspect of cushions, balls, feathers, whips, globules, etc. There are also those which have taken over the external housing of sponges or other corals.

The great variety these colonies present has created an endless naming process and attempt to categorize them. Some have little branching and are whip-like (such as *Elissela paraplexauroides* or *Viminella flagellum*), cable-like (such as *Eunicella filiformis*), or feather-like (such as *Virgularia mirabilis* or those of the *Pennatula* type).

Often, these forms reflect a specialized adaptation for survival in different marine environments, conditioned by hydrodynamics, temperature, etc.

In some cases, the coral colonies form tree-like structures, like most gorgonians or some scleractinias such as *Dendrophyllia ramea* or *Pourtalosmilia anthophyllites*. For these types of colonies, the structure is usually rigid or

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White gorgia (Eunicella singularis) with protruding calyces © OCEANA/ Thierry Lanoy
semi-rigid, but there are also soft body colonies, such as dead man’s fingers (*Alcyonum* spp.) or the sea feathers (*Pennatulacea*), among others.

One of the structures most characteristic of coral formation is the reef. In the Mediterranean, coral reefs are scarce and there are only a few species of colonial anthozoans that have the capacity to create them.

However, there are other cnidarians which form complex and sizeable colonies, even though these may not always be considered reefs. Some examples of these are the anemone colonies of the type *Epizoanthus*, *Parazoanthus* and *Corynactis*, or some corals living in colonies such as the *Madracis pharensis*, *Astroides calycularis*, *Polycyathus muellerae*, *Phyllangia mouchezii* and *Hoplangia durotrix*.

Solitary anthozoans may be found living in the habitats created by other corals. Some deep-water species are often found existing in cold water coral reefs. In the Mediterranean, this is seen with species such as *Desmophyllum cristagalli* or *Stenocyathus vermiformis*.

All anemones live in isolated units or in small colonies, although they can sometimes form habitats when there are enough of them in a given area. This also occurs with many true corals of the Balanophyllidae and Caryophyllidae families.

An alternative favored by some corals is to occupy structures made by other anthozoans. The soft coral *Parerythropodium coralloides* and the false black coral (*Gerardia savaglia*) form such habitats. While they are capable of creating branch-like colonies on their own, they sometimes invade gorgonian colonies and partly or entirely cover them over.

Some species of corals may also appear different according to the environmental conditions in which they have grown.

Although *Cladocora caespitosa* takes its name from its typical presentation in sweeping “grass” carpets or as small cushions, they may rise into shrub-like formations when the hydrodynamics are low and permit it. The white (*Eunicella singularis*) or yellow (*Eunicella cavolini*) gorgonia, may also look differ-
ent depending on the ambient hydrodynamics; while some hardly branch at all, and the branching appears flat, they may also have a fuller, bushy appearance. Even their exoskeletons can be modified.⁹

**Exoskeletons for all tastes**

The exoskeleton of hard corals (scleractinias) is composed of a crystallized form of calcium carbonate (CaCO₃), known as aragonite,¹⁰ which also composes the shells of many mollusks. In rare cases or with varying marine chemicals, aragonite has been found to be a substitute of calcite.¹¹

The high mineralization rate of the soluble calcium carbonate found in corals is maximized in certain symbiotic algae (zooxanthelae) living in their tissue.¹²

There are other corals which use composites of proteins, carbohydrates and allogeneic composites such as gorgonian to form a horn-like skeleton¹³, sometimes dotted with calcareous spicules, common among octocorallias. It is softer than scleractinias, making for greater flexibility. Some octocorallias have opted for an intermediate system, substituting gorgonian for calcium carbonate. This is the case of scleractinias. Thanks to these alterations, their structure is more rigid. This can be seen with red coral (*Corallium rubrum*).

There are also examples of soft skeletons, as with anemones and zoantharias. Or those that have opted for a tube instead of a skeleton, using stinging cells (ptychocysts) and mucus to insulate the polyp, and to fix sand and other particles in the manner of some polychaete worms.

**In touch**

When polyps live in colonies, they must find ways to coordinate themselves. For gorgonians and other octocorallias living in branching colonies, the polyps are in contact internally via living tissues such as the coenenchyme. In addition, the gastrovascular cavities are also intercommunicated via canals and tubes.

But if there can be only one particularly striking technique to stay in touch with one another, it is that exhibited by the stoloniferas corals. These are simple polyps that are united by means of offshoots containing internal canals which maintain continuous contact. When a single polyp or its offshoots is touched, all of the animals retract simultaneously into their calyx.
Coral species of the Mediterranean
More than 200 species of coral (from a total of 5,600 species which have been described worldwide, 500 of which are in Europe) live in the Mediterranean. Some of the species living there are endemic, while others have a subtropical origin from the warmer waters of the Atlantic. Still others are more common in arctic zones, while some are found everywhere.

Anthozoan species found in the Mediterranean:

<table>
<thead>
<tr>
<th>OCTOCORALLIA</th>
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<tbody>
<tr>
<td><strong>Alcyoniidae</strong></td>
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<tr>
<td>- Alcyoniumidae</td>
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<tr>
<td>Dead man’s fingers <em>Alcyonium acaule</em></td>
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<tr>
<td>Dead man’s fingers <em>Alcyonium palmatum</em></td>
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<tr>
<td>False red coral <em>Parerythropodium coraloides</em></td>
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<tr>
<td>- Paralcyoniidae</td>
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<tr>
<td>Maasella edwardsi</td>
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<tr>
<td>Paralcyonium spinulosum</td>
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</tbody>
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| | **Pennatulidae** |
| | - Sea Feather *Pennatula aculeata* |
| | - Phosphorescent Sea Feather *Pennatula phosphorea* |
| | - Red Sea Feather *Pennatula rubra* |
| | - Grey Sea Feather *Pteroeides griseum* |
| | **Virgularidae** |
| | - Sea Pen *Virgularia mirabilis* |

| | **Stolonifera** |
| | - *Cornulariidae* |
| |   Cornucopia *Cornularia cornucopiae* |
| |   Cervera *Cervera atlantica* |
| | - *Clavulariidae* |
| |   Common clavularia *Clavularia crassa* |
| |   Dwarf clavularia *Clavularia carpediem* |
| |   Clavularia marioni |
| |   Clavularia ochracea |
| |   Rolandia *coralloides* |
| |   Sarcodyction catenata |
| |   Scleranthelia *microsclera* |
| |   Scleranthella *rugosa* |

<table>
<thead>
<tr>
<th><strong>Gorgonacea</strong></th>
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<tr>
<td>- Acanthogorgiidae</td>
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<tr>
<td>Acanthogorgia <em>armata</em></td>
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<td>Acanthogorgia <em>hirsuta</em></td>
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<tr>
<td>- Elliselliidae</td>
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<tr>
<td><em>Elisella paraplexauroides</em></td>
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<td><em>Viminella flagellum</em></td>
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<tr>
<td>- Gorgoniidae</td>
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<tr>
<td>Yellow sea fan/gorgonia <em>Eunicella cavolini</em></td>
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<tr>
<td>Cable gorgonia <em>Eunicella filiformis</em></td>
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<tr>
<td><em>Eunicella gazella</em></td>
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<tr>
<td>Senegalese gorgonia <em>Eunicella tabiata</em></td>
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<tr>
<td>White gorgonia <em>Eunicella singularis</em></td>
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<tr>
<td>Pink gorgonia <em>Eunicella verrucosa</em></td>
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<tr>
<td>Guinea gorgonia <em>Leptogorgia guineensis</em></td>
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<tr>
<td>Portuguese gorgonia <em>Leptogorgia fusifanica</em></td>
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<tr>
<td>Leptogorgia <em>saramentsosa</em></td>
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<tr>
<td>Leptogorgia <em>viminalis</em></td>
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<tr>
<td>- Isididae</td>
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<tr>
<td><em>Isidella elongata</em></td>
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<tr>
<td>- Plexauridae</td>
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<tr>
<td>Bebryce <em>mollis</em></td>
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<tr>
<td><em>Echinomuricea klavereni</em></td>
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<tr>
<td>Muriceides <em>lepidia</em></td>
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<tr>
<td>Red gorgonia <em>Paramuricea clavata</em></td>
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<tr>
<td>Spiny gorgonia <em>Paramuricea macrospina</em></td>
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<td>Crown gorgonia <em>Placogorgia coronata</em></td>
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<td><em>Placogorgia massiliensis</em></td>
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<tr>
<td>Spinimuricea <em>atlantica</em></td>
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<tr>
<td>Spinimuricea <em>klavereni</em></td>
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<tr>
<td>North Sea gorgonia <em>Swiftia pallida</em></td>
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<tr>
<td><em>Villogorgia bebrycoides</em></td>
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<tr>
<td>- Primnoidea</td>
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<tr>
<td>Callogorgia <em>verticillata</em></td>
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<tr>
<td>- Corallidae</td>
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<tr>
<td>Red Coral <em>Corallium rubrum</em></td>
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</tbody>
</table>
### HEXACORALLIA

**Actiniaria**
- *Andresiidae*
  - Andresia parthenopea
- *Edwardsiidae*
  - Edwardsia beautempsi
  - Edwardsia claparedii
  - Edwardsia grubii
  - Edwardsia timida
  - Edwardsiella janthina
  - Edwardsiella carnea
  - Scolanthus callimorphus
- *Halcampoididae*
  - Synhalcampella oustromovi
  - Halcampella endromitata
  - Halcampoides purpurea
- *Halocladidae*
  - Anemonactis mazeli
  - Mesacmaea mitchelli
  - Mesacmaea stellata
  - Peachia cylindrica
  - Peachia hastata
- *Boloceroididae*
  - Bunodeopsis strumosa
- *Actiniidae*
  - Actinia atrimaculata
  - Actinia cari
  - Actinia cleopatrae
  - Actinia crystallina
  - Actinia depressa
  - Beadlet anemone Actinia equina
  - Strawberry anemone Actinia fragacea
  - Actinia glandulosa
  - Actinia judaica
  - Actinia mesembryanthemum
  - Actinia phaeochira
  - Actinia rondeletii
  - Actinia rubra
  - Actinia rubripunctata
  - Actinia striata
  - Actinia zebra
  - Anemonia cereus
  - Mediterranean snakelocks anemone Anemonia sulcata
  - Anthopleura baillii
  - Bunodactis rubripunctata
  - Gern Anemone Bunodactis verrucosa
  - Deep-water Anemone Condylactis aurantiaca
  - Thick tentacle anemone Cribrinesis crassa
  - Paranemonia cinerea
  - Paranemonia vouliagmeniensis
  - Pseudactinia melanaster
- *Actinostolidae*
  - Paranthus chromatoderus
  - Paranthus rugosus
- *Aiptasiidae*
  - Aiptasia carnea
  - Aiptasia diaphana
  - Aiptasia saxicola
  - Trumpet anemone Aiptasia mutabilis
  - Aiptasiogoton pellucidus
- *Aliciidae*
  - Alicia costae
  - Alica Alicia mirabilis
- *Aurelianiidae*
  - Imperial anemone Aureliana heterocera
- *Condylanthidae*
  - Segonzactis hartogi
  - Segonzactis platypus
- *Diadumenidae*
  - Orange anemone Diadumene cincta
  - Orange striped anemone Haliplanella lineata
- *Hormathidae*
  - Actinauge richardi
  - Cloak anemone Adamsia carciopados
  - Amphianthus crassus
  - Sea fan anemone Amphianthus dohrnii
  - Parasitic anemone Calliactis parasitica
  - Hormathia alba
  - Hormathia digitata
  - Hormathia coronata
  - Hormathia nodosa
  - Paracalliactis lacazei
  - Paracalliactis robusta
- *Isophellidae*
  - Club tipped anemone Telmatactis cricoides
  - Swimming anemone Telmatactis forskalii
  - Telmatactis solidago
- *Metridiidae*
  - Plumose or Frilled anemone Metridium senile
- *Phymanthidae*
  - Phymanthus pulcher
- *Sagartiidae*
  - Actinothoe clavata
  - Actinothoe sphyrodeta
  - Daisy anemone Cereus pedunculatus
  - Kadophelia bathyalis
  - Octophelia timida
  - Sagartia elegans
  - Sagartia troglodytes
  - Sagartiogeton entellae
  - Sagartiogeton undatus
- *Gonactiniidae*
  - Gonactinia prolifera
  - Protanthea simplex
HEXACORALLIA (continued)

Corallimorpharia
- Corallimorphidae
  Corynactis mediterranea
  Jewel anemone Corynactis viridis
- Sideractidae
  Sideractis glacialis

Scleractinia
- Caryophyllidae
  Cup coral Caryophyllia calveri
  Cup coral Caryophyllia cyathus
  Southern cup coral Caryophyllia inornata
  Devonshire cup coral Caryophyllia smithii
  Ceratotrochus magnaghi
  Coenocathyus anthophyllites
  Coenocathyus cylindricus
  Desmophyllum cristagalli
  Hoplania durotix
  Tuft coral Lophelia pertusa
  Paracyathus pulchellus
  Sphenochrobus andrewianus
  Polycyathus muellerae
  Pourtalismilia anthophyllites
  Phyllangia mouchezii
  Thalamophyllia gasti
- Faviidae
  Thin tube coral Cladocora caespitosa
  Cladocora debilis
- Flabellidae
  Javania cailleti
  Monomyces pygmaea
- Guyniidae
  Guynia annulata
  Stenocathyus vermillonius
- Dendrophylliidae
  Orange coral Astroides calycularis
  Cup coral Balanophyllia cellulosa
  Cup coral Balanophyllia europaea
  Scarlet and gold star coral Balanophyllia regia
  Cladopsammnia rolandi
  Yellow tree coral Dendrophyllia cornigera
  Yellow coral Dendrophyllia ramea
  Sunset cup coral Leptopsammnia pruvoti
- Oculinidae
  White Madrepora Madrepora oculata
  Oculina patagonica
- Pocilloporidae
  Star coral Madracis pharensis

Zoanthidea
- Epizoanthidae
  Brown epizoanthidae Epizoanthus arenaceus
  Epizoanthus frenzeli
  Epizoanthus incrustans
  Epizoanthus mediterraneus
  Epizoanthus paguricola
  Epizoanthus paxi
  Epizoanthus steueri
  Epizoanthus tergestinus
  Epizoanthus univittatus
  Epizoanthus vagus
  Epizoanthus vatovai
- Parazoanthidae
  Gerardia lamarcki
  False black coral Gerardia savaglia
  Yellow cluster anemone Parazoanthus axinellae
- Zoanthidae
  Palythoa axinellae
  Palythoa marioni
  Zoanthus lobatus

Antipatharia
- Antipathes dichotoma mediterranea
- Antipathes graciilis fragilis
- Antipathes subpinnata
- Bathypathes patula
- Leiopathes glaberrima
- Parantipathes larix

Ceriantharia
- Mediterranean tube anemone Cerianthula mediterranea
- Tube anemone Cerianthus lloydii
- Colored tube anemone Cerianthus membranaceus
- Dohm tube anemone Pachycerianthus dohmi
- Pachycerianthus solitarius
- Arachnantus nocturnus
- Dwarf tube anemone Arachnantus oligopus
Six million years ago, towards the end of the Miocene (Messinian) period, there were still some remains of coral reefs from the following genera in the Mediterranean: Porites, Tarbellastrea, Siderastrea, Plesiastrea, Favites, Stylophora, Acanthastrea. Some of them remain as submerged fossils (like at Alborán), others are currently above sea level, and still others straddle both environments, such as those found in Cap Blanc (Mallorca) or the gulf of Antalya and the Taurus Mountains of southwest Turkey. These are examples of fossils from both sides of the Mediterranean.

During the Messinian salinity crisis, the Mediterranean Sea underwent one of its most drastic changes, causing the extinction of many species and the coral reefs. Later, when the straits of Gibraltar opened again, the water rushed in and filling the Mediterranean Sea once again, but the reefs did not reform. Instead, other coral forms were generated representing a great diversity.

The actual origins of corals and reefs in the Mediterranean go far back into geological time. There were coral formations during the Paleocene and Eocene epochs, and much older coral formations have even been discovered that date back to the Triassic, when the Mediterranean was part of the immense, ancient sea of Tethys, more than 200 million years ago. Some of these sites have been excavated at the Italian location of Zorzino.

The oldest coral reef discovered to date is located in the state of Vermont in the United States. It is 450 million years old. However, this reef does not really fall into the category of a “coral reef” as per the current definitions, because, although some corals contributed to its formation, it is not principally the product...
of corals. Neither does it present a pervasive ecosystem, made up of complexly interrelating habitats and the multitude of organisms which depends on and interacts with it. In fact, as per the "modern" definition of a coral reef, the oldest known example is located in the Monte Bolca region of Italy\textsuperscript{22}, belonging to the Eocene epoch. Here were whole communities of fish, including the first known presence of herbivorous ones, and other organisms living in a coral-built reef. For some observers, a shift occurred in the ecological structure of

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Coral reefs some time between the Mesozoic and Cenozoic, 65 million years ago, when the Mediterranean was about to be cut off from the Indo-Pacific zone by the formation of the Arabian Peninsula.

The Mediterranean coral reefs from the Eocene and the marine life which they sheltered show a strong similarity with those that have been found in the Indo-Pacific zone, with an even closer resemblance between some of their fish species than with the fish populations in the tropical Atlantic zone.

Just as the Mediterranean seems to be one of the areas from which modern tropical coral reefs have originated, some deep-sea or cold water reefs may also come from this sea.

The deep-sea coral reef fossils formed by species such as Lophelia pertusa, Madrepora oculata and Desmophyllum dianthus found in the Mediterranean date back to the end of the Pliocene and the early Pleistocene (1.8 million years ago), which makes them the oldest ones found to date.

Coinciding with the early Miocene, it appears that many of these reefs suffered a serious regression and today, only a few zones in this sea have been shown to bear live specimens, such as those found in the Ionian Sea, while their distribution in the Atlantic covers both margins of the northern hemisphere.

Many scientists have mentioned the possibility that the inflow waters from the Mediterranean (known by the acronym MOW -Mediterranean Outflow Water-), larvae of these species then invaded the Atlantic waters, thus propagating through the whole Ocean. As already indicated by Oceana and other authors, some of the principal coral reefs in the deep waters of the Eastern Atlantic are in the flow path of Mediterranean water as it passes through the straits of Gibraltar.

Furthermore, the madreporaria coral that is endemic to the Mediterranean, Cladocora caespitosa, has also lived in this sea for a long period of time. It is known that some reefs date back to the Pliocene and have lasted through the Pleistocene and Holocene up to today. However, today’s reefs are only a small portion of their original range. The Mediterranean madreporaria is in a progressive state of regression.

Exclusive corals and imported corals

However, the Mediterranean appears not only to have “exported” species and reefs. In the last decades, some species of non-native corals have settled in the Mediterranean. This is the case of the orange striped anemone (Haliplanella lineate), and possibly the colonial coral Oculina patagonica.

The colonial coral Oculina patagonica is traditionally considered to be a species that was imported into the Mediterranean.

The first specimens of Oculina patagonica were found in 1966 in Savona (Gulf of Genoa, Italy). They are today well represented
throughout the Mediterranean, especially in areas between Italy, France and Spain, and there is also a second pocket in the Eastern Mediterranean, between Egypt, Israel, Lebanon and Turkey.

At present there is a dispute among scientists as to whether this species is foreign or not. At the very least, doubt exists as to whether it should be excluded from the list of Mediterranean species. The only data on extra-Mediterranean samples of this species come from sub-fossil excavations in the south of Argentina (hence its name) of Tertiary strata. But, there is neither a record of any live specimens of this scleractinia nor of any testimony from the annals of past centuries.

There are many questions to be made regarding this species. When and how was it introduced into the Mediterranean? Is it a relic from the Tertiary? Is *Oculina patagonica* really the specimen found in the Mediterranean? Are there living colonies of *Oculina patagonica* to be found in South America but which have yet to be discovered? Many of these questions still go unanswered.

The orange striped anemone (*Haliplanella lineate*) is originally from the Pacific and is thought to have been introduced in the 19th century into European Atlantic waters on the hulls of ships. It was discovered for the first time in Mediterranean waters off Corsica in 1971.

The Mediterranean also shelters some endemic species of corals. Some of them are typical of this sea, yet may be found in surrounding zones. This is the case of the red gorgonia (*Paramuricea clavata*) which may have traveled as far as the Berlangas Islands of Portugal. As documented by Oceana, they are to be found in the submarine mountains of Gorringe.

Other species that are endemic to the Mediterranean but which may also be found in surrounding areas are *Leptogorgia sarmentosa*, *Maasella edwardsi*, *Actinia striata*, *Astroydes calycularis*, *Balanophylla europaea*, *Cribriopsis crassa*, *Cladocora caespitosa*, *Phymanthus pulcher* and *Corallium rubrum*.
Coral habitats and corals as habitats

Bunodeopsis strumosa on Cymodocea nodosa
© OCEANA/ Juan Cuetos
The forms in which corals congregate give rise to the creation of different types of marine habitats, or else, participate in existing ones. Among the most significant in the Mediterranean are the following:

**Coral reefs**

As mentioned above, the Mediterranean lacks large-scale reefs. Only the biotopes formed by some species may reasonably be classified as such.

In the Mediterranean, only a few species belong to the scleractinians or madreporarians, which is the type of coral that forms the great reefs of the tropics. But the great majority of these specimens are only represented by small colonies or in isolation (or as part of reefs created by other species). Among these, and in the infralittoral and circumlittoral waters, the Mediterranean madreporaria (*Cladocora caespitosa*) stands out as a species extant only in the Mediterranean and adjacent Atlantic waters. It can create large colonies up to four meters in diameter, although it is usually found in smaller colonies of a few hundred polyps. In some areas of the Mediterranean, they can occupy significant zones. This can be seen with the species found in the different reefs of the western Mediterranean, such as in the costal lagoon of Veliko jezero in Croatia, which measure approximately 650 square meters and between four and 18 meters deep.42 *Oculina patagonica* can also form dense colonies and occupy significant areas of the sea bed with abundant sunlight.

Reefs formed by cold water or deep water corals is another type of coral habitat existing in the Mediterranean, mainly formed by tuft coral (*Lophelia pertusa*) and madreporaria (*Madrepora oculata*). This type of reef is also found in extensive areas of the North Atlantic and can generate an ecosystem capable of clustering more than 800 different species, including corals and deep-sea gorgonia. In the Atlantic, reefs have been found extending over several dozen kilometers and reaching up to 30 meters in height43, with an ample range of depths from 40 to over 3,000 meters44.

Today these deep-sea reefs are rare in the Mediterranean. Most of the findings are of fossil or sub-fossil corals, although some live polyps have been found in different areas. The most important of these is in Santa Maria di Leuca (Italy) in the Ionian Sea, where both species appeared together with other deep-sea corals, such as *Desmophyllum dianthus* and *Stenocyathus vermiformis*, in waters from 300 to 1,200 meters deep, occupying areas as large as 400 square kilometers45. Other concentrations of deep-sea corals were found in the Palamós and Cap de Creus canyons of Spain.

In both types of reefs, the temperature and availability of nutrition seem to be the limiting factors in distribution. Salinity, topography, the substrate of the sea floor and light intensity seem to be the variables for the species zooxanthelae46, not to mention the impact of...
human activities such as bottom trawling. In some areas, it has pushed back these formations to less accessible regions such as canyons and ravines.

For deep-sea corals, the hypothesis for measuring the settlement and growth of a reef or colony is influenced by oceanographic and paleo-environmental factors. It is thought that the microbial role in hydrocarbon seepage during carbonate formation facilitates their growth.47

**Coralline algae**

The predominant species which form this vital ecosystem are not corals at all, but as the name indicates, a type of algae. However, one of the most characteristic representatives of these formations are gorgonias, which serve (the environmental function) as “large trees”. This ecosystem is typical in the Mediterranean48, although similar formations may be found in other areas, including the Atlantic.

Some researchers have managed to differentiate up to five types of coralline algae.49 All of them have corals present. Up to 44 species have been counted in this ecosystem.50 Among the most representative are the gorgonia (*Paramuricea clavata, Eunicella cavolinii, E. singularis, E. verrucosa, etc.*), other octocorallians like red coral (*Corallium rubrum*), dead man’s fingers (*Alcyonium sp.*), zoantharia such as the orange colonial anemone (*Parazoanthus axinellae*), and hexacorallia such as the yellow coral (*Leptosamnia pruvoti*), the orange coral (*Astroides calycularis*), etc.
The contribution of gorgonians and corals to coralline algae is significant. They fix nutrients and sift sediments\textsuperscript{51}, producing calcium carbonate\textsuperscript{52} and generating a large biomass\textsuperscript{53}, or can also procure substrate for the settlement of epibionts\textsuperscript{54}.

In this respect, the larger gorgonians are often colonized by a multitude of organisms such as bryozoans (\textit{Pentapora fascialis} or \textit{Turbiellepora avicularis}), hydrozoans (\textit{Eudendrion} sp., \textit{Sertularella} sp.) or sponges (\textit{ Dysidea} sp., \textit{Hemimycale columella}). They are also useful as an egg depository for various species including the Cat shark (\textit{Scyliorhinus canicula}), as Oceana and other researchers\textsuperscript{55} have been able to verify. Eggs are deposited in species such as \textit{ Paramuricea clavata} and \textit{Eunicella cavolini} in Portofino (Italy) and in other areas of the Mediterranean.

**Large concentrations of anemones**

There are some anthozoans which are usually found in large colonies, like the jewel anemone (\textit{Corynactis viridis}) and the yellow cluster anemone (\textit{Parazoanthus axinellae}), but there are also true anemones which although normally found in small groups or in isolation, can occasionally form large colonies, giving rise to unique habitats. This is the case of \textit{Anemonia sulcata} and \textit{Aiptasia mutabilis} found on Mediterranean facies.

In the case of \textit{Anemonia sulcata}, Oceana has documented large concentrations of this species frequently in association with brown algae forests, such as the kelps \textit{Saccorhiza polyschides} and \textit{Laminaria ochroleuca}.  

\[23\]
Concentrations of anemones with these characteristics have already been documented by other researchers on the sea floors of some marine reserves, such as Columbretes or Alborán.

Although Aiptasia mutabilis is often found alone or in small groups, it has also been detected in large concentrations in the company of poriferaria such as Ircinia variabilis, or in rocky areas between prairies of marine seagrasses.

Some species are authentic specialists when it comes to forming a dense cover of colonies on vertical substrates. The jewel anemone (Corynactis sp.) or yellow cluster anemone (Parazoanthus axinellae) can occupy widespread zones of submarine walls. But some hexacorallias also occupy this strategic high ground. Some of them form large colonies such as the orange coral (Astroides calycularis) and star coral (Madracis pharensis), while others form isolated colonies yet become quite numerous, such as the yellow coral (Leptosamnia pruvotii) and different dendrophylliidas and caryophylliidas. Some coral species such as Polycyathus muellerae or Phyllangia mouchezii can mantle entire rocks.

Other hard substrates like gravel floors, small rocks and stones, can also serve as settlement locations. This is the choice of many anemones such as Diadumene cincta, Anemonia melanaster, and Metridium senile.

Some species have taken maximum advantage of the hard structures which exist on the sea floor, whether it occurs naturally or artificially. Small zoanthidas (Epizoantus sp.)

On rocks, walls and hard substrates

The capacity to adhere to different substrates makes corals efficient colonizers, even on very steep rocks and walls. Walls, the costal shelf and high rocks are favorite places for many corals species. These privileged outcrops are ideal for filtering plankton-filled water which usually gets swept upward in these zones, or else are brought here by the currents.
The corals of the Mediterranean can colonize almost any substrate which they find: stones, shells, coral skeletons, bottles, fishing lines, cables, etc.

In caves and fissures

Not all corals like sunlight. Some of them look for caves or hollows in which to grow. Some species have become specialized in shady habitats while others have added them to an already ample habitat range, and others still have retreated to them for lack of choice, forced by over-exploitation of more exposed or accessible zones.

As far as we know today, there are no anthozoans that live exclusively in caves, although some have become more specialized in that type of habitat. Among these are many species of dendrophylliidas, given that the majority of species belonging to this genus does not coexist with any symbiotic algae and therefore they do not need light. One of the dark-water corals is the Southern cup coral (*Caryophyllia infornata*) which is frequently found in caves and under low lying overhangs. Other species often associated with walls and rocks, such as *Polycyathus muellerae*, *Parazoanthus axinellae* or *Leptosamnia pruvoti*, are also quite common in this type of habitat.

However, many corals can simultaneously exist in dark zones such as caves and fissures as well as in open zones. The *Halcampaoides purpurea* anemone lives in caves, as well as on sandy floors and on gravel. Many daisy anemones, such as *Sagartia elegans* or *S. troglodytes* are not exclusive tube-dwellers of such habitats, but it is common to find them in holes as well. One species which used to be found in wider ranging areas has been found limited to caves, fissures and low lying overhangs in many areas where it is commonly found. This is the red coral (*Coralium rubrum*), which has been intensively harvested in more exposed areas that are easily accessible to fishermen, divers and robots.
On muddy and sandy floors

Desert sea floors, or floors composed of fine sediment such as sand and mud, are usually more challenging places for anthozoans to settle on. However, a few species have colonized this terrain in which the colonization strategy must take into account the softness of the substrate. It often shifts, requiring adaptive anchoring systems or complete alternatives altogether.

Some species found on such floors are highly specialized for this habitat. This is the case of the sea feathers, *Funiculina quadrangularis*, *Virgularia mirabilis*, *Pennatula* spp., *Kophobelemon stelliferum*, etc. They are commonly found in marine deserts and sometimes may even form dense colonies. In some Atlantic European waters, *Virgularia mirabilis* densities of up to 10 individuals per square meter have been found, making these areas virtual sea feather forests.

Many species bury part of their skeleton in the soft substrate in order to anchor themselves, and might even retract their bodies entirely inside the sand or mud. This can be seen with some sea feathers and the anemone *Anemonactis mazeli*. *Cerianthus membranaceus* can submerge its tube one meter into the substrate with only the tentacles of its superior end showing through. Oceana was able to verify the presence of this species in mixed communities of crinoideas (*Leptometra phallangium*) and sea urchin (*Stylocidaris affinis*) in sandy floors below 80 meters.

Another species which is characteristic of these floors, but only at depths of 200-300 meters, is *Isidella elongata*, which is an ideal habitat for crustaceans.

The deep-water anemone (*Condylactis aurantiaca*) only appears on sandy bottoms, but it does not delve very far into them, preferring to stay close to sandy areas abutting rock zones. Other anemones which have similar preferences are *Cereus pedunculatus*, *Peachia cylindrica*, and *Andresia partenopea*.

There are also corals which simply sit on the surface of the substrate without anchoring at all, as with *Sphenotrochus andrewianus*, an infralittoral and circalittoral species.
The corals of the Mediterranean

In shallow waters and at great depths

Very restricted luminosity or even with absolute lack of luminosity is sought after by some species. Excluding those species which live in symbiosis with zooxanthellas, corals are sciaphilic animals: that is, they prefer shady areas and even those with absence of light. Even though the most well-known species are found in surface waters, most of the world’s corals grow below the photic zone or optimal light filtration zone. In fact, two-thirds of all known coral species live in dark and cold zones. Deep-sea corals can live at depths of up to 6,000 meters, although the majority live between 500 and 2,000 meters.

The Mediterranean is a good example of this “phobia” to light. The oligotrophia of Mediterranean waters shows that species populating shallow areas with greater turbidity do not start to grow until depths of over 30 or 40 meters, where light has been sufficiently filtered by the water column. Even in the Mediterranean, the distribution of species such as the red gorgonian (Paramuricea clavata) is strongly influenced by the water’s clarity. The Balearic Islands is an example of this: It is one of the zones poorest in nutrients, and therefore the least turbid. Red gorgonian are not seen above 30 meters, while in the Gulf of Lion and the Ligurian Sea it is not uncommon to observe them above 15 meters deep.

We know that some species can even spend part of their day out of the water in inter-tidal zones or in tide pools. This is the case of the beadlet anemone (Actinia equina). To avoid desiccation and the effects of high salinity, they retract their tentacles to reduce exposure to the air, while simultaneously storing water reserves.

For species composed of 80%-90% water, and as such with a low gast content, the challenge to resist pressure at great ocean depths is minor. This allows them to colonize sea abysses at depths greater than 3,000 meters.

However, there are species that seek light, in many cases so that their resident zooxanthellae can photosynthesize it. Cladocora caespitosa is mostly found in light-filled or slightly shaded areas, although some colonies have also been found in deep water. The effects of higher temperatures have also been noted. It increases their calcification, so that they usually seek water at temperatures between 11°C and 25°C, but if they are in temperatures above 28 degrees they lose their zooxanthella and turn white. But not all corals prefer warm waters. Temperature, as we shall see in greater detail, is also a limiting factor for certain species of corals. Deep-sea species such as Lophelia pertusa, prefer water below 13°C, which means Mediterranean depths of 250-300 meters or more.
Dirty water

Dirty water is not a problem for some species of corals. While pollution and turbidity can be fatal for many species of anemones, corals and gorgonians, some anthozoans have become specialists in adapting to damaged ecosystems, such as those found in marine ports or other places with unclean water. This is the case of some anemones such as Diodunene cincta and Aiptasia diaphana.

Scleractinian corals are often the most demanding regarding environmental conditions. However, there are some that have occupied niche habitats in polluted areas, such as Oculina patagonica, frequently seen in commercial ports.

Some corals cluster near locations of anthropogenic spills or runoffs, such as the dead man’s fingers (Alcyonium sp.). Species which are not too picky can find an important source of nutrition from the outflow of residual waters, which have a high density of suspended matter.

The ease with which they adapt to polluted water has made it possible for the orange striped anemone (Haliplanella lineate) to occupy many coastal areas of the Mediterranean. Their arrival in the waters of many European countries has been propagated by ports.

Living on the backs of others

The inherent plasticity of anthozoans has not limited their distribution to particular physical habitats, such as rocks, sands, mud or biological debris (shells, coral skeletons or bryozoans) or non-organic substrates. Many species have preferred to live on live organisms such as seagrass, algae or animals. In some instances, the relation between anthozoan and host is an opportunistic and limited to being table companions. However, some have managed a more specialized and symbiotic relationships.

On algae and seagrasses

Different anemones, usually smaller ones, have adapted to the substrate afforded them by marine plants and algae in order to settle. Species such as Bunodeopsis strumosa are often found on the leaves of marine seagrasses such as Posidonia oceanica or Cymodocea nodosa. Paranemelina cinerea and Paractinia striata have similar tastes. Actinia striata is more common on seagrasses of the Zostera genus.

Others often settle on algae, such as Gonac-tinia prolifera. Some can grow to a large size, like Anemonia sulcata, which manages to anchor on large kelp.
The corals of the Mediterranean

On living creatures

Some look for means of transportation to carry them to new sources of food and in exchange lend their irritating tentacles as a form of defense for their host. The most common anemones in this type of trade are the parasitic anemone (*Calliactis parasitica*), the cloak anemone (*Adamsia carcinopados*) and *Hormathia alba*, which are all common on snail shells inhabited by hermit crabs (genus *Pagurus* and *Dardanus*).²⁴

When it comes to giving a ride to species such as *A. carcinopados* and *H. alba*, there is usually one on the back of each hermit crab, although some species, such as *C. parasitica*, are limited by the surface area of the hermit crab’s shell and the capacity of the crab to drag this weight across the sea floor. Thus, it is not rare to see two, three, or even more anemones on the shells of these animals.

There are also many examples of anthozoans looking for an anchor point from which to optimize access to food sources suspended in...
the water, without having to go from one to place to another; the entire better if the perch is high up. This is the vantage point of the yellow colonial anemone (*Parazoanthus axineelae*) which often seeks the structures offered by branching sponges of the *Axinella* genus. Other anemones have chosen the familiarity of cnidarians, like *Amphiantus dohrni*, which prefers the knoll offered by the large hydrozoan, or some gorgonians such as *Eunicella verrucosa* or *Isidella elongata*. *Protanthea simplex* seeks its fortune on reefs of *Lophelia pertusa*.

**In company: corals and symbiotic/commensal animals**

The anthozoans have created wide variety of relationships between species. Some of the more well-known ones, mentioned above, are those maintained with hermit crabs, or the close sharing between various corals and zooxanthellae algae, a type of dinoflagellate which depends on the light intensity and water temperature. Zooxanthelllas can be found on the Mediterranean madreporaria (*Cladocora caespitosa*)⁷⁸, the snakelocks anemone (*Anemonia viridis*)⁷⁸, the *Paranemoria cinerea*⁸⁰, in star coral (*Madracis pharensis*)⁸¹, and the Mediterranean cup coral (*Balanophyllia europaea*)⁸². Some symbiotic algae have also been found on *Oculina patagonica*, including some endoliths of the *Ostreobium* genus in the coral’s skeleton⁸³. These microalgae fulfill other vital functions such as protecting the corals from bleaching and ultraviolet radiation⁸⁴.

There are different species of small crustaceans that often live in association with anemones, like *Telmatactis cricoides*. In studies carried out on specimens from the Atlantic Madeira and Canary Islands—which are often larger than Mediterranean specimens—it was found that 86% lived symbiotically with an average of 2-3 shrimps, usually of the *Thor amboinensis*⁸⁵ species.

*Phyllangia mouchezii* catching a mauve stinger jellyfish (*Pelagia noctiluca*) © OCEANA/ Juan Cuetos
In the Mediterranean, the shrimp that most often live in symbiosis with anemones are those of the *Periclimenes* genus, such as *P. sagittifer* or *P. amethysteus*. They often live this way on large specimens of *Anemonia sulcata*, *Aiptasia mutabilis*, *Cribrinopsis crassa* and *Condylactis aurantiaca*. It is not strange either to see some mysidaceas, such as *Leptomysis lingvura* nestled between the tentacles of these anemones.

Other crustaceans often live in association with corals, such as the cirripedes balanomorphas. *Megatrema anglicum* is often found on club coral (*Caryophyllia smithii*), yellow coral (*Leptopsammia pruvoti*), *Hoplangia durotrix* or corals of the *Dendrophyllia* and *Balanophyllia* genus.

*Anemonia sulcata* is the queen of specific inter-species relationships. In addition to the species mentioned above, this one can shelter other crustaceans between its tentacles, such as the hairy crab (*Pilumnus hirtellus*), the lesser spider crab (*Maja crispata*), or the spider crab (*Inachus phalangium*). In the latter case, it prefers the more stationary females. It is also the species associated with the only anemone fish of the Mediterranean: the anemone clown fish (*Gobius bucchichii*). This Mediterranean native makes it different from all other clown fish in the world that belong to the Pomacentridae family, not present in the Mediterranean.

However, in some cases roles get reversed and it is the anthozoan which is parasitic on other species or even on other anthozoans, as indicated previously with *Parazoanthus axinellae* on sponges (*Axinella* sp.), *Epizoanthus arenaceus*, *Calliactis parasitica*, *Adamsia palliata* and *Hormathia alba* on hermit crabs, and *Parerythropodium coralloides* and *Gerardia savaglia* on gorgonians.
Coral reproduction

Gerardia savaglia on red gorgonian (Paramuricea clavata) © OCEANA/ Carlos Suárez
The various ways in which anthozoans reproduce has long been used as a method for classifying them, but recent studies91 show that these systems which some species use to reproduce depend to a large extent on the characteristics of the colonies and the environmental conditions to which they are subjected.

As such, the same species may use different methods of reproduction, although there may be a single way that is more characteristic for some species, or at least one observed as such in laboratories or the natural environment. This is a topic which has generated much debate and controversy as well as numerous scientific studies.

Using the current knowledge we have on this matter, we can make the following observations:

**Sexual and asexual reproduction**

Sexual reproduction, that is, reproduction which requires the participation of males and females for the production of eggs (oocytes) and sperm, has always been considered the most normal way for anthozoans. In addition to oviparous fertility, viviparous has also been noted, whereby the female coral becomes “pregnant” through internal fertilization of the ovocyte resulting in polyps which are then expelled or delivered into the environment.

Asexual or vegetative reproduction, on the other hand, is carried out by an isolated polyp and new individuals are created without the participation of the other gender. In this way, colonies (or species) arise with only one sex present. Furthermore, asexual reproduction can take various forms. There are descriptions of budding, transversal and longitudinal fission, basal laceration, fragmentation, encystment, and some more typical methods of sexual reproduction, whether oviparous or viviparous, through parthenogenesis.

Some species which appear to primarily use sexual reproduction can also select the vegetative mode under conditions of stress or as an opportunistic preference, or due to the isolation of the colonies or polyps.

**Synchronized reproduction**

One of the most spectacular methods of sexual reproduction among corals is synchronized reproduction. This is characterized by the synchronization of various colonies of corals (sometimes, from different species), expulsing their sperm and eggs at the same time. This strategy is very common among scleractinians in coral reefs92, and has also been seen among zoanthias93 and even octocorallias94.

With mass production of male and female gametes over a short period of time, the chances that conception will be successful increases and along with the possibility that at least a certain percentage will escape predators.

*Red gorgonian (Paramuricea clavata) and yellow cluster anemone (Parazoanthus axineftae) © OCEANA/ Carlos Suárez*
Moreover, as researchers have observed, some species have demonstrated strategies that increase the chances that their gametes will fuse, by means of a chemical substance which attracts semen.\footnote{95}

In the Mediterranean this type of reproduction exists among certain gorgonians, like *Para- muricea clavata*\footnote{96}, and among madreporarian coral colonies such as *Oculina patagonica*.

In the case of the red gorgonian (*P. clavata*), the synchronization sessions are not unique or concentrated (that is, not all colonies participate in reproduction at the same time), but rather they repeat themselves over several months in spring and summer, three to six days after the full or new moon\footnote{97}.

It is believed that these time periods may give rise to hybrids.\footnote{98} In tropical reefs, some cases have been observed among the *Acropora*\footnote{99} and *Montanstraea*\footnote{100} genus. In the Mediterranean, no such occurrence has yet to be documented.

Oviparous, viviparous

Depending on the way in which corals reproduce, they can create complete new polyps or intermediary phases. Both oviparous and viviparous reproduction, be it sexual or asexual, has been widely documented in various anthozoans.

In sexual reproduction, the generation of a new lineage may occur by means of eggs and their subsequent fertilization, or else, by fertilization of a female ovocyte in the interior of the female polyp of a coral.

In the case of oviparous reproduction, the eggs are fertilized outside the coral. In some species, they are expelled outward, while in others they remain stuck to the colony by means of mucus produced by the polyps. They then mature there until the larvae emerge and settle in their surroundings\footnote{101}.

In most cases, oviparous and viviparous reproduction are the result of sexual reproduction, but they have also been found to occur...
The corals of the Mediterranean

asexually through parthenogenesis\(^\text{102}\). This sometimes occurs with the red anemone or Beadlet anemone (*Actinia equina*), which is found in the Mediterranean and the Atlantic\(^\text{103}\).

**Budding, fission and laceration**

As we have mentioned above, asexual reproduction can give rise to different means of generation of new polyps. One method which has been widely studied is budding. This consists in the production of a bud or yolk by the female polyp, which grows until another polyp sprouts which either takes its place in the coral that produced it or is expelled at such a distance that it finds a new location to settle. Although this type of reproduction is more common among cnidarians, such as hydrozoans or scyphozoans, it has also been reported for various anthozoans.\(^\text{104}\)

Fission occurs when a polyp gives rise to a new polyp. This may occur by transversal or longitudinal fission, depending on whether the polyp buds laterally or on top of the other one. Transversal fission is more common in other cnidarians, although it may occur in anthozoans as well, but this is thought to be exceptional and nearly always provoked under conditions of stress.\(^\text{105}\) Lateral fission is more common among corals and in fact has been found in both octocorallians\(^\text{106}\) and hexacorallians\(^\text{107}\), such as the orange striped anemone (*Haliplanella lineate*)\(^\text{108}\) which has invaded the Mediterranean.

There is another of asexual reproduction which has been found to exist, at least for some anemones\(^\text{109}\) and black corals.\(^\text{110}\) This is fragmentation- the generation of new polyps from a piece of coral, usually a tentacle.

**Egg, larva/planula and polyp phases**

Although asexual reproduction may give rise to new polyps, the normal process for many anthozoans is to pass through different phases until reaching the adult state.

When those which reproduce with eggs hatch, a ciliated larva appears. This is a planula, and for a short period of time (normally a few days) it lives like plankton until it once again anchors to the substrate and gives rise to a new polyp or initiates a colony. What makes it different from all other cnidarians is that it never exists in the medusa phase.

Planulas may be found in the water after newly expelled eggs that were fertilized by sperm are hatched. They may also come directly from a polyp which was fertilized internally and which instead of liberating an egg, waits until it turns into a planula. In other words, the incubation of the eggs may differ from one species to another. While for red coral it is internal,\(^\text{111}\) for red gorgonian it is external.\(^\text{112}\)
White gorgonian can produce an average of four eggs per polyp, which means that a colony usually disperses an average of around 6000 planulas into the water. Red coral has a very low reproduction rate of one planula per polyp, on average.\textsuperscript{114}

In some species the larva have negative floatability to avoid being swept away by currents and to allow them to settle in the vicinity of the polyp or mother colony, as for example the Mediterranean cup coral (\textit{Balanophylla europaea}).\textsuperscript{115}

This negative floatability has also been found in the eggs of zoantharia (\textit{Epizoanthus} sp.), found in the South Pacific at depths between 80 and 200 meters.

### Separate sexes and hermaphrodites

The separation of sexes, that is, the existence of both males and females (gonochorism), is common among corals, not only among individual polyps but also between whole colonies.

In many species in the Mediterranean, the sexes are usually separate. Thus, while a colony is usually composed of exclusively male polyps, another will be exclusively female. This characteristic has been documented in many octocorallian gorgonaceas, such as \textit{Eunicella verrucosa}\textsuperscript{116}, \textit{Eunicella singularis}\textsuperscript{117}, \textit{Paramuricea clavata}\textsuperscript{118}, and \textit{Corallium rubrum}\textsuperscript{119}, and also in hexacorallians and deep-water species (\textit{Enallopsammia rostrata}, \textit{Madrepora oculata} or \textit{Lophelia pertusa})\textsuperscript{120}.

Hermaphroditism is another reproductive strategy of some anthozoans. It is mainly seen in tropical corals of the Pocilloporidae\textsuperscript{121} family, although it is not an exclusive trait.
cup coral *Balanophyllia europaea*\(^{124}\) (this is a rare trait among dendrophyllidas and unique to this genus).

And of course, in the great diversity of corals morphology, there are species which may have both gonochoric and hermaphrodite characteristics. Hermaphroditism is less common among octocorallians. However, some hermaphrodite colonies have been found among coral colonies of *Carioa riisei* studied in the Pacific\(^{125}\) and among the Indo-Pacific gorgonias *Heteroxenia* sp.\(^{126}\), as well as some Mediterranean colonies of *Pareritropodium coralloides*\(^{127}\), among others.
06.

The fight for survival
Of great importance for the development of corals is the energy expended on reproduction, as it can provoke a decrease in growth rates\textsuperscript{128}. In addition, the fight for space with other anthozoans can consume much energy. As such, bigger colonies can better distribute tasks and compete for survival and expansion\textsuperscript{129}.

**Trouble with the neighbours: space**

In the zone where different species of anthozoans, or even colonies of the same species, are found, there is usually a battleground where polyps that are on the “front line” modify their morphology to better fight the competitor. For example, they may develop specialized tentacles\textsuperscript{130}. In fact, corals and anemones have different types of tentacles\textsuperscript{131}: feeder tentacles; tentacles for capturing plankton and suspended particles; feeler tentacles to find out whether there are enemies lurking nearby. The latter may be up to 10 times longer than the feeder tentacles. Hunting tentacles are those which are deployed for combat.

These tentacles are present in Mediterranean species, such as the plumose anemone (*Metridium senile*)\textsuperscript{132} or in the invading orange striped anemone (*Haliplanella lineate*)\textsuperscript{133}.

In the fight for survival, mortality rate and regeneration can play an important role. The capacity of anthozoans to recover after sustaining wounds varies widely. While some species need centuries to rebuild a reef or colony that has been damaged, others regenerate much more quickly. However, the general trend reflects the long-living and slow-growing nature of the species, and damage, be it natural or anthropogenic, is usually a significant challenge.
Competition for space is also found among other marine organisms. When this happens, different species of hydrozoans, bryozoans, etc. colonize the coral structures and thereby provoke their death by covering it. For species such as *Paramuricea clavata*, death caused by process represents half of the natural mortality rate of the species\textsuperscript{134}. For *Eunicella cavolini*, it is the main cause of mortality, along with uprooting\textsuperscript{135}.

**Growth**

Corals must deal with various conditions in order to grow and survive in a marine environment,

One of the determining factors on coral growth is the availability of food. This may be favorable in zones with strong currents or where different water masses mix together. Low levels of sedimentation and turbidity also play an important role.

Most colonies barely grow a few millimeters a year. Such a slow growth rate is especially common in those species which need to grow a calcareous skeleton or create large, branching masses. The longevity of anemones can be quite significant as well.

Unfortunately, little is known about the life of anthozoans, and their growth rate and longevity remains a mystery for a great number of species. However, present data seems to corroborate the estimates regarding longevity. For example, the yellow coral (*Leptosamnia pruvoti*), a colonial scleractinian with a calcium carbonate skeleton, and gorgonian anemone (*Amphianthus dohrni*), a solitary hexacorallia without a skeleton, have estimated life spans of between 20 and 100 years\textsuperscript{136}.

### Examples of growth and longevity studied in some anthozoans\textsuperscript{137}

<table>
<thead>
<tr>
<th>Species</th>
<th>Basal growth (mm/year)</th>
<th>Vertical growth (mm/year)</th>
<th>Longevity (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cladocora caespitosa</em></td>
<td>0.7 - 1.6</td>
<td>3.28 - 6.06</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.9 - 5.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.79 - 6.07</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>1.36 - 4.42</td>
<td></td>
</tr>
<tr>
<td><em>Corallium rubrum</em></td>
<td>0.24 - 0.64</td>
<td></td>
<td>98</td>
</tr>
<tr>
<td><em>Desmophyllum cristagali</em></td>
<td>0.5 - 2</td>
<td>0.5 - 1</td>
<td>70 - 160</td>
</tr>
<tr>
<td></td>
<td>0.1 - 3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Enallopsamnia rostrata</em></td>
<td>0.07</td>
<td>5</td>
<td>210</td>
</tr>
<tr>
<td><em>Primnoa raesediformis</em></td>
<td></td>
<td>1.6 - 2.32</td>
<td>+ 200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 - 2.5</td>
<td></td>
</tr>
<tr>
<td><em>Lophelia pertusa</em></td>
<td></td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td><em>Balanophyllia europaea</em></td>
<td>0.23 - 2.49</td>
<td>1.1 - 2.4</td>
<td>20</td>
</tr>
<tr>
<td><em>Eunicella verrucosa</em></td>
<td></td>
<td>6 - 10</td>
<td>50 - 100</td>
</tr>
<tr>
<td><em>Paramuricea clavata</em></td>
<td></td>
<td>18</td>
<td>+ 30</td>
</tr>
<tr>
<td><em>Leptosamnia pruvoti</em></td>
<td></td>
<td></td>
<td>100 ?</td>
</tr>
<tr>
<td><em>Amphianthus dohrni</em></td>
<td></td>
<td></td>
<td>20 - 100</td>
</tr>
</tbody>
</table>
The false black coral (*Gerardia savaglia*) might possibly be the longest living colonies in the Mediterranean. It is the only zoantharia that can produce a skeleton. In the Pacific, colonies of other species of the genus *Gerardia* might reach 2,700 years of age. In the Mediterranean, it is believed that some *G. savaglia* formations might be more than one thousand years old.

There are specific techniques used to measure the growth of corals. In older colonies, dating can be done with carbon (Ca$^{14}$) or other representative isotopes, such as lead (Pb$^{210}$), radium (Ra$^{226}$), thorium (Th$^{230}$) or uranium (U$^{234}$). For younger animals, the rate of the increase in the thickness and vertical expansion of a polyp or colony can be monitored. Some of the most efficient methods for some species are similar to those used for trees: the rings that form in the skeleton of anthozoans are counted. This has been carried out successfully with sea feathers, gorgonians and scleractinian corals.

Size matters

There is a correlation between size and the age of anthozoans, as well as the nature and extent of damages they may suffer. Larger specimens are more vulnerable to incurring serious damage, although they also show better resiliency in regenerating, while younger specimens have a limited or absent response, although damage may be lesser. This is why the size of colonies is an important factor in the survival of species.

Damage suffered by the colony also brings to light one of the main causes of mortality among anthozoans: excessive growth of epibionts.

Size is not only important for corals or a colony, but it is also a significant factor for a population as a whole. With species such as *P. clavata*, which depend on synchronized reproduction involving numerous colonies, the larger the population, the larger the chances that new colonies will be generated and that the species will survive. The mass mortality suffered by this species in recent years might endanger the survival of this characteristic Mediterranean species.
A seat at the table: coral nutrition

Most anthozoans are suspension feeders. They extend their tentacles and wait for small organisms and particles floating in the water to touch them. Their cnidos then shoot out to catch the nutrients which are brought into their oral disc and subsequently introduced into their gastrovascular sac. The other common form of coral feeding is the use of a mucus layer which particles in suspension adhere to, and are then brought to the digestive tract with the help of cilia.146

For some corals, a large part of their nutrition comes via their symbiotic relationship with small algae living in their gastrodermis. In most cases, these algae are dinoflagellates (zooxanthellae), although green algae have sometimes been found (zoochlorellas).146

Another method is to absorb the cells of organic matter dissolved in the water directly through the ectoderm147.

In the case of soft corals, such as dead man’s fingers, plankton is caught through absorbing water and filtering it like sponges.

Most corals are carnivorous. They feed on zooplankton, although they can also combine this nutrient with small algae or even bacteria. Polyps can also catch prey of even greater size, such as jelly fish. Anemones may even try to catch crustaceans and fish.

Crustaceans are often an important part of the diet of many anthozoans, although what is actually ingested can vary greatly according to the species. Tuft coral (Lophelia pertusa) has been observed catching cumaceans and copepods148, while Mediterranean snakelocks...
The corals of the Mediterranean anemones (*Anemonia sulcata*) and *Cereus pedunculatus* feed on amphipods and decapods. In the case of *Actinia equina*, their preferred food tends to be detritus, while the red gorgonian (*Paramuricea clavata*) ingests eggs and larvae.

**Guess who’s coming to dinner:**

natural predators of corals

The cycle of nature some eat and others are eaten. Corals also form part of the diet of certain animals. While the presence of stinging cells and toxic substances in their bodies has reduced the number of predators preying on them, some species have become immune to their venom and have specialized in consuming them.

In the Mediterranean, there are not any fish which consume corals, unlike in coral reef where it is quite common. Here, the main consumers of corals are mollusks, although there are also some arthropods and worms that choose to feed on polyps.

The most common coral-eating mollusks are snails, especially ovulidas and coralliophilas.

As with Caribbean ovulidae such as the flamingo tongue cowrie (*Cyphoma gibbosum*), they feed on gorgonians. Mediterranean mollusks have become specialists of this type of octocorallian. One of the more common species is *Neosimnia spelta* which devours polyps and live tissue of gorgonians such as *Eunicella verrucosa*, *Eunicella singularis* and *Leptogorgia sarmentosa*. Other species of ovulidae in the Mediterranean are *Pseudosimnia carnea*, *Simnia nicaeensis*, *Simnia purpurea*, *Aperiovula adriatica*, *Aperiovula bellocqae*, *Globovula cavanaghii* and *Pedicularia sicula*.
Regarding the coralliophila snails, most are Indo-Pacific species, but there are at least a dozen in the Mediterranean as well\textsuperscript{152}, including *Coralliophila meyendorffi* and *Babelomurex cariniferus*\textsuperscript{153}, which often feed on the *Cladócora caespitosa* polyp. Other Mediterranean species are *Babelomurex babelis*, *Coralliophila brevis*, *Coralliophila sofiae*, and *Coralliophila squamosa*.

Other mollusks which have also been observed feeding on corals are the epitoniidae snails, such as *Epitonium dendrophyllidae*, which consumes orange corals (*Astroides calycularis*)\textsuperscript{154}, and some nudibranches, such as *Okenia elegans*, which can feed on *Paramuricea clavata*\textsuperscript{155}.

Pycnogonids (*Pycnogonum littorale*), or sea spiders, feed on diverse actinias\textsuperscript{160}, including the plumose anemone (*Metridium senile*)\textsuperscript{161}. Red coral may suffer attacks from mollusks and crustaceans, such as *Pseudosmnia carnea* and *Baissia gasti*, respectively\textsuperscript{162}.

Finally, in more recent times, human beings have also added anthozoans to their diet. In some areas of the Mediterranean, some species of anemone are sold under the generic name “sea urchin” or “urchin” for certain gastronomic dishes.

**Corals with light**

One of the adaptive advantages of some marine species is the possibility of successfully surviving in certain habitats by carrying their own lantern. The luminescence they create may be used to attract prey, avoid predators, communicate, and search for a mate, as well as other functions that are still being researched.

Although for many animals bioluminescence is due to the presence of bacteria such as *Vibrio fischeri* or the existence of specialized cells, corals owe this feat to the presence of luciferin and the enzyme luciferase, which catalyzes its own oxidation and produces light.\textsuperscript{163} Although, like in other cnidarians, it is possible that some species do not need luciferase for their bioluminescence and instead produce a photoprotein (coelenterazine), which reacts in the presence of Ca\textsuperscript{2+} to produce the chemical reaction.\textsuperscript{164}

The pennatulaceas are the octocorallians that have been shown to demonstrate bioluminescence most often. In the Mediterranean, this has been found in *Cavernularia pusilla*, *Veretillum cynomorium*, *Funiculina quadrangularis*, *Virgularia mirabilis*, *Pennatula rubra*, *Pennatula phosphorea* and *Pteroides spinosum*.\textsuperscript{165}
Outside of sea feathers, bioluminescence is quite rare among octocorallians. It has only been observed in a single genus of Pacific alcyonidae (*Eleutherobia* sp.\(^{166}\)) and in a few species of gorgonians of the Isididae family,\(^{167}\) such as *Lepidisis olapa*, *Keratoisis* sp., *Primnoisis* sp., or *Isidella elongata*. The latter may also be found in the Mediterranean.

The only species of anemone which has been found to have bioluminescent properties is the *Hormathia alba*\(^{168}\), a common species in the Mediterranean and in some areas of the Atlantic. This species which can also live on the shells of hermit crabs.

In other species, bioluminescence is exchanged for phosphorescence\(^{169}\), as with Mediterranean snakelocks anemone (*Anemonia sulcata*).

**Corals that move**

Most anthozoans are anchored to the substrate on which they live and stay in the same spot for their entire lifespan. Only during the larval stage do the ciliated planula of some coral and gorgonian species move freely in the sea.

However, some species of anemones or sea feathers can change their location in search of a better one. Or, with the help of a symbiont, they may travel great distances, as with the anemone that lives on the shells of the hermit crab.

Some of them can slowly move away from areas that have become hazardous to their survival, as with *Actinia equina*, *Anemonia Sulcata*, *Anthopleura ballii* and *Sagartia* sp., which can move a few centimeters with the help of their basal disk to avoid exposure following low tide, to flee an enemy or to avoid a light source\(^{170}\).

Others, such as the *Paranemonia cinerea*\(^{171}\), can migrate by moving vertically to new locations according to the season or to hibernate on the sea floor among plant detritus, awaiting a rise in the temperature for them to climb onto the leaves of marine seagrasses.

Others, such as *Telmatactis forskali*\(^{172}\), can swim short distances using their tentacles as fins. This behavior has also been observed in *Bunodeopsis strumosa*, especially when they fall from a seagrass blade. This behaviour has also been observed in anemones of the genus *Boloceroides* and *Gonactinia*\(^{173}\).

Still others are crawlers that use their tentacles to creep along the sea floor, covering several meters in search of a new place to perch themselves. Some studies\(^{174}\) have shown that tube anemones of the genus *Cerianthus* y *Pachycerianthus* can move across the sediment. This behavior has also been observed in sea feathers after they have been torn from their original anchorage point, dragging themselves across the sea bed until they borrow in once again, or swelling up and letting the current carry their bodies to a new location\(^{174}\).
07.

Threats to corals
Coral diseases

At least 18 diseases have been identified around the Mediterranean that can have a massive effect on corals.¹⁷⁶

<table>
<thead>
<tr>
<th>Diseases detected in corals</th>
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<tr>
<td>ASP = Aspergillosis</td>
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<tr>
<td>DSD = Dark Spots Disease</td>
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<td>PLS = Pink Line Syndrome</td>
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<tr>
<td>SEB = Skeletal Eroding Band</td>
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<tr>
<td>VCB = <em>Vibrio corallilyticus</em> Bleaching</td>
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<tr>
<td>WBD I = White Band type 1</td>
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<tr>
<td>WPD = White Pox Disease</td>
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<tr>
<td>WPL II = White Plague type 2</td>
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<tr>
<td>YBD = Yellow Band</td>
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<tr>
<td>BBD = Black Band Disease</td>
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<tr>
<td>FPS = Fungi-protozoic Syndrome</td>
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<tr>
<td>SDR = Shut Down Reaction</td>
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<tr>
<td>SKA = Skeletal Anomalies</td>
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<tr>
<td>VSB = Vibrio shiloi Bleaching</td>
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<td>WBD II = White Band type 2</td>
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<td>WPL I = White Plague type 1</td>
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<td>WPL III = White Plague type 3</td>
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In many cases, mortality is caused by an increase in water temperature or abnormally long periods of high temperatures. In some cases, the pathogen responsible for mortality has not been identified, but in at least 10 of the infections, marine and land fungi, cyanobacteria, bacteria, protozoa, nematodes, algae and crustaceans have been the cause of some of the documented symptoms.

In aspergillosis (ASP), the infectious agent is the land fungus *Aspergillus sidowyi*,¹⁷⁷ which mainly affects gorgonians of the genus *Gorgonia*. In black band disease (BBD), a multitude of microorganisms such as cyanobacteria¹⁷⁸ *Phormidium corallyticum* and *Trichodesmium* spp., cyanobacterium sp., bacteria¹⁷⁹ (*Desulfovibrio* spp., *Beggioa* spp.) and marine fungi¹⁸⁰ have been detected. In the Fungo-protozoic Syndrome (FPS), it is fungi (*Trichoderma* spp., *Cladosporium* spp., *Penicillium* spp. and *Humiola* spp.) and protozoa¹⁸¹. Pink Link Line Syndrome (PLS) has been linked to cyanobacteria¹⁸² (*Phor-midium valderianum*). Skeletal Eroding Band (SEB) is attributed to a protozoan¹⁸³ (*Halofolliculina corallasia*). For Skeletal Anomaly Syndrome (SKA), land fungi¹⁸⁴ such as (*Aspergil-lus sydowii*) and endolíticos¹⁸⁵ have been shown to play a part, in addition to algae¹⁸⁶ (*Entocladia endozoica* and the Syphonals), nematodes¹⁸⁷ (*Podocotyloides stenometra*) and crustaceans¹⁸⁸ (*Petrarca madrepore*). Coral bleaching by bacteria (VCA and VSB) is caused by the bacteria *Vibrio corallilyticus* and *V. shiloi*¹⁸⁹ respectively. A bacterium¹⁹⁰ (*Vibrio charcharia*) has been identified in cases of White Band Disease. White Pox Disease (WPD) also appears to be provoked by bacterium¹⁹¹ (*Serratia marcescens*). And in White Plague (WPL), another bacterium, *Aurantimonas coralicida*¹⁹², seems to be the origin of the disease.
More than 50 species have been affected by high mortality rates or degradation processes which have been traced to the diseases mentioned above. Although the majority of these cases occur in tropical reefs, two of them have been detected in the Mediterranean (VSB and FPS).

In the summer of 1999, a massive die-off of anthozoans and other animals (mollusks, bryozoans, tunicates, and sponges) took place during high waters temperatures down to more than 40 meters deep in the sea of Liguria and the French coasts of Provence. The corals that were affected were red gorgonian (*Paramuricea clavata*), white gorgonian (*Eunicella singularis*), yellow gorgonian (*Eunicella cavolini*), pink gorgonian (*Eunicella verrucosa*), red corals (*Corallium rubrum*), *Leptogorgia sarmentosa*, Mediterranean madreporaria (*Cladocora caespitosa*) and yellow colonial anemone (*Parazoanthus axinellae*). In some areas, between 60% and 100% of the existing colonies were killed, resulting in the deaths of millions of gorgonians and other anthozoans.

For reasons still unknown, the female polyps of the *P. clavata* population had an especially high mortality rate.

Studies have shown that gorgonians suffered a high degree of stress due to the high temperatures and were susceptible to a wide range of microorganisms, including fungi and protozoans. As a result, this disease was named as the Fungio-protozoo Syndrome (SFP).

These occurrences have not been isolated cases. In colonies of *Parazoanthus axinellae*, the mortality rate was repeated over various years, considerably reducing the presence of this species in Portofino and other zones of the Ligurian Sea. Recently, these mortalities have been blamed on high temperatures and the proliferation of a number of pathogenic agents such as cyanobacteria of the *Porphyrosiphon* genus.

In 2003, new mortalities were registered in anthozoan populations of the Mediterranean, which this time extended beyond the French and Italian coast to Spanish waters. During
that year, a high mortality rate among red gorgonians (Paramuricea clavata) was detected and traced to the overgrowth of mucilage\textsuperscript{197} and madreporaria (Cladocora caespitosa) with necrosis\textsuperscript{198} in the Columbretes Islands Marine Reserve, which affected more than 60% of the colonies of both species. Similar mortality rates were detected in other coralline algae colonies from Cabo de Creus to Cabo de Palos\textsuperscript{199}. All cases pointed to abnormally high water temperatures.

The high mortality rates of red gorgonians in the straits of Messina were also attributed to high water temperatures and the concurring increase in mucilaginous algae (Tribrunenum marinum and Acinetospora crinita)\textsuperscript{200}. The same causes were traced to episodes of bleaching observed in Mediterranean madreporaria corals, (Cladocora caespitosa), Mediterranean cup coral (Balanophyllia europaea) or Argentinean coral (Oculina patagonica) in different zones of the western and eastern Mediterranean over the last few decades\textsuperscript{201}.

Bleaching is usually attributed to the bacteria Vibrio shiloi, which can cause extensive damage in large swathes of Oculina patagonica colonies; however, the bacteria appears to be sensitive to ultraviolet radiation, which has therefore spared the more shallow coral colonies\textsuperscript{202}.

Recently, the bearded fireworm (Hermodice carunculata) has been proven to be a disease vector for corals. This polychaete can act as a winter reservoir for pathogens\textsuperscript{203}, preventing the bacteria from dying in cold water months and allowing them to spread outside once ambient temperatures rise again.

**Climate change**

As we have already seen, climate change has been behind the mass die-offs of anthozoans that have occurred in recent years in the Mediterranean Sea. But aside from diseases and bleaching, higher water temperatures have other pernicious effects on anthozoans.

Due to the release of carbon dioxide emissions into the atmosphere, it is predicted that the oceans will increase their absorption of CO\textsubscript{2}, thereby provoking changes in the chemical composition of the water. A larger quantity of CO\textsubscript{2} leads to a lower pH of water, increasing the acidity of the oceans and reducing the availability of carbonate ions. The consequence of this is a reduced calcification rate\textsuperscript{204}, which will affect many marine organisms that need calcite or aragonite to form their skeletons, like corals.

If we take into account that calculations forecasting conditions over this millennium say that the oceans will absorb 90% of anthropogenic CO\textsubscript{2}\textsuperscript{205}, we can understand the changes this will have on the marine ecosystem. Studies indicate decreases in calcification around 40% over the next 50 years, and can even decrease as much as 80% before the end of the century.

In the Mediterranean, climate change is bringing with it other threats to coral life: changes in the abundance of species that are sensitive to changes in water temperature and the introduction and spread of non-native species which may compete with the Mediterranean ones\textsuperscript{206}.

**Other anthropogenic effects on corals**

**Ripping out colonies**

In areas that are popular with divers, the natural mortality rate of gorgonians is increased three-fold by damages and uprooting that occur there\textsuperscript{207}. Significant amounts of death are caused by divers ripping out gorgonians and other large anthozoans through bad diving practices and by damage inflicted through the anchoring of boats in areas where these
colonies are present. Some protected areas in the Mediterranean, such as Medas Islands in Spain or Port Cros in France have suffered damage caused by excessive diving and anchoring in vulnerable zones.

Dredging, beach regeneration, and the construction of coastal infrastructure may move large amounts of sediments or create a change in the location of deposition, thereby affecting corals. It is known that the mechanisms which corals use to avoid burial by an excess of sediment have a high energetic cost associated with them. Furthermore, in some seas such as the Caribbean, the high rate of sedimentation has been traced to diseases that affect gorgonians.

**Fishing and corals**

One of the greatest threats to corals are the various fishing techniques and fishing gears which damage colonies or rip them from the substrate they are anchored too. Bottom trawling and other such methods requiring dragging nets across the sea floor have the gravest impact on these animals.

Oceana has also been able to verify the impact of other fishing gear in contact with the seabed (fixed nets, longlines, and traps). While setting or removing the gear, or while they are dragged by marine currents, they can snag on corals, rip them from their substrate or lacerate them. Nevertheless, dredging and trawling are the techniques which cause the most damage and mortality to populations of coral, gorgonians, sea feathers and anemones. Each day more studies verify the damage these types of gear cause to corals and other benthic sea life.

It is well known that trawling is the principal cause of the deterioration of these ecosystems in many parts of the world. Scientists have recognized that “in general, wherever trawlers drag over coral reefs there is a chance that serious damage will be caused”. The Secretary General of ICES, David Griffith, considers that “dragging a heavy net over a deep-sea reef is similar to driving a bulldozer through a natural reserve. The only way to
The corals of the Mediterranean

protect those reefs is to find out where they are located and to prevent the trawlers from dragging their nets over them”.

Various studies have revealed the damage inflicted on coral reefs by different fishing techniques in zones of Atlantic of depths between 200 and 1,200 meters. Trawlers can destroy up to 33 km² of habitat on the continental shelf in less than 15 days. The United States National Marine Fisheries Service (NMFS) has estimated that in Alaska alone a single trawler can rip out 700 kilos of deep-sea coral in a single cast.

In the Mediterranean, it has been shown that fishing for crustaceans over bottoms with fine sediments that shelter the *Isidella elongata* gorgonian and sea feathers (*Funiculina quadrangularis*) provokes a significant loss of biodiversity. Furthermore, the surfaces harboring these two species in the western Mediterranean have almost disappeared completely due to this type of fishing.

Different conclusions derived from observing gorgonians damaged by fishing gear show how extremely vulnerable their colonies are, as well as the long recovery time they need, sometimes exceeding a century.

But corals do not only suffer damage from direct impacts. Some colonies can be buried or suffer severely reduced feeding capacity due to water turbidity from resuspended sediments after bottom trawling events. The sediment stirred up by trawlers can be redeposited hundreds of meters deeper than its original location, leading to sessile organisms very far away being buried.

When a colony is damaged by fishing gear or anchors, it can lead to the opportunistic settlement of epibionts (hydrozoans and bryozoans) which can then finish them off- by either a coverage that prevents the polyps from feeding, or by creating a greater surface area that is resistant to wave action and currents. They can also be colonized by nematodes and polychaetes which can weaken the colony.

Some fisheries management measures in the Mediterranean could avoid causing damage to some populations of anthozoa.

One regulatory proposal for fishing in the Mediterranean presented by the European Commission seeks to prohibit trawling in waters less than 50 meters deep and to thus protect some of the most vital ecosystems of this sea, such as coralline alga
eas. These measures have been accepted by countries such as Spain and are now part of their national legislation (although there is a lack of a consistent characterization of Mediterranean seabeds, which prevents more efficient protection of these areas). Unfortunately the proposal has not yet been applied in all territorial EU waters because it has been repeatedly blocked by some Mediterranean countries, provoking a legal loophole which only benefits destructive fishing techniques and accentuates the destruction of benthic habitat.

On the other hand, recent decisions rendered by the General Fisheries Council for the Mediterranean (GFCM) prohibit trawling below a depth of 1000 meters and in some marine seamounts and coral reefs could help conserve some reefs and gorgonian gardens in this sea.

Unfortunately, illegal fishing in prohibited areas is a common practice in the Mediterranean, which means that no species of coral is safe from menace.
08. Coral uses
Commercial exploitation of corals

Some species of coral have been sought and collected since antiquity because of their attractive appearance. They have been used as elements of jewelry and costume accessories, and more recently, souvenirs.

The jewelery industry has focused on the exploitation of so-called “precious corals”. Among these are the various species of the Corallium genus. The most sought-after are those that may be found throughout the Mediterranean and adjacent Atlantic waters, such as the red Mediterranean coral (Corallium rubrum). Also highly prized are those of the Pacific, like the red Pacific coral (Corallium regale), pink corals (Corallium secundum y C. laauense) and others (C. japonicum, C. nobile, C. elatius). Black corals, blue coral (Heliopora coerulea), and recently, bamboo corals (Keratosis, Isidella, and Lepidites genera) are also used. ‘Golden’ corals (Gerardia, Narella, Calyptrophora or Callogorgia genera) are also used, although they are less valuable as jewels due to their porosity, small size, fragility and other qualities which make them unsuitable, and they generally wind up on the souvenir market. The large colonies of false black coral (Gerardia savaglia) extracted from the Sea of Marmara are also used to make costume jewelry.

In the Mediterranean, red coral has been the most prized species and has given rise to an industry specialized in extracting it, which has had a large impact on the species and on the seabed itself.

The intensive exploitation of this octocoralians has caused a nearly 70% reduction in the last decades. Extraction has gone from around 100 tons caught per year at the end of the 1970s, to catches of barely 30 tons per year barely 20 years later.

Today is it a rare species despite the fact that it once had a density of more than 1,000 colonies per square meter. That density is only extant today in marine protected areas or in places where access is difficult. Furthermore, many of the colonies existing today are small. In Spanish areas where red coral exploitation is still permitted, 91% of the colonies measure less than five centimeters tall. In Italy, 66% of the colonies that were studied are not reproductive.

The extraction of these corals has traditionally involved very destructive methods, such as the ‘San Andrés Cross’ or the ‘Italian Bar’. The latter instrument consists of a metal bar weighing over a ton with chains and crests made of nets attached to it. This was dragged over the seabed and broke apart the coral. Only a small portion of the uprooted coral was actually captured in the nets and recuperated, while the rest lay lost and dead on the seabed. Sometimes there were up to 2,000 boats dedicated to capturing red coral.

In 1994, the EU prohibited the use of the ‘San Andrés Cross’ and similar systems for capturing red coral, but this method has yet to be included among those prohibited by the Bern Convention.
Corals and medicine

Over the last decades, biomedical research has looked to the sea as a source of new medicine. Sponges and actinia have been among the animals in which new composites for pharmaceutical use have most frequently been found, along with the cnidarians. Gorgonians, corals and anemones are supplying raw materials and useful information to fight diseases. The Mediterranean is seen as an excellent place to seek these species.

Antivirals have been found in the yellow gorgonian (*Eunicella cavolini*). The synthetic composite 9-β-D-arabinosiladenina (ara-A) has been found to be analogous to espongotimidina, a metabolite which is naturally produced by this species along with its close ‘cousin’ spongouridine, analogous to 1-β-D-arabinofuranosiluracil, (ara-U).

Gorgonias are also important as sources of diterpenes: the eunicellin present in the white gorgonian (*Eunicella singularis*) or palmonine found in the pink gorgonian (*Eunicella verrucosa*) are other examples. Other anthozoa have also contributed their share, with today, extraction of red coral is mainly performed by divers who collect it at depths of up to 120 meters, although in some areas they use remotely operated robots with mechanical arms.

Torre del Greco (Italy) is the main market for precious Mediterranean coral. The lack of red Mediterranean coral has obliged the industry to seek imports mainly from other areas, especially in the Pacific. Today the town operates a coral industry which is valued at more than 30,000 million dollars per year.

Given the small sizes of most colonies that still exist today in the Mediterranean, in the last few years a new system to exploit and sell the smaller colonies has come into existence. It consists of melting down the specimens which bear little market value due to their small size, and generating a soft paste used to make various articles of costume jewelry.

Although there organized market, other species of anthozoa may also join the ranks of the souvenir items, like *Cladocora caespitosa* or *Dendrophyllidae* spp. and other scleractinians.

![Tree coral](Dendrophyllia ramea) © OCEANA/ Juan Cuetos

![Eunicella cavolini](© OCEANA/ Juan Cuetos)
cembranolides being found in false red gorgonians (Parerythropodium coralloides)240 and sarcodictine in Stolonifer coral (Sarcodyction catenatum).241

One must not forget the sesterterpene clado-coranes found in Mediterranean madreporaria (Cladocora cespitosa)242, which has pharmaceutical value in the treatment of various diseases, including cancer, as it has potential antitubercular and antibacterial properties that inhibit the growth of Gram-positive bacteria.

Equally important is the false black coral (Gerardia savaglia), which has been found to contain lectin which could potentially be used in the treatment of the Human Immunodeficiency Virus (HIV)243.

New applications for phosphorescent proteins found in some anthozoa are also being sought for their use in detecting and visualizing cancerous cells244.

Anthozoans have great pharmaceutical potential and one of the most singular characteristics of these animals, is their stinging cells and the toxins they contain. As is well known, venoms are very useful compounds in medicine. There are very varied compounds found in corals, including peptides, proteins, phospholipids, phospholipase, glycoproteins, sterols, bioactive amines and carbohydrates245. For example, the paralyzing toxins born by certain anemones, such as those in the Anthopleura and Anemoneia genus, could be useful as local anesthetics246. The equinatoxin found in the beadlet anemone (Actinia equina) may be useful for controlling cholesterol levels247.
Protected corals
Invertebrates are the forgotten ‘souls’ of national, international and EC legislation. It is even worse if they happen to live in the oceans. This is why corals are hardly present in conservation proposals and laws despite their great importance to oceanic ecosystems.

Of the nearly one and a half thousand species listed in the annexes of the EU Habitats Directive, less than 200 are invertebrates. Of these, eight are from the sea, and only one is an anthozoan. Furthermore, of the nearly 200 habitats listed therein, only nine are marine habitats and only one is directly related to corals: the reefs.

In the Bern Convention, the annexes list around 2000 species, of which 130 are invertebrates, some 40 are of marine origin, and five are anthozoans. Moreover, the list prohibiting capture techniques and gear does not include a single vertebrate except in the section regarding the use of explosives and venom for harvesting decapods (crustaceans).

In the Washington Convention (CITES) for controlling the international commerce of endangered species of plants and animals, the three appendices list nearly 35,000 taxons, but only 2,100 of these are invertebrates. In Annex II, however, there are a number of anthozoans, including all of the species belonging to the orders Scleractinia and Antipatharia, as well as the helioporidae and tubiporidae families, which brings the total to more than 1,200 species.

In Europe, there are also some conventions which refer exclusively or particularly to the sea. These are the Barcelona Convention for the protection of the Mediterranean Region and the OSPAR Convention for the protection of the marine environment of the North-East Atlantic.

The Barcelona Convention comprises several different protocols. The Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean is the one focused on marine animals and plants. Together they list some 120 species among the different annexes: 48 are invertebrates, but only five of them are anthozoans.

OSPAR Convention does not include a single anthozoan and only two of the 14 priority habitats have some type of relation to corals: *Lophelia pertusa* reefs and the sea feather clusters and other species which are able to burrow.

Furthermore, the World Conservation Union (IUCN), which has evaluated over 40,000 species, only includes three anthozoans among the nearly 4,000 invertebrates that were analyzed: The Ivell anemone (*Edward sia ivelli*), the starlet anemone (*Nematostella vectensis*) and the pink gorgonian (*Eunicella verrucosa*). These last two are classified as vulnerable.
Corals that are included in international agreements and European regulations

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Less than 20% of the corals living in the Mediterranean have been included under the annexes of the conventions for the protection of animal life. Of these, most of them (85%) are only protected under Annex II of CITES, which does not extend full protection but rather regulates their commercial trade. Furthermore, this control does not cover the fossils of these species, despite their importance for the marine ecosystem, vital both for reef formation as well as for serving as an optimal substrate for the settlement of new colonies.

This means that, excluding CITES, there are six species of anthozoans which are protected under EC legislation or international conventions for the protection of wildlife which have been signed and ratified by the EU. However, only two are included in the lists with maximum protection (Annex II of the Bern Convention and Annex II of the Barcelona Convention). The other species have been included on the list of species for which management plans should be established. Moreover, these species of coral are not protected in their full range of habitat, but only in the Mediterranean.
10. Oceana and corals

Elisella paraplexauroides © OCEANA/ Juan Cuetos
Given the importance of corals, gorgonians and anemones to the marine ecosystem and the uncertain future of many species given the various dangers and degree of vulnerability, Oceana proposes the development of a Management Plan for Mediterranean Anthozoans which includes the following measures:

**Prohibiting the use of destructive fishing gear over coral seabeds**

A first necessary measure for conserving corals is prohibiting the use of trawling, dredging and other similar techniques in places with vulnerable ecosystems, such as those formed by the corals mentioned hereafter for inclusion in the Habitats Directive. This prohibition must also be part of a definitive and approved list used to regulate fishing in the Mediterranean.

Equally important is the execution of resolutions that have already been approved by the GFCM, among which are the protection of the Eratosthenes seamount, the protection of the *Lophelia Pertusa* reef at Santa Maria di Leuca, the cold infiltration of hydrocarbons from the Nile Delta, and the protection from bottom trawling at depths greater than 1,000 meters. All of these should be present in EC legislation.

**Regulating the capture of corals**

To avoid non-selective and high-impact techniques for capturing coral, the definitive prohibition of trawling gear and other apparatus for capturing coral, including robots with mechanical arms, must be passed into law. These methods must be included both within Annex IV of the Bern Convention, as well as Annex VI of the Habitats Directive.

There must also be quotas, closed areas and minimum sizes for red coral or any other commercialized anthozoan. The manufacture of paste derived from small coral specimens must be prohibited.

**Updating and improving European legislation and international conventions for the protection of flora and fauna**

Habitats that are generated or inhabited by anthozoans must urgently be included in Annex I of the Habitats Directive. It should include the different types of coral reefs, gorgonian gardens, coralline algae and anthozoan clusters (sea feathers or gorgonians) in soft sediment bottoms, among other habitats.

Furthermore, many species of corals should become part of the annexes of the Habitats Directive and the Bern Conventions, BARCON and CITES.

For example, Annex I of the Habitats Directive should be included the following species: *Cladocora caespitosa* reefs, deep-sea coral reefs, gorgonian gardens, clusters of *Isidella elongata* and pennatulaceas in fine sediment beds, gorgonian facies and other anthozoan in coralline algae, carbonate mounds, submarine elevations (including seamountains, hills and mounds), cliffs and walls, and fossil and sub-fossil reefs.

Annex II of the Habitats Directive should be listed all the anthozoan species that are vulnerable or threatened, starting with the species mentioned hereafter.

Annex IV of the Habitats Directive, Annex II of BARCON and Annex II of the Bern Convention should add the following species to their lists at the very least: *Astroides calycularis*, *Gerardia savaglia*, *Isidella elongata* and *Funiculina quadrangularis*. 

In the case of red coral, there must be specific limits to oversee the reduction of quotas by 50%, together with recovery plan and a five year monitoring plan to evaluate the evolution of the species so that a moratorium on all captures can immediately be established should their number keep diminishing.
In Annex III of BARCON and in Annex III of the Bern Convention, the following species must be included: Paramuricea clavata, Eunicella singularis, Cladocora caespitosa, Dendrophyllia sp. In addition, all species of antipatharians should be included as well.

In Annex V of the Habitats Directive, all species of scleractinians and antipatharians should be included as a preventive measure to avoid overexploitation and abusive commercialization.

As mentioned above, Annex VI of the Habitats Directive and Annex IV of the Bern Convention should include a description of prohibited anthozoan capture techniques, such as the ‘Italian Bar’, the ‘San Andrés Cross’, and any other trawling gear or mechanic device created for that purpose.

Finally, CITES should include Gerardia savaglia in Appendix I for maximum protection, and Corallium rubrum in Appendix II.

**Evaluation and recovery plans for threatened species**

Given the great unknown that currently exists regarding most Mediterranean anthozoans and their conservation status, a 10-year evaluation plan must be provided for within the Barcelona Convention in order to assess the state of coral populations, gorgonias, and anemones in the Mediterranean.

Once this assessment period is finished, the species of anthozoans which are found to be in danger or vulnerable must then be extended to international conventions and European legislation aimed at preventing the degradation of these populations. Furthermore, a management and recovery plan for the species to be protected should be prepared for inclusion in the annexes of these agreements and laws.

As a matter of urgency, the first studies must focus on those species which are in gravest danger (such as the scleractinians), those which are commercially exploited (such as red coral, false black coral, anemones, etc.), those which face the greatest mortality rates (Paramuricea clavata, Eunicella singularis, Cladocora caespitosa, etc.), those which form and maintain habitats and those of which little is yet known (such as the species of the inferior circumlittoral and the deep-sea species, such as Viminella flagellum, Elisella paraplexauroides, Paramuricea macrospina, Spinimuricea klavereni, and Callogorgia verticillata).

In addition, it is very possible that in the next few years new corals will appear or be discovered in this sea that will be in need of management plans. In fact, Oceana has recently found a new species in the Mediterranean whose known distribution in the Atlantic Ocean was limited to areas like the Bay of Biscay and the Canary Islands. This new species is the whip gorgonian, Spinimuricea atlantica.

**Reducing the impact of human activities on corals**

The Mediterranean countries, especially the European ones, should be more scrupulous in executing their international agreements for reducing CO₂ emissions into the atmosphere in order to avoid the harmful effects that climate change and subsequent acidification of the sea has on coral life. Moreover, they must lead international efforts to achieve more drastic reductions of contaminating gases, since the Mediterranean will be one of the zones most affected by climatic change.

Also, all necessary measures to avoid spilling pollutants into the sea must be enacted, and the International Convention for the Control and Management of Ships Ballast and Sediments, under the International Maritime Or-
The coral organization (IMO) charter for preventing spills and the introduction of non-native species, must be ratified, applied, and improved.

The development of activities which can adversely affect corals, gorgonians, and anemones must not be permitted. These include coastal construction, dredging, quarrying, etc., carried out without first performing due and proper environmental impact studies and sustainability plans.

Marine protected areas

All Mediterranean countries must keep anthozoans in mind as one of the most important values when it comes to creating marine reserves and protected areas.

Control and regulations systems must also be developed for recreational diving and the anchoring of watercraft in areas with vulnerable seabeds, including the development of educational materials.
11. Bibliography

Trumpet anemone (Aiptasia mutabilis) © OCEANA/ Thierry Lancy
01. Introduction


02. Physical characteristics of corals


03. Coral species of the Mediterranean


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04. Corals habitats and corals as habitats


11. Bibliography


05. Coral reproduction


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The corals of the Mediterranean


07. Threats to corals


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08. Coral uses


**09. Protected corals**


**10. Oceana and corals**


![Caryophyllia inornata making room for itself within the Spirastrella cunctatrix sponge](OCEANA/JuanCuetos)
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