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Interpretation Manual of Marine Habitat Types in the Mediterranean Sea

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Note by the Secretariat

In December 2019, the Contracting Parties to the Barcelona Convention adopted the Updated Reference List of Marine Habitat Types for the Selection of Sites to be included in National Inventories of Natural Sites of Conservation Interest in the Mediterranean (Decision IG 24/7). This list includes a total of 117 habitats (up to level 5) and in particular 30 in the Littoral, 26 in the Infralittoral, 24 in the Circalittoral, 13 in the Offshore Circalittoral, 14 in the Upper Bathyal, 8 in the Lower Bathyal and 2 in the Abyssal. A few reference facies and associations have also been proposed in each of the selected key habitats for inclusion in the updated classification. The non-exhaustive list of associations and facies at level 5 is indicative and needs to be continuously updated and improved according to the geographical area and local situations, as well as the increasing state of knowledge.

The Regional Activity Centre for Specially Protected Areas (SPA/RAC) launched the elaboration of the interpretation manual for marine habitats as foreseen in PoW 2020-2021 (Activity 3.2.1.2.c). The objective is to provide countries with a tool to help identify and assess these marine habitats. It is designed as a support and field tool to identify habitats and reduce differences in the interpretation between users of the typology.

The draft interpretation manual is presented to the Fifteenth Meeting of SPA/BD Focal Points for information. It will be sent to the Contracting Parties for national consultation.

INTERPRETATION MANUAL OF THE REFERENCE LIST OF MARINE HABITAT TYPES IN THE MEDITERRANEAN OF THE BARCELONA CONVENTION

Summary

Littoral

Infralittoral

Circalittoral

Offshore circalittoral

Upper bathyal

Lower bathyal

Abyssal

Acronyms used in the manual

SPA/RAC = Specially Protected Areas/Regional Activity Centre

BC = Barcelona Convention

COP = Contracting Parties of the Barcelona Convention

EU = European Union

IMAP = Integrated Monitoring and Assessment Programme of the Mediterranean Sea

EcAp = Ecosystem Approach

SPA/BD Protocol = Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean

MPA = Marine Protected Area

MSFD = Marine Strategy Framework Directive

WFD = Water Framework Directive

EUNIS = EUropean Nature Information System

WoRMS = World Register of Marine Species

Introduction

Background

The elaboration of the interpretation manual of the Barcelona Convention Reference List of Marine Habitat Types in the Mediterranean Sea was based on the following premises:

1. The Contracting Parties (CPs) to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols at their 21st meeting recalled the outcome document of the United Nations Conference on Sustainable Development, entitled "The future we want", endorsed by the General Assembly in its resolution 66/288 of 27 July 2012, in particular those paragraphs relevant to biodiversity;
2. The General Assembly resolution 70/1 of 25 September 2015, entitled "Transforming our world: the 2030 Agenda for Sustainable Development", acknowledged the importance of conservation, the sustainable use and management of biodiversity in achieving the Sustainable Development Goals;
3. The Ministerial Declaration of the United Nations Environment Assembly at its fourth session expressed the international community commitment to implement sustainable ecosystems restoration, conservation, and landscape management measures to combat biodiversity loss, as well as to develop an ambitious and realistic post-2020 global biodiversity framework;
4. The Protocol concerning Specially Protected Areas and Biological Diversity (SPA/BD) in the Mediterranean, in particular Articles 11 and 12 thereof, addressed national and cooperative measures for the protection and conservation of species;
5. The Strategic Action Programme for the Conservation of Biological Diversity in the Mediterranean region (SAP BIO), adopted by the Contracting Parties at their 13th Meeting (COP 13) (Catania, Italy, 11-14 November 2003);
6. The decision IG.22/7, adopted by the CPs at their 19th Meeting (COP 19) (Athens, Greece, 9-12 February 2016), on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP);
7. The decision IG.23/8, adopted by the CPs at their 20th Meeting (COP 20) (Tirana, Albania, 17-20 December 2017), to update the classification of benthic marine habitat types for the Mediterranean region and the Reference List of Marine and Coastal Habitat Types in the Mediterranean, in consultation with Focal Points, with a view of submitting them to the CPs at their 21st Meeting (Naples, Italy, 2-5 December 2019);
8. The commitment to further streamlining the Mediterranean Action Plan Ecological Objectives and associated Good Environmental Status and Targets, as well as the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria into the Regional Action Plans for the conservation of endangered and threatened species and key habitats adopted within the framework of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean;
9. With the decision IG.24/7, the CPs adopted the Updated Classification of benthic marine habitat types for the Mediterranean region and the Updated Reference List of Marine Habitat Types for the Selection of Sites to be included in National Inventories of Natural Sites of Conservation Interest in the Mediterranean (SPA/RAC-UN Environment/MAP, 2019a, b);
10. The CPs are encouraged to use the Reference List of Marine Habitat Types for the Selection of Sites to be included in National Inventories of Natural Sites of Conservation Interest in the Mediterranean, where necessary, as a basis for identifying reference habitats to be monitored at the national level under the IMAP of the Mediterranean Sea and Coast and Related Assessment Criteria.

In this context, the Specially Protected Areas Regional Activity Centre (SPA/RAC) initiated the production of this manual for interpreting the marine habitat types that are listed in the Updated Reference List (SPA/RAC-UN Environment/MAP, 2019b, available at http://www.rac-spa.org/publications#en13). The aim was to provide CPs with a tool to help the identification and the assessment of these reference marine habitats.

Benthic habitat mapping

Benthic habitat mapping consists in the spatial representation of the distribution and extent of physically distinct areas of the seafloor that are associated with groups of species or communities that consistently occur together (Montefalcone et al., 2021 and references therein). A detailed inventory of benthic habitats can illustrate the distribution and abundance of species and the extent of distinct environments. Maps on the distribution of benthic habitats facilitate habitat-based management, such as marine spatial planning and nature conservation (Bianchi et al., 2012; Parravicini et al., 2012). Maps also form the background for environmental impact assessments and monitoring activities and support the requirements of marine legislations, e.g., the Europe Habitat Directive (92/43/EEC), and the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC). Benthic cartography is also the key element to address the new targets of the post-2020 global framework of the Convention on Biological Diversity (CBD) (CBD, 2020) and the EU Biodiversity Strategy for 2030 "Bringing nature back into our lives" (EU, 2020), which state that at least 30% of the EU seas should be protected and 10% should be strictly protected by 2030. Habitat mapping and classifications are crucially important to quantify the spatial extent of key habitats and to identify their status and trends, for developing effective restoration initiatives to mitigate the loss of degraded and carbon-rich ecosystems, according to the global targets of both the CBD (CBD, 2020) and the EU Biodiversity Strategy for 2030 (EU, 2020) that foresee the restoration of at least 15% of degraded ecosystems. Benthic habitat mapping can also be used to predict the distribution of species and communities through habitat suitability modelling (Vassallo et al., 2018; Azzola et al., 2021).

To guarantee a common frame and a shared technical terminology among users involved in benthic habitat mapping, monitoring, and inventory, univocal and standardised habitat classification systems are fundamental. Unified schemes for mapping habitat types also require a certain degree of flexibility that enables the user to mix and match or add and subtract attribute types to produce a map that specifically addresses the objectives. To this end, several habitat classifications have been developed worldwide in the last few decades, which lacked, however, of a common structure and a standardised approach. A review of the existing marine benthic habitat classification schemes can be found in Montefalcone et al. (2021). The EUropean Nature Information System (EUNIS) (Davies and Moss, 1998) and the Barcelona Convention (BC) marine benthic habitat classification for the Mediterranean, adopted by the CPs of the Barcelona Convention (UNEP/MED, 1998, 2006a), are among the most adopted classification systems for the European and Mediterranean seas. The BC classification has been recently revised (SPA/RAC-UN Environment/MAP, 2019a) including the new habitats discovered in the last 30 years, and consistently with the criteria used to revise the EUropean Nature Information System (EUNIS; Evans et al., 2016), which is a comprehensive pan-European system for habitat identification.

The bionomic approach and the depth zonation in the Mediterranean Sea

The definition of an adequate operational unit for cartographic purposes is the first step required for the elaboration of a classification scheme. The distribution of marine organisms is not homogeneous but changes according to several ecological factors, among which light, water movement and substrate typology are generally considered as the most important in the bathymetric zonation of benthic organisms (Pérès and Picard, 1964; Riedl, 1971). The operational unit to describe and classify distinct groups of benthic species, which are functionally integrated according to the environmental features shaping their distribution, was originally defined as 'biocoenosis' in the second half of the 19th century (Morri et al., 2004, and references therein).

The first descriptions of the Mediterranean marine benthic habitats date back to the second half of the 19th century (Marion, 1883; Vatova, 1946). Major steps forward were done after the II World War, thanks to the impressive and productive effort made by the school of Endoume in France, which culminated in the well-known masterpiece "*Nouveau Manuel de bionomie benthique de la mer Méditerranée*" (Pérès and Picard, 1964). For Pérès and Picard (1964), the basic operational unit in the classification used to describe the bathymetric zonation of biological organisms was the biocoenosis (*biocénose* in the original French description). In each biocoenosis, one or more facies (for animal) and/or association (for vegetal), defined as "particular modifications of the appearance or composition of a community", can also be recognised as sub-units. To define these operational units, Pérès and Picard (1964) adopted the bionomic approach, i.e., the description of the environment through biological criteria. They mainly used the faithfulness criterion, which distinguishes a group of species of fixed composition by one or more characteristic species, these latter being defined as located almost exclusively in that bionomic unit (Bianchi and Morri, 2001).

In the following years, the term 'habitat' became the operational classification unit in marine cartography, representing the key component of each seascape. The original meaning of habitat (from Latin, third person singular of the present indicative of the verb 'habitare' = to inhabit) indicates the physical environment where a species lives. According to the EU Habitat Directive (92/43/EEC), a habitat is defined as the "terrestrial or aquatic area differentiated by its geographical, abiotic and biotic characteristics, in which the species live in any state of its life cycle". Today there is an increasing tendency to use the term habitat to actually indicate the biotope (i.e., the physical environment of the biocenosis, not of a single species). Since there is a biunivocal correspondence between the biotope and its biocenosis, and since the biocenosis is an efficient descriptor of the environment (more than the list of physical, geological and chemical characteristics), often the habitat is individuated and named using in reality the biocoenosis. Thus, in many contexts the word habitat is employed as a synonymous of biocoenosis. Indeed, habitats are considered key drivers of diversity, functioning and ecosystem services, and therefore are the subject of regional inventories using hierarchal classification systems and spatial mappings. According to the habitat definition, distinct boundaries between adjacent (and hence discrete) habitat types must be imposed to spatially represent biological patterns.

Since benthic communities' distribution is dependent on zones and substrate typologies, the description of a habitat and the following classification schemes follow a sequential order based on such aspects. According to the bionomic approach of the French school (Pérès and Picard, 1964), two main marine systems have been distinguished as a function of the vertical light gradient: the phytal system, where the light is present and allows algae to survive, and the aphytal system, dominated by heterotrophs mainly living in complete darkness and exceptionally, in its upper range, hosting sparse algae thriving in very dim light conditions. Limits among biological zones are determined by abiotic features, such as: i) exposure to water movement (tides and waves) for the shallow supralittoral and midlittoral zones; ii) amount of light reaching the seafloor for the infralittoral and (offshore) circalittoral zones; iii) pressure, bottom slope, availability of hardgrounds, seafloor currents, and sedimentation for the deep offshore circalittoral, bathyal, and abyssal zones.

The revised biological zones of the marine environment here considered are: littoral (distinguished in supralittoral and midlittoral zones), infralittoral, circalittoral, offshore circalittoral, upper bathyal, lower bathyal, and abyssal. The bathymetric zonation scheme adopted here is represented in Figure 1, where the indicative depth range for each zone are reported.

The habitats developing in the littoral, infralittoral, and circalittoral zones are considered as coastal habitats, developing in correspondence of the shallower portion of the continental shelf. The circalittoral zone is still close to the coast and reaches, an average, 80-100 m of depth (with some exceptions where the continental shelf is exceptionally narrow, as in the Ligurian Sea). This zone is usually shaped by the occurrence of coralligenous reefs, developing in the form of cliffs (where the bioconcretion made up by coralline algae is over the circalittoral rock), outcrops (isolated and small rock formations near the coast with coralline bioconcretion), and platforms (large structures of biogenic origin made up by the bioconcretion of coralline algae on sedimentary bottoms), or by the occurrence of banks (large rock formations with few macroalgae and without a significant bioconstruction).

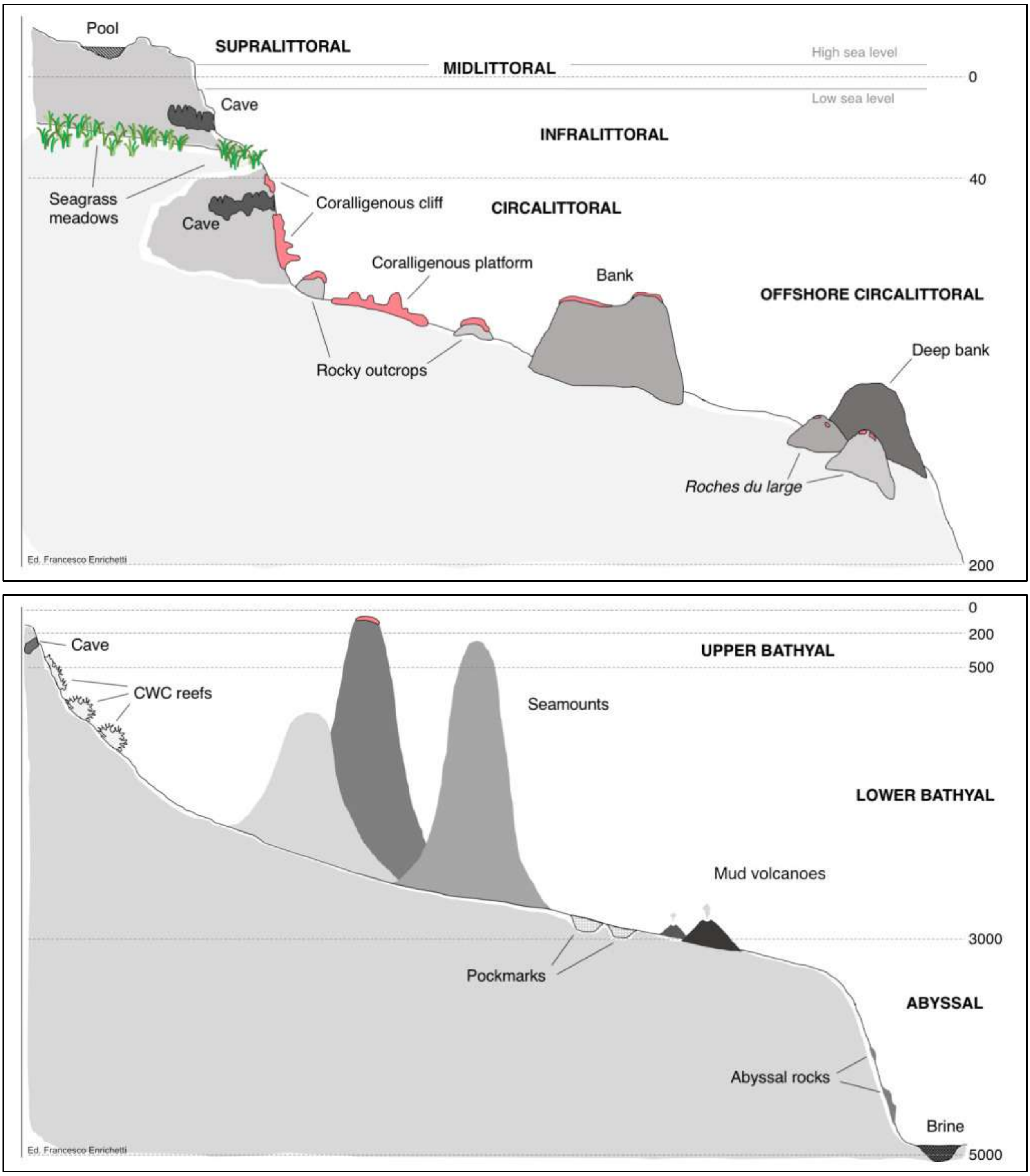

Figure 1. The bathymetric zonation scheme for the Mediterranean Sea. Depth ranges are in meters. In red is represented the bioconcretion made up by coralline algae.

The habitats developing farther from the coast (i.e., offshore circalittoral, upper bathyal, lower bathyal, and abyssal) are considered open sea habitats. The offshore circalittoral develops in proximity of the shelf edge (this latter usually situated at about 120-200 m depth). Here, the offshore circalittoral rock invertebrate-dominated develops the deep banks, which correspond to the "*roches du large*" of Pérès and Picard (1964) (large rocky formations near the shelf edge or even close to the beginning of the bathyal zone, usually deprived of macroalgal cover, limited by the dim light conditions and the high silting rates, with no coralligenous bioconstruction). Deep banks represent one of the main habitats in the offshore circalittoral. A similar habitat is represented also on the top of some seamounts, rocky elevations of more than 100 m emerging from bathyal depths. Some of these structures, emerging in the euphotic zone, may occasionally show coralligenous-like habitats. Along the continental slope, the traditional Mediterranean classification system generally considers only an extended bathyal zone. However, following literature and the most recent discoveries in the deep-sea realm, a further subdivision was made: i) the upper bathyal zone, ranging from 200 m to 500 m depth and embracing most canyon systems and the most extensive deep biogenic habitats; ii) the lower bathyal zone, located between 500 m and 2500-3000 m depth, and including some deep canyons, seamounts, chemosynthetic habitats, and the deep bathyal plains; iii) the abyssal zone (>3000 m), whose existence, widely debated, is here accepted and referred to the deepest and least explored regions of the Mediterranean Sea, hosting the Deep Hypersaline Anoxic Basins (DHABs).

The updated List of Mediterranean habitat types

The first classification of benthic marine habitat types for the Mediterranean region adopted by the CPs to the Barcelona Convention in 1998 (UNEP/MED, 1998, 2006a, available at https://www.rac-spa.org/sites/default/files/doc_fsd/lchm_en.pdf) derived from the classic "*Nouveau Manuel*" (Pérès and Picard, 1964) and has always been considered as the "official list" for the Mediterranean Sea, despite the awareness that it was not a complete list. This classification defined the habitat types using the biocoenosis as the operational unit, with associations and facies in the lower hierarchical level (i.e., the sub-habitats). The first BC classification listed 15 habitats in the supralittoral zone, 29 in the midlittoral, 80 in the infralittoral, 45 in the circalittoral, 12 in the bathyal, and 2 in the abyssal zone, for a total of 183 habitats (including biocoenoses, associations and facies).

An updated version of the first BC classification (UNEP/MED, 2006a) for the Mediterranean marine benthic habitat types was needed to include the increased knowledge gained in recent years and to align the Mediterranean list with the recently revised classification of European habitat types by EUNIS (Evans et al., 2016, available at https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification). In the process of revision and updating of the BC classification, all the other existing regional classifications have been considered with the aim to follow, as much as possible, a common approach and to define a standardised scheme. A synthesis of the process of revision and update can be found in Montefalcone et al. (2021).

To be consistent with most of the existing classifications, the updated BC classification adopts the term 'habitat' as the main operational unit; the habitat, besides being a bionomic unit, can also be interpreted as a statistical-descriptive unit, useful for inventorying and cartographic purposes. According to Pérès and Picard (1964), the main habitat types in the updated BC classification have been defined using the bionomic approach and have been named following a mesological denomination. Habitat types have then been described following the physiognomic criterion (Bianchi and Morri, 2001), which differentiates habitats based on the appearance of assemblages that characterize each habitat. The main habitat types may in turn be characterised by the quantitative redundancy of one or a few species because of the local predominance of certain factors or intense recruitment episodes without, however, essential changes in the total composition. In this regard, several sub-habitats have been defined adopting the term association (dominance of plant species) or facies (dominance of animal species). Only few habitats have been named using a taxonomic denomination at the species level (e.g., reefs of *Cladocora caespitosa*, *Posidonia oceanica* meadow), and associations/facies have usually been named using higher taxonomic levels (e.g., association with Fucales, facies with Bivalvia): this has the advantage of not being influenced by revisions in the taxonomy or nomenclature of species (which occur rather frequently).

Environments highly affected by human pressures (polluted environments, harbours, artificial habitats) have not been considered in the updated BC classification. The presence of some peculiar geomorphologic/hydrologic features (i.e., seamounts, submarine canyons, escarpments, boulder fields, hydrothermal vents, cold seeps, brine pools, and freshwater resurgences) is independent from the depth zone and the substrate typology; consequently, these habitats and are not defined according to the bionomic approach but rather considering the geomorphologic characteristics of the environment. These features can hold a "complex of habitats" and geoforms that cannot be treated in isolation. These peculiar geomorphologic/hydrologic features have thus not been included in the updated BC classification as main habitat types, but their occurrence should be anyway provided with the description of the habitat because of the important role they play in the Mediterranean Sea (UNEP/MAP-RAC-SPA, 2015b). Integrating geomorphology and bionomy is at the base of the ecotipological approach for the classification of benthic marine ecosystems (Bianchi and Zurlini, 1984).

The updated BC classification of the benthic habitat types of the Mediterranean Sea (SPA/RAC-UN Environment/MAP, 2019a; available at http://www.rac-spa.org/publications#en13) follows the same hierarchical frame of the updated EUNIS system (Evans et al., 2016, available at http://eunis.eea.europa.eu) and each habitat is univocally identified by an alpha-numeric code. Both systems contain 3 levels: i) level 1, the environment (i.e., marine benthic, marine pelagic, transitional water, freshwater, and terrestrial); ii) level 2, the depth zone in the marine environment (i.e., littoral, infralittoral, circalittoral, offshore circalittoral, upper bathyal, lower bathyal, and abyssal); and iii) level 3, the region (i.e., Atlantic, Baltic, Black Sea, Arctic, and Mediterranean). In each of the seven depth zones recognized at the level 2, six broad habitat types are defined according to the substrate typology (i.e., rock, biogenic habitat, coarse sediment, mixed sediment, sand sediment, and mud sediment) that are alpha-numerically coded. An important novelty in the two updated classifications is the presence of the "biogenic" substrate typology, i.e. habitats where the seabed substrate is constructed by plants or animals (e.g., coralligenous, *Posidonia* meadows, cold-water coral reefs), which is intended to highlight habitats of greater conservation importance. Each combination of depth zone and substrate type supports a characteristic suite of plant and/or animal assemblages.

The updated BC classification of benthic habitat types of the Mediterranean Sea (SPA/RAC-UN Environment/MAP, 2019a; see Annex 1) contains 35 general habitat types divided among the seven depth zones and the six substrate types (corresponding to the level 1, 2, and 3). Each of the general habitat types may also contain sub-levels. The level 4, identified by numeric codes, includes the main habitat types defined with the mesological approach, by either environmental features such as exposure to water movement, irradiance, sedimentology/morphology, or by the main biological assemblages dominating the habitat (algae or invertebrates). Habitats representing enclaves (i.e., the local existence, for microclimatic reasons, of a biocoenosis within an area occupied by another typical biocoenosis, *sensu* Pérès, 1967) in shallower zones have also been indicated at the level 4. Peculiar environmental and/or morphological situations occurring within the level 4 have further been labelled with alphabetic codes using lower letters (a, b, c, etc.). Water movement is due to waves and currents. Regarding this factor, a coast can be more or less exposed, giving rise to different habitat types, e.g., the so-called "smooth or calm mode" according to the nomenclature adopted by the French school (Pérès and Picard, 1964). In the updated BC classification, the opposite situations in the water movement have been named as "sheltered" and "exposed" at the level 4. Light intensity is another fundamental factor that influences the vertical zonation of biological assemblages, and the updated BC classification differentiates "well illuminated" from "moderately illuminated (i.e., shaded)" habitats always at the level 4. According to the degree of sedimentation, habitats affected by high levels of sedimentation can be further distinguished at this level. A total of 128 main habitat types have been proposed up to the level 4 in the updated BC classification of the Mediterranean marine habitat types (SPA/RAC-UN Environment/MAP, 2019a; see Annex 1).

Finally, the level 5 defines associations and facies and is always labelled with numeric codes. The sub-habitats at the level 5 have usually been defined at higher taxonomic levels rather than at the species level. Some exceptions, however, have been introduced where the habitat is typically shaped by single species (e.g., 'Facies with *Pollicipes pollicipes*'). For each facies and association some examples of characteristic species have been provided in the updated classification, choosing among those species most frequently found within the sub-habitat that define its physiognomic aspect and functioning; the selected species provided as examples should also be easily identifiable from visual inspections. The listed examples of species are not exhaustive as they may represent strictly local and punctual situations and have, thus, only an indicative value: the list of species at the level 5 can be improved and adapted according to each geographical area and to specific local environmental conditions. For instance, facies or associations characterised by non-indigenous species should be defined and then inventoried only in the invaded areas.

With respect to the first BC classification (UNEP/MED, 2006a), which listed a total of 183 habitats (including biocoenoses, associations, and facies), the updated BC classification of the benthic Mediterranean marine habitat types (SPA/RAC-UN Environment/MAP, 2019a; see Annex 1) contains 128 main habitat types up to the level 4 and reaches a total of 394 habitat types enlarging the detail at the level 5 (i.e., association and facies). A total of 211 new habitat types (+115.3%) have been defined in the updated BC classification thanks to recent scientific findings and increased knowledge, especially in the mesophotic and aphotic context. Two new depth zones have been included in the updated BC classification: i) the former circalittoral zone has been divided into a circalittoral zone *senso stricto* and the offshore circalittoral, and ii) the former bathyal zone has been divided into upper bathyal and lower bathyal zones. The hierarchical scheme of this updated classification, with 5 levels, allows representing the most suitable habitat level with respect to the restitution scale of the map and all the habitat types are at the relevant scale for both management of human activities and implementation of conservation policies.

The updated Reference List of Mediterranean habitat types

To support the process of identification of the Specially Marine Protected Areas in the Mediterranean as required by the Protocol concerning Specially Protected Areas and Biological Diversity (SPA/BD Protocol), the updated BC classification has then been used for the selection of the reference marine habitat types, i.e., habitats to be monitored according to the Integrated Monitoring and Assessment Programme (IMAP) and related assessment criteria procedure.

The first list of reference marine benthic habitats for the Mediterranean region, adopted by the CPs to the Barcelona Convention, with the criteria adopted for their selection (UNEP/MED, 2006b), was accompanied by the production of a handbook for the interpretation of the listed reference habitats (Bellan-Santini et al., 2002; Pergent et al., 2007; UNEP/MAP-RAC/SPA, 2015a). Following the same process of updating of the full BC classification list, also the list of reference habitats undertook a consistent process of revision and updating, organised in consultation with 16 national experts from all the CPs of the BC, whose scientific experience covered all the habitat types included in the classification. Afterwards, the list was subjected to the official approval of all the national focal points of the SPA/BIO Protocol, before its final adoption (SPA/RAC-UN Environment/MAP, 2019b, available at http://www.rac-spa.org/publications#en13). The reference benthic habitat types have been selected among the 394 habitats listed in the updated BC classification, according to defined criteria and considering the needs of the Integrated Monitoring and Assessment Program (IMAP, 2017).

Inspired by Ballesteros et al. (2017) and by the FAO's criteria for identification of Vulnerable Marine Ecosystems (VMEs) (FAO, 2009), eight traits have been used to select reference habitats to be included in the updated reference list. While these traits are sometimes correlated, they account for different features of the habitat that make it worthy (or not) of protection. The eight traits used for the selection of reference habitats are the following:

1) Fragility: degree of susceptibility of the habitat to degradation (i.e., loss of its structure and functions) when facing natural and anthropogenic pressures;

2) Resilience^{-1}: inability of the habitat to recover quickly from a disturbance. Usually it is related to life-history traits of the component species that make recovery difficult (e.g., slow growth rate, late age of maturity, low or unpredictable recruitment, long-lived);
3) Uniqueness or rarity: degree of rarity of the habitat, i.e. unusual or very infrequent, at the Mediterranean scale;
4) Importance: the aptitude of the habitat to host rare, threatened, endangered or endemic species that occur only in discrete areas;
5) Species diversity: the number of species hosted in the habitat;
6) Structural complexity: degree of complexity of physical structures created in the habitat by the interaction of its biotic and abiotic components;
7) Capacity of the habitat to modify the physical environment and the ecosystem processes (i.e., geomorphological traits, fluxes of matter and energy), with a particular relevance at the occurrence of bioconstructors;
8) Significance of the habitat to provide ecosystem services, i.e. regulation, provision, habitat, and information services.

To select the reference habitats among the 394 habitats listed in the updated BC classification, an expert judgment procedure based on the Delphi technique has been carried out (refer to Montefalcone et al., 2021 for details). In the procedure, a total of 16 national experts from all the CPs of the BC and of 10 Mediterranean scientists, whose scientific experience covered all the habitat types included in the list, have been involved. Each expert made a private judgment assigning to each habitat types a 3-levels score, from 1 to 3, for each of the eight traits: i) score 1 corresponds to a low level; ii) score 2 to a medium level; and iii) score 3 to a high level. The final score for each habitat type was obtained averaging on all the experts. All habitat types having a rating of 3 in the “uniqueness” or “rarity” trait (i.e., habitats that are extremely rare) have been selected for the inclusion in the updated reference list regardless their final rating. When the main habitat-forming species of a habitat is a non-indigenous species, it has not been selected for inclusion in the updated references list, whatever its final rating. All habitats hosting bioconstructors able to build wide biogenic structures (i.e., reefs or platforms) have always been scored with a value of 3 in the trait “capacity of modifying the physical environment and the ecosystem processes” and have been selected for the inclusion in the reference list regardless their final rating (except those characterised by non-indigenous species).

Inclusion of a habitat in the updated reference list depended on the final score obtained by adding up the scores of the eight traits altogether. The minimum score reached by a habitat is 8 (score 1 to each of the eight traits), whilst the maximum score is 24 (score 3 to each of the eight traits). From the frequency distribution of the final scores of all the habitats listed in the updated BC classification, two groups were clearly identified, separated by the threshold score of 16:

- Priority habitats: are habitats reaching a final score ≥ 16. For these habitats conservation and strict protection is absolutely mandatory;
- Least relevant habitats: are habitats reaching a total score < 16. These habitats do not require specific conservation measures, although a sustainable management of all human activities must be always ensured.

All priority habitats reaching a final score of the eight traits equal or higher than 16 have been retained to update the reference list of marine habitat types (SPA/RAC-UN Environment/MAP, 2019b; see Annex 1). This updated list contains a total of 267 habitat types (up to the level 5), corresponding to 68% of the total habitat types listed in the updated BC classification. The first list of reference habitats (UNEP/MED, 2006b) contained 87 reference habitats up to the level 5 whilst the updated list (SPA/RAC-UN Environment/MAP, 2019b) now includes 86 main habitat types up to the level 4, plus other 181 sub-habitats at the level 5: it means that the number of reference benthic habitats to be inventoried, monitored, and protected has today been improved with 193 new types.

General frame of the interpretation manual

This interpretation manual satisfies the following requirements:

1. updated information provided;
2. scientific rigour;
3. readability also for non-specialists;
4. compatibility with existing classification systems (e.g., EUNIS, EUR 28 European Union Habitat Directive, CORINE).

The previous version of the 'Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest' (UNEP/MAP-RAC/SPA, 2015a, available at http://www.rac-spa.org/publications) was used as a basis to elaborate this interpretation manual.

Each descriptive sheet in the manual has been elaborated according to the following scheme:

On the first page of each sheet, on the left side, all the reference codes for the habitat identification are listed, starting from the code of the updated Barcelona Convention (this code is also reported on the side of each page of the sheet) and including the codes of the revised version of EUNIS (Evans et al., 2016, available at https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification), of the first version of EUNIS (Davies and Moss, 1998), of the European Union Habitat Directive (EUR 28, available at: http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf), and of the CORINE classification, when available. When the habitat described in the sheet has only a partial correspondence with another classification scheme, the word "partim" has been added near the code.

1. In addition, on the first page of each sheet, on the left side, a summary of the main features of the habitat are reported. In particular: i) the biological zone of the marine environment (supralittoral, midlittoral, infralittoral, circalittoral, offshore circalittoral, upper bathyal, lower bathyal, and abyssal); ii) the nature of the substratum, distinguishing from soft (coarse, mixed, sand, mud sediments), to hard (rock and biogenic); iii) the average depth range where the habitat usually develops; iv) the position of the habitat, distinguished in coastal (for the habitats developing in the littoral, infralittoral, and circalittoral depth zones), open sea (for the habitats developing below the circalittoral zone), and paralic for the habitats of transitional waters; v) hydrodynamic conditions, defined as variable, weak (i.e., sheltered), moderate, strong or very strong (i.e., exposed); vi) the average salinity range where the habitat usually develops; vii) the average temperature range where the habitat usually develops; viii)the suitability of the habitat for monitoring programs.
2. The descriptive sheet is organized in chapters, providing a complete description of the main features of each habitat type. The first one is the "Description of the habitat", where the general characteristics used to identify the habitat and its main features are reported.
3. The "Geographic distribution" provides information on the distribution of the habitat within the Mediterranean Sea.
4. The "Associated habitats" lists all the other benthic habitats that can be found in association with, or in close vicinity to, the habitat described in the sheet; for each listed habitat the relative code of the BC classification is also provided.
5. The "Related reference habitats" reports other reference habitats (with their code) listed in the updated BC list that display some similar features (usually in terms of dominant or associated species).
6. In the "Possible confusion" chapter are listed all the other habitats that can be confused with the habitat described in the sheet.

7. The “Typical species and associated communities” lists all main species dominating the habitat, and the main species that can be found in the associated community. The nomenclature of the animal species has been checked on the standard World Register of Marine Species (WoRMS Editorial Board, 2021, available at https://www.marinespecies.org/), but for *Lophelia pertusa* we decided to maintain this well-established nomenclature (instead of the new name *Desmophyllum pertusum*). Algal species names were checked on AlgaeBase database (available at https://www.algaebase.org/).
8. In the “Conservation interest and ecological role” the main ecological functions supported by the habitat are provided. Occurrence of endemic species within the habitat (among the dominant species) is also reported (also referring to Coll et al., 2010 and Bianchi et al., 2012).
9. In the “Economic importance” the ecosystem services provided to humans by the habitat are listed. The main ecosystem services considered are those listed by Solomidi et al. (2012) and Paoli et al. (2017), which are provision services (e.g., materials, food, genetic resources availability), habitat services (e.g., due to the creation of three-dimensional structure that amplifies the space available for marine organisms), regulation services (e.g., carbon cycle, water clearing, climate change mitigation), information and cultural services, which embrace scientific research and monitoring, teaching, recreation (e.g., for those habitats with great aesthetic value for underwater tourism), inspiration (e.g., for photos, films, and painting or literary creations) and spiritual value (e.g., cultural traditions). When available, the economic value of the habitat has also been reported.
10. In the “Vulnerability and potential threats” the main pressures likely to affect the status of the habitat and the vulnerability of the habitat to both natural and human-induced pressures are described.
11. The “Protection and management” describes the specific protection measures already implemented for the habitat (or for the dominant species associated to the habitat). References to inclusion in the Annexes of the Habitats Directive (92/43/EEC), of the Bern Convention on the conservation of wildlife and natural environment of Europe, of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA & BD Protocol, Barcelona Convention), and in the IUCN European Red List of species and marine habitats are also provided.
12. The “Suitability of the habitat for monitoring” indicates whether the habitat has been indicated as suitable in monitoring plans. The document ‘Monitoring protocols for IMAP Common Indicators related to biodiversity and non-indigenous species, which includes the guidelines for monitoring marine benthic habitats in the Mediterranean’ (UNEP/MED, 2019) was used as a reference for the inventory and monitoring methods for habitat characterization and status evaluation. The adoption of the habitat in the frame of the WFD and the MSFD has also been indicated.
13. The “Reference” section lists a representative selection of the consulted literature used to update the information reported in each descriptive sheet. Some relevant documents widely used in most of the sheets have not been provided in each of them to avoid repetitions, but they have been provided at the end of the reference list of this interpretation manual.

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Descriptive sheets (1 to 108)

1. MA1.51 Supralittoral rock
2. MA1.51a Supralittoral euryhaline and eurythermal pools
3. MA1.52 Midlittoral caves
4. MA1.53 Upper midlittoral rock
5. MA1.54 Lower midlittoral rock
6. MA1.542 Association with Fucales
7. MA1.544 Facies with *Pollicipes pollicipes*
8. MA1.54a Midlittoral euryhaline and eurythermal pools
9. MA2.51 Platforms of encrusting Corallinales
10. MA2.54 Banks of dead leaves of macrophytes
11. MA3.51 Supralittoral coarse sediment, MA4.51 Supralittoral mixed sediment, MA5.51 Supralittoral sand, MA6.51 Supralittoral mud
12. MA3.511, MA4.511, MA5.511, MA6.511 Association with macrophytes
13. MA3.52 Midlittoral coarse sediment, MA4.52 Midlittoral mixed sediment, MA5.52 Midlittoral sand, MA6.52 Midlittoral mud
14. MA6.521a Association with halophytes or marine angiosperms
15. MB1.51 Algal-dominated infralittoral rock
16. MB1.51a Well illuminated infralittoral rock exposed, MB1.51c Well illuminated infralittoral rock sheltered
17. MB1.511a, MB1.511c Association with Fucales
18. MB1.513a Association with encrusting Corallinales creating belts
19. MB1.514a, MB1.514c Association with *Caulerpa prolifera*
20. MB1.516a, MB1.516c Facies with zooxanthellate Scleractinia
21. MB1.51b Moderately illuminated infralittoral rock exposed, MB1.51d Moderately illuminated infralittoral rock sheltered
22. MB1.51e Lower infralittoral rock moderately illuminated
23. MB1.52 Invertebrate-dominated infralittoral rock
24. MB1.52a Moderately illuminated infralittoral rock, exposed or sheltered
25. MB1.524a Facies with azooxanthellate Scleractinia
26. MB1.53 Infralittoral rock affected by sediment
27. MB1.537 Facies with endolithic species
28. MB1.55 Coralligenous (enclave of circalittoral)
29. MB2.51 Reefs of Vermetidae
30. MB2.52 Reefs of *Sabellaria* spp.
31. MB2.53 Reefs of *Cladocora caespitosa*
32. MB2.54 *Posidonia oceanica* meadow, on rock (MB2.541), on matte (MB2.542), on sand, coarse or mixed sediment (MB2.543)
33. MB2.545 Natural monuments/Ecomorphoses of *Posidonia oceanica* (fringing reef, barrier reef, stripped meadow, atoll)
34. MB2.546 Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.
35. MB2.547 Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica*
36. MB3.51 Infralittoral coarse sediment mixed by waves, MB3.52 Infralittoral coarse sediment under the influence of bottom currents
37. MB5.52 Well sorted fine sand
38. MB5.521 Association with indigenous marine angiosperms
39. MB5.53 Fine sand in sheltered waters
40. MB5.539 Facies with *Tritia* spp. and nematodes in hydrothermal vents
41. MB5.542 Association with Fucales
42. MB6.51 Habitats of transitional waters (estuaries and lagoons)

43. MB6.511 Association with marine angiosperms or other halophytes
44. MC1.51 Coralligenous cliffs
45. MC1.51a Algal-dominated coralligenous
46. MC1.512a Association with Fucales or Laminariales
47. MC1.51b Invertebrate-dominated coralligenous, MC1.51c Invertebrate-dominated coralligenous covered by sediment
48. MC1.512b, MC1.512c Facies with large and erect sponges
49. MC1.514b, MC1.514c Facies with Alcyonacea
50. MC1.516b, MC1.516c Facies with the Zoantharia *Savalia savaglia*
51. MC1.52 Continental shelf rock
52. MC1.52a Coralligenous outcrops, MC1.52b Coralligenous outcrops covered by sediment
53. MC1.52c Deep banks
54. MC1.53 Semi-dark caves and overhangs
55. MC1.53a Walls, MC1.53b Roof
56. MC1.531a, MC1.531b Facies with sponges
57. MC1.533a, MC1.533b Facies with *Corallium rubrum*
58. MC1.534a, MC1.534b Facies with Scleractinia
59. MC1.536a, MC1.536b Facies with Bryozoa
60. MC1.53d Brackish water caves or caves subjected to freshwater runoff
61. MC1.531d Facies with lithistid sponges
62. MC2.51 Coralligenous platforms
63. MC3.51 Coastal detritic bottoms
64. MC3.511 Association with Laminariales
65. MC3.514 Facies with Alcyonacea
66. MC3.515 Facies with Pennatulacea
67. MC3.518 Facies with Bryozoa
68. MC3.52 Coastal detritic bottoms with rhodoliths
69. MC3.521 Association with maërl
70. MC3.522 Association with *Peyssonnelia* spp.
71. MC4.51 Muddy detritic bottoms
72. MC6.51 Coastal terrigenous mud
73. MC6.511 Facies with Alcyonacea and Holothuroidea
74. MD1.51 Offshore circalittoral rock invertebrate-dominated, MD1.52 Offshore circalittoral rock invertebrate-dominated covered by sediment
75. MD1.514, MD1.524 Facies with Antipatharia
76. MD1.515, MD1.525 Facies with Scleractinia
77. MD1.53 Deep offshore circalittoral banks
78. MD1.532 Facies with Alcyonacea
79. MD2.51 Offshore reefs
80. MD3.51, MD4.51 Offshore circalittoral detritic bottoms
81. MD3.511, MD4.511 Facies with the Bivalvia *Neopycnodonte* spp.
82. MD3.514, MD4.514 Facies with Crinoidea
83. MD5.51 Offshore circalittoral sand
84. MD6.51 Offshore terrigenous sticky mud
85. ME1.51 Upper bathyal rock invertebrate-dominated
86. ME1.512 Facies with large and erect sponges
87. ME1.513 Facies with Antipatharia
88. ME1.514 Facies with Alcyonacea
89. ME1.516 Facies with Cirripedia
90. ME1.518 Facies with the Bivalvia *Neopycnodonte* spp.
91. ME1.52 Caves and ducts in total darkness
92. ME2.51 Upper bathyal reefs

93. ME2.512 Facies with large and erect sponges
94. ME2.513 Facies with Scleractinia
95. ME2.515 Facies with Serpulidae
96. ME2.52 Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges
97. ME3.51 Upper bathyal coarse sediment
98. ME6.51 Upper bathyal mud
99. ME6.512 Facies with Pennatulacea
100. ME6.513 Facies with Alcyonacea
101. ME6.51B Facies with Bryozoa
102. ME6.51C Facies with giant Foraminifera
103. MF1.51 Lower bathyal rock
104. MF1.512 Facies with Alcyonacea
105. MF1.514 Facies with chemosynthetic benthic species
106. MF6.51 Lower bathyal sandy mud
107. MG1.51 Abyssal rock
108. MG6.51 Abyssal mud


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Supralittoral rock

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.51**
- **EUNIS 2019: MA151**
- **EUNIS 2007: B3.1**
- **EC: 1170 (partim)**
- **CORINE: 18.16**

LOCATION OF THE HABITAT

Zone	Supralittoral
Nature of the substratum	Hard (rock)
Depth range	Above mean sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Variable
Temperature	Variable
Suitability for monitoring	Yes, but not applied

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Photo credits:
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SUPRALITTORAL

MA1.5 Littoral rock

MA1.51 Supralittoral rock

Description of the habitat

While the term ‘supratidal’ refers explicitly to the tidal features of an area, the definition of ‘supralittoral’ is based on the biotic assemblages. The two terms are often used interchangeably, but do not match closely. The supralittoral zone is located above the level of the highest tides of calm waters and therefore normally emerged, even if more or less regularly reached by seawater spray. The supralittoral zone undergoes immersions only exceptionally. In seas with wide tidal range, this immersion happens regularly during the highest equinoctial tides. In seas with small tidal range, like the Mediterranean, the immersion is irregular, being mainly due to wave action. The vertical extension of this zone varies according to the exposure: it may be only 10-15 cm in sheltered areas but may reach some meters in exposed situations. The supralittoral rock is an ecologically complex habitat characterized by variable salinity (switching from fresh water during rains to crystallized salt in dry weather), dehydration, wind and sun exposition, extreme temperature oscillations (the surface temperature of the rock can rise up to over 60 °C in summer, and fall below zero in winter), and mechanical stress associated with seawater splash, often with sand or pebbles, with strong abrasive effects. The amount of salt reaching the supralittoral zone with splash or high waves has been estimated at ca 20 $kg \cdot m^{-2} \cdot a^{-1}$! Haloclastic processes trigger cliff erosion through the penetration of saline water into structural discontinuities of the bedrock and its evaporation, with the subsequent deposition of salt crystals, which can grow from solution, expand due to heating or change their volume due to hydration. The modification in the volume of the crystals causes an increase of the pressure on crevice walls, leading to the fragmentation of the rock. Salt weathering, together with wetting and drying cycles and bioerosion, may thus be important in notch formation.

Geographic distribution

Supralittoral rock occurs all around the Mediterranean coastline, which is rocky for the most part (around 54%).

Associated habitats

Above the supralittoral, an adlittoral zone may be identified, characterized by the presence of halophytic vegetation and belonging to the terrestrial domain. It borders and defines the upper limit of the supralittoral rock. Conversely, the lower limit of the supralittoral rock is bounded by the upper midlittoral rock, the first truly marine habitat. Rock pools (MA1.51a) may occur within the supralittoral zone. Other associated habitats are ‘Association with Cyanobacteria and lichens’ (MA1.511), ‘Association with Ochrophyta’ (MA1.512), ‘Facies with Gastropoda and/or with Chthamalidae’ (MA1.513), ‘Wracks of dead leaves of macrophytes’ (MA1.51b).

Related reference habitats

Typical supralittoral species may thrive on the borders of ‘Supralittoral euryhaline and eurythermal pools’ (MA1.51a). The boundary between the supralittoral rock and the ‘Upper midlittoral rock’ (MA1.53) is rarely sharp, and species belonging to the latter habitat may colonize the lower part of the former. Affinities between these two habitats may also be due to motile invertebrates moving among them.

Possible confusion

Confusions are possible at the boundary with the upper midlittoral rock, where supralittoral and midlittoral species may co-exist.

Typical species and associated communities

The supralittoral rock is a very harsh environment, where not many organisms can survive. Species of terrestrial origin must tolerate the presence of salt; those of marine origin must be extremely resistant to desiccation. At the upper boundary of the supralittoral zone, sparse members can still be found of the maritime association of flowering plants named *Crithmo-Staticetum*, typical of the adlittoral zone, the last terrestrial zone: examples include *Crithmum maritimum*, *Limbarda crithmoides*, and *Limonium sinuatum.* Lizards of the genus *Podarcis*, with many geographic species and subspecies, may patrol the supralittoral in search of small crustacean prey when availability of potential insect prey in the adlittoral is reduced. The supralittoral zone proper begins with a kind of abiotic ‘no man's land’. In reality, this apparent bare rock is inhabited by different species of lichens, such as *Verrucaria adriatica* (on limestone) and *V. amphibia* (on siliceous rock), which resemble tar spots. Macroalgae are absent, because the salty aerosol sprayed by waves is too weak to enable colonization by marine vegetation, but epi- and endolithic Cyanobacteria are normally abundant, and include *Blennothrix lyngbyacea*, *Chroococcus turgidus*, *C. varius*, *Entophysalis deusta*, *Gloeocapsa salina*, *Hyella balani*, *H. caespitosa*, *Kyrtuthrix dalmatica*, *Lyngbya confervoides, Pannus punctiferus*, *Phormidium nigroviride*, *Rivularia polyotis*, *R. atra*, *Solentia paulocellulare*, and others (with regional differences). The dominance of one or the other species makes the rock take on a different dark colour: blackish, brown, ash green or bluish gray. Other microorganisms include Bacteria (e.g., species of the genus *Rubrobacter* and the families Flammeovirgaceae, Phyllobacteriaceae, Rhodobacteraceae, and Trueperaceae) and halotolerant Archaea. Endolithic Cyanobacteria operate an active bioerosion of the bedrock, especially on carbonate coasts. Among the animals, a typical supralittoral species is *Fucellia maritima*, a dipteran similar to flies, from which it differs because its wings fold over each other at rest, instead of remaining apart. It feeds on plant and animal detritus. The isopod *Ligia italica* is more similar to its terrestrial relatives (suborder Oniscidea) than to marine ones. It feeds on detritus and is active by day, walking on completely dry rocks. During their reproductive period, females plunge into the sea, where their eggs are laid and hatch. The littorinid gastropod *Melarhaphe neritoides* is the dominant animal in the supralittoral rock, reaching a density of nearly 100 individuals·m^{-2}, especially in exposed coasts. It is capable of alternating aquatic and aerial respiration, and its tiny blackish-brown shells throng near cracks in rocks, where humidity is retained. *M. neritoides* feeds on Cyanobacteria and grazing with its radula enhances the bioerosion rate: a single individual of *M. neritoides* may remove about 25 mg·a^{-1} of rock. Another littorinid species, *Echinolittorina punctata*, occurs in the southern Mediterranean Sea. Its shell is a little larger than that of *M. neritoides*, reaching 1 cm in diameter. The range of *E. punctata* has recently expanded northward to reach the Italian coasts of Apulia and Latium. Large individuals of both species are common at higher levels, and small ones at lower levels. Both species do not move when on a dry surface: they close the operculum and remain attached to the rock by a rim of mucus round the fore-edge of the shell; with increased desiccation they hide in small crevices. Although chthamalid barnacles characterize the upper midlittoral rock, where they form distinctive belts, the species *Microeuraphia depressa* may be found in the lower part of the supralittoral zone.

It occurs with single individuals or small groups in crevices and narrow grooves, reaching maximum densities of 28 to 73 individuals·m^{-2}. It can resist desiccation by retaining a small amount of water in the shell, and may tolerate temperatures higher than 60 °C. It is a suspensivore using its cirri to seize (during storms) small preys and organic debris suspended in the water. Cirri come out from its shell only during the backflow of water following wave withdrawal: when the water speed is low (<4 cm·s^{-1}), the cirri contract at a very rapid rate to actively capture food particles; when water speed is faster, the capture of food particles becomes passive. The occasions when *M. depressa* is reached by waves, and can therefore feed, are rare: the species is able to survive long periods of fasting (several weeks). As a whole, supralittoral rock organisms are not homogeneously distributed through the habitat, differences arising according to shore types and distance from the sea. Three main subzones may be recognized from land to sea: an upper subzone colonized by lichens; a middle subzone dominated by *M. neritoides*; and a lower subzone with *M. neritoides* and *M. depressa*. Visually, two subzones can be distinguished based on colour: a yellowish-grey in the lower part and a wider black above, possibly due to the dark cyanobacterial film.

Conservation interest and ecological role

The supralittoral rock is a sort of ecotone between land and sea, in which biota and selective pressures from both environments can co-occur. Species living exclusively in this habitat exhibit unique adaptations of major ecological and evolutional interest.

Economic importance

This habitat provides humans with two major kinds of ecosystem services: provisioning services and cultural services. The former consist in the biotechnological potential of the microorganisms living in supralittoral rock. The latter include the teaching opportunities that intact locales on rocky capes offer to schoolchildren, and the scientific interest: for instance, the on-going range extension of *Echinolittorina punctata* linked to seawater warming suggests that this species may be a practical and easy-to-monitor indicator of climate change. The monetary value of this habitat has not been assessed yet.

Vulnerability and potential threats

The biota inhabiting the supralittoral rock is supposedly resistant to adverse environmental conditions. However, this habitat is heavily impacted by human trampling and other tourist-related or maritime activities, especially when located on gently sloping and easily accessible rocky coastlines, which become often covered by asphalt and cement. Even when located on inaccessible steep cliffs, this habitat remains anyway vulnerable to surface water pollution (oils, surfactants, nutrients).

Protection and management

No specific protection measures are envisaged for this habitat. Virtually all marine protected areas include rocky coast, where the supralittoral zone is supposedly subtracted to unsustainable human use.

Suitability of the habitat for monitoring

Lichen cover and fauna abundance may be easily monitored though time, and would provide relevant information on the ecological modifications due to climate change and/or local human impacts.

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Fucellia maritima
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Ligia italica
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Melarhaphe neritoides
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Supralittoral euryhaline and eurythermal pools

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.51a**
- **EUNIS 2019: MA152**
- **EUNIS 2007: A1.42**
- **EC: 1170 (partim)**
- **CORINE: 18.17**

LOCATION OF THE HABITAT

Zone	Supralittoral
Nature of the substratum	Hard (rock)
Depth range	Above mean sea level
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	0 to 300
Temperature	7 °C to 34+ °C
Suitability for monitoring	Yes, but not applied

Authors:
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Photo credits:
G. Massa, C. Morri

SUPRALITTORAL

MA1.5 Littoral rock

MA1.51 Supralittoral rock

MA1.51a Supralittoral euryhaline and eurythermal pools

Description of the habitat

Depressions within the supralittoral rock may be filled with seawater, during storms, or with meteoric water, in rainy days with calm sea, originating the so-called rock pools (also splash pools). Depending on distance from the sea, rainfall, seasonality, and other factors, a great variety of rock pool types exist, whose classification is based on their genesis and geometry. They are generally circular to spindle-shaped, centimetres to decimetres deep and decimetres to metres wide. Physico-chemical erosion by both marine and meteoric waters, mechanical erosion by waves, and bioerosion by endolithic microalgae and molluscs grazing upon them (dense population of *Melaraphe neritoides* may remove more than 1 mm·a^{-1} of rock) are the major genetic agents, especially on carbonate rocks. Being disconnected from the sea, and due to their small volume (hardly exceeding a few tens of litres), rock pools are greatly sensitive to meteorological variability: exposure to the sun may lead to the evaporation of seawater, increasing salinity up to 300 and eventually precipitating salt crystals; on the contrary, rainfall decreases salinity, giving rise to brackish or even freshwater habitats. Temperature variations are also important, and may range from less than 7 °C (in winter) to more than 34 °C (in summer). Similar variability has been measured for other parameters: for instance, in Ligurian Sea rock pools, the pH vary from 7.3 to 8.9, and the amount of particulate organic matter suspended in the water vary from less than 20 mg·l^{-1} to more than 350 mg·l^{-1}. Notwithstanding the shallow depth of rock pools, waters are often stratified, and three layers may be recognized: a surface layer, with highly variable physico-chemical conditions; an intermediate layer, comparatively stable but poor in oxygen; and a deep layer, characterized by higher salinity. Ecologically, rock pools may be divided into two main types: temporary, with high salinity and abundant organic substances; and semi-permanent, with reduced salinity due to the continuous supply of rain water.

Geographic distribution

Rock pools can be observed in the supralittoral zone of most rocky shores, which occur all around the Mediterranean coastline. There are regional differences in species occurrence in the various geographic sub-basins of the Mediterranean.

Associated habitats

Rock pools are nested in the supralittoral rock, and can be found through the supralittoral zone. Rock pools located high on the shore may come in contact with the adlittoral zone, whilst those low on the shore may occur in the vicinity of the midlittoral rock. Wracks of dead leaves of macrophytes (MA1.51b) may be associated to this habitat.

Related reference habitats

Species belonging to the ‘Supralittoral rock’ (MA1.51) may colonize the borders of the rock pools: border erosion by mollusc grazing is a major agent of pool enlargement. Species from the ‘Upper midlittoral rock’ (MA1.53), the ‘Lower midlittoral rock’ (MA1.54), the ‘Midlittoral euryhaline and eurythermal pools’ (MA1.54a), and even the ‘Algal-dominated infralittoral rock’ (MB1.519) may occasionally be found inside rock pools, brought there by storm waves.

Possible confusion

Rock pools located low on the shore may be confused with tide pools, which occur in the midlittoral rock and are more or less regularly inundated by the sea.

Typical species and associated communities

Rock pools are extreme habitats populated by eurythermal and euryhaline organisms of terrestrial, freshwater or marine origin, able to face the wide variability of environmental parameters. These extreme conditions can cause high mortality in most of the resident organisms, leading to recurrent local extinctions, followed by recolonization. Accordingly, rock pool dwellers have developed behavioural or physiological mechanisms that allow them to escape or endure adversity. Organisms capable of flying, like some insects, can actively move between pools during periods of drought, whereas other taxa produce resistance stages to overcome adverse periods in situ. Phytoplankton includes diatoms, phytoflagellates and unicellular chlorophytes. *Oxyrrhis marina* is one of the most common phytoflagellates. Chlorophytes comprise several species, such as *Brachiomonas submarina*, *Dunaliella salina*, *Stephanoptera gracilis*, *Tetraselmis subcordiformis* and *T. tetrathele*. *S. gracilis* dominates when the salinity is high, *D. salina* when the water approaches saturation. On the bottom of the pools, cyanobacteria form green or brown compact phototrophic biofilm, some of which thicken over the spring to form microbial mats; in full summer, microbial mats shrink, detach from the exposed substrate, harden and progressively calcify. Common cyanobacteria include *Hyella caespitosa*, *Kyrtuthrix dalmatica, Lyngbya salina* and *Rivularia nitida*. The highest cyanobacterial diversity is found when salinity is high. Germlings of green and brown macroalgal species belonging to *Ulva*, *Cladophora* and *Sphacelaria* may be embedded in biofilms and microbial mats and gradually grow to form more or less extensive ephemeral macroalgal covers in spring; over the summer, macroalgal cover diminishes and may eventually disappear. Heterotrophic protists are represented by ciliates, such as *Condylostoma patens*, *C. rugosa*, *Euplotes trisulcatus*, and *Fabrea salina*, among many others. *F. salina* dominates in summer and can withstand salinities of up to 200 before getting encysted. *C. patens* dominates in spring and autumn, with salinities not exceeding 60. Among the metazoans, the free-living nematode *Anticoma acuminata* is well adapted to the rock pool environment: it forms dense populations in summer, with salinities ranging from 35 to 75. Rotifers typical of this habitat are *Encentrum marinum* and *Testudinella clypeata*, which survive unfavourable periods in a stage of latent life; *Colurella obtusa* may also be found in rock pools, but is not typical. Among the Crustaceans, the harpaticoid copepod *Tigriopus fulvus* is one of the most characteristic animals of rock pools, where it may be present with active stages throughout the year, whenever water is available. Its salinity optimum is between 38 and 45, but it remains active and reproduces at higher salinities; only when salinity reaches 180, *T. fulvus* enters a state of latent life, while death intervenes at 230. *T. fulvus* is currently considered a polytypic species and includes the subspecies *T. f. fulvus* from the Western Mediterranean, *T. f. adriatica* from Croatia, and *T. f. algirica* from Algeria. The actual diversity of the genus *Tigriopus* in the Mediterranean Sea needs to be further investigated. The amphipod *Parhyale aquilina*, which thrives especially in midlittoral coarse sand, reproduces well in rock pools and tolerates salinities exceeding 65. Species that can be found accidentally in rock pools include the mite *Copidognathus tabellio* and several midlittoral and infralittoral gastropods that may be brought in by storm waves and do not survive for long. Insects have several species commonly thriving in rock pools, the most important ones belonging to dipterans and coleopterans. The former use coastal rock pools only during part of their life cycle, while some of the latter spend the whole life cycle there. The absence of fish, which predate on their larvae, make rock pools ideal micro-environments for dipterans. *Anopheles sacharovi*, *Culex modestus*, *Culiseta litorea*, *Ochlerotatus caspius* and *O. detritus* (among others) may be found in rock pools but are not typical of these environments. The only dipterans specializing in life in rock pools belong to the genus *Acartomyia*: *A. mariae* (western Mediterranean), *A. zammitii* (central Mediterranean, Adriatic Sea, Aegean Sea), and *A. phoeniciae* (Levantine basin). Their larvae crowd by thousands, tolerating salinities up to 200 (*A. mariae*) or even 280 (*A. phoeniciae*); in early summer, before the pools dry up, they metamorphose and fly away. Among coleopterans, *Bembidion steinbuehleri*, *Agabus conspersus* and other water beetles can be found, but most prominent are the species of the genus *Ochthebius* belonging to the so-called "*Calobius*" lineage: *O. adriaticus adriaticus* (Croatia), *O. a. moreanus* (Crete), *O. a. pleuralis* (Crete), *O. asper* (Greece), *O. biltoni* (Sicily), *O. brevicollis* (Eastern Mediterranean), *O. celatus* (Tyrrhenian Sea, Central and Eastern Mediterranean), *O. cortomaltese* (Malta), *O. evae* (south Spain), *O. lejolisii* (south Spain), *O. quadricollis* (western Mediterranean), *O. subinteger* (Baleares and Corsica), *O. urbanelliae* (Tyrrhenian Sea, Ionian Sea, Adriatic Sea). These small beetles measure about 2 mm, and are brown-black in colour. They are phytophagous and detrivorous. The adults do not swim and slowly tread the bottom and walls of the rock pool, but must emerge to breathe: a felting of hairs on the ventral surface of their abdomen allows them storing air bubbles. They are numerous from spring to summer, but may be there all year round. Mating occurs in spring and autumn, and the eggs are laid singly on organic debris. The larvae live on the bottom and feed on organic matter. Species of *Ochthebius* tolerate salinities between 26 and 152, but have their optimum at 50 to 80. When salinity becomes too high, adults can fly away in search of pools that suit them better.

Conservation interest and ecological role

Rock pools are peculiar ecosystems where species of terrestrial, freshwater or marine origin coexist and interact functionally. Species living exclusively in this habitat exhibit unique adaptations of major ecological and evolutionary interest. The Mediterranean climate, characterized by a long period of summer drought and rainy winters with mild temperatures, is the least extensive of the temperate climates: the rock pools of the microtidal Mediterranean Sea are influenced more by the atmospheric climate than by the marine climate, and have therefore few equivalents in the world.

Economic importance

The ecosystems services that rock pools provide to humans are essentially cultural services, which include the teaching opportunities that rock pools offer to schoolchildren, and the scientific interest: high fragmentation and environmental harshness make rock pools elective habitats where to study evolutionary (speciation) and ecophysiological and behavioural mechanisms (adaptation to extreme conditions). There are also important applied aspects, as *Tigriopus fulvus* is known to be a useful test species in ecotoxicology.

Vulnerability and potential threats

The biota inhabiting rock pools is adversely selected, and therefore extremely resistant to harsh environmental conditions. This notwithstanding it suffers human impact, especially littering. Climate change has been also blamed for impacting this habitat: the average water temperature in a rock pool located near Genoa (Italy), first studied in 1987 and revisited in 2014, increased from 22.1 °C (range = 16.5-27.0 °C) to 25.9 °C (range = 21.8-31.4 °C); concomitantly, the population density of *Tigriopus fulvus* decreased fivefold.

Protection and management

No specific protection measures exist for this habitat. Virtually all marine protected areas include rocky coasts, whose supralittoral pools are supposedly subtracted to human impact.

Suitability of the habitat for monitoring

Protist and macrofauna abundances may be easily monitored though time, and would provide relevant information on the ecological modifications due to climate change and/or local human impacts.

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Salt precipitation in a hypersaline rock pool (© C. Morri)

Ephemeral macroalgal growth in spring (© C. Morri)

Ochthebius quadricollis (© G. Massa)


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Midlittoral caves

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.52**
- **EUNIS 2019: MA155**
- **EUNIS 2007: A1.44**
- **EC: 8330 (partim)**
- **CORINE: 12.7**

LOCATION OF THE HABITAT

Zone	Midlittoral (supralittoral to upper infralittoral)
Nature of the substratum	Hard (rock)
Depth range	Sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 34 and 39
Temperature	10 °C to 28°C
Suitability for monitoring	Yes

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C.N. Bianchi, P. Dendrinos, V. Gerovasileiou, V. Mačić

MIDLITTORAL

MA1.5 Littoral rock

MA1.52 Midlittoral caves

Description of the habitat

Sea caves are coastal cavities of various size containing marine water, and may be submerged (if they open below sea level) or semi-submerged, extending above and below the sea surface, and thus more exposed to and affected by sea-surface dynamics. Sea caves are formed by different processes in various rock types (such as dissolution of bedrock by water circulating through karstic network, fracturing, and differential non-dissolution erosion), but especially in semi-submerged caves the mechanical action by the waves may also be important in shaping the morphology of the cavity and in influencing the composition of the biota that lives there. Semi-submerged marine caves typically have a terrestrial part, with the characteristics of a land cave but receiving the influence of marine spray or even occasional high waves, and a submerged part, which shares most features of semi-dark caves but is more exposed to wave action. What really identifies semi-submerged caves is the narrow band at sea level where the rock is covered with a distinctive crust of red algae in dim light. This midlittoral portion of the semi-submerged caves may extend further inside the coastal cliff, in darker conditions: here, algae disappear and the biota is represented only by animal species. The high degree of air humidity allows midlittoral species to live high with respect to average sea level, in what would be the supralittoral zone outside the cave.

Geographic distribution

Rock constitutes around 54% of the Mediterranean coastline, and marine caves may occur wherever there are rocky cliffs, especially if made of limestone. Our knowledge about midlittoral caves, however, is restricted to a few sites, mostly along the northern coasts.

Associated habitats

Midlittoral caves are usually in contiguity with the normal rocky supralittoral, midlittoral, and shallow infralittoral habitats. In addition, they are in contact with terrestrial caves and submerged caves, either semi-dark or dark. Biotic interchanges among these different habitats are therefore frequent and, depending also on the degree of exposure, may partially upset the normal zonation schemes. Midlittoral caves may be associated with 'Association with encrusting Corallinales or other Rhodophyta' (MA1.521).

Related reference habitats

Affinities may be found between midlittoral caves and shallow 'Semi-dark caves and overhangs' (MC1.53), 'Supralittoral rock' (MA1.51), 'Upper midlittoral rock' (MA1.53), 'Lower midlittoral rock' (MA1.54), 'Association with encrusting Corallinales creating belts' (MA1.531, MA1.541), and 'Platforms of encrusting Corallinales' (MA2.51). These affinities are in part due to motile invertebrates moving among them.

Possible confusion

The topographic location at sea level and the distinctive pink-red-mauve colour of the fine algal crust covering the rock make this habitat unmistakable. Confusion, however, may arise at the transitions to subaerial and submerged parts of the cavity.

Typical species and associated communities

The most characteristic species of midlittoral caves are two red crust-forming algae: *Hildenbrandia rubra* is pink-red to dark red in colour, velvety to the touch, and is highly tolerant to variations in salinity, temperature and light conditions; *Phymatolithon lenormandii* is calcified, hard and rugose, and pink-red to mauve in colour. The moss-like, dark purple in colour, red alga *Catenella caespitosa* and the dark green cyanobacterium *Rivularia atra* can also participate in this association. In absence of light, this algal belt may be replaced by the typical littoral chthamalid *Microeuraphia depressa* and the beadlet anemones *Actinia mediterranea* and *A. prasina*. Chitons, limpets and the two littoral crabs *Pachygrapsus marmoratus* and *Eriphia verrucosa* are among the most frequent motile invertebrates. In submerged caves that exhibit inner chambers with air bells, a belt of the deep circalittoral bivalve *Neopycnodonte cochlear* may form in what would be the 'midlittoral' zone. The shallow submerged part of midlittoral caves is typically inhabited by encrusting and massive sponges, among which a miniaturized form of *Aplysina aerophoba*; in the south-western Mediterranean it may harbour spectacular mats of the colonial scleractinian coral *Astroides calycularis*, bright orange in colour. The subaerial part of the cavities is populated by terrestrial arthropods, such as acari, pseudoscorpions, centipedes and insects, by seabirds (e.g. *Hydrobates pelagicus*, *Phalacrocorax aristotelis*) and rock pigeons (*Columba livia*), and by bats (e.g. *Miniopterus schreibersii*, *Myotis blythi*, *Tadarida teniotis*). The Mediterranean monk seal *Monachus monachus*, in regions where it is still present, exploits semi-submerged caves to rest, moult, give birth to, and nurse pups. It finds refuge in marine caves after the intense human persecution to which it has been exposed since classical antiquity. The species enter coastal caves with underwater or semi-submerged access, provided that these are characterized by emerged internal beaches or rocky platforms on which the species may haul-out. Caves used by monk seals for breeding have specific characteristics: they need to be well protected from wind and waves and human disturbance in order to guarantee pup survival. This implies the presence of factors such as: an entrance with a protective barrier against strong waves, a long entrance corridor, a well sheltered shallow internal pool, beaches that are always above high tide level, and a wide subaerial chamber.

Conservation interest and ecological role

Notwithstanding low diversity and lack of strictly exclusive species, semi-submerged caves have a heritage and aesthetical value. In addition, those caves that have an emerged internal chamber may be important for the conservation of bats and the monk seal *Monachus monachus*.

Economic importance

The ecosystems of semi-submerged caves offer information and provision services to humans. When cave porches are large enough, they can be enjoyed by tourists who can access by swimming, snorkelling or boating. In some Mediterranean countries, people enter marine caves to harvest bird eggs. Anglers use semi-submerged caves as a base for their activity. No monetary evaluation is available yet for this habitat.

Vulnerability and potential threats

Little is known about the consequences of water warming and sea level rise on midlittoral caves. Pollution by hydrocarbons is to be considered as a serious threat for the biota. Floating litter and debris can accumulate in the inner part of the cave. Unrestricted human visitation, especially with motorboats, can be a significant source of impact.

Protection and management

Marine caves are protected according to the Resolution no. 4 of the Council of Bern Convention (which listed them as endangered natural habitat type), by the Habitats Directive of the European Union, and by the Mediterranean Action Plan of the United Nations Environment Programme. The Mediterranean monk seal *Monachus monachus*, included as endangered (EN) in the IUCN Red List of threatened species and listed in the Annex II (endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, is one of the most emblematic and charismatic species inhabiting marine caves. Even in regions where the monk seal does not occur anymore, there is often historical evidence of the use of caves by this species: in Italy, for instance, many traditional marine cave names, such as ‘Grotta delle Sirene’ (= Mermaids Cave) or ‘Grotta del Bue Marino’ (= Sea Ox Cave), derive from the (past) occurrence of monk seals there. Maintenance of this habitat, therefore, may help the future recovery of Mediterranean populations of *M. monachus*. The survival of important monk seal populations in the north-eastern Mediterranean, especially in the Aegean Sea, is linked to the availability of high numbers of suitable cave habitats across the coasts and insular locations of the region coupled with the extensive coastline of the insular locations, which provide protection from human disturbance and prevailing winds. Considering that the species has a very prolonged lactation period, marine caves represent a habitat of high conservation value for its survival.

Suitability of the habitat for monitoring

Caves are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for the monitoring of dark habitats (included marine caves) in the Mediterranean Sea. In the Eastern Mediterranean Sea, several marine caves are monitored for the pupping activity of monk seals using remote photography and video.

Mauve-coloured algal crust
(© P. Dendrinos)

Monachus monachus (© P. Dendrinos)

Microeuraphia depressa
(© C.N. Bianchi)

Actinia mediterranea
(© V. Mačić)

Miniopterus schreibersii
(© V. Mačić)

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Upper midlittoral rock

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.53**
- **EUNIS 2019: MA153**
- **EUNIS 2007: A1.13**
- **EC: 1170 (partim)**
- **CORINE: 18.22 (partim)**

LOCATION OF THE HABITAT

Zone	Midlittoral
Nature of the substratum	Hard (rock)
Depth range	At mean sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 34 and 39, may be lower when emerged during heavy rain
Temperature	10 °C to 28 °C, may vary under the influence of air temperature
Suitability for monitoring	Yes, but not applied

Authors:
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Photo credits:
C.N. Bianchi, G. Dore, C. Morri

MIDLITTORAL

MA1.5 Littoral rock

MA1.53 Upper midlittoral rock

Description of the habitat

The phrase ‘intertidal zone’ explicitly refers to the tidal properties of an area, and thus is delimited by physical limits. On the contrary, the ‘midlittoral zone’ is defined by the biotic assemblages, and its boundaries are marked by floro-faunal changes. The two zonation systems are sometimes used interchangeably, but do not match closely. In macrotidal seas, the intertidal may extend upward to include the lower part of the supralittoral and downward to include the upper part of the infralittoral. In the microtidal Mediterranean Sea, the height of the waves and the irregular variations of the sea level due to winds and atmospheric pressure are more important than tides in setting the boundaries of the midlittoral zone. Emersions and immersions are therefore irregular, not periodic as the water level fluctuations due to the lunisolar tides are. In most Mediterranean shores tidal range does not exceed 30 cm; only in a few regions, such as the Northern Adriatic and the Gulf of Gabes, tidal range may reach 1 m or more. On the midlittoral rock, two different habitats can be recognized according to the height above sea level and hence the different degree of wetting: the upper midlittoral rock is located mostly above mean sea water level, whilst the lower midlittoral rock extends below the mean sea water level. The upper midlittoral rock is only moistened by the spray from the waves. Its vertical extent is highly variable depending on exposure: the more exposed the shoreline, the greater its width, and may exceed 2 m.

Geographic distribution

Upper midlittoral rock can be observed all around the Mediterranean coastline, which is 54% rocky. Species composition of the corresponding assemblage, however, may differ according to the geographic sector.

Associated habitats

The upper midlittoral rock adjoins the supralittoral rock landwards and the lower midlittoral rock seawards. In both cases, boundaries may be indistinct. Associated habitats are: ‘Association with encrusting Corallinales creating belts’ (MA1.531), ‘Association with Bangiales or other Rhodophyta, or with Chlorophyta’ (MA1.532), ‘Facies with Bivalvia’ (MA1.533), ‘Facies with Gastropoda and/or with Chthamalidae’ (MA1.534).

Related reference habitats

Species belonging to the ‘Supralittoral rock’ (MA1.51) may colonize the highest reaches of the upper midlittoral rock. Similarly, species of the ‘Lower midlittoral rock’ (MA1.54) may be found on the seaward edge of the upper midlittoral rock. Motile invertebrates from both habitats can frequently go grazing or foraging for detritus in the upper midlittoral rock, during emersions or immersions, respectively.

Possible confusion

Confusions are possible at the boundaries with the supralittoral rock (landwards), where supralittoral and midlittoral species may co-exist, and the lower midlittoral rock (seawards), which has some species in common with the upper midlittoral rock.

Typical species and associated communities

The most characteristic species of the upper midlittoral rock are chthamalid barnacles. *Microeuraphia depressa* thrives in the lower part of the supralittoral zone, and may appear in the highest verge of the upper midlittoral rock. The two midlittoral species, *Chthamalus stellatus* and *C. montagui*, may be abundant enough to form large patches, due to their gregarious habit; they may reach densities of more than 310 individuals$\cdot$m^{-2}. Their shells are whitish-grey to pale brown in colour. Both species are sospensivores: their cirri capture small planktonic prey and organic debris suspended in the water. Cirri stretch out of the shell openings during storms following wave withdrawal: when the water flows back at low speed (<4 cm$\cdot$s^{-1}), the cirri contract at a very rapid rate to actively capture food particles; when water speed is faster, the capture of food particles becomes passive. The vertical extent of the rock with chthamalids is indicative of the exposure of shores to storms: the higher the barnacle patches on the shore, the greater the exposure. In exposed locales, *C. stellatus* is more abundant than *C. montagui*. When the two species coexist, their spatial distribution varies locally, but *C. montagui* is often more abundant high in the shore, *C. stellatus* low in the shore. Differences in spatial distribution may also depend on bedrock lithology. While barnacles are crowded when the exposure is considerable, in sheltered places Cyanobacteria are more abundant. They include both epilithic (e.g., *Calothrix scopulorum* and *Scytonematopsis crustacea*) and endolithic species (e.g., *Brachytrichia quoyi* and *Entophysalis granulosa*). Endolithic species, which are also able to penetrate the shells of barnacles, are more abundant on calcareous rocks, which they corrode chemically. Cyanobacteria are grazed by limpets, which increase bioerosion scraping with the hard and resistant teeth of their radula: a single limpet may remove up to about 8 g$\cdot$a^{-1} of rock. Limpets are gastropod molluscs bearing a conical shell with a roughly oval outline, which adapts to the substrate to which the animal adheres and retains a quantity of water sufficient to prevent dehydration when out of water. Adhesion is also made possible by the secretion of a viscous substance. Different species of limpets may be found through the midlittoral zone. *Patella rustica* has an elevated light brown shell, and lives comparatively higher on the shore, reaching also the supralittoral zone; it may exhibit densities of over 100 individuals$\cdot$m^{-2}. *Patella ulyssiponensis* has a flattened, radially greenish and white shell. *Patella ferruginea* is the largest, and has a rusty-coloured shell with wide ridges and notched edges; it is a protandric species, individuals larger than 60 mm being normally females. It has a rather restricted range in the SW Mediterranean, reaching its northern limit in the Tuscan Archipelago. The Mediterranean range of *Cymbula safiana*, which has a brown shell, is even narrower: it is only found on the African coasts of the Alboran Sea. The range of the false limpet *Siphonaria pectinata* is similar, but is apparently extending eastwards. Limpets also graze the early stages of macroalgae, thus controlling their development. Only few macroalgal species rich in mucilage (a defence against drying out) may be abundant, especially in exposed locales with comparatively cooler waters. Examples include the crustose Phaeophycean *Hapalospongidion macrocarpum*, the filamentous Rhodophytes *Bangia fuscopurpurea* and *Polysiphonia sertularioides*, the encrusting calcareous Rhodophyte *Lithophyllum papillosus*, and the leafy Rhodophyte *Pyropia leucosticta*. These macroalgae peak in spring: under the high summer temperatures and the drier climate, they shrink and die out. Only toward the lower edge of the upper midlittoral rock, the crinkly Rhodophyte *Rissoella verruculosa* (whose primary production may exceed 1200 $g_{DW}\cdot m^{-2}\cdot a^{-1}$) develops a dense algal belt on exposed shores, especially on siliceous rock. *R. verruculosa* is perennial, and its basal encrusting thallus persists during the warm season. Already in early summer, however, the belt appear dehydrated and faded. This belt borders on the lower midlittoral rock, and preludes to the typical algal belts that characterize the latter habitat. *R. verruculosa* is often accompanied by the other red alga *Nemalion elminthoides*, popularly known as ‘sea spaghetti’ because of its aspect (and it is edible, too!). The crab *Pachygrapsus marmoratus* move throughout the midlittoral zone to forage.

Conservation interest and ecological role

The upper midlittoral rock is the first habitat inhabited by fully marine populations, which exhibit physiological or behavioural adaptations to tolerate prolonged emersion.

Economic importance

The ecosystem services provided to humans by the upper midlittoral rock include both provisioning services and information services. Provision services are essentially represented by the harvesting of sea spaghetti and limpets, locally appreciated as sea food; overexploitation has depleted the populations of *Patella ferruginea* in some areas. Information services are due to the scientific interest. The midlittoral rock is the favourite environment of experimental ecologists, who can easily manipulate natural situations to verify hypotheses regarding, for example, the importance of grazing in influencing algal development. The simplicity of the assemblages and their accessibility facilitate research, and many models in modern ecology derive from experiments carried out in the midlittoral zone. The other side of the coin is that midlittoral organisms are highly specialized and therefore differ from those which live always submerged: thus, generalizations from midlittoral ecology may not be applicable to the whole marine domain. The apparent on-going range extension of *Siphonaria pectinata* linked to seawater warming suggests that this species may be a practical and easy-to-monitor indicator of climate change. The vertical extent of the rock with chthamalid barnacles allows estimating the average exposure of a shore to storms even in calm sea conditions. No assessment of the monetary value of this habitat is available yet.

Vulnerability and potential threats

This habitat is heavily impacted by human trampling and other tourist-related or maritime activities, especially when located on gently sloping and easily accessible rocky coastlines. Even when located on inaccessible steep cliffs, this habitat remains anyway vulnerable to surface water pollution (oils, surfactants, nutrients).

Protection and management

Patella ferruginea is considered one of the most endangered marine invertebrates in the Western Mediterranean; consistently, it is included in the Annex II (List of endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean; in the Appendix II (Strictly protected fauna species) of the Bern Convention on the Conservation of European Wildlife and Natural Habitats; and in the Annex IV (Species in need of strict protection) of the EU Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora). *Cymbula safiana* (as *Patella nigra*) is included in the Annex II of the Barcelona Convention. Virtually all marine protected areas include rocky coast, where the upper midlittoral zone is supposedly subtracted to unsustainable human use.

Suitability of the habitat for monitoring

Barnacle and limpet abundance and algal cover may be easily monitored through time, and would provide important information on the ecological alterations suffered by the upper midlittoral rock because of climate change and/or local human impacts.

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Chthamalids and *Polysiphonia sertularioides* (© C. Morri)

Chthamalus montagui (© C.N. Bianchi)

Pachygrapsus marmoratus (© C.N. Bianchi)

Patella rustica and *P. ulyssiponensis* (© C. Morri)

Patella ferruginea (© G. Dore)

Nemalion elminthoides (© C.N. Bianchi)

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MIDLITTORAL

MA1.5 Littoral rock

MA1.54 Lower midlittoral rock

Lower midlittoral rock

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.54**
- **EUNIS 2019: MA154**
- **EUNIS 2007: A1.14 (partim), A1.23 (partim), A1.34 (partim)**
- **EC: 1170 (partim)**
- **CORINE: 18.22 (partim)**

LOCATION OF THE HABITAT

Zone	Midlittoral
Nature of the substratum	Hard (rock)
Depth range	At mean sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 34 and 39 (may be lowered by rain during low sea)
Temperature	10 °C to 28 °C
Suitability for monitoring	Yes, but not applied

Authors:
C.N. Bianchi, C. Morri

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C.N. Bianchi, C. Morri

Description of the habitat

The word ‘midlittoral’ is often considered synonymous of ‘intertidal’, so that the two are used interchangeably. In reality, they do not match closely: ‘intertidal’ explicitly refers to the tidal properties of an area, and thus considers physical limits, while ‘midlittoral’ refers to the biotic assemblages and considers floro-faunal changes. In macrotidal seas, the intertidal zone may extend upward to include the lower part of the supralittoral zone and downward to include the upper part of the infralittoral zone. In microtidal seas, such as the Mediterranean, the height of the waves and the irregular variations of the sea level due to winds and atmospheric pressure are more important than tides in setting the boundaries of the midlittoral zone. Emersions and immersions are therefore rather irregular, not periodic as the water level fluctuations due to the lunisolar tides are. In most Mediterranean shores tidal range does not exceed 30 cm; only in a few regions, such as the Northern Adriatic and the Gulf of Gabes, tidal range may reach 1 m or more. On the midlittoral rock, two different habitats can be recognized according to the height above sea level and hence the different degree of wetting: while the upper midlittoral rock is just moistened by the sea spray, the lower midlittoral rocks is maintained wet by the waves. It may be few decimetres to 1 m wide according to exposure.

Geographic distribution

Lower midlittoral rock occurs all around the Mediterranean coastline, with regional variations in species occurrence.

Associated habitats

The lower midlittoral rock borders on the upper midlittoral rock landwards, and on the infralittoral rock seawards. The boundary between the midlittoral and the infralittoral zone, marked by a comparatively sharp floro-faunal change and easily recognizable in the field, is called ‘biological zero’, and should be preferred to the mean sea level in ecological studies. The biological zero varies locally depending on exposure: it lies above mean sea level in exposed situations, and below mean sea level in sheltered areas.

The lower midlittoral rock may host ‘Association with encrusting Corallinales creating belts’ (MA1.541), ‘Association with Fucales’ (MA1.542), ‘Association with algae (algal belts), except Fucales and encrusting Corallinales’ (MA1.543), ‘Facies with *Pollicipes pollicipes*’

(MA1.544), ‘Facies with Vermetidae’ (MA1.545), ‘Facies with Bivalvia’ (MA1.546), ‘Facies with Gastropoda’ (MA1.547), ‘Midlittoral euryhaline and eurythermal pools’ (MA1.54a) and - just above the biological zero - the ‘Platforms of encrusting Corallinales’ (MA2.51).

Related reference habitats

Species belonging to the ‘Upper midlittoral rock’ (MA1.53) may colonize the highest reaches of the lower midlittoral rock. Similarly, species of the ‘Algal-dominated infralittoral rock’ (MB1.51) may be found above the biological zero in eutrophic situations. Species from the lower midlittoral rock may enter ‘Midlittoral caves’ (MA1.52).

Possible confusion

Confusions are possible at the boundaries with the upper midlittoral rock (landwards), as many motile species wander through the whole midlittoral zone, and the infralittoral rock (seawards), as some among the most tolerant infralittoral species may occur, in enclave, where local topography allows maintaining a high degree of wetting.

Typical species and associated communities

The most characteristic feature of the lower midlittoral rock is the presence of a series of algal belts, often called ‘horizons’, which develop parallel to the shoreline. The first belt, made by the Rhodophytes *Rissoella verruculosa* and *Nemalion elminthoides*, sets the border with the upper midlittoral rock. Two crustose Ochrophytes, *Nemoderma tingitanum* and *Pseudoralfsia verrucosa*, are found in the lower part of this habitat through the Mediterranean: the former is brown-yellow in colour and prefers exposed rocks; the latter is black and prefers sheltered locales. Other belts may be restricted to certain regions and/or be indicative of particular environmental situations. The Chlorophyte *Ulva intestinalis*, sometimes accompanied by the Ochrophyte *Scytosiphon lomentaria*, abound in sheltered and polluted areas. In slightly polluted waters, the Ochrophyte *Hydroclathrus clathratus* may be common, especially in the E Mediterranean. The Cyanobacterium *Rivularia atra* forms small blackish spheres in ‘degraded’ situations. The Chlorophyte *Bryopsis muscosa* develops in winter and spring on exposed shores of the NW Mediterranean. The Ochrophyte *Fucus virsoides* is endemic of the N Adriatic, where tides are comparatively important. The seaward limit of the lower midlittoral rock is typically characterized by belts made by encrusting calcareous Rhodophytes, such as *Lithophyllum papillosum*, *Neogoniolithon brassica-florida*, and especially *Lithophyllum byssoides*, which in exposed areas with pure waters of the W Mediterranean builds important bioconcretions, up to 2 m wide. The anfractuosities of the bioconcretions harbour a rich minute fauna, including the exclusive species *Lasaea rubra* (bivalve) and *Spirorbis infundibulum* (serpulid polychaete) and species of terrestrial origin such as the spider *Mizaga racovitzai* and the pseudoscorpion *Pselaphochernes litoralis*. Sessile invertebrates are rarely abundant in the lower midlittoral rock: only the beadlet anemones *Actinia mediterranea* and *A. cari* may be considered common. However, the stalked barnacle *Pollicipes pollicipes* may form facies in exposed places of North African coast of the Alboran Sea, and the hydroid *Paracoryne huvei* develops encrusting pink patches during winter in NW Mediterranean. The small Bivalve *Mytilaster minimus* may locally abound in crevices. Motile species are numerous: the typical midlittoral limpets, such as *Patella ferruginea*, *P. rustica*, *P. ulyssiponensis*, are often flanked by the infralittoral species *P. caerulea*, which tolerates periods of emersion. The keyhole limpets of the genus *Diodora*, such as *D. gibberula*, *D. graeca*, *D. italica* and others with restricted regional distributions, are similar to limpets, but have a slit at the apex of their shell. Other molluscs that graze on algae include trochid gastropods (*Phorcus articulatus*, *P. richardi*, *P. turbinatus*, *Steromphala divaricata*, *S. varia*, etc.), pulmonates (*Onchidella celtica*, *Trimusculus mammillaris*), and chitons (*Acanthochitona fascicularis*, *Lepidochitona caprearum*). Two common crabs are *Pachygrapsus marmoratus* and *Eriphia verrucosa.* Many other species of molluscs, polychaetes, and crustaceans thrive in the anfractuosities of the rock or of the bioconcretions.

Conservation interest and ecological role

The diverse and highly specialized biota of the lower midlittoral rock is of great ecological interest. The typical succession of algal belts or horizons represents a unique seascape.

Economic importance

Beside provisioning services (seafood harvesting), the main ecosystem services to humans provided by the lower midlittoral rock are information and cultural services, due to the scientific interest. The midlittoral rock is the favourite environment of experimental ecologists, who can easily manipulate natural situations to verify hypotheses regarding, for example, the importance of grazing in influencing algal development. A further important information service is the definition of the biological zero, marked by the appearance of typical infralittoral species such as the brown alga *Ericaria amentacea*, the red alga *Ellisolandia elongata*, the mussel *Mytilus galloprovincialis*, or the barnacle *Perforatus perforatus*. The individuation of the biological zero in the field has fundamental applied importance in environmental monitoring and pollution assessment studies. Under eutrophic conditions, *E. elongata* and *M. galloprovincialis* may colonize the lowest verge of the midlittoral zone in winter-spring. No assessment of the monetary value is available yet for this habitat.

Vulnerability and potential threats

This habitat is impacted by human trampling and other tourist-related or maritime activities, and is vulnerable to surface water pollution (oils, surfactants, nutrients). The lower midlittoral rock is threatened by the invasion of alien species. The Indopacific keyhole limpets *Diodora funiculata* and *D. ruppellii* compete with the native congenerics in the Levant Sea; the Indopacific mussel *Brachidontes pharaonis* is displacing the native *Mytilaster minimus* in many areas of the southern Mediterranean; the West Atlantic crab *Percnon gibbesi* contends the ecological niche of the native *Pachygrapsus marmoratus* through the whole Mediterranean.

Protection and management

Stretches of rocky coast, with their midlittoral zone, are included in virtually all marine protected areas, but no specific protection measures are envisaged for the lower midlittoral rock. Some species thriving in this habitat, such as *Lithophyllum byssoides* and *Patella ferruginea*, are considered in need of protection by international conventions (Barcelona, Bern) and/or the European Habitats Directive.

Suitability of the habitat for monitoring

Identity and extent of the algal belts and the abundance of key invertebrate species may be easily monitored through time, and would provide important information on the ecological status of the lower midlittoral rock.

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Littoral algal belts
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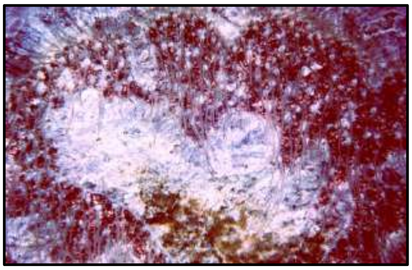
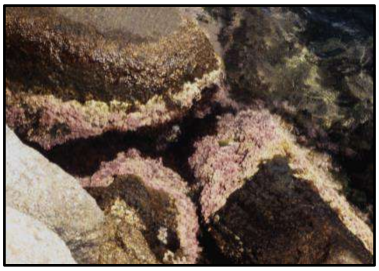
Pseudoralfsia verrucosa
(© C.N. Bianchi)


Paracoryne huvei
(© C.N. Bianchi)


Diodora italica, out the water (left) and splashed by the incoming wave (right) (© C.N. Bianchi)


Steromphala varia
(© C. Morri)


Percnon gibbesi
(© C.N. Bianchi)


Biological zero: *Ralfsia verrucosa* / *Ellisolandia elongata* (© C. Morri)


Ellisolandia elongata and *Mytilus galloprovincialis*
(© C. Morri)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Association with Fucales

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.542**
- **EUNIS 2019: MA1548**
- **EUNIS 2007: A1.316**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Mdlittoral
Nature of the substratum	Hard (rock)
Depth range	At mean sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 34 and 39 (may be lowered by rain during low sea)
Temperature	10°C to 28°C
Suitability for monitoring	Yes

Author:
L. Piazzi, F. Rindi

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LITTORAL

MA1.5 Littoral rock

MA1.54 Lower midlittoral rock

MA1.542 Association with Fucales

Description of the habitat

The association is primarily constituted by *Fucus virsoides*. The association is typical of intertidal hard substrata (both natural and artificial) and it can be found mostly in areas less exposed to wave action and characterised by the presence of the significant tides, low temperatures and the vicinity of freshwater inputs.

Geographic distribution

Fucus virsoides is endemic to the Adriatic Sea and is considered a glacial relict. It is a common species in the intertidal zone of the northern Adriatic, it is also distributed in few points in the eastern coast of the Adriatic and its southern range limit is situated along the Albanian coast.

Associated habitats

This association is included in the 'Lower midlittoral rock' (MA1.54), and it may have possible contact with other association and facies of the same zone, such as 'Association with encrusting Corallinales creating belts' (MA1.541), 'Association with algae (algal belts), except Fucales and encrusting Corallinales' (MA1.543), 'Facies with *Pollicipes pollicipes*' (MA1.544), 'Facies with Vermetidae' *(*MA1.545), 'Facies with Bivalvia' (MA1.546), and 'Facies with Gastropoda' (MA1.547).

Related reference habitats

Although this association is primarily constituted by *Fucus virsoides*, other habitats dominated by Fucales can be mostly found in the infralittoral zone in correspondence of the 'Well illuminated infralittoral rock exposed' (MB1.511a) and sheltered (MB1.511c), of the 'Lower infralittoral rock moderately illuminated' (MB1.511e), and in the 'Habitats of transitional waters' (MB1.542, MB5.542).

Possible confusion

Fucus virsoides is the only species of the genus present in the Mediterranean Sea and no confusion is possible.

Typical species and associated communities

Beyond *Fucus virsoides,* the association is also characterized by the macroalgae *Gelidium spathulatum*, *G. pulvinatum*, *Bangia* spp.

Phormidium flexuosum and *Rivularia polyotis*. *Patella caerulea*, *Mytilus galloprovincialis*, *Actinia equina* and *Balanus* spp. are among the invertebrates that may inhabit the algal assemblages.

Conservation interest and ecological role

Fucus virsoides is a canopy-forming species that creates a peculiar habitat increasing the biodiversity of the system. Moreover, the sub-layer assemblage may be considered an infralittoral enclave, with species finding a favorable biotope under the *F. virsoides* fronds. Finally, *F. virsoides* is endemic to the Adriatic Sea and is considered a glacial relict, thus the Association is extremely important from the floristic and heritage point of view.

Economic importance

The economic importance of this association has not been assessed yet.

Vulnerability and potential threats

Fucus virsoides has suffered a regression in recent decades, which has been attributed to long-term natural and human-induced changes in the biotic and abiotic conditions. The species is tolerant to wide fluctuations in temperature, salinity and nutrient concentration. However, climate-driven threats in the form of severe storm events and/or extreme high tides and temperatures have been mentioned as an important factor influencing its distribution and abundance. Moreover, it is sensitive to increased bedrock instability and overgrazing by limpets. Recent studies showed deleterious effects of low concentration of glyphosate-based herbicides on *F. virsoides*.

Protection and management

Fucus virsoides is listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995).

Suitability of the habitat for monitoring

Littoral macroalgal communities shall be assessed within the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC). The CARLIT method for the assessment of the ecological quality of rocky coast, allows to monitor extensive geographical areas in a short time scale.

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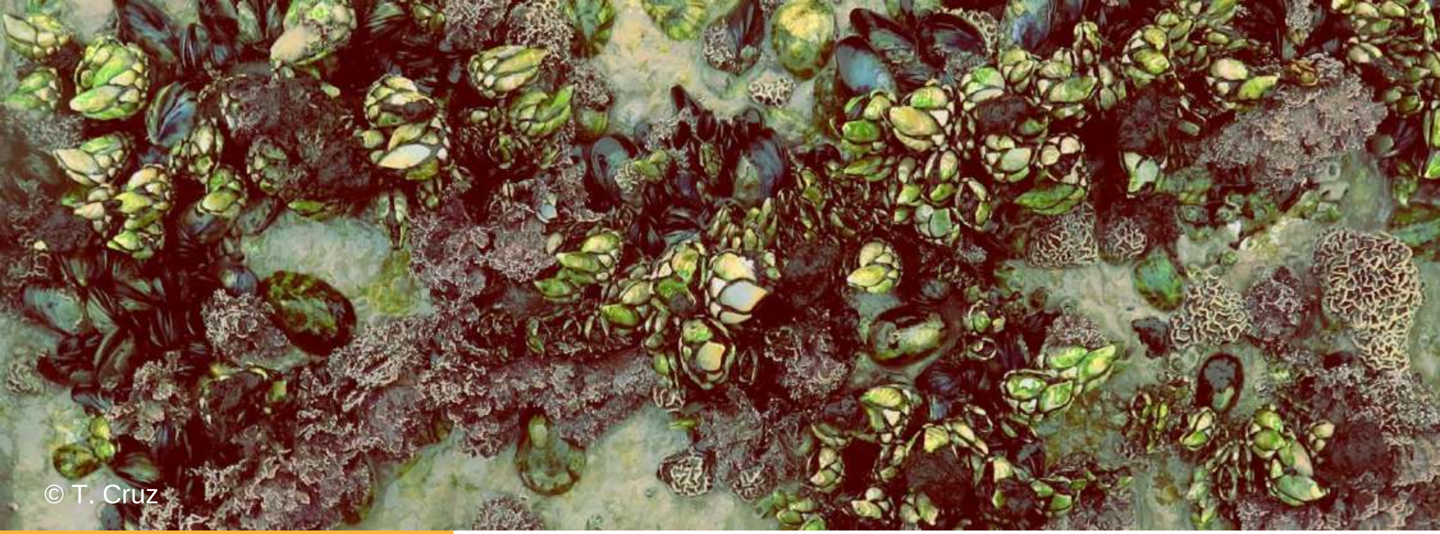
Fucus virsoides (© C. Battelli)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Facies with *Pollicipes pollicipes*

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.544**
- **EUNIS 2019: MA1541**
- **EUNIS 2007: A1.142**
- **EC: 1170 (partim)**
- **CORINE: 18.22 (partim)**

LOCATION OF THE HABITAT

Zone	Midlittoral
Nature of the substratum	Hard (rock)
Depth range	At mean sea level
Position	Coastal
Hydrodynamic conditions	Strong to very strong
Salinity	Between 34 and 39
Temperature	10 °C to 28 °C
Suitability for monitoring	Yes, but not applied

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MIDLITTORAL

MA1.5 Littoral rock

MA1.54 Lower midlittoral rock

MA1.544 Facies with *Pollicipes pollicipes*

Description of the habitat

This facies is located in the lower midlittoral of very exposed rocky shores and cliffs, its upper limit lying a few decimetres above mean sea level. It is characterized by the presence of the stalked barnacle *Pollicipes pollicipes*, a cirriped crustacean. *P. pollicipes* may form clusters of sessile individuals attached to each other and to the primary substratum within a complex biological matrix. The species has a flexible, muscular stalk, known as the peduncle, which supports the main body known as the capitulum. The capitulum is triangular in shape and white-grey in colour, and is protected by numerous plates of different sizes. Six pairs of thin, feather-like cirri can be seen to arise from within the mantle cavity and are used for feeding. The peduncle may reach over 10 cm in length and is strongly attached to the substratum by a cement extruded at the base of the peduncle, which resists repeated battering in exposed conditions. The abundance of the species is controlled by predation (by seabirds and starfish - not to forget humans!), which may vary along wave exposure gradients at a different spatial and temporal scales.

Geographic distribution

Pollicipes pollicipes is generally found from Ireland and SW Great Britain to NW Spain, Portugal and W Africa down to Senegal. In the Mediterranean, it is restricted to the Alboran Sea, in Catalan Bay (Gibraltar) and along the N African coast to Algiers, but it is generally rare and does not form facies as dense as in the Atlantic. Old records from the Mediterranean coasts of Spain and France need confirmation.

Associated habitats

The facies with *Pollicipes pollicipes* is situated between the ‘Upper midlittoral rock’ (MA1.53) and the ‘Infralittoral rock’ (MB1.5). In particular, it may be directly in contact with the ‘Facies with Gastropoda and/or with Chthmalidae’ (MA1.534) and the ‘Well illuminated infralittoral rock exposed’ (MB1.51a). There may be species in common with the ‘Facies with Bivalvia’ (MA1.546) and the ‘Facies with Gastropoda’ (MA1.547). Other associated habitats may be ‘Association with encrusting Corallinales creating belts’ (MA1.541), ‘Association with Fucales’ (MA1.542), ‘Association with algae (algal belts), except Fucales and encrusting Corallinales’ (MA1.543), and ‘Facies with Vermetidae’ (MA1.545).

Related reference habitats

The facies with *Pollicipes pollicipes* shares species with other reference habitats of the 'Lower midlittoral rock' (MA1.54).

Possible confusion

The superficially similar species of the family Lepadidae (the largest in the Mediterranean being *Lepas anatifera*) live attached to floating objects and not to midlittoral rock. *Scalpellum scalpellum* is another species of stalked barnacle living in the Mediterranean Sea, but is smaller than *Pollicipes pollicipes* and occurs much deeper (usually below 50 m).

Typical species and associated communities

Pollicipes pollicipes is a simultaneous hermaphrodite, capable of fertilising other nearby individuals by transmitting sperm through a penis, and also of brooding its own eggs in its mantle cavity. Adults produce approximately 30,000-130,000 eggs per brood and have multiple broods per year. Larvae are gregarious and settle intensively on conspecifics, which helps creating a benign habitat with reduced physical and biological stresses and facilitates mating. Notwithstanding wide interannual variability, recruitment occurs mainly in mid-summer to mid-autumn. Growth rates vary between 0.11 and 0.66 mm per month. Longevity may reach 20-30 years in the wild. Its diet mainly consists of zooplankton, but may also include detritus. Associated species are those typical of the midlittoral rock, and include algae (*Caulacanthus ustulatus*, *Nemalion elminthoides*, *Rivularia bullata*, *Ulva laetevirens*), beadlet anemones (*Actinia mediterranea*), limpets (*Cymbula safiana*, *Patella ferruginea*, *P. rustica*, *Siphonaria pectinata*) and other gastropods (*Phorcus turbinatus*), chitons (*Acanthochitona fascicularis*, *Rhyssoplax olivacea*), acorn barnacles (*Chthamalus montagui*, *C. stellatus*), and shore crabs (*Pachygrapsus marmoratus*).

Conservation interest and ecological role

Pollicipes pollicipes is very rare in the Mediterranean Sea; several aspects of its biology and ecology are yet to be studied. Dense clusters of individuals enhance habitat heterogeneity, thus increasing biodiversity.

Economic importance

Pollicipes pollicipes is an appreciated seafood since antiquity: the soft part of the peduncle (muscle and ovary) are eaten boiled and are considered a delicacy. The species is therefore an important economic resource and is intensively harvested on intertidal and shallow subtidal rocky shores wherever it is abundant. In Portugal and Spain, its commercial value can reach 200 €·kg^{-1} in restaurants. *Lepas anatifera* has a similar gastronomic utilization, but a much lower economic value. *P. pollicipes* is harvested with a hand-held scraper: being abundant in very exposed shores, its exploitation may be a dangerous activity, and likely to undergo extended periods of cessation due to rough sea conditions. Aquaculture is being sought as an alternative to supply the market and to diminish pressure upon natural populations. In addition to food provision, *P. pollicipes* offers information services, being a candidate sentinel species for coastal contamination.

Vulnerability and potential threats

The facies with *Pollicipes pollicipes* is vulnerable to surface water pollution (oils, surfactants, nutrients) and overharvesting by humans, which may also damage the leftover clumps of the species by trampling and hasty collecting.

Protection and management

No specific protection exists for the Mediterranean examples of this facies. Along the west Iberian coastal area, where the exploitation of *Pollicipes pollicipes* is intense, national and regional management strategies do exist to regulate harvesting, and include release of licenses, size and bag limits, and catch reporting.

Suitability of the habitat for monitoring

Little is known about the numerical consistency and conservation status of the Mediterranean populations of *Pollicipes pollicipes*. Monitoring of both the species and the harvest effort should be a priority. Although the midlittoral zone should be easily accessible, exposure to rough sea may complicate the implementation of regular surveys.

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Pollicipes pollicipes (© D. Caffier)

Dense cluster on an overhang (© M.C. Salles)

Individuals with protruding cirri (© V. Maran)

Lepas anatifera (© C.N. Bianchi)


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Midlittoral euryhaline and eurythermal pools

Reference codes for identification:

- **BARCELONA CONVENTION: MA1.54a**
- **EUNIS 2019: MA154A**
- **EUNIS 2007: A1.234**
- **EC: 1170 (partim)**
- **CORINE: 18.22 (partim)**

LOCATION OF THE HABITAT

Zone	Midlittoral
Nature of the substratum	Hard (rock)
Depth range	At sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 32 and 40 (may be lower during heavy rain at low sea)
Temperature	10 °C to 29 °C
Suitability for monitoring	Yes, but not applied

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MIDLITTORAL

MA1.5 Littoral rock

MA1.54 Lower midlittoral rock

MA1.54a Midlittoral euryhaline and eurythermal pools

Description of the habitat

Depressions and hollows within the midlittoral rock permanently filled with sea water are called tide pools. Tide pools have various shapes and sizes but are normally shallow, their depth rarely exceeding 1 m. As they form near mean sea level, tide pools are never completely isolated from the sea. In macrotidal seas, these pools exist as separate bodies of water only at low tide, while are completely connected with the sea at high tide: cycles of isolation from and connection with the sea are therefore regular and rather short. In the microtidal Mediterranean Sea, the importance of the tide is small with respect to the height of the waves and the sea level variations due to winds and atmospheric pressure: isolations and connections are therefore irregular, not periodic as the water level fluctuations due to the lunisolar tides are. In any case, tide pools remain completely separated from the sea for only a comparatively short time, which prevents extreme variations in the physico-chemical conditions of the water by rainfall or evaporation. Salinity is normally comprised between 32 and 40, but vertical stratification of salinity may occur during periods of isolation from the sea. Water temperature changes seasonally between 10 °C and 29 °C, but can also show sensible variations on a daily basis. Oxygen content (normally above 90% of saturation) and pH may fluctuate because of biological processes and water fluxes. Fluctuations in the physico-chemical regime tend to be smaller in tide pools located lower on the shore, making them more benign habitats for the biota.

Geographic distribution

Tide pools can be observed in the midlittoral zone of most Mediterranean rocky shores. Regional differences in species occurrence may exist.

Associated habitats

Tide pools are nested in the midlittoral rock, and can be found throughout the midlittoral zone. Tide pools located comparatively high on the shore may occur in the vicinity of the supralittoral rock, whereas those low on the shore may be in contact with the upper infralittoral rock.

Related reference habitats

Species belonging to the ‘Upper midlittoral rock’ (MA1.53) and the ‘Lower midlittoral rock’ (MA1.54) may colonize the borders of the tide pools. Most tide pool dwellers are species typical of the ‘Algal-dominated infralittoral rock’ (MB1.519).

Possible confusion

Tide pools located comparatively high on the shore may be confused with rock pools, which occur in the supralittoral rock and are much more isolated from the sea.

Typical species and associated communities

Although they inhabit the midlittoral zone, organisms living in tide pools do not undergo alternating emersion and submersion. Most species have infralittoral affinity, provided that they can tolerate greater environmental change with respect to their strictly infralittoral relatives. Typical midlittoral species are restricted to the borders of the tidal pools. It has therefore said that tide pools do not represent a midlittoral habitat, but correspond to infralittoral enclaves in the midlittoral zone. The kind of organisms thriving in tide pools varies from diatoms to macroalgae and from invertebrates to fish. Species richness is positively correlated with tide pool depth and volume, and with topographic heterogeneity. Infralittoral algae find in tide pools refuges from herbivory: large herbivorous fish, such as *Sarpa salpa*, do not enter tide pools, and sea urchins, such as *Arbacia lixula* and *Paracentrotus lividus*, are uncommon there (when present, however, their grazing may condition algal development). Resident herbivorous snails may be abundant but have little effect on algal cover. Similarly, large predator fish are absent from tide pools, which makes them refuges also for the invertebrates. Macroalgae in tide pools comprise several tens of species, with a majority of Rhodophyta, followed by Chlorophyta and Ochrophyta. A distinct and persistent vertical zonation pattern of macroalgae can be observed on the walls of steeply sided tide pools. At the bottom of the pool, perennial species of Fucales, such *Cystoseira compressa*, *Ericaria brachycarpa*, *E. crinita* and *Sargassum vulgare*, are normally dominant. Other common species are *Dictyota dichotoma*, *Ellisolandia elongata*, *Halopteris scoparia, Hypnea musciformis*, *Padina pavonica*, and *Ulva australis*, while the ephemeral algae *Ceramium diaphanum* and *Cladophora rupestris* may be abundant in certain situations. When the Fucales are abundant, the macroalgal assemblage is typically organized in three layers: a basal substratum cover by encrusting red algae, a species-rich understory, and a canopy of Fucales. Such a complex spatial organization favours a diverse associate fauna. Dominance of different algal groups is indicative of water quality and environmental stress: assemblages are dominated by Fucales in pristine conditions and by Ulvales in more stressed environments, whilst intermediate situations are characterized by the coralline alga *E. elongata*. Among the invertebrates, cnidarians are represented by *Actinia mediterranea*, common on shaded walls, and by *Anemonia viridis* and *Exaiptasia diaphana*, which can be found on the bottom of the pool. Among molluscs, limpets, such as *Patella caerulea*, *P. ulyssiponensis* and *Siphonaria pectinata*, normally stay on the walls of the pool. The snails *Cerithium vulgatum*, *Columbella rustica*, *Conus ventricosus*, *Phorcus turbinatus*, *Pisania striata* and *Steromphala umbilicaris*, among others, creep on both walls and bottom. The mussel *Mytilus galloprovincialis* may abound in certain pools. The shrimp *Palaemon elegans*, the hermit crab *Clibanarius erythropus*, and the crabs *Eriphia verrucosa*, *Pachygrapsus marmoratus*, *Pilumnus hirtellus* and *Xantho poressa* are the main crustaceans. Besides sea urchins, echinoderms may be represented by the sea star *Coscinasterias tenuispina*. Several small fish species, especially blennids, inhabit tide pools: *Parablennius sanguinolentus* is the most abundant, *Zebrus zebrus* the most typical; other species are *Coryphoblennius galerita*, *Microlipophrys dalmatinus*, and *Salaria pavo*. The gobiid *Chromogobius quadrivittatus* and the tripterygiid *Tripterygion tripteronotum* may also be common.

Conservation interest and ecological role

Tide pools reduce stress in the intertidal zone, providing shelter to algae and invertebrates, thus enhancing local biodiversity. The specific characteristics of tide pools such as depth, volume, orientation, shading and flushing rate, make each individual pool unique. The virtual absence of tides on most Mediterranean shores makes of the Mediterranean tide pools a particular biotope, of which it would be interesting to seek the equivalent in other warm seas provided with tides of various amplitudes.

Economic importance

The ecosystems services that tide pools provide to humans are essentially cultural and information services, which include the teaching opportunities that tide pools offer to students of natural sciences. Scientific research holds a major importance: because of their variable characteristics, well-defined boundaries and manageable size, tide pools can serve as experimental mesocosms to test general ecological theories about community organization. For assemblages where active migration is not possible (e.g., macroalgae, sessile invertebrates), the theory of island biogeography can be tested, with the open ocean acting as the ‘mainland’ and the individual pools as ‘islands’. However, tide pools have the peculiarity to be an intermediate habitat type between the infralittoral zone and the emergent substrata of the rocky midlittoral zone, so that caution is advised when applying models developed in tide pools to other marine systems. Last but not least, tide pools are a source of inspiration not only for naturalists and marine biologists. The American writer and Nobel laureate John Steinbeck wrote: “It is advisable to look from the tide pool to the stars and then back to the tide pool”.

Vulnerability and potential threats

Tide pools are vulnerable to oil spills and other forms of pollution and littering. They may be easily devastated by coastal zone developments, including seaside resorts and all kinds of concrete, sediment and debris inputs. Tide pools are particularly prone to the invasion of alien species, whose successful establishment is presently favoured by sea water warming: major examples include the alga *Caulerpa cylindracea* and the crab *Percnon gibbesi*, which have spread through the Mediterranean and may outcompete native species.

Protection and management

No specific protection measures are envisaged for this habitat. Virtually all marine protected areas include rocky coasts, where the tide pools possibly present are supposedly subtracted to human impact. *Cymbula safiana*, restricted to the African coasts of the Alboran Sea, is included (as *Patella nigra*) in the Annex II (List of endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean.

Suitability of the habitat for monitoring

Macroalgal cover and invertebrate and fish abundances may be easily monitored though time, and would provide relevant information on the ecological modifications due to climate change and/or local human impacts.

Algal zonation on the wall of a tide pool (© C. Morri)

Halopteris scoparia on the floor of a tide pool (© C. Morri)

Ulva australis (© C. Morri)

Actinia mediterranea, out the water (left, © C. Morri) and partially immersed (right, © G. Dore)

Phorcus turbinatus and *Caulerpa cylindracea* (© F. Caroli)

Columbella rustica (© C.N. Bianchi)

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Platforms of encrusting Corallinales

Reference codes for identification:

- **BARCELONA CONVENTION: MA2.51**
- **EUNIS 2019: MA1542, MA1552**
- **EUNIS 2007: A1.141, A2.7**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Midlittoral
Nature of the substratum	Hard (rock)
Depth range	At mean sea level
Position	Coastal
Hydrodynamic conditions	Strong
Salinity	Between 34 and 39 (may be lowered by rain during low sea)
Temperature	10°C to 28°C
Suitability for monitoring	Yes

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LITTORAL
MA2.5 Littoral biogenic habitat
MA2.51 Platforms of encrusting Corallinales

Description of the habitat

The habitat is mostly constituted by calcareous concretions built by the red algae *Lithophyllum byssoides*. The distribution of *L. byssoides* is limited to the intertidal zone, where these algae thrives on vertical or subvertical rocky surfaces, especially those facing North. Due to the limited Mediterranean tidal range (20-40 cm), this zone corresponds to a narrow belt ~1 m wide, located just above the mean sea level. Beyond *L. byssoides* other non-geniculate coralline algae (*Neogoniolithon* spp.) may co-occur in this zone. In favorable environmental conditions (unpolluted, dim light and high hydrodynamism), numerous *L. byssoides* thalli coalesce and form thick concretions that cover the rocky bottom, sometimes protruding up to 2 meters from the colonized rocky surface. These rims are called “encorbellements”, when they protrude a little, or “trottoirs”, when protrude considerably. When present, *L. byssoides* rims usually are not continuous along the shoreline but are best developed in inlets, crevices or other spots that provide partially shaded conditions and some shelter from wave action. The internal organization of a *L. byssoides* rim is composed of three different parts: (i) a porous outer layer of living alga, a few centimeters deep, located on the upper and vertical surfaces of the rim, resting upon an unconsolidated layer of dead thalli, (ii) an inner hardened multi-layered zone resulting from deposition processes filling-up the interstices between lamellae with a hardened sedimentary matrix, and (iii) a lower eroded surface that is dead and profusely colonized by subtidal organisms.

Geographic distribution

The habitat is relatively common in the western and central Mediterranean Sea, but it does not occur in the easternmost parts of the basin.

Associated habitats

The habitat is included in the ‘Lower midlittoral biogenic habitat’ (MA2.51). It may have contact with ‘Association with Fucales’ (MA1.542), ‘Association with algae, except Fucales and Corallinales’ (MA1.543), ‘Facies with *Pollicipes pollicipes*’ (MA1.544), ‘Facies with Vermetidae’ (MA1.545), ‘Facies with Bivalvia’ (MA1.546), ‘Facies with Gastropoda’ (MA1.547), ‘Reefs of *Sabellaria* spp.’ (MA2.52), and ‘Reefs of Vermetidae’ (MA2.53).

Related reference habitats

The habitat may be also found in the ‘Upper midlittoral rock’ (MA1.531), in the ‘Lower midlittoral rock’ (MA1.541), and in the ‘Well illuminated infralittoral rock exposed’ (MB1.513a) as ‘Association with encrusting Corallinales creating belts.

Possible confusion

The habitat cannot be confused with others in the intertidal zone. Other coralline structures of similar dimension may be found in subtidal habitats.

Typical species and associated communities

Other algae are usually associated with a well-developed rim of *Lithophyllum byssoides* (e.g., *Chaetomorpha* spp.*i Palisada perforata*, *Pterocladiella melanoidea*, and *Taenioma nanum*). The lower part of the rims is profusely colonized by sciaphilic algae and invertebrates that are similar to those living in clefts and caves. At the base of the living part of the rims many endolithic Cyanophyceae can be observed. Various types of bioeroders (sponges of the genus *Cliona*) and boring species (molluscs of the genus *Lithophaga*, etc.) are also present, reducing the stability of the rim by creating tunnels and cavities into the bioconstruction. The polychaete *Spirorbis infundibulum* is exclusive to this habitat.

Conservation interest and ecological role

Due to such habitat-building capacity, *Lithophyllum byssoides* is considered a species of great ecological importance. The three-dimensional massive reefs increase the biodiversity of littoral systems and are a marker of the mean sea level, testifying a stability of the sea level over several centuries. The formation of a thick rim of *L. byssoides* is a slow process that requires decades, centuries, or sometimes millennia.

Economic importance

Lithophyllum byssoides rims provide regulating (i.e., carbon sequestration), and cultural ecosystem services to humans. The economic importance of this association has not been assessed yet.

Vulnerability and potential threats

Lithophyllum byssoides is threatened by several anthropogenic impacts acting at different spatial scales. It is sensitive to pollution, coastal development, water turbidity and trampling. Global warming is another important threat for this species. The increased amount of CO_2 produces higher acidification of the sea water with negative consequences on biogenic calcareous concretions. The building up of this species is linked to a stable or very slowly rising sea-level. In fact, the present well-developed algal rims were formed in ~300 years of sea-level stabilization, throughout the last cold phase in the history of the Earth's climate, known as the Little Ice Age. The current rate of sea-level rise appears too fast for the growth capacities of *L. byssoides* rims and many of these biogenic formations are already submerged and dead and all of them are threatened with extinction in the medium term. Moreover, a further threat is related to the high cryptic genetic diversity of *L. byssoides* that encompasses several distinct clades, possibly species, which have much more restricted geographical distribution.

Protection and management

Due to its ecological importance, *Lithophyllum byssoides* is listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention) and in the Appendix I (Strictly protected flora species) of the Bern Convention.

Suitability of the habitat for monitoring

Lithophyllum byssoides has limited tolerance to environmental impacts caused by pollution, coastal development and sedimentation. Well-developed populations of this species are considered evidence of high environmental quality and *L. byssoides* rims have been selected as bio-indicator in the framework of the European Water Framework Directive (2000/60/EC). Moreover, due to the narrow vertical distribution of *L. byssoides* associated with the mean water mark, rims are considered good indicators of near stable or slowly rising sea level over long periods. A study based on carbon 14 (^{14}C) dating of rims allowed the reconstruction of sea-level variation correlated to climate changes for the last 1,500 years. *L. byssoides* rims are normally monitored through the CARLIT method but a more specific approach based on field census (photographic, random quadrat and line transect methods) has been proposed to analyze the ecological quality of rims based on the assessment of *L. byssoides* condition (live, dead, epiphytic, broken, or eroded) and the assessment of the percentage cover of live and dead *L. byssoides* areas.

“Trottoir” of *Lithophyllum byssoides* (© G. Sartoni)

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Banks of dead leaves of macrophytes

Reference codes for identification:

- **BARCELONA CONVENTION: MA2.54**
- **EUNIS 2019: MA2561**
- **EUNIS 2007: A2.131**

LOCATION OF THE HABITAT

Zone	Lower midlittoral, with possible extension into the supralittoral
Nature of the substratum	Hard (biogenic)
Depth range	At mean sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 34 and 39 (may be lowered by rain during low sea)
Temperature	10 °C to 28 °C
Suitability for monitoring	Not known

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LITTORAL

MA2.51 Lower midlittoral biogenic habitat

MA2.54 Banks of dead leaves of macrophytes

Description of the habitat

This is a biogenic habitat made up by the accumulation of macrophytes debris, both seagrass and terrestrial halophytic plants (e.g., *Salicornia* spp.), but it is mostly made by dead *Posidonia oceanica* leaves and/or leaves of other seagrass species (e.g., *Cymodocea nodosa*, *Zostera noltei*). When large masses of dead leaves and debris accumulate along the coastline (depositing over rock, coarse, mixed and sand sediments), they create a monumental and permanent biogenic structure called as 'bank' or '*banquette*' using the original French name. These banks may be few centimetres to hundreds of metres wide, and up to 3 m high and develops in the littoral zone from the lower to the upper midlittoral, and with possible extension into the supralittoral zone. When the amount of accumulated debris is lower (deposits of few centimetres high) and does not persist permanently on the coastline but it is under a seasonal dynamic, the habitats they create are called as 'Deposit of dead leaves of macrophytes' when accumulates on supralittoral (MA3.51a, MA4.51a, MA5.51a) and midlittoral (MA3.52a, MA4.52a, MA5.52a) sediments, and 'Wracks of dead leaves of macrophytes ' (MA1.51b) when accumulates on supralittoral rock.

The accumulation of dead leaves and debris (in banks, deposits, or wracks) is a very dynamic process throughout the year, varying according to the season and the hydrodynamic conditions of the site. Formation of banks and deposits depends on the availability of leaf debris in the surf zone. It usually accumulates during late summer and autumn, and in winter part of these banks/deposits is destroyed by erosive phenomena during storms and the leaf debris is further fragmented, transported as floating material and then moved far away or at depths down to the bathyal level. The temperature is highly variable (also reaching very high values of 50°C during the summer) and the daily differences in temperature may be more than 20°C.

Banks, deposit and wracks of macrophytes debris always include a large amount of sediment of the upper beach and also a fairly amount of anthropogenic litter.

Geographic distribution

This habitat occurs in the entire Mediterranean, where seagrass meadows and terrestrial halophyte plants are present along the coastline.

Associated habitats

Banks of dead leaves of macrophytes (also deposits and wracks) can be found associated with virtually all the habitats of the ‘Supralittoral rock’ (MA1.51), of the ‘Upper midlittoral rock’ (MA1.53), of the ‘Lower midlittoral rock’ (MA1.54), of the ‘Supralittoral coarse sediment’ (MA3.51), of the ‘Supralittoral mixed sediment’ (MA4.51), of the ‘Supralittoral sand sediment (MA5.51), of the ‘Supralittoral mud sediment (MA6.51), of the ‘Midlittoral coarse sediment’ (MA3.52), of the ‘Midlittoral mixed sediment’ (MA4.52), of the ‘Midlittoral sand sediment’ (MA5.52), and of the ‘Midlittoral mud sediment’ (MA6.52).

Related reference habitats

‘Deposit of dead leaves of macrophytes’ on supralittoral coarse (MA3.51a), mixed (MA4.51a), sand (MA5.51a) sediments; ‘Deposit of dead leaves of macrophytes’ on midlittoral coarse (MA3.52a), mixed (MA4.52a), sand (MA5.52a) sediments; ‘Wracks of dead leaves of macrophytes ’ on supralittoral rock (MA1.51b); ‘Association with macrophytes’ on supralittoral coarse (MA3.511), mixed (MA4.511), sand (MA5.511), mud (MA6.511) sediments; ‘Association with indigenous marine angiosperms’ on midlittoral coarse (MA3.521), mixed (MA4.521), sand (MA5.521) sediments; ‘Association with halophytes or marine angiosperms’ on midlittoral mud (MA6.521a); ‘Association with indigenous marine angiosperms or other halophytes’ in the habitats of transitional waters on rock (MB1.541), sand (MB5.541), and mud (MB6.511); ‘*Posidonia oceanica* meadows’ (MB2.54), on rock (MB2.541), on matte (MB2.542), on sand, coarse or mixed sediment (MB2.543); ‘Natural monuments/Ecomorphoses of *Posidonia oceanica*’ (MB2.545); ‘Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.’ (MB2.546); ‘Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica*’ (MB2.547); ‘Association with indigenous marine angiosperms’ in well sorted fine sand (MB5.521) and in sheltered waters (MB5.531).

Possible confusion

Banks of dead leaves of macrophytes may be confused only with the similar related reference habitats, i.e. the ‘Deposit of dead leaves of macrophytes’ on supralittoral (MA3.51a, MA4.51a, MA5.51a) and midlittoral (MA3.52a, MA4.52a, MA5.52a) sediments, and the ‘Wracks of dead leaves of macrophytes ’ on supralittoral rock (MA1.51b). The distinction among these three formations is made according to size, location and dynamics:

- Bank or *banquette*: a very large biogenic structure of few centimetres to several metres wide, and up to 2 m high, which is mainly permanent through the year;
- Deposit: the amount of accumulated leaves and debris on the shoreline can be wide but it is usually few centimetres high and does not persist permanently on the shoreline being influenced by seasonal dynamics;
- Wrack: a small amount of dead leaves and debris accumulated into pools and crevices of the littoral rock.

Typical species and associated communities

The habitat is created by dead leaves of the seagrass *Posidonia oceanica*, *Cymodocea nodosa*, and *Zostera noltei* and of the terrestrial halophyte plants. The fauna associated to banks of dead leaves of macrophytes (and to deposits and wracks) is temporary and is made up mainly by detritivores, scavenging species and their predators (such as sea birds). The main macrofaunal taxa are represented by the insects Coleoptera, Dermaptera, Diptera, Hymenoptera, Orthoptera and Thysanoptera, the Chilopoda centipedes and millipedes, the Araneae dwelling spiders, the crustaceans Amphipoda (e.g. *Orchestia* spp.), Isopoda (e.g. *Halophiloscia couchii*, *Tylos ponticus*) and Decapoda, the molluscs Gastropoda (e.g. *Haminoea navicula*, *Myosotella myosotis*, Truncatella *subcylindrica*) and Bivalvia (e.g. *Abra alba*, *Cerastoderma glaucum*, *Loripes orbiculatus, Ruditapes decussatus*), Polychaeta (e.g. *Prionospio multibranchiata*), Oligochaeta, and Sipuncula.

Conservation interest and ecological role

The habitat, especially when it is well developed in banks or wide deposits, constitutes the most effective natural protection for the beach against erosion dissipating the wave energy. The vertical and horizontal wave swash in the case of seagrass bank/deposit presence seems to be approximately one-third of that in the case of their absence. Dead leaves and debris of macrophytes constitute the basis of a rich trophic web characterised by the presence of detritivores, and originate ecological corridors.

The foredune systems are constituted of alternating layers of seagrass dead leaves and sediment. The residual nutrient content of dead matter represents an important input of nitrogen and carbon, contributing to the accretion of the foredunes and their colonization by halophilous pioneer vegetation. Debris and dead leaves may also return to the sea during winter storms, where they are subject to microbian activity entering the trophic web and becoming one of the major constitutive elements. An average of 60 kg m^{-3} of sediment can be trapped in seagrass banks, and their removal can influence the sediment budget of beaches.

Economic importance

In the past, necromasses were considered a common feature of the Mediterranean shoreline landscape. In some areas of the Mediterranean, seagrass leaves are still used in cattle feed, as compost for fertilization following special treatments, and in construction industries as thermal insulation material on roofs. Many species find in banks/deposits/wracks of dead leaves of macrophytes a refuge and a temporary or permanent habitat. Banks of dead leaves provide regulating services, such as carbon sequestration, coastal protection, and nutrient recycling; provisioning services, such as food production, materials and genetic resources availability (due to the biodiversity they host); habitat services, due to the creation of a three-dimensional structure that amplifies the space available; and information services, in terms of scientific research. The coastal protection against erosion is among the most important ecosystem services the habitat provides.

Vulnerability and potential threats

This habitat develops is areas particularly affected by trampling and anthropogenic waste. The habitat may be directly destroyed by the development of clean beaches in resorts and touristic areas. Although the high ecological role they play, banks and deposits are usually removed from beaches mainly for aesthetic reasons and for tourism purposes, using heavy machinery without the use of grid systems. Removal can negatively affect both the morphology of the beach, in terms of flattering and obliteration of sedimentary features, and the functioning of coastal ecosystems, due to the permanent loss of nutrients and sediments. The removal of 1000 m^3 of debris represents a loss of 19-44 m^3 of sediment. Also, the removal deprives the environment of the additions of organic material and destroy the associated fauna.

Protection and management

Removal of dead leaves and debris represents a crucial operation that must be actuated with the maximum caution. Management strategies lack of specific laws and regulations: existing legislation is not easy to apply as a true classification of dead leaves of macrophytes stranded on beaches as waste is not available yet. The best management solution from the ecological point of view is the maintenance of banks and deposits on-site, to ensure all their services and the mechanical protection of beaches. This strategy is applicable whenever the presence of accumulation does not conflict with tourist activities and in coastal areas where the erosive phenomenon is strong, and always within marine protected areas. This solution is foreseen in the model of the ‘ecological beach’, firstly proposed in France and recently implemented and applied in Italy, where dead leaves of macrophytes are viewed as a natural and valuable component of the coastline. To successfully spread this model, several activities must be implemented, such as a regulatory framework, the collection of data about the occurrence of deposits, management protocols and educational programs for the dissemination of the ecological and economic value of the beach deposits, aimed at switching the perception of this phenomenon towards a positive appraisal.

When it is not possible to maintain banks/deposits on site, removal should be performed with the maximum care and limited to the touristic summer season. Biomass should be transported in the backshore of the same beach to feed the foredunes, or can be moved in nearby beaches that are vulnerable to erosion and employed in shore protection measures. In certain situations, the burying of biomasses on site is also possible.

Today the recycling of dead leaves and debris can be carried out to product compostable material. This solution partly offset transport costs and avoid landfill charges at municipal solid waste treatment plants. Dumps disposal must be the last solution and is the most expensive choice in terms of economic and ecological cost; it must be applied wherever true hazard to human health, such as putrefactive phenomena and mixing with human waste make non compatible the maintenance of stranded debris with the beach-users. Thus, banks and deposits can be removed and treated as municipal waste, according the existing legislation.

Suitability of the habitat for monitoring

This habitat, as well as other related reference habitats of deposits and wracks of dead leaves of macrophytes, are not contemplated in monitoring programs (IMAP of Barcelona Convention, Water and Marine Strategy Directives).

Wracks of dead leaves of macrophytes on supralittoral rock (MA1.51b) (© M. Montefalcone)

Banks of dead leaves of *Posidonia oceanica* (MA2.51a) (© M. Montefalcone)

Deposit of dead leaves of macrophytes on supralittoral sands (MA5.51a), with psammophylous plant *Pancratium maritimum* (MA5.511) (© M. Montefalcone)

Deposit of dead leaves of macrophytes on midlittoral sands (MA3.52a) (© M. Montefalcone)

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LITTORAL

MA3.5 Littoral coarse sediment, MA4.5 Littoral mixed sediment, MA5.5 Littoral sand, MA6.5 Littoral mud

MA3.51 Supralittoral coarse sediment, MA4.51 Supralittoral mixed sediment, MA5.51 Supralittoral sand, MA6.51 Supralittoral mud

MA3.511, MA4.511, MA5.511, MA6.511 Association with macrophytes

Description of the habitat

This association is characterised by macrophytes that develop in the supralittoral zone on a substrate consisting of soft sediments, including sand, coarse, gravel, pebbles, shingle or cobbles, and mud sediment, which are often unstable. This habitat develops in the supralittoral zone of marine, brackish and even fresh waters near the mouths of rivers and represents a small portion of the emergent sandy beaches extending from the beach berm (just above the high tide mark) to the dune and foredune systems (which belong to the terrestrial adlittoral zone). This habitat normally does not include the habitats of consolidated dunes, which are often characterized by woody vegetation, are influenced by marine aerosol or by the capillarity of sea water, but are not reached, except in exceptional cases, by the spray of sea water. The habitat may also include temporary or - rarely - semi-permanent pools, fed by splashes of sea and meteoric water.

The halophytic vegetation of this zone is strongly influenced by sand mobility, soil salinity, water availability, nutrient status, and temperature, which depend on the seasonal variations of the ground water level and on the distance from the sea. The rapid drainage, the scarce possibility of retaining water on the surface, and the instability of the substrate limit these macrophytes to a small number of highly adapted species, although an increase in specific diversity can be observed proceeding landward. Macrophytes communities are thus dominated by psammophylous-halophilous species, made by emerging and rooting perennial plants able to tolerate some extent of salt concentration and with a wide ecological range. These plants display one ore more of these functional traits: 1) very developed roots to be able to reach deep water that is scarce on the surface; 2) resistance to the brackish environment, and to the tiny salt crystals carried by winds that can damage buds and leaves; 3) a low or a prostrate habitus to oppose the wind with a limited resistance; 4) seeds and seedlings well adapted to the effects of sand burial; 5) leaves with a light color to protect themselves from the sun’s rays; 6) surface of the leaves reduced to a

Association with macrophytes

Reference codes for identification:

- **BARCELONA CONVENTION: MA3.511, MA4.511, MA5.511, MA6.511**
- **EUNIS 2019: MA551**
- **EUNIS 2007: B1.1, B1.22, B1.31, B1.32**
- **EC: 1210, 2110, 2120**
- **CORINE: 16, 16.12, 16.2, 16.3**

LOCATION OF THE HABITAT

Zone	Supralittoral
Nature of the substratum	Soft (coarse, mixed, sand, mud sediments)
Depth range	Above mean sea level
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	From low-salinity brackish waters to hypersalinity
Temperature	Extremely variable
Suitability for monitoring	Yes, but not applied

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minimum and covered with a light coat to avoid excessive transpiration (the loss of water could be lethal); 7) accumulation of water in the aerial parts, which often have leaf and/or stem succulence; 8) reduced transpiration, to avoid excessive evaporation caused by strong solar radiation. The pioneer vegetation enhances particle trapping and organic matter accumulation contributing to the development of the dune systems. Macrophytes also act as a buffer by dissipating wind energy, reducing turbulence and thus sediment erosion. On the other hand, these plants serve as a buffer by trapping wind-eroded particles from the landward side. Wracks made by marine phanerogam debris can be washed up from nearby meadows and deposited in this zone. These wracks always include a fairly sizeable part of other additional elements of anthropogenic or natural origin.

The habitat is dominated by stress-tolerant halophylous psammophytes such as *Cakile maritima*, *Salsola* spp., *Thinopyrum junceum*, *Euphorbia peplis* and *Calamagrostis arenaria* or by halophylous ruderal therophytes such as *Xanthium strumarium*. The common reed *Phragmites australis,* the spiny rush *Juncus acutus* and *Carex arenaria*, and other sand grasses and sedges can be abundant.

Geographic distribution

This habitat may occur in the entire Mediterranean in correspondence of suprallitoral soft sediments.

Associated habitats

Macrophytes can be associated with virtually all the habitats of the supralittoral zone, especially with those on sand and mixed sediment and, to a lesser extent, with those of coarse sediment or mud. Associated habitats can be ‘Deposit of dead leaves of macrophytes’ (MA3.51a, MA4.51a, MA5.51a), ‘Beaches with slowly-drying wracks’ (MA3.51b, MA4.51b, MA5.51b), ‘Beaches with slowly-drying wracks under glassworts’ (MA6.51a), and ‘Banks of dead leaves of macrophytes (*banquette*)’ (MA2.51a). In the zonation of the coastal dune system, this habitat can be in contact with the habitats of the ‘Midlittoral sand’ (MA5.52), which can occur at the seaward edge, and with those habitats often filled with groundwater causing interdunal waterbodies (ponds or lagoons) and other ‘Habitats of transitional waters’ (MA6.52a).

Related reference habitats

This habitat is related with the ‘Association with halophytes or marine angiosperms’ (MA6.521a) in transitional waters.

Possible confusion

The meaning of the term macrophytes is here referred to halophytic plants large enough to be easily visible and not limited to aquatic macroalgae, bryophytes and vascular plants. This habitat cannot be confused being characterized by plant species living on soft sediments in the supralittoral zone, which carry out their vegetative and reproductive cycle in the emerged form.

Typical species and associated communities

The supralittoral plant community is dominated by annual or perennial psammophylous and halophilous herbs and grasses and is strictly linked to these habitats: 1) Annual vegetation of drift lines; 2) Embryonic shifting dunes; 3) Shifting dunes along the shoreline with *Calamagrostis arenaria* (white dunes). The habitat is more rarely linked to the following habitats: 1) Fixed coastal dunes with herbaceous vegetation (grey dunes); 2) *Crucianellion maritimae* fixed beach dunes; 3) *Malcolmietalia* dune grasslands; 4) *Brachypodietalia* dune grasslands with annuals; 5) Coastal dunes with *Juniperus* spp. Dunes with *Cisto-Lavanduletalia* sclerophyllous scrubs can be considered totally excluded from this habitat.

The habitat with annual vegetation of drift lines includes communities of annual plants that start the dune building, occur on beaches with sand and/or fine gravel near the shoreline, where the organic matter brought by the waves accumulates and decomposes, creating a substrate rich in sea salts and organic matter decomposition. The most frequent or diagnostic species are the halophytes *Cakile maritima*, *Salsola kali*, *Euphorbia peplis*, *E. paralias*, *Mattiola sinuata*, *M. tricuspidata*, *Glaucium flavum*, and the nitrophylous and ruderal *Xanthium strumarium*, *Atriplex prostrata*, and *Raphanus raphanistrum* subsp. *landra*. The vegetation of embryonic shifting dunes represents the first stage of the plant colonization, which allows the spread of many other species, feeding the dune construction process; it is dominated by *Thinopyrum junceum* and other psammophylous perennial plants such as *Sporobolus virginicus*, *Cyperus capitatus*, *Otanthus maritimus*, *Echinophora spinosa*, *Eryngium maritimum*, *Medicago marina*, *Calystegia soldanella*, and *Pancratium maritimum*. White dunes (shifting or more stabilized inner dunes) form the seaward cordons of dune systems along the sand coasts; this habitat represents a semi-permanent stage, and the vegetation is dominated by *Calamagrostis arenaria*, *Echinophora spinosa*, *Anthemis maritima*, *Eryngium maritimum*, *Euphorbia paralias*, *Medicago marina*, *Cyperus capitatus*. The reed *Phragmites australis* can be locally dominant as it tolerates salty waters and varying nutrient concentrations from oligotrophic to eutrophic, but it is rare in very nutrient-poor waters. It spreads by a dense web of rhizomes and stolons, and secondly by wind-dispersed seeds, forming impenetrable barriers that do not allow other species taking root, except some *Cladium mariscus* plants. The giant reed *Arundo donax* and other similar species (e.g., *A. donaciformis*, *A. plinii*) spread often in the supralittoral zone influenced by human interventions. Some invasive alien species, such as *Carpobrotus acinaciformis*, *C. edulis*, *Oenothera* spp., *Cenchrus* spp., and *Yucca gloriosa* can also be found. Sedges (*Scirpus* spp. and *Carex* spp.) belonging to the family Cyperaceae are also common where the water table emerges, at least seasonally.

Conservation interest and ecological role

Salt-tolerant plants are now receiving increased attention from botanists and agriculturists because soil salinity is increasing in many parts of the world (due to low quality irrigation water, high evaporation-to-rainfall ratios and rising sea levels associated with global warming), and particularly in arid regions where salinity problems are very crucial. As along the shores of freshwater bodies, macrophytes tend to produce extensive root networks in coarse grained sediments of the supralittoral zone, allowing for a stronger holdfast and for an effective sequestration of the scarce nutrients in such sediments. This extensive root network also results in a reduced likelihood of uprooting and a more stable sediment. Macrophytes also support a rich biodiversity and are of major importance for migratory birds as they constitute wintering grounds. Their production can represent an important part of the primary production in coastal environments.

Economic importance

Macrophytes can be exploited for an array of uses like fodder, fuel wood, edible oil-seed, medicines, landscaping, and environment conservation through carbon sequestration. They also contribute to the stabilization of coasts and beaches against erosion. Other uses include the utilization in laundry detergent, paper production, herbal tea, seafloor fixation, as a green cover, as ornamental plants and as hedge. Macrophytes provide regulating services, such as carbon sequestration and nutrient recycling; provisioning services, such as food production, materials and genetic resources availability (due to the biodiversity they host); habitat services, due to the creation of a three-dimensional structure that amplifies the space available for associated organisms; and information services, in terms of scientific research and monitoring.

Vulnerability and potential threats

This habitat is highly vulnerable being directly affected by various anthropogenic pressures along the coast, such as trampling and waste. The main threats are linked to coastal development and urban activities (direct destruction for land reclaim, dredging, modification of hydrodynamics and sediment budget, pollution, eutrophication), living resources exploitation, global warming and sea-level rise. Sea-level rise may decrease overall plant diversity by selecting species that are more tolerant to sustained flooding and by the loss of those species that are less competitive to changing conditions. Where landward migration is impeded, rising sea levels are likely to promote the conversion of this vegetated habitat into unvegetated open water systems.

Protection and management

Associations with macrophytes in the supralittoral zone are part of the Natura 2000 habitat types of the Annex I of the EU Habitat Directive, e.g., Annual vegetation of drift lines (code 1210), Embryonic shifting dunes (code 2110), Shifting dunes along the shoreline with *Calamagrostis arenaria* (ex *Ammophila arenaria*) (white dunes) (code 2120). Among psammophylous species there are many endangered and some endemic species; some of these are listed in the Annex I (‘Strictly protected flora species’) of the Bern Convention on the conservation of wildlife and natural environment of Europe.

Suitability of the habitat for monitoring

This habitat is not contemplated in monitoring programs (IMAP of Barcelona Convention, Water and Marine Strategy Directives).

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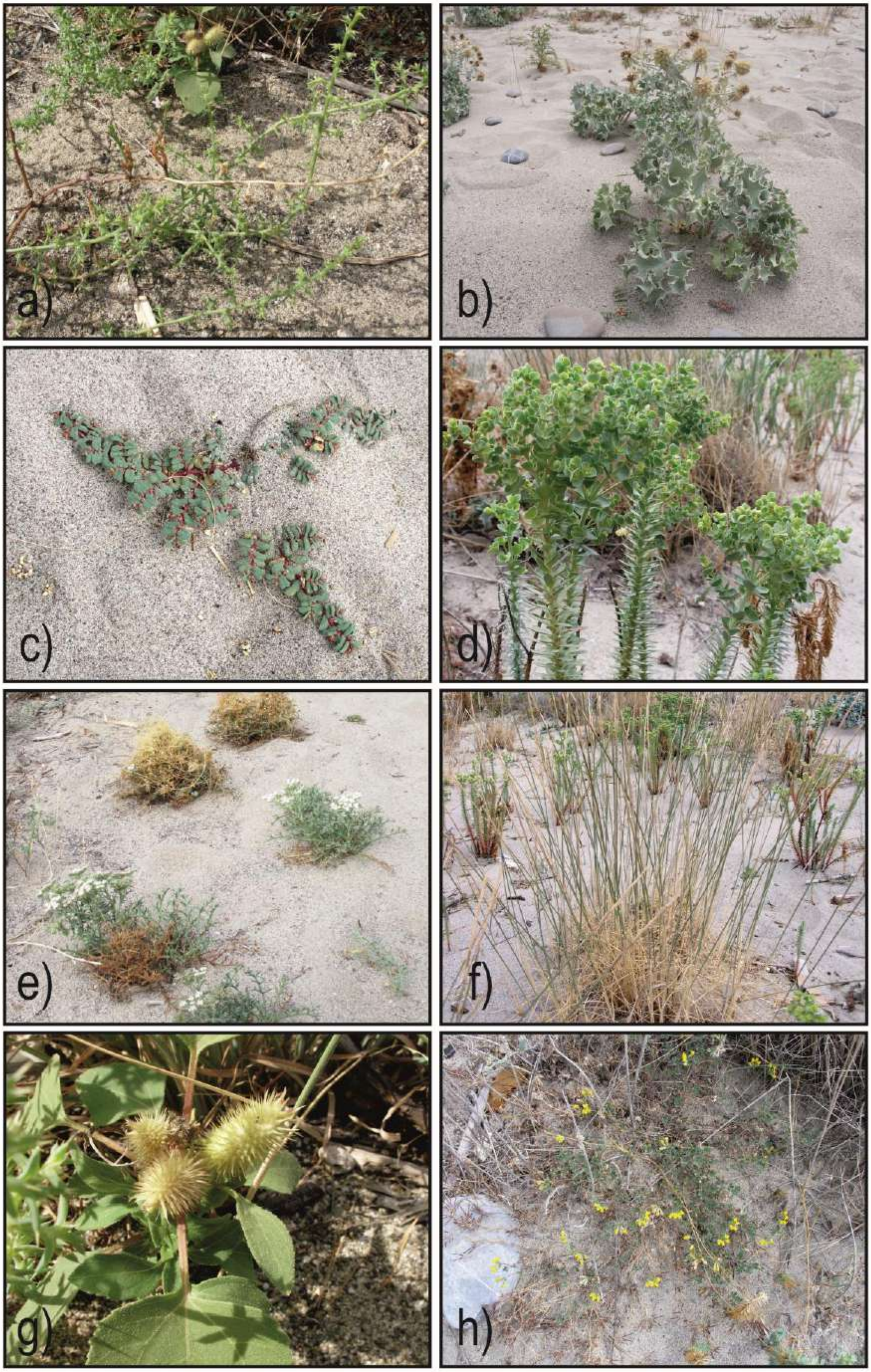

Association with macrophytes in the supralittoral sand: *Cakile* sp. (a); *Eryngium maritimum* (b); *Euphorbia peplis* (c); *Euphorbia paralias* (d); *Echinophora* sp. (e); *Thinopyrum junceum* (f); *Xanthium strumarium* (g); *Lotus cytisoides* (h) (© M. Mariotti)


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Association with halophytes or marine angiosperms

Reference codes for identification:

- **BARCELONA CONVENTION: MA6.521a**
- **EUNIS 2019: MA251,MA252, MA253, MA254, MA5531, MA6511, MB554, MB652**
- **EUNIS 2007: A2.52, A2.53, A2.54, A2.55, A2.5511, A2.2, A2.3, A5.53, A5.3**
- **EC: 1130, 1140, 1150*, 1310, 1320, 1410, 1420, 1510***
- **CORINE: 11.3, 11.33, 11.41, 13.2, 14, 15, 23.2**

LOCATION OF THE HABITAT

Zone	Midlittoral
Nature of the substratum	Soft (mud, muddy-sand)
Depth range	At sea level
Position	Paralic
Hydrodynamic conditions	Weak
Salinity	From low-salinity brackish waters (0.5) to hypersalinity (45+)
Temperature	Extremely variable
Suitability for monitoring	Yes

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Photo credits:
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LITTORAL

MA6.5 Littoral mud

MA6.52 Midlittoral mud

MA6.52a Habitats of transitional waters

MA6.521a Association with halophytes or marine angiosperms

Description of the habitat

This association is characterised by aquatic Tracheophyta that develop in the habitats of transitional waters (e.g., coastal lagoons, estuaries, sea inlets, marshes, littoral ponds) of the midlittoral zone, mainly on soft bottoms formed by mud or muddy-sand (the granulometry is variable according to the course of the river bed). Halophytic vegetation is mainly composed by succulent and perennial plants enable to evade and/or tolerate salinity by various eco-physiological mechanisms. The main factors controlling vegetation are water salinity in the growing season and the depth and period of flooding. The salinity is variable over the short or long term (daily to annual), and usually the surface salinity is low whereas that of the deep layer, in contact with the benthic fauna, is much higher. The temperature is also variable. Tides are weak and only cause minor changes in the water's chlorinity. Littoral mud typically forms extensive mudflats, though dry compacted mud can form steep and even vertical structures, particularly at the top of the shore adjacent to saltmarshes. The banks are relatively stable, but the beds change during the violent winter flooding. In the absence of a strong tide effect, the transition is rapid between the (freshwater) limnic environment and the marine environment, and there is no gradient in the distribution of the organisms, which occurs patchily. The species present in this habitat are characterised by very rapid cycles of development. Halophytes can also tolerate some extent of immersion in salty waters, being salt tolerant plants adapted to the extremely variable conditions of the midlittoral zone. Characteristic halophytes include about a dozen plants with relevant covers. The most abundant are: *Sarcocornia* spp., *Salicornia* spp., *Limonium* spp., *Halimione portulacoides*, *Juncus* spp., *Spartina* spp., *Suaeda* spp., *Salsola* spp., *Kochia* spp., *Arthrocnemum macrostachyum*, *Atriplex portulacoides*, and *Scirpus* spp. These associations belong to various Natura 2000 habitats including 1310, 1320, 1410, 1420 1510*. Physiochemical proprieties of transitional intertidal habitats are stressful for most angiosperms, as only few species can tolerate the anoxic, chemically reduced, high-saline soils typical of these ecosystems, such as *Zostera* spp. and *Ruppia* spp. (see sheet MB6.511 for details on these plants of transitional waters).

Geographic distribution

Association with halophytes or marine angiosperms can develop at the scale of the whole Mediterranean Sea, but are particularly abundant in the North-Western Adriatic Sea where the habitats of transitional waters are dominant.

Associated habitats

Halophytes (upper midlittoral zone) and aquatic angiosperms (lower midlittoral zone and infralittoral zone) of transitional waters can be associated with the ‘Habitats of salinas’ (MA6.522a). This habitat may also be in contact with the ‘Fine sand in very shallow waters’ (MB5.51), the ‘Fine sand in sheltered waters’ (MB5.53), the ‘Association with Fucales’ (MB5.542), the ‘Association with photophilic algae’ (MB5.543), the ‘Facies with Polychaeta’ (MB5.544), and the ‘Facies with Bivalvia’ (MB5.545).

Related reference habitats

This habitat is related with the ‘Habitats of transitional waters’ (MB1.54, MB5.54) in the infralittoral zone, especially the priority habitat 1150* (coastal lagoons) that includes most of the bottoms of transition environments, and with their ‘Association with aquatic angiosperms or other halophytes’ (MB1.541, MB5.541). It also shares some halophytes with the ‘Beaches with slowly-drying wracks under glassworts’ (MA6.51a) and with the Association with macrophytes (MA6.511). Some of the characteristic aquatic angiosperms of this habitat may also be found in the ‘Association with indigenous marine angiosperms’ in well sorted fine sand (MB5.521) and in fine sand in sheltered waters (MB5.531).

Possible confusion

The habitat dominated by halophytes cannot be confused being characterized by species living in the midlittoral zone of transitional waters and estuaries, which carry out most, or even all, of their vegetative and reproductive cycle in the emerged form, differently to aquatic angiosperms (i.e., *Zostera* spp., *Ruppia* spp.) that can emerge only during the low tide. A possible confusion may occur in the distinction between the angiosperm species.

Typical species and associated communities

The emergent and submerged vegetation shows a gradient from the upland to the open water, starting from the supralittoral community dominated by shrubs and trees and with an understorey of halophytic emergent wetland plants. The lower midlittoral zone of coastal lagoons hosts the aquatic angiosperms *Zostera marina*, *Z. noltei*, *Ruppia cirrhosa*, and *R. maritima* and, in the most desalinated areas, *Zannichellia palustris, Althenia filiformis* and *Stuckenia pectinata* (see sheet MB6.511 for details on these plants). In correspondence of river deltas different transitional water habitats can develop, each showing a peculiar associated community. The brackish ponds show a vegetation community similar to that of coastal lagoons, but in the presence of salinities lower than 10 psu the reed *Phragmites australis* can be absolutely dominant, forming impenetrable barriers that do not allow other species taking root, except some *Cladium mariscus* plants. In the presence of higher or highly variable salinities, halophytes prevail with a fringe of *Salicornia* spp. in the wetter areas, whilst *Sarcocornia* spp., *Juncus* spp., *Salsola* spp., *Halimione portulacoides*, *Limonium* spp., *Puccinellia* spp., *Inula crithmoides*, *Spartina* spp., *Artemisia maritima* and *Shoenus* spp. in the more elevated and remote from the sea areas. In the inner delta are frequent *Suaeda* spp., *Kochia* spp., *Salsola* spp. In brackish riparian marshes near the river deltas several *Juncus* spp. and *Scirpus* spp. dominate the vegetation. Other halophytes that may be present in this habitat include *Crithmum maritimum, Aeluropus* spp., *Aster* spp., *Carex* spp., *Eleocharis* spp., *Ranunculus* spp., *Senecio* spp., *Trifolium* spp., *Arthrocnemum macrostachyum*, *Atriplex portulacoides*, *Halocnemum strobilaceum*, *Limoniastrum monopetalum*, etc.

Communities associated with vascular plants are those of the euryhaline and eurythermal environments (see sheet MB6.51 for more details). Little oxygen penetrates muddy sediments, and an anoxic layer is often present only within a few millimetres of the sediment surface. Littoral mud can support rich infaunal communities characterised by polychaetes, bivalves and oligochaetes, whereas on the plants many species of gastropods, arachnids and insects are very common.

Conservation interest and ecological role

Although economic consideration of halophytes and other salt-tolerant plants is just beginning, they are now receiving increased attention from botanists and agriculturists because soil salinity is increasing in many parts of the world, and particularly in arid regions where salinity problems are very crucial. Increased attention result from low quality irrigation water (water with high salt content), high evaporation-to-rainfall ratios and, in coastal lowlands, from rising sea levels associated with global warming. These plants support a rich biodiversity and are of major importance for migratory birds and constitute wintering grounds for thousands of ducks, coots, geese, and flamingos. Halophytes, some macroalgae and aquatic angiosperm production can represent an important part of the primary production in transitional environments. Coastal lagoons are important nursery areas for many fish species ad provide food for large number of waterfowl. River deltas are breeding and feeding habitat for many species of resident birds and provide food for many populations of migrating weterfolw. Aquatic angiosperms play an essential ecological role also in terms of sedimentary balance, bottom and shoreline stability, water oxygenation and associated biodiversity.

Economic importance

Halophytic flora can be exploited for an array of uses like fodder (e.g. *Salsola* spp.), fuel wood, edible oil-seed, medicines, landscaping, and environment conservation through carbon sequestration. They also contribute to the stabilization of coasts and beaches. Some plants can provide the starch, sugar, protein, fiber, and tannin materials (e.g. *Suaeda* spp., *Salicornia* spp.). Other uses of halophytes include the utilization in reclamation of saline lands, laundry detergent, paper production, herbal tea, seafloor fixation, as a green cover, as ornamental plants and as hedge. Aquatic plants provide regulating services, such as carbon sequestration and nutrient recycling; provisioning services, such as food production, materials and genetic resources availability (due to the biodiversity they host); habitat services, due to the creation of a three-dimensional structure that amplifies the space available for associated organisms; and information services, in terms of scientific research and monitoring.

Vulnerability and potential threats

Even thought that aquatic plants in transitional waters are well adapted to highly dynamic and often stressful environmental conditions, they are highly vulnerable being directly affected by various anthropogenic pressures along the coast. The main threats are linked to coastal development and urban activities (direct destruction for land reclaim, dredging, modification of hydrodynamics and sediment budget, pollution, eutrophication), living resources exploitation, global warming and sea-level rise. Sea-level rise may decrease overall plant diversity by selecting species that are more tolerant to sustained flooding, or through the loss of mid-and high-marsh species that are less competitive to changing conditions. Where landward migration is impeded, rising sea levels are likely to promote the conversion of this transitional habitat into unvegetated open water systems.

Protection and management

Habitats of transitional waters are listed in the Natura 2000 habitat types of the Annex I of the EU Habitat Directive, i.e. Estuaries (code 1130), Mudflats and sandflats not covered by seawater at low tide (code 1140), Coastal lagoons (code 1150*, also a priority habitat), Annual pioneer vegetation of *Salicornia* and other species of muddy and sandy areas (code 1310), *Spartina* meadows (*Spartinion maritimae*) (code 1320), Mediterranean flooded pastures (*Juncetalia maritimi*) (code 1410), Mediterranean and Thermo-Atlantic prairies and fruit groves (*Sarcocornetea fruticosi*) of brackish marshes (code 1420), Mediterranean salt steppes (*Limonietalia*) (code 1510*, also a priority habitat). Among halophytes there are many endangered and endemic species. Some species of the genus *Salicornia*, *Salsola*, *Kochia*, *Puccinellia, Suaeda* and *Limonium* are listed in the Annex I (‘Strictly protected flora species’) of the Bern Convention on the conservation of wildlife and natural environment of Europe.

Aquatic angiosperms are considered worthy of protection. *Zostera noltei* and *Z. marina* are listed in the Annex II “List of endangered or threatened species” to the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA & BD Protocol, Barcelona Convention). *Z. marina* also enjoys protection by the Bern Convention on the conservation of wildlife and natural environment (Annex I, ‘Strictly protected flora species’). The Action Plan for the Conservation of Marine Vegetation in the Mediterranean, adopted in 1999 by the Contracting Parties to the Barcelona Convention, set priorities and management activities to be undertaken to protect seagrass meadows. Many Mediterranean countries included marine angiosperms in their national lists of protected species.

Suitability of the habitat for monitoring

Due to the sensitivity of aquatic plants to environmental alterations, they are commonly used as excellent indicators of the overall environmental quality. Aquatic angiosperms have been included as common indicators in the guidelines for monitoring marine habitats in the Mediterranean Sea, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Halophytes and aquatic angiosperms of transitional habitats have also been defined as biological quality elements in the European Directives on environmental quality assessment (under the Water Framework Directive and the Marine Strategy Framework Directive). Due to the limited number of halophytes, the presence of sensitive taxa is more difficult to comply with; however, in transitional environments, the more diverse the plant communities, the healthier the zone is considered to be. This is why the species diversity is the main diagnostic tool adopted in monitoring programs. In transitional waters, ecological status evaluation is also made by using aquatic angiosperms and macroalgae through the adoption of the *Macrophyte Quality Index.*

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The halophytes *Aster tripolium* (left panel) and *Limonium serotinum* (right panel) (© A. Sfriso)


M. Montefalcone

Algal-dominated infralittoral rock

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.51**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	0 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photos credit:
M. Montefalcone, A. Tommasi

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.51 Algal-dominated infralittoral rock

Description of the habitat

Algal-dominated infralittoral rock is distributed on rocky substrates from the surface down to 30-40 m depth, depending on water clarity and bottom slope. The distinctive feature of the habitat is the dominance of macroalgae over invertebrates.

Geographic distribution

The association is distributed on all Mediterranean rocky coasts.

Associated habitats

The habitat occurs in the 'Infralittoral rock' (MB1.5) and may have possible contact with 'Coralligenous (enclave of circalittoral)' (MB1.55), '*Posidonia oceanica* meadows' (MB2.54), 'Invertebrate-dominated infralittoral rock' (MB1.52), 'Reefs of Vermetidae' (MB2.51), 'Reefs of *Sabellaria* spp.' (MB2.52), 'Reefs of *Cladocora caespitosa*' (MB2.53). Other habitats associated with Algal-dominated infralittoral rock are 'Association with Fucales' (MB1.511a, MB1.511c, MB1.511e), 'Association with photophilic algae, except Fucales, encrusting Corallinales and Caulerpales' (MB1.512a, MB1.512c), 'Association with encrusting Corallinales' (MB1.513a, MB1.511b, MB1.513c, MB1.511d), 'Association with *Caulerpa prolifera*' (MB1.514a, MB1.512b, MB1.514c, MB1.512d, MB1.513e), 'Association with non-indigenous Mediterranean *Caulerpa* spp.' (MB1.515a, MB1.513b, MB1.515c, MB1.513d, MB1.514e), 'Facies with Scleractinia' (MB1.516a, MB1.515b, MB1.516c, MB1.516e), 'Facies with Bivalvia' (MB1.517a), 'Facies with Echinoidea on encrusting Corallinales' (MB1.518a), 'Facies with Hydrozoa' (MB1.514b), 'Facies with Alcyonacea' (MB1.514d, MB1.515e), 'Association with Laminariales' (MB1.512e), and 'Association with Laminariales (kelp beds)' (MB1.512e).

Related reference habitats

'Well illuminated infralittoral rock, exposed' (MB1.51a), 'Moderately illuminated infralittoral rock exposed' (MB1.51b), 'Well illuminated infralittoral rock sheltered' (MB1.51c), 'Moderately illuminated infralittoral rock sheltered' (MB1.51d), 'Lower infralittoral rock moderately illuminated' (MB1.51e).

Possible confusion

The habitat could be confused with the infralittoral ‘Coralligenous (enclave of circalittoral)’ (MB1.55) but this latter develops on biogenic substrates.

Typical species and associated communities

Due to the wide bathymetric range and different environmental conditions that characterize the habitat, many different assemblages can develop. Two main habitats may be distinguished along the bathymetric gradient: a deeper habitat with more stable environmental conditions and a shallower habitat that is strongly controlled by water movements and light irradiance. In relation to these two environmental factors, four main communities may be distinguished within the shallower habitat: well-lit exposed, moderately-lit exposed, well-lit sheltered, moderately-lit sheltered. Well-lit exposed assemblages are dominated by Fucales. Moderately-lit exposed assemblages are characterized by sciafilous macroalgae living in exposed areas, such as *Plocamium cartilagineum*, *Shottera nicaense, Gelidium melanoideum* and *Cladophora pellucida*. Well-lit sheltered assemblages are characterized by photophilous algae, such as *Padina pavonica, Dictyota dichotoma, Acetabularia acetabulum.* Moderately-lit sheltered assemblages included sciaphilous species, such as *Peyssonnelia* spp., *Flabellia petiolata, Sphaerococcus coronopifolius* and *Chrysymenia ventricosa*.

Conservation interest and ecological role

The habitat is the most extensive in the Mediterranean coastal rocky bottom. Since it consists mostly of autotrophic organisms, it plays a key role in the productivity and carbon cycle of the coastal system. It is characterised by high biodiversity, hosts many commercially important organisms and includes many species of conservation interest, such as Fucales, Laminariales and coralline algae.

Economic importance

Due to their role in supporting primary production and biodiversity, the habitat provides provisional (food through fisheries) and regulatory (carbon sequestration, nutrient recycling) ecosystem services. To date, the economic value of the habitat has not been assessed except for rocky habitat dominated by Fucales that has been estimated 1.28 em € m^{-2}.

Vulnerability and potential threats

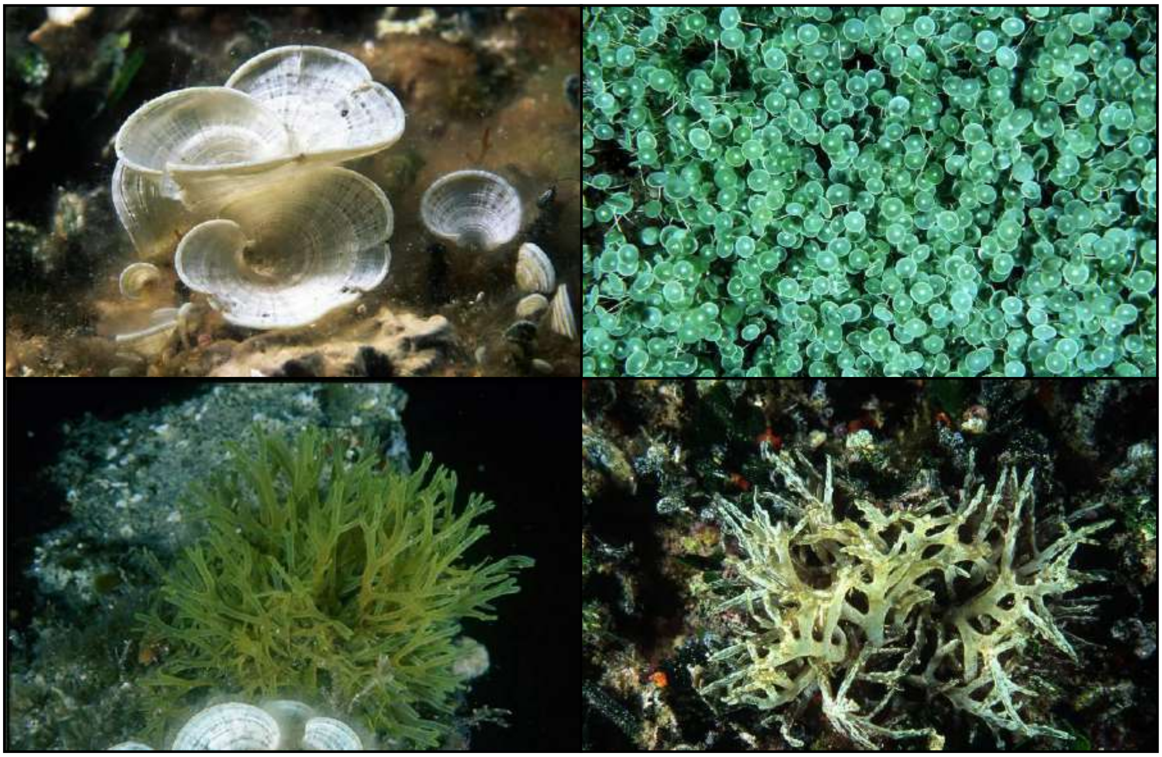
Depending on the variety of assemblages that characterize the habitat, different levels of vulnerability may occur. In general, because of its proximity to the coastline, the habitat is exposed to most human pressures. In particular, coastal algal assemblages are threatened by pollution, sedimentation, shoreline modification, eutrophication, sea urchins overgrazing and invasion by alien species. Sea urchins can eliminate all fleshy algae causing a shift to barren grounds. High nutrient concentration and sedimentation rates can erode biodiversity and enhance the spread of opportunistic species, leading to widespread biotic homogenization. Alien organisms can out-compete and eliminate native macroalgae.

Protection and management

Several key species of the habitat, such as Fucales, Laminariales and coralline algae are listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995), and in the Appendix I “Strictly protected flora species” of the Bern Convention.

Suitability of the habitat for monitoring

Macroalgae are considered suitable biological indicators to assess the ecological status of marine environment in the context of the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC). Several indices have been proposed to assess the ecological quality of Mediterranean macroalgal assemblages: CARLIT is used to evaluate very shallow assemblages, EEI can be employed in all infralittoral zone, M-ALEX has been developed to assess the ecological quality of assemblages in relation to the level of invasion of alien species.



Padina pavonica (top left), *Acetabularia acetabulum* (top right)*, Dictyota dichotoma* (bottom left)*, Chrysymenia ventricosa* (bottom right) (© A. Tommasi)

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Association with Fucales

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.511a, MB1.511c**
- **EUNIS 2019: MB1512,MB1513, MB151F, MB151G, MB151H, MB151J, MB151K, MB151L**
- **EUNIS 2007: A3.23A, A3.23B, A3.23C, A3.23D, AB.23D, A3.239, A3.132, A3.234**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	0 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
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INFRALITTORAL

MB1.5 Infralittoral rock

MB1.51 Algal-dominated infralittoral rock

MB1.51a Well illuminated infralittoral rock exposed

MB1.51c Well illuminated infralittoral rock sheltered

MB1.511a, MB1.511c Association with Fucales

Description of the habitat

The association is an algal-dominated assemblage characterized by beds of canopy-forming Fucales of the genera *Cystoseira, Ericaria, Gongolaria* and *Sargassum*. These algal assemblages mostly occur in exposed and well-illuminated rocky bottoms. The association develops from the surface to 30-40 m depth, depending on environmental conditions, especially water clarity.

Geographic distribution

The association is distributed on all the Mediterranean coasts, although the dominant species may change depending on biogeographical and ecological conditions.

Associated habitats

The habitat is included in the 'Algal-dominated infralittoral rock' (MB1.51), and it may have possible contact with 'Coralligenous (enclave of circalittoral)' (MB1.55), '*Posidonia oceanica* meadows' (MB2.54), 'Invertebrate-dominated infralittoral rock' (MB1.52), 'Reefs of Vermetidae' (MB2.51), 'Reefs of *Sabellaria* spp.' (MB2.52), and 'Reefs of *Cladocora caespitosa*' (MB2.53). This habitat may be found associated with 'Association with photophilic algae, except Fucales, encrusting Corallinales and Caulerpales' (MB1.512a, MB1.512c), 'Association with encrusting Corallinales' (MB1.513a, MB1.513c), 'Association with *Caulerpa prolifera*' (MB1.514a, MB1.514c, MB1.513e), 'Association with non-indigenous Mediterranean *Caulerpa* spp.' (MB1.515a, MB1.515c, MB1.514e), 'Facies with Scleractinia' (MB1.516a, MB1.516c, MB1.516e), 'Facies with Bivalvia' (MB1.517a), 'Facies with Echinoidea on encrusting Corallinales' (MB1.518a), 'Facies with Alcyonacea' (MB1.515e), 'Association with Laminariales' (MB1.512e), and 'Association with Laminariales (kelp beds)' (MB1.512e).

Related reference habitats

‘Association with Fucales’ can also be found in the lower infralittoral rock moderately illuminated (MB1.511e), in the habitats of transitional waters (MB1.542, MB5.542), in the lower midlittoral rock (MA1.54), in the algal-dominated coralligenous (MC1.512a), and in the coralligenous platforms (MC2.512).

Possible confusion

The habitat could be confused with the circalittoral ‘Association with Fucales or Laminariales’ (MC1.512a) but it develops in shallow waters on rocky bottoms, while the latter habitat develops on a biogenic substrate.

Typical species and associated communities

The association is distributed within wide bathymetric and biogeographic ranges, so many species may dominate assemblages locally. The most important Fucales are *Ericaria amentacea, Ericaria brachycarpa, Ericaria crinita, Cystoseira crinitophylla, Gongolaria sauvageauana, Gongolaria montagnei, Cystoseira compressa* and *Sargassum vulgare*. In addition to Fucales the association may include other erect and encrusting algae, sponges and bryozoans that can emerge from the canopy. Axes and tophules of canopy-forming Fucales support a large number of epibionts including algae, bryozoans, hydrozoans and several Didemnidae ascidians. The association hosts a very diverse assemblage of mobile invertebrates, mostly amphipods, decapods, gastropods and polychaetes.

Conservation interest and ecological role

The species of the association are perennial organisms, endemic in the Mediterranean Sea. Canopy-forming macroalgae constitute important secondary substrates that increase the structural complexity of hard bottoms, providing habitat, shelter, food, and nursery areas suitable for a multitude of marine organisms, both epiphytic and mobile. Thus, canopy-forming algae enhance biodiversity and productivity of benthic systems. Moreover, these assemblages have a key role in carbon dioxide sequestration and climate change mitigation.

Economic importance

Due to their role in supporting biodiversity and food webs, these long-lived brown algae provide important provisional (food through fisheries) and regulatory (carbon sequestration, nutrient recycling) ecosystem services. The economic value of the rocky habitat dominated by Fucales has been estimated equal to 1.28 em € m^{-2}.

Vulnerability and potential threats

Fucales are in decline in several areas of the Mediterranean due to several human pressures. The causes of this decline can change in relation to species, depth and geographic area. The main threats are coastal urbanization, pollution, eutrophication, sedimentation, and overgrazing by sea urchins. Moreover, invasion by alien species may also contribute to the observed decline of these assemblages, as direct and indirect effects have been observed in assemblages invaded by alien algae, such as *Lophocladia lallemandii* and *Womersleyella setacea*.

Protection and management

There is a growing attention towards the conservation status of macroalgal forests as they are included in the “Rocky reefs” habitat (code 1170, Directive 92/43/EEC, Annex I). Fucales are listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention), and several species in the Appendix I “Strictly protected flora species” of the Bern Convention.

Suitability of the habitat for monitoring

Fucales assemblages are considered biological indicators to assess the ecological status of marine environment in the context of the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC). The CARLIT method allows monitoring extensive geographical areas in a short period of time. To date only shallow assemblages (0-1m depth) are contemplated in monitoring programs, while deeper assemblages should also be considered because of their key ecological role and sensitivity to major human-induced disturbances in coastal areas.

Ericaria amentacea (© A. Tommasi)

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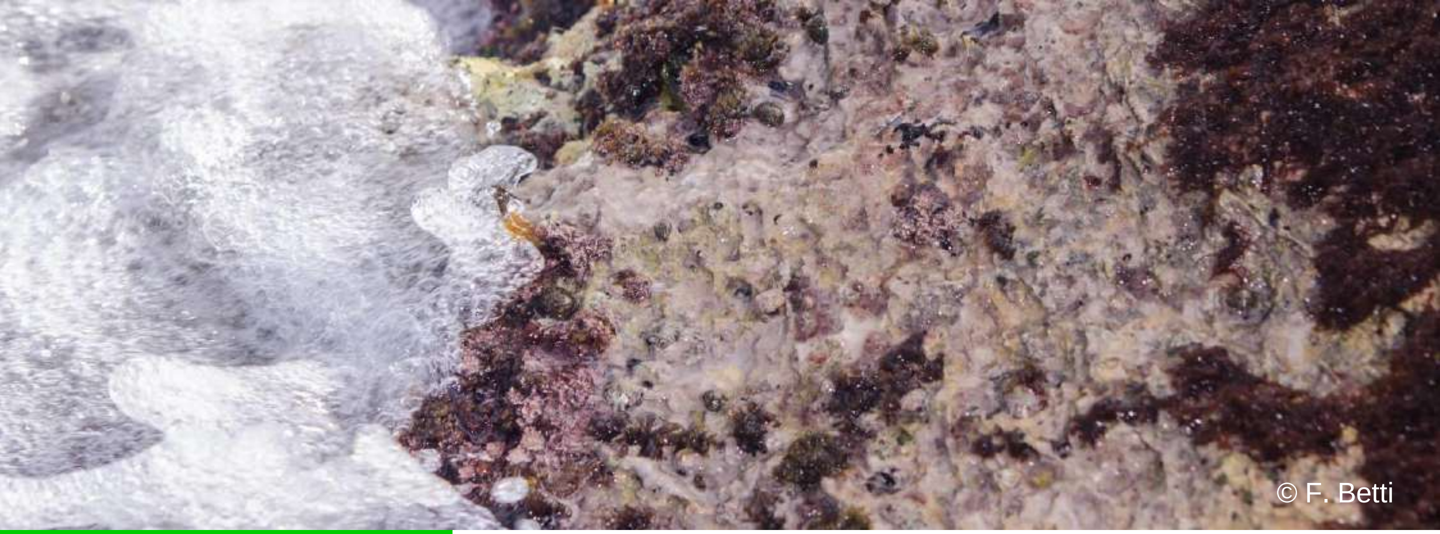
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Association with encrusting Corallinales creating belts

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.513a**
- **EUNIS 2019: MA1543, MA1546**
- **EUNIS 2007: A1.144, A1.232**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	0 m to 2 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Yes, but not applied

Author:
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Photo credits:
G. Sartoni, F. Betti

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.51 Algal-dominated infralittoral rock

MB1.51a Well illuminated infralittoral rock exposed

MB1.513a Association with encrusting Corallinales creating belts

Description of the habitat

The association is constituted by calcareous structures mostly built by the coralline algae *Tenarea tortuosa*, *Titanoderma trochanter, Lithophyllum incrustans, Lithophyllum woelkerlingii, Lithophyllum dentatum* and *Neogoniolithon brassica-florida*. The association develops in the infralittoral fringe, between the sea surface and about 1.5 m, in well-lit and exposed hard substrate habitats and it may appear as calcareous ridge often very fragile, depending on the species present. In peculiar confined habitats, *Neogoniolithon brassica-florida* may build spectacular reefs several kms long.

Geographic distribution

The association, although rare, may be present in most of the Mediterranean Sea with different species. *Tenarea tortuosa* is an endemic species only present in the Adriatic and the eastern Mediterranean Sea. *Titanoderma trochanter* is endemic to the eastern Mediterranean and the Adriatic Sea. *Lithophyllum incrustans* and *Lithophyllum dentatum* are widely distributed in the Mediterranean, although more common in the western than in the eastern. *Lithophyllum woelkerlingii* has been reported from Corsica, Sardinia, Sicily and Algeria. *Neogoniolithon brassica-florida* is widespread in the Mediterranean Sea, but evident reefs are present in Tunisia, Greece and Turkey.

Associated habitats

The habitat develops on ‘Algal-dominated infralittoral rock’ (MB1.51), and it may have possible contact with the ‘Invertebrate-dominated infralittoral rock’ (MB1.52). It may be found associated with ‘Association with Fucales (MB1.511a), ‘Association with photophilic algae, except Fucales, Corallinales and Caulerpales’ (MB1.512a), ‘Facies with Bivalvia’ (MB1.517a), and ‘Facies with Echinoidea on encrusting Corallinales (barren ground)’ (MB1.518a).

Related reference habitats

'Moderately illuminated infralittoral rock exposed' (MB1.51b), 'Well illuminated infralittoral rock sheltered' (MB1.51c), 'Moderately illuminated infralittoral rock sheltered' (MB1.51d).

Possible confusion

No confusion with other habitats is possible.

Typical species and associated communities

The association is distributed within a wide biogeographical range, and it may have different building species, thus variable associated species may be found. Normally, the coralline structures in exposed sites may be interspersed with Fucales beds or photophilous macroalgal assemblages. Bigger structures in sheltered areas may spread on Sabellariidae platforms.

Conservation interest and ecological role

The calcareous structures built by coralline algae increase the complexity of the substrate, host highly diverse assemblages, and have an important role in CO_2 sequestration. Moreover, many species are endemic of the Mediterranean Sea and evident structures are rare in the Basin.

Economic importance

Such as other calcareous biogenic habitats, the Association provides both regulatory (i.e., carbon sequestration) and cultural ecosystem services to humans. The economic importance of the Association has not been assessed yet.

Vulnerability and potential threats

The association is sensitive to pollution, coastal development, trampling and global warming. The increased amount of CO_2 produces higher acidification of the sea water with negative consequences on biogenic calcifications.

Protection and management

Tenarea tortuosa, *Titanoderma trochanter* and *Lithophyllum woelkerlingii* are listed in in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995).

Suitability of the habitat for monitoring

Well-developed coralline biocostructions are considered evidence of high environmental quality. The association is normally monitored through the CARLIT method, but more specific approaches should be considered.

Neogoniolithon brassica-florida (left panel) and *Lithophyllum woelkerlingii* (right panel) (© G. Sartoni)

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Association with *Caulerpa prolifera*

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.514a, MB1.514c**
- **EUNIS 2019: MB5536**
- **EUNIS 2007: A5.284**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock), soft (sand, mud) and matte
Depth range	0 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Not known

Author:
L. Piazzi

Photo credits:
G. Sartoni

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.51 Algal-dominated infralittoral rock

MB1.51a Well illuminated infralittoral rock exposed

MB1.51c Well illuminated infralittoral rock sheltered

MB1.514a, MB1.514c Association with *Caulerpa prolifera*

Description of the habitat

The chlorophyte *Caulerpa prolifera* is the only native species of *Caulerpa* in the Mediterranean, as the co-generic specie *Caulerpa ollivieri* is currently considered a synonym. *C. prolifera* forms permanent dense meadows usually extending on muddy sands, but also on the dead matte of the seagrass *Posidonia oceanica* and rocky bottom, in sheltered waters at depths from 1 to 40 m. *C. prolifera* can be found in monospecific algal meadows or mixed meadows with seagrasses, mostly *Cymodocea nodosa*. Such meadows include a series of stolons from which grow erect, flattened fronds and fine rhizoids toward the substratum. *C. prolifera* is a subtropical macroalga and its growth-reproductive cycle depends on water temperature: meadows have significant regression during winter and significant growth when temperatures rise.

Geographic distribution

The association is distributed on all the Mediterranean coasts.

Associated habitats

The habitat develops on ‘Algal-dominated infralittoral rock’ (MB1.51), ‘Well illuminated infralittoral rock, exposed’ (MB1.51a), ‘Moderately illuminated infralittoral rock exposed’ (MB1.51b), ‘Well illuminated infralittoral rock sheltered’ (MB1.51c), ‘Moderately illuminated infralittoral rock sheltered’ (MB1.51d), ‘Lower infralittoral rock moderately illuminated’ (MB1.51e), ‘Invertebrate-dominated infralittoral rock’ (MB1.52), Fine sand in sheltered waters (MB5.53), and it may have possible contact with ‘*Posidonia oceanica* meadows’ (MB2.54). Other associated habitats may be ‘Association with Fucales’ (MB1.511a, MB1.511c, MB1.511e), ‘Association with photophilic algae, except Fucales, encrusting Corallinales and Caulerpales’ (MB1.512a, MB1.512c), ‘Association with encrusting Corallinales’ (MB1.513a, MB1.511b, MB1.513c, MB1.511d), ‘Association with non-indigenous Mediterranean *Caulerpa* spp.’ (MB1.515a, MB1.513b, MB1.515c, MB1.513d, MB1.514e), 'Facies with Scleractinia' (MB1.516a, MB1.515b, MB1.516c, MB1.516e), 'Facies with Bivalvia' (MB1.517a), 'Facies with Echinoidea on encrusting Corallinales' (MB1.518a), 'Facies with Hydrozoa' (MB1.514b), 'Facies with Alcyonacea' (MB1.514d, MB1.515e), 'Association with Laminariales' (MB1.512e), and 'Association with Laminariales (kelp beds)' (MB1.512e).

Related reference habitats

'Association with *Caulerpa prolifera*' (MB1.512b, MB1.512d, MB1.513e, MB1.521a, MB5.533), 'Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.' (MB2.546), 'Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica*' (MB2.547).

Possible confusion

This association may be confused with 'Association with non-indigenous Mediterranean *Caulerpa* spp.' (MB1.515a, MB1.513b, MB1.515c, MB1.513d, MB1.514e). Only *C. prolifera* has flattened laminar fronds.

Typical species and associated communities

Caulerpenine, the most abundant secondary metabolite of *C. prolifera*, prevents grazing by herbivores but also the settlement of most epiphytes. In contrast, the dense and continuous canopy of *C. prolifera* supports the presence of a diverse and abundant benthic macrofauna, mostly polychaetes, gastropods and amphipods, which change seasonally as a result of the algae's vegetative cycle. Abundant fish assemblages and populations of the cephalopod *Sepia officinalis* have been described in *C. prolifera* beds.

Conservation interest and ecological role

Caulerpa prolifera dense beds possess a high sediment retention capacity and the accumulated sediment induces a certain amount of organic enrichment and changes in granulometric composition that, together with the shelter provided by vegetation, allow the establishment of dense animal populations.

Economic importance

To date, the economic value of *Caulerpa prolifera* beds has not been evaluated yet.

Vulnerability and potential threats

Caulerpa prolifera beds are generally expanding in the Mediterranean Sea enhanced by increasing fine sediment and nutrients. *C. prolifera* may suffer competition with introduced co-generic species.

Protection and management

Caulerpa ollivieri is listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995) but it should be excluded from the list because it is only a dwarf ecomorph of *C. prolifera*, which is a non-threatened or protected species.

Suitability of the habitat for monitoring

Generally, the habitat does not require monitoring programs.

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Caulerpa prolifera bed (© G. Sartoni)


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Facies with zooxanthellate Scleractinia

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.516a, MB1.516c**
- **EUNIS 2019: MB151E (partim)**
- **EUNIS 2007: A3.238 (partim)**
- **EC: 1170 (partim)**
- **CORINE: 11.24 (partim)**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	2 m to 30+ m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes (partim)

Authors:
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Photo credits:
C.N. Bianchi, F. Boero, S. Guerrieri, D.K. Kersting, C. Morri

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.51 Algal-dominated infralittoral rock

MB1.51a Well illuminated infralittoral rock exposed
MB1.51c Well illuminated infralittoral rock sheltered

MB1.516a, MB1.516c Facies with zooxanthellate Scleractinia

Description of the habitat

Sessile invertebrates that harbour photosynthetic endosymbionts in their tissues may thrive successfully amidst macroalgae - the primary space-occupiers in well illuminated infralittoral rock. The endosymbionts may be dinoflagellates (zooxanthellae), cyanobacteria (zoocyanellae), or chlorophytes (zoochlorellae). The animals hosting photosynthetic symbionts get part of their energetic needs thanks to the translocation of photosynthates from their endosymbionts, and complete their nutritional needs of proteins and lipids capturing plankton. There is no universally accepted term for organisms that functionally lie between autotrophs and heterotrophs. The word mixotrophs is primarily employed for microorganisms that assimilate organic compounds as carbon sources but not as energy sources. The term polytrophs refers to the capacity to obtain nutrients in more than one way: most filter feeders are actually polytrophs in that they can incorporate both particulate and dissolved organic matter. As zooxanthellate, zoocyanellate, and zoochlorellate animals combine autotrophy and heterotrophy, they have been named 'combo' organisms. The importance of zooxanthellate scleractinian corals is obvious in the tropics, where they build coral reefs. Some species, however, also exist in the Mediterranean Sea, where they may be accompanied by other zooxanthellate cnidarians and/or by zoocyanellate sponges. These combo species may abound in three main situations: 1) at the transition between photophilic and sciaphilic habitats (e.g. lower infralittoral zone, entrance of submarine caves); 2) in overgrazed shallow-water habitats (the so-called 'urchin barrens'); 3) in turbid habitats at infralittoral depths.

Geographic distribution

Zooxanthellate scleractinians can be found all over the Mediterranean Sea, where they occur from very shallow depths to more than 30 m; deeper records are exceptional or derive from identification errors. They tolerate winter temperatures as cold as 10 °C in the northern Adriatic and summer temperatures over 25 °C in the southern Mediterranean.

Associated habitats

The facies with zooxanthellate Scleractinia may be in contact or even intermixed with other habitats of the ‘Algal-dominated infralittoral rock’ (MB1.51), and may also border on ‘Coralligenous’ habitats (MB1.55, MC1.51), ‘Semi-dark caves and overhangs’ (MC1.53), and ‘*Posidonia oceanica* meadows on rock’ (MB2.541).

Related reference habitats

The facies with zooxanthellate Scleractinia have many species in common with other infralittoral habitats, and especially with the ‘Association with Fucales’ (MB1.511a, MB1.511c, MB1.511e) and the ‘Reefs of *Cladocora caespitosa*’ (MB2.53).

Possible confusion

The polyps of zooxanthellate scleractinians are characterized by shadows of greenish to brownish colours that make them easily distinguishable from their azooxanthellate relatives.

Typical species and associated communities

The most common zooxanthellate scleractinians in the Mediterranean Sea are the solitary *Balanophyllia europaea* and the colonial *Cladocora caespitosa*. The zooxanthellate form of the colonial *Madracis pharensis* may also participate in this habitat (whilst the azoxanthellate form inhabits submarine caves), as well as the cryptogenic *Oculina patagonica* and the alien *Oulastrea crispata*. Other combo (although not scleractinian) species that can be found there are the zoxanthellate sea anemone *Anemonia viridis*, the zoxanthellate paralcyoniid *Maasella edwardsii*, the shallow-water zooxanthellate form of the gorgonian *Eunicella singularis* (whose azooxanthellate form lives deeper), and the zoocyanellate sponges *Chondrilla nucula* and *Petrosia ficiformis*. The associate biota may include photophylic algae (e.g., *Dictyota dichotoma*, *Padina pavonica*, *Treptacantha ballesterosii*), emiphotophilic algae (e.g., *Codium bursa*, *Dictyopteris polypoidioides, Sphaerococcus coronopifolius*), or antisciaphilic algae (e.g., *Flabellia petiolata*, *Halimeda tuna*, *Peyssonnelia squamaria*) according to the specific situation. Only in sea-urchin barrens, characterized by reduced cover of macroalgae (the principal competitors of combo organisms), the assemblage accompanying zooxanthellate scleractinians is somewhat typical, with the coralline alga *Lithophyllum incrustans*, the sponge *Crambe crambe*, the vermetid gastropod *Vermetus triquetrus*, and the encrusting bryozoans *Reptadeonella violacea* and *Schizoporella dunkeri*.

Conservation interest and ecological role

The ecological role of combo organisms in temperate seas deserves further studies. Due to the rarity of combo organisms in the present-day Mediterranean Sea, their conservation is mandatory. Many motile species live associated to the colonies of zooxanthellate scleractinians. *Anemonia viridis* hosts several commensals, such as the opossum shrimp *Leptomysis lingvura*, the spider crab *Inachus phalangium*, the shrimps *Periclimenes amethysteus* and *P. aegylios*, and the fish *Gobius bucchichi*.

Economic importance

Zooxanthellate scleractinians provide regulating services, for instance in the carbon cycle and in other biogeochemical cycles; zoocyanellate sponges, in particular, may be important in nitrogen cycle. All combo organisms offer information services to scientific research: the nature of their symbiosis with microphotoautrophs - which may be obligate or facultative according to the host species - involves ecological and evolutionary aspects worthy of investigation. Zooxanthellate sponges may also supply provision services as they produce bioactive substances that are isolated for different purposes in industry. The monetary value of this habitat has not been calculated yet.

Vulnerability and potential threats

Most combo organisms are slow growing and long living, so that their resilience is expectedly low. Summer heatwaves have been shown to cause recurrent mortalities of zooxanthellate scleractinians, among other organisms. Elevated temperature combined with overgrowth by invasive macroalgae - such as *Caulerpa cylindracea* and *Lophocladia lallemandii* - reduce photosynthetic efficiency and induce polyp tissue necrosis. Ocean acidification may confer competitive advantage to zooxanthellate sea anemones (and fleshy algae) over zooxanthellate scleractinians. Human impacts, such as pollution and increased sediment load, are detrimental to combo organisms.

Protection and management

All scleractinian coral species are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). All Mediterranean zooxanthellate anthozoans are included in the IUCN Red List: *Cladocora caespitosa* is classified as Endangered (EN); *Eunicella singularis* as Near Threatened (NT); *Anemonia viridis*, *Balanophyllia europaea*, and *Oculina patagonica* as Least Concern (LC); *Maasella edwardsii* as Data Deficient (DD). No specific protection measures have been implemented yet.

Suitability of the habitat for monitoring

Cladocora caespitosa is included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system.

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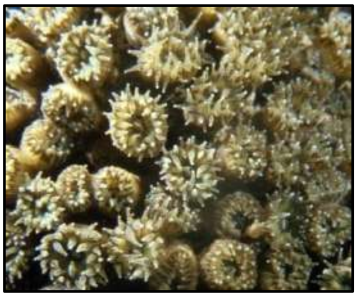
Balanophyllia europaea
(© C. Morri)



Cladocora caespitosa
(© C. Morri)

C. caespitosa amidst
emiphotophilic algae
(© D.K. Kersting)

Madracis pharensis,
zooxanthellate form
(© S. Guerrieri)

Oculina patagonica (© C. Morri)

O. patagonica in a sea-urchin
barren (© C.N. Bianchi)

Oulastrea crispata
(© D.K. Kersting)

Anemonia viridis
(© C.N. Bianchi)

Maasella edwardsii
(© S. Guerrieri)

Eunicella singularis
(© C.N. Bianchi)

Chondrilla nucula
(© F. Boero)

Petrosia ficiformis with
Peltodoris atromaculata
(© C.N. Bianchi)

Reptadeonella
violacea and
Schizoporella dunkeri
(© C. Morri)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Lower infralittoral rock moderately illuminated

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.51e**
- **EUNIS 2019: MB15 (partim)**
- **EUNIS 2007: A3 (partim)**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	~20 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 23°C
Suitability for monitoring	Yes

Authors:
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Photo credits:
M. Montefalcone

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.51 Algal-dominated infralittoral rock

MB1.51e Lower infralittoral rock moderately illuminated

Description of the habitat

The habitat of the lower infralittoral rock moderately illuminated and dominated by macroalgae develops on rocky substrates from about 20 m depth, which is the limit of the moderately illuminated infralittoral rock, down to about 40 m depth. Deep-water algal communities deserve particular attention due to their floristic uniqueness and ecological and biogeographical interest. As they are usually abundant in the close vicinity to the limit of their physiological light compensation point, these algal species have low community dynamics, low growth rates, long life-spans and low recruitment rates. Fucales and Laminariales can thrive in reduced light conditions, ranging between 0.3% and 10% of the surface irradiance and on rocky bottoms exposed to strong unidirectional currents. Encrusting Corallinales may occur at greater depths, dominated by calcified red algae that develop in dim light conditions, which however do not develop an extensive biogenic calcareous layer as it happens in the infralittoral ‘Coralligenous (enclave of circalittoral)’ (see sheet MB1.55). Gorgonians, scleractinians and sponges may be accompanying species in this habitat.

Geographic distribution

This habitat is well represented along all the rocky coasts of the Mediterranean.

Associated habitats

Associated habitats are ‘Association with Fucales’ (MB1.511e), ‘Association with Laminariales’ (MB1.512e), ‘Association with *Caulerpa prolifera*’ (MB1.513e), ‘Association with non-indigenous Mediterranean *Caulerpa* spp.’ (MB1.514e), ‘Facies with Alcyonacea’ (MB1.515e), and ‘Facies with Scleractinia’ (MB1.516e). The habitat may be in contact with the ‘Moderately illuminated infralittoral rock, exposed and sheltered (MB1.51b and MB1.51d, respectively), the ‘Invertebrate-dominated infralittoral rock’ (MB1.52), the ‘Infralittoral rock affected by sediment’ (MB1.53), the ‘Coralligenous (enclave of circalittoral)’ (MB1.55), the ‘Semi-dark caves and overhangs’ (MB1.56), the ‘Reefs of Vermetidae’ (MB2.51), the ‘Reefs of *Sabellaria* spp. (MB2.52), the ‘Reefs of *Cladocora caespitosa*’ (MB2.53), the ‘*Posidonia oceanica* meadows’

(MB2.54), the ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), the ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), and the ‘Well sorted fine sand’ (MB5.52).

Related reference habitats

Related reference habitats can be the ‘Well illuminated infralittoral rock exposed’ (MB1.51a), the ‘Well illuminated infralittoral rock sheltered’ (MB1.51c), the ‘Moderately illuminated infralittoral rock exposed’ (MB1.51b), the ‘Moderately illuminated infralittoral rock sheltered’ (MB1.51d), the Invertebrate-dominated infralittoral rock (MB1.52), the Infralittoral rock affected by sediment (MB1.53), the infralittoral ‘Coralligenous (enclave of circalittoral)’ (MB1.55), and the Algal-dominated coralligenous (MC1.51a).

Possible confusion

This habitat can be confused with the ‘Moderately illuminated infralittoral rock exposed (MB1.51b) and sheltered’ (MB1.51d), which are located at depths immediately above (i.e., from about 3 m to about 20 m). The depth range represent the main discriminating factor. The dominance by macroalgal species can be used to discriminate among this habitat and the habitats of the infralittoral rock invertebrate-dominated (MB1.52 and MB1.53). This habitat can be also confused with the infralittoral ‘Coralligenous (enclave of circalittoral)’ (MB1.55), and with the ‘Algal-dominated coralligenous’ (MC1.51a), which however display a biogenic calcareous layer edified by coralline algae.

Typical species and associated communities

The association with Fucales is represented by deep water erect canopy-forming algal species such as *Ericaria zosteroides, Treptacantha ballesterosii, Sargassum* spp. Association with Laminariales includes *Laminaria rodriguezii.* Dictyotales are common in this habitat and include *Dictyopteris polypodioides, Dictyota* spp., and *Zonaria tournefortii.* Other brown algae present in this habitat are *Cladostephus spongiosum* and *Phyllariopsis brevipes.* Red algae are well represented in the lower infralittoral rock and include *Chrysymenia ventricosa*, *Jania virgata*, *Lythophyllum* spp., *Amphiroa rigida*, *Mesophyllum* spp., *Tricleocarpa fragilis*, *Phyllophora crispa*, *Sphaerococcus coronopifolius*, *Peyssonnelia* spp., *Botryocladia botryoides*, and *Sebdenia monardiana.* The native *Caulerpa prolifera* and the non-indigenous *Caulerpa* spp. (i.e., the invasive *Caulerpa cylindracea* and *Caulerpa taxifolia*) may be common and sometimes dominant species. Other frequent green algae in the lower infralittoral rock are *Codium* spp., *Halimeda tuna*, *Flabellia petiolata*, and *Valonia utricularis*. Facies with Alcyonacea includes *Alcyonium* spp., *Maasella edwardsi*, *Paralcyonium spinulosum*, *Corallium rubrum*, *Eunicella* spp., *Paramuricea clavata*, and *Paramuricea macrospina.* Many scleractinia corals such as *Caryophyllia* spp., *Phyllangia americana mouchezii*, *Polycyathus muellerae*, *Balanophyllia* spp., and *Leptosammia pruvoti* are common in the lower infralittoral rock. Encrusting sponges (e.g., *Spirastrella cunctatrix*) and small sponges (e.g., *Chondrosia reniformis*, *Petrosia ficiformis, Axinella* spp.) are often associated with this habitat. Associated vagile communities of the lower infralittoral rock are mainly dominated by crustaceans, molluscs, echinoderms and fish.

Conservation interest and ecological role

Brown canopy-forming macroalgae (Fucales, Laminariales) are ecosystem engineers and habitat-formers as their canopy increase the structural complexity of the habitat providing shelter and food for many associated species. Algal species that can thrive in relatively deep waters constitute highly structured and diverse communities that are poorly known compared to those of shallow waters. Availability of high algal biomasses supports many herbivorous fish species and higher predators, and the appearance of erect alcyonaceans and calcified scleractinians promotes the creation of a three-dimensional environment increasing the habitat complexity and diversity.

Economic importance

This habitat offers regulatory services to humans (i.e., carbon sequestration, nutrient recycling), provisioning services in terms of food production through fisheries and genetic resources availability (due to the high biodiversity it hosts), information services in terms of scientific research and monitoring, habitat services due to the creation of three-dimensional structures that amplifies the space available for marine organisms. To date the economic value of this habitat has not been assessed (but see sheet MB1.51a for an estimation of the natural capital associated with macroalgae of the genus *Cystoseira*).

Vulnerability and potential threats

Because of their slow demographic changes, these communities may be easily affected by perturbations such as grazing or mechanical damages induced by anchoring, changes in water transparency, and competition with alien invasive species (such as the alien algae *Womersleyella setacea* and *Caulerpa cylindracea*), and thus they can be excellent indicators of anthropogenic disturbances. Causes of decline in deep water algal assemblages are also direct pulling up by fishing nets, eutrophication, overgrazing by sea urchins and global warming. The construction of nests by the sparid fish *Spondyliosoma cantharus* has been identified as a possible cause of episodic disturbance in deep-water algal assemblages.

Protection and management

Several key species in this habitat, such as Fucales and Laminariales, are listed in the Annex II (endangered and threatened species) of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995), and in the Appendix I (strictly protected flora species) of the Bern Convention. Extensive loss of macroalgal forests in shallow waters favored large-scale restoration interventions; however, the depth and the low accessibility of deep macroalgal assemblages make this kind of restoration actions unworkable in this habitat. Regulation and correct management of coastal areas are thus the main tools for the conservation of such a fragile habitat.

Suitability of the habitat for monitoring

The canopy-forming macroalgae belonging to the genus *Cystoseira* are among the most sensitive species used in ecological quality assessment programs. Macroalgae are considered suitable biological indicators to assess the ecological status of marine environment in the context of the IMAP of Barcelona Convention, the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC). Several indices have been proposed to assess the ecological quality of the Mediterranean macroalgal assemblages: EEI can be employed in the whole infralittoral zone and M-ALEX has been developed to assess the ecological quality of assemblages in relation to the level of invasion of alien species. Its accessibility makes this habitat still investigable by scuba diving with many different not-destructive techniques, such as visual surveys or photography.

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Invertebrate-dominated infralittoral rock

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.52**
- **EUNIS 2019: MB15 (partim)**
- **EUNIS 2007: A3 (partim)**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	0 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Not known

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Photo credits:
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INFRALITTORAL

MB1.5 Infralittoral rock

MB1.52 Invertebrate-dominated infralittoral rock

Description of the habitat

The habitat of invertebrate-dominated infralittoral rock develops on sub-vertical and vertical rocky substrata from the surface down to about 40 m depth and is characterized by the dominance of invertebrates with respect to macroalgae. Especially at the shallowest depths, this habitat is subject to seasonal variations in sea water temperature, and it is therefore particularly vulnerable to the effect of water warming. Scleractinian corals, alcyonaceans, zoantharians, and sponges are the dominant invertebrates of this habitat.

Geographic distribution

This habitat is distributed along all the coasts of the Mediterranean, but it has been mainly described and studied in the northern sectors along the French, Spanish, Italian, and Greece coasts.

Associated habitats

Associated habitats are ‘Association with *Caulerpa prolifera*’ (MB1.521a), ‘Association with non-indigenous Mediterranean *Caulerpa* spp.’ (MB1.522a), ‘Facies with small sponges’ (MB1.523a), ‘Facies with azooxanthellate Scleractinia’ (MB1.524a), ‘Facies with Alcyonacea’ (MB1.525a). This habitat may be in contact with the ‘Algal-dominated infralittoral rock’ (MB1.51), the ‘Infralittoral rock affected by sediment’ (MB1.53), the ‘Coralligenous (enclave of circalittoral)’ (MB1.55), the ‘Semi-dark caves and overhangs’ (MB1.56), the ‘Reefs of Vermetidae’ (MB2.51), the ‘Reefs of *Sabellaria* spp. (MB2.52), the ‘Reefs of *Cladocora caespitosa*’ (MB2.53), the ‘*Posidonia oceanica* meadows’ (MB2.54), the ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), the ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), and the ‘Well sorted fine sand’ (MB5.52).

Related reference habitats

Related reference habitats are ‘Moderately illuminated infralittoral rock, exposed or sheltered’ (MB1.52a), ‘Infralittoral rock affected by sediment’ (MB1.53), ‘Coralligenous (enclave of circalittoral)’ (MB1.55), ‘Semi-dark caves and overhangs’ (MB1.56), and ‘Coralligenous cliffs (MC1.51).

Possible confusion

This habitat can be confused with the infralittoral ‘Coralligenous (enclave of circalittoral)’ (MB1.55), which is similarly characterized by alcyonaceans and zoantharians. Nevertheless, unlike the infralittoral coralligenous, this habitat does not display a biogenic calcareous layer edified by coralline algae.

Typical species and associated communities

Due to the wide bathymetric distribution and the different environmental conditions that characterize this habitat, it may host many different assemblages. According to the bathymetric gradient, in the shallowest infralittoral rock the green algae *Caulerpa* spp., other photophilic algae, scleractinian corals such as *Cladocora caespitosa*, *Polycyathus muellerae*, *Astroides calycularis* (which forms facies mostly in the south-western Mediterranean) and *Pourtalosmilia anthophyllites,* the zoantharian *Parazoanthus axinellae*, and sponges can be found. In the deepest infralittoral rock (or on shaded overhangs), sciaphilous algae (e.g., Corallinales, Peyssonneliales), alcyonaceans such as *Eunicella cavolini*, *Eunicella singularis*, and *Paramuricea clavata* and the solitary bright yellow coral *Leptopsammia pruvoti* become frequent, as well as bryozoans, hydrozoans, annelids, and ascidians. Vagile communities are mainly dominated by the molluscs, crustacean, and various fish assemblages.

Conservation interest and ecological role

Mediterranean shallower communities are usually dominated by macroalgae, while deeper communities are dominated by suspension feeders. In this context, the habitat ‘Invertebrate-dominated infralittoral rock’ represents an important source of biodiversity in the infralittoral zone and contributes to its spatial heterogeneity. Occurrence of long-lived erect Alcyonacea and calcified Scleractinia within this habitat generates three-dimensional space and habitat for either sessile or mobile associated fauna.

Economic importance

The habitat of invertebrate-dominated infralittoral rock offers provisioning services to humans, such as genetic resources availability (due to the high biodiversity it hosts), regulating services (i.e., CO_2 and climate regulation, natural carbon sequestration and storage), information services in terms of scientific research (carbon cycle in the sea, climate change studies) and recreation (visitation by scuba diving tourists), habitat services due to the creation of three-dimensional structures that amplifies the space available for marine organisms. To date the economic value of this habitat has not been assessed.

Vulnerability and potential threats

The habitat of invertebrate-dominated infralittoral rock is directly affected by human activities that insist along the coast, which cause alteration in sedimentation, the presence of dissolved pollutants and the presence of waste on the bottom. Furthermore, this habitat is often affected by mechanical destruction due to anchoring. Because of its shallow distribution, this habitat is particularly sensitive to global warming. During the last two decades many mass mortality events in the species composing this habitat (e.g., scleractinians and alcyonaceans) have been recorded. The increased sea water temperature makes this habitat suitable for the establishment of alien species: the spread of the non-indigenous *Caulerpa cylindracea* on rocky bottoms is considered today as one of the most threatening invasive event, as it competes with the native communities and represents one of the major cause of rocky habitat homogenization.

Protection and management

All scleractinian coral species are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). *Astroides calycularis* is included in the Annex II (endangered and threatened species) of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995). *Astroides calycularis* and *Leptopsammia pruvoti* are included in the IUCN Red List as ‘Vulnerable’ (VU); *Eunicella cavolini* and *Eunicella singularis* as ‘Near Threatened’ (NT).

Suitability of the habitat for monitoring

Despite its ecological role and sensitivity to major human-induced disturbances, the habitat is not contemplated in monitoring programs (IMAP of Barcelona Convention, Water Framework Directive 2000/60/EC, Marine Strategy Framework Directive 2008/56/EC). Due to the vulnerability of this habitat to climate change, many of its typical species represent target species for assessing the effects of global warming. Its accessibility makes this habitat easily investigable by scuba diving with many different not-destructive techniques, such as visual surveys or photography.

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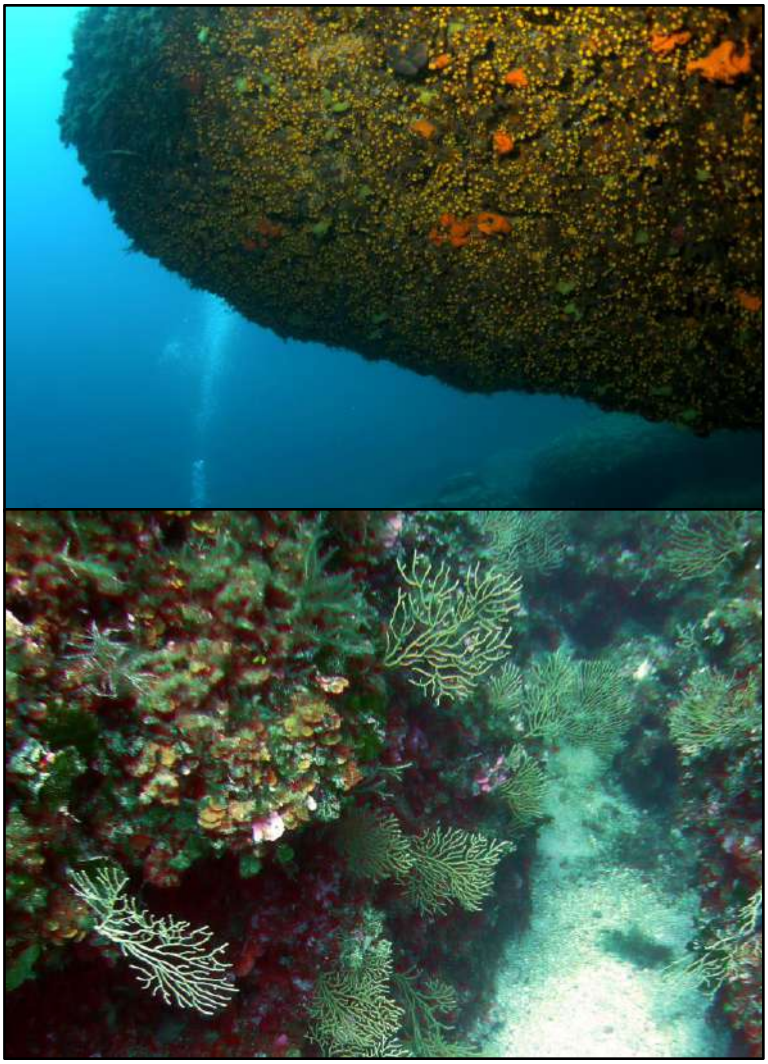

Invertebrate-dominated infralittoral rock dominated by *Leptopsammia pruvoti* and small sponges on a shaded overhang (upper panel, © A. Azzola) and by *Eunicella cavolini* (lower panel, © M. Montefalcone)


© M. Montefalcone

Moderately illuminated infralittoral rock, exposed or sheltered

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.52a**
- **EUNIS 2019: MB15 (partim)**
- **EUNIS 2007: A3 (partim)**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	~3 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Not known

Authors:
M. Montefalcone, A. Azzola

Photo credits:
M. Montefalcone, A. Azzola

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.52 Invertebrate-dominated infralittoral rock

MB1.52a Moderately illuminated infralittoral rock, exposed or sheltered

Description of the habitat

The habitat 'Moderately illuminated infralittoral rock, exposed or sheltered' is dominated by invertebrates and develops on sub-vertical and vertical rocky substrates in the shady portions of shallow rocky reefs and in the deepest zone of the infralittoral rock, down to about 40 m depth. This habitat also characterizes the entrance of caves, overhangs and crevices occurring in the infralittoral zone. Dominant species of this habitat are invertebrates. According to hydrodynamic conditions, azooxanthellate scleractinian corals usually characterize more sheltered areas, whilst alcyonaceans and zoantharians mainly characterize more exposed areas.

Geographic distribution

This habitat is well represented along the Mediterranean coasts, even though it has been mainly investigated in the northern sectors along the French, Spanish, Italian, and Greece coasts.

Associated habitat

This habitat occurs within the 'Invertebrate-dominated infralittoral rock' (MB1.52) and the associated habitats are 'Association with *Caulerpa prolifera*' (MB1.521a), 'Association with non-indigenous Mediterranean *Caulerpa* spp.' (MB1.522a), 'Facies with small sponges (sponge ground)' (MB1.523a), 'Facies with azooxanthellate Scleractinia' (MB1.524a), 'Facies with Alcyonacea' (MB1.525a). This habitat may be in contact with the 'Algal-dominated infralittoral rock' (MB1.51), the 'Infralittoral rock affected by sediment' (MB1.53), the 'Coralligenous (enclave of circalittoral)' (MB1.55), the 'Semi-dark caves and overhangs' (MB1.56), the 'Reefs of Vermetidae' (MB2.51), the 'Reefs of *Sabellaria* spp. (MB2.52), the 'Reefs of *Cladocora caespitosa*' (MB2.51), the '*Posidonia oceanica* meadows' (MB2.54), the 'Infralittoral coarse sediment mixed by waves' (MB3.51), the 'Infralittoral coarse sediment under the influence of bottom currents' (MB3.52), and the 'Well sorted fine sand' (MB5.52).

Related reference habitats

Related reference habitats are 'Infralittoral rock affected by sediment' (MB1.53), 'Coralligenous (enclave of circalittoral)' (MB1.55), 'Semi-dark caves and overhangs' (MB1.56), and 'Coralligenous cliffs' (MC1.51).

Possible confusion

Some environmental factors that characterize the habitat of moderately illuminated infralittoral rock, such as dim-light conditions and sub-vertical or vertical slopes, are the same that characterize the infralittoral coralligenous habitat when it develops in enclave (see MB1.55), with which this habitat can thus be confused. Both habitats are characterized by facies with alcyonaceans (i.e., *Eunicella* spp., *Corallium rubrum*) and with scleractinians. Nevertheless, these two habitats can be distinguished by the absence of a biogenic calcareous layer edified by coralline algae in the moderately illuminated infralittoral rock.

Typical species and associated communities

Characteristic species of moderately illuminated infralittoral rock, exposed and sheltered, are all sciaphilous, and the most typical belong to the phyla Porifera and Cnidaria. Some typical sponges are *Agelas oroides, Axinella damicornis, Axinella verrucosa, Chondrosia reniformis, Crambe crambe, Ircinia* spp*., Oscarella lobularis, Petrosia ficiformis, Phorbas tenacior.* Typical cnidarians are azooxanthellate scleractinian corals, such as the colonial bright orange *Astroides calycularis* (which forms facies mostly in the south-western Mediterranean), the solitary bright yellow coral *Leptopsammia pruvoti* (often a dominant species), *Polycyathus muellerae*, and the small white coral *Pourtalosmilia anthophyllites.* The alcyonacean red coral *Corallium rubrum* is often a dominant species on overhangs, and the zoantharian *Parazoanthus axinellae* is often dominant. Other common elements of this habitat are the bryozoans *Myriapora truncata* and *Reteporella grimaldii* and the hydrozoans *Eudendrium* spp. In the more exposed areas, facies with gorgonians (i.e., *Eunicella cavolini*, Eunicella *singularis*, and *Paramuricea clavata*) become frequent. Vagile communities are made by the molluscs *Cratena peregrina*, *Elysia timida, Flabellina affinis, Peltodoris atromaculata, Thuridilla hopei*, the crustaceans *Plesionika narval*, *Scyllarides latus*, *Scyllarus arctus*, and the fish *Apogon imberbis*. Even though that coralline algae do not build a biogenic substrate in this habitat, algae of the genus *Lithophyllum*, *Mesophyllum*, and *Peyssonnelia* may be somehow abundant, as well as the green algae *Flabellia petiolata* and *Caulerpa* spp.

Conservation interest and ecological role

This habitat is characterised by a high species richness, thus representing a biodiversity hotspot in the infralittoral rocky zone of the Mediterranean. Occurrence of long-lived erect Alcyonacea and calcified Scleractinia within this habitat generates three-dimensional space and habitat for either sessile or mobile associated fauna, enhancing the spatial heterogeneity.

Economic importance

The moderately illuminated infralittoral rock offers provisioning services to humans, such as genetic resources availability (due to the high biodiversity it hosts), regulating services (i.e. CO_2 and climate regulation, natural carbon sequestration and storage), information services in terms of scientific research (carbon cycle in the sea, climate change studies) and recreation (visitation by scuba diving tourists), habitat services due to the creation of three-dimensional structures that amplifies the space available for marine organisms. To date the economic value of this habitat has not been assessed.

Vulnerability and potential threats

Due to its proximity to the coastline, this habitat may be directly affected by human pressures, such as pollution, eutrophication, mechanical destruction by anchoring, and coastal development. Because of its shallow distribution in the infralittoral zone, this habitat is particularly sensitive to global warming and to its direct effects, such as mass mortality events and spread of alien species (see sheet MB1.52 for further details).

Protection and management

All scleractinian coral species are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). *Astroides calycularis* is included in the Annex II (endangered and threatened species) of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995). *Astroides calycularis* and *Leptopsammia pruvoti* are included in the IUCN Red List as ‘Vulnerable’ (VU); *Eunicella cavolini* and *Eunicella singularis* as ‘Near Threatened’ (NT).

Suitability of the habitat for monitoring

Despite its ecological role and sensitivity to major human-induced disturbances, the habitat is not contemplated in monitoring programs (IMAP of Barcelona Convention, Water Framework Directive 2000/60/EC, Marine Strategy Framework Directive 2008/56/EC). Due to the vulnerability of this habitat to climate change, many of its typical species represent target species for assessing the effects of global warming. Its accessibility makes this habitat easily investigable by scuba diving with many different not-destructive techniques, such as visual surveys or photography.

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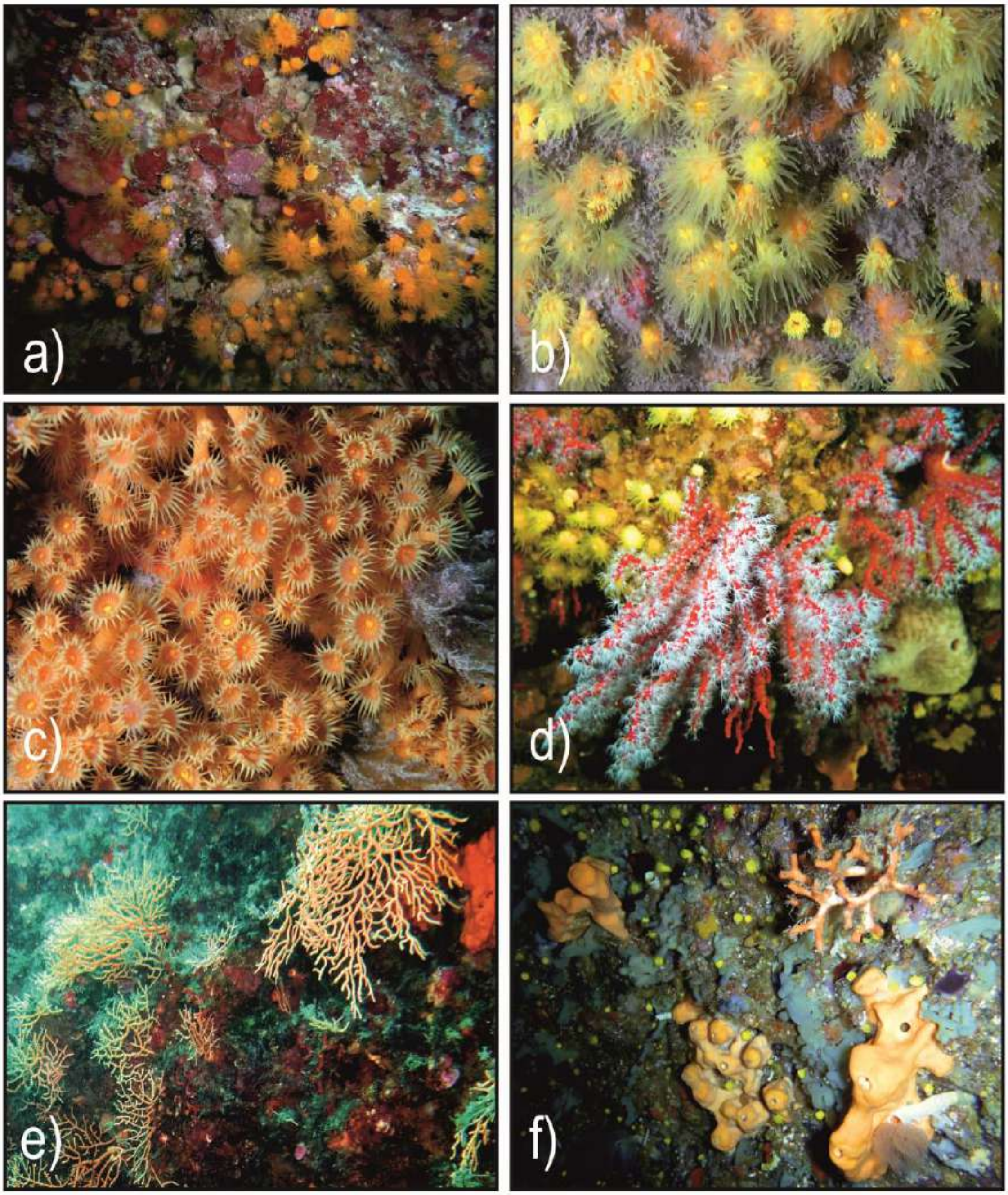
Moderately illuminated infralittoral rock dominated by invertebrates on a shaded overhang, the zoantharian *Parazoanthus axinellae*, the sponge *Oscarella lobularis*, and the alcyonacean *Corallium rubrum* (© M. Montefalcone)



The azooxanthellate scleractinian coral *Astroides calycularis* with the Rhodophyta *Peyssonnelia squamaria* (a), the solitary coral *Leptopsammia pruvoti* (b), the zoantharian *Parazoanthus axinellae* (c), the red coral *Corallium rubrum* with *Leptopsammia pruvoti* and the sponge *Chondrosia reniformis* (d), the gorgonian *Eunicella cavolini* (e), the small sponges *Agelas oroides* and *Oscarella lobularis* with *Leptopsammia pruvoti* and the bryozoan *Myriapora truncata* (f). (a, d, e, f © M. Montefalcone; b, c © A. Azzola)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Facies with azooxanthellate Scleractinia

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.524a**
- **EUNIS 2019: MB151Q (partim)**
- **EUNIS 2007: A3.23l (partim)**
- **EC: 1170 (partim)**
- **CORINE: 11.24 (partim), 11.25 (partim)**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	0.5 m to 15+ m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes (partim)

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Photo credits:
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INFRALITTORAL

MB1.5 Infralittoral rock

MB1.52 Invertebrate-dominated infralittoral rock

MB1.52a Moderately illuminated infralittoral rock, exposed or sheltered

MB1.524a Facies with azooxanthellate Scleractinia

Description of the habitat

Most azooxanthellate scleractinians are sciaphilic and live in the depths or in submarine caves. A few, however, can thrive in shallow water and tolerate a moderate light intensity. Three species, in particular, may be common in such situation: the solitary *Balanophyllia regia* (golden yellow to orange), and the colonial *Phyllangia americana mouchezii* (red-brown with whitish tentacles, sometime completely white) and *Astroides calycularis* (bright orange, rarely yellow). However, only *A. calycularis* can form true facies: gregarism of the crawling planulae helps producing dense monospecific stands that may cover the rock up to 90% between just below the sea surface and about 15 m depth. In exposed places, the species typically exhibits massive colonies and polygonal corallites, whilst in sheltered places colonies tend to have a bush-shaped morphology with almost circular corallites. The three species may also occur deeper (*B. regia* down to 25 m, *P. americana mouchezii* to 55 m or more, and *A. calycularis* to 40-50 m) but not as abundant as in shallow water.

Geographic distribution

Balanophyllia regia is mostly distributed in the western Mediterranean, while it is absent from the Adriatic and there is only one confirmed record (Crete) from the eastern Mediterranean. *Phyllangia americana mouchezii* occurs all over whole Mediterranean Sea. *Astroides calycularis* is endemic to the Mediterranean Sea (although little extending west of Gibraltar in the Ibero-Moroccan Gulf). It occurs mostly in the south-western part of the basin and around Sicily, its northern limit coinciding with the February surface isotherm of 14°C; recent occurrences in the northern Tyrrhenian, the central Adriatic, and the northern Ionian (in need of confirmation) have been considered linked to sea water warming and subsequent change in thermohaline circulation. Based on fossil evidence, *A. calycularis* was more widely distributed throughout the western Mediterranean during warmer periods of the Pleistocene, but has subsequently disappeared from the northern

Mediterranean: thus, the species can be considered as an indicator of Quaternary climate oscillations.

Associated habitats

The facies with azooxanthellate Scleractinia may be in contact or even intermixed with other habitats of the ‘Algal-dominated infralittoral rock’ (MB1.51), and may also border on ‘Coralligenous’ habitats (MB1.55, MC1.51) and ‘Semi-dark caves and overhangs’ (MC1.53).

Related reference habitats

The facies with azooxanthellate Scleractinia has many species in common with other infralittoral habitats, such as the ‘Algal-dominated infralittoral rock’ (MB1.51) and the ‘Invertebrate-dominated infralittoral rock’ (MB1.52). *Astroides calycularis*, *Phyllangia americana mouchezii*, and - to a lesser extent - *Balanophyllia regia* may penetrate ‘Semi-dark caves and overhangs’ (MC1.53), participating in the ‘Facies with Scleractinia’ (MC1.534a).

Possible confusion

Balanophyllia regia can be mistaken for *Leptopsammia pruvoti*, which is larger and decidedly sciaphilic, thriving in overhangs and caves. *Phyllangia americana mouchezii* can be mistaken for *Polycyathus muellerae* or *Hoplangia durotrix*, whose corallites are smaller. The yellow variety of *Astroides calycularis* can be mistaken by the zoantharian *Parazoanthus axinellae*, which is deprived of carbonate skeleton.

Typical species and associated communities

The associate biota is not characteristic of the habitat, and includes species in common with other infralittoral rock habitats. The base of the corallite of *Balanophyllia regia* if often encrusted by coralline algae. The small barnacle *Adna anglica* attaches to the calcareous skeletons of scleractinians; it is to be considered as an epibiont, rather than a parasite, but may cause the deformation of the corallite.

Conservation interest and ecological role

The Facies with azooxanthellate Scleractinia hosts a rich invertebrate fauna. More than 80 species, mainly crustaceans, annelids and molluscs, have been found associated to the colonies of *Astroides calycularis*. This species holds ecological importance as a bio-builder, and its facies is sometimes referred to as ‘pseudo-reef’ in the scientific literature. It is the first coral species in which polyps were observed to cooperate to prey upon large jellyfish. Being endemic to the Mediterranean, *A. calycularis* has an intrinsic heritage value.

Economic importance

Azooxanthellate scleractinians provide information services to humans, in terms of recreation (visitation by scuba diving tourists), scientific research (carbon cycle in the sea, biogeographic patterns, climate change), and inspiration (underwater photography). The monetary value of this habitat has not been estimated yet.

Vulnerability and potential threats

These azooxanthellate scleractinians need clean and well-oxygenated waters, and are therefore sensitive to pollution by sewage and hydrocarbons and to increased levels of sedimentation caused by coastal urbanization. Ocean acidification may hamper the deposition of their carbonate skeleton. Recreational diving and artisanal fishery can damage scleractinians by accidental contact and entanglement with fishing gears, respectively. Date mussel harvesting is destructive for this facies; and information on its present status and resilience after disturbances reveals it suffers from cumulative human impact.

Protection and management

All scleractinian species are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). Mediterranean azooxanthellate anthozoans are included in the IUCN Red List: *Balanophyllia regia* and *Phyllangia americana mouchezii* are classified as Data Deficient (DD), *Astroides calycularis* as Least Concern (LC). *A. calycularis* is also included in the Annex II (endangered and threatened species) of the

Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. No specific protection measures have been implemented yet.

Suitability of the habitat for monitoring

Astroides calycularis is included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system.

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Balanophyllia regia
(© V. Lamare doris.ffessm.fr)

B. regia (© A. Terrón-Sigler)

Leptopsammia pruvoti
(© C. Morri)

Astroides calycularis
(© C.N. Bianchi)

A. calycularis, yellow variety
(© C.N. Bianchi)

Parazoanthus axinellae
(© C. Morri)

Phyllangia americana mouchezii
(© R. Rodolfo Metalpa)

P. a. mouchezii, white variety, amidst *P. axinellae*
(© A. Terrón-Sigler)

A. calycularis with crawling planula (© A. Terrón-Sigler)


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Infralittoral rock affected by sediment

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.53**
- **EUNIS 2019: MB15 (partim)**
- **EUNIS 2007: A3 (partim)**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	0 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Not known

Authors:
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Photo credits:
M. Montefalcone, A. Azzola

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.53 Infralittoral rock affected by sediment

Description of the habitat

The habitat ‘Infralittoral rock affected by sediment’ develops on both sub-vertical and vertical rocky substrates, but especially on flat bottoms where sediment mostly accumulates. This habitat mainly occurs near river mouths, in areas characterised by sediment resuspension due to bottom currents, and in highly anthropized coastal areas. The depth range of this habitat (it may develop from the surface down to about 40 m depth) depends on environmental factors, such as light penetration, often limited by suspended sediments, and turbulence of water, which influences sediment transport and resuspension. The presence of fine sediment (clay, silt, detritus, or more frequently fine sand) in the infralittoral rocky habitats depends on a variety of natural processes. The major inputs of sediments to coastal areas come from rivers, atmospheric transport, erosion of cliffs and resuspension of sediments from nearby soft-bottoms. In addition, various benthic and pelagic organisms may represent a source of sediments.

Sedimentation is an important ecological factor controlling development of sessile organisms on rocky substrates; however, an excessive deposition of sediment may cause dramatic alterations in the structure of benthic communities, particularly by limiting the settlement and development of algal populations. Dominant species of this habitat are, therefore, invertebrates and in particular sponges, scleractinians, alcyonaceans, ascidiaceans, and bivalves.

Geographic distribution

The habitat is widespread along all the Mediterranean coasts, and its distribution is obviously influenced by sediment deposition on the bottom. This habitat is therefore mainly present in the vicinity of the mouths of main rivers, such as for instance the Ebro on the Spanish coast, the Rhône on the French coast and the Po on the Italian coast. In addition, this habitat is frequent in areas where the intense coastal urbanization causes enhanced water sedimentation and turbidity.

Associated habitats

Associated habitats are ‘Facies with small sponges’ (MB1.531), ‘Facies with large and erect sponges’ (MB1.532), ‘Facies with Scleractinia’ (MB1.533), ‘Facies with Alcyonacea’ (MB1.534), ‘Facies with Ascidiacea’ (MB1.535), ‘Facies with Bivalvia’ (MB1.536), and ‘Facies with endolitic species’ (MB1.537). This habitat may be in contact with the ‘Algal-dominated infralittoral rock’ (MB1.51), the ‘Coralligenous (enclave of circalittoral)’ (MB1.55), the ‘Semi-dark caves and overhangs’ (MB1.56), the ‘Reefs of Vermetidae’ (MB2.51), the ‘Reefs of *Sabellaria* spp. (MB2.52), the ‘Reefs of *Cladocora caespitosa*’ (MB2.53), the ‘*Posidonia oceanica* meadows’ (MB2.54), the ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), the ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), the ‘Well sorted fine sand’ (MB5.52), the ‘Fine sand in sheltered waters’ (MB5.53), the ‘Infralittoral mud sediment’ (MB6.5), ‘Coralligenous’ (MC1.51), ‘Coastal detritic bottoms’ (MC3.51), ‘Coastal detritic bottoms with rhodoliths’ (MC3.52), ‘Muddy detritic bottoms’ (MC4.51) and ‘Coastal terrigenous mud’ (MC6.51).

Related reference habitats

Related reference habitats are ‘Invertebrate-dominated infralittoral rock’ (MB1.52), ‘Moderately illuminated infralittoral rock, exposed or sheltered’ (MB1.52a), ‘Coralligenous (enclave of circalittoral)’ (MB1.55), ‘Reefs of *Cladocora caespitosa*’ (MB2.53), ‘Coralligenous cliffs’ (MC1.51), ‘Invertebrate-dominated coralligenous covered by sediment’ (MC1.51c), ‘Coralligenous outcrops’ (MC1.52a), ‘Coralligenous outcrops covered by sediment’ (MC1.52b).

Possible confusion

This habitat is dominated by invertebrates, as in the case of the habitats ‘Invertebrate-dominated infralittoral rock’ (see sheet MB1.52) and ‘Moderately illuminated infralittoral rock, exposed or sheltered’ (see sheet MB1.52a), with which it can be confused. The deposition of a significant amount of sediment is evidently the main factor for distinguishing these habitats. This habitat can also be confused with the infralittoral ‘Coralligenous (enclave of circalittoral)’ (MB1.55), which however displays a biogenic calcareous layer edified by coralline algae.

Typical species and associated communities

Sediment deposition represents one of the most important factors affecting the structure of rocky benthic communities in this habitat. Composition and distribution of species are often closely related to spatial and temporal changes in sediment load. Along a gradient of increasing levels of sediment, an important variation in the relative abundance of some species can be observed, marked by the disappearance of macroalgae and by the increased abundance of filter feeding invertebrates. The habitat of infralittoral rock affected by sediments is mainly dominated by species with well defined morphological and physiological traits: i) long-lived species, more resistant to adjusting to the stress imposed by the sediment; ii) opportunistic species, able to quickly recolonise areas where other organisms have been removed by the sediment; iii) migratory species, able to move according to the amount of sediment; iv) species that bind and trap sediments; v) species capable of regenerating the tissue removed or abraded by the sediment; vi) species with an erect morphology, that prevents settlement of sediment; and vii) species with physiological adaptations to withstand darkness and anaerobic conditions.

Due to the similar environmental conditions (i.e., rocky substrate and low light intensity), most of the species inhabiting this habitat are the same of that of the habitat ‘Moderately illuminated infralittoral rock, exposed and sheltered’ (see sheet MB1.52a). Nevertheless, the most typical species in this habitat are the large and erect sponges such as *Axinella cannabina* and *Axinella polypoides*, the scleractinian *Cladocora caespitosa*, the arborescent alcyonaceans *Eunicella* spp. and *Leptogorgia* spp., the bivalve *Pholas dactylus* and the endolitic species *Lithophaga lithophaga* and *Cliona* spp. (see sheet MB1.537). Other abundant species in this habitat may be the sponges *Axinella damicornis*, *Axinella verrucosa* and *Crambe crambe*, the cnidarians *Anemonia viridis*, *Balanophyllia europaea*, *Epizoanthus arenaceus*, *Parazoanthus axinellae*, *Eudendrium* spp. and *Sertularella ellisii*, the anellids *Brachiomma* spp. and *Sabella spallanzani*, the bivalve *Mytilus galloprovincialis* and the tunicate *Styela plicata.* In the vagile fauna associated to this habitat can be found the gastropods *Cerithium vulgatum* and *Gibbula magus*, the nudibranchs *Cratena peregrina* and *Flabellina* spp.*,* and various fish assemblages*.*

Conservation interest and ecological role

This habitat is characterised by a high species richness, thus representing a biodiversity hotspot in the infralittoral rocky zone of the Mediterranean. Occurrence of long-lived erect sponges and alcyonaceans within this habitat generates three-dimensional space and habitat for either sessile or mobile associated fauna, enhancing the spatial heterogeneity. A high concentration of nutrients and organic matter is accumulated within deposited sediments, and their resuspension contributes to organic matter cycling in marine ecosystems. In this context, this habitat plays an important role in materials flow, connecting sediment sources (e.g., river mouths) with the water column.

Economic importance

The habitat of infralittoral rock affected by sediments offers provisioning services to humans, such as genetic resources availability (due to the high biodiversity it hosts), regulating services (i.e., CO_2 and climate regulation, natural carbon sequestration and storage), information services in terms of scientific research (carbon cycle in the sea, climate change studies) and recreation (visitation by scuba diving tourists), habitat services due to the creation of three-dimensional structures that amplifies the space available for marine organisms. To date the economic value of this habitat has not been assessed. Facies with Bivalvia and with endolitic species (e.g., *Lithophaga lithophaga*) are highly exploited for consumption and have a high market value. Nevertheless, the economic value of this habitat has not yet been assessed.

Vulnerability and potential threats

Over the past few decades, an increase in water turbidity and in sedimentation load on rocky reefs has occurred globally because of human activities. The major causes can be related to industrial and domestic discharges, mining activities, modification of the coastal environment (e.g., construction of roads, bridges, tunnels, harbours and replenishment of beaches), aquaculture, dredging, and land reclamation. Such increase in sediment loads has been recognised as one of the major threats to marine biodiversity at global scale. Coastal rocky reefs are the most sensitive habitats to this pressure, as excessive deposition of sediments may cause dramatic alterations in the structure of benthic communities. Macroalgae (e.g., Fucales and Laminariales) are particularly vulnerable to high sedimentation levels that reduce availability of space for settlement and light penetration, which are especially needed in their early development stages. In the most exposed areas, large-grained sediments (such as sand and detritus) may scour or abrade the organism tissues or even remove them completely from the bottom. In this context, the increased sedimentation and the consequent reduction of some benthic species, favour the settlement of more opportunistic alien species, such as *Caulerpa cylindracea* and *Womersleyella setacea*. In sheltered areas, suspended particles may interfere with filter feeding benthic invertebrates. Recent studies demonstrated the role of fine sediments in the formation and maintenance of turf-forming algal assemblages, which affect rocky reef ecosystems by limiting space for macroalgae populations and by impoverishing the structure of the benthic communities.

Protection and management

The species *Axinella cannabina*, *Axinella polypoides* and *Cladocora caespitosa* are included in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995). All scleractinian coral species are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). Due to intense harvesting, the species *Lithophaga lithophaga* is included in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995), in the Annex IV of the Habitat Directive, in the Annex II of the Bern Convention, and in the Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). Moreover, the European Regulation (EU 1967/2006) prohibits its capture, transport and sale.

Suitability of the habitat for monitoring

Despite its sensitivity, the habitat is not contemplated in monitoring programs (IMAP of Barcelona Convention, Water Framework Directive 2000/60/EC, Marine Strategy Framework Directive 2008/56/EC). Nevertheless, identifying the main pathways of sediment dispersal and accumulation would be important to predict the impact of major human-induced disturbances. Many species characterizing this habitat are protected by international laws and their conservation status should be constantly monitored. Its accessibility makes this habitat easily investigable, also by scuba diving, with many different non-destructive techniques. A wide range of sediment traps, including funnels, cylinders, boxes, jars and flasks, have been tested both in laboratory and in field studies. Sediment traps are used to obtain a representative sample of material moving or settling in the water column and can therefore be used to provide a measure of the quantity and the size fractions of sediment deposited on particular habitats.

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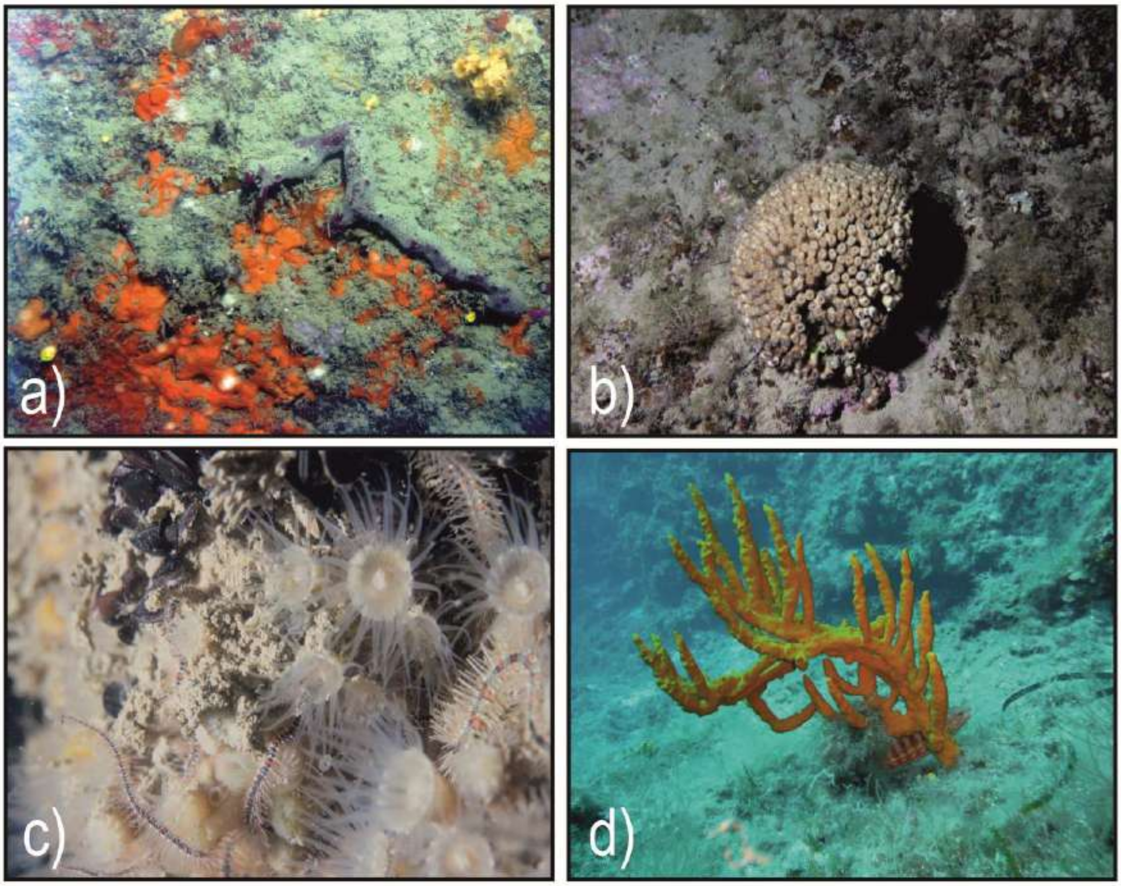

Infralittoral rock affected by sediments dominated by the sponge *Crambe crambe* (a), the scleractinian *Cladocora caespitosa* (b), the zoantharian *Epizoanthus arenaceus* (c), and the arborescent sponge *Axinella polypoides* (d) (a, b, c © A. Azzola; d © M. Montefalcone)


© M. Montefalcone

Facies with endolithic species

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.537**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	0 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Not known

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Photo credits:
M. Montefalcone

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.53 Infralittoral rock affected by sediments

MB1.537 Facies with endolithic species

Description of the habitat

The facies dominated by endolithic organisms mainly occurs in the infralittoral rock within the habitat 'Infralittoral rock affected by sediments', usually on sub-vertical and vertical rocky limestone substrates. This habitat may be found from the surface down to about 40 m depth, both in well-lit areas dominated by photophilic macroalgal communities and in shaded areas where coralligenous formations develop. Endolitic species are a special category of rock transforming organisms capable of boring into solid substrates, which contain calcium carbonate and which were manufactured by living organisms, creating cavities through a combination of mechanical and chemical actions, the latter by excreting acids that dissolve the rock. There are thousands of known species of endoliths (mainly among Bacteria and Fungi), but the only boring species that thrive inside limestone rock and are able to develop facies include the perforating sponges of the genus *Cliona* and bivalves. Among bivalves, the date mussel *Lithophaga lithophaga* is particularly abundant in subtidal shallow rocky reefs (up to 6 m depth).

Geographic distribution

This facies can develop all along the Mediterranean coasts where limestone infralittoral rock occurs.

Associated habitats

This habitat can be found associated with 'Facies with small sponges' (MB1.531), 'Facies with large and erect sponges' (MB1.532), 'Facies with zooxanthelate Scleractinia (MB1.533), 'Facies with Alcyonacea' (MB1.534), 'Facies with Ascidiacea' (MB1.535), 'Facies with Bivalvia' (MB1.536). This habitat may be in contact with the 'Algal-dominated infralittoral rock (MB1.51), the 'Coralligenous (enclave of circalittoral)' (MB1.55), the 'Reefs of Vermetidae' (MB2.51), the 'Reefs of *Sabellaria* spp. (MB2.52), and the 'Reefs of *Cladocora caespitosa*' (MB2.53).

Related reference habitats

Endolithic species can also be found within the 'Coralligenous cliffs' habitat (MC1.51), the 'Shelf edge rock' (MC1.52), the 'Semi-dark caves and overhangs' (MC1.53), and the 'Coralligenous platforms' (MC2.51).

Possible confusion

The habitat dominated by endolithic species is easily identifiable from the typical "holes" left by their excavating activity inside the rock, especially those made by bivalves. *Cliona* spp. occurrence cannot be easily visible when they form tiny perforation chambers in the substrate (the alpha form), whereas they appear more evident when partially protrude outside the rock with small papillae (the beta growth stage), inside which the characteristic oscules open.

Typical species and associated communities

Among bivalves, typical endolithic species are *Lithophaga lithophaga*, *Rocellaria dubia*, *Irus irus*, *Petricola lithophaga*, *Striarca lactea*, *Leiosolenus aristatus*, and *Pholas dactylus*. They live between the intertidal down to 25 m depth. Shallow depth (between 0-3 m) is less suitable to these species due to hydrodynamics, which limit larval settlement and juvenile growth rate. Endolithic bivalves may outcompete each other for the space availability; however, the boring activity of the sponge *Cliona* spp. has been shown to increase the substrate structural complexity facilitating the settlement of endolithic bivalves on artificial structures. When molluscs fixe themselves in a particular point of a rocky reef, they make this choice for the life, and are then unable to move. Through an extroflectable siphon, they are able to capture suspended particles in sea water to feed themselves. Among endolithic bivalves the date mussel *Lithophaga lithophaga* is the most common and abundant in the Mediterranean Sea, where high abundance have been reported within 10 m depth, with maximum values around 1600 individuals m^{-2}.

The encrusting-looking piercing sponges of the genus *Cliona* (e.g., *C. viridis*, *C. celata, C. schmidti*) are a highly adaptable genus of the family Clionaidae, which have a global distribution in the Mediterranean occurring from shallow waters down to 30-40 m depth. *Cliona* spp. can be very large extending up to several square meters. The size of the sponge is often limited by light availability. Some clionid sponges are presumed to pass through three putative growth stages: boring, encrusting, and massive stages, also known as alpha, beta, and gamma. Boring sponges range in colour from yellow to orange and light brown and pale green. They are able to bioerode calcium carbonate substrates such as limestone, coral, mollusc shells, and coralline algae. They create a canal system by chemically etching out carbonate material for shelter and during the process simultaneously create sediment. *Cliona* spp. are not predators and do not derive any nutrients from their host; however, they are competitors for space on appropriate substrates. They are not only excavators but are also capable of encrusting the surface and smothering the host. Many *Cliona* species host symbiotic dinoflagellate zooxanthellae. The abundance of the boring sponges increases as a function of eutrophication and is also dependent upon the available carbonate substrata. The abundance of *Cliona* spp. has been shown to be positively correlated with that of sea urchins and negatively correlated with fleshy algal cover. Sponge cover has been reported as 2 to 8% in the photophilic community, 5 to 30% in the sciaphilious community, and up to 7% in caves.

The hard substrates inhabited by bioeroders are among the most rich and diverse habitats of the subtidal zone, and are characterized by a huge variety of associated sessile species. The basal layer on the rock surface is covered by a very complex community featured by the presence of encrusting algae, sponges, and bryozoans. Above this layer, an intermediated layer made by bushy macroalgae, cnidarians and tunicates is observed. An upper layer of arborescent organisms, such as macroalgae (*Cystoseira* spp.), erect and large sponges, and gorgonians, might develop in particular environment conditions, providing several microhabitats where vagile invertebrates and fishes thrive, feed and reproduce, increasing the biodiversity of the system. Natural predators, such as starfishes (*Marthasterias glacialis*, *Echinaster sepositus*, *Coscinasterias tenuispina*, *Ophidiaster ophidianus*) can predate endolitic bivalves inside holes everting the stomach, while some gastropods species (*Muricopsis cristata*, *Stramonita haemastoma*, *Ocenebra erinaceus*, *Euthria cornea*) use long proboscis.

Conservation interest and ecological role

Bioerosion activity makes fine sediments available for bioconstructor organisms that integrate sediment particles into coralligenous formations. Borers therefore provide an important service for epilithic communities. As bioeroders, they also play an important role in the carbonate cycle.

Economic importance

The facies with endolithic bivalves, and especially *Lithophaga lithophaga,* is highly exploited for consumption by mussel fishery, and has therefore a high market value. Nevertheless, to date the economic value of this habitat has not been assessed.

Vulnerability and potential threats

Endolithic species may be significantly impacted by enhanced levels of sedimentation and by effects of global climate change. Most clionids, however, are able to withstand and adapt to varying environmental conditions such as temperature, hydrodynamism, and sedimentation load. Date mussel fishery caused dramatic impacts over large areas in the past decades and is considered as one of the most widespread and harmful anthropogenic impacts on temperate subtidal rocky habitats. Rocks were broken by scuba divers, manually by hammers, sledgehammers or using specific devices (underwater hammer/diver drillers). The use of explosives has been also reported in some areas of the Moroccan and Croatian coastlines. The total removal of the top layer of substrate, together with its rich epibenthic community, allows date mussel harvesting and leaves completely bare and smoothed rock, with scattered empty holes. In addition, the slow growth rate of *Lithophaga lithophaga* (15 to 30 years are needed to reach 5 cm in length) contributes to exacerbate the negative impact of date mussel fishery over large spatial scales, and several decades are necessary for date mussels to recover after harvesting. Exploited sites vary in extension from scattered bare patches to several kilometres of completely deserted coast (such as Apulia and Albania). Destructive harvesting of date mussels causes huge direct impact on benthic communities, resulting in a shift from a multilayer and highly complex community to a simplified habitat structure. Mechanical damage also alters the geomorphological characteristics of the substrate by reducing the structural complexity of the rocky surface and modifying the inclination and roughness of the slope (shadowing effect). Depletion of the benthic cover in areas affected by date mussel fishery may facilitate sea urchins development and their grazing on algae and newly settled organisms. By preventing the recovery of benthic communities, sea urchins favour the persistence of barrens over the long term, leading to a regime shift from vegetated to barren habitats.

Protection and management

The collection, possession and trade of *Lithophaga lithophaga* is strictly prohibited under international directive and conventions in all Mediterranean countries. The species is included in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention 1995), in the Annex IV of the Habitat Directive, in the Annex II of the Bern Convention, and in the Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). Despite these regulations, illegal international trade continues to take place, particularly in the North-West Africa and South-East European countries. Today, the breeding of this species is being tried, which would limit poaching.

Suitability of the habitat for monitoring

This habitat is not contemplated in any monitoring programs (IMAP of Barcelona Convention, Water Framework Directive 2000/60/EC, Marine Strategy Framework Directive 2008/56/EC).

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The endolitic sponge *Cliona viridis* that partially come out from the rocky substrate with small papillae (in the beta growth stage) with opened oscules (© M. Montefalcone)

Coralligenous (enclave of circalittoral)

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.55**
- **EUNIS 2019: MB25**
- **EUNIS 2007: A5.535, A5.6**
- **EC: 1170**
- **CORINE: 11.25, 11.251**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock)
Depth range	15 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
A. Tommasi

INFRALITTORAL

MB1.5 Infralittoral rock

MB1.55 Coralligenous (enclave of circalittoral)

Description of the habitat

Coralligenous habitat is a hard substrate of biogenic origin consisting of calcareous structures edified by coralline algae grown at low irradiance levels and in relatively calm waters. Normally coralligenous develops on circalittoral rocky substrates but, in some cases coralline algae built calcareous structures in infralittoral bottoms, alternating with seagrass or algal beds, which has been often included in the so-called “coralligenous in enclave”. This habitat is considered by some authors as an impoverished facies of the coralligenous biocoenosis, as it is found at shallower depths, where light is more intense, resulting in depleted calcareous algae diversity and low biocostruction. Other authors consider the infralittoral coralligenous as a transitional assemblages between the infralittoral photophilous communities and the deeper coralligenous biocoenosis. However, in some cases coralline algae constitute conspicuous structures several decimeters thick even in infralittoral bottoms, forming peculiar habitat. Coralligenous as an enclave in the infralittoral, can form small discontinuous organogen formations.

Geographic distribution

This habitat can be distributed throughout the Mediterranean Sea, but is little common.

Associated habitats

The habitat occurs on ‘Infralittoral rock’ (MB1.5) and may have possible contact with ‘Algal-dominated infralittoral rock’ (MB1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coastal detritic bottoms’ (MC3.51 and MC3.52), ‘Muddy detritic bottoms’ (MC4.51), and ‘Coastal terrigenous mud’ (MC6.51).

Related reference habitats

‘Coralligenous cliffs’ (MC5.51), ‘Algal-dominated coralligenous’ (MC1.51a), ‘Invertebrate-dominated coralligenous’ (MC1.51b), ‘Invertebrate-dominated coralligenous covered by sediment’ (MC1.51c), ‘Coralligenous outcrops’ (MC1.52a), ‘Coralligenous outcrops covered by sediment’ (MC1.52b), ‘Coralligenous platforms’ (MC2.51).

Possible confusion

The habitat could be confused with ‘Coralligenous cliffs’ (MC1.51) and ‘Algal-dominated coralligenous’ (MC1.51a). Like this latter habitat, infrallittoral coralligenous differs from coralligenous cliffs in having softer sciaphilous algae and fewer invertebrate species. Infralittoral coralligenous develops in shallower waters than coralligenous cliffs and it is normally interspersed with other typical infralittoral habitats.

Typical species and associated communities

Coralline algae are the primary habitat builders, along with the encrusting *Peyssonnelia* spp. Associated assemblages are dominated by sciaphilous algae, such as the Chlorophyta *Halimeda tuna, Codium bursa* and *Flabellia petiolata*, the Ochrophyta *Halopteris filicina, Sargassum hornschuchii*, and *Cystoseira montagnei*, and the Rhodophyta *Sphaerococcus coronopifolius, Laurencia chondrioides*, and *Tricleocarpa fragilis*. Because of the depth at which the habitat develops, less sciaphilous algae can also be found, such as *Dictyota* spp. and *Padina pavonica*. The most common invertebrates are sponges, the anthozoans *Eunicella singularis* and *Cladocora caespitosa*, the bryozoan *Myriapora truncata* and the ascidian *Halocynthia papillosa*.

Conservation interest and ecological role

The infralittoral coralligenous supports biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages.

Economic importance

The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. Moreover, the assemblages dominated by erect Alcyonacea are mostly appreciated by divers. To date, the economic value of the habitat has not been evaluated yet.

Sargassum hornschuchii (left panel), *Eunicella singularis* (right panel) (© A. Tommasi)

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. Because of the depth at which the habitat develops, it is particularly threatened by thermal anomalies and mechanical destruction by anchoring.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities (UNEP/MAP 2017). Moreover, several coralligenous invertebrates belonging to Porifera, Cnidaria, Bryozoa, Mollusca, Crustacea and Echinodermata are listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention), and in the Appendix I “Strictly protected flora species” of the Bern Convention.

Suitability of the habitat for monitoring

Coralligenous habitat has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). The ecological quality of coralligenous shall also be assessed within the Marine Strategy Framework Directive. Several methods and ecological indices have recently been proposed to detect the ecological quality of the coralligenous habitat and to be employed in monitoring programs and impact evaluation studies. However, the habitat has been less investigated than circalittoral coralligenous, because it is considered a depleted or transitional habitat. In contrast, the habitat has the same conservation interest and ecological role as circalittoral coralligenous and it may be particularly vulnerable to human impacts. Therefore, the habitat should be evaluated in monitoring programs. Monitoring is preferably done through SCUBA divers because of the depth range and scattered distribution.

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Reefs of Vermetidae

Reference codes for identification:

- **BARCELONA CONVENTION: MB2.51**
- **EUNIS 2019: MA154A (partim), MA2551, MB151β, MB2511**
- **EUNIS 2007: A1.234 (partim), A2.7 (partim), A3.133**
- **EC: 1170 (partim)**
- **CORINE: 11.253 (partim)**

LOCATION OF THE HABITAT

Zone	Infralittoral (partly extending in the lower midlittoral)
Nature of the substratum	Hard (rock)
Depth range	0 m to 1.5 m
Position	Coastal
Hydrodynamic conditions	Strong
Salinity	Between 36 and 39
Temperature	14 °C to 28 °C
Suitability for monitoring	Yes, but not applied

Authors:
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Photos credit:
F. André, F. Caroli, R. Chemello, E. Trainito

INFRALITTORAL

MB2.5 Infralittoral biogenic habitat

MB2.51 Reefs of Vermetidae

Description of the habitat

Vermetidae are sessile gastropods in which the typical snail-shaped shell is lost in an early developmental phase, to take the form of a calcareous encrusting tube. Larval gregariousness leads some species to form aggregations of tubes on rocky shores, in the uppermost part of the infralittoral zone (infralittoral fringe), partly extending in the lower midlittoral. Tubes may completely cover the rocky substrate with a thin crust or numerous layers, several decimetres thick and metres wide, deposited by subsequent generations. Depending on the slope of the rocky substrate, this biogenic construction can develop into a rim or cornice (on vertical walls), levelling ledge (on sloped rocks), or sub-horizontal platform or terrace growing in a seaward direction and commonly referred to as reefs or by their French name of ‘trottoir’. Well developed reefs are embedded in a calcareous matrix formed primarily by coralline algae (accompanied by other epilithic and endolithic species), and are functionally similar to tropical coral fringing reefs. On the most developed vermetid reefs, an outer and an inner margin can be identified. The outer margin is the most biologically active portion, composed by tightly packed vermetid tubes (up to 60,000·m^{-2}); the inner margin is less densely packed and is subjected to emersion during low tide. Between the two margins, shallow depressions, called ‘cuvettes’, can be found, which can hold water during low tide.

Geographic distribution

Vermetid bioconstructions are found in tropical, sub-tropical, and warm temperate coastal areas worldwide. In the Mediterranean Sea they are restricted to the southern and warmest sectors, the February surface isotherm of 14 °C apparently setting their northern limit. Over the last three decades, in coincidence with seawater warming and surface isotherm shifting, their range is expanding northward, where they appear as crusts and rims.

Associated habitats

The facies with vermetids is in contact with other habitats occurring in the rocky infralittoral fringe and lower midlittoral zone.

Related reference habitats

In well developed vermetid platforms, the outer margin may share species with the ‘Algal-dominated infralittoral rock exposed’ (MB1.51a), and especially with the ‘Association with Fucales’ (MB1.511a, MB1.511c). Similarly, the inner margin may host species of the ‘Lower midlittoral rock’ (MA1.54). The cuvettes resemble ‘Midlittoral euryhaline and eurythermal pools’ (MA1.54a).

Possible confusion

Position at sea level and morphology make this habitat easily recognizable. Trottoirs may also be formed by the coralline alga *Lithophyllum byssoides* in the ‘Platforms of encrusting Corallinales’ (MA2.51) in the lower midlittoral zone.

Typical species and associated communities

Mediterranean vermetid reefs are formed by four species of *Dendropoma*, once confused under the name *D. petraeum*. Genetic studies, corroborated by phenotypic correspondences, have revealed a complex of cryptic species with non-overlapping ranges: *D. lebeche* in the south-western Mediterranean (North Africa, South Spain) and neighbouring Atlantic (Cadiz to Casablanca); *D. cristatum* in Sicily, Malta and Tyrrhenian Sea; *D. anguliferum* in the Levant Sea; and a yet undescribed species in the Ionian-Aegean area. *Vermetus triquetrus,* another solitary or gregarious species of vermetid, sometimes occurs in permanently submerged parts of the reef. Vermetid tubes are cemented by the coralline alga *Neogoniolithon brassica-florida*, which represent a non secondary component of the reef. Other organisms may participate in the bioconstruction: the foraminiferan *Miniacina miniacea*, the coralline algae *Lithophyllum incrustans*, *L. byssoides* and *Neogoniolithon mamillosum*, and encrusting bryozoans. Boring organisms, such as Cyanobacteria, Chlorophyceae, sponges, bivalves, and sipunculid worms, act as bioeroders. Below the outer margin, the vermetid reef is usually fringed by a characteristic upper subtidal belt made by the canopy-forming alga *Ericaria amentacea*. Red algae of the genera *Chondrophycus, Laurencia* and *Palisada* may form carpets on the outer ridge of the vermetid reef. Species living in the anfractuosities of the vermetid reef include the crustacean *Calcinus tubularis* (within the tubes), the sea-urchin *Arbaciella elegans* (in cavities), and the date mussel *Lithophaga lithophaga* (in actively bored holes). Other molluscs can be found on the margins of the reef, such as *Cardita calyculata, Lepidochitona caprearum, Mytilaster minimus, Onchidella celtica* and *Patella ulyssiponensis*, or in the cuvettes, such as *Barleeia unifasciata*, *Eatonina cossurae*, *Patella caerulea*, and *Pisinna glabrata*. The polychaetes *Palola siciliensis*, *Perinereis cultrifera* and *Platynereis dumerilii* may be abundant. Three crab species of the genus *Pachygrapsus*, *P. marmoratus*, *P. maurus* and *P. transversus*, move through the reef, and are preyed upon by another crab, *Eriphia verrucosa.* Fish are mostly represented by *Parablennius zvonimiri, Scartella cristata, Tripterygion delaisi, T. melanurum*, and *T. tripteronotum.*

Conservation interest and ecological role

Vermetid reefs are complex and three-dimensional structures that enhance the local biodiversity. More than 400 species live associated to vermetid reefs, including 130 species of algae, 50 of molluscs, 70 of polychaetes, and 30 of fishes. The four cryptic species of *Dendropoma* that built the bioconstructions are regional endemics exhibiting small ranges; they reproduce by brooding encapsulated larvae, and their ability to disperse is very limited. All these characteristics make them particularly prone to extinction. The recent dramatic shrinkage of the populations of *Dendropoma anguliferum* along the coasts of Israel and Lebanon is already a cause of concern.

Economic importance

The facies with vermetids provides multifarious ecosystem services. Habitat services are due to the creation of a three-dimensional environment that amplifies the available space for intertidal organisms. Food availability, mostly consisting in the harvesting of seafood (limpets), represents the provision services. Information services include recreation, as the platforms are used by bathers, and scientific research: vermetid bioconstructors are increasingly studied as natural archives of palaeoclimatological significance, as they allow retrieving information about sea-level variations and past sea surface temperature and other water properties over the last two millennia. Regulating services range from the active role of vermetid reefs in the carbon cycle, to water clearing by their filtration activity (which helps counteracting coastal eutrophication), to physical protection of the coastline from the erosion by waves. The latter service is perhaps the most important: its monetary value has been quantified in 415-702·10^3 €·km^{-1}·a^{-1}.

Vulnerability and potential threats

Vermetid reefs are a fragile ecosystem, vulnerable to surface water pollution (oils, surfactants, nutrients) and human trampling, boating and harvesting. Environmental degradation and coastal urbanization threaten their survival. Global climate change, with sea level rise and ocean acifidification, is detrimental to vermetids. It has been calculated that, unless CO_2 emissions are reduced and conservation measures taken, vermetid reefs are in danger of extinction within the present century. Another threat is represented by invasive alien species, such as the bivalve *Brachidontes pharaonis* and the crab *Percnon gibbesi*, which compete with native dwellers.

Protection and management

Considering the environmental importance of vermetid reefs and their role for Mediterranean biodiversity, specific conservation strategies are desirable. The *Dendropoma petraeum* complex is included in the Appendix II (Strictly protected fauna species) of the Bern Convention on the Conservation of European Wildlife and Natural Habitats, and in the Annex II (List of endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. However, only a minority of vermetid reefs is incorporated in marine protected areas.

Suitability of the habitat for monitoring

Easy recognition and access of vermetid reefs should facilitate their monitoring. Information on their dynamics, present status, and resilience after disturbances is virtually lacking. The use of unmanned aerial vehicle technology has been proved suitable for monitoring and conservation programs.


Densely packed vermetid tubes on reef outer margin (© E. Trainito)


Dendropoma cristatum (© R. Chemello)


Vermetus triquetrus (© F. André)


Calcinus tubularis (© F. Caroli)


Scartella cristata (© F. Caroli)


Percnon gibbesi (© F. Caroli)


Trampling and seafood harvesting on a vermetid platform (© R. Chemello)

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INFRALITTORAL

MB2.5 Infralittoral biogenic habitat

MB2.52 Reefs of *Sabellaria* spp.

Reefs of *Sabellaria* spp.

Reference codes for identification:

- **BARCELONA CONVENTION: MB2.52**
- **EUNIS 2007: A5.612 (partim)**
- **EUNIS 2019: MB2541 (partim)**
- **EC: 1110 (partim)**
- **CORINE: 11.253 (partim)**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Soft (sand, in proximity of some rock)
Depth range	0 m to 7 m
Position	Coastal
Hydrodynamic conditions	Strong
Salinity	Between 34 and 39
Temperature	10 °C to 28 °C
Suitability for monitoring	Yes, but not applied

Authors:
C.N. Bianchi, C. Morri

Photo credits:
C.N. Bianchi, C. Morri

Description of the habitat

The sedentary polychaetes of the genus *Sabellaria* are sessile, tube-dwelling species that can build large aggregations up to one meter high and tens of square metres wide. Such worms reefs consist of tubes cemented to each other, creating compact structures that are at the origin of the common names of ‘sandcastle worms’ and ‘honeycomb worms’ for these polychaetes. The morphology of *Sabellaria* bioconstructions ranges from more or less thick crusts, to mounds, to mushrooms (derived from differential erosion at mound base), to banks (derived from coalescence and fusion of neighbouring thick layers and mounds plus vertical accretion). Two species of *Sabellaria* are known to be reef-building in the Mediterranean Sea: *Sabellaria alveolata* and *S. spinulosa*. The two species are distinguished by the shape of the outer opercular paleae, their dentition pattern, and the absence or presence of nucal spines. Most of the known *Sabellaria* reefs in the Mediterranean are built by *S. alveolata*, whilst *S. spinulosa* usually occurs with single individuals, often within the reefs built by its congener. However, reefs built by *S. spinulosa* have been recently described along the Italian coast of the Adriatic Sea. In both cases, reefs are formed by millions of tubes built by sand grains and shell fragments glued by proteinaceous secretions. Tubes consist of an internal organic membrane and three agglutinated layers: a thin inner layer of flat grains arranged side by side; a thick mid layer with a frame of relatively large sub-spherical grains with cavities partly filled by smaller grains; and a thin outer layer of large, flat to curved, usually biogenic clasts diverging towards the opening. The sediment agglutinated in the tubes falls within medium and coarse sands, with subordinate fine sands and granules. Sandy sediments are mainly quartz-feldspathic in composition, but biogenic carbonates are always important. Worms select grains and bioclasts on the basis of their grain size and shape, and not of their composition. Mediterranean *Sabellaria* reefs occur in the upper infralittoral zone, mostly between 0 m and 7 m depth, on sandy seafloor in proximity of some rock or hard substrate. They often reach the sea surface and may remain exposed at low sea. Reef development starts from the settlement of pioneer larvae on exposed hard substrates (e.g. stones) within sandy bottoms or at the base of rock and boulders lying on sand. The newly settled individuals build small structures, their tubes growing at a rate of 4.4-6 $mm \cdot d^{-1}$. Adult worms produce chemical cues that attract other larvae, which have a gregarious behaviour and tend to settle on conspecifics. Reef accretion depends on abundant sand supply and strong water movement. On the other hand, vigorous wave action may cause the destruction of portions of the reef. Further larvae, however, may settle on dead remains and restart accretion. *Sabellaria* reefs are therefore extremely dynamic systems: they may persist in an area for long although individual clumps may regularly form and disintegrate. Thus, the age of these bioconstructions greatly exceeds the life span of the individual worms (*S. alveolata* can live up to 9 years, whilst *S. spinulosa* is an annual species): the reef may repeatedly follow a cyclical progression of settlement, growth, and destruction phases. In Latium and Sicily there are reefs of *Sabellaria alveolata* first described in the 1950s and still existing without apparent major change.

Geographic distribution

The knowledge on *Sabellaria* reefs in the Mediterranean Sea is too fragmentary to evaluate their distribution and quantity. They are widespread, although discontinuous, in the western Mediterranean and Ionian Sea (built by *S. alveolata*), as well as in the Adriatic Sea (built by *S. spinulosa*). No information is available about the Eastern Mediterranean. Recent studies on this habitat have been carried out chiefly along the Italian coasts.

Associated habitats

Sabellaria reefs are in contact with the ‘Infralittoral sand’ (MB5.5). When developing at the base of rocks on sandy floor, they may also border on the ‘Infralittoral rock’ (MB1.5), the ‘Association with photophilic algae’ (MB1.512c), and the ‘Association with encrusting Corallinales’ (MB1.513c, MB1.511d).

Related reference habitats

The biota associated with *Sabellaria* reefs may have species in common with the ‘Invertebrate-dominated infralittoral rock’ (MB1.52), the ‘Infralittoral rock affected by sediment’ (MB1.53), the ‘*Posidonia oceanica* meadow’ (MB2.54), and the ‘Well sorted fine sand’ (MB5.52).

Possible confusion

Location and aspect should make this habitat unmistakable.

Typical species and associated communities

Sabellaria reefs do not host a distinctive associated fauna, with the possible exception of the polychaete *Eulalia ornata*, which seems to be characteristic of this habitat. However, the reefs create an array of microhabitats suitable for the settlement of a rich and diversified fauna, which include species from either hard or soft bottoms. *Sabellaria* reefs are known to provide habitat to more than 150 species of invertebrates, comprised by about two third of motile taxa, such as Gastropoda, Polychaeta Errantia, Decapoda, Amphipoda, Isopoda, Tanaidacea, Echinodermata, and by one third of sessile or sedentary taxa, such as Porifera, Cnidaria, Bryozoa, Bivalvia, Nemertea, Sipuncula, Polychaeta Sedentaria, Cirripedia, Tunicata. The most abundant taxa are crustaceans, polychaetes and molluscs. Crustaceans are represented chiefly by *Apseudes holthuisi*, *Gammaropsis ulrici*, *Plumulojassa ocia*, *Quadrimaera inaequipes*, and *Pilumnus hirtellus*. The latter occurs in summer with both ovigerous females and juveniles, suggesting that *Sabellaria* reefs play a nursery role for this crab. The most common polychaetes are *Arabella iricolor*, *Nereis splendida*, and *Syllis garciai*. Molluscs are represented by both bivalves, such as *Lentidium mediterraneum*, *Mytilus galloprovincialis*, and *Striarca lactea*, and gastropods, such as *Tritia incrassata*. Among the other taxa, the sipunculan *Phascolosoma granulatum* and the ophiurid *Amphipholis squamata* are noteworthy. Paradoxically, species richness is higher in the dead portions of the reef, suggesting that the filtering activity by living worms is able to hamper the settlement of other benthic species. Dead reef portions may be encrusted by the coral *Cladocora caespitosa*, the oyster *Ostrea edulis*, and the bryozoan *Schizoporella errata*, thus originating a polytypic bioconstruction. *Sabellaria* reefs are attractive for some fish such as *Syngnathus abaster*. *Gobius niger* and *Octopus vulgaris* hide in cavities at the base of the reef, while juveniles of *Boops boops*, *Diplodus puntazzo*, *D. sargus*, *Lithognathus mormyrus*, *Mullus surmuletus*, *Sarpa salpa*, *Serranus cabrilla* and *Sphyraena viridensis* swim around the reef, seeking refuge in its anfractuosities in case of danger. The blennies *Parablennius gattorugine*, *P. rouxi* and *P. sanguinolentus* are common reef residents.

Conservation interest and ecological role

Sabellaria alveolata and *S. spinulosa* are ecosystem engineers: they are able to create and maintain a biogenic habitat that modify the physical-chemical features of the surrounding environment, modulating the distribution and abundance of the resources for other species and allowing the formation of special communities. Similarly to other biogenic habitats, the reefs of *Sabellaria* are living three-dimensional structures that provide architectural complexity and shelter for several hard and soft bottom species, thus enhancing local biodiversity. They supply food, nursery and refuge from predators, and condition local hydrodynamics and biogeochemical cycles.

Economic importance

Besides habitat services, due to the creation of a three-dimensional environment that amplifies the available space for the shallow water biota, *Sabellaria* reefs provide regulating services, because of the active role the worms exert in water clearing (their filtration activity helps counteracting coastal eutrophication) and of the physical protection of the coastline from erosion, as they retain suspended sand grains and create a barrier against storms. A hitherto unexplored potential provision service resides in the active substances (infochemicals) that the worms use as a chemical language. The monetary value of this habitat has not been assessed yet.

Vulnerability and potential threats

Anglers break portions of *Sabellaria* reefs to extract worms to be used as bait. Being made of agglutinated sand, *Sabellaria* reefs are fragile structures, which are severely impacted by human trampling and by the increasing intensity and frequency of extreme weather events due to climate change. Despite the tolerance of *Sabellaria* species to poor water quality, eutrophication is detrimental to their reefs: increasing inputs of nutrients on the shore cause massive green algae blooms, which hamper the larval recruitment of the worm. Surface water pollution (oils, surfactants, nutrients) and changes in hydrological and sediment regimes resulting from coastal engineering works are other major threats to this living habitat.

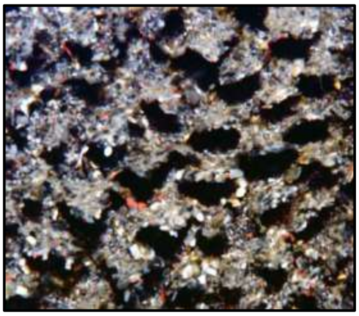
Protection and management

This habitat does not benefit of any special form of protection. Due to the lack of information on its distribution and status, it is included in the European Red List of Habitats as ‘Data Deficient’. Virtually no Marine Protected Area includes *Sabellaria* reefs.

Suitability of the habitat for monitoring

Easy recognition and accessibility of *Sabellaria* reefs should facilitate their monitoring. The health of the reefs can be determined with reference to the proportions of newly settled worms, tubes with crisp opening, tubes with worn opening, and empty tubes. Information on reef dynamics, present status, and resilience after disturbances is virtually lacking. The use of close-range underwater photogrammetry has been proved suitable for future monitoring and conservation programs.

A pictorial view of *Sabellaria alveolata* in its tube (© C. Morri)



The surface of a reef, with tube openings (© C.N. Bianchi)

Dried reef fragment, showing the compact arrangement of tubes (© C. Morri)

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Reefs of *Cladocora caespitosa*

Reference codes for identification:

- **BARCELONA CONVENTION: MB2.53**
- **EUNIS 2019: MB151E (partim)**
- **EUNIS 2007: A3.238 (partim)**
- **EC: 1170 (partim)**
- **CORINE: 11.251 (partim)**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rocks or seafloor with stable stones and pebbles)
Depth range	3 m to 30 m
Position	Coastal, locally in 'marine lakes'
Hydrodynamic conditions	Variable
Salinity	Between 34 and 39
Temperature	10 °C to 28 °C
Suitability for monitoring	Yes

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INFRALITTORAL

MB2.5 Infralittoral biogenic habitat

MB2.53 Reefs of *Cladocora caespitosa*

Description of the habitat

When abundant, the colonial and zooxanthellate scleractinian coral *Cladocora caespitosa* may typically occur in two main formations: beds and banks. Beds are composed by numerous small (10-30 cm in diameter) sub-spherical colonies in dense populations. Banks are made up of large colonies, reaching several decimetres in height and covering areas of several square metres. Banks originate from beds under conditions of undisturbed accretion by means of three mechanisms: (i) fusion of adjacent colonies; (ii) 'pouring' of the incipient build-up due to gravity; and (iii) inclusion of satellite colonies. Mixed distributions of beds and banks can also be found, while a third formation has been recently described: free-living coral nodules or coralliths (about 5 cm in diameter). Banks are the most important bioconstructions of *C. caespitosa* and may deserve to be called reefs. Their calcification rates may reach 1.7 $kg \cdot CaCO_3 \cdot m^{-2} \cdot a^{-1}$, which is comparable to the values of many tropical reef corals. Corallites are cylindrical and exhibit growth rates that may exceptionally exceed 5 $mm \cdot a^{-1}$. By extratentacular (rarely intratentacular) budding, corallites develop lateral branches that grow upward parallel to the parent corallite. Sexual reproduction occurs in summer before full moon. Polyp expulsion and possibly fragmentation (through the formation of coralliths under particular conditions) are potential mechanisms for dispersion.

Geographic distribution

Cladocora caespitosa is endemic to the Mediterranean Sea, and occurs throughout the whole basin. It is known from the Marmara Sea but does not seem to occur in the Black Sea. There are records from the neighbouring eastern Atlantic, such as southern Portugal (Algarve) and Morocco (Agadir). Reefs are known especially from Spain, Italy, Croatia and Greece. Fossil records indicate that reefs were more developed during warmer phases of the Quaternary, being especially found in terraced deposits of Middle to Late Pleistocene age. The present range of *C. caespitosa* reefs in the Mediterranean Sea has apparently decreased compared to their fossil distribution.

Associated habitats

Reefs of *Cladocora caespitosa* typically develop in turbid shallow waters or at the lower limit of the infralittoral zone, partly within or near habitats belonging to the ‘Algal-dominated infralittoral rock’ (MB1.51), such as the ‘Lower infralittoral rock moderately illuminated’ (MB1.51e), the ‘Infralittoral rock affected by sediment’ (MB1.53), or certain aspects of the ‘Infralittoral coarse sediment’ (MB3.5). They may also border on ‘Coralligenous’ habitats (either MB1.55 or MC1.51), and ‘*Posidonia oceanica* meadows’ (MB2.54).

Related reference habitats

Cladocora caespitosa may be a component of other infralittoral facies with Scleractinia (especially MB1.516a and MB1.516c), but does not form reefs there.

Possible confusion

The cryptogenic colonial and zooxanthellate scleractinian coral *Oculina patagonica* may form sizeable colonies in shallow areas where *C. caespitosa* may also thrive. The scleractinian coral *Polycyathus muellerae* is frequently confused with *C. caespitosa*, even in the scientific literature, but it is not zooxanthellate and thrives in sciaphilic habitats, being part of completely different biotic assemblages, either infralittoral (MB1.524a) or circalittoral, such as the ‘Facies with Scleractinia’ (MC1.534a, MC1.534b) of submarine caves and certain coralligenous formations (MB1.55, MC1.51), even with high silt deposition. Its colonies are usually encrusting and do not reach reef-like sizes.

Typical species and associated communities

Reefs are formed by *Cladocora caespitosa* alone. Many species, either sessile or mobile, may be found associated to the reefs, but none seems exclusive to that habitat. The macroalgae most frequently found on the reefs include *Dictyota dichotoma*, *Padina pavonica*, *Peyssonnelia* spp., *Codium bursa*, and *Halimeda tuna*, among others. The cryptofauna contains more than one hundred species belonging to at least eleven major phyla (Porifera, Cnidaria, Platyhelminthes, Nemertea, Mollusca, Sipunculida, Annelida, Arthropoda, Bryozoa, Echinodermata, and Chordata). Among the most frequent and abundant species are the bivalves *Hiatella arctica* and *Rocellaria dubia*, the sipunculid *Phascolosoma granulatum*, the polychaetes *Lysidice ninetta* and *Eunice vittata*, the crustacean decapod *Athanas nitescens*, the sea urchin *Psammechinus microtuberculatus*, and the brittle star *Ophiothrix fragilis*. The abundance of juveniles suggests that *C. caespitosa* reefs may represent a nursery ground for many invertebrates. Serpulids (mainly *Serpula concharum*, *Hydroides pseudouncinata*, and *Vermiliopsis striaticeps*) encrust the corallite basis, acting as binders of the bioconstruction, while boring sponges (such as *Cliona viridis*) erode the corallites close to the living tissue until they break off the colony. The gastropods *Coralliophila meyendorffii* and *Babelomurex cariniferus* are specialized corallivores, while the polychaete *Flabelliderma cinari* may be a mutualistic symbiont that removes detritus and pathogens. Among fish, *Gobius cruentatus*, *Parablennius rouxi*, and *Symphodus cinereus* are considered reef resident species.

Conservation interest and ecological role

As other biogenic habitats, the reefs of *Cladocora caespitosa* increase the topographic heterogeneity of the seafloor, thus enhancing benthic diversity by offering refuge and nursery area to many cryptic species. Coral mucus, whose production averages $8.5\ \mu g_{DW} \cdot polyp^{-1} \cdot h^{-1}$, has high nutritional value and represents a significant food source for consumers. The role of major habitat former is not restricted to the living colonies of *C. caespitosa* but extends also to the accumulation of dead and subfossil corallites in the neighbouring sediments, increasing their content of coarse carbonate fractions. *C. caespitosa* reefs are the only coral bioherms native to the Mediterranean Sea. They play a still little studied role in the carbon cycle. Due to their rarity in the present-day Mediterranean Sea, their conservation is an important concern and should be mandatory.

Economic importance

The reefs of *Cladocora caespitosa* provide regulating services, such as those associated to the carbon cycle; provisioning services, such as organic production (which may indirectly involve the food webs of commercial species) and genetic resources availability (due to the biodiversity they host); habitat services, as the creation of a three-dimensional structure amplifies the space available for marine organisms; and information services, in terms of either recreation (they are natural monuments that attract scuba diving tourists) or scientific research and monitoring. *C. caespitosa* is a long-lived species with a slow growth rate and supplies an excellent fossil record: therefore, it represents a valid indicator of recent and past climate change; it also acts as a recorder of metals, chemicals and other pollutants, allowing to track and date human impacts. It is considered a living fossil and has enabled discovering survival strategies that were only known from extinct corals. No estimates of the monetary value of *C. caespitosa* reefs are available to date; comparisons with the calculations done for tropical coral reefs are inadequate due to the huge difference of spatial scale.

Vulnerability and potential threats

Although *C. caespitosa* exhibits an intrinsic capacity to recover from tissue injuries, in recent decades it has suffered polyp bleaching and necrosis due to seawater warming and summer heat waves. Physical damage due to anchoring has been reported. Its slow dynamics makes *C. caespitosa* highly vulnerable to catastrophic events. Eutrophication, mucilage, and excess sedimentation are detrimental to *C. caespitosa*, which also suffers from competition with filamentous and turf algae, and with invasive algae (e.g., *Caulerpa cylindracea, Lophocladia lallemandii*); on the contrary, erect algal canopies have been shown to protect polyps from abrasion injuries, thus creating mixed *C. caespitosa* - Fucales habitats.

Protection and management

Since 2015, *C. caespitosa* has been added to the endangered category of the IUCN Red List. However, and notwithstanding growing awareness of the threats faced by *C. caespitosa* reefs, no specific protection measures have been implemented yet.

Suitability of the habitat for monitoring

Long term persistence and easy recognition make the reefs of *Cladocora caespitosa* the ideal target for long-term monitoring. *C. caespitosa* has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Unfortunately, only few time series about this habitat are available to date, and information on its resilience after disturbances and present status is almost lacking.

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Bank (© P. Kružić)

Bed (© P. Kružić)

Corallith (© D.K. Kersting)

Extratentacular budding (© G. Galletta)

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Posidonia oceanica meadow

Reference codes for identification:

- **BARCELONA CONVENTION: MB2.54 (MB2.541, MB2.542, MB2.543)**
- **EUNIS 2019: MB252**
- **EUNIS 2007: A5.535**
- **EC: 1120**
- **CORINE: 11.34**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Soft (sand, coarse, mixed sediment), hard (rock) and matte
Depth range	0.5 m to 40 m
Position	Coastal, exceptionally in paralic
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39, up to 43 in paralic
Temperature	10 to 28°C
Suitability for monitoring	Yes

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INFRALITTORAL

MB2.5 Infralittoral biogenic habitat

MB2.54 *Posidonia oceanica* meadow

MB2.541 on rock, MB2.542 on matte, MB2.543 on sand, coarse or mixed sediment

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Description of the habitat

Posidonia oceanica is a seagrass (Magnoliophyta) endemic to the Mediterranean, and its meadows represent the characteristic habitat of the infralittoral zone and a climax ecosystem, i.e. the highest level of development and complexity that an ecosystem can reach. Meadows develop on almost all kind of substrata (rock, matte, sand, coarse, and mixed sediment) between the surface down to about 40 m depth and the light represents one of the main limiting factor. The plant's structure shows an epigeous portion, corresponding to leaf shoots (average 30-80 cm in height with seasonal variability) and an endogenous portion, the matte, which develops high underwater terraces. The matte, made by entangled rhizomes, roots and sediment that fills the interstices, and the *P. oceanica* meadow that grows above, has a vertical growth that vary between 0.4 to 1 cm per year. *P. oceanica* prefers well oxygenated waters and shows a rather wide tolerance to temperature (between 10 and 28°C) and hydrodynamics variations. On the contrary, the plant is sensitive to desalination and usually favours a salinity between 36 and 39, although it can be exceptionally found in lagoons with a salinity up to value of 43.

Geographic distribution

Sensitive to desalination, *Posidonia oceanica* disappears at the mouths of rivers, in brackish lagoons and near the Strait of Gibraltar. *P. oceanica* meadows cover about 1.5% of the total Mediterranean Sea surface (about 1,224,707 ha) and occur in 16 Mediterranean countries. Meadows are less abundant in the Levantine Sea, whilst sparse occurrence and even complete absence of *P. oceanica* meadows are reported in the Marmara Sea and in the Black Sea, respectively. Along the western Mediterranean basin, *P. oceanica* meadows are widespread, but due to the low salinity values, they are rare or even absent in the northern Adriatic Sea. At about 250 km east from the Gibraltar strait, the complex mixing of different density waters between the Atlantic Ocean and the Mediterranean Sea represents the western boundary of *P. oceanica* distribution.

Associated habitats

Posidonia oceanica can be found on well sorted fine sand, also in sheltered waters, within the habitat 'Association with indigenous marine angiosperms' (MB5.521, MB5.531), in the 'Algal-dominated infralittoral rock' (MB1.51) and in the 'Invertebrate-dominated infralittoral rock' (MB1.52). Sometimes the matte of *P. oceanica* can be eroded by hydrodynamics creating channels of coarse sediment with typical associated assemblages, which correspond to the habitats 'Infralittoral coarse sediment mixed by waves' (MB3.51) and 'Infralittoral coarse sediment under the influence of bottom currents' (MB3.52).

Related reference habitats

'Natural monuments/Ecomorphoses of *Posidonia oceanica* (fringing reef, barrier reef, stripped meadow, atoll)' (MB2.545); 'Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.' (MB2.546); 'Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica*' (MB2.547). The dead leaves of the plant, degraded by waves and microorganisms, can accumulate along the littoral forming small deposits, wracks or banks of dead leaves, the latter formation known as *banquette*, which are also reference habitats (MA1.51b, MA2.54, MA3.51a, MA3.52a, MA4.51a, MA4.52a, MA5.51a, MA5.52a) because of their important role in shoreline protection and because they represent a refuge and nourishment for insects, amphipods, and isopods.

Possible confusion

No confusion is possible with this habitat. In the Mediterranean, the other seagrass meadows are essentially made up by smaller species (i.e., *Cymodocea nodosa, Zostera noltei* and *Zostera marina),* which do not constitute a monumental formations such as the matte.

Typical species and associated communities

Meadows are made by *Posidonia oceanica*. Associated communities can be distinguished in sessile species living on the leaf blade (called epiphytes), which are made by diatoms, bacteria, red and brown encrusting algae, erect filamentous algae, bryozoans (with the exclusive *Electra posidonia*), hydrozoans (with the exclusive *Sertularia perpusilla*), and ascidians. Epiphytes on the rhizomes are mainly made by sponges, ascidians, foraminifera and bryozoans. The vagile species capable of moving within the meadow are mollusks, crustaceans, polychaetes, echinoderms, and fish. 70% of the total animal species of meadows is made up by herbivores. Among these the most abundant are echinoderms, in particular *Paracentrotus lividus*, one of the few organisms able to feed directly the leaves. Among the molluscs, the typical and almost exclusive inhabitant of meadows is *Pinna nobilis*, the largest bivalve in the Mediterranean that is highly threatened by collective fishing, pollution, and disease linked to global warming. Most of the fish species are carnivorous and show variations in specific abundance due to recruitment and migration over the year. In the shallow and sheltered meadows there is a great abundance of the herbivore *Sarpa salpa*, which represents 40-70% of the summer fish fauna. The infauna community is dominated by polychaetes and few molluscs and crustaceans. Meadows of *P. oceanica* can be found in association with the other common Mediterranean seagrass *Cymodocea nodosa* and with the alien algal species *Caulerpa taxifolia, Caulerpa cylindracea,* and *Lophocladia lallemandii*, especially when meadows are degraded.

Conservation interest and ecological role

Posidonia oceanica meadows play an essential ecological role in terms of primary production (partly exported to other ecosystems), water oxygenation, associated biodiversity, sedimentary balance, bottom and shoreline stability, mitigation of climate change (imprisoning huge amounts of carbon within the matte).

Economic importance

Many species of commercial interest find in the meadow a spawning and nursery area and a temporary or permanent habitat. In some areas of the Mediterranean, the leaves are still used in cattle feed and are used as compost for fertilization following special treatments. The production of biogas is currently being analyzed. Extract of *Posidonia oceanica* leaf contains various polyphenolic substances that can be used for food preservation, having antioxidant and antifungal properties, as well as anti-diabetic and vasoprotective properties.

Posidonia oceanica meadows provide regulating services, such as carbon sequestration and nutrient recycling; provisioning services, such as food production, materials and genetic resources availability (due to the biodiversity they host); habitat services, due to the creation of a complex three-dimensional structure that amplifies the space available for marine organisms; and information services, in terms of scientific research and monitoring. The many ecosystem services provided by the meadows result in high economic value and high natural capital. Estimates, based on calculation of resources employed by nature to provide considered services, leaded to an economic value of *P. oceanica* equal to 172 €$m^{-2}a^{-1}$. The disappearance of meadows has negative effects on the whole environment, and the loss of a single linear meter of seagrass meadow can lead to the disappearance of several meters of the beach in front, due to erosion. Furthermore, regression of the meadows causes the loss of biodiversity and the deterioration in water quality. These effects could also lead to a huge decrease of tourism in the affected area.

Vulnerability and potential threats

Posidonia oceanica meadows are highly vulnerable being directly affected by various human pressures along the coast. Given their very slow growth rate, destruction of meadows is often irreversible on a human-life scale. The main threats are linked to coastal development (direct destruction, modification of hydrodynamics and sediment budget, increased turbidity, pollution), pleasure boating (anchoring), living resources exploitation (trawling, fish farming), and global warming. Another potential threat is linked to the competition with the two alien species *Caulerpa taxifolia* and *Caulerpa cylindracea*, which have been shown to substitute the seagrass in degraded environments leading to an ecosystem phase-shift.

Protection and management

Posidonia oceanica is listed in the Annex II “List of endangered or threatened species” to the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA & BD Protocol, Barcelona Convention). The Action Plan for the Conservation of Marine Vegetation in the Mediterranean, adopted in 1999 by the Contracting Parties to the Barcelona Convention, set priorities and management activities to be undertaken to protect *P. oceanica* and its formations (i.e., meadows). Management interventions for *P. oceanica* meadows should be focused on: controlling water quality; banning unauthorized mooring and providing facilities and ecological moorings where concentration of boats is high; banning trawling over the entire meadow; respecting the ban of development over the meadows and restricting it near them; improve the public awareness on the ecological role of meadows; setting up meadow monitoring networks. Many Mediterranean countries included *Posidonia oceanica* in their national lists of protected species. The species also enjoys protection by other international policies: meadows are defined as priority habitats in the Annex I of the Habitats Directive (92/43/EEC, code 1120*) and are protected under the Bern Convention on the conservation of wildlife and natural environment of Europe (Annex I, ‘Strictly protected flora species’). The habitat of *P. oceanica* meadow is defined as ‘vulnerable’ by the IUCN European Red List of marine habitats.

In the associated communities can be found other legally protected species listed in the Annex II of the SPA & BD Protocol, such as the bivalve *Pinna nobilis* (considered as ‘critically endangered’ by IUCN), the grouper *Epinephelus marginatus* (‘endangered’ by IUCN), the sea-horse *Hippocampus guttulatus* (‘near threatened’ by IUCN), the black-striped pipefish *Syngnathus abaster*, the starfish *Asterina pancerii*, the sea urchin *Paracentrotus lividus*, and occasionally the slipper lobster *Scyllarides latus.*

Suitability of the habitat for monitoring

Due to the high sensitivity of *Posidonia oceanica* to any environmental alterations, it is commonly used as an excellent indicator of the overall environmental quality. *P. oceanica* has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. *P. oceanica* is defined as biological quality element also in the European Directives on water and marine quality assessment (under the Water Framework Directive and the Marine Strategy Framework Directive, respectively).

Posidonia oceanica meadow on rock (MB2.541) (© M. Montefalcone)

Posidonia oceanica meadow on matte (MB2.542) (© M. Montefalcone)

Posidonia oceanica meadow on sand (MB2.543) (© M. Montefalcone)

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Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.

Reference codes for identification:

- **BARCELONA CONVENTION: MB2.546**
- **EUNIS 2019: MB2524**
- **EUNIS 2007: A5.5354**
- **EC: 1120**
- **CORINE: 11.34**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Soft sediments and matte
Depth range	0.5 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

Photo credits:
M. Montefalcone, G. Pergent

INFRALITTORAL

MB2.5 Infralittoral biogenic habitat

MB2.54 *Posidonia oceanica* meadow

MB2.546 Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.

Description of the habitat

This association is characterised by the presence, within the *Posidonia oceanica* meadow, of the other Mediterranean seagrass *Cymodocea nodosa* and/or of the green algae belonging to the genus *Caulerpa,* either native (*C. prolifera*) or alien (*C. taxifolia* and *C. cylindracea*). The picture at the top of this page shows an example of association among *P. oceanica*, *Cymodocea nodosa* and *Caulerpa taxifolia*.

This association may occur under particular environmental conditions (on soft sediments in sheltered waters or within bays, where some siltation is present) or where *P. oceanica* meadows are degraded due to high levels of human pressure and show reduced density and coverage of the bottom. These associated species colonize the sediment and the unvegetated matte between the *P. oceanica* shoots. In shallow waters the ecomorphoses created by *P. oceanica*, such as the 'barrier reef', the 'stripped meadow' and the 'atoll', are usually associated with *Cymodocea nodosa* and *Caulerpa* spp. (see sheet MB2.545).

Geographic distribution

This association can potentially occur in all coastal areas of the Mediterranean Sea where *Posidonia oceanica* meadows occur (see sheet MB2.54) and where the environmental conditions are suitable for the colonization by the associated species. Most of these associations have been described in highly anthropized coastal areas, where regressed meadows have been progressively substituted by *C. nodosa* or by *Caulerpa* spp., as in the north-western Mediterranean.

Associated habitats

The association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp. can be found in correspondence of 'Dead matte of *Posidonia oceanica*' (MB2.544) and of the habitats 'Well sorted fine sand' (MB5.52) and 'Fine sand in sheltered waters' (MB5.53), included their sub-habitats, e.g. 'Association with *Halophila stipulacea*' (MB5.522, MB5.532), 'Association with photophilic algae' (MB5.523, MB5.535).

Related reference habitats

‘*Posidonia oceanica* meadow’ (MB2.54); ‘Natural monuments/ Ecomorphoses of *Posidonia oceanica*’ (MB2.545); ‘Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica*’ (MB2.547), ‘Association with *Caulerpa prolifera*’ (MB1.514a, MB1.512b, MB1.514.c, MB1.512d, MB1.513e, MB1.521a, MB5.533), ‘Association with indigenous marine angiosperms’ (MB5.521, MB5.531).

Possible confusion

No confusion is possible with this habitat, which is always characterized by the occurrence of *Posidonia oceanica* and other macrophytes.

Typical species and associated communities

Cymodocea nodosa is another common seagrass of the Mediterranean and has shorter and thinner light green leaves with respect to *P. oceanica.* The green algae of the genus *Caulerpa* (*C. prolifera, C. taxifolia*, and *C. cylindracea*) are all easily identifiable because they display a typical morphology and shape of the thallus (see some pictures in the sheet MB2.547).
Associated communities are the same as those associated to the habitats ‘*Posidonia oceanica* meadows’ (see sheet MB2.54), ‘Association with *Caulerpa prolifera*’ (see sheet MB1.514a), and ‘Association with indigenous marine angiosperms’ (see sheet MB5.521) regarding the species associated with *Cymodocea nodosa*.

Conservation interest and ecological role

Seagrass meadows and macroalgal assemblages play an essential ecological role in terms of primary production (partly exported to other ecosystems), water oxygenation, associated biodiversity, sedimentary balance, bottom and shoreline stability, mitigation of climate change (imprisoning huge amounts of carbon within the matte in the case of *Posidonia oceanica* meadows).

Economic importance

Many species of commercial interest find in seagrass meadows a spawning and nursery area and a temporary or permanent habitat. Meadows and macroalgae provide regulating services (carbon sequestration and nutrient recycling), provisioning services (food production, materials and genetic resources availability, biodiversity), habitat services, and information services (scientific research and monitoring). See also the descriptive sheets of the habitats ‘*Posidonia oceanica* meadows’ (MB2.54), of its ecomorphoses (MB2.545), and of the ‘Association with *Caulerpa prolifera*’ (MB1.514a).

Vulnerability and potential threats

The main threats to this habitat are linked to coastal development (direct destruction, modification of hydrodynamics and sediment budget, increased turbidity, pollution), pleasure boating (anchoring), living resources exploitation (trawling, fish farming), and global warming. All the associated species, i.e. *Cymodocea nodosa* and the algae *Caulerpa prolifera*, *C. taxifolia*, and *C. cylindracea*, have high spreading rates and show higher tolerance to altered environmental conditions than *P. oceanica*, and are thus prone to replace regressed *P. oceanica* meadows under a human pressure regime. The replacement is not intended as the direct consequence of competition between species by rather as a process at the ecosystem level: the biota associated with *C. nodosa* or with *Caulerpa* spp. is very different from the one more diverse and exclusive associated with *P. oceanica*. The progressive change of the foundation species may lead to a complete substitution of assemblages within the same habitat, causing what is usually called an ecosystem phase-shift.

Protection and management

In general, this habitat benefits of the same protection and management measures undertaken for the habitat ‘*Posidonia oceanica* meadows’ (MB2.54), for its ecomorphoses (MB2.545), and for the habitat ‘Association with indigenous marine angiosperms’ (MB5.521), as also *Cymodocea nodosa* deserves all the efforts requested for seagrass meadows conservation. No specific protection and management measures are planned for all species of the genus *Caulerpa*.

Suitability of the habitat for monitoring

Healthy *Posidonia oceanica* meadows are normally monospecific. When *P. oceanica* forms mixed meadow with *Cymodocea nodosa,* it is often considered as an indicator of stressed conditions. The Substitution Index has been proposed to measure the amount of replacement of *P. oceanica* by its potential substitutes (i.e., *C. nodosa* and the algae of the genus *Caulerpa*) and to define the ecological quality of *P. oceanica* meadows according to European Directives (Water and Marine Strategy).

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Association of *Posidonia oceanica* with *Cymodocea nodosa* (© M. Montefalcone)

Association of *Posidonia oceanica* with *Cymodocea nodosa*
(upper panel © M. Montefalcone, lower panel © G. Pergent)

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Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica*

Reference codes for identification:

- **BARCELONA CONVENTION: MB2.547**
- **EUNIS 2019: MB2523 (partim)**
- **EUNIS 2007: A5.5353 (partim)**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Dead matte
Depth range	0.5 m to 40 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Yes

Author:
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Photo credits:
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INFRALITTORAL

MB2.5 Infralittoral biogenic habitat

MB2.54 *Posidonia oceanica* meadow

MB2.547 Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica*

Description of the habitat

This habitat occurs where dead matte of *Posidonia oceanica* has been recolonized by the other Mediterranean seagrass *Cymodocea nodosa* and/or by the green algae belonging to the genus *Caulerpa,* either native (*C. prolifera*) or alien (*C. taxifolia* and *C. cylindracea*). When *P. oceanica* meadows are degraded, due to natural (e.g., hydrodynamics) or anthropogenic pressures, dead matte becomes a favourable substrate for the instalment of these associated species (known as 'substitutes') having a comparatively higher tolerance to altered environmental conditions and a faster growth, and they can spread and establish in a degraded meadow within few years.

Geographic distribution

This association may develop in all coastal areas of the Mediterranean Sea where *Posidonia oceanica* meadows occur (see sheet MB2.54) and where altered environmental conditions leaded, at the initial stage, to a regression of *P. oceanica* and, secondarily, to the colonization of dead matte by the associated species. Most of these associations have been described in the highly urbanized coastal areas of the north-western Mediterranean.

Associated habitats

The association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica* can be found in correspondence of 'Dead matte of *Posidonia oceanica*' (MB2.544), and of the habitats 'Well sorted fine sand' (MB5.52) and 'Fine sand in sheltered waters' (MB5.53), included their sub-habitats, e.g. 'Association with *Halophila stipulacea*' (MB5.522, MB5.532), 'Association with photophilic algae' (MB5.523, MB5.535).

Related reference habitats

'*Posidonia oceanica* meadow' (MB2.54), 'Natural monuments/ Ecomorphoses of *Posidonia oceanica*' (MB2.545), 'Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.' (MB2.546), 'Association with *Caulerpa prolifera*' (MB1.514a, MB1.512b, MB1.514.c, MB1.512d, MB1.513e, MB1.521a, MB5.533), ‘Association with indigenous marine angiosperms’ (MB5.521, MB5.531).

Possible confusion

Dead matte is often buried by sand preventing its direct recognition, and can then be confused with a bottom of fine sand covered by photophilic algae (MB5.523 and MB5.535).

Typical species and associated communities

Cymodocea nodosa is a common seagrass of the Mediterranean and can be easily distinguished from *P. oceanica.* The green algae of the genus *Caulerpa* (*C. prolifera, C. taxifolia*, and *C. cylindracea*) are all easily identifiable because they display a typical morphology and shape of the thallus (see some pictures at the end of this sheet).
The communities associated with *Caulerpa* spp. are diverse and dominated by polychaetes, gastropods, and amphipods, which change seasonally as a result of the algae vegetative cycle. Abundant fish assemblages and populations of the cephalopod *Sepia officinalis* have been described in *C. prolifera* beds (see also the sheet MB1.514a for further details). Associated communities of *Cymodocea nodosa* beds can be distinguished in sessile species living on the leaf blade (called epiphytes), which are made mainly by red algae (Ceramiales and Corallinales), with a minor contribution by diatoms, cyanobacteria, hydrozoans, and ascidians. The vagile associated species are gastropods, bivalves, crustaceans, polychaetes, and fish. *C. nodosa* is often associated with the alien seagrass *Halophila stipulacea* (in the southern sectors of the Mediterranean), and with other photophilic algae (see also the sheet MB5.521). The communities associated with dead matte of *P. oceanica* are dominated by polychaetes, gastropods, amphipods and bivalves and by photophilic algae and their associated fauna. The bivalve *Pinna nobilis*, a legally protected species listed in the Annex II of the SPA & BD Protocol and considered as ‘critically endangered’ by IUCN, finds in the matte an ideal substrate for its establishment.

Conservation interest and ecological role

After regression, natural recolonization of dead matte, via seeds, vegetative fragments or marginal spread of the living meadow are extremely slow and may require centuries. Artificial restoration of degraded habitats can help the natural recovery, but only when the main causes of regression will be removed. When a regressed meadow is recolonized by the two native substitutes *C. nodosa* and *C. prolifera,* it would theoretically be able to naturally recover in the long term as both substitutes are pioneer species in the ecological succession of *P. oceanica* meadows. On the contrary, the replacement of *P. oceanica* by the alien algae *C. taxifolia* and *C. cylindracea* may be hardly imagined as reversible, none of the two belonging to the successional series leading to *P. oceanica* meadows. The replacement of a foundation and constructional species like *P. oceanica* by a non-constructional species like all the substitutes (especially when they are algae) may be seen as a significant community change known as phase shift.

Economic importance

Many species of commercial interest find in seagrass meadows a spawning and nursery area and a temporary or permanent habitat. Meadows and macroalgae provide regulating services (carbon sequestration and nutrient recycling), provisioning services (food production, materials and genetic resources availability, biodiversity), habitat services, and information services (scientific research and monitoring). For further details refer also to the habitats ‘Association with *Caulerpa prolifera*’ (sheet MB1.514a) and ‘Association with indigenous marine angiosperms’ (sheet MB5.521).

Vulnerability and potential threats

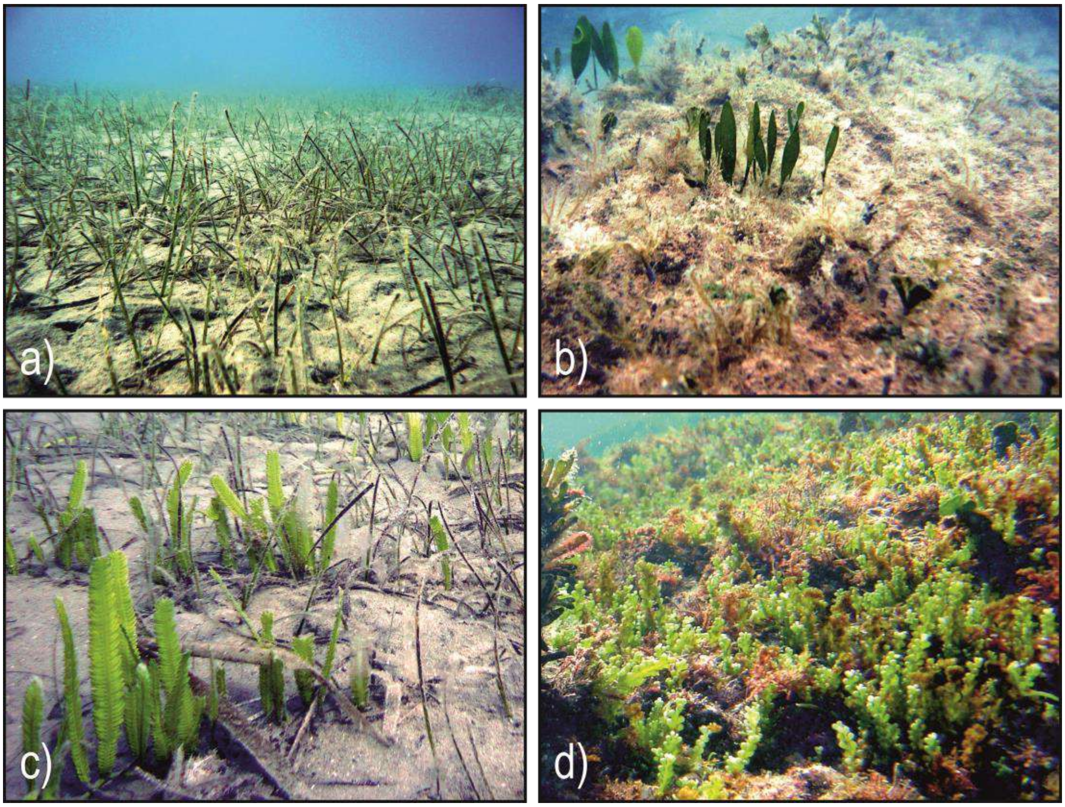
The main threats to this habitat are linked to coastal development (direct destruction, modification of hydrodynamics and sediment budget, increased turbidity, pollution), pleasure boating (anchoring), living resources exploitation (trawling, fish farming), and global warming. *Cymodocea nodosa* and the algae *Caulerpa prolifera*, *C. taxifolia* and *C. cylindracea* have higher spreading rates and higher tolerance to environmental alteration than *P. oceanica* (see also sheet MB2.546 for details).

Protection and management

In this habitat only *Cymodocea nodosa* deserves all the protection and management measures requested for seagrass meadows (see also sheet MB5.521). No specific protection and management measures are planned for *Caulerpa* spp.

Suitability of the habitat for monitoring

This habitat is not contemplated in monitoring programs (IMAP of Barcelona Convention, Water and Marine Strategy Directives). The Substitution Index and the Phase Shift Index have been proposed to quantify the degree of replacement of seagrass by substitutes and to measure the intensity of phase shift exhibited by seagrass meadows, according to European Directives (Water and Marine Strategy). The Phase Shift Index also provides a tool for evaluating the irreversibility of change undergone by a regressed *P. oceanica* meadow, necessary for assessing its resilience.



Association of *Cymodocea nodosa* (a), *Caulerpa prolifera* (b), *Caulerpa taxifolia* (c), and *Caulerpa cylindracea* (d) with dead matte of *Posidonia oceanica* (© M. Montefalcone)

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Well sorted fine sand

Reference codes for identification:

- **BARCELONA CONVENTION: MB5.52**
- **EUNIS 2019: MB552**
- **EUNIS 2007: A5.236**
- **EC: 1110**
- **CORINE: 11.22**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Soft (sand)
Depth range	2 m to 25 m
Position	Coastal
Hydrodynamic conditions	Variable, relatively strong
Salinity	Between 36 and 39 (slight desalination is likely)
Temperature	10 to 28°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

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INFRALITTORAL

MB5.5 Infralittoral sand
MB5.52 Well sorted fine sand

Description of the habitat

The habitat of well sorted fine sand (*sables fins bien calibrés*, SFBC, using the original French name) is very well delimited by bathymetry (2-25 m) and sedimentology (fine sand >90%, very low proportion of fine particles <63 mm, organic matter <2%); it occurs in zones with relatively strong water movements and occupies vast bottom areas along the coasts. Locally, this habitat tolerates a slight reduction in salinity of the water near estuaries and surrounding some Mediterranean ponds. It is characterized by a well recognized oligotrophic community, with relatively low number of dominant species but associated with a high diversity. It may present a certain impoverishment of the community when in presence of some euryhaline species. When the wave action becomes too strong, the associated community can also be impoverished. Soft-bottom macrobenthic communities are mainly composed by infaunal organisms (polychaetes, bivalves, gastropods, and amphipods). The seagrass *Cymodocea nodosa* is a typical exuberant species, and it constitutes the well defined sub-habitat of 'Association with indigenous marine angiosperms' (MB5.531). The well sorted fine sand can also be locally colonised by other seagrass (e.g., *Posidonia oceanica*, *Zostera noltei*, *Halophila stipulacea*) or by photophilic algae.

Geographic distribution

The habitat occurs in the whole Mediterranean Sea, but it is well recognized at the scale of the western basin of the Mediterranean where it has been studied at numerous locations, mainly along the French, Spanish, Italian, and Algerian coasts.

Associated habitats

Habitats associated with well sorted fine sand can be 'Association with indigenous marine angiosperms' (MB5.521), 'Association with *Halophila stipulacea*' (MB5.522), 'Association with photophilic algae' (MB5.523). The habitat may be in contact with the 'Algal-dominated infralittoral rock' (MB1.51), the 'Invertebrate-dominated infralittoral rock' (MB1.52), the 'Habitats of transitional waters' (MB5.54), the 'Infralittoral rock affected by sediment' (MB1.53), the 'Reefs of Vermetidae' (MB2.51), the 'Reefs of *Sabellaria* spp.' (MB2.52), the '*Posidonia oceanica* meadows' (MB2.54), the 'Infralittoral coarse sediment mixed by waves' (MB3.51), the 'Infralittoral coarse sediment under the influence of bottom currents' (MB3.52), and the 'Fine sand in very shallow waters' (MB5.51).

Related reference habitats

Well sorted fine sand can also be found in ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Natural monuments/Ecomorphoses of *Posidonia oceanica*’ (MB2.545), ‘Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.’ (MB2.546), ‘Fine sand in sheltered waters’ (MB5.53), and in the ‘Habitats of transitional waters’ (MB5.54).

Possible confusion

This habitat can be confused with the ‘Fine sand in very shallow waters’ (MB5.51), which develops in shallower waters (<2 m), and with the ‘Fine sand in sheltered waters’ (see sheet MB5.53), which develops in protected and sheltered environments (e.g., small coves). The transition from the fine sand in very shallow waters to the well sorted fine sand is not clear and often constitutes an area where there is mixing, particularly during strong hydrodynamic events (whether a high degree of water movement or prolonged calm).

Typical species and associated communities

Species characteristic of the well sorted fine sand community, which can be found in what can be considered as a ‘reference state’, are: the polychaetes *Owenia fusiformis* (often a dominant species), *Prionospio caspersi*, *Sigalion mathildae*, *Diopatra neapolitana*, and *Ditrupa arietina*; the bivalves *Spisula subtruncata* (often a dominant species), *Lucinella divaricata*, *Thracia phaseolina*, *Fabulina fabula*, *Pharaonella astula*, *Acanthocardia tuberculata*, *Donax* spp., and *Chamelea gallina*; the gastropods *Acteon tornatilis*, *Tritia mutabilis*, *Neverita josephinia*; the amphipods *Ampelisca tenuicornis* and *A. brevicornis, Hippomedon massiliensis*, and *Pariambus typicus*. Isopods, decapods, tanaid, phoronid, echinoderms (e.g., *Astropecten* spp., *Echinocardium cordatum*), and fish (e.g., *Pomatoschistus microps*, *Callionymus risso*, *Trachinus draco*, *Solea solea*) become the accompanying species. *Cymodocea nodosa* is the typical seagrass species in this habitat, although also *Posidonia oceanica* often develops on fine sand (see sheet MB2.54), whilst *Zostera noltei* is rather uncommon. The alien seagrass *Halophila stipulacea* is becoming abundant in the southern sectors of the Mediterranean. Photophilic algae can also colonize the surface layer of fine sands.

Conservation interest and ecological role

Well sorted fine sand has a fundamental role in maintaining the balance of beaches. The habitat is a feeding area for flat fish. A high conservation interest is linked with the development of seagrass meadows on fine sand (see also sheet MB5.521).

Economic importance

Flat fish of commercial interest are associated with this habitat. It thus provides provisioning services, such as food production and genetic resources availability (due to the biodiversity it hosts), and information services in terms of scientific research and monitoring. To date the economic value of this habitat has not yet been assessed.

Vulnerability and potential threats

Well sorted fine sand communities, being located in shallow waters, are directly subject to a multitude of human pressures: outfalls of urban waste, dredging and beach nourishments with sand collected from this habitat at shallow depths (<10 m), embankments for coastal development, industries, harbours, etc. Fish trawling may still have an impact, in spite of its prohibition at a distance of less than three nautical miles from the coastline, due to the importance of this habitat for flat fish. This habitat is also changing in response to global warming. As the habitat develops in high-energy environments, it is recurrently subjected to natural physical perturbations. This ensures the selection of characteristic species adapted to living in clean sand intensely reworked by a combination of strong wave action and swell, implying that the community has a high resilience and is able to recover rapidly after a perturbation.

Protection and management

Although the habitat is subject to many human activities from the littoral, no specific protection measures have been implemented yet. Traditional fishing should be properly managed and bottom trawling, which may be practiced on this habitat, must be regulated.

Suitability of the habitat for monitoring

Benthic communities of soft-bottoms are usually employed as indicators in monitoring programs during the implementation of the European Water Framework and the Marine Strategy Framework Directives. The description of the community structure, i.e. the species living in well sorted fine sand and their abundances, as well as the species richness (usually measuring the Shannon diversity index), biomass and more rarely production are commonly used indicators. The change from oligotrophic (normal situation) to eutrophic conditions (with enhanced nutrient and organic matter inputs) is followed by an increase of abundances and the presence of sentinel or tolerant species reflecting organic pollution. A number of ecological indices has been proposed to detect long-term changes in soft-bottom benthic communities under natural stressors, based on species classification in ecological groups.

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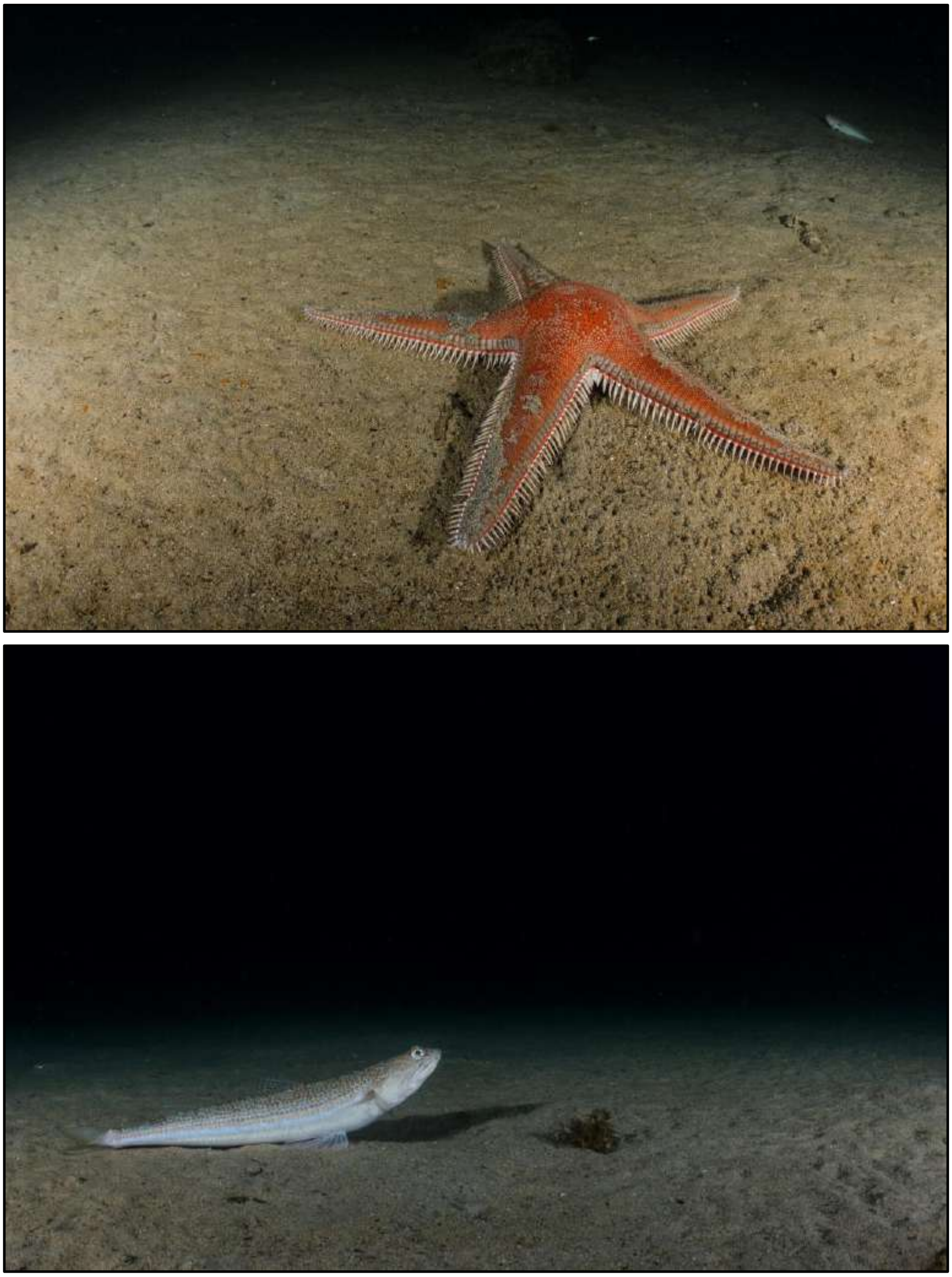
Cymodocea nodosa meadow on well sorted fine sand
(© M. Montefalcone)

Posidonia oceanica meadow on well sorted fine sand
(© M. Montefalcone)



Astropecten aranciacus (upper panel) and *Synodus saurus* (lower panel)
(© F. Betti)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Association with indigenous marine angiosperms

Reference codes for identification:

- **BARCELONA CONVENTION: MB5.521**
- **EUNIS 2019: MB5521, MB5534, MB5535**
- **EUNIS 2007: A5.53131, A5.53132, A5.53322**
- **CORINE: 11.33, 11.332, 113.321**

LOCATION OF THE HABITAT

Zone	Infralittoral, with possible extension into the midlittoral
Nature of the substratum	Soft (sand, coarse, mixed sediment)
Depth range	0 m to 30 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 28°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

Photo credits:
M. Montefalcone, A. Sfriso

INFRALITTORAL

MB5.5 Infralittoral sand

MB5.52 Well sorted fine sand

MB5.521 Association with indigenous marine angiosperms

Description of the habitat

This association is characterised by marine Tracheophyta that develop on soft bottoms formed by well sorted fine sand, also in sheltered waters (MB5.531), where the water is actively renewed and there is no trace of desalination. *Cymodocea nodosa* is the main seagrass species that develops large meadows with its typical epiflora. *Zostera noltei* is another seagrass that may create beds in this habitat, although it is more common on muddy sands in sheltered and colder waters, where there is an active deposit of fine matter (see sheet MB5.53), and in the habitats of transitional waters (see sheet MB6.511). The epifauna of this vascular plants is poor. Association with *Halophila stipulacea* (MB5.522), being an alien Lessepsian seagrass species, has not been defined a priority habitat, and it has not been included in this association. Meadows of *Posidonia oceanica* on sand are not contemplated in this association being included in a specific habitat type (see sheet MB2.543).

Meadows can develop between the surface down to about 40 m depth and the light represents one of the main limiting factor. *Zostera noltei* can support certain periods of emersion, so that the association with indigenous marine angiosperms can be found also in the midlittoral zone, on coarse (MA3.521), mixed (MA4.521), and sand (MA5.521) sediments.

Geographic distribution

Association with indigenous marine angiosperms can develop at the scale of the whole Mediterranean Sea where soft sediments occur.

Associated habitats

Indigenous marine angiosperms can be associated with ‘Association with *Halophila stipulacea*’ (MA3.522, MA4.522, MA5.522, MB5.522, MB5.532), ‘Association with *Caulerpa prolifera*’ (MB5.533), ‘Association with non-indigenous Mediterranean *Caulerpa* spp.’ (MB5.534), ‘Association with photophilic algae’ (MB5.523, MB5.535), ‘Facies with Bivalvia’ (MA5.524, MB5.536), ‘Facies with Polychaeta’ (MA5.523, MB5.537), ‘Facies with Crustacea Decapoda’ (MB5.538).

The habitat may be in contact with the ‘Algal-dominated infralittoral rock’ (MB1.51), the ‘Invertebrate-dominated infralittoral rock’ (MB1.52), the ‘Habitats of transitional waters’ (MB5.54), the ‘Infralittoral rock affected by sediment’ (MB1.53), the ‘Reefs of Vermetidae’ (MB2.51), the ‘Reefs of *Sabellaria* spp. (MB2.52), the ‘Reefs of *Cladocora caespitosa*’ (MB2.53), the ‘*Posidonia oceanica* meadows’ (MB2.54), the ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), the ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), the ‘Fine sand in very shallow waters’ (MB5.51), and the ‘Fine sand in sheltered waters’ (MB5.53). Indigenous marine angiosperms can also be in contact with the habitats of the midlittoral zone.

Related reference habitats

Indigenous marine angiosperms can also be found within the ‘*Posidonia oceanica* meadows’ (MB2.54), in ‘Natural monuments/Ecomorphoses of *Posidonia oceanica*’ (MB2.545), in the ‘Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.’ (MB2.546), in ‘Fine sand in sheltered waters’ (MB5.53), and in the ‘Habitats of transitional waters’ of the infralittoral zone (MB1.54, MB5.54, MB6.51). This habitat may also be partially related with midlittoral sediments, coarse (MA3.521), mixed (MA4.521), and sand (MA5.521), and with the ‘Habitats of transitional waters’ on midlittoral mud (MA6.52a).

Possible confusion

This habitat cannot be confused being characterized by seagrass meadows. *Cymodocea nodosa* and *Zostera noltei* are small seagrass species that form smaller meadows (or beds) with respect to *Posidonia oceanica*.

Typical species and associated communities

Meadows are made by *Cymodocea nodosa* and *Zostera noltei. Zostera marina* is another Mediterranean seagrass, but it can be considered a relict species as its distribution is extremely localised and limited to coastal areas with freshwater inflows*. C. nodosa* creates shallow and sparse beds in more open and less muddy environments; it has light green or greyish-green narrow leaves, but they can be up to 40 cm long. This plant produces small rhizomes that are 1 mm in diameter and grow only horizontally. *C. nodosa* lives both along the coasts with considerable salinity and in coastal areas with hypoaline waters, such as lagoons. In brackish areas it forms mixed meadows with *Zostera* spp., but it is replaced by them in the zones where the salinity is further reduced, such as at the mouth of rivers. *Zostera noltei* has a shallower distribution and can tolerate various levels of salinity, being found on fine sand in the intertidal and the shallow subtidal habitats of bays, estuaries, and lagoons. It has very narrow leaves incised at the apex and cannot be confused with *C. nodosa.* Its leaves are up to 22 cm long and contain air spaces that make them buoyant. *Zostera noltei* can be confused only with *Zostera marina*, but the latter has leaves with evident ribs and smooth and not toothed edges. See also the sheet MB5.541 for further details on seagrass species (and of their associated communities) in transitional waters.

Associated communities of *Cymodocea nodosa* beds can be distinguished in sessile species living on the leaf blade (called epiphytes), which are made mainly by red algae (Ceramiales and Corallinales), with a minor contribution by diatoms, cyanobacteria, hydrozoans, and ascidians. The vagile associated species are gastropods, bivalves, crustaceans, polychaetes, and fish. *C. nodosa* is often associated with *Posidonia oceanica* on fine sand (see sheet MB2.54), with the alien seagrass *Halophila stipulacea* (in the southern sectors of the Mediterranean), and with photophilic algae such as the native *Caulerpa prolifera* and the alien *Caulerpa cylindracea*.

Conservation interest and ecological role

Marine angiosperms play an essential ecological role in terms of primary production (partly exported to other ecosystems), water oxygenation, associated biodiversity, sedimentary balance, bottom and shoreline stability. Seagrass meadows are also an important rearing ground for juvenile fish. *Cymodocea nodosa* can replace *Posidonia oceanica* in degraded environments. Regressed *P. oceanica* meadows, however, would theoretically be able to naturally recover in the long term once the main pressures causing regression are eliminated, as *C. nodosa* is considered a pioneer species in the ecological succession of *P. oceanica* meadows.

Economic importance

Many species of commercial interest find in seagrass meadows a spawning and nursery area and a temporary or permanent habitat. Seagrass meadows provide: regulating services, such as carbon sequestration and nutrient recycling; provisioning services, such as food production, materials and genetic resources availability (due to the biodiversity they host); habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms; and information services, in terms of scientific research and monitoring. Large amounts of seagrass detritus often accumulate on the coastline, consolidating beaches and preventing their erosion (see also the sheet MA2.51a). The disappearance of a meadow has negative effects on the whole environment: it causes the loss of biodiversity and the deterioration in water quality. New secondary metabolites have been extracted from *C. nodosa* for their antibacterial properties, and the phenolic chicoric acid has been recently discovered from this plant as a major bioactive compound for preventing chronic diseases.

Vulnerability and potential threats

Seagrass meadows are highly vulnerable being directly affected by various human pressures along the coast. The main threats are linked to coastal development (direct destruction, modification of hydrodynamics and sediment budget, increased turbidity, pollution), pleasure boating (anchoring), living resources exploitation (trawling, fish farming), and global warming.
C. nodosa has a faster growth rate and a higher turnover compared to *P. oceanica*; it is thus considered a more tolerant species and can resist, in spite of other seagrass, along the highly anthropized coastlines.

Protection and management

All seagrass are considered worthy of protection. *Cymodocea nodosa*, *Zostera noltei* and *Z. marina* are listed in the Annex II “List of endangered or threatened species” to the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA & BD Protocol, Barcelona Convention). The Action Plan for the Conservation of Marine Vegetation in the Mediterranean, adopted in 1999 by the Contracting Parties to the Barcelona Convention, set priorities and management activities to be undertaken to protect all seagrass meadows. Many Mediterranean countries included marine angiosperms in their national lists of protected species. *Cymodocea nodosa* and *Zostera marina* also enjoy protection by the Bern Convention on the conservation of wildlife and natural environment of Europe (Annex I, ‘Strictly protected flora species’). In the communities associated with *C. nodosa* can be found legally protected species listed in the Annex II of the SPA & BD Protocol, such as the sea-horse *Hippocampus guttulatus* (considered as ‘near threatened’ by IUCN) and the sea urchin *Paracentrotus lividus.*

Suitability of the habitat for monitoring

Due to the sensitivity of marine angiosperms to environmental alterations, they are commonly used as excellent indicators of the overall environmental quality. Seagrass has been included as common indicators in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Seagrass have also be defined as biological quality elements in the European Directives on water and marine quality assessment (under the Water Framework Directive and the Marine Strategy Framework Directive, respectively).

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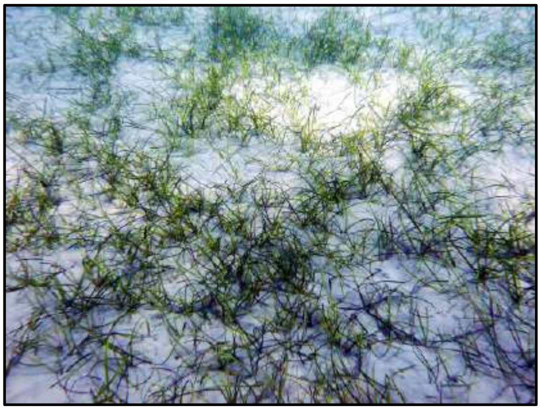

Bed of *Cymodocea nodosa* on well sorted fine sand (© M. Montefalcone)

Bed of *Zostera noltei* (© A. Sfriso)


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Fine sand in sheltered waters

Reference codes for identification:

- **BARCELONA CONVENTION: MB5.53**
- **EUNIS 2019: MB553**
- **EUNIS 2007: A5.28**
- **EC: 1160**
- **CORINE: 11.22**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Soft (sand, muddy sand)
Depth range	1 m to 3 m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39 (slight desalination is likely)
Temperature	10 to 28°C
Suitability for monitoring	Not known

Author:
M. Montefalcone

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M. Montefalcone, G. Pergent

INFRALITTORAL

MB5.5 Infralittoral sand

MB5.53 Fine sand in sheltered waters

Description of the habitat

The habitat of fine sand in sheltered waters (*sables vaseux de mode calme*, SVMC, using the original French name) is located in protected coves and embayments, in environments sheltered from the wave action, where the influence of freshwater is generally limited and a substrate consisting of a muddy-sandy sediment, sometimes mixed with a small amount of gravel, occurs. The bathymetry ranges around 1 m depth, and rarely is deeper than 3 m. These shallow areas are characterised by very variable environmental conditions, fairly strong sedimentation, variable climate, with very great differences in temperature between winter and summer and even during the same day, with the possibility of rainwater runoff or ground water seepage, and are under the influence of human pressures. The habitat presents a well developed zonation of benthic communities, with macrophytes, filtering and burrowing species. These communities have generally a high biodiversity. The limit of shallow water is sometimes defined by the distribution of the *Zostera* spp., *Ruppia maritima*, and *Potamogeton* spp. associations.

Geographic distribution

Knowledge on the habitat distribution is uneven, but it can be present along the whole Mediterranean Sea coastline where sheltered environments occur.

Associated habitats

Habitats associated with the fine sand in sheltered waters can be ‘Association with indigenous marine angiosperms’ (MB5.521), ‘Association with *Halophila stipulacea*’ (MB5.522), ‘Association with *Caulerpa prolifera*’ (MB5.533), ‘Association with non-indigenous Mediterranean *Caulerpa* spp.’ (MB5.534), ‘Association with photophilic algae (except Caulerpales)’ (MB5.535), ‘Facies with Bivalvia’ (MB5.536), ‘Facies with Polychaeta’ (MB5.537), ‘Facies with Crustacea Decapoda’ (MB5.538), ‘Facies of *Tritia* spp. and nematodes in hydrothermal vents’ (MB5.539). The habitat may be in contact with the ‘Algal-dominated infralittoral rock’ (MB1.51), the ‘Invertebrate-dominated infralittoral rock’ (MB1.52), the ‘Habitats of transitional waters’ (MB5.54), the ‘Infralittoral rock affected by sediment’ (MB1.53), the ‘Reefs of Vermetidae’ (MB2.51), the ‘Reefs of *Sabellaria* spp.’ (MB2.52), the ‘*Posidonia oceanica* meadows’ (MB2.54), the ‘Infralittoral coarse sediment mixed by waves' (MB3.51), the 'Infralittoral coarse sediment under the influence of bottom currents' (MB3.52), the 'Well sorted fine sand' (MB5.52), and the 'Fine sand in very shallow waters' (MB5.51).

Related reference habitats

Fine sand in sheltered waters is related with '*Posidonia oceanica* meadows' (MB2.54), 'Natural monuments/Ecomorphoses of *Posidonia oceanica*' (MB2.545), 'Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.' (MB2.546), 'Well sorted fine sand' (MB5.52), and with the 'Habitats of transitional waters' (MB5.54, MB6.51).

Possible confusion

This habitat can be confused with the 'Fine sand in very shallow waters' (MB5.51) and with the 'Well sorted fine sand' (MB5.52). This habitat, however, develops only in protected and sheltered environments (e.g., small coves and embayments). The muddy sands in sheltered waters can sometimes be confused also with the mud sediment of the habitats of transitional waters, i.e. estuaries and lagoons (see sheet MB6.51). In this case the habitat shows markedly a more desalinated environment. Confusion is only possible in rare geomorphological situations: at the entrance of a lagoon and in correspondence of a watercourse emptying into a shallow bay.

Typical species and associated communities

Macrophytes are typically associated with this habitat. The association with the seagrass *Cymodocea nodosa* is present when the water is actively renewed and there is no trace of desalination. Association with the seagrass *Zostera noltei* on superficial muddy sand in sheltered waters creates a bed in areas where there is an active deposit of fine matter and there are traces of desalination. *Ruppia maritima* and *Potamogeton* spp. can also occur in desalinated environments. The epifauna on the vascular plants is poor. Association with the native algae *Caulerpa prolifera* is also common on superficial fine sand in sheltered waters in the warmest areas. In areas without epiflora the decapods *Upogebia pusilla* develops a typical facies where the soil is compacted and allows for tunnels creation. Other typical facies are made by the bivalves *Polititapes aureus*, located mainly in channels and ponds with a marked addition of organic matter and *Loripes orbiculatus*. The benthic invertebrate community of fine sand in sheltered waters is also characterized by polychaetes (*Paradoneis lyra*, *Heteromastus filiformis,* and the alien *Branchiomma luctuosum*), gastropods (*Cerithium vulgatum*), other decapods (*Clibanarius erythropus*, *Carcinus aestuarii*), and sipunculids (*Golfingia (Golfingia) vulgaris vulgaris*).

Conservation interest and ecological role

This is a very productive environment, mainly because of very intense phytoplanktonic and microphytobenthic developments. The productive capacity is often exploited by humans (fishing for clams and cockles or collecting bait). This habitat represents an environment where birds can feed. A high conservation interest is linked with the development of seagrass meadows on sheltered fine sand (see sheet MB5.521).

Economic importance

Certain facies are exploited, either for molluscs (*Polititapes aureus*), whose market value for consumption is high, or for fishing bait (*Marphysa*, *Arenicola*, *Perinereis*, etc.). The habitat provides provisioning services, in terms of food production and genetic resources availability (due to the biodiversity it hosts). To date the economic value of this habitat has not yet been assessed.

Vulnerability and potential threats

This habitat can disappear because the area is filled in or because the natural or artificial barriers are eliminated to facilitate the movement of water or of boats. The intense fishing for molluscs or bait causes anarchic modification of the sedimentary bed. The habitat also suffers for the accumulation of detritus and pollutants because the water is insufficiently renewed and because of strong temporary sedimentation. It may also be affected by increased eutrophication when the site is used for shellfish farming (e.g., *Mytilus galloprovincialis*).

Protection and management

This habitat must be conserved and managed against any kind of development involving embankments or hydrodynamics modifications. The seagrass *Cymodocea nodosa* and *Zostera noltei* enjoy in the Mediterranean a legal protected status. Monitoring the quality of the water (especially for pollutants able to settle in sediments that afterwards remain undisturbed because of the weak water movement) should be recommended in these areas of heavy sedimentation. The cleaning up of waste washed up by the sea or coming from the land should be done with care in order not to destroy the biotope.

Suitability of the habitat for monitoring

This habitat is not contemplated in any monitoring program (IMAP of Barcelona Convention, Water and Marine Strategy Directives).

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A meadow of *Cymodocea nodosa* in sheltered waters (© G. Pergent)


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Facies with *Tritia* spp. and nematodes in hydrothermal vents

Reference codes for identification:

- **BARCELONA CONVENTION: MB5.539**
- **EUNIS 2019: MB5537**
- **EUNIS 2007: A5.285**
- **EC: 1180**
- **CORINE: 11.22 (partim)**

LOCATION OF THE HABITAT

Zone	Infralittoral (to circalittoral)
Nature of the substratum	Soft (sand, also with seagrass), hard (rock)
Depth range	0.5 m to 30+ m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Variable
Temperature	13 °C to 35+ °C
Suitability for monitoring	Yes, but not applied

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INFRALITTORAL

MB5.5 Infralittoral sand

MB5.53 Fine sand in sheltered waters

MB5.539 Facies with *Tritia* spp. and nematodes in hydrothermal vents

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Description of the habitat

Hydrothermalism in the Mediterranean Sea results from the collision of the African and European tectonic plates. High heat flows in the resulting volcanic arcs and back-arc extensional areas set-up hydrothermal convection systems in shallow coastal waters. Phase separation is a common feature. Vent water compositions range from reduced salinity with only slightly reduced pH, to a salinity as high as 53 with a pH as low as 2, and with enrichments in sulphide and heavy metals. Vent water temperature is usually higher than the ambient seawater. The major component of the vented gas is carbon dioxide, with lesser amounts of sulphur dioxide, hydrogen sulphide, methane and hydrogen. White or coloured algo-minero-bacterial mats are found around the vent fluid outflows. Minerals in these mats include elemental sulphur, silicates, arsenic, mercury and iron compounds. The point where the fluid escapes may be encircled by a sediment coloured orange by the precipitation of arsenic sulphides and yellow due to elemental sulphur. The area at a short distance from the vent centre, or above underlying brine seeps, is often covered with a whitish mat due to sulphur bacteria and silicate, with zones coloured brown-green by diatoms and cyanobacteria. Whitish filamentous bacterial mats attach to rocks surrounding the vent outlets, and a white layer of bacteria and of mineral precipitates may cover seagrass leaves.

Geographic distribution

Shallow-water hydrothermal vents are widespread in the Mediterranean Sea, owing to the active volcanism of the area. Major systems are known along the volcanic arc in the Southern Tyrrhenian Sea (Aeolian Islands, Cape Palinuro, Phlegrean area) and along the Hellenic Volcanic Arc in the Aegean Sea (Methana Peninsula and the islands of Milos, Santorini and Kos).

Associated habitats

The facies with *Tritia* spp. and nematodes in hydrothermal vents is found in shallow water fine sands, but hydrothermal vents may also occur in seagrass meadows, amidst rocks at various depths, and within caves, differently affecting the local biotic assemblages.

Related reference habitats

The facies with *Tritia* spp. and nematodes in hydrothermal vents is typically nested in the habitat ‘Fine sand in sheltered waters’ (MB5.53). Shallow-water hydrothermal vents, however, may also occur close to or within the ‘Association with indigenous marine angiosperms’ (MB5.521), the ‘Algal-dominated infralittoral rock’ (MB1.51), the ‘Continental shelf rock’ (MC1.52), the ‘Semi-dark caves and overhangs’ (MC1.53), the ‘Caves and ducts in total darkness’ (ME1.52), and other habitats on the continental shelf.

Possible confusion

The facies with *Tritia* species and nematodes in hydrothermal vents is easily recognised by the fluid column that rise from the seafloor, and the characteristic bacterial mats on the surrounding substrata.

Typical species and associated communities

Characteristic species, which are able to thrive in these extreme conditions, can be found among prokaryotes (bacteria and archaea). They are involved in the transformation of inorganic compounds released from the vent emissions into biomass, and are therefore at the basis of the hydrothermal system food web. Archaea include extremophilic (thermophilic and/or acidophilic) species, and especially hyperthermophilic Crenarchaeota. Iron bacteria and large sulphur bacteria (e.g., *Beggiatoa* sp. and *Achromatium volutans*) are common. Species of the gastropod *Tritia* (*T. corniculum*, *T. cuvierii*, *T. incrassata*, *T. neritea*) may abound in systems with overlying fine sands. *T. neritea*, for instance, may occur in very high densities ($>200\cdot\mathrm{m}^{-2}$), tolerating elevated salinity, temperature, and sulphide concentrations up to 1 mM. It often clusters around the periphery of gas vents, using suitable rock or seagrass as substrata for egg deposition. The species is also found on the bacterial mats, where it ingests large quantities of bacteria and diatoms but also scavenges on animals killed by the extreme conditions of the brine seeps and by the rising gases. Scavenging nematodes of the genera *Oncholaimus* and *Daptonema*, tolerant of low pH and sulphides, are common around the periphery of the venting area. Sulphide-tolerant annelids such as *Capitella* sp. and *Limnodriloides pierantonii* may also occur. A number of macrobenthic species (e.g. the amphipod *Ampelisca ledoyeri*, the mud shrimp *Necallianassa truncata*, and the lancelet *Branchiostoma lanceolatum*) demonstrate some preference to areas surrounding vents. Fish are attracted by the upward flow of water generated by the gas plumes or flares and may station themselves over the bubble columns. Hydrothermal vents with high sulphide occurring in seagrass meadows exclude *Posidonia oceanica*, thus favouring the more tolerant *Cymodocea nodosa*. Enrichment in silica may favour the growth of the sponge *Geodia cydonium.* In areas where vents contain only carbon dioxide and no toxic substances, the presence of calcifying species is reduced, and the macrobenthic assemblages are dominated by fleshy algae and smaller-bodied, generalist invertebrates.

Conservation interest and ecological role

Hydrothermal vents host novel species of prokaryotes (44% of the archaeal lineages isolated from Mediterranean hydrothermal vents represent novel phyla), and many benthic species show local adaptations and possible sibling species. Five recently described species of *Amphiglena* (Polychaeta, Sabellidae) are exclusive of four Mediterranean vent systems. A high epifaunal diversity surrounds some of the vents. Endosymbiosis between bacteria and nematodes has recently been discovered at some sites. Biological productivity is enhanced at oxic/anoxic interfaces in vent sites, and may support a flourishing community of consumers.

Economic importance

Shallow-water hydrothermal vent systems and their associated biota offer provision and information services to humans. Microorganisms living there represent an almost untapped resource for enzymes with improved catalytic properties and biomolecules potentially valuable in biotechnology. Vents are a source of recreation (visitation by scuba diving tourists), but are above all important for scientific research. The first description of shallow-water hydrothermal vents in the Mediterranean Sea dates back to at least 1860, when Dumas called ‘bollitore’ (= boiler) the gaseous manifestations in the Caldera of Panarea (Aeolian Islands, Italy). This notwithstanding, they have been much less investigated than their deep-sea counterparts, discovered more than a century later. While deep-sea hydrothermal vents give rise to a distinct ecosystem, fuelled by chemolithotrophy and methanotrophy, those on the continental shelf induce change in otherwise 'normal' ecosystems. They emit warm water, carbon dioxide, toxic chemicals, nutrients and reduced compounds that mimic climate and human impacts on marine ecosystems. These vents are natural laboratories where the responses of populations, communities and whole ecosystems to such stressors can be studied – something that cannot be replicated in mesocosms. Natural CO_2 vents are useful as a proxy to investigate the ecological effects of ocean acidification, one of the expected consequences of the greenhouse effect and global change. The monetary value of this habitat has not been assessed yet.

Vulnerability and potential threats

Commercial (tourism, harvesting of genetic resources, mineral exploitation, fishing) and scientific (sampling, instrument deployment, experimental setup) activities can potentially impact morphological, geochemical and biological dynamics of vent ecosystems.

Protection and management

Considering the importance and the peculiarity of the habitat of shallow-water hydrothermal vents, management measures should be recommended to guarantee their conservation. Deep-sea vent ecosystems are protected in many countries, such as Canada (Endeavour Hydrothermal Vents Marine Protected Area), Mexico (Guaymas Basin and Eastern Pacific Rise Hydrothermal Vents Sanctuary), Portugal (Azores Hydrothermal Vent Marine Protected Areas), and United States (Mariana Trench National Monument), but no similar initiatives exist to date for Mediterranean shallow-water vent ecosystems. The planned establishment of a marine protected area in the Aeolian Islands (Italian Law 979/82, art. 31) may help conserve the shallow-water hydrothermal vents existing there. Specific locations of the Hellenic Volcanic Arc are designated for protection, but implementation is yet pending (https://mpatlas.org/countries/GRC/map).

Suitability of the habitat for monitoring

Easy recognition of vents, by the presence of bubble plumes and white mats on the seabed, should facilitate their monitoring. Little is known about the persistence of hydrothermal vent structures and the stability of the biotic assemblages at Mediterranean sites. Information on their dynamics, present status, and resilience after disturbances is virtually lacking.

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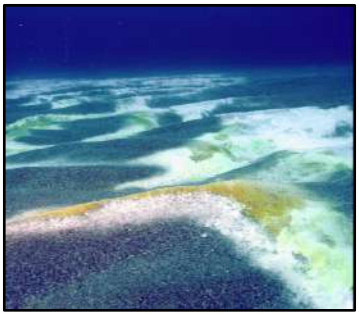
Tritia neritea gathering
(© A.J. Southward)

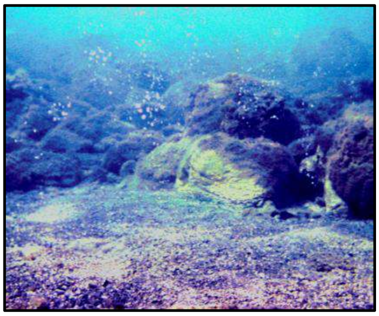
White mat of bacteria and silicate precipitates
(© T. Dailianis)



White mat with patches of yellow elemental sulphur and orange arsenic sulphides
(© T. Dailianis)

Venting on sand
(© T. Dailianis)

Venting within seagrass
(© T. Dailianis)



Venting amidst rocks
(© C.N. Bianchi)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Association with Fucales

Reference codes for identification:

- **BARCELONA CONVENTION: MB5.542**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Hard (rock), soft (sand, mud)
Depth range	0 m to 5 m
Position	Paralic
Hydrodynamic conditions	Weak
Salinity	Between 15 and 45+
Temperature	5 to 30°C
Suitability for monitoring	Yes

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Photo credits:
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INFRALITTORAL

MB1.5 Infralittoral rock

MB5.54 Habitats of transitional waters (estuaries and lagoons)

MB5.542 Association with Fucales

Description of the habitat

The association is characterized by the Fucales *Gongolaria barbata* and *Cystoseira aurantia. G. barbata* grows anchored to rocky substrate. *C. aurantia* is a free-living species that can form dense masses together other pleustophytic macroalgae on sandy-silty bottoms in coastal lagoon. The pleustophytic association can be found mostly at depths ranging from 1 to 3 m of water where hydrodynamic effects are minimal but has also been observed in wave-influenced and shallower sites. The association is normally located in the central areas of lagoons relatively far from nutrient sources, or near the sea-mouth according to eutrophication degree of the basin.

Geographic distribution

The association is distributed in lagoons all around the Mediterranean coasts.

Associated habitats

The habitat develops in 'Habitats of transitional waters (estuaries and lagoons)' (MB5.54), and it may have possible contact with the 'Association with marine angiosperms or other halophytes' (MB1.541, MB5.541), 'Association with photophilic algae except Fucales' (MB5.543), 'Facies with Polychaeta' (MB5.544), 'Facies with Bivalvia' (MB5.545).

Related reference habitats

'Association with Fucales' on rocks in the habitats of transitional waters (MB1.542).

Possible confusion

Gongolaria barbata is the only Fucales developing in transitional waters. The pleustophytic association may be confused with the pleustophitic 'Association with photophilic algae (except Fucales)' (MB5.543); the presence of *Cystoseira aurantia* in algal masses characterises the association.

Typical species and associated communities

Beyond *Cystoseira aurantia*, the pleustophytic association may be dominated by *Gracilariopsis longissima, Gracilaria bursa-pastoris, Alsidium corallinum, Chaetomorpha linum, Valonia aegagropila, Ulva* spp., *Cladophora* spp. The floating macroalgal bed may be compacted by a structure of vertical tubules of the Polychaeta *Ficopomatus enigmaticus.* Other species present in the floating mat include *Polysiphonia* spp., *Ceramium* spp., *Spyridia filamentosa* and *Ectocarpus siliculosus*.

Conservation interest and ecological role

The association is a typical Mediterranean lagoon assemblage with an important role in the productivity and biodiversity of the transitional water system. Although nithrophilic, under stressed conditions the association drifts towards the dominance of increasingly tolerant species, especially of a consequence of dystrophic events, representing a valuable bio-indicator.

Economic importance

To date the economic value of the association has not been evaluated yet.

Vulnerability and potential threats

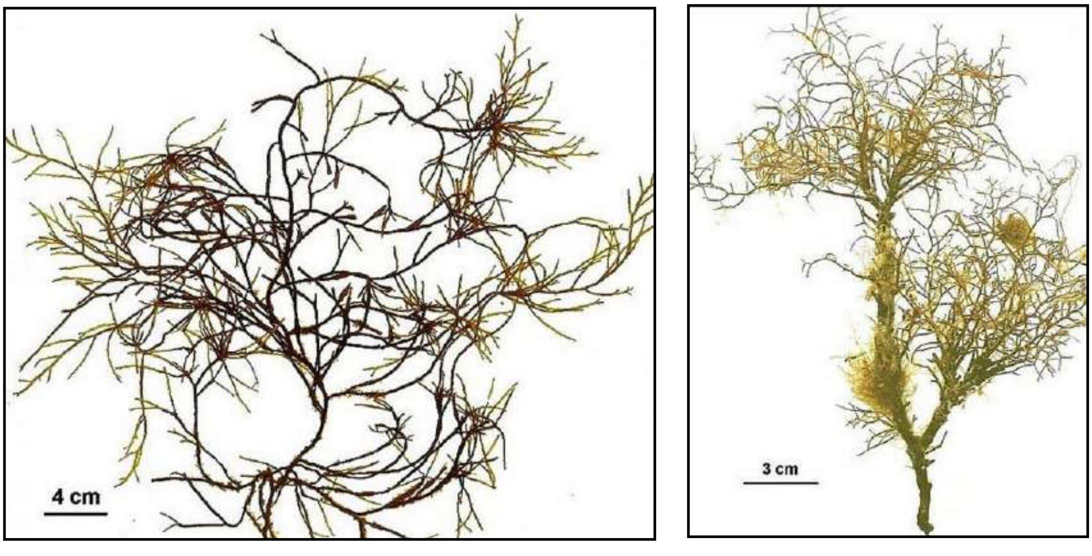
Although consituted by nithrophilic species, the association disappears when eutrophication is too high, and it is substituted by more tolerant assemblages mostly dominated by Chlorophyta. During the decay of the macroalgal masses, blooms of dinoflagellate and cyanobacteria can develop. Biological invasions are an additional threat to the association which can be replaced by more competitive alien species.

Protection and management

Cystoseira aurantia and *Gongolaria barbata* are listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention).

Suitability of the habitat for monitoring

Macroalgal assemblages of lagoons shall be assessed under the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC). The Rapid quality index (R-MaQI) is widely used to evaluate the ecological quality of Mediterranean transitional water. However, a more specific tool for Fucales lagoon assemblages should be considered.



Cystoseira aurantia (left panel) and *Gongolaria barbata* (right panel) (© G. Sartoni)

Gracilaria bursa-pastoris (left panel) and *Gracilariopsis longissima* (right panel)
(© G. Sartoni)

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INFRALITTORAL

MB1.5 Infralittoral rock, MB5.5 Infralittoral sand, MB6.5 Infralittoral mud

MB1.54, MB5.54, MB6.51 Habitats of transitional waters (estuaries and lagoons)

Habitats of transitional waters (estuaries and lagoons)

Reference codes for identification:

- **BARCELONA CONVENTION: MB1.54, MB5.54, MB6.51**
- **EUNIS 2019: MA553 (partim), MA651 (partim), MB152 (partim), MB253 (partim), MB2531 (partim), MB554 (partim), MB652 (partim)**
- **EUNIS 2007: A2.2 (partim), A2.3 (partim), A3 (partim), A5.3 (partim), A5.6 (partim), A5.529 (partim), A5.53 (partim)**
- **EC: 1130, 1150**
- **CORINE: 13.2, 21**

LOCATION OF THE HABITAT

Zone	Infralittoral
Nature of the substratum	Soft (sand, mud), rarely hard (rock, biogenic)
Depth range	0 m to 7+ m
Position	Paralic
Hydrodynamic conditions	Weak
Salinity	0.5 to 45+
Temperature	5 °C to 30 °C
Suitability for monitoring	Yes

Authors:
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Description of the habitat

Transitional (or mixohaline) waters are primarily defined as bodies of surface water in the vicinity of river mouths, partially saline in character as a result of their proximity to coastal waters but substantially influenced by freshwater flows. This definition applies well to estuaries, but not to coastal lagoons. From a geographical point of view, estuaries and lagoons are different, but large and complex river deltas commonly include both estuarine and lagoon-like portions. From an ecological point of view, the phrase transitional waters encompasses tidal estuaries and non-tidal brackish water lagoons, as well as fjords, deltas, rias, coastal ponds, and sabkhas, which are not ecotones between freshwater and marine ecosystems, and where the respective proportions of dissolved salts may be different from that of diluted marine water. A comprehensive term for all these ecosystems is ‘paralic’ (from ancient Greek παρἀ, close, and ἅλς ἀλός, salt, sea). The seaward boundaries of paralic ecosystems may commonly be a salinity limit (the lack of freshwater influence), a physiographic feature, or based on modelling; the freshwater boundary may be defined by either a tidal limit or a fresh/salt boundary. Transitional waters are traditionally classified according to their salinity, as in the so-called Venice System: hyperhaline (> 40), euhaline (40-30), polyhaline (30-18), mesohaline (18-5), and oligohaline (5-0.5). In this classification, sea waters are euhaline (but not mixohaline) and fresh (limnetic) waters have a salinity <0.5. The limits of the classes are established on the basis of the distribution of selected indicator species; a major boundary in species distribution is the so-called ‘horohalinicum’, which occurs where salinity is around 5-8 and thus roughly corresponds to the passage from mesohaline to oligohaline waters. An alternative classification, which takes into account the zonation of the whole community, is based on the degree of confinement, independently of the salinity. Confinement is essentially a hydrological notion reflecting the rate of water exchange. Thus, up to six biotic zones are recognized in paralic ecosystems: zone I is located in the immediate vicinity of the communications with the sea and is inhabited by strictly thalassic (marine) species; in zone II stenohaline marine species disappear; zone III is dominated by euryhaline marine species; zone IV is defined by the loss of all thalassic fauna, all the species present being strictly paralic; zone V is characterized by a severe reduction in the benthic macroinfauna richness, the so-called ‘artenminimum’ (i.e. the minimum in the number of species); finally, zone VI represents the passage to freshwater or evaporitic environments. Salinity in transitional waters typically varies on both a daily and seasonal basis. Paralic basins are normally shallow, rarely exceeding a few metres depth; in exceptionally deep salt lakes (e.g. Faro in Sicily) water stratification occurs, deep waters being anoxic and hence azoic. Shallow, laminar waters also imply great variations in temperature. The bottom sediment is usually mud or sandy-mud, hard substrates being rare.

Geographic distribution

Transitional waters occur all along the Mediterranean coastline. The north-Adriatic lagoons differ from all others for a series of climatic, hydrological and biological characteristics that make them similar to those of the western European coasts: consequently, they are defined as ‘subatlantic’. The remaining lagoons are typically Mediterranean in all their aspects and are therefore defined as ‘eumediterranean’. The latter are in turn divided into ‘mesomediterranean’, corresponding to the northern Mediterranean lagoons, and ‘xeromediterranean’, located in the southern Mediterranean and subjected to a more arid climate.

Associated habitats

Transitional water habitats may be in contact with both freshwater habitats landwards and marine habitats seawards. The latter may include ‘Infralittoral sand’ (MB5.5), ‘Infralittoral mud’ (MB6.5), and ‘Infralittoral rock’ (MB1.5), especially the ‘Association with photophilic algae’ (MB1.512a). Similarities may exist with the biological communities living in harbours. In the marginal areas such as the evaporitic pole, ‘Habitats of salinas’ (MA6.522a) may develop. Inside transitional waters, the ‘Association with photophilic algae’ (MB5.543), the ‘Facies with Polychaeta’ (MB5.544), and the ‘Facies with Bivalvia’ (MB5.545) may occur, as well as further reference habitats. Transitional waters also include several reference habitats, among which the ‘Association with halophytes or marine angiosperms’ (MA6.521a), the ‘Association with marine angiosperms or other halophytes’ (MB1.541, MB5.541), and the ‘Association with Fucales’ (MB1.542, MB5.542).

Related reference habitats

Paralic ecosystems may share species with the ‘Fine sand in sheltered waters’ (MB5.53), the ‘Algal-dominated infralittoral rock’ (MB1.51), the ‘Well illuminated infralittoral rock sheltered’ (MB1.51c), the ‘Invertebrate-dominated infralittoral rock’ (MB1.52), the ‘Infralittoral rock affected by sediment’ (MB1.53), and the ‘Association with *Caulerpa prolifera’* (MB1.514c, MB5.533).

Possible confusion

The topographic situation of estuaries and lagoons makes them unmistakable. Recognizing the exact boundaries with freshwater or marine ecosystems, however, is sometimes difficult.

Typical species and associated communities

The biota living in transitional waters is made up by highly euryhaline and eurythermal species. The composition of the communities is practically the same whether the salinity remains almost unchanged (higher or lower than the normal value for the neighbouring sea) or whether it shows large fluctuations. Among the most characteristic species of the sediment infauna are the bivalves *Abra segmentum*, *Cerastoderma glaucum*, *Gastrana fragilis*, *Loripes orbiculatus* and *Scrobicularia plana*, the polychaetes *Alitta succinea* and *Hediste diversicolor*, and the crab *Carcinus aestuarii.* Phanerogamic stands may be present made by *Cymodocea nodosa, Zostera marina*, *Z. noltei*, *Ruppia maritima*, *R. cirrhosa* or *Stuckenia pectinata* (in the order of decreasing salinity). The hydroids *Cordylophora caspia* (in less saline waters) and *Laomedea angulata* (in more saline waters) and the anemone *Paranemonia cinerea* are epiphytic on the leaves. Many small crustaceans swim among the leaves, such as the amphipods *Gammarus aequicauda, G. locusta* and *Microdeutopus gryllotalpa*, the isopods *Cyathura carinata, Idotea chelipes* and *Lekanesphaera hookeri*, and the shrimps *Palaemon adspersus* and *P. antennarius* (in oligohaline to freshwater). Molluscs include the gastropods *Ecrobia ventrosa*, *Pirenella conica*, *Rissoa fragilis*, *R. membranacea* and *Theodoxus* *fluviatilis* (in oligohaline to freshwater), and the small mussel *Mytilaster marioni*. Starting from any hard substrate available (shells, stones, reeds), the serpulid polychaete *Ficopomatus enigmaticus* is capable to form sizeable build-ups or even reefs, which harbour a diverse associate fauna. Its calcareous tubes are encrusted by the barnacles *Amphibalanus eburneus* and *A. improvisus* and by the bryozoans *Amathia gracilis*, *Conopeum seurati*, *Victorella muelleri* and *V. pavida*. Some amphipod species live within the reefs: *Chaetogammarus olivii*, *Echinogammarus pungens*, *Leptocheirus pilosus, Monocorophium acherusicum* and *M. insidiosum*. The brown alga *Ectocarpus siliculosus*, the red alga *Gracilariopsis longissima* and green algae of the family Ulvaceae (*Ulva prolifera*, *U. rigida*, etc.) may be abundant. Many fish thrive in estuaries and lagoons. Many of them are marine euryhaline species that enter transitional waters to forage or find shelter. Among the most common are grey mullets: *Chelon auratus*, *C. labrosus, C. ramada*, *C. saliens* and *Mugil cephalus* (in the order of increasing euryhalinity). A few species are amphihaline or diadromous (i.e. migrate between the sea and freshwater). Anadromous fish (migrate from the sea up into fresh water to spawn) include the lampreys *Lampetra fluviatilis* and *Petromyzon marinus* and the clupeid *Alosa fallax*. The extremely rare sturgeons *Acipenser naccarii* and *A. sturio* are also anadromous. Catadromous fish (migrate from fresh water down into the sea to spawn) are represented by the eel *Anguilla anguilla*. The most typical resident fish are represented by three gobiids and three cyprinodontids. The gobiids are *Knipowitschia panizzae* (NE Italy, Slovenia and Croatia, with records from Greece needing to be confirmed), *Pomatoschistus canestrinii* (NE Italy and Croatia) and *P. tortonesei* (Sicily and Lybia). The cyprinodontids are *Aphanius almiriensis* (Greece), *A. fasciatus* (whole Mediterranean) and *A. iberus* (Spain); a fourth species, *A. dispar*, has recently penetrated from the Red Sea into the Levantine Basin through the Suez Canal. Numerous species of birds, either resident or migrant, thrive in paralic ecosystems, feeding on fish and invertebrates.

Conservation interest and ecological role

Transitional waters play a major role in coastal ecology and host a peculiar biodiversity, providing vital habitats for many organisms, including endangered species. They are important for many biogeochemical processes and are the most productive natural ecosystems of the whole biosphere. For many coastal fishes, transitional waters represent important nursery areas and physical refuges from predation for their juveniles. Estuaries and lagoons are stopovers in migration or nesting and feeding areas for birds. The existence of strong environmental gradients and their variability create a mosaic of different habitats that makes each paralic basin unique and worth of conservation.

Economic importance

Transitional waters are among the most used and valuable habitats on earth, and represent complex social-ecological systems that provide ecosystem services for human welfare. The main services they offer include provision services, regulating services, and information and cultural services. Fishery and aquaculture (mainly fish and shellfish) can be key in the regional economy, producing a monetary value that may exceed 100,000 $€\cdot ha\cdot a^{-1}$. Further provision services are represented by the harvest of algal biomass for biofuel, food industry, nutraceuticals (alginates, carrageenins, agar, agaroses), agriculture (fertilizers, feed), pharmaceutical (phycoerythrin), cosmetics, textile, and paper industry, with variable market prices. Regulation and protection services, which include biogeochemical cycling, climate buffering, sediment retention, mitigation of extreme events (e.g. floods) and others, may total over 15,000 $€\cdot ha\cdot a^{-1}$. Among information services, leisure, recreation and tourism have a monetary value of about 2,000 $€\cdot ha\cdot a^{-1}$. The importance of paralic ecosystems for training and research should also be emphasized, representing in many cases open-air laboratories. Finally, the services of these ecosystems deliver not only livelihoods and wellbeing but also numerous benefits with have societal, aesthetic and heritage value. The cultural and sociological aspects are underlined by the presence, since historical times, of human settlements. The cultural services of the Venice lagoon, a UNESCO World Heritage, represent approximately 10,000 $€\cdot ha\cdot a^{-1}$.

Vulnerability and potential threats

Intense and multifarious human uses make transitional waters one of the most threatened ecosystems in the world. Urbanization, habitat destruction, pollution, water withdrawal, and overexploitation are the main causes of their degradation. Increasing eutrophication may lead to more severe and frequent dystrophic crises in summer, with catastrophic mass mortalities of fish and invertebrates. Climate change is affecting estuaries and lagoons. These habitats are generally shallow, and therefore particularly exposed to the effects of temperature increase. Sea level rise and changes in rainfall and storminess regime would affect watershed runoff and erosion, flushing rates, water circulation, salinity, dissolved oxygen concentration and nutrients inputs, with cascading effects on lagoon biogeochemistry. Paralic ecosystems are particularly prone to the invasion of alien species, deliberately (e.g., for aquaculture) or accidentally introduced, and are major hotspots of non-indigenous species diversity.

Protection and management

Transitional waters require a holistic management involving economists, naturalists, and environmental scientists. Estuaries and lagoons fall under the aegis of the Ramsar Convention on Wetlands (1971). The European red list of marine habitats of the European Union classifies the communities of Mediterranean midlittoral estuarine mud as endangered, and the communities of Mediterranean infralittoral estuarine rock as vulnerable. Many transitional waters host bird sanctuaries and are therefore Special Protection Areas according to the Birds Directive of the European Union. Several paralic fish species are protected according to international agreements. *Acipenser naccarii* is 'Critically Endangered', possibly extinct in the wild, according to the IUCN Red List of Threatened Species. It is also included in the Annex II (list of endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean; in the Appendix II (strictly protected fauna species) of the Bern Convention on the Conservation of European Wildlife and Natural Habitats; in the Washington Convention on International Trade in Endangered Species of wild flora and fauna (CITES); in the Annex II (species requiring designation of Special Areas of Conservation) and in theAannex IV (species in need of strict protection) of the Habitats Directive on the Conservation of natural habitats and of wild fauna and flora of the European Union. *Acipenser sturio* is 'Critically Endangered' according to the IUCN and is included in the Annex II of the Barcelona Convention, in the Appendix II of the Bern Convention, in CITES, and in the Annexes II and IV of the Habitats Directive. *Alosa fallax* is included in the Annex III (list of species whose exploitation is regulated) of the Barcelona Convention, in the Appendix III (protected fauna species) of the Bern Convention, and in the Annexes II, IV and V (species in which member countries may decide for themselves how to manage the population) of the Habitats Directive. *Anguilla anguilla* is 'Critically Endangered' according to the IUCN (the numbers of eels reaching Europe is thought to have declined by more than 90% since the 1970s, due to overfishing, parasites such as the nematode *Anguillicola crassus*, barriers to migration such as hydroelectric dams, pollution, and changes in Atlantic water circulation); it is also included in CITES and in the Annex III of the Barcelona Convention. *Aphanius almiriensis* is 'Critically Endangered' according to the IUCN. *Aphanius fasciatus* is included in the Annex II of the Barcelona Convention, in the Appendix II of the Bern Convention, and in the Annex II of the Habitats Directive. *Aphanius iberus* is 'Endangered' according to the IUCN and is included in the Annex II of the Barcelona Convention and in the Appendix II of the Bern Convention. *Knipowitschia panizzae* is included in the Annex II of the Habitats Directive. *Lampetra fluviatilis* is included in the Annex III of the Barcelona Convention, in the Appendix III of the Bern Convention, and in the Annexes II and V of the Habitats Directive. *Petromyzon marinus* is included in the Annex III of the Barcelona Convention, in the Appendix III of the Bern Convention, and in the Annex II of the Habitats Directive. *Pomatoschistus canestrinii* is included in the Annex II of the Barcelona Convention, in the Appendix III of the Bern Convention, and in the Annex II of the Habitats Directive. *Pomatoschistus tortonesei* is 'Endangered' according to the IUCN and included in Annex II of the Barcelona Convention.

Suitability of the habitat for monitoring

Criteria for the monitoring of transitional waters are presented in the Annex V of the Water Framework Directive of the European Union, and the Guidance Document No 7 provides a common understanding on the requirements and a list of indicators to adopt. Several indices to evaluate the environmental quality of transitional waters have been developed, but their application remains partial to date.

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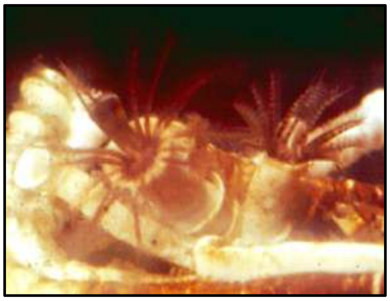
Cerastoderma glaucum (© C.N. Bianchi)

Gammarus aequicauda (© C.N. Bianchi)

Carcinus aestuarii (© C.N. Bianchi)

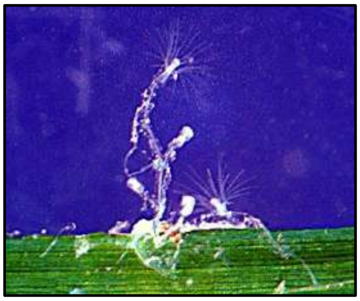


Ficopomatus enigmaticus (© C.N. Bianchi)

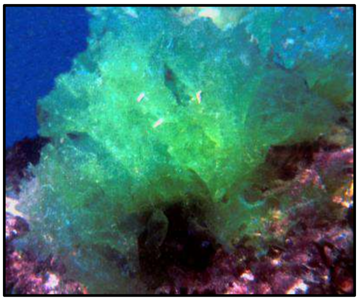
Paranemonia cinerea (© C. Morri)

Chelon auratus (© C.N. Bianchi)

Cymodocea nodosa (© C.N. Bianchi)



Laomedea angulata (© C. Morri)



Ulva rigida (© C.N. Bianchi)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Association with marine angiosperms or other halophytes

Reference codes for identification:

- **BARCELONA CONVENTION: MB6.511**
- **EUNIS 2019: MB5541, MB5542, MB5544, MB5545, MB6521, MB6522, MB6524, MB6525**
- **EUNIS 2007: A5.5342, A5.542, A5.5332, A5.5333**
- **EC: 1130, 1150*, 1160 (partim)**
- **CORINE: 11.33, 11.41, 23.2**

LOCATION OF THE HABITAT

Zone	Infralittoral, with extension into the lower midlittoral
Nature of the substratum	Soft (mud, sand), hard (rock, oyster banks)
Depth range	0 to few meters
Position	Paralic
Hydrodynamic conditions	Usually weak, but also high near the main channels
Salinity	From low-salinity brackish waters to hypersalinity
Temperature	Extremely variable
Suitability for monitoring	Yes

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INFRALITTORAL

MB6.5 Infralittoral mud

MB6.51 Habitats of transitional waters

MB6.511 Association with marine angiosperms or other halophytes

Description of the habitat

This association is characterised by aquatic Tracheophyta that develop in the habitats of transitional water systems (e.g., coastal lagoons, estuaries, sea inlets, marshes, littoral ponds) of the infralittoral zone, on soft bottoms formed by mud (clay and silt) or sand (MB5.541) and on hard rocky bottoms (MB1.541), where the salinity is variable over the short or long term (daily to annual), and where also the temperature and all the other environmental parameters show extreme values. Characteristic species include the seagrasses *Cymodocea nodosa*, *Zostera marina, Z. noltei*, the aquatic angiosperms *Ruppia cirrhosa* and *R. maritima*, and the halophytes *Stuckenia pectinata* (formerly *Potamogeton pectinatus*) and *Zannichellia palustris*. Beds develop in shallow waters, between the surface down to few meters of depth, but they can support certain periods of emersion, so that the association with marine angiosperms or other halophytes is very common also in the lower midlittoral zone (see sheet MA6.521a).

Geographic distribution

Association with marine angiosperms or other halophytes can develop at the scale of the whole Mediterranean Sea where extensive transitional water systems occur. Seagrass beds of transitional waters have been described mostly in the western Mediterranean and the Adriatic Sea.

Associated habitats

Marine angiosperms or other halophytes of transitional waters can be associated with ‘Association with Fucales’ (MB1.542, MB5.542), ‘Association with photophilic algae’ (MB5.543), ‘Facies with Polychaeta’ (MB5.544), and ‘Facies with Bivalvia’ (MB5.545).
The habitat may be in contact with ‘Reefs of Vermetidae’ (MB2.51), ‘Reefs of *Sabellaria* spp. (MB2.52), ‘Fine sand in very shallow waters’ (MB5.51), and ‘Fine sand in sheltered waters’ (MB5.53).

Related reference habitats

This habitat is related with the ‘Association with marine angiosperms’ on rocky (MB1.541) and sandy (MB5.541) bottoms, and with the ‘Association with halophytes or marine angiosperms’ on midlittoral mud (MA6.521a). Some of the characteristic species of the association with aquatic angiosperms in transitional waters can also be found within the habitats of ‘Fine sand in sheltered waters’ (MB5.53) and ‘Well sorted fine sand’ (MB5.52).

Possible confusion

This habitat cannot be confused being characterized mainly by aquatic angiosperms and macroalgae. Some seagrass species of transitional waters (e.g., *Cymodocea nodosa,* occasionally *Zostera* spp.) can also be found on sandy bottoms in marine coastal waters. A possible confusion may also occur in the distinction between the angiosperm species.

Typical species and associated communities

Zostera noltei develops in lagoons, bays, and estuaries that are subject to wide ranges of salinity, on different substrata, but it prefers the muddy bottoms of the intertidal and the shallow subtidal habitats, where it develops monospecific populations. As the other seagrasses, it has very narrow leaves incised at the apex, which can be up to 40-60 cm long and 0.7-1.7 mm width and contain air spaces that make it buoyant. *Zostera noltei* could be confused only with *Zostera marina*, with which it may constitute mixed populations, but the latter has bigger leaves up to 1 m long and 5-7 mm width, with evident ribs and smooth edges and generally develops at greater depths. *Zostera marina* is considered a cold relict species as its distribution is extremely localized and limited to coastal areas with freshwater inflows; it can be found in lagoons with high water renewal, especially at the edges of the channels where temperature is lower and, more rarely, in sheltered coastal areas. Both *Zostera* species are very sensitive to eutrophication that triggers thionitrophilic macroalgae or phytoplankton blooms, turbidity and water pollution.

Cymodocea nodosa is generally the most abundant seagrass species close to the lagoon mouths, where the sediment is sandy, and salinity is higher. It colonizes sediments down to a depth of approx. 30 cm and its rhizomes form a dense perennial network contrary to *Zostera,* which goes down to 5-10 cm and has rhizomes that die in the distal part. Occasionally, *C. nodosa* can form mixed meadows with *Zostera* spp. (see sheet MB5.521 for more details on the former species).

Ruppia spp. are cosmopolitan salt-tolerant aquatic angiosperms that live submerged on muddy bottoms in the habitats of transitional waters. Two species occur in the Mediterranean, *Ruppia cirrhosa* and *R. maritima*. *Ruppia maritima* is more frequent in temporary peripheral environments, in very shallow waters with low salinity (basically from 5 to 40 psu or more). It has small leaves, 30-40 cm long and 0.4-0.7 mm width, with toothed edges at the apical part of the leaves. It is present in permanent or semi-permanent (short drying up) environments, subject to the most extreme conditions and withstands hypersaline environments, being found also in saltwork basins. *Ruppia cirrhosa* prefers depths of 0.5-1 m where it can form extensive meadows. This species emits the leaf bundles directly from the rhizomes or from herbaceous stems even over 1 m long. These carry packages of 3-5 leaves of 15-17 cm in length by 0.8-1.0 mm in width. Leaves taper to 0.5-0.6 mm at the apex with toothed edges at the apical part and numerous tannic cells to avoid grazing. *Stuckenia pectinata* is a halophytic plant, perennially submerged except for inflorescences, with long stems and small, mostly undivided, linear and non-floating leaves that range from 5 to 18 cm in length and 0.25 to 2.5 mm in width. It develops on muddy and sandy bottoms in shallow, very low salinity (0 to 10 psu) waters of ponds that are rich in organic matter.

The associated community is that of the euryhaline and eurythermal environments (see sheet MB6.51 for more details). *Zannichellia palustris*, *Chara* spp., and *Althenia filiformis* are accompanying plant species. The alien seagrass *Halophila stipulacea* can be sometimes associated with *Zostera* spp. in the southern regions of the Adriatic and the Mediterranean Sea. There is a fauna with freshwater affinities, which is dominated by insects (Heteroptera, Odonata, Diptera). A rich infaunal community is found in the sediment colonized by aquatic angiosperms. When leaves emerge from the surface for long periods, they create a multidimensional substrate for macro and microalgae. Sessile species live on the leaf blades (called epiphytes), which are represented mainly by macro and microalgae, especially diatoms, cyanobacteria and macrofaunal organisms, such as hydrozoans, bryozoans, and ascidians. The associated vagile species are gastropods, crustaceans, polychaetes, and fish (e.g., *Zosterisessor ophiocephalus* that lives associated with *Zostera* spp. beds, *Syngnathus acus*, *S. abaster*, *S. typhle*, *Gasterosteus aculeatus*, *Anguilla anguilla*). Many grazing gastropods, such as *Bittium reticulatum* and *Potamopyrgus antipodarum*, are found in this habitat and juveniles of *Mytilus edulis* have even been observed settled on *Stuckenia pectinata* leaves.

Conservation interest and ecological role

Aquatic angiosperms play an essential ecological role in terms of primary production (partly exported to other ecosystems), water oxygenation, associated biodiversity, sedimentary balance, bottom and shoreline stability. The habitat they create is an important spawning ground for fish and a shelter for young fishes; they also offer a major source of food for birds and support for many invertebrates. The stems, leaves and seeds of *Stuckenia pectinata*, *Ruppia* spp. and *Zostera noltei* are eaten by ducks. *Zostera marina* and *C. nodosa* contribute relatively little to feeding birds, but they act as refuge for a diversified associated fauna.

In addition to the high primary production, plant biomass and the epiphytic algae attached to the floating leaves are important for the diet of selected herbivorous waterfowl species and represent a permanent important reservoir of nutrients. On the contrary, thionitrophilic and ephemeral macroalgae, such as the Ulvaceae, grow in the pools inside the meadows and degrade easily, so that their harvest may help to prevent eutrophication and dystrophic crises.

Economic importance

Aquatic angiosperms provide: regulating services, such as carbon sequestration and nutrient recycling; provisioning services, such as food production, materials and genetic resources availability (due to the biodiversity they host); habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms; and information services, in terms of scientific research and monitoring. Large deposit of plant detritus often accumulate on the coastline, consolidating beaches and preventing their erosion and providing huge amounts of nutrients (see also the sheet MA2.51a).

Vulnerability and potential threats

Aquatic angiosperms are highly vulnerable being directly affected by various anthropogenic pressures along the coast. The main threats for habitats of transitional waters are linked to coastal development and urban activities (direct destruction, modification of hydrodynamics and of sediment budget, increased turbidity, pollution, eutrophication), living resources exploitation (clam harvesting and fish farming), and global warming.

Protection and management

All aquatic angiosperms are considered worthy of protection. *Zostera noltei* and *Z. marina* are listed in the Annex II “List of endangered or threatened species” to the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA & BD Protocol, Barcelona Convention). The Action Plan for the Conservation of Marine Vegetation in the Mediterranean, adopted in 1999 by the Contracting Parties to the Barcelona Convention, set priorities and management activities to be undertaken to protect all seagrass meadows. Many Mediterranean countries included marine angiosperms in their national lists of protected species. *Zostera marina* also enjoys protection by the Bern Convention on the conservation of wildlife and natural environment of Europe (Annex I, ‘Strictly protected flora species’).

Suitability of the habitat for monitoring

Due to the sensitivity of aquatic angiosperms to environmental alterations, they are commonly used as excellent indicators of the overall environmental quality. Aquatic angiosperms have been included as common indicators in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. These aquatic plants have also been defined as biological quality elements in the European Directives on water and marine quality assessment (under the Water Framework Directive and the Marine Strategy Framework Directive, respectively). In transitional waters, ecological status evaluation is made by using aquatic angiosperms and macroalgae through the adoption of the *Macrophyte Quality Index.* The halophyte *Stuckenia pectinata* has been proposed as a hyperaccumulator, which is useful for monitoring the level of metals in the environment.

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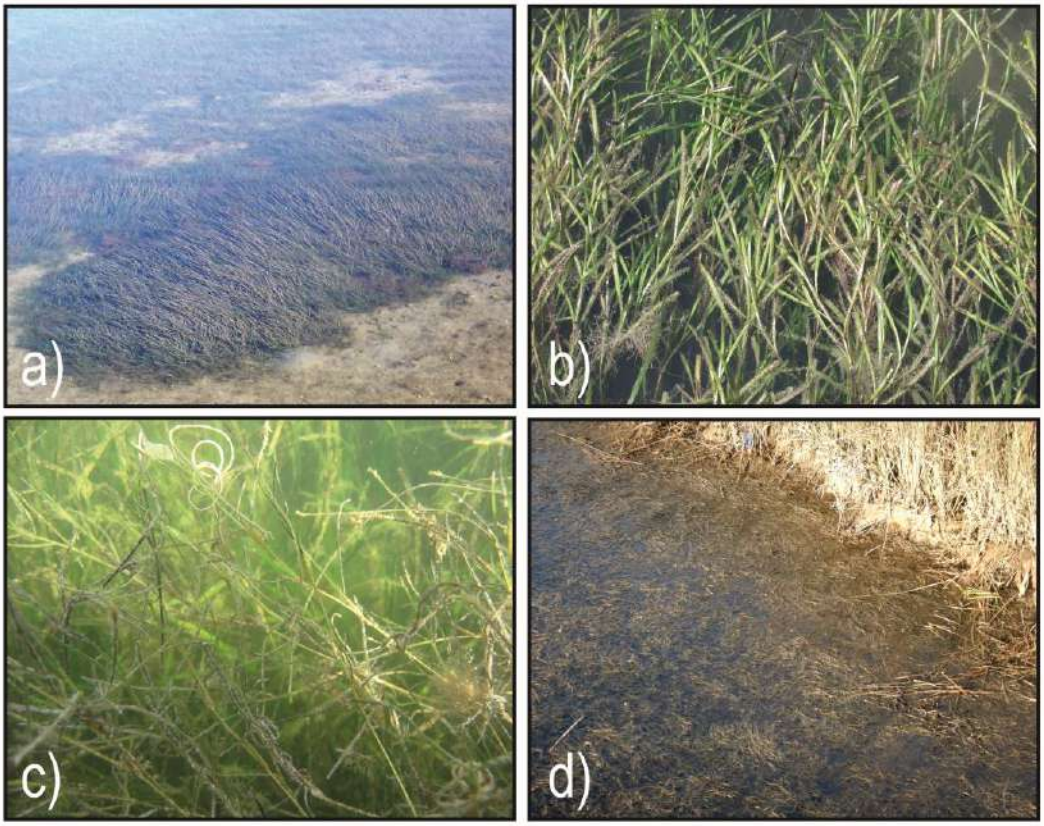

Beds of *Zostera noltei* (a), *Zostera marina* (b), *Ruppia cirrhosa* (c), and *Ruppia maritima* (d) (© A. Sfriso)

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Coralligenous cliffs

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.51**
- **EUNIS 2019: MC151**
- **EUNIS 2007: A4.26, A4.32**
- **EC: 1170**
- **CORINE: 11.251, 11.252**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Hard (rock)
Depth range	25 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.51 Coralligenous cliffs

Description of the habitat

Coralligenous habitat is a hard substratum of biogenic origin mainly produced by the accumulation of calcareous encrusting algae growing in dim light conditions (from 0.05% to 3% of the surface irradiance). Therefore, the main criterion used to identify the coralligenous habitat is the presence of calcareous structures edified by coralline algae grown at low irradiance levels and in relatively calm waters. Several coralligenous morphologies have been described, Coralligenous cliffs refer to the form developing on circalittoral rocky substrates. The distribution of the coralligenous habitat is subject to a combination of biotic and abiotic factors. The main factors are light, movement of the water, temperature, deposit of sediment and biological interactions. Coralligenous cliffs develop at temperatures from 10 to 22°C and at salinity ranges between 36 and 39. The average depth of this habitat is between 30 and 90 m, but it can be found between 25 and 150 m depending on environmental conditions (water turbidity, currents, exposition). Coralligenous structures are normally very complex allowing the development of different associated communities all characterized by high biodiversity. ‘Algal-dominated coralligenous’ (MC1.51a) and ‘Invertebrate-dominated coralligenous’ (MC1.51b and MC1.51c) are the main sub-habitats.

Geographic distribution

Coralligenous habitat is common all around the Mediterranean coasts. It covers a surface area of about 2763 km^2 in 16 Mediterranean countries, i.e., Albania, Algeria, Croatia, Cyprus, France, Greece, Italy, Israel, Lebanon, Libya, Malta, Monaco, Morocco, Spain, Tunisia, and Turkey.

Associated habitats

Coralligenous cliffs develop on ‘Circalittoral rock’ (MC1.5) and may be also found in the external part of the habitat ‘Semi-dark caves and overhangs’ (MC1.53). Coralligenous cliffs may have possible contact with ‘Algal-dominated infralittoral rock’ (MB1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coastal detritic bottoms’ (MC3.51 and MC3.52), ‘Muddy detritic bottoms’ (MC4.51), and ‘Coastal terrigenous muds’ (MC6.51). Other associated habitats can be ‘Association with encrusting Corallinales’ (MC1.511a), ‘Association with Fucales or Laminariales’

(MC1.512a), ‘Association with sciaphilic algae (except Fucales, Laminariales, encrusting Corallinales, and Caulerpales)’ (MC1.513a), ‘Association with non-indigenous Mediterranean *Caulerpa* spp.’ (MC1.514a), ‘Facies with small sponges’ (MC1.511b), ‘Facies with large and erect sponges’ (MC1.512b), ‘Facies with Hydrozoa’ (MC1.513b, c), ‘Facies with Alcyonacea’ (MC1.514b, c), ‘Facies with Ceriantharia’ (MC1.515b, c), ‘Facies with Zoantharia’ (MC1.516b, c), ‘Facies with Scleractinia’ (MC1.517b, c), ‘Facies with Vermetidae and/or Serpulidae’ (MC1.518b, c), ‘Facies with Bryozoa’ (MC1.519b, c), ‘Facies with Ascidiacea’ (MC1.51Ab, c).

Related reference habitats

‘Algal-dominated coralligenous’ (MC1.51a), ‘Invertebrate-dominated coralligenous’ (MC1.51b), ‘Invertebrate-dominated coralligenous covered by sediment’ (MC1.51c), ‘Coralligenous outcrops’ (MC1.52a), ‘Coralligenous outcrops covered by sediment’ (MC1.52b), ‘Coralligenous platforms’ (MC2.51), and ‘Coralligenous (enclave of circalittoral)’ (MB1.55).

Possible confusion

The coralligenous cliffs on the circalittoral rock can be confused with the coralligenous in enclave in the infralittoral rock (MB1.55), the ‘Coralligenous outcrops’ (MC1.52a, b) and the ‘Coralligenous platforms’ (MC2.51). The main criterion to distinguish these habitats is their spatial and bathymetrical distribution, as their structure and morphology may be quite similar. In fact, coralligenous cliffs develop on coastal circalittoral rocks, while coralligenous in enclave in the infralittoral rock develops on shallower infralittoral rocks, coralligenous outcrops and coralligenous platforms may be found on the continental shelf and on shelf edge and they develop on both rocky and detritic bottoms.

Typical species and associated communities

The main components of coralligenous are algal builders, animal builders, bioeroders, associated macroalgal assemblages, associated sessile invertebrate assemblages, associated mobile invertebrates and fish assemblages.

Algal builders are mostly coralline algae (*Mesophyllum alternans, M. expansum, M. macroblastum, M. philippii, Lithophyllum stictiforme, L. cabiochiae, Titanoderma pustulatum, Neogoniolithon mamillosum*). Calcareous *Peyssonnelia* (*P. polymorpha, P. rosa-marina*) may also contribute as coralligenous builders. The main animal builders are bryozoans (*Schizomavella* spp., *Schizobrachiella* spp., and *Turbicellepora* spp.), serpulids and scleractinians (*Dendrophyllia* spp., *Madracis pharensis, Leptopsammia pruvoti*, *Caryophyllia* spp.). Several species of sponges of the genus *Cliona*, three species of molluscs, two species of polychaetes of the genus *Polydora* and two sipunculids have been described as coralligenous bioeroders.

The associated assemblages exhibit a stratified structure, with a basal, an intermediate, and an upper layer. The basal layer consists of encrusting and turf macroalgae and invertebrates (encrusting sponges, bryozoans, and ascidians). The intermediate layer includes erect small macroalgae and invertebrates, mostly sponges, anthozoans and bryozoans. The upper layer is characterized by large and erect sponges, by Alcyonacea and by Fucales, Tilopteridiales and Laminariales. The most characteristics mobile invertebrates are the echinoderms *Astrospartus mediterraneus, Antedon mediterranea, Centrostephanus longispinus, Echinus melo* and the crustaceans *Palinurus elephas, Homarus gammarus, Scyllarides latus*. Several fish species are considered typical of coralligenous habitat: *Anthias anthias*, *Labrus mixtus*, *Acantholabrus palloni*, and *Lappanella fasciata* are just some examples.

Conservation interest and ecological role

Coralligenous reefs represent one of the most important coastal ecosystems of the Mediterranean Sea for distribution, biodiversity, biomass, and role in the carbon cycle. Coralligenous biogenic build-ups are present along 30% of the Mediterranean coasts, harboring about 20% of species of the basin including many organisms considered vulnerable or endangered. Coralligenous concretions support biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages. According to some recent estimates, coralligenous concretions are known to host over 1600 taxa. The high biodiversity hosted by bioconstructions is related to their complex three-dimensional structure that support different microhabitats allowing the coexistence of taxa with different ecological requirements.

The great variety and abundance of highly productive calcareous organisms makes coralligenous one of the most important CO_2 sinks and carbonate producers on the Mediterranean continental shelf. Coralline algae, due to their calcareous skeletons, act as a carbon dioxide sink in geological times and as carbon sources on a human timescale. They take carbon from seawater where it is available as dissolved ions and fix it into their skeletal structures. When these skeletal structures disaggregate, they become important sources of inorganic carbon.

Economic importance

Coralligenous reefs provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. Coralligenous concretions facilitate the aggregation of fishes of commercial interest for feeding (which is the case of many large predators) and during the spawning. The coralligenous habitat is an iconic seascape and a preferred diving spot for divers due to high biodiversity, fish abundance and complex topography to explore.

To date, the economic value of coralligenous reefs has not been evaluated yet. A regional-scale study (about 1000 km of coastline concerned) evaluated the SCUBA diving activities on coralligenous habitat to generate an annual economic revenue of € 4.7 M.

Vulnerability and potential threats

Coralligenous is considered very sensitive to human-induced impacts as the maintenance of this habitat is related to a delicate balance between bio-construction and bio-erosion, which can be easily disrupted by environmental alterations. Steady environmental conditions is a key factor for development and survival of coralligenous concretions and assemblages. The main threats on coralligenous habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change.

Correlative and experimental studies highlighted severe shifts in the structure of macroalgal coralligenous assemblages subjected to increase of nutrient concentration and sedimentation rate and to invasion of introduced macroalgae (e.g., *Caulerpa cylindracea* and *Womersleyella setacea*). Modifications of assemblages are related to the loss of their complexity and heterogeneity due to a decrease of both alpha and beta diversity and of perennial structuring species and an increase of ephemeral organisms. Thus, these anthropogenic impacts may lead to a generalized biotic homogenization of the habitat. Evident signs of necrosis have been described in many benthic coralligenous taxa subject to mucilage overgrowth, such as sponges, scleractinians, encrusting coralline algae, and gorgonians. Coralligenous is one of the Mediterranean habitats mostly disturbed by thermal anomalies and ocean acidification. Marine heatwaves cause mass mortality of coralline algae, scleractinians, and gorgonians. Changes in pH values interfere with the calcification of coralline algae and invertebrates with a calcareous skeleton.

Protection and management

Coralligenous habitat is first and foremost listed in the council of the European Union (EC) No 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea and states that “Fishing trawl nets, dredges, shore seines or similar nets above coralligenous habitats and maërl beds shall be prohibited” (Article 4.2). This statement shall be applied to all Natura 2000 sites (where coralligenous is included in the EC Habitat 1170 “Reefs”), all special protected areas and all Specially Protected Areas of Mediterranean Interest (SPAMI), which have been designated for the purpose of the conservation of the habitats under either Directive 92/43/EEC or Decision 1999/800/EC (Article 4.4). The Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea describes the main threats and promotes those activities that generally overlap the conservation of biodiversity: protect species and habitats, improve knowledge of marine and coastal biodiversity, reduce negative impacts on biological diversity, promote sectoral policies in favor of biodiversity (e.g., tourism, agriculture), adopt institutional and legal measures, create marine protected areas. The Marine Strategy Framework Directive (2008/56/EC) includes coralligenous among the “special habitats types” that should be assessed. The Directive is also the first legislative instrument that recognizes “seafloor integrity” as one of the descriptors to be evaluated for assessing the Good Environmental State of the marine environment. In the European IUCN Red List of marine habitats, Mediterranean coralligenous habitats are classified as ‘Data Deficient’.

Several legally protected species listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention) (e.g., *Savalia savaglia*) and in the Annex III (e.g., *Corallium rubrum*, *Antipathes* spp.), and in Appendix II – strictly protected fauna species of the Bern Convention, can be found in the associated communities.

Suitability of the habitat for monitoring

Coralligenous assemblages are considered sensitive to anthropogenic pressures. Many studies have described some important modifications in the structure of coralligenous assemblages subject to several kinds of environmental alterations, suggesting that these communities may represent a suitable indicator of human-induced impacts. Coralligenous habitat has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention), where a standardized monitoring procedure (named 'STAR') is reported. The ecological quality of coralligenous shall also be assessed within the Marine Strategy Framework Directive.

Several methods and ecological indices have recently been proposed to detect the ecological quality of the coralligenous habitat and to be employed in monitoring programs and impact evaluation studies. The indices of ecological quality obtained through the application of these methods are based on both biocenotic and seascape approaches and on measures of structural and functional complexity. The habitat may be sampled with both remotely operated vehicles, mostly suitable for deeper (>40 m) and horizontal substrata, and SCUBA divers, mostly suitable for shallower (<40 m) and vertical substrata.

Labrus mixtus (left panel) and *Scorpaena scrofa* (right panel) (© A. Tommasi)

Algal-dominated coralligenous (left panel) and invertebrate-dominated coralligenous (right panel) (© A. Tommasi)

Coralligenous seascape (© A. Tommasi)

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Algal-dominated coralligenous

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.51a**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Hard (rock)
Depth range	25 m to 80 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
A. Tommasi

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.51 Coralligenous cliffs

MC1.51a Algal-dominated coralligenous

Description of the habitat

The algal-dominated coralligenous habitat is constituted by a hard substratum of biogenic origin mainly produced by the accumulation of calcareous encrusting algae growing in dim light conditions mostly colonized by macroalgae. The habitat is distributed at a depth corresponding to the shallowest part of coralligenous depth range, between 25-30 to 70-80 m depth, depending on the clarity of the water.

Geographic distribution

The algal-dominated coralligenous habitat is potentially distributed everywhere coralligenous is present.

Associated habitats

The algal-dominated coralligenous is included in ‘Coralligenous cliffs’ (MC1.51). The habitat may have possible contact with ‘Algal-dominated infralittoral rock’ (MB1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coastal detritic bottoms’ (MC3.51 and MC3.52), ‘Muddy detritic bottoms’ (MC4.51), and ‘Coastal terrigenous muds’(MC6.51). Other associated habitats can be ‘Association with encrusting Corallinales’ (MC1.511a), ‘Association with Fucales or Laminariales’ (MC1.512a), ‘Association with sciaphilic algae (except Fucales, Laminariales, encrusting Corallinales, and Caulerpales)’ (MC1.513a), ‘Association with non-indigenous Mediterranean *Caulerpa* spp.’ (MC1.514a).

Related reference habitats

‘Invertebrate-dominated coralligenous’ (MC1.51b), ‘Invertebrate-dominated coralligenous covered by sediment’ (MC1.51c), ‘Coralligenous outcrops’ (MC1.52a), ‘Coralligenous outcrops covered by sediment’ (MC1.52b), ‘Coralligenous platforms’ (MC2.51), and ‘Coralligenous (enclave of circalittoral)’ (MB1.55).

Possible confusion

The habitat could be confused with the coralligenous in enclave of infralittoral (MB1.55), ‘Coralligenous outcrops’ (MC1.52a, b), ‘Coralligenous platforms’ (MC2.51). The algal-dominated coralligenous may be distinguished by a greater abundance of macroalgae compared to invertebrates. The coralligenous in enclave of infralittoral may also have high macroalgal abundance, but it develops in shallower waters.

Typical species and associated communities

The assemblages developing on the coralline algae exhibit a stratifies structure, with a basal, an intermediate and an elevate layer. The basal layer consists of encrusting (macroalgae *Peyssonnelia* spp., *Palmophyllum crassum*, *Zanardinia typus*) and turf (*Botryocladia* spp., *Rodriguezella* spp., *Eupogodon planus*). The intermediate layer includes erect small macroalgae, such as the Chlorophyta *Halimeda tuna* and *Flabellia petiolata,* the Ochrophyta *Halopteris filicina* and the Rhodhophyta *Osmundea pelagosae, Meredithia microphylla, Fauchea spp., Sebdenia* spp., *Kallymenia* spp., *Halymenia* spp. The erect layer is characterized by Fucales (*Carpodesmia zosteroides, Treptacantha usneoides, Cystoseira montagnei* var. *compressa, C. dubi, Sargassum hornschuchii*), Tilopteridiales (*Phyllariopsis brevipes* and *P. purpurascens*) and Laminariales (*Laminaria rodriguezii* and *L. ochroleuca*). A depth gradient may be also observed. The shallower zone is mostly characterized by *Peyssonnelia* spp., *Flabellia petiolata, Halimeda tuna, Phyllophora crispa, Meredithia microphylla,* while the deepest zone by *Palmophyllum crassum*, *Rodriguezella* spp., *Eupogodon planus, Sebdenia* spp., *Kallymenia* spp. In particular hydrodynamic conditions, rheophile assemblages are characterized by the Ochrophyta *Sporochnus pedunculatus* and *Arthrocladia villosa*, the Chlorophyta *Umbraulva dangeardii* and the Rhodophyta *Osmundaria volubilis.*

Conservation interest and ecological role

The algal dominated coralligenous supports biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages. In particular, the habitat includes assemblages dominated by canopy-forming macroalgae, which increase the already high structural complexity of the coralligenous system, enhancing biodiversity and productivity.

Economic importance

The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. Moreover, canopy-forming algae may provide a nursery habitat for many species with an economic value. To date, the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. Moreover, the algal assemblages are particularly sensitive to the increase of sedimentation and water turbidity. The lower limits of vertical distribution of the habitat can regress to shallower depth under conditions of reduced water transparency. The structure of macroalgal coralligenous assemblages may shift as consequence of an increase of nutrients concentration. In eutrophic conditions, perennial low growth macroalgae may be substituted by ephemeral rapid growing taxa, leading to a biotic homogenization of the communities.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities (UNEP/MAP 2017). Fucales, Laminariales and several Rhodophyta (e.g., *Kallymenia spathulata, Ptilophora mediterranea, Sphaerococcus rhizophylloides)* are listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention), and in the Appendix I “Strictly protected flora species” of the Bern Convention.

Suitability of the habitat for monitoring

Coralligenous habitat has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention).

The ecological quality of coralligenous shall also be assessed within the Marine Strategy Framework Directive. Several methods and ecological indices have recently been proposed to detect the ecological quality of the coralligenous habitat and to be employed in monitoring programs and impact evaluation studies. Algal dominated coralligenous is particularly sensitive to impacts such as sedimentation, water turbidity and eutrophication. The main descriptors of stress or disturbance are the shift of the assemblage structure and in particular the disappearance of sensitive taxa, such as canopy forming algae, and the spread of tolerant and opportunistic species such as turf forming algae.

Lithophyllum stictiforme (© A. Tommasi)

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Association with Fucalel or Laminariales

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.512**
- **EUNIS 2019: MC1511, MC1512, MC1513, MC1514, MC1515, MC1518**
- **EUNIS 2007: A4.261, A4.262, A4.263, A4.264, A4.2615, A4.268**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Hard (rock)
Depth range	25 m to 60 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
G. Sartoni, L. Piazzi

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.51 Coralligenous cliffs

MC1.51a Algal-dominated coralligenous

MC1.512a Association with Fucales or Laminariales

Description of the habitat

The association is an algal-dominated coralligenous characterized by Fucales and Laminariales growing on calcareous coralline structures in deep water. Typical species are the Fucales *Ericaria zosteroides, Cystoseira dubia, Cystoseira montagnei* var. *compressa, Gongolaria usneoides* and *Sargassum hornschuchii* and the Tilopteridiales *Phyllariopsis brevipes* and *P. purpurascens*. The Laminariales *Laminaria rodriguezii* and *L. ochroleuca* may be rarely found. *Ericaria funkii* and *Sargassum acinarium* are also found in the association. These algal assemblages occur on hard substrata exposed to strong unidirectional currents and light levels ranging from 1% to 0.3% of surface irradiance. The association primarily develops between 25 and 60 m depth, but the range may be wider depending on environmental conditions, especially water clarity.

Geographic distribution

The association with Fucales and Laminariales is potentially distributed wherever coralligenous is present. Although these assemblages appear to be widespread throughout the Mediterranean, available quantitative data are extremely rare.

Associated habitats

The association with Fucales and Laminariales is included in the 'Algal-dominated coralligenous' (MC1.51a). The association may have possible contacts with 'Algal-dominated infralittoral rock' (MB1.51), '*Posidonia oceanica* meadows' (MB2.54), and 'Coastal detritic bottoms' (MC3.51). Other associated habitats can be 'Association with encrusting Corallinales' (MC1.511a), 'Association with sciaphilic algae (except Fucales, Laminariales, encrusting Corallinales, and Caulerpales)' (MC1.513a), 'Association with non-indigenous Mediterranean *Caulerpa* spp.' (MC1.514a).

Related reference habitats

Association with Fucales can also be found in the in the 'Well illuminated infralittoral rock exposed' (MB1.511a), in the 'Lower infralittoral rock moderately illuminated' (MB1.511e), in the habitats of transitional waters (MB1.542, MB5.542), in the 'Lower midlittoral rock' (MA1.54), and in the 'Coralligenous platforms' (MC2.512). The association may also develop on 'Coastal detritic bottoms with rhodoliths' (MC3.52), and 'Coralligenous (enclave of ciraclittoral)' (MB1.55) in the infralittoral zone.

Possible confusion

This association could be confused with the other aassociations with Fucales in the infralittoral rock (MB1.511a, MB1.511c, MB1.511e), with the 'Association with Laminariales in the 'Lower infralittoral rock moderately illuminated' (MB1.512e) and in the 'Coastal detritic bottoms' (MC3.511). The dominant and characteristic species are different among these habitats. Moreover, MB1.511a and MB1.511c develop in shallower waters.

Typical species and associated communities

Beyond Fucales, Tilopteridiales and Laminariales, the association can include other erect algae, such as *Arthrocladia villosa, Sporochnus pedunculatus, Dictyopteris membranacea, Umbraulva dangeardii, Phyllophora crispa, Osmundaria volubilis, Carpomitra costata*, and *Cryptonemia palmetta*. The basal layer may be composed by *Peyssonnelia* spp. Sponges (e.g., *Petrosia ficiformis, Axinella* spp., *Spongia coelosia,* and *Sarcotragus* spp.), bryozoans, and ascidians constitute the dominant associated sessile macrofauna.

Branches, axes and tophules of these canopy-forming taxa support a large amount of epibionts including algae (e.g., *Vertebrata subulifera, Halopteris filicina, Dictyota* spp., *Sphacelaria cirrosa*), bryozoans (e.g., *Amathia semiconvoluta, Beania hirtissima, Calpensia nobilis,* and *Savignyella lafontii*), small hydrozoans, and several Didemnidae ascidians.

Conservation interest and ecological role

Most of the typical species of the association are perennial organisms, endemic to the Mediterranean Sea. Canopy-forming macroalgae provide shelter, food and nursery areas for a multitude of marine organisms. Canopy-forming macroalgae constitute important secondary substrates that increase the structural complexity of hard bottoms, providing suitable habitat, shelter, food and nursery areas for a multitude of marine organisms, both epiphytic and mobile. Thus, canopy-forming algae enhance the biodiversity and productivity of benthic systems. Moreover, these assemblages play a key role in carbon dioxide sequestration and climate change mitigation.

Economic importance

Through their role in supporting biodiversity and food webs, these long-lived brown algae provide critical provisional (food through fisheries) and regulating (carbon sequestration, nutrient recycling) ecosystem services. To date the economic value of circalittoral beds of Fucale and Laminariales has not been assessed yet.

Vulnerability and potential threats

Deep-water Fucales assemblages are declining in several areas of the Mediterranean, although the ultimate causes of this decline are not fully understood. Changes in water turbidity and sedimentation, direct lifting of fishing nets, eutrophication and global change are to blame. Furthermore, invasion by alien species may also contribute to the observed decline in these assemblages, as the recruitment of canopy-forming algae may be inhibited by the overgrowth of alien algae, such as *Womersleyella setacea* and *Caulerpa cylindracea*. Recruitment of Fucales in deep water is low, enhancing their vulnerability as it can be very difficult for these forests to balance losses if mortality rates increase due to anthropogenic disturbances.

Protection and management

There is an increasing attention towards the conservation status of macroalgae forests as they are included in the "Rocky reefs" habitat (code 1170, Directive 92/43/EEC, Annex I). Fucales and Laminariales, *Laminaria rodriguezii,* are listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention) and in the Appendix I "Strictly protected flora species" of the Bern Convention.

Suitability of the habitat for monitoring

Fucales assemblages are considered biological indicators to assess the ecological status of the marine environment in the context of the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC), but so far only shallow assemblages are covered in monitoring programs. Deep water Fucales are sensitive to several human impacts and can be useful ecological indicators of the ecological status of coralligenous habitat. Although several studies have reported interesting observations on deep-sea canopy-forming algae, further surveys and monitoring programs are needed to learn more about their distribution, health and dynamics.

Ericaria zosteroides, Cystoseira montagnei var. *compressa, Phyllariopsis brevipes,* and *Sargassum hornschuchii* (from left to right) (© G. Sartoni)

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Facies with large and erect sponges

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.512b, MC1.512c**
- **EUNIS 2019: MC151G (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral, offshore circalittoral, occasionally infralittoral
Nature of the substratum	Hard (rock, biogenic)
Depth range	25 m to 200 m
Position	Coastal and open sea
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Not known

Authors:
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M. Montefalcone, T. Giaccone, M. Bertolino, M. Bo , M. Ponti, T. Dailianis

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.51 Coralligenous

MC1.51b Invertebrate-dominated coralligenous

MC1.51c Invertebrate-dominated coralligenous covered by sediment

MC1.512b, MC1.512c Facies with large and erect sponges

Description of the habitat

This facies is a component of the invertebrate-dominated coralligenous community, also covered by sediment, and is dominated by large, erect and long-lived sponges such as, for instance, the species *Geodia cydonium*, *Agelas oroides*, *Axinella cannabina*, *A. polypoides*, *Ircinia* spp., *Sarcotragus* spp., *Spongia* (*Spongia*) *lamella, S.* (*S.*) *officinalis*, *Cacospongia mollior*, and *Aplysina cavernicola*. This facies develops in the upper layer of the coralligenous seascape and has often been found in coralligenous reefs where gorgonians are absent or do not create their typical facies.

The habitat usually develops in the circalittoral zone under dim light conditions and at depths corresponding to those of the coralligenous community, between 25 m to about 130 m, or even deeper (down to 180-200 m) in the Eastern Mediterranean basin. In the circalittoral this facies can also be found on coralligenous platforms (MC2.515) and on detritic bottoms (without or with rhodoliths, MC3.512 and MC3.524, respectively). Facies with large and erect sponges can also be found at the borders of the circalittoral zone: at shallower depths, in the infralittoral zone, on rock affected by sediment (MB1.532), whilst at greatest depths, in the offshore circalittoral zone, on invertebrate-dominated rock, also covered by sediment (MD1.512 and MD1.522, respectively).

Geographic distribution

The facies with large and erect sponges can potentially be distributed wherever in the circalittoral zone. Knowledge of its distribution in the Mediterranean Sea, however, remains fragmentary but is likely that its abundance is higher than originally predicted. *Axinella cannabina* is a warm-water thermophilic species and is more abundant in the eastern and southern sectors of the Mediterranean Sea.

Associated habitats

Large and erect sponges can also be found in facies with smaller-sized sponges, associated to ‘Algal-dominated coralligenous’ (MC1.51a), especially with the brown alga *Ericaria zosteroides* and associated with most of the typical facies of the 'Invertebrate-dominated coralligenous' (MC1.51b) (e.g., gorgonians, bryozoans). They can also be found on biodetritic bottoms with sparse rocks (MC3.51), often associated with the white gorgonian *Eunicella verrucosa*, associated with rhodolith beds (MC3.52), on soft circalittoral substrates, and sometimes in caves and overhangs (MC1.53).

Related reference habitats

'Coralligenous platforms' (MC2.515), 'Coastal detritic bottoms' (MC3.512), 'Coastal detritic bottoms with rhodoliths' (MC3.524), 'Offshore circalittoral rock invertebrate-dominated' (MD1.512), also covered by sediment (MD1.522), 'Infralittoral rock affected by sediment' (MB1.532).

Possible confusion

Large and erect sponges cannot be confused with other benthic organisms.

Typical species and associated communities

Typical erect sponges are *Axinella cannabina* and *A. polypoides.* They can be visually recognized based on their erect shape. *A. polypoides* has a stalk and dichotomous and occasionally coalescent branches circular or oval in cross-section, yellow colour shifting to orange, smooth surface and stellate oscules. Especially at the shallowest depths, *A. polypoides* exhibits two different morphologies: a 'bush-like' growth form and a 'cane-like' growth form, such as that of *A. cannabina*. *A. cannabina* has a very particular erect shape, often with one or, at most, two main stalks and few branches. In general, both along the main axis and along the branches, there are numerous small lateral segments with an oscule that gives to this sponge a wrinkled appearance. Large sponges are typically *Ircinia oros*, *Sarcotragus foetidus*, *S. spinosulus, Spongia* (*Spongia*) *lamella*, *S.* (*S.*) *officinalis*, and *Cacospongia mollior*. This group of sponges can be identified for their massive shape, conulose surface and usually dark and grey colours, although distinguishing each species underwater is rather difficult. Only *S.* (*S.*) *lamella* is recognized by its typical vase- or fan-shape. *Geodia cydonium* presents a more or less globose shape and lobate surface, while *Aplysina cavernicola* is characterized by digitate body with each process bearing one oscule, and both display a typical yellow colour. The massive orange sponge *Agelas oroides* can be very abundant in the Aegean and Levantine Seas.

The nudibranch *Phyllidia flava* and the epibiotic zoantharian *Parazoanthus axinellae* are often associated with *Axinella* spp. Many other invertebrates and vertebrates (e.g., fish) can find refuge and a suitable habitat on branched sponges. Epibionts (e.g., algae) often cover the wide surface of massive sponges. The gastropod *Tylodina perversa* is often found feeding on the sponge *Aplysina cavernicola*. *Geodia cydonium* usually hosts several species of epi- and endo-biotic polychaetes. Demosponges, in general, host a rich symbiotic community of eubacteria and sometimes of Archea.

Conservation interest and ecological role

Axinella cannabina is endemic to the Mediterranean. Large and erect sponges act as marine ecosystem engineers and habitat formers, as they play a significant role in benthic-pelagic coupling and provide suitable habitat for a variety of other marine species owing to their erect and bushy, three-dimensional structure or to their massive morphology. Little is known about the conservation status of most of the species of large and erect sponges.

Economic importance

Through their role in supporting high biodiversity, these long-lived large and erect sponges provide provisioning services, such as materials and genetic resources availability, habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms, and information services, in terms of scientific research and monitoring. Recently the suitability of large sponges to provide spongin-like collagen for biomedical applications has been investigated. To date the economic value of large and erect sponges has not yet been assessed.

Vulnerability and potential threats

Their massive and erect growth form makes these species susceptible to mechanical damage caused by human activities such as anchoring, fishing and derelict fishing gears, collection by divers as a curio, and entanglement by mucilage filaments. Since these assemblages develop in productivity-rich locations, which are particularly sought after by artisanal fisheries, sponges are often found smothered by abandoned fishing gears. No quantitative data are available about the degree and intensity of damage. Quantitative data indicate that, in localities deprived of any form of protection, population size of erect and massive sponges decreased. Mortality events of sponges have been recorded in coincidence with recent summer heat waves and the ongoing seawater warming trend.

Protection and management

Geodia cydonium, *Axinella cannabina*, *A. polypoides*, *Sarcotragus foetidus*, and *Aplysina cavernicola* are listed in the Annex II “Endangered or threatened species”, whilst *Spongia* (*Spongia*) *officinalis* and *S.* (*S.*) *lamella* in the Annex III “Species whose exploitation is regulated” of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention). *Axinella polypoides* and *Aplysina cavernicola* are also listed in the Annex II “Strictly protected fauna species” of the Bern Convention, *Spongia* (*Spongia*) *officinalis* and *S.* (*S.*) *lamella* in the Annex III “Protected fauna species” of the same convention. All these species are defined as ‘Endangered’ in many regional IUCN Red lists (e.g., Italy, France, Montenegro). However, further information is needed to improve knowledge about the conservation status of these sponges in the Mediterranean Sea.

Suitability of the habitat for monitoring

Large and erect sponges are not included in monitoring programs because the suitability of this habitat as biological indicator to assess the ecological status of the marine environment has not been evaluated yet.

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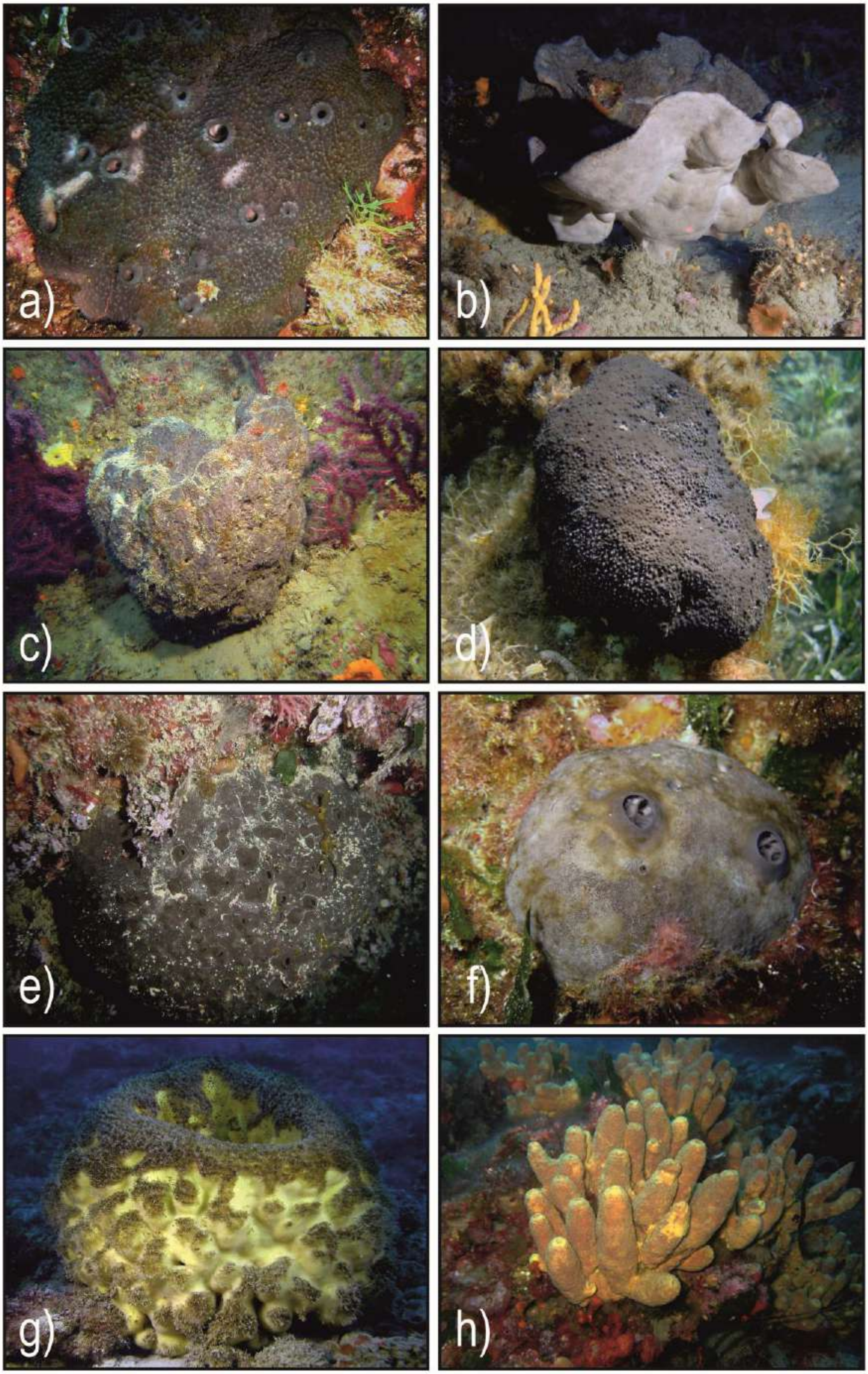
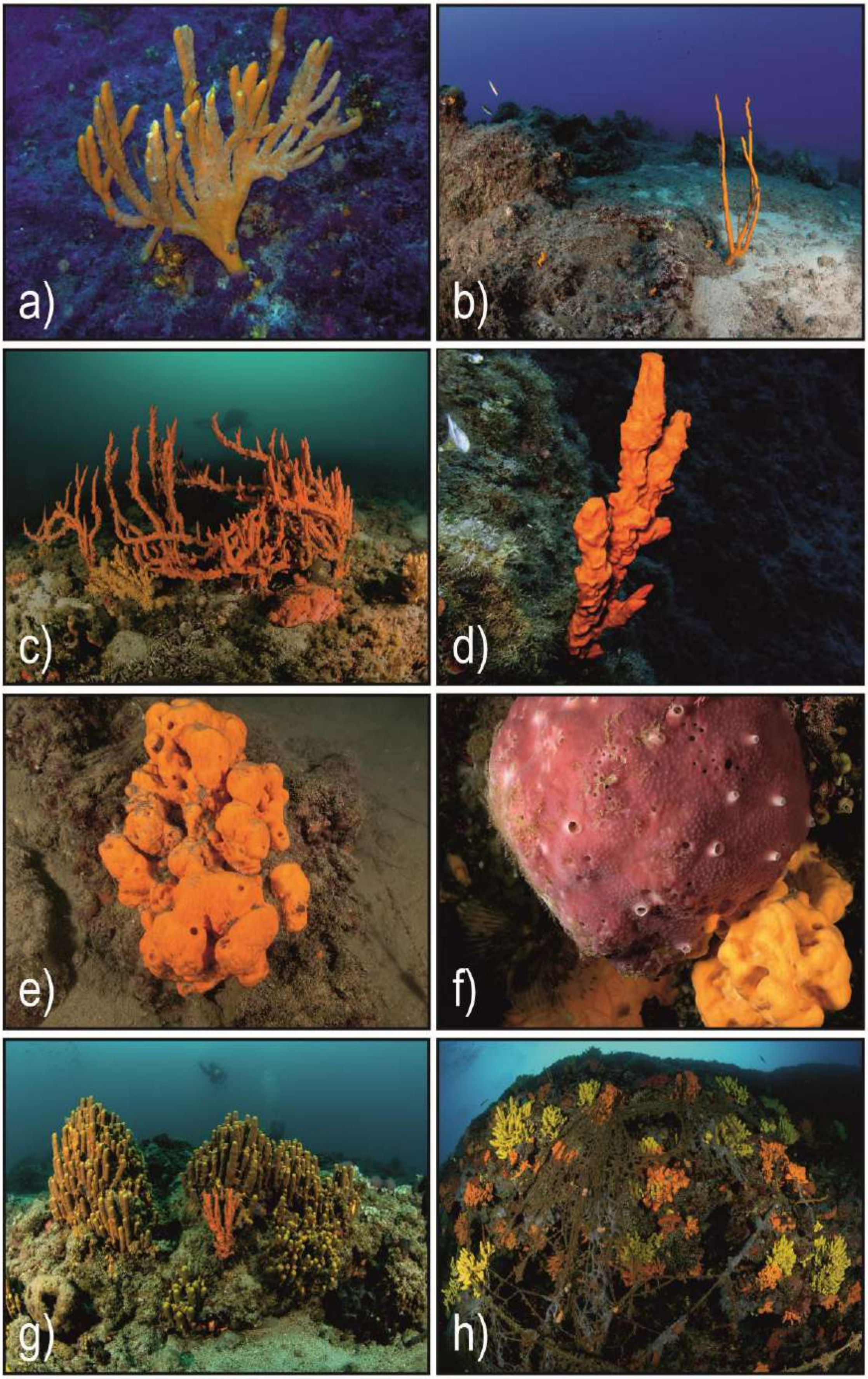


The large sponges *Spongia* (*Spongia*) *officinalis* (a); *Spongia* (*Spongia*) *lamella* (b); *Sarcotragus foetidus* (c); *Sarcotragus spinosulus* (d); *Cacospongia mollior* (e); *Ircinia oros* (f); *Geodia cydonium* (g); *Aplysina cavernicola* (h) (a, d, e, f , h © M. Bertolino; b © M. Bo; c © M. Montefalcone; g © M. Ponti)



The erect sponges *Axinella polypoides* (a, b) and *Axinella cannabina* (c, d); *Agelas oroides* (e); *Ircinia variabilis* (f); *Aplysina aerophoba* and *Axinella cannabina* (g); assemblage of erect and massive sponges covered by abandoned fishing gear (h) (a © M. Bertolino; b, c, e, f, g, h © T. Dailianis; d © T. Giaccone)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Facies with Alcyonacea

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.514b, MC1.514c**
- **EUNIS 2019: MC1519, MC151A, MC151B, MC151E**
- **EUNIS 2007: A4.269, A4.26A, A4.26B, A4.322**

LOCATION OF THE HABITAT

Zone	Circalittoral, infralittoral
Nature of the substratum	Hard (rock, biogenic)
Depth range	25 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

Photo credits:
E. Trainito, M. Montefalcone, S. Musumeci, C.N. Bianchi

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.51 Coralligenous

MC1.51b Invertebrate-dominated coralligenous

MC1.51c Invertebrate-dominated coralligenous covered by sediment

MC1.514b, MC1.514c Facies with Alcyonacea

Description of the habitat

This is the most typical facies of the upper layer of the coralligenous seascape. This facies is a component of the invertebrate-dominated coralligenous community, also covered by sediment, and is dominated by arborescent and long-lived alcyonacean species, such as the gorgonians *Eunicella cavolini, E. singularis, E. verrucosa*, *Leptogorgia* spp*.*, *Paramuricea clavata*, and *P. macrospina*, the red coral *Corallium rubrum* and the alcyonids *Alcyonium acaule* and *Paralcyonium spinulosum. C. rubrum* is in enclave in the coralligenous assemblages being a typical facies of the semi-dark caves and overhangs (MC1.533a, MC1.533b). This facies creates the habitat usually known as 'animal forests'. The habitat mainly develops in the circalittoral zone with dim light conditions and at depths corresponding to those of the coralligenous, between 25 m to about 130 m. Alcyonaceans usually grow on vertical slopes or on overhanging faces, but they can also develop on sub-vertical slopes or horizontal substrates being able to withstand a slight sedimentary deposit. In the circalittoral this facies can also be found on coralligenous outcrops, also covered by sediment (MC1.523a, MC1.523b, respectively) and on coralligenous platforms (MC2.517). Facies with Alcyonacea can also be found at shallower depths in the infralittoral zone, on moderately illuminated algal-dominated infralittoral rock exposed and shelterd (MB1.51b, MB1.51d, respectively), on lower infralittoral rock moderately illuminated (MB1.515e), on moderately illuminated invertebrate-dominated infralittoral rock sheltered (MB1.525a), and on infralittoral rock affected by sediment (MB1.534).

Geographic distribution

The facies with Alcyonacea can potentially be distributed wherever in the circalittoral zone where coralligenous reefs, rocky and coastal detritic bottoms are present.

Associated habitats

Facies with Alcyonacea can be associated with facies and associations of the 'Coralligenous cliffs' habitat (MC1.51), especially with those of the 'Invertebrate-dominated coralligenous' (MC1.51b, MC1.51c), with

'Coralligenous outcrops' (MC1.52a, MC1.52b) and 'Coralligenous platforms' (MC2.51), with 'Deep banks' (MC1.52c), with 'Semi-dark caves and overhangs' (MC1.53), with the facies and associations of 'Coastal detritic bottoms' (MC3.51) and 'Coastal detritic bottoms with rhodoliths' (MC3.52), and sometimes with those of 'Muddy detritic bottoms' (MC4.51) and 'Coastal terrigenous mud' (MC6.51). This habitat may have possible contact with 'Algal-dominated infralittoral rock' (MB1.51), 'Invertebrate-dominated infralittoral rock (MB1.52), and with '*Posidonia oceanica* meadows' (MB2.54).

Related reference habitats

Facies with Alcyonacea can be found in moderately illuminated algal-dominated infralittoral rock (MB1.514b, MB1.514d), in lower infralittoral rock moderately illuminated (MB1.515e), in moderately illuminated invertebrate-dominated infralittoral rock sheltered (MB1.525a), and in infralittoral rock affected by sediment (MB1.534). This facies is also often found in the infralittoral coralligenous (MB1.55) and in semi-dark caves and overhangs (MB1.56) when they are in enclave in the infralittoral zone. The habitat is also found in coralligenous outcrops (MC1.523a, MC1.523b), in deep banks (MC1.522c), in semi-dark caves and overhangs (MC1.533a, MC1.533b), in coralligenous platforms (MC2.517), in coastal detritic bottoms (MC3.514) in coastal detritic bottoms with rhodoliths (MC3.526), in muddy detritic bottoms (MC4.512), in coastal terrigenous mud (MC6.511), in offshore circalittoral rock invertebrate-dominated (MD1.513), also covered by sediment (MD1.523, and in deep offshore circalittoral banks (MD1.532).

Possible confusion

Facies with Alcyonacea cannot be confused with any other habitat.

Typical species and associated communities

Gorgonians and alcyonids are the typical species of this habitat. The different species of gorgonians can be distinguished on the base of the shape and colour of the colony. The yellow gorgonian *Eunicella cavolini* (rarely light pink) has colonies up to 40-50 cm high with a fan-shaped cylindrical branches largely growing in a single plane and smooth and short branches. The white gorgonian *Eunicella singularis* has a branching structure with a small number of nearly-vertical branches and a few side branches, all smooth. Occurrence of symbiotic zooxanthellae in this sea fan causes the greenish coloration of its polyps. *E. cavolini* and *E. singularis* may also develop in the moderately illuminated infralittoral rock. *E. singularis* might be confused with the other white sea fan *E. verrusosa,* but the latter can be distinguished because it usually grows in a single plane with rougher and denser branches. *E. verrucosa* tolerates a certain degree of turbidity and can be also distributed on detritic substrates. Among *Leptogorgia* species, *L. sarmentosa* is the most widely distributed in the circalittoral. It has a bushy habitus and can vary its colour from pale yellow to brick-red and has straighter, more slender branches with smaller polyps with respect to other sea fans, and it is usually found in turbid waters (in this situation also at shallower depths) and on detritic substrates. *Paramuricea clavata* is among the biggest sea fans (up to 1 m high), with a typical purple-red colour and a single plane colony. Under certain conditions, i.e. in deep or turbid waters, some colonies may be yellow coloured. *P. macrospina* can live in sympatry with *P. clavata* and shows a morphological plasticity that may lead, sometimes, to an erroneous classification as *P. clavata*. The most reliable character to discriminate between *P. macrospina* and *P. clavata* is the number of rows of spindles in the collaret of the polyps. The alcyonid *Alcyonium acaule* and *Paralcyonium spinulosum* are colonial soft-corals. *A. acaule* forms clumps of pink, brown-red to brown-orange fleshy masses of finger-like lobes, and its colony can reach up to 20 cm of height. The colony surface is entirely covered by white, yellow or red polyps, from the base to the top of the lobes. Colonies of *P. spinulosum* vary between 2 and 10 cm, and its size increases with depth. The trunk is retractable and its colour is whitish or translucent pinkish with conspicuous white sclerites; polyps are white and distributed over the entire length of the trunk. Also the red coral *Corallium rubrum* can be found in this habitat under specific environmental conditions, i.e. limpid and cold waters and on overhangs. The dark red colour of C*. rubrum c*olonies and their white polyps make this species unmistakable.

Sponges (e.g., *Agelas oroides, Ircinia* spp., *Sarcotragus* spp.*)*, serpulids (e.g., *Salmacina dysteri)*, other cnidarians (e.g., *Caryophyllia smithii, Leptopsammia pruvoti)*, bryozoans (e.g., *Schizomavella* spp., *Smittina cervicornis, Myriapora truncata)*, tunicates (e.g., *Halocynthia papillosa, Microcosmus sabatieri)*, and encrusting coralline algae are all typical species associated with this facies. The nudibranchs *Marionia blainvillea* and *Duvaucelia odhneri* feed on sea fans. The gastropod *Simnia spelta* mimics *E. singularis* and feeds and lays its eggs on its branches. Epibionts are very abundant on sea fan's branches, such as algae, serpulids (e.g., *Salmacina dysteri*, *Filograna implexa*), bryozoans (e.g., *Adeonella calveti*, *Turbicellepora avicularis*, *Reteporella* spp., *Pentapora fascialis*), colonial tunicates, and the molluscs *Pteria hirundo* and *Anomia ephippium.*

The incrustant alcyonid *Alcyonium coralloides* often overgrown on *E. singularis*, *E. cavolini* and *Paramuricea clavata* killing the sea fan's soft tissues spreading along the branches of its slow-growing host. Facies with the zoantharians *Parazoanthus axinellae* and *Savalia savaglia* (MC1.516b, MC2.518, MD1.517) are often associated with this habitat. *Savalia savaglia*, in particular, overgrows on *Paramuricea clavata* in its early phase of development. Many other vagile invertebrates can find in branched alcyonaceans a refuge and a suitable habitat.

Conservation interest and ecological role

Animal forests promote morphological complexity and functioning of marine habitats. Long-lived erect Alcyonacea act as marine ecosystem engineers and habitat formers, as they plays a significant role in benthic-pelagic coupling and generate three-dimensional space and habitat for many mobile invertebrates, thus enhancing biodiversity, the beauty of the seascape and the interest of divers. *Eunicella singularis*, *Eunicella cavolini*, *Paramuricea clavata* and *Paramuricea macrospina* are endemic to the Mediteraranean.

Economic importance

Through its role in supporting high biodiversity, the facies with Alcyonacea offers provisioning services to humans, such as materials and genetic resources availability, habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms, and information services, in terms of scientific research and monitoring. Erect Alcyonacea also add services of recreation having a great aesthetic value for underwater tourism and being mostly appreciated by divers and photographers. Compounds have been separated from sea fans to make antibiotic. *Corallium rubrum* is an important Mediterranean economic resource, and its populations have long been commercially exploited for jewellery since the ancient times (see also the sheet MC1.533a). To date, the economic value of Alcyonacea has not yet been assessed.

Vulnerability and potential threats

Erect Alcyonacea are long-lived, slow growing and slow recruiting species and display a low resilience to human pressures. Assemblages are particularly damaged by fishing gears, bottom trawling, anchoring, and by diving activities. Alcyonacea are sensitive to entanglement by mucilage filaments and suffer for thermal anomalies. Severe diseases are triggered by a complex combination of pathogenic microbial and abnormally high seawater temperatures, and several mass mortality events have been recorded in the Mediterranean in coincidence with summer heat waves and the ongoing seawater warming trend. Gorgonians are often popularly collected for use in aquarium and as souvenirs. *Corallium rubrum* is a precious and target species that may be harvested illegally. Filter feeders also suffer for the increase in the concentration of fine sediment and organic matter.

Protection and management

Among Alcyonacea only the red coral *Corallium rubrum* is included in the Annex II "Endangered or threatened species" of the Bern Convention, in the Annex III "Species whose exploitation is regulated" of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention), and in the Annex V (species which are of interest to the European Union, of which the taking or exploitation of wild may be subject to management decisions) of the Council Directive 92/43/EEC (Habitats Directive). *Corallium rubrum* is also listed as "Endangered" in the IUCN Red List of threatened species and is included in the list of the Convention on International Trade in Endangered Species of wild flora and fauna (CITES). Nevertheless the growing awareness of the threats due to global warming and direct mechanical damages, no specific protection measures have been yet implemented for all the other Alcyonacea species. In order to preserve areas where animal forests are well developed and are still relatively well structured, the European Union has been committed in the establishment of special areas of conservation (SAC) for the Natura 2000 network.

Suitability of the habitat for monitoring

Facies with Alcyonacea are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The long-term persistence and easy recognition of this habitat make it particularly suitable for monitoring, and all methods proposed for monitoring coralligenous (see sheet MC1.51) can be effectively used also on this typical facies. The habitat may be particularly suitable for assessing specific pressures, such as mechanical damage, mucilage blooms, and climate change. For instance, the rate of necrosis of erect Alcyonacea is considered a useful indicator of climate-related stress. The monitoring of this habitat is performed by scuba diving at shallower depths and through remote operated vehicles in the deepest part of the circalittoral zone.

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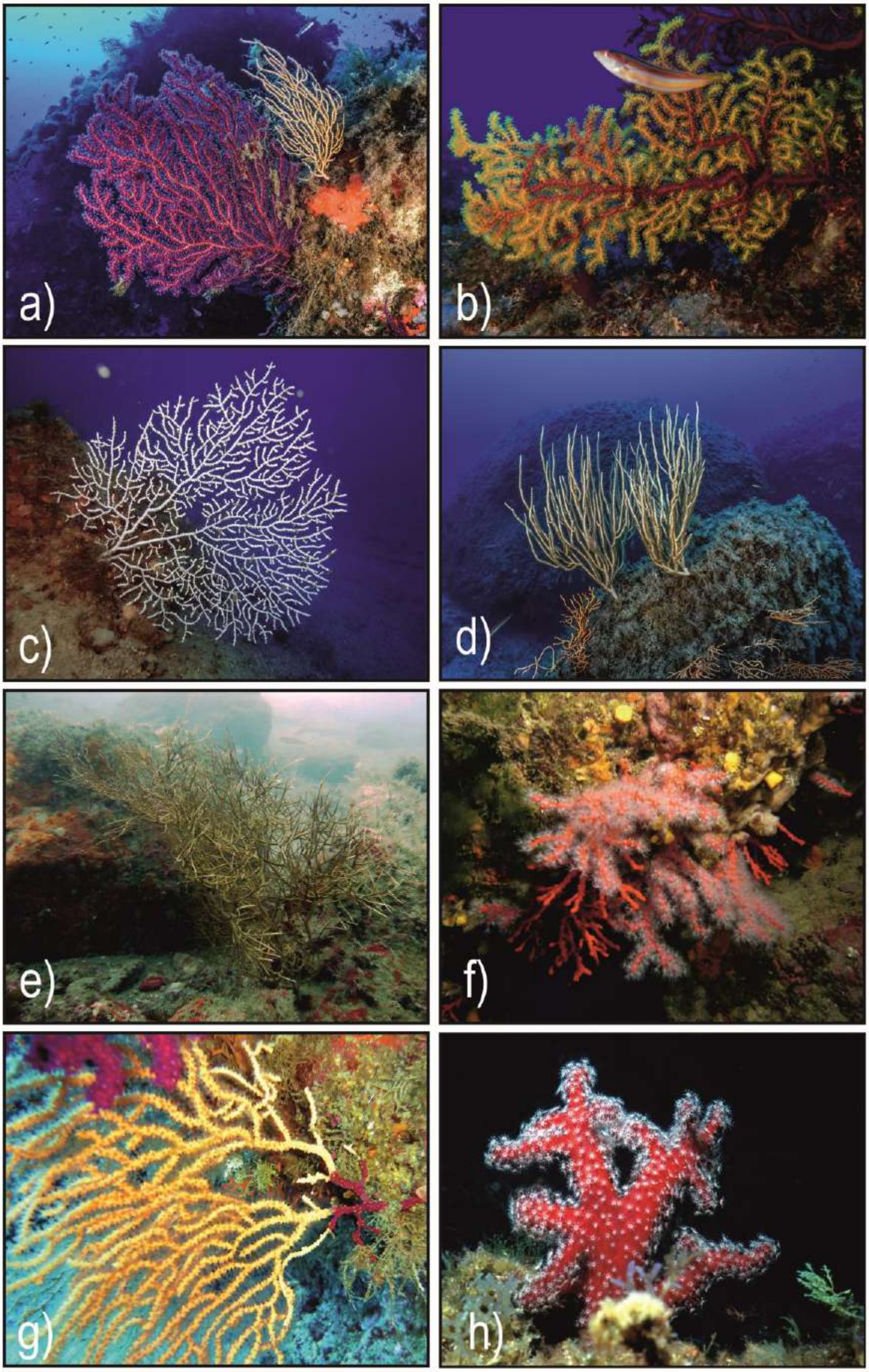

The gorgonians *Paramuricea clavata* and *Eunicella cavolini* (a); *P. clavata* displaying its double colouring purple and yellow (b); *Eunicella verrucosa* (c); *E. singularis* (d); *Leptogorgia sarmentosa* (e); the red coral *Corallium rubrum* (f); *Alcyonium coralloides* overgrowing on the base of *E. cavolini* colony (g); *Alcyonium acaule* (h) (a, d © E. Trainito, Capo Carbonara MPA; b © S. Musumeci; c, e, f, g © M. Montefalcone; h © C.N. Bianchi)


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Facies with the Zoantharia *Savalia savaglia*

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.516b, MC1.516c**

LOCATION OF THE HABITAT

Zone	Circalittoral, offshore circalittoral
Nature of the substratum	Hard (rock, biogenic)
Depth range	25 m to 150 m
Position	Coastal and open sea
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Not known

Author:
M. Montefalcone

Photo credits:
E. Trainito, M. Montefalcone

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.51 Coralligenous

MC1.51b Invertebrate-dominated coralligenous

MC1.51c Invertebrate-dominated coralligenous covered by sediment

MC1.516b, MC1.516c Facies with the Zoantharia *Savalia savaglia*

Description of the habitat

This facies is a component of the invertebrate-dominated coralligenous community, also covered by sediment, and is made by the arborescent and long-lived zaontharian *Savalia savaglia*. The facies usually develops in the circalittoral zone with dim light conditions and at depths between 25 m to about 150 m, on a rough seafloor with steeply sloping rocks within the coralligenous habitat. In the circalittoral this facies can also be found on coralligenous platforms (MC2.518). *Savalia savaglia* can thrive at greater depths, being found in the offshore circalittoral rock invertebrate-dominated, also covered by sand (MD1.517 and MD1.527, respectively).

Savalia savaglia is a parasitic zoantharian that colonizes the organic axis of its hosts for mechanical support, benefiting the zoantharian by raising well above the substrate, while avoiding the investment of energy to build its own skeleton. The parasitic behaviour of *S. savaglia* toward its hosts (i.e., *Paramuricea clavata*, *Eunicella* spp., *Anthipathes* spp.) represents an extreme case of parasitism, because when the host is completely engulfed by *S. Savaglia*, it becomes able to produce a hard layered proteinaceous black skeleton (from which derives its common name ‘false black coral’) deposited on the host skeleton (it is the unique zoantharian able to produce a rigid and thick skeleton), which can reach large sizes (up to 2 m high, with a main axis diameter up to 14 cm) and attain 2,700 years of age.

Geographic distribution

The facies with *Savalia savaglia* is a rare component of the mesophotic zone of the Mediterranean Sea, even if it could be potentially distributed wherever arborescent gorgonians occur, with a thermophilous chorology.

Associated habitats

Facies with the Zoantharia *Savalia savaglia* can be associated with facies and associations of the coralligenous habitats (MC1.51, MC2.51), especially with those of the 'Invertebrate-dominated coralligenous' (MC1.51b, MC1.51c), and with the facies of the offshore circalittoral rock invertebrate-dominated (MD1.517, MD1.527). This habitat is always in association with the 'Facies with Alcyonacea' (MC1.514b, MC1.514c, MC2.517, MD1.513, MD1.523).

Related reference habitats

This habitat can be also found on coralligenous platforms (MC2.518) and in the offshore circalittoral rock invertebrate-dominated (MD1.517), also covered by sediment (MD1.527).

Possible confusion

Savalia savaglia cannot be confused with any other species for its large, tree-like yellow colony and the yellow colour of its polyps (it is also frequently called 'gold coral').

Typical species and associated communities

The white gorgonian *Eunicella singularis*, *Paramuricea clavate*, and *Anthipates* spp. are the typical hosts of this species. Sponges, other cnidarians, bryozoans, molluscs, tunicates, and encrusting coralline algae are all typical sessile species associated with this facies. Many other vagile invertebrates can find in this branched zoantharian a refuge and a suitable habitat.

Conservation interest and ecological role

Savalia savaglia is endemic of the Mediterranean. Being a component of the animal forests, *S. savaglia* promotes morphological complexity and functioning of marine habitats. Because of its longevity and its large, rigid three-dimensional skeleton, it is considered a marine ecosystem engineer and a habitat former, providing structural habitat for a large number of associated faunal species, thus enhancing biodiversity and playing a significant role in benthic-pelagic coupling. It is also a target species for divers and photographers.

Economic importance

Through its role in supporting high biodiversity, the facies with *Savalia savaglia* offers provisioning services to humans, such as materials and genetic resources availability, habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms, and information services, in terms of scientific research and monitoring. *S. savaglia* also adds services of recreation being mostly appreciated by divers and photographers. To date, the economic value of *Savalia savaglia* has not yet been assessed.

Vulnerability and potential threats

Savalia savaglia is a long-lived, slow growing and slow recruiting species and displays a low resilience to human pressures. It is particularly damaged by fishing gears (entangled ghost nets) or by trawling. It is also commercially exploited as gold coral for souvenirs.

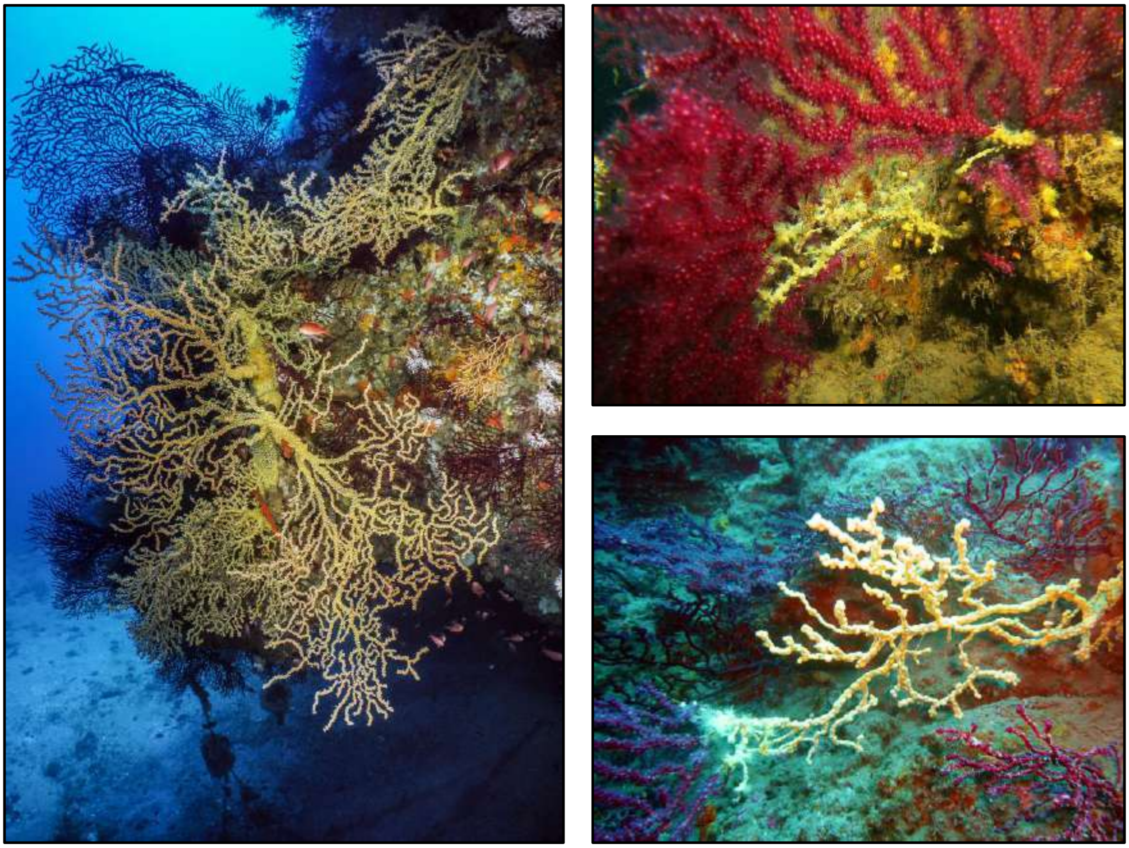
Protection and management

Owing to its rarity, *Savalia savaglia* is included in the Annex II "Endangered or threatened species" of the Bern Convention and of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention).

Suitability of the habitat for monitoring

Savalia savaglia is not included in monitoring programs as biological indicator to assess the ecological status of the marine environment. However, *S. savaglia* is among the animals with the longest life span on Earth, which makes it an important paleo-indicator. In addition, its protected status gives the environment a high natural value.

MC1.516b, MC1.516c Facies with the Zoantharia *Savalia savaglia*



Savalia savaglia colonies on *Paramuricea clavata*
(on the left © E. Trainito, Capo Carbonara MPA; on the right © M. Montefalcone)

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Continental shelf rock

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.52**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Hard (rock)
Depth range	40 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 15°C
Suitability for monitoring	Yes

Author:
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Photo credits:
M. Di Fiore

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.52 Continental shelf rock

Description of the habitat

Continental shelf rock are rocky bottoms that emerge from the soft bottoms of the continental shelf at depths typically ranging from 40 to 150 m. Deep banks may have variable bioconstruction by coralline algae. The habitat can be highly variable depending on depth, bottom morphology, surrounding seafloor, and the presence of bioconstruction. Thus, different assemblages can be found.

Geographic distribution

Continental shelf rocks are described around most of the Mediterranean coasts.

Associated habitats

Continental shelf rocks are included in the ‘Circalittoral rock’ (MC1.5). They may have contact with ‘Coastal detritic bottoms’ (MC3.51 and MC3.52), ‘Muddy detritic bottoms’ (MC4.51), and ‘Coastal terrigenous mud’ (MC6.51). Associated habitats are ‘Facies with small sponges’ (MC1.521a, b), ‘Facies with Hydrozoa’ (MC1.522a, b), ‘Facies with Alcyonacea’ (MC1.523a, b, MC1.522c), ‘Facies with Antipatharia’ (MC1.524a, b, MC1.521c), ‘Facies with Scleractinia’ (MC1.525a, b, MC1.523c), ‘Facies with Bryozoa‘ (MC1.526a, b), ‘Facies with Polychaeta’ (MC1.527a, b), ‘Facies with Bivalvia’ (MC1.528a, b), and ‘Facies with Brachiopoda’ (MC1.529a, b).

Related reference habitats

‘Deep banks’ (MC1.52c), ‘Coralligenous outcrops’ (MC1.52a, MC1.52b), ‘Coralligenous cliffs’ (MC1.51), ‘Coralligenous platforms’ (MC2.51).

Possible confusion

The habitat may host assemblages similar to those occurring in the ‘Coralligenous cliffs’ (MC1.51) and ‘Coralligenous platforms’ (MC2.51). Continental shelf rock may be distinguished because it is localised far from the coasts and at depths greater than 40 m.

Typical species and associated communities

Different assemblages may be found depending on depth, morphology of bottom, surrounding seafloor and presence of biocostruction.

The main facies include sponges (*Axinella cannabina, A. polypoides, Aplysina aerophoba, Haliclona mediterranea*), alcyonaceans (*Eunicella cavolini, Paramuricea clavata, Corallium rubrum, Alcyonum acaule, Nidalia studeri*), antipatharians (*Antipathella subpinnata*), scleractinians (*Dendrophyllia* spp*., Madracis pharensis*) and bryozoans (*Pentapora fascialis*).

Conservation interest and ecological role

The continental shelf rocks, especially those characterised by biogenic structures, support biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages.

Economic importance

The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. To date, the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. In particular, the habitat is threatened by fishing activities and sedimentation.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities (UNEP/MAP 2017).

Continental shelf rock with *Corallium rubrum* (left panel) and *Astrospartus mediterraneus* on *Axinella* spp. (right panel) (© M. Di Fiore)

Suitability of the habitat for monitoring

The continental shelf rocks, especially those characterised by biogenic structures, have been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). The ecological quality of the habitat shall also be assessed within the Marine Strategy Framework Directive. Several methods and ecological indices have recently been proposed to detect the ecological quality of the habitat and to be employed in monitoring programs and impact evaluation studies. Monitoring is preferably conducted through remotely operated vehicles.

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Coralligenous outcrops; Coralligenous outcrops covered by sediments

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.52a, MC1.52b**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Hard (rock)
Depth range	40 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 15°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
IAS-CNR, IMC, ISPRA

CIRCALITTORAL
MC1.5 Circalittoral rock
MC1.52 Continental shelf rock
MC1.52a Coralligenous outcrops
MC1.52b Coralligenous outcrops covered by sediment

Description of the habitat

Coralligenous outcrops are calcareous structures of biogenic origin produced primarily by encrusting algae. They can develop on rocky outcrops or have a completely biogenic origin. They consist of individual metric structures, with an area of about 1-10 m^2 and an elevation up to 2 m. These structures are recognizable individually, although they may appear clustered in tens or hundreds. The depth distribution of the habitat ranges from about 40 to 150 m on the continental shelf.

Geographic distribution

Coralligenous outcrops are distributed around all the Mediterranean continental shelf.

Associated habitats

Coralligenous outcrops are included in ‘Continental shelf rock’ (MC1.52). They may have contact with ‘Coastal detritic bottoms’ (MC3.51 and MC3.52), ‘Muddy detritic bottoms’ (MC4.51), and ‘Coastal terrigenous muds’ (MC6.51). Associated habitats are ‘Facies with small sponges’ (MC1.521a, b), ‘Facies with Hydrozoa’ (MC1.522a, b), ‘Facies with Alcyonacea’ (MC1.523a, b, MC1.522c), ‘Facies with Antipatharia’ (MC1.524a, b, MC1.521c), ‘Facies with Scleractinia’ (MC1.525a, b, MC1.523c), ‘Facies with Bryozoa‘ (MC1.526a, b), ‘Facies with Polychaeta’ (MC1.527a, b), ‘Facies with Bivalvia’ (MC1.528a, b), and ‘Facies with Brachiopoda’ (MC1.529a, b).

Related reference habitats

‘Deep banks’ (MC1.52c), ‘Coralligenous cliffs’ (MC1.51), ‘Coralligenous platforms’ (MC2.51).

Possible confusion

The habitat may be confused with ‘Coralligenous platforms’ (MC2.51). The structure of assemblages may be similar among these habitats, but coralligenous outcrops are individual structures surrounded by mobile substrates on the continental shelf.

Typical species and associated communities

The assemblages that develop on coralline algae exhibit a stratifies structure, similar to that of ‘Coralligenous platforms’ (MC2.51). The basal layer can include encrusting algae, sponges, bryozoans, scleractinians, and ascidians. The intermediate layer is characterized by small erect macroalgae and invertebrates. The erect layer consists mostly of large and erect sponges and Alcyonacea.

Conservation interest and ecological role

The coralligenous outcrops support biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages.

Economic importance

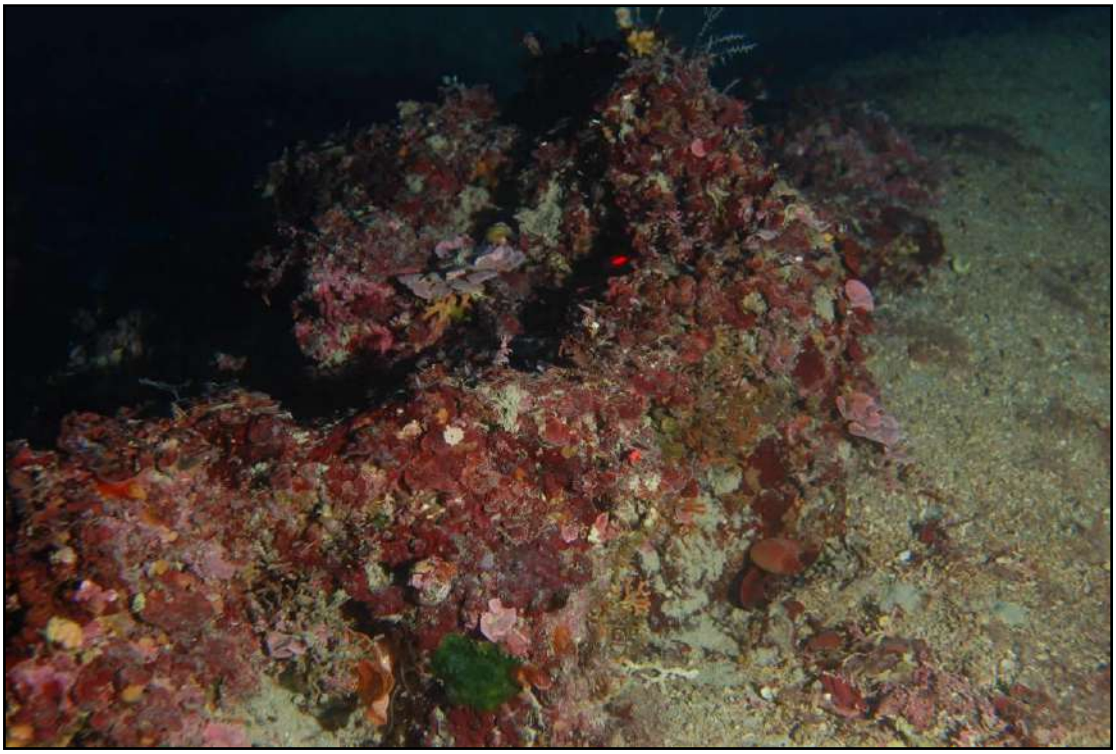
The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. To date, the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. In particular, the habitat is threatened by fishing activities and sedimentation.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities (UNEP/MAP 2017).



Coralligenous outcrops (© ISPRA)

Suitability of the habitat for monitoring

Coralligenous habitat has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). The ecological quality of coralligenous shall also be assessed within the Marine Strategy Framework Directive. Several methods and ecological indices have recently been proposed to detect the ecological quality of the coralligenous habitat and to be employed in monitoring programs and impact evaluation studies. Monitoring is preferably conducted through remotely operated vehicles.

Coralligenous outcrops (© IAS-CNR, IMC)

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Deep banks

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.52c**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Hard (rock)
Depth range	40 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 15°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
M. Di Fiore

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.52 Continental shelf rock

MC1.52c Deep banks

Description of the habitat

Deep banks are rocky bottoms (shoals, ridges, etc.) that emerge from the soft bottoms of the continental shelf at depths typically ranging from 40 to 150 m. Deep banks may have variable bioconstruction by coralline algae. Habitat can be highly variable depending on depth, bank morphology, surrounding seafloor, and the presence of bioconstruction. Thus, different assemblages can be found.

Geographic distribution

Deep banks are described around most of the Mediterranean coasts.

Associated habitats

Deep banks are included in ‘Continental shelf rock’ (MC1.52). They may have contact with ‘Coastal detritic bottoms’ (MC3.51 and MC3.52), ‘Muddy detritic bottoms’ (MC4.51), and ‘Coastal terrigenous muds’ (MC6.51). Associated habitats are ‘Facies with Antipatharia’ (MC1.521c), ‘Facies with Alcyonacea’ (MC1.522c), ‘Facies with Scleractinia’ (MC1.523c).

Related reference habitats

‘Coralligenous outcrops’ (MC1.52a, MC1.52b), ‘Coralligenous cliffs’ (MC1.51), ‘Coralligenous platforms’ (MC2.51).

Possible confusion

The habitat hosts assemblages similar to those occurring in the ‘Coralligenous cliffs’ (MC1.51), ‘Coralligenous outcrops’ (MC1.52a, b) and ‘Coralligenous platforms’ (MC2.51). These habitats may be distinguished by differences in the degree of bioconstruction, bottom morphology, and localization.

Typical species and associated communities

Different assemblages may be found depending on depth, morphology of banks, surrounding bottoms and presence of biocostruction. The shallower banks (40-80m) may host large and erect sponges (*Axinella cannabina, A. polypoides, Aplysina aerophoba, Haliclona mediterranea*), Alcyonacea (*Eunicella cavolini, Paramuricea clavata, Corallium rubrum, Alcyonum acaule*), bryozoans (*Pentapora fascialis*). On the deeper banks it is also possible to find *Antipathella subpinnata, Ellisella paraplexauroides*, and the gold coral *Savalia savaglia*.

Conservation interest and ecological role

The deep banks, especially those characterised by biogenic structures, support biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages.

Economic importance

The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. To date, the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. In particular, the habitat is threatened by fishing activities and sedimentation.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities.

Deep banks with *Paramuricea clavata, Aplysina aerophoba*, and *Corallium rubrum*
(© M. Di Fiore)

Suitability of the habitat for monitoring

The habitat has the same suitability for monitoring as ‘Coralligenous cliffs’ (MC1.51) and all methods proposed for that habitat can also be used for deep banks. Monitoring is preferably conducted through remotely operated vehicles (ROVs) and technical diving.

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Semi-dark caves and overhangs

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.53**
- **EUNIS 2019: MC152**
- **EUNIS 2007: A4.71 (partim)**
- **EC: 8330 (partim)**
- **CORINE: 11.26 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral (also in enclave in the infralittoral)
Nature of the substratum	Hard (rock), soft (sediment)
Depth range	2 m to 60+ m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes

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C. Morri,

Photo credits:
C.N. Bianchi, F. Boero ,
V. Gerovasileiou

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

Description of the habitat

The semi-dark cave habitat is typically found at the entrance of caves and even under caverns and overhangs that would not be topographically characterized as true caves. Its distinctive feature is the dramatic decrease of light soon after the entrance of the cave: the light intensity characterizing semi-dark caves is typically comprised between 1% and 0.01% of the sunlight at the sea surface. Reduced illumination constitutes a limiting factor for the development of vegetal life, so that the biotic assemblages are nearly exclusively composed of animals, even if located in shallow waters (infralittoral zone).

Geographic distribution

Submarine caves, with semi-dark portions, exist along all the Mediterranean rocky coasts. More than 3000 submarine caves have been inventoried in the Adriatic, Aegean, Ionian, Levantine, Ligurian, Provençal and Tyrrhenian seas, whilst they are scarcer (or simply not known) along the North Africa coast.

Associated habitats

On walls at the entrance of semi-dark caves either ‘Algal-dominated infralittoral rock’ (MB1.51) or ‘Coralligenous’ (MB1.55 and MC1.51) assemblages may develop, according to depth and topography. Inside large cavities, the semi-dark zone is typically followed by the habitat of ‘Caves and ducts in total darkness’ (ME1.52). In semi-submerged caves, the semi-dark zone may also be in contact with the habitat of ‘Midlittoral caves’ (MA1.52). In limestone rocks, the infiltration of rainwater through the karstic network creates the conditions for the development of the habitat of ‘Brackish water caves or caves subjected to freshwater runoff’ (MC1.53d). The pavement of semi-dark caves is normally covered with sediment that may be in contact with external sedimentary habitats. ‘Facies with sponges’ (MC1.531a, MC1.531b), ‘Facies with Hydrozoa’ (MC1.532a, MC1.532b), ‘Facies with *Corallium rubrum*’ (MC1.533a, MC1.533b), ‘Facies with Scleractinia’ (MC1.534a, MC1.534b), ‘Facies with Zoantharia’ (MC1.535a, MC1.535b), ‘Facies with Bryozoa’ (MC1.536a, MC1.536b), and ‘Facies with Ascidiacea’ (MC1.537a, MC1.537b). ‘Facies with lithistid sponges’ (MC1.531d) are usually associated to brackish water caves or caves subjected to freshwater runoff.

Related reference habitats

Biological assemblages comparable to those on the walls and roofs of semi-dark caves can be frequently found in the anfractuosities of coralligenous formations (MB1.55 and MC1.51) or even deeper habitats (MD1.51, MD1.52, MD1.53, MD2.51). The assemblages thriving in the sediment at the floor of the cave may show affinities with those of the 'Coastal detritic bottoms' (MC3.51) or the 'Circalittoral mud sediment' (MC6.5).

Possible confusion

The topographic location should make this habitat unmistakable.

Typical species and associated communities

The biota thriving in semi-dark caves is rich and diversified, with more than 1000 species recorded to date. The majority of species is found on walls and roofs, which are typically covered by sessile organisms belonging mostly to sponges, cnidarians, and bryozoans, which may form distinctive facies. Sessile species, such as the sponge *Sarcotragus pipetta* and the colonial scleractinian coral *Polycyathus muellerae*, may also colonize the cave pavement, provided it is rocky and not covered by sediment. The infauna living in the sedimentary floor is less known with respect to the epifauna of rocky substrates. Cave sediments are predominantly muddy, but often include a coarse fraction, made of either mineral, coming from the outside, or biogenic, originating from fallen fragments of skeletons and calcareous shells of the organisms present on walls and roof. The species richest phyla in the sediments are polychaetes, molluscs, and crustaceans, other phyla being less represented. Generally, the most abundant species is the sipunculid *Onchnesoma steenstrupii*, otherwise reported from bathyal muds. Common are also the bivalve *Gouldia minima* and the polychaete *Aponuphis bilineata*, typically linked to heterogeneous sediments. Other frequently reported species are indicator of sediment instability, such as the bivalves *Corbula gibba* and *Thyasira flexuosa*, the polychaetes *Levinsenia gracilis*, *Lumbrineris latreilli, Paradoneis lyra* and *Spio multioculata*, and the ophiurid *Amphiura chiajei*. Certain large tube-dwelling (e.g., *Arachnanthus oligopodus, Cerianthus membranaceus,* and *Pachycerianthus solitarius)* or burrowing (e.g., *Halcampoides purpureus*) anthozoans can be locally abundant. As far as meiobenthos, nematodes are the most abundant taxon, followed by harpacticoid copepods. New species of tardigrades, gastrotrichs and priapulids have been described from cave sediments and are apparently exclusive to such habitat. The most characteristics mobile invertebrates belong to the crustaceans, and in particular to the decapods *Homarus gammarus*, *Palinurus elephas*, *Scyllarides latus*, and *Scyllarus arctus*. The gastropods *Naria spurca* and *Luria lurida* are more commonly observed in caves than elsewhere. Several fish species may shelter in semi-dark caves; juveniles, in particular, find there refuge from predators. Most common fish species include *Apogon imberbis*, *Conger conger*, *Phycis phycis*, and *Sciaena umbra*; while the gobids *Corcyrogobius liechtensteini*, *Didogobius splechtnai*, *Gammogobius steinitzi*, and *Thorogobius ephippiatus* are characteristic.

Conservation interest and ecological role

Marine caves are acknowledged as 'biodiversity reservoirs' and 'refuge habitats' of great conservation value, as they harbour a rich biodiversity, which includes a considerable number of rare, endangered, and protected species. The presence of caves in rocky coasts may provide additional resources for fishes (e.g. refuge against predators, sand patches within a rocky matrix) compared to rocky reefs without caves, thus affecting local species richness and distribution patterns.

Economic importance

Semi-dark cave ecosystems offer provisioning and information services to humans. Provisions include food, ornaments, and natural medicine and genetic resources. Several fishes and crustaceans that shelter in marine caves or use them as nursery habitats are of commercial interest. Two species commonly found in semi-dark caves, the precious coral *Corallium rubrum* and the bath sponge *Spongia officinalis*, have been exploited for centuries. The sessile biota of semi-dark caves has biotechnological interest as potential source of bioactive substances and for bioenergy and bioremediation. The information services of semi-dark caves consist of recreation, scientific research, inspiration, and spiritual values. The aesthetic value of semi-dark caves make them popular locations for scuba diving.

The high and unique biodiversity of marine caves has attracted marine scientists since the eighteenth century, when the Italian naturalist Filippo Cavolini reached submerged caves near Sorrento (Bay of Naples, Italy) with the aid of a rudimentary equipment; in the middle of the twentieth century, the Austrian marine biologist Rupert Riedl addressed the study of marine caves, motivated by the expectation of extraordinary new findings, and later wrote: “we will show you … things you did not even dream about”. The unique fauna thriving in semi-dark caves is a source of inspiration for underwater photographers. The spiritual values of semi-dark caves may be analogous to that of terrestrial caves, which have been important for religion and culture. The monetary value of this habitat has not been calculated yet.

Vulnerability and potential threats

Marine caves are unique and fragile ecosystems threatened by multiple global and local pressures. Severe storm waves may abrade walls and roofs and perturb the sedimentary floor, thus causing mortality of the cave-dwelling organisms. Sea water temperature anomalies have induced important alterations to both the motile and sessile components of cave communities. Similar impacts are caused by urbanization and coastal works (expansion of harbours and marinas, beach nourishment, etc). Scuba divers entering semi-dark caves may unintentionally damage the biota by colliding with rocky walls, resuspending sediment, and exhaling air bubbles that accumulate at the cave roof. Illegal spearfishing (e.g., of *Sciaena umbra* and *Phycis phycis*) is also of concern. An additional potential threat to Mediterranean marine cave communities is the spread of non-indigenous species, especially in the Levantine basin.

Protection and management

The first instances of protection date back to the 1970s but only more recently have led to concrete initiatives by the Resolution no. 4 of the Council of Bern Convention (which listed them as endangered natural habitat type), by the Habitats Directive of the European Union, and by the Mediterranean Action Plan of the United Nations Environment Programme. However, in most countries no specific regulations or management plans are implemented. About two thirds of the Mediterranean Marine Protected Areas (MPAs) include marine caves, but few MPAs have set limitations regarding the maximum number of divers or have required permits for visiting caves. Many species dwelling in semi-dark caves are protected according to international conventions. For instance, the Bern Convention and/or the Barcelona Convention envisage the protection of the sponges *Spongia officinalis* and *Sarcotragus pipetta* (as *Ircinia p.*), the precious coral *Corallium rubrum,* the gastropods *Naria spurca* (as *Erosaria s.*) and *Luria lurida*, the decapod crustaceans *Homarus gammarus*, *Palinurus elephas*, *Scyllarides latus*, and *Scyllarus arctus*, the fish *Sciaena umbra*, and other species that can be found frequently or occasionally in semi-dark caves.

Suitability of the habitat for monitoring

Semi-dark caves are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Several protocols have recently been proposed for the monitoring of semi-dark caves, and the UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (included marine caves) in the Mediterranean Sea. An ecosystem-based index of ecological quality has been purposely developed for semi-dark caves.

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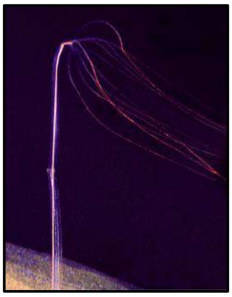
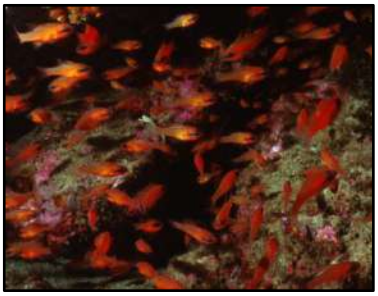


Halcampoides purpurea
(© C.N. Bianchi)

Pachycerianthus solitarius
(© C.N. Bianchi)

Scyllarides latus
(© V. Gerovasileiou)

Thorogobius ephippiatus
(© V. Gerovasileiou)



Apogon imberbis schooling
(© C.N. Bianchi)

Phycis phycis
(© C.N. Bianchi)

Sciaena umbra
(© C.N. Bianchi)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Walls, Roof

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.53a, MC1.53b**
- **EUNIS 2019: MC152 (partim); MC1521 (partim)**
- **EUNIS 2007: A4.71 (partim); A4.712 (partim)**
- **EC: 8330 (partim)**
- **CORINE: 11.26 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral (also in enclave in the infralittoral)
Nature of the substratum	Hard (rock)
Depth range	2 m to 60+ m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

MC1.53a Walls, MC1.53b Roof

Description of the habitat

Rocky walls and roofs of semi-dark caves are profusely colonized by sessile invertebrates, such as sponges, hydroids, anthozoans, bryozoans and ascidians. Biological cover is often greater than 100%, due to epibiosis and the development of an upper layer thanks to the upward vertical growth of massive and arborescent species. This biotic upper layer is typically found near the entrance, whilst encrusting species become dominant as far one proceeds inside the cavity.

Geographic distribution

As semi-dark caves open in rocky cliffs, walls and roofs are present in all of the 3000+ marine caves existing along the Mediterranean coasts. This habitat is mostly known in the Adriatic, Aegean, Ionian, Levantine, Ligurian, Provençal and Tyrrhenian seas, whilst little information exists on the North Africa coast. Most records correspond to shallow (<20 m depth) caves, while knowledge on deep caves is scarce.

Associated habitats

Walls at the entrance of semi-dark caves may host either ‘Algal-dominated infralittoral rock’ (MB1.51) or ‘Coralligenous’ (MB1.55 and MC1.51) assemblages, according to depth and topography. Inside large cavities, the semi-dark zone is typically followed by the habitat of ‘Caves and ducts in total darkness’ (ME1.52). In semi-submerged caves, walls may also be in contact with the habitat of ‘Midlittoral caves’ (MA1.52). In limestone rocks, the infiltration of rainwater through the karstic network creates the conditions for the development of the habitat of ‘Brackish water caves or caves subjected to freshwater runoff’ (MC1.53d). Different facies may be recognized on walls and roofs of semi-dark caves, such as ‘Facies with sponges’ (MC1.531a, MC1.531b), ‘Facies with Hydrozoa’ (MC1.532a, MC1.532b), ‘Facies with *Corallium rubrum*’ (MC1.533a, MC1.533b), ‘Facies with Scleractinia’ (MC1.534a, MC1.534b), ‘Facies with Zoantharia’ (MC1.535a, MC1.535b), ‘Facies with Bryozoa’ (MC1.536a, MC1.536b), and ‘Facies with Ascidiacea’ (MC1.537a, MC1.537b). ‘Facies with lithistid sponges’ (MC1.531d) are usually associated to brackish water caves or caves subjected to freshwater runoff.

Related reference habitats

Biological assemblages comparable to those on the walls and roofs of semi-dark caves can be frequently found in the anfractuosities of the coralligenous formations (MB1.55 and MC1.51) or even deeper habitats (MD1.51, MD1.52, MD1.53, MD2.51).

Possible confusion

The topographic location should make this habitat unmistakable. The sessile biota covering walls and roofs is often recognizable by their bright colours of yellow, orange, pink or red.

Typical species and associated communities

Walls and roofs of semi-dark caves are characterized by the dominance of sessile invertebrates, especially sponges (e.g., *Agelas oroides)*, cnidarians (e.g., *Corallium rubrum*, *Leptopsammia pruvoti*), and bryozoans (*Adeonella calveti*), which typically form distinct facies. Ascidians may be represented by several species, either colonial or solitary, with *Pyura dura* sometimes reported as typical. In limestone caves, walls and roofs are bored by the bivalve *Lithophaga lithophaga*. Although dominance of sessile animals remains always obvious on walls and roofs of semi-dark caves, some sciaphilic macroalgae may still occur, such as the chlorophyte *Palmophyllum crassum* and some encrusting rhodophytes belonging to the families Corallinaceae and Peyssoneliaceae. The most characteristics mobile invertebrates climbing on cave walls and roofs belong to polychaetes, gastropods and crustaceans, with in particular the decapods *Dromia personata*, *Galathea strigosa*, *Lysmata seticaudata*, and *Scyllarides latus*. The fish *Zeugopterus regius* has the particularity to 'stick' to the walls of caves, its oval flat body acting as a sucker.

Conservation interest and ecological role

Walls and roofs of semi-dark caves harbour a rich biodiversity, which includes a considerable number of rare, endangered, and protected species.

Economic importance

The ecosystem of walls and roofs of semi-dark cave offers provisioning and information services to humans. Provisions include ornaments, natural medicine and genetic resources. Two species commonly found on walls and roofs of semi-dark caves, the precious coral *Corallium rubrum* and the bath sponge *Spongia officinalis*, have been exploited for centuries. The sessile biota on walls and roofs of semi-dark caves has biotechnological interest as potential source of bioactive substances and for bioenergy and bioremediation. The information services of the walls and roofs of semi-dark caves consist of recreation, scientific research, and inspiration. The high aesthetic value of walls and roofs of semi-dark caves make them popular locations for scuba diving. The biota thriving on walls and roofs of semi-dark cave has been the subject of scientific research since the beginning of scientific diving, which has led to important discoveries in marine biology and ecology. The colourful sponges and corals that cover the walls of submarine caves are a source of inspiration for underwater photographers. No estimation of the monetary value of this habitat is available to date.

Vulnerability and potential threats

Marine caves are unique and fragile ecosystems threatened by multiple global and local pressures. Severe storm waves may abrade walls and roofs, thus damaging the sessile biota. Sea water temperature anomalies have induced mass mortality events in sponges and other organisms. Urbanization and coastal works (harbour and marina expansion, beach nourishment, etc.) cause sediment deposit, which suffocates sessile invertebrates. Species with erect morphologies are slow-growing, fragile, and thus highly vulnerable to mechanical damage caused by divers colliding unintentionally with them. Scuba diving may adversely affect the sessile biota also by sediment resuspension and accumulation of exhaled air bubbles at the cave ceiling. Illegal harvesting of bath sponges (*Spongia officinalis*), precious coral (*Corallium rubrum*), and date mussel (*Lithophaga lithophaga*), as well as spearfishing (e.g., of *Sciaena umbra* and *Phycis phycis*), are also of concern.

Protection and management

The Resolution no. 4 of the Council of Bern Convention lists marine caves among the endangered natural habitat types. Also, the Habitats Directive of the European Union and the Mediterranean Action Plan of the United Nations Environment Programme consider semi-dark caves in need of protection. However, in most countries no specific regulations or management plans are implemented. Among the most emblematic and charismatic species inhabiting semi-dark caves is the precious coral *Corallium rubrum*, listed as 'Endangered' (EN) in the IUCN Red List of threatened species, and included in the Annex II (List of endangered or threatened species) of the Bern Convention, in the Annex III (List of species whose exploitation is regulated) of the SPA/BD Protocol of the Barcelona Convention, and in the Annex V (species which are of 'interest' to the European Union) of the Council Directive 92/43/EEC (Habitats Directive) on the conservation of natural habitats and of wild fauna and flora. Other protected species listed in Annex II of the Bern Convention and/or Annex III of the SPA/BD Protocol of the Barcelona Convention, such as the sponges *Aplysina cavernicola* and *Spongia officinalis*, the scleractinian *Astroides calycularis*, the gastropods *Naria spurca* (as *Erosaria s.*) and *Luria lurida*, the bivalve *Lithophaga lithophaga*, the decapod crustaceans *Homarus gammarus*, *Palinurus elephas*, *Scyllarides latus* and *Scyllarus arctus*, and the sea-urchin *Centrostephanus longispinus*, thrive on walls and roofs of semi-dark caves.

Suitability of the habitat for monitoring

Semi-dark caves are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Several protocols have recently been proposed for the monitoring of semi-dark caves, and the UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for the monitoring of dark habitats (included marine caves) in the Mediterranean Sea. However, examples of application are still limited.

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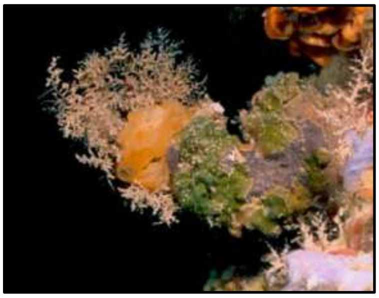
Parazoanthus axinellae, with *Corallium rubrum* in the background (© C.N. Bianchi)



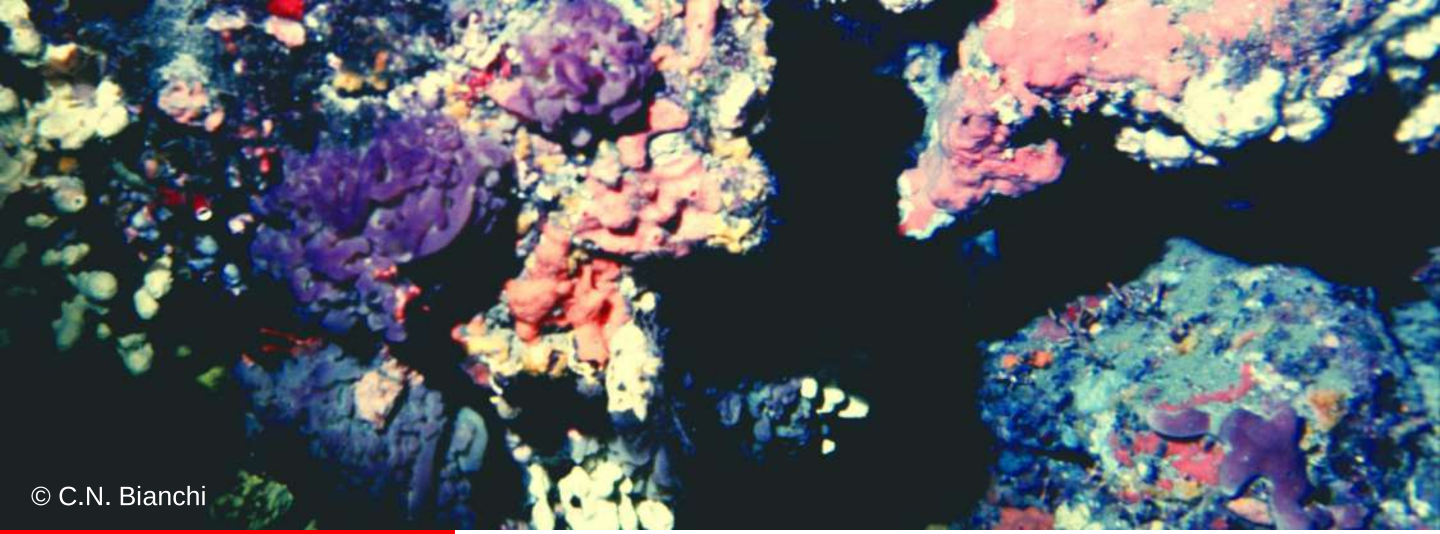
Eudendrium armatum within a sponge-dominated assemblage (© F. Boero)

Palmophyllum crassum amidst sponges and *Corallium rubrum* (© C.N. Bianchi)

Pyura dura (© V. Gerovasileiou)

Lysmata seticaudata (© C.N. Bianchi)

Zeugopterus regius (© J.G. Harmelin)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Facies with sponges

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.531a, MC1.531b**
- **EUNIS 2019: MC1522 (partim)**
- **EUNIS 2007: A4.713 (partim)**
- **EC: 8330 (partim)**
- **CORINE: 11.26 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral (also in enclave in the infralittoral)
Nature of the substratum	Hard (rock)
Depth range	2 m to 60+ m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

MC1.53a Walls, MC1.53b Roof

MC1.531a, MC1.531b Facies with sponges

Description of the habitat

Sponges dominate in terms of both diversity and biomass the assemblages of submarine caves, especially on the walls of their semi-dark portions. Due to the decrease of light, and hence of the space-competing algae, sponges turn marine caves into a real 'sponge realm', covering the substrate up to 100% and forming true facies dominated by massive and erect species, or by encrusting species. Among the most common massive and/or erect species forming facies in semi-dark caves are *Agelas oroides* and *Aplysina cavernicola* (in the Western Mediterranean): the former is orange, the latter yellow. With the gradual decrease of light intensity, *Petrosia ficiformis* passes from a pink-brown colour (due to its cyanobacterial symbionts) to a completely white colour. *Chondrosia reniformis* passes from marbled brown to white. The most frequently recorded encrusting sponges forming facies in semi-dark caves include *Aaptos aaptos* (greyish yellow to reddish dark brown), *Diplastrella bistellata* (whitish to yellowish), *Haliclona mucosa* (pale brown), *Hexadella racovitzai* (pale pink), *H. pruvoti* (golden yellow), *Phorbas tenacior* (blue), and *Spirastrella cunctatrix* (orange-red).

Geographic distribution

Sponge facies can be observed in the whole Mediterranean Sea, at various depths. Nevertheless, important differences in species occurrence exist according to the geographic sector and even to individual caves, indicating the fragmentation and individuality of this habitat.

Associated habitats

The facies with sponges often occur patchy in close vicinity or even intermixed with other facies of the semi-dark caves, i.e. 'Facies with Hydrozoa' (MC1.532a, MC1.532b), 'Facies with *Corallium rubrum*' (MC1.533a, MC1.533b), 'Facies with Scleractinia' (MC1.534a, MC1.534b), 'Facies with Zoantharia' (MC1.535a, MC1.535b), 'Facies with Bryozoa' (MC1.536a, MC1.536b), and 'Facies with Ascidiacea' (MC1.537a, MC1.537b).

Related reference habitats

Many sponge species thriving in semi-dark caves can also be found in the coralligenous formations (MB1.55 and MC1.51) or in deeper rocks (e.g. MD1.512, ME1.512, ME2.512). Similarly, some of the species forming facies in semi-dark caves, and especially the encrusting ones, can penetrate into ‘Caves and ducts in total darkness’ (ME1.52) but are generally less abundant there.

Possible confusion

Topography, and the dominance of colourful massive or encrusting sponges make this habitat unmistakable.

Typical species and associated communities

Although normally less abundant than the facies-forming species, other common sponges in semi-dark caves include *Acanthella acuta*, *Aplysilla sulfurea*, *Axinella damicornis*, *Clathrina coriacea*, *Cliona viridis*, *Erylus discophorus*, *Geodia cydonium, Haliclona fulva*, *H. sarai*, *Ircinia oros*, *Oscarella tuberculata*, *Penares euastrum*, *P. helleri*, *Spongia (Spongia) officinalis*, *S. virgultosa*, and *Terpios gelatinosus*. The large erect species *Axinella cannabina* and *A. polypoides* may be present in certain semi-dark caves. A highly diverse fauna of motile invertebrates (especially crustaceans and polychaetes) live associated with massive and erect sponges, which act as ‘living hotels’; cave-dwelling crustaceans are attracted by sponge metabolites. The opistobranch *Peltodoris atromaculata* is commonly found on *Petrosia ficiforms* and *H. fulva*, which it feeds on selectively.

Conservation interest and ecological role

More than 300 sponge species, which constitute nearly half of the total Mediterranean sponge diversity, have been recorded from marine caves. A high proportion (41%) of the cave-dwelling sponges are Mediterranean endemics, with more than 30 species that are only known from caves to date; 40 of the 57 species of Mediterranean Keratosa (horny sponges) can be found in caves. As other suspension feeders, sponges play an important role in benthic pelagic coupling. Cave-dwelling sponges exert chemical mediation and distant interaction for the homing behaviour of cave-dwelling crustaceans.

Economic importance

The facies with sponges offers provisioning and information services to humans. Provisions are mostly represented by the production of bioactive substances and by bath sponges, e.g. *Spongia (Spongia) officinalis* and others, a cultural heritage with over 5,000 years of history. The information services of the facies with sponges consist of recreation (visitations by scuba diving tourists), scientific research (ecological gradients, competition for space), and inspiration (the colourful sponges are an appreciated subject of underwater photography). The monetary value of this habitat has not been calculated yet.

Vulnerability and potential threats

The facies with sponges is a poorly resilient ecosystem threatened by multiple global and local pressures. Sea water temperature anomalies have been shown to cause mortality in massive sponges. Urbanization and coastal works (expansion of harbours and marinas, beach nourishment, etc) reduce the cover of massive and erect forms in favour of encrusting ones. Sediment resuspension caused by the passage of scuba divers may clog the filtering apparatus of sponges.

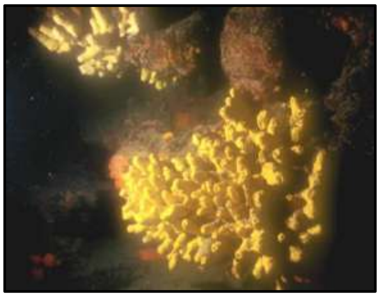
Protection and management

As they occur within marine caves, the facies with sponges are protected by the EU Habitats Directive (habitat code 8330 ‘Submerged or partially submerged sea caves’) and the ‘Action plan for the conservation of the coralligenous and other calcareous bio-concretions’ of the Barcelona Convention, which also integrates semi-dark cave communities. Some of the sponges thriving in this habitat are included among the species in need of some form of protection or management according to different international conventions. *Aplysina cavernicola* and *Axinella polypoides* are listed in the Appendix II (strictly protected fauna species) of the Bern Convention on the Conservation of European Wildlife and Natural Habitats, and in the Annex II (endangered and threatened species) of the Barcelona

Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. The latter list also contains *Aplysina aerophoba*, *Axinella cannabina* and *Geodia cydonium*, which can be found in Mediterranean Sea caves. Bath sponges, e.g. *Spongia (Spongia) officinalis*, are included in both the Appendix III (protected fauna species) of the Bern Convention and the Annex III (species whose exploitation is regulated) of the Barcelona Convention.

Suitability of the habitat for monitoring

As a part of the semi-dark caves, the facies with sponges are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Several protocols have recently been proposed for the monitoring of semi-dark caves, and the UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (included marine caves) in the Mediterranean Sea. However, examples of application are still limited.

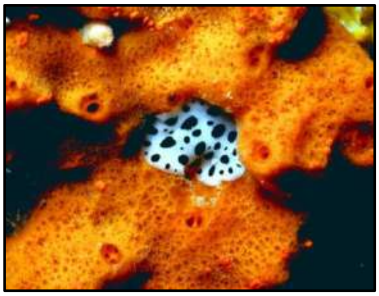

Aplysina cavernicola
(© C.N. Bianchi)


Agelas oroides
(© V. Gerovasileiou)


Ircinia oros and other massive sponges
(© V. Gerovasileiou)


Spirastrella cunctatrix
(© V. Gerovasileiou)


Peltodoris atromaculata on depigmented *Petrosia ficiformis* (© V. Gerovasileiou)


Peltodoris atromaculata on *Haliclona fulva* (© J. Vacelet)

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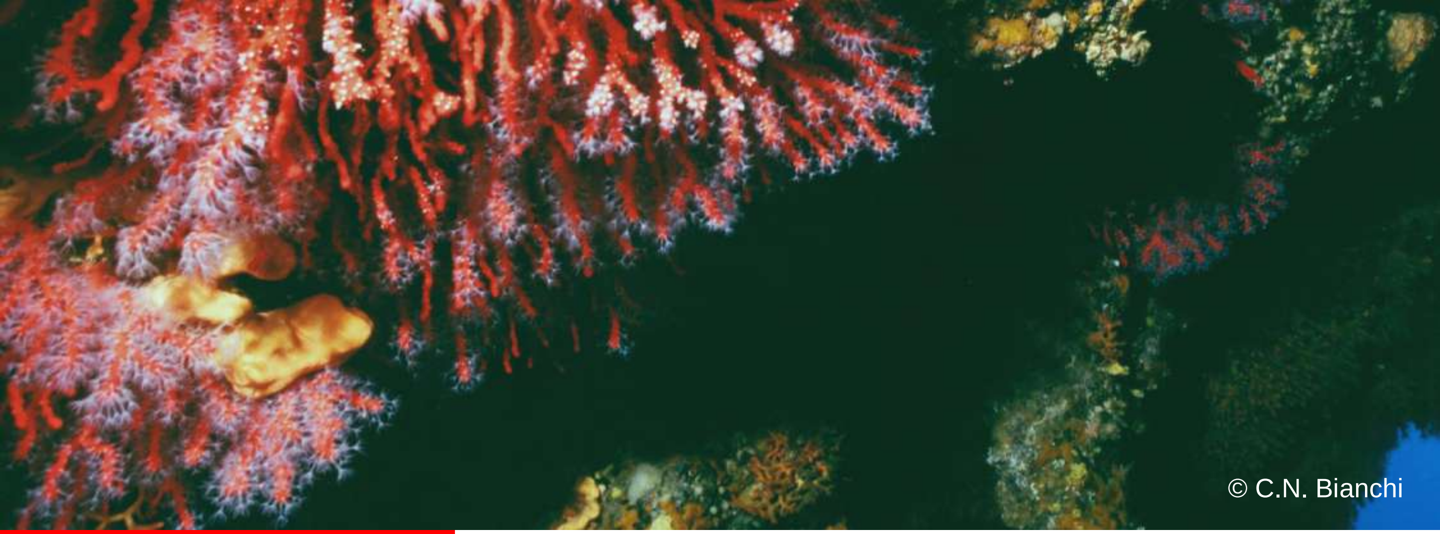
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Facies with *Corallium rubrum*

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.533a, MC1.533b**
- **EUNIS 2019: MC1522**
- **EUNIS 2007: A4.713**
- **EC: 8330 (partim)**
- **CORINE: 11.26 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral (also in enclave in the infralittoral)
Nature of the substratum	Hard (rock, including biogenic rock)
Depth range	10 m to 200+ m
Position	Coastal
Hydrodynamic conditions	Weak, with some current and no sedimentation
Salinity	Between 36 and 39
Temperature	10 °C to 23 °C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

MC1.53a Walls, MC1.53b Roof

MC1.533a, MC1.533b Facies with *Corallium rubrum*

Description of the habitat

Several alcyonacean species, such as the alcyonid *Alcyonium acaule* and the gorgonians *Eunicella cavolini* and *Paramuricea clavata*, can colonize semi-dark caves, especially near the entrance. However, only the red coral *Corallium rubrum* can form true facies, with dense monospecific stands especially on the cave roof. Two situations can be distinguished: (i) coastal populations, down to 50 m depth, characterised by high density (up to 1000 colonies·m^{-2}) and small colony size (height <5 cm); (ii) deeper populations, down to more than 200 m, characterised by low density (<100 colonies·m^{-2}) and large colony size. *C. rubrum* is a long-lived species exhibiting an arborescent growth form, which can reach 50 cm in height (weight >2 kg). The average annual growth rate of young colonies is about 1 mm·a^{-1} for the basal diameter, and 10 mm·a^{-1} for the height; growth rate decreases with colony age: after 5 years it becomes 0.2-0.5 mm·a^{-1} for the basal diameter and 1-2.5 mm·a^{-1} for the height. Colonies taller than 20 cm and thicker than 2 cm in basal diameter have become very rare because of intensive harvesting, the red coral being appreciated in jewellery. Minimum harvestable size (7 mm basal diameter) is reached in 30-40 years.

Geographic distribution

The facies with *Corallium rubrum* is distributed throughout the Mediterranean Sea, and especially in the western basin; in the eastern basin it is rarer and occurs deeper. Historical records exist of its occurrence in the near Atlantic (South Portugal, Morocco, Senegal, Cape Verde islands).

Associated habitats

The facies with *Corallium rubrum* often occur patchy in close vicinity or even intermixed with other facies of the semi-dark caves, i.e. 'Facies with sponges' (MC1.531a, MC1.531b), 'Facies with Hydrozoa' (MC1.532a, MC1.532b), 'Facies with Scleractinia' (MC1.534a, MC1.534b), 'Facies with Zoantharia' (MC1.535a, MC1.535b), 'Facies with Bryozoa' (MC1.536a, MC1.536b), and 'Facies with Ascidiacea' (MC1.537a, MC1.537b).

Related reference habitats

High densities of *Corallium rubrum* can be also found in certain coralligenous formations (MB1.55 and MC1.51) or even deeper circalittoral and bathyal habitats (MD1.51, MD1.52, MD1.53, MD2.51).

Possible confusion

The dark red colour of *Corallium rubrum* colonies and their white polyps make this habitat unmistakable. However, as it frequently occurs under coralligenous ledges in certain areas, it has been erroneously considered as a facies of the 'Coralligenous cliffs' (MC1.51).

Typical species and associated communities

The facies with *Corallium rubrum* has many species in common with the other facies of the semi-dark caves. The solitary scleractinian *Leptopsammia pruvoti* is frequently found abundant amidst the colonies of *Corallium rubrum*. The small pontonine shrimps *Balssia gasti* lives associated with the red coral: it is not clear whether the association is a form of commensalism (i.e., cleaning behaviour), predation or simply acrophily. On the contrary, the gastropod mollusc *Pseudosimnia carnea* is known to feed on the polyps. The sponge *Delectona ciconiae* bores in the scleraxis and may cause the detachment of the colony.

Conservation interest and ecological role

Being a passive suspension feeder, *Corallium rubrum* contributes to the energy transfer from the water column to the cave community; as other habitat formers, it provides biologically-generated three-dimensional space for many mobile invertebrates.

Economic importance

The facies with *Corallium rubrum* offers provisioning and information services to humans. The red coral is an important Mediterranean resource with huge historical, economic and cultural involvements. Its populations have long been commercially exploited since antiquity for jewellery. Raw red coral quotation in the jewellery market varies from 250 to 10,000 euros·kg^{-1}. The information services include cultural values, as the species has been traditionally attributed an apotropaic (i.e., against bad luck) or sexual significance. More recently, its contribution to the scenic quality of diving sites has added services of recreation to scuba tourists and of inspiration to underwater photographers.

Vulnerability and potential threats

Intensive harvesting has caused a severe depletion of most commercial stocks of *Corallium rubrum*. The average annual yield decreased from around 100 tons to only 28 tons in 100 years, demonstrating the severe overexploitation of the resource. The majority of deep red coral banks has been abandoned because harvesting is no longer profitable. Low fecundity and recruitment and slow growth rate raise concern about the resilience of overexploited populations. Recovery probably takes long and the populations of several areas might be unable to re-colonise old and overexploited sites. The few historical data series available indicate a dramatic shift in the size structure of over-harvested populations in recent decades. Besides harvesting, other human impacts can be important: despite the skeleton of *C. rubrum* is one of the hardest bio-minerals, colonies are fragile and can be easily broken by the contact of scuba divers, and lost fishing lines can entangle and broke the branches of the colonies. Other main sources of mortality of red coral include dislodgement from the substrate due the action of boring species or seismic movements, and sedimentation increase. Mass mortality events have been recorded in coincidence with recent summer heat waves and the ongoing seawater warming trend.

Protection and management

The red coral *Corallium rubrum* is listed as 'Endangered' (EN) in the IUCN Red List of threatened species, and is included in the Annex II (List of endangered or threatened species) of the Bern Convention, in the Annex III (List of species whose exploitation is regulated) of the SPA/BD Protocol of the Barcelona Convention, and in the Annex V (species which are of 'interest' to the European Union, of which the taking or exploitation of wild may be subject to management decisions) of the Council Directive 92/43/EEC (Habitats Directive) on the conservation of natural habitats and of wild fauna and flora. The long history of red coral harvesting is a paramount example of long-lasting, highly specialized exploitation, selectively addressed toward a single species. Concern has been expressed by fishermen and industry for the declining returns. For 2000 years, red coral has been harvested utilising non-selective trawling gears, which are now banned in most Mediterranean countries; today, harvesting is allowed only by scuba divers and regulated by specific laws. Prohibition of coral harvesting in overexploited areas has been adopted by several countries. International concern for conservation motivated attempts to regulate the trade of the red coral by including all the species of the genus *Corallium* in the lists of the Convention on International Trade in Endangered Species of wild flora and fauna (CITES); such attempts have failed due to insufficient information to meet CITES criteria. Management needs should operate a distinction between shallow and deep *C. rubrum* populations. Shallow populations, living at depths <50 m, have been severely depleted in the past due to easy access. At present they have little or no economic value but high naturalistic and touristic value. Their exploitation must be avoided. The establishment of Marine Protected Areas in sites where shallow red coral populations thrive will be of help. The exploitation of deep dwelling populations (below 50 m), which are nowadays the main target of commercial harvesting, needs a careful management based on population and harvest data and analyses of demographic trends.

Suitability of the habitat for monitoring

As a part of the semi-dark caves, the facies with *Corallium rubrum* are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Several protocols have recently been proposed for the monitoring of semi-dark caves, and the UNEP Regional Activity Centre of Tunis has published the guidelines for monitoring of dark habitats (included marine caves) in the Mediterranean Sea. Non-destructive methods, such as photographic surveys, should be encouraged to avoid collecting colonies of *C. rubrum*.

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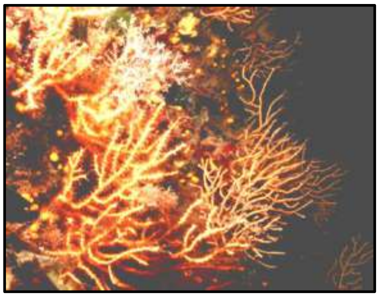
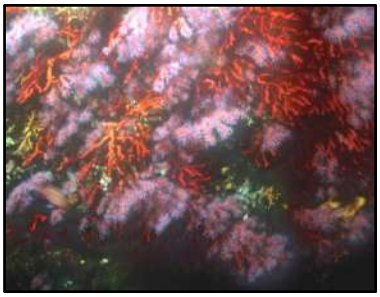

Eunicella cavolini with hydroid epibiont (© C.N. Bianchi)


Corallium rubrum (© C.N. Bianchi)


Leptopsammia pruvoti amidst *Corallium rubrum* (© C. Morri)


Balssia gastii (© M. Abbiati & G. Santangelo)


Pseudosimnia carnea (© S. Guerrieri)


Scleraxis bored by *Delectona ciconiae* (© G. Bavestrello)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Facies with Scleractinia

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.534a, MC1.534b**
- **EUNIS 2019: MC1522 (partim); MC1523 (partim)**
- **EUNIS 2007: A4.713 (partim); A4.714 (partim)**
- **EC: 8330 (partim)**
- **CORINE: 1126 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral (also in enclave in the infralittoral)
Nature of the substratum	Hard (rock, including biogenic rock)
Depth range	3 m to 60+ m
Position	Coastal
Hydrodynamic conditions	Sheltered
Salinity	Between 36 and 39
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

MC1.53a Walls, MC1.53b Roof

MC1.534a, MC1.534b Facies with Scleractinia

Description of the habitat

Scleractinian corals are common in marine caves, where they can dominate visually in more or less dense monospecific or polyspecific facies. Such facies develop mainly on the roof of semi-dark zones, but some species also colonize the dark zones. The solitary bright yellow *Leptopsammia pruvoti* may reach a density of over 700 individuals·m^{-2} on walls and overhangs. The azooxanthellate form of the colonial *Madracis pharensis*, with small white polyps, may cover roofs and overhangs up to 100%, forming distinctive knobs and tubercles. The colonial *Polycyathus muellerae*, which tolerates slight siltation, may growth not only on roof and walls but also on current-swept rocky pavements. Other common and abundant species are *Caryophyllia inornata*, *Hoplangia durotrix*, and *Cladopsammia rolandi* (in the south-western Mediterranean). The colonial bright orange *Astroides calycularis* may form facies mostly in the south-western Mediterranean. Large and arborescent colonies of the yellow-orange *Dendrophyllia ramea* may be observed on overhangs below 25 m depth in the Alboran Sea. Species less frequently recorded in caves include *Balanophyllia regia*, *Monomyces pygmaea*, *Phyllangia americana mouchezii*, and *Thalamophyllia gasti*; *Ceratotrochus magnaghii*, *Guynia annulata* (in areas with fresh water seepage), and *Paracyathus pulchellus* may be comparatively more abundant in the dark zone. Lack of competition, food availability, and reduced wave stress may produce gigantism in some of these species.

Geographic distribution

Facies with Scleractinia have been reported from all over the Mediterranean Sea, at various depths. Nevertheless, differences do exist according to the geographic sector and even to individual caves, indicating the fragmentation and individuality of this habitat. The facies with *Leptopsammia pruvoti* (reported from >60 caves, especially in the NW Mediterranean) and *Madracis pharensis* (reported from >40 caves, especially in the SE Mediterranean) seem to be the most common.

Associated habitats

The facies with Scleractinia often occur patchy in close vicinity or even intermixed with other facies of the semi-dark caves, i.e. ‘Facies with sponges’ (MC1.531a, MC1.531b), ‘Facies with Hydrozoa’ (MC1.532a, MC1.532b), ‘Facies with *Corallium rubrum*’ (MC1.533a, MC1.533b), ‘Facies with Zoantharia’ (MC1.535a, MC1.535b), ‘Facies with Bryozoa’ (MC1.536a, MC1.536b), and ‘Facies with Ascidiacea’ (MC1.537a, MC1.537b).

Related reference habitats

Virtually all the scleractinian corals thriving in semi-dark caves can also be found in coralligenous formations (MB1.55 and MC1.51) or in deeper offshore circalittoral and upper bathyal rocks (e.g., MD1.515, ME1.515). Similarly, some of the species forming facies in semi-dark caves can penetrate into ‘Caves and ducts in total darkness’ (ME1.52) but are generally less abundant there.

Possible confusion

The distinctive form and colour of scleractinian corals should make this habitat unmistakable. However, when occurring in the anfractuosities of the ‘Coralligenous’ formations (MB1.55 and MC1.51), it may be erroneously considered as part of the latter habitat.

Typical species and associated communities

The facies with Scleractinia have many species in common with the other facies of the semi-dark caves. The sponge *Haliclona fulva*, in particular, is often found together with *Leptopsammia pruvoti* on vertical walls. The small barnacle *Adna anglica* lives in association with scleractinian corals where it attaches to their calcareous skeletons. It is to be considered as an epibiont, rather than a parasite, but may cause the deformation of the corallite. It has especially been observed on *L. pruvoti*, *Hoplangia durotrix*, *Phyllangia americana mouchezii*, and *Caryophyllia inornata*, where it can affect 30-50% of the corals. The phoronid *Phoronis hippocrepia* and the sabellid worm *Pseudopotamilla reniformis* can settle on the corallite base of solitary corals. Many bryozoans, sponges and serpulids encrust and may overgrowth the corallites; the bryozoan *Cribrilaria radiata* shows preference for the coral substrate. The sponge *Delectona madreporica* and the bivalve *Hiatella arctica* bore in the coral skeleton and may cause detachment from the substrate.

Conservation interest and ecological role

Beside their intrinsic aesthetic and heritage value, all the facies with Scleractinia host a diverse community of either sessile or mobile associated fauna.

Economic importance

The facies with Scleractinia provides information services to humans, in terms of recreation (visitation by scuba diving tourists), scientific research (carbon cycle in the sea, biogeographic patterns), and inspiration (underwater photography). The monetary value of this habitat has not been assessed yet.

Vulnerability and potential threats

Slow population turnover (over 10 years), high juvenile mortality, and low growth rate made scleractinian corals poorly resilient. They are threatened by pollution, sedimentation, sea water warming and contact by scuba divers.

Protection and management

As they occur within marine caves, the facies with Scleractinia are protected by the EU Habitats Directive (habitat code 8330 ‘Submerged or partially submerged sea caves’) and the ‘Action plan for the conservation of the coralligenous and other calcareous bio-concretions’ of the Barcelona Convention, which also integrates semi-dark cave communities. All scleractinian coral species are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). Mediterranean cave-dwelling species are included in the IUCN Red List: *Dendrophyllia ramea* is classified as ‘Vulnerable’ (VU); *Astroides calycularis*, *Caryophyllia inornata*, *Leptopsammia pruvoti*, *Madracis pharensis*, *Monomyces pygmaea*, and *Polycyathus muellerae* are classified as ‘Least Concern’ (LC); *Balanophyllia regia*, *Ceratotrochus magnaghii*, *Cladopsammia rolandi*, *Guynia annulata*, *Hoplangia durotrix*, *Paracyathus pulchellus*, *Phyllangia americana mouchezii*, and

Thalamophyllia gasti are classified as ‘Data Deficient’ (DD). *A. calycularis* and *D. ramea* are also included in the Annex II (endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean.

Suitability of the habitat for monitoring

As a part of the semi-dark caves, the facies with Scleractinia are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Several protocols have recently been proposed for the monitoring of semi-dark caves, and the UNEP Regional Activity Centre of Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (including marine caves) in the Mediterranean Sea. However, examples of application are still limited.

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Leptopsammia pruvoti
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Madracis pharensis,
azooxanthellate form
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Caryophyllia inornata
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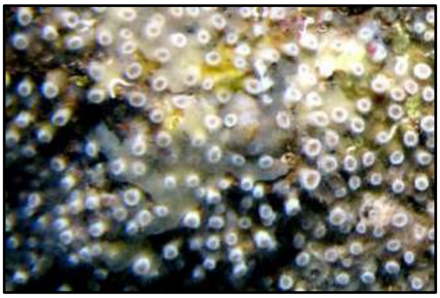
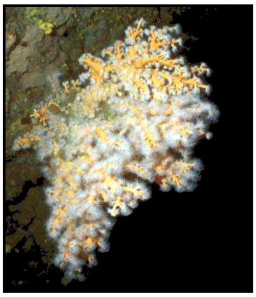
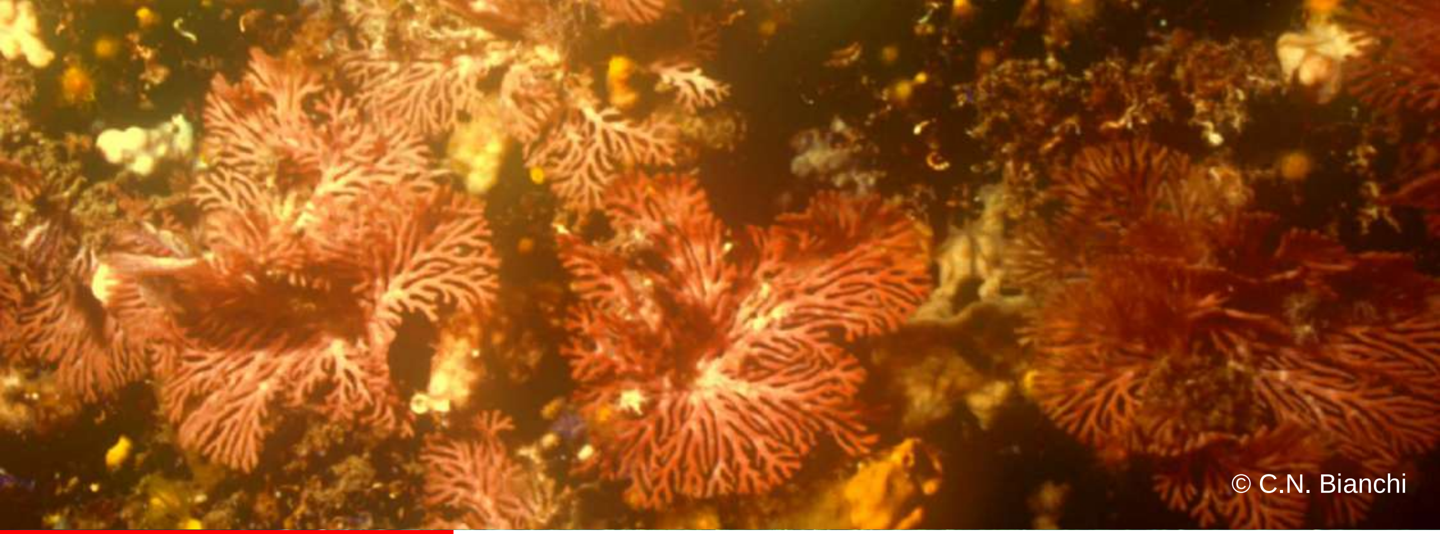


Polycyathus muellerae
(© V. Gerovasileiou)

Astroides calycularis (© C. Morri)



Dendrophyllia ramea
(© C.N. Bianchi)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Facies with Bryozoa

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.536a, MC1.536b**
- **EUNIS 2019: MC1522 (partim)**
- **EUNIS 2007: A4.713 (partim)**
- **EC: 8330 (partim)**
- **CORINE: 11.26 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral (also in enclave in the infralittoral)
Nature of the substratum	Hard (rock, including biogenic rock)
Depth range	5 m to 60+ m
Position	Coastal
Hydrodynamic conditions	Sheltered
Salinity	Between 36 and 39
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

MC1.53a Walls, MC1.53b Roof

MC1.536a, MC1.536b Facies with Bryozoa

Description of the habitat

Mediterranean marine caves are the single habitat richest in bryozoans, hosting more than 200 species, several of which were first described from caves. A number of species occur with high cover, thus forming distinctive bryozoan facies. Two bryozoan facies, in particular, can be identified. The first is composed of large and erect species, such as *Adeonella calveti*, *A. pallasii*, *Exidmonea atlantica*, *Hornera frondiculata*, *Myriapora truncata, Reteporella elegans, R. grimaldii*, *R. mediterranea*, *Schizoretepora serratimargo*, and *Smittina cervicornis*, and is located near the entrance of semi-dark caves, where it may create a three-dimensional habitat up to several cm high. The second one is formed by encrusting species, such as *Celleporina caminata, Cribrilaria radiata, Hippaliosina depressa*, and *Onychocella marioni*, and is situated in the transitional zone between the semi-dark and dark cave (occasionally extending to the outer portion of the dark zone), where it may constitute a multilayered nodular or wrinkled aggregate a few cm thick, totally covering the rock.

Geographic distribution

Both facies have been initially described for the NW Mediterranean, but have been subsequently observed in other geographical sectors. They are presumably present all over the Mediterranean Sea, but there are geographical differences: *Adeonella calveti*, for instance, is common in the W Mediterranean but is replaced by *A. pallasii* in the Adriatic and E Mediterranean; *Schizoretepora serratimargo* is typical of the Adriatic and E Mediterranean. Non-indigenous bryozoan species with Indo-Pacific affinities have been recorded in marine caves of the Ionian Sea and the Levantine basin.

Associated habitats

The facies with Bryozoa often occur patchy in close vicinity or even intermixed with other facies of the semi-dark caves, i.e. 'Facies with sponges' (MC1.531a, MC1.531b), 'Facies with Hydrozoa' (MC1.532a, MC1.532b), 'Facies with *Corallium rubrum*' (MC1.533a, MC1.533b), 'Facies with Scleractinia' (MC1.534a, MC1.534b), 'Facies with Zoantharia' (MC1.535a, MC1.535b), and 'Facies with Ascidiacea'

(MC1.537a, MC1.537b). This facies can even penetrate (partly) in the dark cave habitat, especially in presence of some water current.

Related reference habitats

Large and erect cave-dwelling bryozoans can also be found in the ‘Facies with Bryozoa’ of the coralligenous cliffs (MC1.519b) and of the coastal detritic bottoms (MC3.518), while encrusting species can be found in other crevicular microhabitats (including the anfractuosities of the coralligenous bioconcretions), under small hard substrates in ‘Coastal detritic bottoms’ (MC3.51), in deep-sea rocks (e.g., MD1.51, ME1.51, ME2.51), and in ‘Caves and ducts in total darkness’ (ME1.52). As a whole, bryozoans thriving in caves belong to five ecological categories: cave species, sciaphilic and/or coralligenous species, deep-water species, shallow-shelf species, and shelf species.

Possible confusion

Although some of the erect and branched bryozoan species can at first sight be mistaken for alcyonaceans (e.g., the so-called ‘false red coral’ *Myriapora truncata*), topography and aspect make both facies with Bryozoa of submarine caves well recognizable.

Typical species and associated communities

The facies with Bryozoa have many species in common with the other facies of the semi-dark caves. Among the erect bryozoan species, *Adeonella calveti*, *A. pallasii*, and *Reteporella mediterranea* are perhaps the most typical of semi-dark caves and overhangs. The diminutive vermetid gastropod *Thylaeodus rugulosus* settle on erect bryozoan species, while the sponge *Halisarca harmelini* lives in symbiosis with *Smittina cervicornis*. The nudibranch *Kaloplocamus ramosus* feeds on different bryozoans. *Novocrania anomala* and other cave brachiopods, has well as the scleractinian coral *Madracis pharensis,* may participate in the bioconcretions of the bryozoan facies at the transition between the semi-dark and dark cave.

Conservation interest and ecological role

Both facies with Bryozoa of semi-dark caves produce 3D structures and host a diverse community of sessile and mobile fauna.

Economic importance

The facies with Bryozoa, and especially the one with large and erect species, provide information services to humans, in terms of recreation (visitation by scuba diving tourists), scientific research (carbon cycle in the sea), and inspiration (underwater photography). No estimate of the monetary value of this facies is available yet.

Vulnerability and potential threats

Erect calcified bryozoans are fragile species, easily broken by accidental contact by scuba divers. Severe storms and summer hot waves have been shown to cause mortality in large erect bryozoan species.

Protection and management

As they occur within marine caves, the facies with Bryozoa are protected by the EU Habitats Directive (habitat code 8330 ‘Submerged or partially submerged sea caves’) and the ‘Action plan for the conservation of the coralligenous and other calcareous bio-concretions’ of the Barcelona Convention, which also integrates semi-dark cave communities. No specific management measures have been established for bryozoans. The Annex II (endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean includes *Hornera lichenoides* as the only bryozoan species: however, *H. lichenoides* is a northern species that has probably been confused with the Mediterranean endemic *H. frondiculata*.

Suitability of the habitat for monitoring

As parts of semi-dark caves, the facies with Bryozoa are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Several protocols have recently been proposed for the monitoring of semi-dark caves, and the UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (including marine caves) in the Mediterranean Sea. However, examples of application are still limited.

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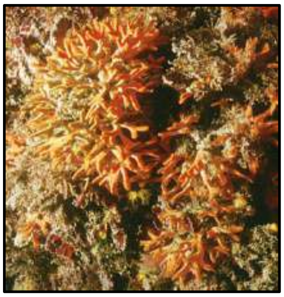

Adeonella calveti
(© C.N. Bianchi)

Reteporella mediterranea
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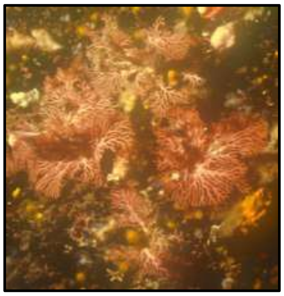
Reteporella grimaldii
(© C. Morri)



Hornera frondiculata
(© C.N. Bianchi)

Smittina cervicornis
(© C.N. Bianchi)

Exidmonea atlantica with *A. calveti* (© J.G. Harmelin)

Adeonella pallasii and *Schizoretepora serratimargo*
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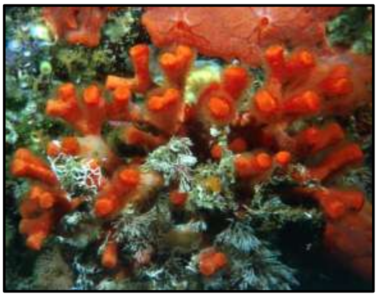

Myriapora truncata
(© C. Morri)


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Brackish water caves or caves subjected to freshwater runoff

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.53d**
- **EUNIS 2007: A4.71 (partim), A4.715 (partim)**
- **EUNIS 2019: MC152 (partim)**
- **EC: 8330 (partim)**
- **CORINE: 11.26 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral (typically in enclave in the infralittoral)
Nature of the substratum	Hard (rock)
Depth range	0.5 m to 20+ m
Position	Coastal
Hydrodynamic conditions	Weak (confined habitat)
Salinity	Between 0.5 and 37
Temperature	10 °C to 26 °C
Suitability for monitoring	Yes

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F. Vitale, H. Zibrowius

CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

MC1.53d Brackish water caves or caves subjected to freshwater runoff

Description of the habitat

Beside strictly marine caves, karst systems located in the coastal zone harbour a number of cave types ranging from sea caves with freshwater seepage, to estuarine caves, coastal solution sinkholes, and anchialine or marginal caves. The whole spectrum of intermediate situations exists among these types; salinity can be stable or fluctuating, with a wide range of values between almost freshwater to oligo-, meso-, poly-, and euhaline waters. Freshwater seepage (usually sporadic or seasonal) in the inner and upper portions of submarine caves normally has little influence on the general hydrological features of cave water (which remains fully marine for the most part), but is responsible for a strong local impoverishment of the sessile biota; in the inner chambers with an ascending profile, a lens of freshwater may overlay the sea water, with little mixing and the formation of a halocline. Estuarine caves represent the final portion of an ‘underground river’, with complex hydrodynamics and hydrochemistry, and a transition from fresh to marine water, causing a zonation of biota adapted to different salinity zones. Coastal sinkholes, typically provided with pressure line tunnels that maintain contact with the sea, may become filled by meteoric water; in this way, mixohaline water ponds originate where brackish-water organisms may get in contact with marine cave fauna. Anchialine (from the Greek ‘ἀγχίαλος’, near the sea) or marginal caves contain saline or brackish groundwater of marine origin but maintain a limited connection to the sea.

Geographic distribution

Examples of brackish water caves can be found in all limestone Mediterranean coasts hosting karst systems. They have been studied specifically in the Balearic Islands (Spain), Sardinia and Salento (Italy), Croatia, Greece, Cyprus, and Israel.

Associated habitats

Brackish water caves are usually associated with large and complex coastal cave systems where they are normally in contiguity with fully marine caves, either semi-dark or dark. The continental end members of estuarine caves are frequently freshwater caves. Coastal sinkholes may be in contact with epigean fresh or brackish water habitats. Anchialine caves are typically isolated, and therefore little influenced by the surrounding ecosystems.

Related reference habitats

Affinities can be found with ‘Semi-dark caves and overhangs’ (MC1.53) and especially with ‘Caves and ducts in total darkness’ (ME1.52). These affinities are in part due to euryhaline invertebrate motile fauna capable of moving among them and to marine sessile invertebrates close to the cave entrance. Faunal elements of the ‘Habitats of transitional waters (estuaries and lagoons)’ (MA6.52a) may colonize brackish water caves.

Possible confusion

In some cases the location of the cave may help recognizing this habitat, but it not always easy to get the difference with fully marine caves, especially in transition areas. The blurring effect of the halocline, when present, can be visually detected while scuba diving. The composition of the fauna is often the best way to distinguish this cave types from freshwater or marine caves.

Typical species and associated communities

The fauna thriving in this types of caves is as different as their environmental conditions are. In marine caves with freshwater seepage through the karstic system, a number of peculiar species may become unusually abundant, such as the serpulid *Metavermilia multicristata*, the tiny ‘serpuliform’ scleractinian coral *Guynia annulata* (which can reach a density of 153 individuals·dm^{-2}), the hypersilicified desmas-bearing ‘rock sponges’ belonging to the so-called ‘Lithistida’ (a disused taxonomic name), and Homoscleromorph sponges of the genera *Oscarella* and *Plakina*. A further peculiarity is the development of ‘biostalactites’ formed by metazoans-microbial associations, with different sizes and morphologies. These biostalactites start as cordon-like structures made by the tubes of the serpulid *Protula*, well represented in many coastal and upper bathyal habitats. Its tubes act as the nucleus of carbonate crusts a few centimetres thick, containing bryozoans (e.g., *Disporella hispida* and *Hippomenella mucronelliformis*), serpulids (e.g., *Semivermilia crenata* and *Vermiliopsis labiata*), brachiopods (e.g., *Megathiris detruncata* and *Novocrania anomala*), foraminifers (e.g., *Rhizonubecula adherens*), plus fine-grained microbial carbonates. It has been suggested that the *Protula* tubes (filled by micrite) in the nuclei represent the remnants of pioneer populations that formed aggregates during the early cave colonization phase, in response to a relatively high food supply from seawater inflow and the mineral provision by the intruding continental waters. In bell-shaped chambers of marine caves, meteoric waters percolating through the karstic network may create inner ‘lakes’ where the salinity can fall to oligohaline values, to re-acquire near normal marine values during periods of greater wave action, which causes complete water renewal in the whole cave. In these conditions, the sessile fauna can disappear (a part from some euryhaline serpulids) but motile species, such as the shrimp *Palaemon serratus*, may be common. Estuarine caves are inhabited by a scanty fauna, which includes exclusive species such as the sponge *Protosuberites mereui* and exhibits a marked zonation with very poor assemblages in the inner tracts, more subjected to episodic freshwater inflow, and richer ones, comprising opportunist and generalist species, at the marine entrance. The pressure line tunnels of coastal sinkholes similarly host an impoverished marine cave fauna, whilst typical brackish water species, such as the hydroid *Cordylophora caspia*, may colonize the continental end of the tunnels. As far as anchialine caves, well known Mediterranean species include the sponge *Higginsia ciccaresei*, from brackish water caves of Salento (Italy), and the palaemonid shrimp *Typhlocaris*, with four species known to date: *T. ayyaloni* and *T. galilea*, from Israel; *T. lethaea*, from Libya; and *T. salentina*, from Italy. Estuarine and anchialine caves may have been the pathway for the penetration, over evolutionary time scales, of species of marine origin into freshwater caves: the best example is *Marifugia cavatica*, the only existing freshwater serpulid probably originated from Miocene brackish water ancestors; it occurs in coastal karstic systems of the Northern Adriatic. *Congeria kusceri*, the only bivalve living in freshwater caves, is sympatric with *M. cavatica* and possibly shares a similar evolutionary history.

Conservation interest and ecological role

Brackish water caves are extreme environments that host a number of rare, specialized and exclusive taxa, with high levels of endemicity. Over recent decades, the scientific exploration of brackish water caves, and especially those of the anchialine type, has led to outstanding discoveries of novel taxa that exhibit unique adaptations. It is possible that some of these taxa are the result of ecological specialization from generalist parent taxa that penetrated caves from external environments in the past, including ancestral taxa or palaeoendemics, e.g. remnants of the (sub)tropical fauna that thrived in the Mediterranean Sea during warm periods of its history.

Economic importance

The ecosystems of brackish water caves have heritage value and offer information services to humans, especially for scientific research, as the fauna living there often represents unique evolutionary cases. The monetary value of this habitat has not been assessed yet.

Vulnerability and potential threats

Little is known about the consequences of water warming and sea level rise on brackish water caves. Sea water acidification may jeopardize the carbonate deposit in biostalactites, and the calcareous skeletons of sessile organisms. Pollution of phreatic continental waters and of marine coastal waters may represent a serious threat for the biota.

Protection and management

All marine caves, including their brackish water counterparts, are protected according to the Resolution no. 4 of the Council of Bern Convention (which listed them as endangered natural habitat type), by the Habitats Directive of the European Union, and by the Mediterranean Action Plan of the United Nations Environment Programme. The bivalve *Congeria kusceri* is listed in Annexes II and IV of the Habitats Directive.

Suitability of the habitat for monitoring

Caves are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (including marine caves) in the Mediterranean Sea. However, examples of application are virtually inexistent, also because of the technical and safety problems linked to diving in these types of caves.

Guynia annulata
(@ J. Stolarski & H. Zibrowius)

Protula
(@ C.N. Bianchi)

Incipient serpulid biostalactite
(@ V. Gerovasileiou)

Cordylophora caspia
(@ C. Morri)

Palaemon serratus
(@ C.N. Bianchi)

Higginsia ciccaresei
(@ F. Vitale)

Typhlocaris salentina
(@ N. Ciccarese)

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Facies with lithistid sponges

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.531d**
- **EUNIS 2019: MC152**
- **EUNIS 2007: A4.71**

LOCATION OF THE HABITAT

Zone	Circalittoral (typically in enclave in the infralittoral)
Nature of the substratum	Hard (rock)
Depth range	0.5 m to 20+ m
Position	Coastal
Hydrodynamic conditions	Weak (confined habitat)
Salinity	Between 0.5 and 37
Temperature	10°C to 26°C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC1.5 Circalittoral rock

MC1.53 Semi-dark caves and overhangs

MC3.53d Brackish water caves or caves subjected to freshwater runoff

MC3.531d Facies with lithistid sponges

Description of the habitat

Lithistids or rock sponges are desmas-bearing demosponges with hypersilicified skeleton. They occur typically in deep-sea habitats but may be found in certain shallow marine caves. The marine cave habitat seems to be particularly favourable for lithistids, harbouring 10 out of the 13 (77%) Mediterranean species. Lithistids are found in some, but not all marine caves. Their absence from some caves and presence in others may be associated with the presence of deep-sea sources of propagules, physiographic conditions of the seabed and environmental factors which affect the settlement of larvae and their development. Abundant and dense populations, which can form large masses, have been found only in marine caves of the eastern Mediterranean Sea, which are subjected to freshwater runoff. These populations usually develop in cave zones with freshwater mixing. Smaller specimens may be found in dark caves and also at the inner and upper portions of caves with freshwater infiltrations through cracks and fissures, which are sporadic and/or seasonal. This association between dense populations of lithistids with freshwater influx is probably explained by the higher concentration of silica in water (up to 11 times higher than outside caves and comparable to deep seawater at several hundred meters depth), delivered to the caves by freshwater sources, that promotes the development of these hypersilicified sponges. While lithistid demosponges and other taxa (e.g., geodiids and associated macro-invertebrates) seem to be benefited by – or at least they can tolerate – freshwater input up to a certain level, on the other hand, these conditions may be responsible for a local impoverishment of biota and the creation of specific facies or even azoic zones.

Geographic distribution

Lithistid demosponges have been reported from marine caves of Greece, Lebanon, Croatia, Sardinia, France and Spain. However, facies of dense lithistid populations are known only from specific caves with freshwater influx in the Eastern Mediterranean Sea (Greece and Lebanon). Given the scarcity of scientific information regarding this particular cave type, and the wide distribution of caves with freshwater runoff in limestone coasts, it is assumed that this facies is more common than we know.

Associated habitats

Lithistid sponges can be found in both semi-dark and dark caves, with of without freshwater runoff. Dark marine caves present analogies with deep-sea environments (e.g., lack of light and oligotrophy). Some lithistids are known exclusively from a small number of Mediterranean marine caves which are located hundreds of kilometres away. This suggests that their likely source of propagules is from unknown deep-water populations.

Related reference habitats

This facies presents affinities with the following habitat types and facies: ‘Semi-dark caves and overhangs’ (MC1.53), ‘Facies with sponges’ (MC1.531a), ‘Caves and ducts in total darkness’ (ME1.52), ‘Upper bathyal rock invertebrate-dominated’ (ME1.51), and ‘Facies with large and erect sponges’ (ME2.512).

Possible confusion

This facies is easy to identify when consisting of large-sized rock sponges with characteristic folded plates. However, some species have small size (few centimetres) and encrusting, low domical morphology, either rounded or irregular in shape. In addition, taxonomic identification of lithistid sponges is challenging. Several taxa are known only from one or two specimens and no systematic studies exist regarding intraspecific or environmental variability in their morphology. As far as their spiculation is concerned, specific regions in the same sponge can differ in structure, function and details of spicule morphology and types. Some spicule types may also exhibit high variability. Systematic studies combining morphological and molecular identification are needed. For all the above reasons, this sponge facies could remain undetected by non-specialists.

Typical species and associated communities

A total of 10 lithistid demosponges are known from Mediterranean marine caves. Six of these species are endemic, so far known only from a single or a few marine caves and could be considered ‘cave-exclusive’ *sensu lato*. However, some species are probably originated from deep-water populations whose propagules were upwelled to dark shallow caves. Only a few lithistids are known to form dense facies, including masses with folded plates and large cavities (e.g., *Neophrissospongia endoumensis* and *Microscleroderma lamina*). Several invertebrate taxa (e.g., crinoids, sea urchins, and gastropod molluscs) often find shelter in these cavities. Small-sized sessile taxa (e.g., brachiopods and thinly encrusting sponges) often develop on their hard surfaces. Therefore, lithistids seem to have an important ecosystem engineering role in the marine cave ecosystem, providing micro-habitats to various taxa. In addition to the lithistid populations, other “hypersilicified” sponges (geodiids) may also develop in high abundances and/or size in marine caves with freshwater influx.

Conservation interest and ecological role

This facies consists of rare, endemic (cave-exclusive) and deep-water lithistid sponges. Several species are known only from a single or a few marine caves. Some species were suggested to be “palaeoendemic” remnants of the fauna that thrived in the Mediterranean Sea during warm periods of its geological history. However, under the light of recent evidence, these sponges have probably colonized marine caves from adjacent deep-water areas not earlier than 7,000–3,000 years ago, after the last glaciation. Although little information exists about the growth rate of lithistid demosponges, calculations based on related deep-water species suggest that large sponge masses of *Neophrissospongia endoumensis* in a marine cave of Crete (Greece) could be approximately 769-909 years old (the largest specimen observed was about 100 cm large). The occurrence of such slow-growing and ecosystem-engineering invertebrates of deep-water origin in shallow marine caves highlight an urgent need for further study, appropriate management and conservation actions.

Economic importance

This facies is characterized by high heritage value and offers information services to humans, especially for various fields of scientific research (e.g., marine ecology, deep-sea biology, cave biology, palaeobiology, evolutionary biology), because lithistid sponges represent unique faunal elements and include slow-growing (living fossils), endemic and deep-water species. Some marine caves where lithistids occur are also popular locations for marine-based recreational activities, such as scuba diving.

Vulnerability and potential threats

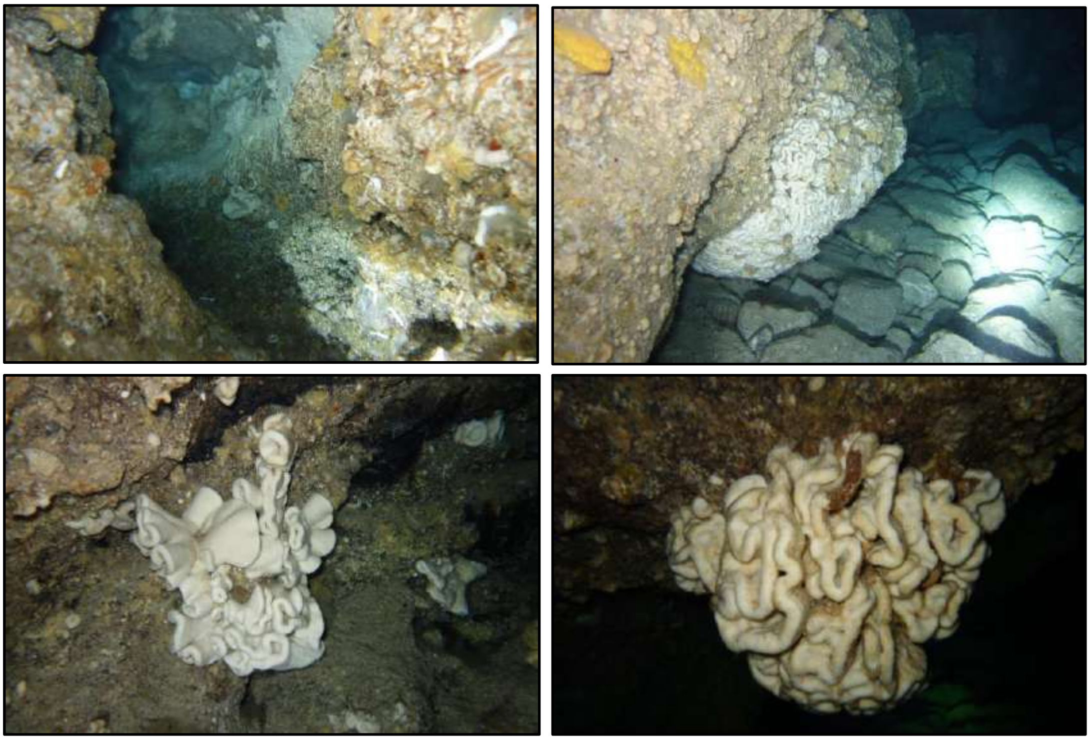
No information is available about the vulnerability and potential threats of this facies. Marine caves are considered unique and fragile habitats threatened by multiple global and local pressures. Several natural and human-induced threats and pressures impact on marine cave communities, such as water temperature rise, pollution, coastal infrastructure constructions, and unregulated recreational activities. The consequences of water warming and sea level rise on marine caves with freshwater runoff is unknown. Pollution of phreatic continental waters and of marine coastal waters may represent a serious threat for the biota. In addition, several non-indigenous taxa have been recorded in caves of the Eastern Mediterranean Sea where lithistids occur (i.e., Greece and Lebanon). Nevertheless, the potential impacts of the above-mentioned threats/pressures on this facies are completely unknown, highlighting the need for monitoring and conservation initiatives.

Protection and management

All marine caves are protected according to the Resolution no. 4 of the Council of Bern Convention (which listed them as endangered natural habitat type), by the Habitats Directive of the European Union, and by the Mediterranean Action Plan of the United Nations Environment Programme.

Suitability of the habitat for monitoring

Brackish water caves are included within the guidelines for monitoring marine habitats in the Mediterranean Sea, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (including marine caves) in the Mediterranean Sea. However, examples of application are virtually inexistent, due to the lack of funding, awareness and partly because of the technical and safety problems linked to diving in marine caves.



Facies and large masses of the lithistid demosponge *Neophrissospongia endoumensis* in shallow marine caves of the eastern Mediterranean Sea (© V. Gerovasileiou)

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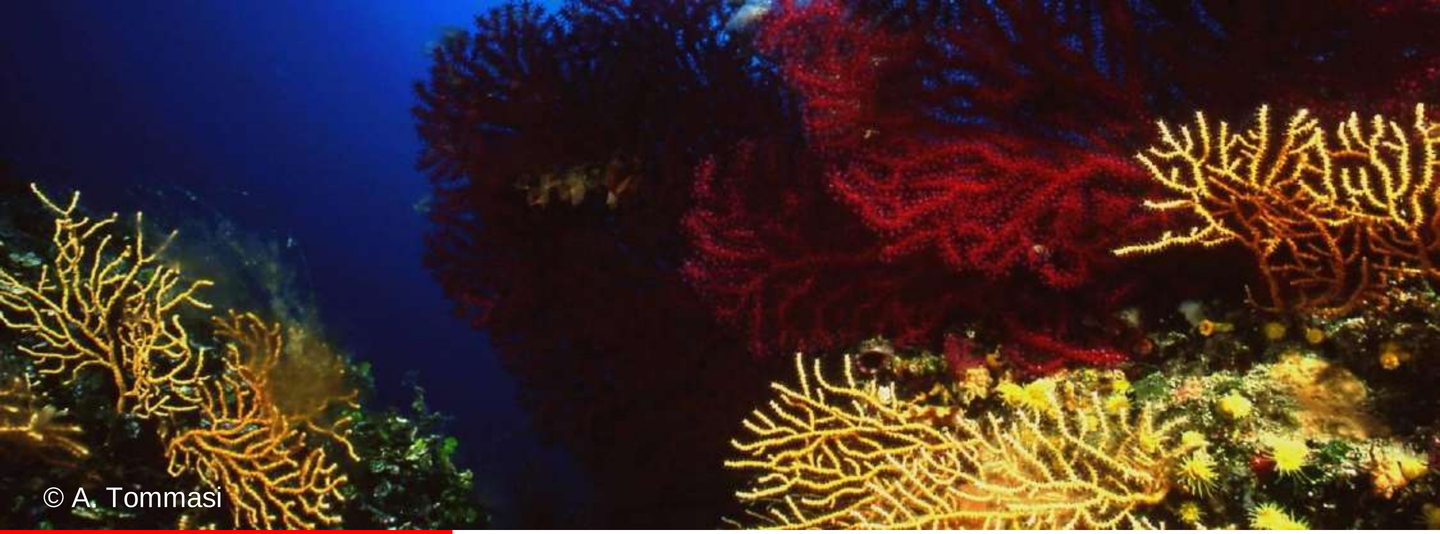
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Coralligenous platforms

Reference codes for identification:

- **BARCELONA CONVENTION: MC2.51**
- **EUNIS 2019: MC251**
- **EUNIS 2007: A4.26D**
- **EC: 1170**
- **CORINE: 11.251, 11.252**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Hard (rock)
Depth range	30 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 15°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
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CIRCALITTORAL

MC2.5 Circalittoral biogenic habitat

MC2.51 Coralligenous platforms

Description of the habitat

Coralligenous platforms are biogenic structures mostly edified by coralline algae with a variable thickness ranging from 0.5 to several meters (3-4). They are mainly built on more or less horizontal substrates and have a very complex morphology often leading to a very typical cavernous structure. Coralligenous platforms are mostly surrounded by sedimentary substrates and may develop from the coalescence of rhodoliths or grow on rocky outcrops. The planimetric geometry of this habitat is really variable: from circular to ellipsoidal to sub rectangular shapes, more or less elongated, covering from a few square meters to tens of square kilometers.

Geographic distribution

Coralligenous platforms are distributed around all the Mediterranean coasts.

Associated habitats

Coralligenous platforms are included in the 'Circalittoral biogenic habitat' (MC2.5). Coralligenous platforms may have possible contact with '*Posidonia oceanica* meadows' (MB2.54), 'Coastal detritic bottoms' (MC3.51), and 'Coastal detritic bottoms with rhodoliths' (MC3.52). Associated habitats are 'Association with encrusting Corallinales' (MC2.511), 'Association with Fucales' (MC2.512), 'Association with non-indigenous Mediterranean *Caulerpa* spp.' (MC2.513), 'Facies with small sponges' (MC2.514), 'Facies with large and erect sponges' (MC2.515), 'Facies with Hydrozoa' (MC2.516), 'Facies with Alcyonacea' (MC2.517), 'Facies with Zoantharia' (MC2.518), 'Facies with Scleractinia' (MC2.519), 'Facies with Vermetidae and/or Serpulidae' (MC2.51A), 'Facies with Bryozoa' (MC2.51B), and 'Facies with Ascidiacea' (MC2.51C).

Related reference habitats

'Deep banks' (MC1.52c), 'Coralligenous outcrops' (MC1.52a, MC1.52b), 'Coralligenous cliffs' (MC1.51).

Possible confusion

The habitat could be confused with 'Coralligenous cliffs' (MC1.51) and 'Coralligenous outcrops'(MC1.52a, b). The structure of assemblages is similar among these habitats, but coralligenous platforms develop horizontally on coastal detritic bottoms. Coralligenous platforms are large tabular buildups, a morphology that allows them to be distinguished from coralligenous outcrops.

Typical species and associated communities

The assemblages developing on coralline algae exhibit a structure similar to that of coralligenous habitat. The dominant organisms may be large and erect sponges (e.g., *Axinella cannabina, A. polypoides, Sarcotragus* spp.*, Haliclona mediterranea*), Alcyonacea (e.g., *Corallium rubrum*, *Eunicella cavolini, E. verrucosa, E. singularis, Paramuricea clavata, Alcyonum acaule*), Zoantharia (e.g., *Parazoanthus axinellae*, *Savalia savaglia*), bryozoans (e.g., *Pentapora fascialis, Myriapora truncata*), Fucales or Laminariales depending on depth and geographical distribution.

Conservation interest and ecological role

The coralligenous platforms support biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages.

Economic importance

The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. To date, the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. In particular, the habitat is threatened by fishing activities and sedimentation.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities (UNEP/MAP 2017).

Suitability of the habitat for monitoring

Coralligenous habitat has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). The ecological quality of coralligenous shall also be assessed within the Marine Strategy Framework Directive. Several methods and ecological indices have recently been proposed to detect the ecological quality of the coralligenous habitat and to be employed in monitoring programs and impact evaluation studies. The monitoring is normally performed through Remotely Operated Vehicles (ROVs) or technical diving.

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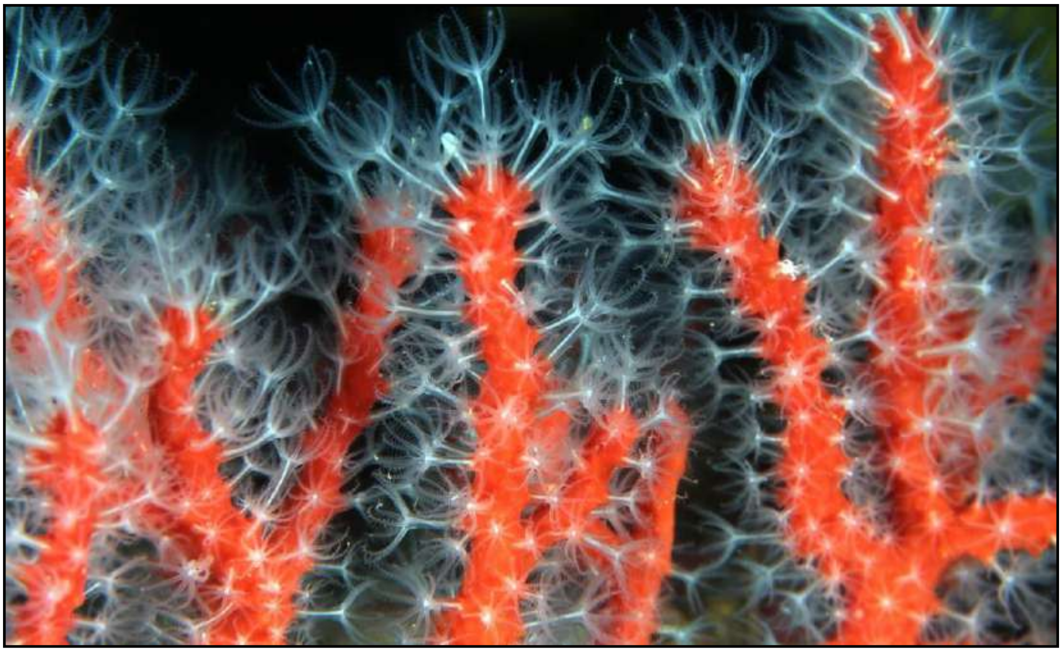
Paramuricea clavata (left panel) and *Savaglia savaglia* (right panel) (© A. Tommasi)



Corallium rubrum (© A. Tommasi)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Coastal detritic bottoms

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.51**
- **EUNIS 2019: MC351**
- **EUNIS 2007: A5.46**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (coarse sediment)
Depth range	30 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
A. Tommasi, IAS-CNR, IMC,
F. Betti

CIRCALITTORAL

MC3.5 Circalittoral coarse sediment

MC3.51 Coastal detritic bottoms

Description of the habitat

The coastal detritic bottom is one of the most extensive ecosystems on the Mediterranean continental shelf, occurring at depths between 30 and 150 m. It is a soft bottom constituted by organogenic and bioclastic sediments, originating from predominant local rocks and/or shell fragments of dead molluscs, bryozoans, echinoderms and rhodoliths or from adjacent ecosystems (e.g., coralligenous and photophilous infralittoral reefs). The interstices between these various components are partially filled by a greater or lesser proportion of sand and mud. The muddy portion is usually less than 20%. The habitat can vary greatly, depending on depth, adjacent ecosystems and hydrodynamic conditions.

Geographic distribution

The coastal detritic bottoms are present throughout the Mediterranean Sea.

Associated habitats

The habitat is included in the ‘Circalittoral coarse sediment’ (MC3.5). The habitat may have contact with ‘Coralligenous cliffs’ (MC1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coralligenous platforms’ (MC2.51), ‘Deep banks’ (MC1.52c), ‘Coralligenous outcrops’ (MC1.52a, b), and ‘Coastal detritic bottoms with rhodoliths’ (MC3.52). The habitat may be associated with the ‘Association with Laminariales’ (MC3.511), ‘Facies with large and erect sponges’ (MC3.512), ‘Facies with Hydrozoa’ (MC3.513), ‘Facies with Alcyonacea’ (MC3.514), ‘Facies with Pennatulacea’ (MC3.515), ‘Facies with Polychaeta (*Salmacina-Filograna* complex included)’ (MC3.516), ‘Facies with Bivalvia’ (MC3.517), ‘Facies with Bryozoa’ (MC3.518), ‘Facies with Crinoidea’ (MC3.519), ‘Facies with Ophiuroidea’ (MC3.51A), ‘Facies with Echinoidea’ (MC3.51B), ‘Facies with Ascidiacea’ (MC3.51C).

Related reference habitats

‘Coastal detritic bottoms with rhodoliths’ (MC3.52), ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), and ‘Offshore circalittoral detritic bottoms’ (MD3.51, MD4.51).

Possible confusion

This habitat could be confused with other soft bottoms, such as ‘Circalittoral sand’ (MC5.5) and ‘Circalittoral mixed sediment’ (MC4.5). The presence of organogenic and bioclastic sediments is a distinctive character of the habitat.

Typical species and associated communities

The habitat is characterized by high biodiversity with assemblages that can vary depending on geographic areas, depth and environmental conditions. Many taxa are considered as characteristic of this habitat. Laminariales, large and erect sponges (e.g., *Sarcotragus* spp., *Axinella* spp.), Alcyonacea (e.g., *Alcyonium* spp., *Eunicella* spp., *Leptogorgia sarmentosa*), Pennatulacea (e.g., *Pennatula* spp., *Pteroeides* spp., *Virgularia mirabilis*), Polychaeta (*Salmacina-Filograna* complex), Bivalvia (e.g., *Pecten jacobaeus*), Bryozoa (e.g., *Turbicellepora incrassata*, *Frondipora verrucosa*, *Pentapora fascialis*), Crinoidea (e.g., *Leptometra* spp.), Ophiuroidea (e.g., *Ophiura* spp., *Ophiothrix* spp.), Echinoidea (e.g., *Neolampas* spp., *Spatangus purpureus*) can be considered among the most iconic taxa. The assemblages also include echinoderms (*Astropecten irregularis, Anseropoda placenta, Luidia ciliaris*), molluscs (*Flexopecten flexuosus, Laevicardium oblungum, Acanthocardia deshayesi, Moerella donacina*), polychaetes (*Laetmonice hystrix, Petta pusilla*) and crustaceans (*Paguristes eremita, Anapagurus laevis, Ebalia tuberosa, E. edwardsi*).

Conservation interest and ecological role

The habitat hosts a very high specific diversity and develops many facies linked to the expansion of particular and ecologically important taxa, therefore it is an important fishing area, particularly for artisanal fishing.

Economic importance

The habitat is an important fishing area, particularly for artisanal fishing, and represents an essential portion of the Mediterranean halieutic resources. To date the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The coastal detritic bottoms are subject to various sedimentary additions brought down either by rivers flooding that can increase the concentration of fine sediments and organic matter. The increase in fine sediments can lead to the shift toward muddy detritic bottom resulting in altered assemblages. Moreover, these fine particles additions are usually loaded with various pollutants, particularly in wastewater, which can act directly on the characteristic species of the assemblages. Increased fine sediment and organic matter can lead to the disappearance of typical taxa, the spread of species with broad ecological requirements, decreased diversity and widespread biotic homogenization. The coastal detritic bottoms may also be threatened by physical damage caused mostly by bottom trawling. Finally, the spread of invasive alien species, such as *Caulerpa cylindracea* may lead to the loss of typical macrozoobenthic assemblages.

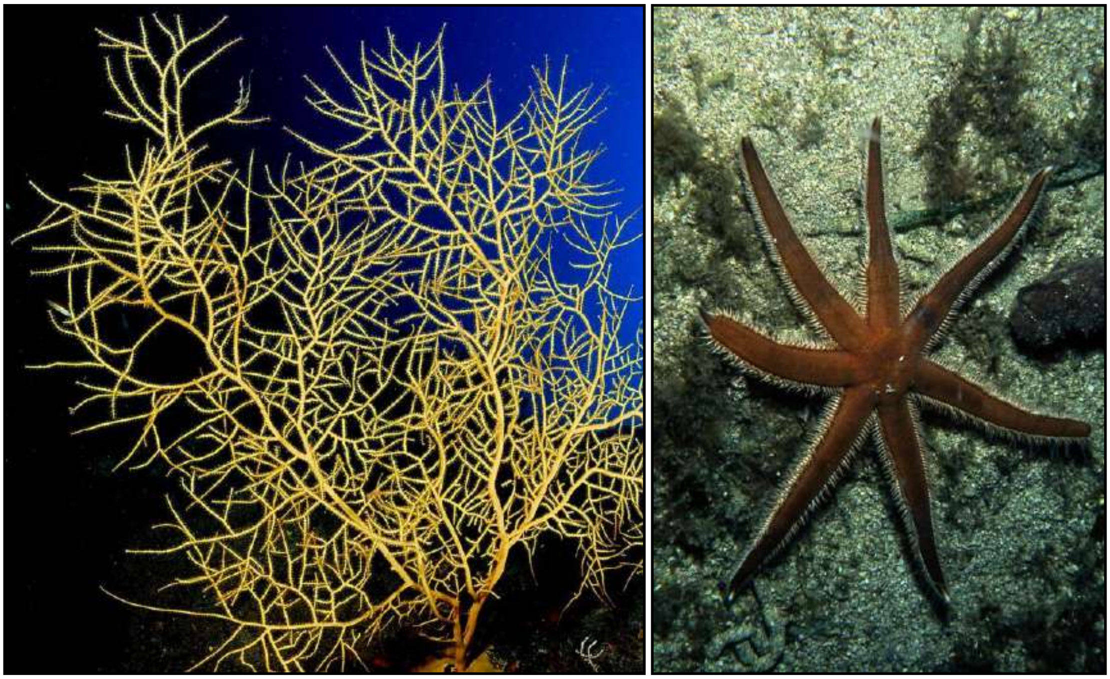
Protection and management

The habitat is not protected and assessed as ‘Data Deficient’ in the European IUCN Red List.

Suitability of the habitat for monitoring

The macro-zoobenthos of Mediterranean soft bottoms, including detritic bottoms, is considered a useful tool in monitoring programs and impact assessment studies. Several benthic groups, such as amphipods, crustaceans or polychaetes, have been used as indicators of stress or pollution. Community structure has also been used in impact assessment studies. Ecological quality of the habitat must be assessed according to the European Directives (Water Framework Directive and the Marine Strategy Framework Directive). Metrics used in the assessment studies include ecological quality indices, richness and Shannon’s diversity. The habitat was mostly studied through the analysis of samples taken from box-corers or grabs. Moreover, the use of remotely operated vehicles may allow the study of epifaunal assemblages.

Recently, a photographic method has been proposed to evaluate the ecological quality of the habitat by identifying the bottom type (percentage of mud, sand and bioclastic sediments), the coverage of dead leaves of *Posidonia oceanica*, the cover of living organisms (percentage of Corallinales, Peyssonneliaceae, *Caulerpa cylindracea* and other organisms), the diversity of spot species (average number of species per photoquadrate) and the average density of macroinvertebrates (e.g., Holothuridae, Asteridae, Cnidaria).



Leptogorgia sarmentosa (left panel) and *Luidia ciliaris* (right panel)
(© A. Tommasi)

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Ophiopsila aranea (left upper panel), *Echinaster sepositus* (right upper panel), *Semicassis granulata* (left lower panel), and *Bolinus brandaris* (right lower panel)
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Association with Laminariales

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.511**
- **EUNIS 2019: MC3517**
- **EUNIS 2007: A5.52L**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (coarse sediment)
Depth range	40 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 15°C
Suitability for monitoring	Yes, but not applied

Author:
L. Piazzi

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CIRCALITTORAL

MC3.5 Circalittoral coarse sediment

MC3.51 Coastal detritic bottoms

MC3.511 Association with Laminariales

Description of the habitat

The association is mainly characterized by *Laminaria rodriguezii*. Beds of *Laminaria ochroleuca* are also found in Mediterranean areas with Atlantic influence (Alboran Sea) and in the Strait of Messina. The association occurs on circalittoral detritic beds, especially where rhodolith beds are present, and on deep rocky bottoms or sea mounts, slopes, and rocky ledges of offshore islands. The association has been observed mostly between 70 and 150 m, but can be found at shallower depths (up to 40 m) on the seafloor or in upwelling systems. The association develops under conditions of dim light, permanent temperature below 15°C, highly transparent seawater, and steady unidirectional currents.

Geographic distribution

The association is distributed in the western Mediterranean Sea, the Strait of Sicily, Adriatic Sea, and the Sea of Marmara.

Associated habitats

The association with Laminariales is included in 'Coastal detritic bottoms' (MC3.511) and in 'Coastal detritic bottoms with rhodoliths' (MC3.523). The habitat may be associated with 'Facies with large and erect sponges' (MC3.512, MC3.524), 'Facies with Hydrozoa' (MC3.513, MC3.525), 'Facies with Alcyonacea' (MC3.514, MC3.526), 'Facies with Pennatulacea' (MC3.515, MC3.527), 'Facies with Polychaeta (*Salmacina-Filograna* complex included)' (MC3.516), 'Facies with Bivalvia' (MC3.517), 'Facies with Bryozoa' (MC3.518), 'Facies with Crinoidea' (MC3.519), 'Facies with Ophiuroidea' (MC3.51A), 'Facies with Echinoidea' (MC3.51B), 'Facies with Ascidiacea' (MC3.51C), 'Facies with Zoantharia' (MC3.528), 'Facies with Ascidiacea' (MC3.529), and 'Association with maërl' (MC3.521).

Related reference habitats

The association may be also present on 'Deep banks' (MC1.52c) and 'Offshore circalittoral rock invertebrate-dominated (MD1.51), also covered by sediments' (MD1.52). Some affinities occur with the 'Association with Laminariales (kelp beds)' (MB1.512e) in the lower infralittoral rock moderately illuminated, and the 'Association with Fucales or Laminariales' (MC1.512a) in the coralligenous cliffs.

This association is characterized by Laminariales, while in coralligenous cliffs it is dominated by Fucales with occasional presence of Laminariales and Tilopteridiales. Kelp beds (MB1.512e) develops in the shallower waters of the infralittoral zone.

Typical species and associated communities

In addition to Laminariales, the association may include other erect algae, such as *Cystoseira montagnei* var. *compressa*, Ericaria *zosteroides, Phyllariopsis brevipes*, and *P. purpurascens.* Many epibionts (mostly macroalgae, hydrozoans and bryozoans, but also sponges, polychaetes and ascidians) are present on the oldest part of *Laminaria* fronds. Infaunal assemblages are those of the coastal detritic bottom biocenosis, perhaps slightly depleted, with some abundance of gravelly species.

Conservation interest and ecological role

The association with Laminariales constitutes a habitat of high conservation value, as these Mediterranean deep-sea kelp forests increase the structural complexity of hard and soft bottoms providing suitable habitats, shelter and food for many epiphytic and mobile organisms.

Economic importance

Like other canopy-forming macroalgae, Laminariales increase the biodiversity and productivity of benthic systems providing provisional (food through fisheries) and regulating (carbon sequestration, nutrient recycling) ecosystem services. To date the economic value of Mediterranean beds of Laminariales has not been assessed yet.

Vulnerability and potential threats

Deep-water Laminariales assemblages are declining in several areas of the Mediterranean under pressures from bottom trawling activities and changes in turbidity and water sedimentation.

Protection and management

Laminaria rodriguezii is listed in the Annex II of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention), and in the Appendix I “Strictly protected flora species” of the Bern Convention. It has recently been proposed for inclusion as an endangered species under IUCN criteria.

Suitability of the habitat for monitoring

The association with Laminariales may represent a useful indicator of human pressure. Bed extent and density can provide information on impacts from trawling and sedimentation. The habitat can be surveyed through Remotely Operated Vehicles (ROVs) or technical diving.

Laminaria rodriguezii with *Antedon mediterranea* (© M. Bo)

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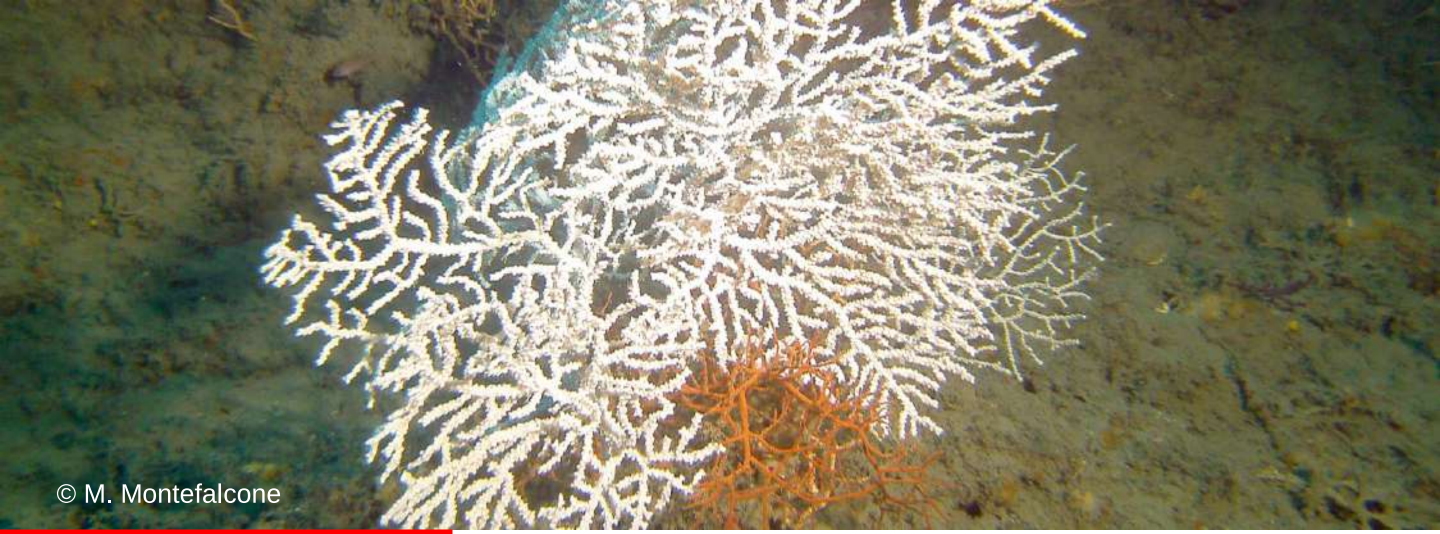
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Facies with Alcyonacea

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.514**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (coarse sediment)
Depth range	25 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

Photo credits:
M. Montefalcone, S. Canese

CIRCALITTORAL

MC3.5 Circalittoral coarse sediment
MC3.51 Coastal detritic bottoms
MC3.514 Facies with Alcyonacea

Description of the habitat

This facies is a component of the coastal detritic bottom community (also with rhodoliths, MC3.526), and is dominated by arborescent and long-lived alcyonacean species, such as the gorgonians *Eunicella cavolini, E. singularis, E. verrucosa*, *Leptogorgia* spp.*,* *Paramuricea macrospina*, and the alcyonid *Paralcyonium spinulosum.* As on the circalittoral rock, this facies creates the habitat usually known as ‘animal forests’. The habitat develops in the circalittoral zone with dim light conditions and at depths between 25 m to about 150 m, although it could be occasionally found also in the offshore circalittoral detritic bottoms (MD3.51, MD4.51). The substrate is horizontal and is made by coarse sand, gravel, pebbles, shingle and cobbles, which are often unstable due to tidal currents and/or wave action.

Geographic distribution

The facies with Alcyonacea on coastal detritic bottom is widely distributed in the circalittoral zone of the entire Mediterranean.

Associated habitats

This habitat can be associated with facies and associations of the ‘Coastal detritic bottoms’ (MC3.51) and of the ‘Coastal detritic bottoms with rhodoliths’ (MC3.52), i.e. association with Laminariales, with maërl, and with *Peyssonnelia* spp., and facies with large and erect sponges, Hydrozoa, Pennatulacea, Zoantharia, Polychaeta, Bivalvia, Bryozoa, Crinoidea, Ophiuroidea, Echinoidea, Ascidiacea, Gastropoda. The habitat may have contact with the habitats of coralligenous (MC1.51, MC1.52a, MC1.52b, MC2.51), of deep banks (MC1.52c), and of ‘*Posidonia oceanica* meadows’ (MB2.54).

Related reference habitats

Facies with Alcyonacea can also be found in moderately illuminated algal-dominated infralittoral rock (MB1.514b, MB1.514d), in lower infralittoral rock moderately illuminated (MB1.515e), in moderately illuminated invertebrate-dominated infralittoral rock sheltered (MB1.525a), and in infralittoral rock affected by sediments (MB1.534).

This facies is also often found in the coralligenous (MB1.55) and in the semi-dark caves and overhangs (MB1.56) habitats when they are in enclave in the infralittoral zone. The facies can be found on coralligenous outcrops (MC1.523a, MC1.523b), on deep banks (MC1.522c), in semi-dark caves and overhangs (MC1.533a, MC1.533b, MC1.533c), in coralligenous platforms (MC2.517), in muddy detritic bottoms (MC4.512), in coastal terrigenous mud (MC6.511), in offshore circalittoral rock invertebrate-dominated (MD1.513), also covered by sediment (MD1.523), and in the deep offshore circalittoral banks (MD1.532). Some species (e.g., *Paralcyonium spinulosum*, *Paramuricea* spp.) can also be found in the 'Upper bathyal coarse sediment' habitat (ME3.51).

Possible confusion

Facies with Alcyonacea cannot be confused with any other habitat. The presence of organogenic and bioclastic sediment is a distinctive character of the substrate in this habitat; however, it could be confused with other soft bottoms, such as 'Circalittoral sand' (MC5.5) and 'Circalittoral mixed sediment' (MC4.5).

Typical species and associated communities

Gorgonians and alcyonids are the characteristic species of this habitat. The most typical gorgonians growing on detritic bottoms are the white *Eunicella singularis* and *E. verrusosa*, the yellow *Eunicella cavolini*, *Paramuricea macrospina*, *Leptogorgia sarmentosa* and *L. viminalis.* The colonies of *Leptogorgia viminalis* are yellow, brown or violet branched in one plane with upright branches, those of *L. sarmentosa* are brick-red to pale yellow, branched in all directions with branches thin, often overhanging, and thus direction downwards. The typical alcyonids are *Paralcyonium spinulosum* and *Alcyonium palmatum*. See sheet MC1.514b for a detailed description of these species.

Communities of coastal detritic bottoms are characterized by high biodiversity. Laminariales, large and erect sponges, pennatulaceans, bryozoans, polychaetes, bivalves, crinoids, ophiurids, echinoids, crustaceans and tunicates are the most characteristic components. Epibionts are also very abundant on sea fan's branches. Many other vagile invertebrates can find in branched alcyonaceans a refuge and a suitable habitat. More details on the communities associated with coastal detritic bottoms can be found in the sheet MC3.51.

Conservation interest and ecological role

Long-lived erect Alcyonacea act as marine ecosystem engineers and habitat formers, as they plays a significant role in benthic-pelagic coupling and generate three-dimensional space and habitat for many mobile invertebrates, thus enhancing biodiversity, the beauty of the seascape and the interest of divers. *Eunicella singularis*, *Eunicella cavolini*, and *Paramuricea macrospina* are endemic to the Mediterranean.

Economic importance

Through its role in supporting high biodiversity, the facies with Alcyonacea offers provisioning services to humans, such as materials and genetic resources availability, habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms, and information services, in terms of scientific research and monitoring. To date, the economic value of Alcyonacea has not yet been assessed. Coastal detritic bottoms, in general, are important fishing areas, particularly for artisanal fishing.

Vulnerability and potential threats

Erect Alcyonacea are long-lived, slow growing and slow recruiting species and display a low resilience to human pressures. Assemblages are particularly damaged by fishing gears, bottom trawling and anchoring. Alcyonacea are sensitive to entanglement by mucilage filaments and suffer for thermal anomalies. Severe diseases are triggered by a complex combination of pathogenic microbial and abnormally high seawater temperatures, and several mass mortality events have been recorded in the Mediterranean in coincidence with summer heat waves and the ongoing seawater warming trend. Filter feeders suffer for the increase in the concentration of fine sediment and organic matter. See also the sheet MC3.51 for other threats specific of coastal detritic bottoms.

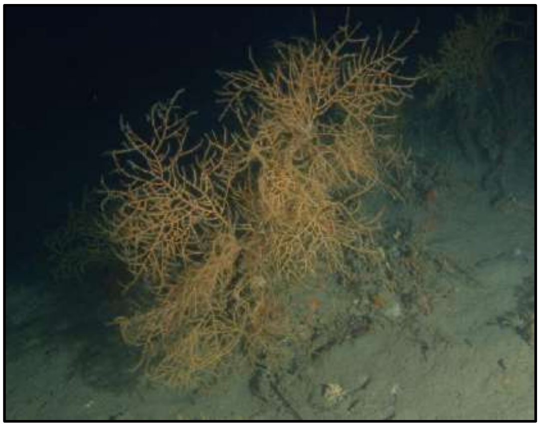
Protection and management

Nevertheless the growing awareness on the threats due to global warming and direct mechanical damages, no specific protection measures have been implemented yet for the Alcyonacea species. In order to preserve areas where animal forests are well developed and still relatively well structured, the European Union has been committed in the establishment of special areas of conservation (SAC) for the Natura 2000 network. In general, the habitat of coastal detritic bottoms is not protected and has been assessed as 'Data Deficient' in the European IUCN Red List.

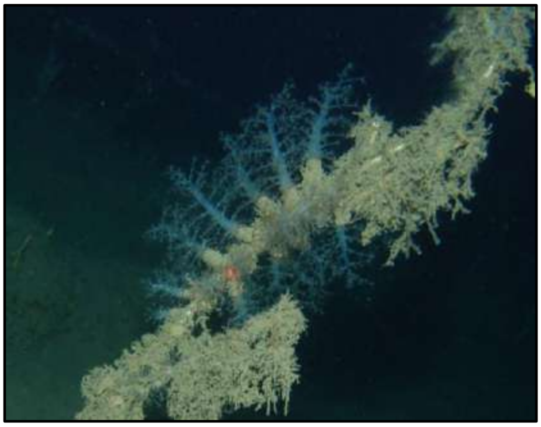
Suitability of the habitat for monitoring

Facies with Alcyonacea are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The long-term persistence and easy recognition of this habitat make it particularly suitable for monitoring, and all methods proposed for monitoring facies with Alcyonacea in the coralligenous habitat (see sheet MC1.51) can be effectively used also for monitoring coastal detritic bottoms. This habitat may be particularly suitable for assessing specific pressures, such as mechanical damage, mucilage blooms, and climate change. Ecological quality of coastal detritic bottoms must be assessed under the European Directives (Water Framework and Marine Strategy). In deep waters, the use of remotely operated vehicles may allow for the study of epimegabenthos assemblages. At shallower depths, a photographic method has been recently proposed to evaluate the ecological quality of coastal detritic bottoms, which among others considers the diversity of the main taxa and the average density of macro-invertebrates.

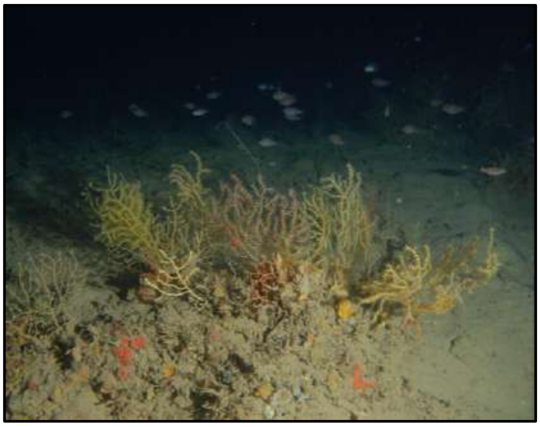
The gorgonian *Eunicella verrucosa* with the ascidians *Halocinthia papillosa* (© M. Montefalcone)



The gorgonian *Leptogorgia sarmentosa* (© S. Canese, ISPRA)



The alcyonid *Paralcyonium spinulosum* (© S. Canese, ISPRA)



The gorgonian *Paramuricea macrospina* (© S. Canese, ISPRA)

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Facies with Pennatulacea

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.515**
- **EUNIS 2019: MC6513 (partim), MD6511 (partim)**
- **EUNIS 2007: A5.392 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral to lower bathyal
Nature of the substratum	Soft (coarse, sand, mud)
Depth range	10 m to 800 m
Position	Coastal, open sea (continental shelf, shelf edge, slope, canyons, seamounts)
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Authors:
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CIRCALITTORAL

MC3.5 Circalittoral coarse sediment

MC3.51 Coastal detritic bottoms (without rhodoliths)

MC3.515 Facies with Pennatulacea

Description of the habitat

Pennatulaceans, generally known as sea pens, represent an order of anthozoan octocorallians showing specific adaptations to live partially buried in soft bottoms. Monospecific or mixed aggregations occur on horizontal or sub-horizontal detritic, sandy and muddy sediments, along the continental shelf, shelf edge, canyons and seamounts down to the bathyal plain. Mediterranean sea pens are important habitat-forming species, reaching sizes generally ranging from 5 to 60 cm and up to 210 cm for *Funiculina quadrangularis*.

Facies dominated by *Pennatula rubra* are common from the circalittoral to the upper bathyal, generally occurring from 10 to 280 m. *Pennatula rubra* facies can host other sea pens, including *Pennatula phosphorea, Pteroeides griseum* and *Cavernularia pusilla*. These species display a similar bathymetric distribution (about 10-350 m), but the two former species have been occasionally recorded down to 800 m. Pennatulaceans density estimations result strictly dependent on the adopted sampling technique: data derived from trawling bycatch generally underestimates local patches of very high densities, only being accurately determined using video imaging. *Pennatula rubra* can reach maximum densities of up to 2 colonies m^{-2}, *Pteroeides griseum* reaches 6.6 colonies m^{-2} and *Cavernularia pusilla* forms aggregations of up to 4.2 colonies m^{-2}.

Veretillum cynomorium and *Virgularia mirabilis* are other common species with a wide bathymetric distribution and the ability to form mixed or monospecific aggregations. *Veretillum cynomorium* occurs between 10 and 260 m, being generally more common at circalittoral depths, where its density can reach up to 4.2 colonies m^{-2}. Similarly, dense facies of *Virgularia mirabilis* typically occurs in shallow waters, with some isolated records reporting this species down to about 600 m. Many of the Mediterranean sea pens are capable of limited movement, but the ability of *Virgularia mirabilis* to rapidly retract into the sediments allows this species to colonize instable habitats with a high content of gravel sediments.

Finally, *Kophobelemnon stelliferum* and *Funiculina quadrangularis* are known to form mixed or monospecific assemblages on bathyal muds; the first species extends its bathymetric distribution from 70 to 860 m, reaching densities of up to 2 colony m^{-2} in areas characterized by scarce slope.

Funiculina quadrangularis creates one of the most characteristic facies of the upper bathyal, reaching densities of up to 1 colony m^{-2}. It can occur between 40 and 860 m, generally on compact muds characterized by moderate inclination.

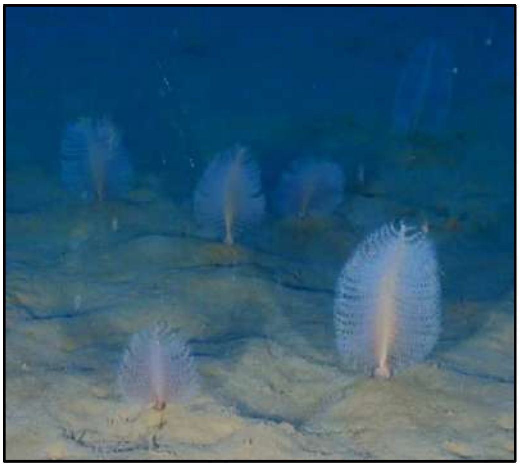
Geographic distribution

The species of the genera *Pennatula*, *Pteroeides*, *Veretillum*, *Virgularia*, *Cavernularia* and *Funiculina* present a wide spatial distribution, being recorded in the whole Mediterranean Sea, from the western to the eastern basin. Records of these species have been reported from the Alboran Sea, North African coasts, Balearic Sea, Gulf of Lion and Corse Island, Ligurian and Tyrrhenian seas, Sicily Channel, Adriatic Sea, Ionian Sea, Aegean Sea, Marmara and towards Lebanon and Egypt coasts. *Pennatula aculeata* represents an exception, being only reported from the coasts of Granada and Gibraltar Strait, from 150 to 300 m. *Kophobelemnon stelliferum* (70-227 m) is mainly distributed in the wester basin (Alboran Sea, Balearic Sea, Ligurian Sea, Tyrrhenian Sea, Sicily Strait and Ionian Sea) with only one record from the Aegean Sea. The remaining species are less common and their distribution results concentrated in a single area: *Protoptilum carpenteri* has been reported only from the Ionian Sea between 240 and 450 m, whereas records of *Crassophyllum thessalonicae* only come from the Aegean Sea (30-60 m). Finally, *Funiculina quadrangularis* is considered a cosmopolitan species of the Mediterranean bathyal muds and it will be considered separately (see sheet ME6.512).

Associated habitats

The ‘Facies with Pennatulacea’ dominated by species of the genus *Pennatula*, *Pteroeides*, *Veretillum and Virgularia* occupies a wide bathymetrical range, being typical of the ‘Coastal detritic bottoms’ (MC3.51), also with rhodoliths (MC3.52), ‘Muddy detritic bottoms’ (MC4.51), ‘Coastal terrigenous muds’ (MC6.51) and ’Offshore terrigenous sticky muds’ (MD6.51). It also extends to the ‘Upper bathyal detritic sand’ (ME5.51), ‘Upper bathyal muds’ (ME6.51) and ‘Lower bathyal muds’ (MF6.51). Within these habitats, the facies with pennatulaceans can be found intermixed or adjacent to several other soft bottoms facies including those dominated by maërl (MC3.521), small sponges (ME5.511, ME6.511), hydrozoans (MC4.511), alcyonaceans (e.g., MC4.512, MC6.511, ME6.513), ceriantharians (MD6.515, ME6.51A), scleractinians (ME5.518, ME6.514), polychaetes (e.g., MC4.514, MD6.512), gastropods (MC6.513), bivalves (e.g., MD6.513, ME5.515, ME6.518), crustacean decapods (ME6.515), brachiopods (MD6.514, ME5.516, ME6.519), bryozoans (MC3.518, ME5.517, ME6.51B), echinoderms (e.g., MC4.515, ME5.514, ME6.516), ascidiaceans (MC4.516), and giant foraminifera (ME6.51C). Finally, pennatulaceans can occur adjacent to hard bottoms, thus can be observed in close proximity or intermixed with typically hard-bottoms facies.

Pennatula rubra on sandy and muddy bottoms
(© S. Canese, ISPRA)



Pennatula rubra aggregation
(© OCEANA)

Related reference habitats

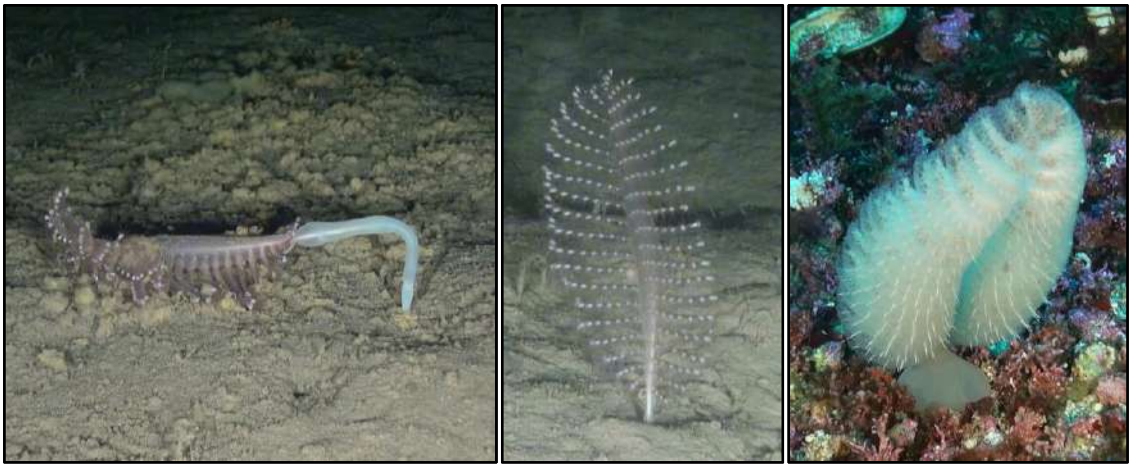
The ‘Facies with Pennatulacea’ is related to other facies dominated by pennatulaceans occurring in the ‘Coastal detritic bottoms with rhodoliths’ (MC3.52), ‘Muddy detritic bottoms’ (MC4.51), ‘Coastal terrigenous muds’ (MC6.51), and in the ‘Offshore terrigenous sticky mud’ (MD6.51).

Possible confusion

Pennatulacean species identification at times can be difficult from ROV footage only. For example, *Pennatula rubra* and *Pennatula phosphorea* are very similar, and can be distinguished only from the polyps’ distribution pattern on the leaves. *Pteroeides griseum* is generally identifiable because of the white, large sclerites protruding among the polyps. *Virgularia mirabilis* can be confused with a small colony of *Funiculina quadrangularis*, but in *Virgularia mirabilis* the polyps cover the axe base, whereas in *Funiculina quadrangularis* this area is naked. Furthermore, *Funiculina quadrangularis* can be confused with *Protoptilum carpenteri*, which occurs in the same habitat, but this latter show a reddish appearance. Finally, some pennatulaceans (e.g., *Veretillum cynomorium*, *Kophobelemnon stelliferum, Cavernularia pusilla*) can be confused with soft corals. In the case of *Kophobelemnon stelliferum*, the large size of its polyps (up to 5 cm in length) departing from the axis generally confirm the species identification.

Typical species and associated communities

Pennatulacean facies of the circalittoral and offshore circalittoral are dominated by monospecific or mixed aggregations of the species *Pennatula rubra* (IUCN Red List VU), *Pennatula phosphorea* (IUCN Red List VU), *Pteroeides griseum* (IUCN Red List VU), *Cavernularia pusilla*, *Veretillum cynomorium*, *Virgularia mirabilis*, *Kophobelemnon stelliferum* and *Funiculina quadrangularis* (IUCN Red List VU), with the two latter species generally displaying a more bathyal distribution. Sea pens may host specialized symbionts, mainly shrimps (e.g., *Periclimenes* sp.), crabs (e.g., *Latreillia elegans*) and ophiuroids. The facies is characterized by other soft-bottom species including small sponges (e.g., *Axinella* spp., *Thenea muricata*, *Rhizaxinella pyrifera*), large hydrozoans (*Lytocarpia myriophyllum*, *Nemertesia antennina*), soft corals (e.g., *Alcyonium palmatum*), scleractinians (e.g., *Caryophyllia smithii*), anemones (e.g., *Mesacmaea mitchellii*), cerianthids (e.g., *Cerianthus membranaceus*), polychaetes (e.g., *Lanice conchilega*, *Aphrodite aculeata),* gastropods (e.g., *Aporrhais* spp., *Galeodea echinophora*), bivalves (e.g., *Nucula sulcata*, *Acanthocardia aculeata*), cephalopods (e.g., *Eledone* spp., *Scaeurgus unicirrhus*), crustacean decapods (e.g., *Alpheus glaber*, *Goneplax rhomboids*, *Liocarcinus* spp., *Medorippe lanata*, *Homola barbata*, *Munida* spp., *Dardanus arrosor*), bryozoans e.g. (*Smittina cervicornis*, *Reteporella* spp.), echinoderms (e.g., *Antedon mediterranea*, *Holothuria* sp., *Parastichopus regalis*, *Ophiura ophiura*, *Anseropoda placenta*, *Astropecten* spp., *Cidaris cidaris*, *Stylocidaris affinis*), and ascidians (*Diazona violacea*). Pennatulacean aggregations also attract fish fauna, including, among others, *Lepidorhombus whiffiagonis*, *Helicolenus dactylopterus*, *Merluccius merluccius* (IUCN Red List VU), *Phycis blennoides* and *Trigla lyra.*



Pennatula phosphorea (left, center panels) and *Pteroeides griseum* (right panel)
(© OCEANA)

Conservation interest and ecological role

Facies dominated by pennatulaceans play a fundamental ecological role increasing structural complexity of otherwise homogeneous habitat. They enhance local biodiversity by attracting a rich associated fauna, including infaunal species, which enhance deep sediment oxygenation. Sea pens may act as substrate and refuge for eggs, larvae and juvenile of invertebrates and fishes, thus resulting essential for the most delicate stages of several species. They also play a fundamental role in the pelagic-benthic coupling by altering the water current flow and retaining nutrients and plankton. For all these reason, facies with pennatulaceans are considered of primary conservation interest.

Economic importance

The economic importance of this facies is mainly linked to its role as a nursery area for several species including some of economic importance (e.g., *Merluccius merluccius*).

Vulnerability and potential threats

Trawling activities represent a major threat to pennatulaceans-dominated habitats. The mechanical impact of the gear increases habitat fragmentation through direct specimen removal. Pennatulaceans generally share the same habitat of some commercially valuable species, including the Norway lobster, the rose shrimp and the European hake and are often observed as bycatch. They have been reported declining in different areas of the Mediterranean Sea characterized by intense bottom trawling, including the Adriatic Sea, the Ligurian Sea and off Algeria. *Pteroeides griseum* has been reported as one of the most frequent bycatch species collected in the Gulf of Lion, with 5.7 specimens collected per trawling hour. The same study reports collection rates of about 0.3 and 0.9 specimens h^{-1} for *Pennatula rubra* and *Pennatula phosphorea*, respectively. All these species has been reported as “frequent” (33-39%) or “very frequent” (72%) in the bottom trawling bycatch between 50 and 200 m depth, whereas between 200 and 400 m depth only *Pennatula rubra* and *Pteroeides griseum* are reported as occasional and frequent, respectively. The withdrawal and re-settling ability of certain species may facilitate their recovery when displaced from the sea floor.

Bottom trawling also produces indirect impacts through sediment resuspension, which reduces the filtering ability of the polyps and changes the granulometry and distribution of organic matter of the seafloor. Longevity and growth rates are not known for the Mediterranean sea pens, but it has been suggested that they may reach a sexual maturity at 5/6 years and may live for over a decade. Considering their exposure to trawling impact, together with their sessile habitus and their long-life cycles, *Pennatula rubra*, *Pennatula phosphorea*, *Pteroeides griseum* and *Funiculina quadrangularis* are classified as ‘Vulnerable’ species in the Mediterranean Sea by the International Union for the Conservation of Nature (IUCN).

Veretillum cynomorium
(© OCEANA)

Protection and management

Pennatulacean aggregations have been recognised as Essential Fish Habitats (EFHs) and Sensitive Habitats (SHs), indicative of Vulnerable Marine Ecosystems (VMEs), by the General Fisheries Commission for the Mediterranean (GFCM). Two Fisheries Restricted Areas (FRAs) have been created where facies dominated by pennatulaceans occur (Gulf of Lion, Jabuka/Pomo Pit). In addition, *Pennatula rubra*, *Pennatula phosphorea*, *Pteroeides griseum*, *Kophobelemnon stelliferum* and *Funiculina quadrangularis* have been assessed by the IUCN in the Anthozoan Red List. All the habitat classification lists provided for the Mediterranean Sea mention the facies with pennatulaceans, and the Mediterranean Action Plan of the Barcelona Convention included the sea pens facies as part of the so-called "Dark Habitats", which deserve protection. Their inclusion in the Natura 2000 network has been proposed by the European Union to protect populations thriving on the continental shelf, slope and seamounts. Finally, a transboundary large marine protected area (LMPA), specifically a no-trawl area, has also been proposed in the Adriatic Sea as a conservation tool able to trigger ecological, socio-economic and political benefits in an intensely-used marine region.

Suitability of the habitat for monitoring

Sea pens have been adopted as indicators of environmental status in the context of the Marine Strategy Framework Directive (2008/56/CE), specifically under the descriptors "biodiversity" and "integrity of the seafloor". In addition, general indications for inventorying and monitoring this habitat are given under RAC/SPA Dark Habitats Action Plan.

Surveys on bottom trawling discard have been widely adopted to infer sea pens presence together with other traditional sampling methods (e.g. grabs and dredges). These techniques, however, can introduce a sampling bias in defining sea pens spatial distribution due to their natural patchiness. For this reason, some authors encourage a non-invasive multi-disciplinary approach. ROV surveys allows to obtain essential information, including occurrence, abundance, morphometry, health status and signs of anthropic impact, and multi-beam echo-sounding and side-scan sonar techniques allow to evaluate the extent and status of the facies as well as the occurrence of trawl scars on the sea bottom.

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Virgularia mirabilis detail of the colony and aggregation on soft bottoms with *Diazona violacea* and *Serranus cabrilla* (© F. Betti, left panel, and S. Canese, ISPRA, right panel)

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Facies with Bryozoa

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.518**
- **EUNIS 2019: MC3513**
- **EUNIS 2007: A5.463**

LOCATION OF THE HABITAT

Zone	Circalittoral, offshore circalittoral, upper bathyal
Nature of the substratum	Soft (coarse), hard (rock, biogenic)
Depth range	25 m to 500+ m
Position	Coastal and open sea
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

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M. Montefalcone, S. Canese, C.N. Bianchi

CIRCALITTORAL

MC3.5 Circalittoral coarse sediment

MC3.51 Coastal detritic bottoms

MC3.518 Facies with Bryozoa

Description of the habitat

This facies is a component of the coastal detritic bottoms and is characterized by the dominance of erect and calcified large bryozoans unattached or fixed to small substrates, which belong to different species in different situations. Only *Turbicellepora avicularis* seems to be a nearly constant element on detritic bottoms. Other common species are *Frondipora verrucosa*, *Pentapora fascialis*, *Smittina cervicornis*, *Myriapora truncata*, *Hornera frondiculata*. The habitat usually develops in the circalittoral zone with dim light conditions on coarse sediments and at depths between 25 m to about 150 m. In the circalittoral this facies is also usually found on rock in the habitat of invertebrate-dominated coralligenous (MC1.519b), also covered by sediment (MC1.519c), on coralligenous outcrops (MC1.526a), and on coralligenous platforms (MC2.51B). Within the coralligenous assemblages erect calcified bryozoans belong to the bioconstructor species of the intermediate layer, whilst encrusting bryozoans are part of the basal layer. Facies with bryozoans are also frequent at greater depths, in the offshore circalittoral zone on invertebrate-dominated rock (MD1.51B), also covered by sediment (MD1.52B), and in the upper bathyal zone on detritic sand (ME5.517). Colonies of erect bryozoans can form plurispecific aggregates and are often associated with concretions and nodules of calcified algae, sciaphilous soft algae, and other invertebrates like hydrozoans, alcyonarians, and ascidians.

Geographic distribution

The facies with Bryozoa is widely distributed in the circalittoral, offshore circalittoral, and upper bathyal zones of the entire Mediterranean.

Associated habitats

This facies can be associated with the habitats of the ‘Coastal detritic bottoms’ (MC3.51), of the ‘Invertebrate-dominated coralligenous’ (MC1.51b, MC1.51c), of the ‘Coralligenous outcrops’ (MC1.52a, MC1.52b), of the ‘Coralligenous platforms’ (MC2.51), of the ‘Offshore circalittoral rock invertebrate-dominated’ (MD1.51, MD1.52), and of the ‘Upper bathyal detritic sand’ (ME5.51). Some examples of associated taxa are Laminariales, Porifera, Hydrozoa, Alcyonacea, Antipatharia, Ceriantharia, Pennatulacea, Zoantharia, Polychaeta, Bivalvia, Crinoidea, Ophiuroidea, Echinoidea, Ascidiacea, Brachiopoda, Scleractinia.

Related reference habitats

Facies with Bryozoa can also be found in the circalittoral zone on ‘Invertebrate-dominated coralligenous’ (MC1.519b), also covered by sediment (MC1.519c), on coralligenous outcrops (MC1.526a), and on ‘Coralligenous platforms’ (MC2.51B). In the offshore circalittoral zone it can be found on ‘Offshore circalittoral rock invertebrate-dominated’ (MD1.51B), also covered by sediment (MD1.52B). In the upper bathyal zone this facies can develop on ‘Upper bathyal detritic sand’ (ME5.517). Facies with calcified bryozoans can also be found in ‘Semi-dark caves and overhangs’ (MC1.536a) and on ‘Upper bathyal mud’ (ME6.51B).

Possible confusion

Facies with Bryozoa cannot be confused with any other habitat. Erect and calcified large bryozoans, often with vivid colours (from egg yellow to orange-red) can be easily identified. The presence of organogenic and bioclastic sediment is a distinctive character of the substrate when the habitat develops on coastal detritic bottoms; however, the substrate could be confused with other soft bottoms, such as ‘Circalittoral sand’ (CM5.5) and ‘Circalittoral mixed sediment’ (MC4.5).

Typical species and associated communities

More than 170 species of bryozoans have been described inhabiting detritic or sandy bottoms, offshore circalittoral rock and coralligenous. The most common erect calcified bryozoans are: *Turbicellepora avicularis*, *Frondipora verrucosa*, *Pentapora fascialis*, *Smittina cervicornis*, *Adeonella calveti*, *Reteporella* spp., *Myriapora truncata*, *Cellaria fistulosa*, *Caberea boryi*, *Tubulipora plumosa*, *Hornera frondiculata*, and *H. Mediterranea* (this latter species has never been found on rock, but it lays free at the surface of soft and detritic bottoms, with the base attached on small substrates). Colonies, which vary in shape and growth-form from branches (often dichotomous) of radially arranged zooids to erect uni- and bi-laminate colonies, sometimes convoluted in a rosette shape, can attain sizes of 5-50 cm in three-dimensions, also creating large agglomerates. The general shape and branching type of erect bryozoan colony are typical and allow a correct identification of the species, even underwater. Examples of encrusting bryozoans include *Schizomavella* spp., *Schizoporella* spp., *Cellepora pumicosa*, *Escharina* spp., and *Beania* spp. Colour of their colonies ranges in the various shades of orange.

Macroalgae, large and erect sponges, pennatulaceans, polychaetes (e.g., *Salmacina dysteri*), bivalves (e.g., *Pecten jacobaeus*), gorgonians, alcyonids, crinoids, ophiurids, echinoids (e.g., *Spatangus purpureus*), crustaceans and tunicates are the most characteristic companion species of facies with bryozoans. Among gorgonians *Eunicella singularis*, which is replaced in turbid waters by *Eunicella verrucosa* and *Leptogorgia sarmentosa*, are the most abundant on detritic bottoms. Further details on the communities associated with coastal detritic bottoms can be found in the sheet MC3.51.

The erect *Hornera frondiculata* (on the left) and the encrusting *Schizomavella* (*Schizomavella*) *mamillata* (on the right) bryozoans (© M. Montefalcone)

Conservation interest and ecological role

Hornera frondiculata and *H. mediterranea* are endemic to the Mediterranean. Erect bryozoans may constitute the first nuclei of a bioconcretioning activity on detritic bottoms, sometimes together with calcareous red algae forming rhodoliths. As other calcified organisms, most bryozoans are bioconstructors, and they act as marine ecosystem engineers and habitat formers. They are among the major animal calcifiers in coralligenous reefs, where they belong to the intermediate layer. Their calcification rates range between 30-300 g $CaCO_3$ $m^{-2}·a^{-1}$ and may reach 1,240 g $CaCO_3$ $m^{-2}·a^{-1}$ for *Pentapora fascialis* in exceptional conditions. They provide biogenic three-dimensional structure, owing to their erect and bushy habitus, for a variety of other marine species, thus increasing the topographic heterogeneity of the seafloor and enhancing the benthic diversity. They are nursery grounds for some juvenile fish species and are associated with commercial fishing grounds. The role of calcified bryozoans is not restricted to living colonies but extend also to the accumulation of dead skeletons in the neighbouring sediments, increasing their content of coarse carbonate fractions, as well as in the deep habitats (e.g., thanatocoenosis). Bryozoans are found in the fossil record since the early Ordovician, and they have a considerable value in palaeoenvironmental interpretation. This habitat has been little studied, and the conservation status of bryozoans is rather uneven, although of important concern.

Economic importance

Calcified bryozoans, especially the erect and large species, provide regulating services, such as carbon cycle, provisioning services through their role in supporting high biodiversity, habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms, and information services, in terms of scientific research and monitoring. To date, the economic value of erect bryozoans has not yet been assessed. Coastal detritic bottoms, in general, are also important fishing areas, particularly for artisanal fishing.

Vulnerability and potential threats

Erect growth forms make bryozoans susceptible to mechanical damage caused by human activities such as anchoring, trawling and derelict fishing gears, sometimes collection or breakage by divers. Eutrophication, pollution, mucilage, and high sedimentation are detrimental to bryozoans, which may also suffer from competition with filamentous and turf algae, and with invasive macroalgae (e.g., *Caulerpa cylindracea*, *Lophocladia lallemandii*). Mortality events of bryozoans have been recorded in coincidence with recent summer heat waves and the ongoing seawater warming trend. Under very high CO_2 conditions, calcification rates of bryozoans are significantly lower. Bryozoans are also highly vulnerable to catastrophic events.

Protection and management

Notwithstanding growing awareness of the threats faced by fragile calcified bryozoans, no specific protection measures have been implemented yet. *Hornera frondiculata* (erroneously cited as *Hornera lichenoides*) is the only bryozoans species listed in the Annex II "Endangered or threatened species" of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention), although it is not clear why it was designated as threatened being a rather common species. Recently, a restoration intervention of *Pentapora fascialis* has been tested, through the recruitment enhancement and the transplantation of adult colonies.

Suitability of the habitat for monitoring

All habitats where bioconstructors occur are defines as priority habitats and thus are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. Erect bryozoans are considered sensitive to human impacts and suitable bioindicators, but species respond differently to pressures. *Myriapora truncata* is the less sensitive, being often the only bryozoans present in highly degraded situations, while *Smittina cervicornis* and *Reteporella grimaldii*, preferring the less polluted environments, are the most sensitive; other species, such as *Pentapora fascialis* and *Adeonella calveti*, were indicated as intermediate between the two groups above. This habitat may be particularly suitable for assessing specific pressures, such as mechanical damage deriving from anchoring and trawling.

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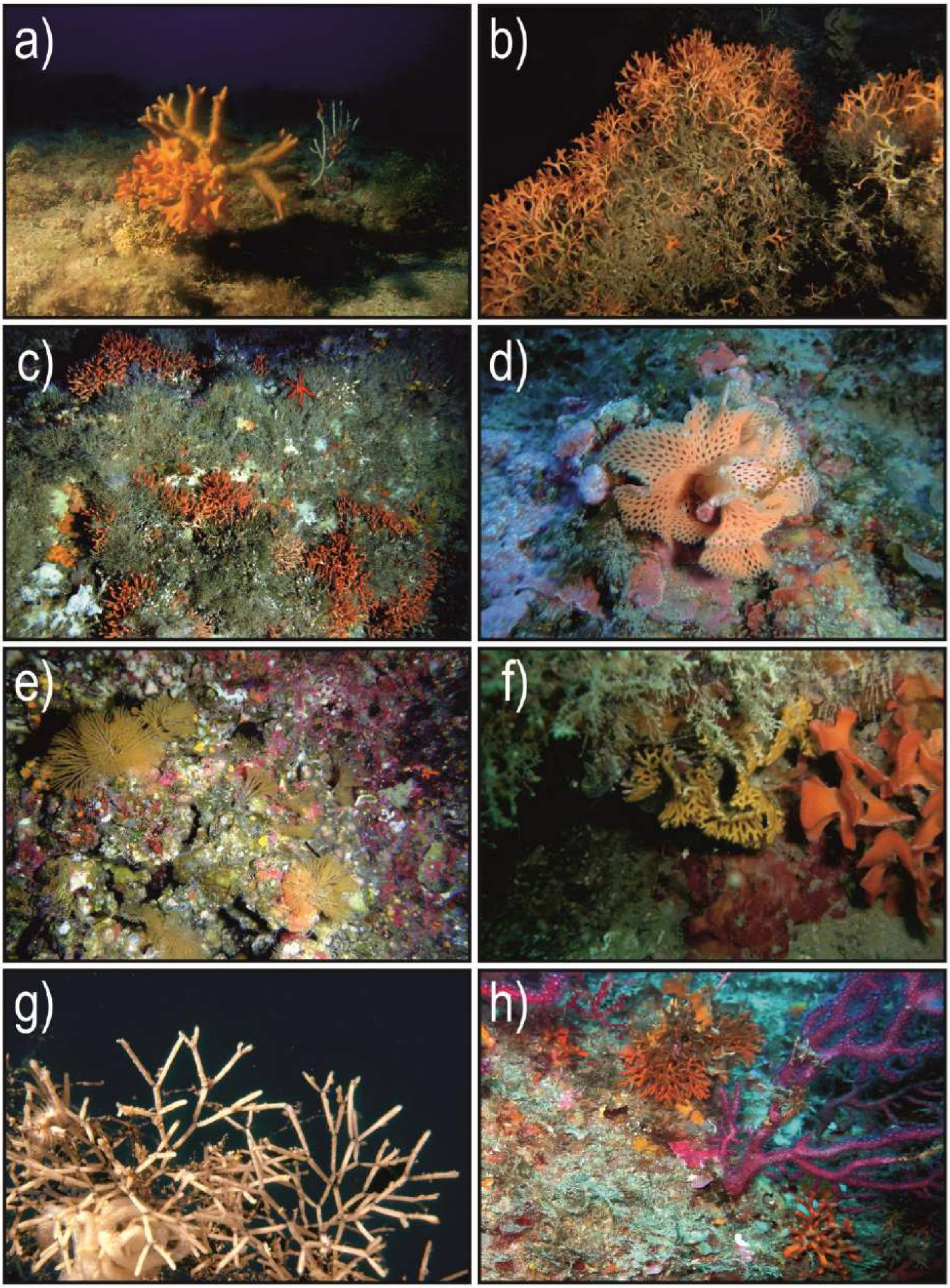

Turbicellepora avicularis and *Pentapora fascialis* on detritic bottom (a); *Pentapora fascialis* (b); *Myriapora truncata* (c); *Reteporella grimaldii* (d); *Caberea boryi* (e); *Frondipora verrucosa* and *Pentapora fascialis* (f); *Cellaria fistulosa* (g); *Miriapora truncata*, *Smittina cervicornis* and *Pentapora fascialis* (h) (a, g © C.N. Bianchi; b, c © S. Canese, ISPRA; d, e, f, h © M. Montefalcone).

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Coastal detritic bottoms with rhodoliths

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.52**
- **EUNIS 2019: MC352, MC3521**
- **EUNIS 2007: A5.516**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (coarse sediment)
Depth range	30 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
L. Piazzi, D. Basso

Photo credits:
L. Piazzi

CIRCALITTORAL

MC3.5 Circalittoral coarse sediment

MC3.52 Coastal detritic bottoms with rhodoliths

Description of the habitat

Rhodolith beds are formed by the accumulation of various species of unattached red nongeniculate calcareous algae (Rhodophyta). They are composed of living and dead thalli and could be found between 30 and 150 m depth in normal marine conditions. They occur in coarse coastal detritic areas under the influence of bottom currents. Different dominant species characterize the Mediterranean rhodolith beds, probably on the basis of biogeography and local environmental conditions. The most common species are *Lithothamnion corallioides*, *Lithothamnion valens, Lithothamnion minervae, Lithophyllum racemus, Phymatolithon calcareum, Spongites fruticulosus*. Differences in the intensity and type of hydrodynamics and species composition can result in differences in the growth form, structure, and shape of rhodoliths that can be summarized into three main morphologies: small and compact pralines, unattached branches (maërl), and large, irregular, boxwork rhodoliths.

Geographic distribution

Rhodolith beds are described throughout the Mediterranean Sea although they have a patchy distribution.

Associated habitats

The habitat is included in the ‘Circalittoral coarse sediment’ (MC3.5). The habitat can have contact with ‘Coralligenous cliffs’ (MC1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coralligenous platforms’ (MC2.51), ‘Deep banks’ (MC1.52c), ‘Coralligenous outcrops’(MC1.52°, b) and ‘Coastal detritic bottoms’ (MC3.51). The habitat may be associated with the ‘Association with maërl’ (MC3.521), ‘Association with *Peyssonnelia* spp.’ (MC3.522), ‘Association with Laminariales’ (MC3.523), ‘Facies with large and erect sponges’ (MC3.524), ‘Facies with Hydrozoa’ (MC3.525), ‘Facies with Alcyonacea’ (MC3.526), ‘Facies with Pennatulacea’ (MC3.527), ‘Facies with Zoantharia’ (MC3.528), and ‘Facies with Ascidiacea’ (MC3.529).

Related reference habitats

‘Coastal detritic bottoms’ (MC3.51), ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), ‘Offshore circalittoral detritic bottoms’ (MD3.51, MD4.51), and ‘Association with maërl or rhodolithes’ (MB3.511, MB3.521).

Possible confusion

No confusion is possible with this habitat.

Typical species and associated communities

Rhodolith beds are known to be biodiversity hotspots, hosting a highly diverse community. The most frequent species of epiflora are the Phaeophyceae *Cystoseira montagnei, Ericaria zosteroides*, *Zanardinia typus, Arthrocladia villosa, Carpomitra costata, Nereia filiformis, Sporochnus pedunculatus*, and the Rhodophyta *Osmundaria volubilis* and *Kallymenia* spp. Sessile fauna includes Alcyonacea (e.g., *Eunicella singularis*), sponges (e.g., *Haliclona fulva Siphonochalina coriacea*, and *Axinella cannabina*) and ascidians (e.g., *Polycarpa mamillaris, Aplidium elegans, Ascidia mentula*). Rhodolith beds host a very diverse and complex mobile assemblages mostly characterized by amphipods, decapods, polychaetes, gastropods, and bivalves.

Conservation interest and ecological role

Rhodolith beds are characterized by a remarkably diverse community as they are important secondary substrates that increase the structural complexity of soft bottoms by providing suitable habitats for many epiphytic and mobile organisms. Rhodolith beds are also important in climate regulation through their role as carbonate production hotspots and deep benthic primary production.

Economic importance

Rhodolith beds are providers of provisional (as essential fish habitats), regulating (through their role as hot-spots of carbonate production and deep benthic primary production) and supporting (as ecosystem engineers fostering complex ecological interactions) ecosystem services. To date the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

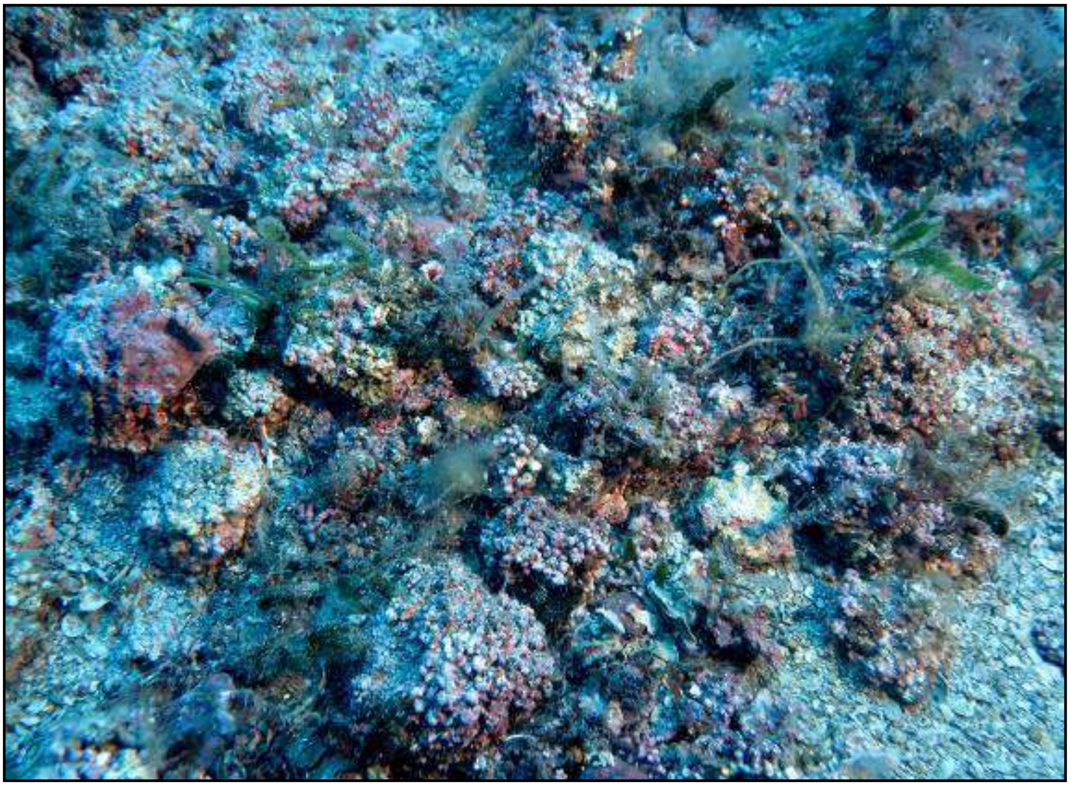
Rhodolith beds may be threatened by physical damage mostly caused by bottom trawling, that can lead to change in species diversity and functional relationships. Other pressures on rhodolith beds include degradation of water quality (i.e., pollution from sewage or from aquaculture effluents), smothering effects resulting from changes in sedimentation rates, ocean warming and acidification. Moreover, the spread of invasive alien species, such as *Womersleyella setacea* and *Caulerpa cylindracea,* may be an insidious threat.

Protection and management

The Habitats Directive includes *Phymatolithon calcareum* and *Lithothamnion corallioides* in Annex V, among those species subject to exploitation and for which Member States have to ensure appropriate management measures. The Council of the European Union 1967/2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, establishes the banning of specific fishing gear on coralligenous or maërl beds. A special plan for the protection of the Mediterranean rhodolith beds is present within the framework of the United Nations Programme Mediterranean Action Plan (UNEP-MAP-RAC/ SPA, 2008). More recently, the Marine Strategy Framework Directive (2008/56/EC) included Rhodolith beds among the habitats to be assessed.

Suitability of the habitat for monitoring

Rhodolith beds are among the habitats which are to be assessed under the Marine Strategy Framework Directive (2008/56/EC) to achieve the Good Ecological Status and they have been included in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). Acoustic methods are currently the most cost-effective technique for mapping rhodolith beds, coupled with ground truth by ROV and box-coring. Information that has been proposed for describing rhodolith beds includes average percent live thalli cover and live cover thickness, live/dead rhodolith ratio, dominant rhodolith morphologies, and identification of the most common and volumetrically important calcareous algal species.



Rhodolith beds (© L. Piazzi)

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Association with maërl

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.521**
- **EUNIS 2019: MC3523**
- **EUNIS 2007: A5.513**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (coarse sediment)
Depth range	30 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

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CIRCALITTORAL

MC3.5 Circalittoral coarse sediment

MC3.52 Coastal detritic bottoms with rhodoliths

MC3.521 Association with maërl

Description of the habitat

Maërl are rhodolith beds composed of non-nucleated, unattached and branched twig-like coralline algae. The characteristic species in the association are *Lithothamnion corallioides* and *Phymatolithon calcareum*.

Geographic distribution

Maërl beds are described throughout the Mediterranean Sea although they have a patchy distribution.

Associated habitats

The Association is included in ‘Coastal detritic bottoms with rhodoliths’ (MC3.52). The habitat can have contact with ‘Coralligenous cliffs’ (MC1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coralligenous platforms’ (MC2.51), ‘Deep banks’ (MC1.52c), and ‘Coastal detritic bottoms’ (MC3.51). The habitat may be associated with ‘Association with *Peyssonnelia* spp.’ (MC3.522), ‘Association with Laminariales’ (MC3.523), ‘Facies with large and erect sponges’ (MC3.524), ‘Facies with Hydrozoa’ (MC3.525), ‘Facies with Alcyonacea’ (MC3.526), ‘Facies with Pennatulacea’ (MC3.527), ‘Facies with Zoantharia’ (MC3.528), ‘Facies with Ascidiacea’ (MC3.529).

Related reference habitats

‘Infralittoral coarse sediment mixed by waves’ (MB3.51), ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), ‘Association with maërl or rhodoliths’ (MB3.511, MB3.521).

Possible confusion

This association can be confused with other rhodolith beds, but maërl are constituted by only branching, twig-like coralline algae.

Typical species and associated communities

Maërl increases the complexity of detritic bottoms leading to greatly diverse assemblages. Maërl provides a surface to which other seaweeds or invertebrates (hydroids, bryozoans) can attach. The maërl bed community is characterized by abundant vagile epifauna. The molluscan community is composed by suspension feeders, herbivores and carnivores of both circalittoral hard and soft bottom (e.g., *Haminoea hydatis, Gibberula jansseni*, and *Modiolula phaseolina*). Small decapods, amphipods, polychaetes, and echinoderms may be also abundant in maërl beds.

Conservation interest and ecological role

Maërl beds are characterized by a remarkably diverse community as they are important secondary substrates that increase the structural complexity of soft bottoms by providing suitable habitats for many epiphytic and mobile organisms. Maërl beds are also important in climate regulation through their role as carbonate production hotspots and deep benthic primary production.

Economic importance

Maërl beds are providers of provisional (as essential fish habitats), regulating (through their role as hot-spots of carbonate production and deep benthic primary production) and supporting (as ecosystem engineers fostering complex ecological interactions) ecosystem services. To date the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

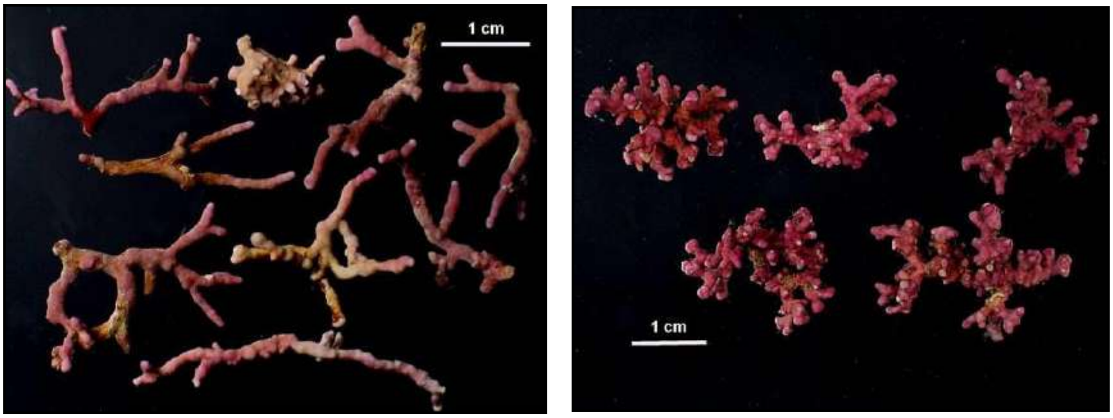
Maërl beds may be threatened by physical damage mostly caused by bottom trawling, degradation of water quality (i.e., pollution from sewage or from aquaculture effluents), the spread of invasive alien species, smothering effects resulting from changes in sedimentation rates, ocean warming, and acidification.

Protection and management

The Habitats Directive includes *Phymatolithon calcareum* and *Lithothamnion corallioides* in Annex V, among those species subject to exploitation and for which Member States have to ensure appropriate management measures. The Council of the European Union 1967/2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, establishes the banning of specific fishing gear on coralligenous or maërl beds. A special plan for the protection of the Mediterranean Maërl beds is present within the framework of the United Nations Programme Mediterranean Action Plan (UNEP-MAP/RAC-SPA).

Suitability of the habitat for monitoring

Maërl beds are among the habitats which are to be assessed under the Marine Strategy Framework Directive (2008/56/EC) to achieve the Good Ecological Status and they have been included in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). Acoustic methods are currently the most cost-effective technique for mapping Maërl beds, coupled with ground truth by ROV and box-coring.



Lithothamnion corallioides and *Phymatolithon calcareum* (© G. Sartoni)

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To be added

Association with *Peyssonnelia* spp.

Reference codes for identification:

- **BARCELONA CONVENTION: MC3.522**
- **EUNIS 2019: MC3522**
- **EUNIS 2007: A5.52H**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (coarse sediment)
Depth range	30 m to 70 m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
G. Sartoni

CIRCALITTORAL

MC3.5 Circalittoral coarse sediment

MC3.52 Coastal detritic bottoms with rhodoliths

MC3.522 Association with *Peyssonnelia* spp.

Description of the habitat

The association consists of rhodolith beds composed of free-living *Peyssonnelia* spp. normally developing on detritic bottoms from 30 to 70 m depth. The most common calcified species are *Peyssonnelia rosa-marina* and *P. inamoena.* Different species may become dominant as a response to slightly different environmental conditions.

Geographic distribution

Free *Peyssonnelia* beds are described throughout the Mediterranean Sea although they have a patchy distribution.

Associated habitats

The association is included in ‘the Coastal detritic bottoms with rhodoliths’ (MC3.52) and it can have contact with ‘Coralligenous cliffs’ (MC1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coralligenous platforms’ (MC2.51), and ‘Coastal detritic bottoms’ (MC3.51). The habitat may be associated with ‘Association with maërl’ (MC3.521), ‘Association with Laminariales’ (MC3.523), ‘Facies with large and erect sponges’ (MC3.524), ‘Facies with Hydrozoa’ (MC3.525), ‘Facies with Alcyonacea’ (MC3.526), ‘Facies with Pennatulacea’ (MC3.527), ‘Facies with Zoantharia’ (MC3.528), ‘Facies with Ascidiacea’ (MC3.529).

Related reference habitats

‘Coastal detritic bottoms with rhodoliths’ (MC3.52), ‘Association with maërl’ (MC3.521), ‘Association with maërl or rhodoliths’ (MB3.511, MB3.521).

Possible confusion

The association can be confused with other rhodolith beds, but it is dominated by free-living *Peyssonnelia* species.

Typical species and associated communities

Several free non-calcified *Peyssonnelia* species, such as *P. rubra, P. squamaria, P. bornetii*, and *P. harveyana* may occur in the assemblages.

Free *Peyssonnelia* beds increase the complexity of detritic bottoms leading to highly diverse communities. High species richness has been described in associated macroalgal assemblages while faunal assemblages are less well known.

Conservation interest and ecological role

Peyssonnelia spp. are important secondary substrates that increase the structural complexity of soft bottoms by providing suitable habitats for many epiphytic and mobile organisms. *Peyssonnelia* spp. beds are also important in climate regulation through their role as carbonate production hotspots and deep benthic primary production.

Economic importance

Peyssonnelia spp. beds are providers of provisional (as essential fish habitats), regulating (through their role as hot-spots of carbonate production and deep benthic primary production) and supporting (as ecosystem engineers fostering complex ecological interactions) ecosystem services. To date the economic value of the habitat has not been evaluated.

Vulnerability and potential threats

Peyssonnelia spp. beds may be threatened by physical damage mostly caused by bottom trawling, degradation of water quality (i.e., pollution from sewage or from aquaculture effluents), the spread of invasive alien species, smothering effects resulting from changes in sedimentation rates, ocean warming and acidification.

Protection and management

Peyssonnelia spp. association is included in ‘Coastal detritic bottoms with rhodoliths’ (MC3.52), thus it is protected against fishing by the Council of the European Union 1967/2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea. A special plan for the protection of the Mediterranean Maërl beds is present within the framework of the United Nations Programme Mediterranean Action Plan (UNEP/MAP-RAC/ SPA).

Suitability of the habitat for monitoring

Peyssonnelia spp. beds are among the habitats which are to be assessed under the Marine Strategy Framework Directive (2008/56/EC) to achieve the Good Ecological Status and they have been included in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). Acoustic methods are currently the most cost-effective technique for mapping Maërl beds, coupled with ground truth by ROV and box-coring.

Peyssonnelia rosa-marina f. *saxicola* and f. *rosa-marina* (© G. Sartoni)

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Muddy detritic bottoms

Reference codes for identification:

- **BARCELONA CONVENTION: MC4.51**
- **EUNIS 2019: MC451**
- **EUNIS 2007: A5.38**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (mud, coarse sediment)
Depth range	30 m to 150 m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
M. Di Fiore, A. Tommasi

CIRCALITTORAL

MC4.5 Circalittoral mixed sediment

MC4.51 Muddy detritic bottoms

Description of the habitat

Muddy detritic bottoms are characterized by the presence of both fine sediment and organogenous/bioclastic sediment. The habitat develops in areas where a detritus bottom is covered by mud formed by terrigenous deposits from rivers. Gravel, sand and mud are mixed in varying amounts, but mud is always predominant. Sedimentation is slow enough to allow the development of sessile epifauna.

Geographic distribution

Muddy detritic bottoms are present throughout the Mediterranean Sea.

Associated habitats

The habitat is included in ‘Circalittoral mixed sediment’ (MC4.5). The habitat can have contact with ‘Coralligenous cliffs’ (MC1.51), ‘*Posidonia oceanica* meadows’ (MB2.54), ‘Coralligenous platforms’ (MC2.51), ‘Deep banks’ (MC1.52c), and ‘Coralligenous outcrops’ (MC1.52a, b). The habitat may be associated with the Facies with Hydrozoa’ (MC4.511), ‘Facies with Alcyonacea’ (MC4.512), ‘Facies with Pennatulacea’ (MC4.513), ‘Facies with Polychaeta’ (MC4.514), ‘Facies with Ophiuroidea’ (MC4.515), and ‘Facies with Ascidiacea’ (MC4.516).

Related reference habitats

‘Coastal detritic bottoms’ (MC3.51), ‘Coastal detritic bottoms with rhodoliths’ (MC3.52), ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52), and ‘Offshore circalittoral detritic bottoms’ (MD3.51, MD4.51).

Possible confusion

The habitat may be confused with other soft bottoms, such as ‘Circalittoral sand’ (MC5.5) ‘Circalittoral mud sediment’ (MC6.5), and ‘Circalittoral coarse sediment’ (MC3.5). The presence of both fine sediment and organogenous/bioclastic sediment is a distinctive character of the habitat.

Typical species and associated communities

The habitat is characterized by detritic muddy and mixed soft bottom organisms. Characteristic taxa of this habitat are represented by Hydrozoa (e.g., *Lytocarpia myriophyllum, Nemertesia* spp.), Alcyonacea (e.g., *Alcyonium* spp., *Leptogorgia sarmentosa, Spinimuricea* spp.), Pennatulacea (e.g., *Veretillum cynomorium, Ptereoides* spp.), Echinoidea (e.g., *Cidaris cidaris*), and Ascidiacea. The assemblages also include the molluscs *Serratina serrata, Turritelllinella tricarinata, Abra prismatica, Nucula nitidosa,* the polychaetes *Aphrodita aculeata, Polyodontes maxillosus, Leiocapitella dollfusi,* the Sipunculida *Golfingia elongata*, the Isopoda *Natatolana neglecta*, the Ophiuroidea *Ophiothrix* spp. and the Holothuridae *Pseudothyone raphanus*.

Conservation interest and ecological role

The habitat includes facies characterized by distinctive and ecologically important taxa and it is an important fishing area.

Economic importance

The habitat is an important fishing area, but to date its economic value has not been assessed yet.

Vulnerability and potential threats

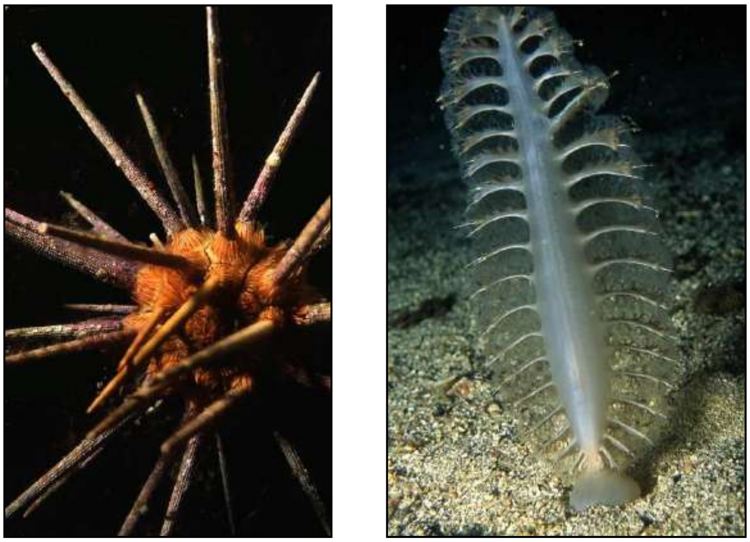
Mixed detritic bottoms may be altered by increased organic matter and river pollutants or by flooding, that can directly affect characteristic species in the assemblages. The habitat may be threatened by physical damage caused primarily by trawling.

Protection and management

The habitat is not protected and it is assessed as ‘Data Deficient’ by the European IUCN Red List.

Suitability of the habitat for monitoring

The macro-zoobenthos of Mediterranean soft bottoms is considered a useful tool in monitoring programs and impact assessment studies and should be assessed according to the European Directives. The habitat was mostly studied through the analysis of samples taken from box-corers or grabs. Moreover, the use of remotely operated vehicles may allow the study of epifaunal assemblages.



Cidaris cidaris (left) and *Ptereoides spinosa* (right) (© A. Tommasi)

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Coastal terrigenous mud

Reference codes for identification:

- **BARCELONA CONVENTION: MC6.51**
- **EUNIS 2019: MC651**
- **EUNIS 2007: A5.39**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (mud)
Depth range	30 m to 150 m
Position	Coastal
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
A. Tommasi, ISPRA

CIRCALITTORAL

MC6.5 Circalittoral mud sediment

MC6.51 Coastal terrigenous mud

Description of the habitat

The habitat is characterized by a muddy, more or less clayey sediment, mostly of fluvial origin. The development of sessile epifauna is rarer than in other soft bottoms.

Geographic distribution

Coastal terrigenous mud bottoms are present throughout the Mediterranean Sea.

Associated habitats

The habitat is included in ‘Circalittoral mud’ (MC6.5). The habitat can have contact with ‘Coralligenous cliffs’ (MC1.51), ‘Coralligenous platforms’ (MC2.51), ‘Deep banks’ (MC1.52c), and ‘Coralligenous outcrops’(MC1.52a, b). Associated habitats may be ‘Facies with Alcyonacea and Holothuroidea’ (MC6.511), ‘Facies with Pennatulacea’ (MC6.512), and ‘Facies with Gastropoda’ (MC6.513).

Related reference habitats

This habitat, and its associated communities, can be related to ‘Muddy detritic bottoms’ (MC4.51), ‘Offshore terrigenous sticky mud’ (MD6.51), ‘Upper bathyal mud’ (ME6.51), ‘Lower bathyal sandy mud’ (MF6.51), and ‘Abyssal mud’ (MG6.51).

Possible confusion

The habitat could be confused with other soft bottoms, especially ‘Muddy detritic bottoms’ (MC4.51). The sediment that composes this habitat is always pure mud, more or less clayey.

Typical species and associated communities

Several taxa are considered as characteristic of this habitat, such as Alcyonacea (e.g., *Alcyonium* spp.), Holothuroidea (e.g., *Parastichopus.* spp., *Holoturia tubulosa, Oestergrenia digitata*), Pennatulacea (e.g., *Pennatula* spp.*, Virgularia mirabilis*), and Gastropoda (e.g., *Turritella* spp.). The assemblage also includes the polychaetes *Sternaspis scutata* and *Aphrodita aculeata*, the bivalves *Acanthocardia paucicostata*, the crustacean *Medorippe lanata* and *Goneplax rhomboides*.

Conservation interest and ecological role

The habitat includes facies characterized by particular and ecologically important taxa and it is an important fishing area.

Economic importance

The habitat is an important fishing area, but to date its economic value has not been assessed yet.

Vulnerability and potential threats

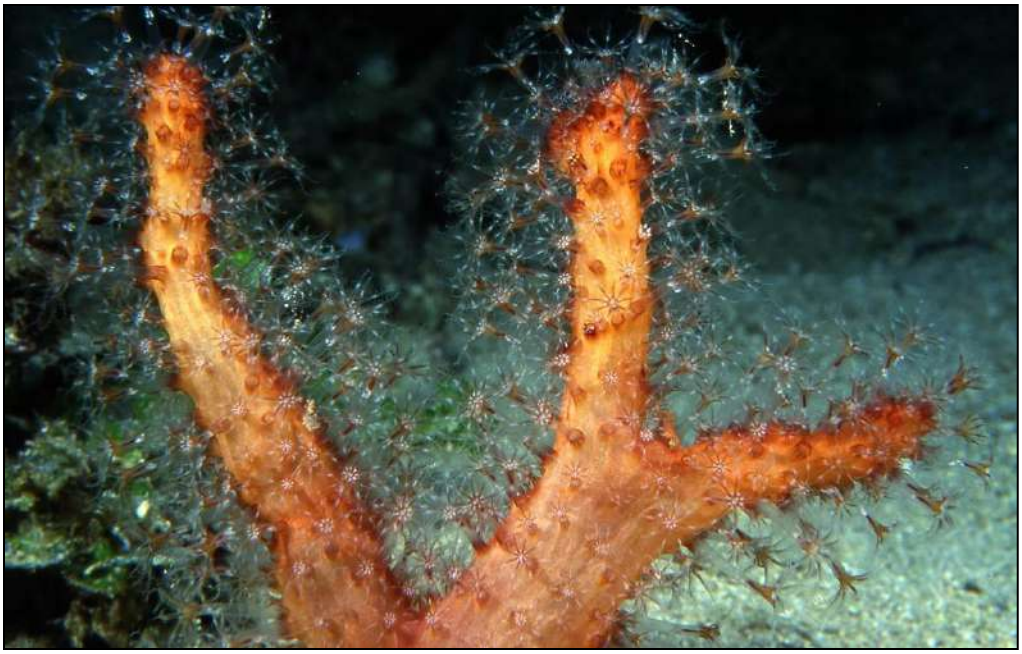
The habitat is subjected to impacts such as coastal pollution, coastal development, fishing and sediment contamination. The combined effects of urbanization, fisheries, aquaculture and sedimentation have led to a shift in the associated species assemblages.

Protection and management

The habitat is not protected, and it is assessed as ‘Data Deficient’ in the European IUCN Red List.

Suitability of the habitat for monitoring

The macro-zoobenthos of Mediterranean soft bottoms is considered a useful tool in monitoring programs and impact evaluation studies and should be assessed according to European Directives. The habitat was mostly studied through the analysis of samples taken from box-corers or grabs. Moreover, the use of remotely operated vehicles (ROVs) may allow the study of epifaunal assemblages.



Alcyonum palmatum (© A. Tommasi)

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Facies with Alcyonacea and Holothuroidea

Reference codes for identification:

- **BARCELONA CONVENTION: MC6.511**
- **EUNIS 2017: MC6514**
- **EUNIS 2007: A5.393**

LOCATION OF THE HABITAT

Zone	Circalittoral
Nature of the substratum	Soft (mud and mixed sediment)
Depth range	25 m to 150 m
Position	Coastal
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 22°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

Photo credits:
M. Bo, S. Canese (ISPRA), F. Betti

CIRCALITTORAL

MC6.5 Circalittoral mud sediment

MC6.51 Coastal terrigenous mud

MC6.511 Facies with Alcyonacea and Holothuroidea

Description of the habitat

This facies occurs in coastal terrigenous mud and in muddy detritic bottoms (MC4.512) and is dominated by arborescent and long-lived alcyonacean species, such as the gorgonians *Spinimuricea* spp. and the alcyonids *Alcyonium palmatum* and *Paralcyonium spinulosum*, often associated with *Holoturoidea* species. The habitat develops in the circalittoral zone at depths between 25 m to about 150 m on bottoms characterized by mud or mixed sediment.

Geographic distribution

The facies with Alcyonacea and Holothuroidea can potentially be distributed wherever in the circalittoral zone of the Mediterranean Sea where terrigenous mud and muddy detritic bottoms are present.

Associated habitats

This habitat can be associated with all the other facies included in the habitats ‘Muddy detritic bottoms’ (MC4.51) and ‘Coastal terrigenous mud’ (MC6.51), i.e. facies with Hydrozoa, Pennatulacea, Polychaeta, Ophiuroidea, Ascidiacea, Gastropoda. The habitat may have contact with the habitats of coralligenous (MC1.51, MC1.52a, MC1.52b, MC2.51), of deep banks (MC1.52c), and of coastal detritic bottoms (MC3.51, MC3.52).

Related reference habitats

Facies with Alcyonacea and Holothuroidea is a typical habitat of muddy detritic bottoms and of coastal terrigenous mud, difficulty found elsewhere.

Possible confusion

Facies with Alcyonacea and Holothuroidea on mud or muddy detritic bottom cannot be confused with any other habitat.

Typical species and associated communities

Gorgonians, alcyonids and holoturians are the typical elements of this habitat. Among gorgonians *Spinimuricea klavereni* is the most abundant sea fan species in this habitat. Its colonies are low branched, and often with a single whitish axis that is generally attached to stones or shell on muddy bottoms; it can be found from the Western Mediterranean to the Alboran Sea. The congeneric *Spinimuricea atlantica* is rarer, which is differentiated from *S. klavereni* only by more ramified aspect of colonies and presence of ramified sclerites in the coenenchyme. Among alcyonids, the colonial soft-corals *Alcyonium palmatum* and *Paralcyonium spinulosum* are common. *A. palmatum* forms clumps of pink, brown-red to brown-orange fleshy masses of finger-like lobes (usually named 'dead man's fingers'), and its colony can reach up to 50 cm. The colony surface is entirely covered by whitish polyps. Colonies of *P. spinulosum* vary between 2 and 10 cm, and its size increases with depth. The trunk is retractable and its colour is whitish or translucent pinkish with conspicuous white sclerites; polyps are white and distributed over the entire length of the trunk. Typical holothurian species are *Parastichopus regalis* (its colour is variable, from brown with nuance of yellow to red, the sides being constellated with maculae possible blanches, up to 35 cm in length), *Oestergrenia digitata* (its colour is pink or red-brown, sometimes purple, up to 30 cm in length), *Holothuria tubulosa* (its general colour is a shade of brown and the surface is covered with numerous dark-coloured, conical, thorn-like papillae, up to 45 cm in length).

Due to the heterogeneous nature of the seabed (mud, sand, gravel, organogenic detritus), rich communities can develop, which are often very diverse. The associated community includes infaunal polychaetes, sipunculids, echinoderms, bivalves, and burrowing anemones such as *Cerianthus* spp. When hard substrates are available (shell debris and stones), the surface enables epifaunal species to become established, particularly hydroids. Pennatulaceans, ophiurans, ascidians, molluscs, and crustaceans are also common associated elements to this habitat.

Conservation interest and ecological role

Spinimuricea klavereni is endemic to the Mediterranean Sea, but information on its biology and ecology is very limited. Arborescent organisms promote morphological complexity and functioning of marine habitats. Long-lived erect Alcyonacea act as marine ecosystem engineers and habitat formers, as they plays a significant role in benthic-pelagic coupling and generate three-dimensional space and habitat for many mobile invertebrates, thus enhancing biodiversity. *S. klavereni* is considered an opportunistic gorgonian with a high tolerance to anthropogenic disturbances, able to recover more quickly from impacts than other slow-growing, long-lived gorgonians such as *Paramuricea clavata* or *Eunicella cavolini*. Sea cucumbers have an important ecological role: they reduce the organic load while excreting inorganic nitrogen and phosphorus, playing major roles in nutrient recycling and enhancing the productivity of the ecosystem. Despite their ecological and economic importance, information on holothurians biology and ecology is scarce.

Economic importance

Through its role in supporting biodiversity, the facies with Alcyonacea and Holothuroidea offers provisioning services to humans, such as materials and genetic resources availability, and habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms. Coastal terrigenous mud and muddy detritic bottoms are important fishing areas. Sea cucumbers are expensive seafood product in many markets. To date, the economic value of the habitat 'Facies with Alcyonacea and Holothuroidea' has not been assessed yet.

Vulnerability and potential threats

Erect Alcyonacea are long-lived, slow growing and slow recruiting species and display a low resilience to human pressures. Assemblages are particularly damaged by fishing gears, trawling and anchoring and are sensitive to entanglement by mucilage filaments. Sea cucumbers are used for food in some countries and are object of commercial fishery, and they are also often collected by divers.

Protection and management

Nevertheless the growing awareness of the threats due to direct mechanical damages, no specific protection measures have been implemented yet for this habitat. *Spinimuricea klaverini* is listed as 'Data Deficient' in the IUCN Red List.

Suitability of the habitat for monitoring

The macro-zoobenthos of the Mediterranean soft bottoms is considered a useful tool in monitoring programs and impact assessment studies and is usually assessed according to the European Directives (see also sheet MC3.51). The long-term persistence and easy recognition of this habitat make it particularly suitable for monitoring, and for assessing specific pressures, such as mechanical damage by trawling and pollution. Recently, a photographic method has been proposed to evaluate the ecological quality of detritic habitats, which among others considers the average density of macro-invertebrates (e.g., Holothuroidea, Cnidaria) and could be applied also on the habitats of coastal terrigenous mud and muddy detritic bottoms.

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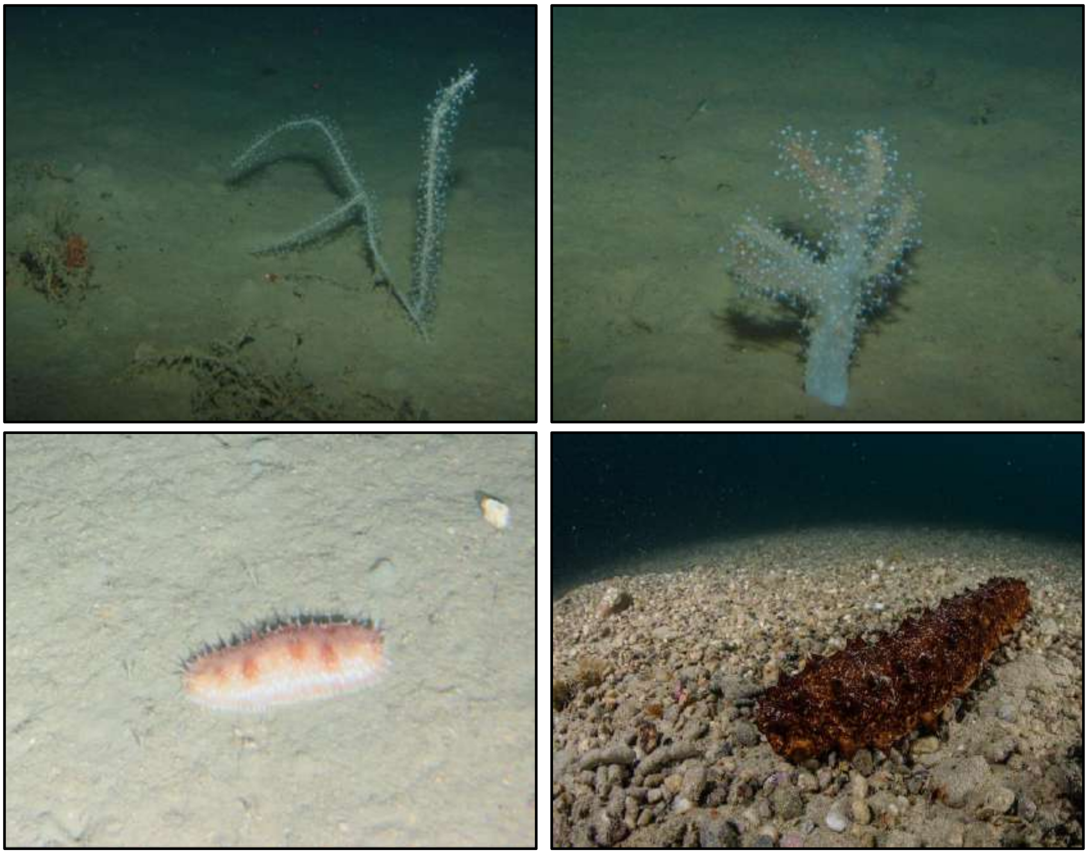

The gorgonian *Spinimuricea klavereni* (upper left panel © S. Canese, ISPRA), the alcyonid *Alcyonium palmatum* (upper right panel © S. Canese, ISPRA), the holothurian *Parastichopus regalis* (lower left panel © M. Bo), and the holothurian *Holothuria tubulosa* (lower right panel © F. Betti)


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Facies with Antipatharia

Reference codes for identification:

- **BARCELONA CONVENTION: MD1.514, MD1.524**
- **EUNIS 2019: MD151, MC151F (partim)**
- **EUNIS 2007: A4.1, A4.2, A4.3**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Hard (rock)
Depth range	(30)-50 m up to ~600 m
Position	Coastal, open sea (continental shelf, shelf edge, slope, canyons, seamounts)
Hydrodynamic conditions	Moderate to strong
Salinity	Between 36 and 39
Temperature	13 to 16°C
Suitability for monitoring	Yes

Authors:
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OFFSHORE CIRCALITTORAL

MD1.5 Offshore circalittoral rock

MD1.51 Offshore circalittoral rock invertebrate-dominated, MD1.52 Offshore circalittoral rock invertebrate-dominated covered by sediment

MD1.514, MD1.524 Facies with Antipatharia

Description of the habitat

This facies, dominated by the arborescent black coral *Antipathella subpinnata*, occurs mainly on sub-horizonal or gently sloping hardgrounds (2-30°) (rarely sub-vertical). In the shallower portion of its distribution it can be found also on rocks with coralline-cover. This species occurs as small, isolated patches or dense forests, monospecific or intermixed with other habitat-forming alcyonaceans and antipatharians. The largest forests are generally found on elevated rocky reliefs (e.g., pinnacles, outcrops, boulders) exposed to moderate or strong currents. Here colonies can grow up to 150 cm high (usually around 60-70 cm) and may show high densities (up to 7 colonies m^{-2}), with standing crops of thousands of colonies. The dense canopy forms a highly three-dimensional environment. On offshore rocky outcrops subjected to high silting levels (>60%), *Antipathella subpinnata* often occurs as loosely branched, scattered specimens up to 30-40 cm high. It is a stenothermal species living between 13-15°C, with the shallower populations able to withstand plumes of summer water at 16°C. The main factors driving the distribution and the structure of *Antipathella subpinnata* forests are the availability of rock, dim light or darkness, currents (minimum of 0.08 m sec^{-1}), moderate to light inclination, low to moderate silting, trophic supply, biotic interactions with other habitat-formers, and fishing intensity.

Similarly to *Antipathella subpinnata*, also *Parantipathes larix* shows a bathymetric optimum of distribution in the offshore circalittoral rocky habitats, with the possibility, although more rare, to form dense monospecific forests (up to 4 colonies m^{-2} and on average covering 30 m^2 of seafloor) both on the smooth flanks (10-35°) of small outcropping rocks (5-15 m high) and sub-outcropping rocky slopes subjected to high sedimentation (at times related to land input). Small patches are known from pluri-specific forests intermixed with other antipatharians and gorgonians. The canopy formed by *Parantipathes larix* colonies is about 100 cm high, even if colonies as tall as 240 cm are known. Colonies are often monopodial or poorly branched, with a bottle-brush morphology, creating a less three-dimensional habitat, however highly branched colonies have been observed, probably in less hydrodynamic sites. Differently from *Antipathella subpinnata*, this species seems to better tolerate high silting levels.

Geographic distribution

Antipathella subpinnata is an Atlanto-Mediterranean species. Large populations are known from the Macaronesian area, where however the cogeneric *Antipathella wollastoni* is dominant. The greatest part of the global population is found in the Mediterranean basin, where this species is found throughout the area from about 50 m to about 600 m, but mainly between 60-150 m. An exceptionally shallow record is known from the Chafarinas Islands (Alboran Sea) (one colony at 32 m). Forests are known from the Alboran Sea, North African coasts, Balearic Sea, Gulf of Lion, Ligurian and Tyrrhenian seas, Sicily Channel, Adriatic and Ionian seas, and Aegean Sea. Overall, is considered one of the most common facies of the western Mediterranean mesophotic zone, both along the continental platform, canyons and seamounts' summits. Dense populations have been reported also on iron wrecks. Isolated colonies can be found on other materials (e.g. concrete).

Parantipathes larix is also an Atlanto-Mediterranean species, with the majority of the populations found in the Mediterranean basin. It has been reported from 100 m to about 500 m with a similar geographic distribution to *Antipathella subpinnata*. Deeper records of *Parantipathes* (500-2000 m depth) are currently under taxonomic investigation because they might be attributed to a deep Atlantic congeneric species.

Associated habitats

Facies with *Antipathella subpinnata* are commonly found in the 'Offshore circalittoral rock invertebrate-dominated' habitat (MD1.51) as distinct forests, as well as intermixed or adjacent to facies with large and erect sponges (M1.512), alcyonaceans (MD1.513), and scleractinians (MD1.515). The understory of the coral canopy, depending on the silt cover, may hosts 'Facies with small sponges' (MD1.511), small alcyonaceans (MD1.513), as well as scleractinians (MD1.515), polychaetes (MD1.518), bivalves (MD1.519), brachiopods (MD1.51A), and bryozoans (MD1.51B). Adjacent detritic, mixed, sandy or muddy sediments commonly host 'Facies with Pennatulacea' (MD6.511), 'Facies with Bivalvia' (MD6.513), and 'Facies with Ceriantharia' (MD6.515). Similar associations are observed over coralligenous outcrops and coralligenous deep banks, where antipatharians (*Antipathella subpinnata* and *Parantipathes larix*) can be adjacent or intermixed with numerous invertebrates (MC1.521a, MC1.522a, MC1.522c, MC1.523a, MC1.523c, MC1.525a, MC1.526a) depending on the silting level. Finally, facies dominated by *Antipathella subpinnata* and *Parantipathes larix* (and other black corals) can be occasionally found also over 'Upper bathyal rock invertebrate-dominated' (ME1.51) and 'Upper bathyal biogenic habitat' (ME2.5).

Related reference habitats

The 'Facies with Antipatharia' described here shares the same characteristics of the antipatharians-dominated habitats found on deep offshore circalittoral banks (MD1.531), coralligenous outcrops found along the continental shelf (MC1.524a), also covered by sediment (MC1.524b), and circalittoral deep banks (MC1.521c).

Possible confusion

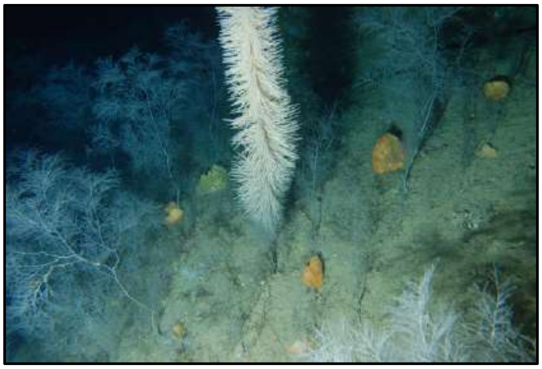
The facies dominated by *Antipathella subpinnata* is easily distinguishable both from the forests of *Parantipathes larix* (bottle-brush morphology) and from those dominated by *Leiopathes glaberrima* (sparsely branched, with larger polyps), although the arborescent morphology of this latter species, coupled to its occasionally white phenotype, and the fact that they can be intermixed, may lead to mis-identification with *Antipathella subpinnata*, especially from ROV images obtained from a certain distance. Both *Leiopathes glaberrima* and *Antipathes dichotoma* (this latter characterized by opaque yellow, large polyps and long, loose flexible branches) generally thrive at major depths (see sheet ME1.513), with *Antipathes dichotoma* never observed forming dense, exclusive forests. *Antipathella wollastoni* is not a possible source of confusion in the Mediterranean context due to its rarity (few records near the Gibraltar Strait), morphology (dense ramifications and orange coloration) and generally shallower distribution. No alcyonaceans can be confused with *Antipathella subpinnata*, being most of the known white gorgonian species smaller and fan-shaped. Traditionally, the parasitic zoanthid *Savalia savaglia* (MD1.517) has been referred to as 'false black coral', and may be mis-identified for *Antipathella subpinnata* by non expert; its bathymetric distribution, however, only minimally overlaps with that of the black coral and its morphological and ecological characteristics are clearly different.

Typical species and associated communities

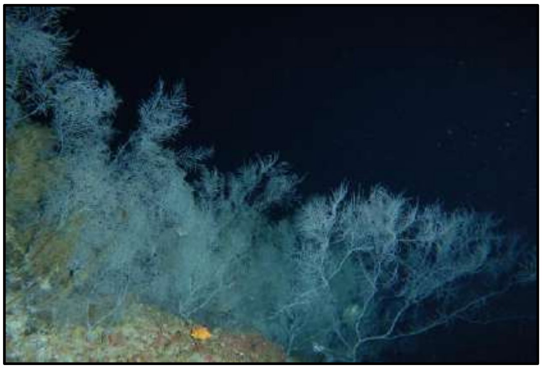
Forests of *Antipathella subpinnata* (Annex II SPA/BD, Annex III Bern, IUCN Red List NT) may be monospecific or, as frequently happens in the Mediterranean Sea, are mixed with gorgonians; in particular, within the coralligenous habitat, this black coral has been recorded within dense forests of *Paramuricea clavata* and *Eunicella cavolinii* together with sponges (for example *Axinellae* spp., *Haliclona mediterranea*, *Aplysina aerophoba*) and bryozoans (e.g., *Myriapora truncata*). At deeper depths, this facies has been recorded on rocky outcrops together with *Antipathes dichotoma* (Annex II SPA/BD, Annex III Bern, IUCN Red List NT), *Parantipathes larix* (Annex II SPA/BD, Annex III Bern, IUCN Red List NT), *Leiopathes glaberrima* (Annex II SPA/BD, Annex III Bern, IUCN Red List EN), the scleractinian *Dendrophyllia cornigera* (Annex II SPA/BD, IUCN Red List EN), large-sized gorgonians as *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Acanthogorgia hirsuta*, *Viminella flagellum* and various small-sized alcyonaceans (*Corallium rubrum* (Annex III SPA/BD, Bern, IUCN Red List EN, Habitat Directive), *Villogorgia bebrycoides*, *Bebryce mollis*, *Muriceides lepida*, *Chironephtya mediterranea*). Intermixed forests usually show a higher abundance of alcyonaceans with respect to black corals. Among other filter-feeders are reported also *Pachastrella monilifera*, *Poecillastra compressa*, *Diazona violacea*, *Halocynthia papillosa*, and *Sabella pavonina*.

Antipathella subpinnata is known to host a rich and diverse microbiome, showing a variability depending on the local environmental conditions and the season, supporting an ability to acclimate to environmental changes. The colonies host several species of epibionts generally organized in large masses settled on the dead branches. The most common species are the serpulids *Filograna* spp., hydroids, the bivalve *Pteria hirundo*, the bryozoans *Schizoporella* spp., *Turbicellepora avicularis* and *Pentapora fascialis*, the ascidian *Clavelina* dellavallei, and occasionally some macroalgae. Large vagile species move in the forest's understory, such as *Octopus vulgaris*, *Neomaja goltziana*, *Palinurus elephas*, *Homarus gammarus*, cidarids, *Holothuria* spp., *Hacelia attenuata*, *Peltaster placenta*, *Echinus melo*. With regard to the species associated to the living portions (and considered more strictly specific symbionts), this species host *Ectopleura* hydroids, crabs and pycnogonids, as well as the cryptic polyclad *Anthoplana antipathellae* laying circular cocoons of eggs on the ramifications. *Scyliorhinus* spp. eggs are occasionally observed. A rich fish community is always seen moving through the ramifications of the corals with peaks in the plurispecific black coral forests. Frequent inhabitants are *Anthias anthias* and *Capros aper* schools, *Phycis phycis*, *Labrus mixtus*, *Serranus cabrilla*, *Conger conger*, *Lappanella fasciata*, *Acantholabrus palloni*, *Helicolenus dactylopterus*, *Mola mola*, and *Zeus faber*. Among sharks, *Scyliorhinus* spp. and *Galeus melastomus* are observed. Various pelagic fish species, some of commercial interest, are observed more or less occasionally in the water column surrounding the forest.

Unlike the forests of *Antipathella subpinnata*, those formed by *Parantipathes larix* do not host the same rich associated fauna. The preference of this species for silted environments may have an influence in this regard together with a less three-dimensional canopy. With regard to the species found on the living portions, there is the crab *Anamathia rissoana* and an un-identified species of ostracod. The asteroid *Peltaster placenta* has been observed feeding on the coral tissues.



A forest of *Antipathella subpinnata* mixed with *Parantipathes larix* and large sponges (© S. Canese, ISPRA)



A sea star *Peltaster placenta* is visible nearby the forest of *Antipathella subpinnata* (© S. Canese, ISPRA)

Conservation interest and ecological role

From an ecological point of view, black corals are considered ecosystem engineers, habitat-forming species able to create complex three-dimensional habitats, characterized by peculiar physico-chemical features promoting high levels of biodiversity and ecosystem functioning. The dense coral canopies, thanks also to resistant and flexible skeletons, occupy topographic reliefs subjected to complex hydrographic regimes such as those found on seamounts' summits, ridges, rocky outcrops and shoals that enhance the re-suspension of nutrients and the settling of large filter-feeders. Beside enhancing the three-dimensionality and biological heterogeneity of the environment and representing a refuge area for numerous vagile species, the canopies locally modify the surrounding bottom current flow, enhancing pelagic-benthic coupling, in terms of organic matter and larval entrapment. The diet of *Antipathella subpinnata* is based on pico-nanoplankton in autumn and mesozooplankton in spring. Also, the long-term persistence of the colonies in the environment represent an important carbon sink on the seafloor. In addition to this, the coral branches are a suitable substrate for some shark species and cephalopods to lay eggs on, representing an important mesophotic nursery habitat. Other species may use the forest for breeding and spawning areas. The effect of the forest in increasing energy transfer reflects also in the surrounding soft bottoms, increasing biodiversity and biomass of fauna at all levels. The biocoenoses dominated by arborescent black corals is vertically stratified, meaning that within and below the canopy the forest hosts a diverse understory fauna, which in turn attracts numerous vagile predators form nearby areas. The world distribution of the *Antipathella* genus strongly suggests the status of Tethyan relict.

Economic importance

Historical data report occasional black coral collections in Mediterranean waters since Roman Ages. Traces of modern trade activity of black corals for jewellery in the Mediterranean basin have been found, mainly among France, Cyprus, Croatia and Morocco, even if no precise indication on the species is given. *Leiopathes glaberrima* was occasionally collected in the Malta region for exploitment purposes in the 1980s. Probably due to the fact that black coral forests are mostly out of scuba diving reach, that antipatharians are under CITES regulations (Ann. B), that the skeletons are not easy to manipulate, and that their profit values are lower than that of precious corals *sensu stricto*, at present, no traditional use, commerce or trade activity is known for Mediterranean species, besides local artisanal manufacturing with accidental bycatch fragments. Numerous species of commercial interest frequent *Antipathella subpinnata* and *Parantipathes larix* forests, making them an indirect target for a large part of the coastal artisanal and recreational fishermen and giving these habitats an indirect economic importance.

Vulnerability and potential threats

With respect to anthropogenic threats, fishing activities represent the main source of declining for Mediterranean populations of *Antipathella subpinnata* and *Parantipathes larix*. Longlining is generally practiced over deep untrawlable hardgrounds that are good habitats for coral forests, thus increasing the probability of coral bycatch, given also the catchability of the species, in terms of size, branching and density, as well as gear used. Their resistant skeleton enhances the entanglement and, if the colony is not uprooted, it may be broken or the entrapped line may cause wounds, which are successively colonized by fast-growing species, increasing the chances for the epibiosis to turn into necrosis and eventually mortality. Besides longlines, also benthic nets (trammel and gillnets) set in the proximity of the hardgrounds may result in entanglement, mechanical damage, sediment resuspension and clogging, finally leading to a reduction of tridimensionality, alteration of biogeochemical cycles, and ultimately loss of biodiversity. These species may potentially be subjected to mass mortality events possibly related to deep bottom turbid currents, thermal anomalies or land pollution, but they can also be threatened by trawling silt resuspension, seafloor drilling activities for oil exploration or mining. The recovery ability of these species is triggered by their biological traits. The populations of both these species are naturally fragmented depending on the availability of substrate. In both cases, most of the global populations are Mediterranean, with a higher number of dense forests for *Antipathella subpinnata* with respect to *Parantipathes larix* that is generally most scattered. Both are considered longevous, slow-growing species with one spawning season per year (late summer) and an estimated minimum maturity age of various decades, corresponding to tall colonies, which generally represent a small percentage of the populations and have a higher catchability.

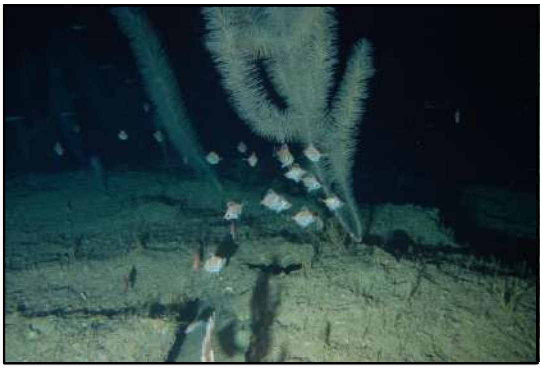
These species are generally considered with low larval dispersal ability, however, at least for *Antipathella subpinnata*, a high genetic connectivity was found among coastal, shallow-water populations with a marked separation from deep, offshore ones, which overall appears more isolated, impacted by fishing and hence more vulnerable. It should be taken into consideration that, besides larvae, *Antipathella subpinnata* may potentially rely also on fragmentation and polyp bail-out as dispersal strategies, which probably explains its colonization success in the basin.

Protection and management

Coral aggregations have been internationally identified as special ecological features that require protection under the Convention of Biological Diversity. More specifically, “Coral Garden” habitats, as those formed by black corals on hardgrounds, are considered sensitive habitats, contributing to the formation of Vulnerable Marine Ecosystems (VMEs) potentially impacted by deep-sea fisheries. This is the reason why it has been recommended the establishment of Fisheries Restricted Areas (FRAs) where such VMEs are known to be or likely to occur in order to put into action an ecosystem-based fishery management of deep ecosystems, as recently carried out in the Gulf of Lion (REC. GFCM/33/2009/1), as part of a large network of protected areas. Some local initiatives have also been recently promoted in the Southern Tyrrhenian Sea (SCI “Scogli d’Isca”) and Ligurian Sea (SCI “Isola di Bergeggi”) in order to expand the protection boundaries to off-shore habitats hosting *Antipathella subpinnata*. Other Mediterranean SCI host black corals (e.g., Seco de Los Olivos). So far, these species are not documented in any coastal Marine Protected Area (MPA), but the extension of the lower bathymetric limits of some areas may be able to include part of the known populations. Black corals are included in CITES Appendix II, Annex III of Bern Convention, and Annex II of Barcelona Convention. There are some specific management initiatives to preserve the black coral resource, such as that operated by the Maltese government (black corals listed under Schedule VI of LN 311 of 2006). They have been assessed by IUCN in the Anthozoan Red List, and the Mediterranean Action Plan of the Barcelona Convention included black corals-dominated habitats as part of the so-called “Dark Habitats”, which deserve protection. Management measures focused on the protection of the deep assemblages are challenged by the difficulties to control the fishing activities in Mediterranean international waters.

Suitability of the habitat for monitoring

Habitat-forming black corals are indicators of environmental status and their occurrence, density, degree of epibiosis, demography are important parameters obtained from ROV surveys, use to monitor biodiversity, seafloor litter and integrity in the context of the Marine Strategy Framework Directive (2008/56/CE). Monitoring may also be carried out by means of photogrammetry techniques and, remotely, by side scan sonar and multi-beam echosounder. General indications for inventorying and monitoring this habitat are given under RAC/SPA Dark Habitats Action Plan. Observations based on by-catch only may underestimate the longline impact, since corals may be lost during hauling or may be damaged *in situ*. Multi-parametric ecological indexes, based on MSFD protocols, have been developed to evaluate the status and pressures of hardbottom mesophotic megabenthic assemblages, including also black corals.



A forest of *Parantipathes larix* with a school of *Capros aper* (© S. Canese, ISPRA)

Neomaja goltziana moving on a deep hardground (© S. Canese, ISPRA)

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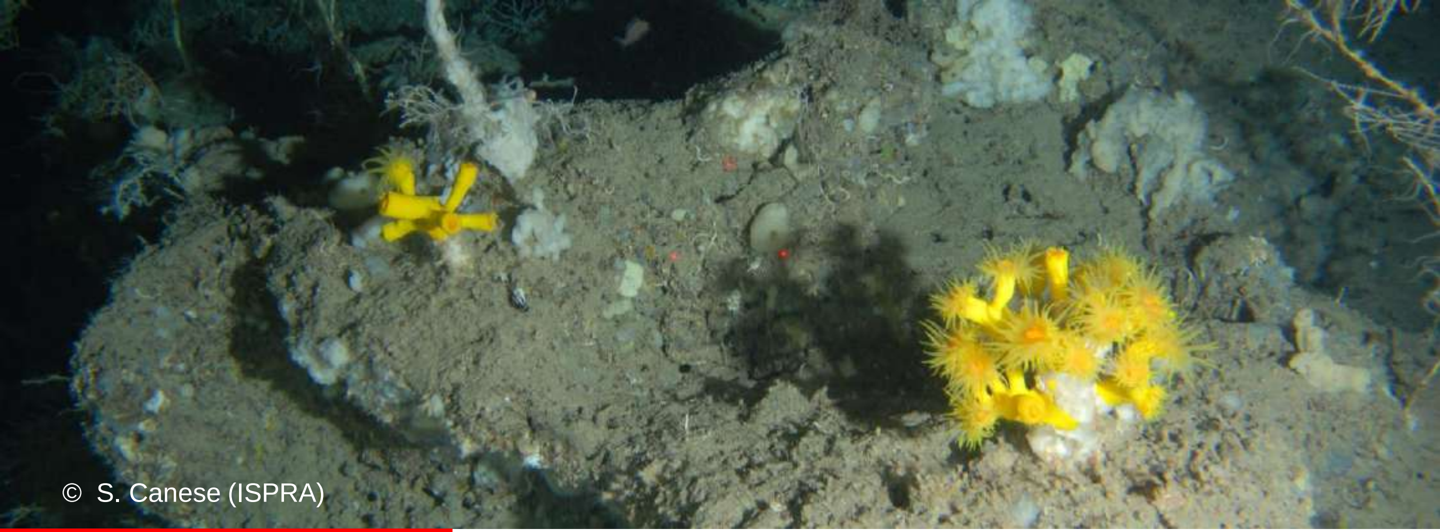

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Facies with Scleractinia

Reference codes for identification:

- **BARCELONA CONVENTION: MD1.515, MD1.525**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral, circalittoral
Nature of the substratum	Hard (rock), occasionally soft (coarse)
Depth range	30 m to 700+ m
Position	Open sea (continental shelf, shelf edge, canyons, and seamounts)
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 16°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

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OFFSHORE CIRCALITTORAL

MD1.5 Offshore circalittoral rock

MD1.51 Offshore circalittoral rock invertebrate-dominated, MD1.52 Offshore circalittoral rock invertebrate-dominated covered by sediment

MD1.515, MD1.525 Facies with Scleractinia

Description of the habitat

Scleractinian corals of the genus *Dendrophyllia* (*Dendrophyllia cornigera* and *Dendrophyllia ramea*) are a consistent component of the temperate mesophotic and deep cold-water coral ecosystems in the Mediterranean Sea, where they form wide aggregations or scattered patches. This habitat mainly develops in the offshore circalittoral zone and close to the edge of the continental shelf, in extremely dim light or dark conditions, but it can extend its bathymetric range up to deep-sea ecosystems (between 70-100 m and 730 m). *Dendrophyllia* spp. develop on rocky cliffs of varying inclination but are able to settle also on sub-horizontal substrates, where sedimentation rates can be higher. *Dendrophyllia* spp. may occasionally settle on boulders and on incoherent sedimentary detritic substrates, rarely forming aggregations. In the offshore circalittoral this facies is found in the 'Offshore circalittoral rock invertebrate-dominated' (MD1.515) and in the 'Offshore circalittoral rock invertebrate-dominated covered by sediment' (MD1.525). It can also be found in the 'Deep offshore circalittoral banks' (MD1.533). A facies dominated by *Dendrophyllia* spp. can be found at shallower depths (below 30 m depth) in the circalittoral zone, within the habitats of 'Coralligenous outcrops' (MC1.525a), 'Coralligenous outcrops covered by sediment' (MC1.525b), 'Deep banks' on the continental shelf rock (MC1.523c), and 'Coralligenous platforms' (MC2.519). Colonies of *Dendrophyllia ramea* may be also observed on overhangs of submerged caves below 30 m depth in the Alboran Sea.

Geographic distribution

Scleractinian corals are distributed all over the Mediterranean Sea, from the circalittoral to the offshore circalittoral zone, where rocky substrates are present. A bathymetric zonation of these corals can be defined: (i) zooxantellate corals in shallow waters (with *Cladocora caespitosa* as the major bioconstructor); (ii) zooxanthellate and azooxanthellate corals at intermediate depths, approximately between 30 and 200 m (mostly dominated by *Dendrophyllia cornigera* and *D. ramea*); and (iii) azooxanthellate cold-water corals below 200 m depth, mostly dominated by *Madrepora oculata* and *Lophelia pertusa* (= *Desmophyllum pertusum*). However, information about the spatial distribution of *Dendrophyllia* spp. is still poor and fragmented, although a decreasing trend toward the eastern basin has been described in literature. *D. cornigera* has a wide spatial distribution, a high trophic plasticity and populates a wide range of environments, suggesting that it may have less restrictive environmental needs to settle and grow compared to those of other cold-water corals or to other zooxanthellate corals. The tolerance to comparatively higher temperatures allows *D. cornigera* to settle at shallower depths, where temperatures are too warm for more sensitive temperate coral species. *D. ramea* is considered rare in the Mediterranean Sea and with a patchy distribution, being known from 11 sites mainly distributed in the south-western basin. It has been observed in the shallow rocky bottoms of the Alboran Sea, in the Adriatic Sea, in Greece, Cyprus, and in the Levantine Basin. The environmental and ecological factors regulating the distribution of *D. ramea* are still poorly known, but available information suggest that this species preferentially thrives at shallower depths (approximately from 30 to 150 m), thus requiring warmer conditions.

Associated habitats

Facies with Scleractinia can be found adjacent or intermixed to facies with small sponges (MD1.511, MD1.521), large and erect sponges (MD1.512, MD1.522), alcyonaceans (MD1.513, MD1.523), antipatharians (MD1.514, MD1.524), ceriantharians (MD1.516, MD1.526), zoantharians (MD1.517, MD1.527), polychaetes (MD1.518, MD1.528), bivalves (MD1.519, MD1.529), brachiopods (MD1.51A, MD1.52A), and bryozoans (MD1.51B, MD1.52B). On coralligenous platforms the facies with Scleractinia can also be associated with encrusting Corallinales (MC2.511), Fucales (MC2.512), non-indigenous Mediterranean *Caulerpa* spp. (MC2.513), hydrozoans (MC2.516), vermetids and/or serpulids (MC2.51A), and ascidians (MC2.51C). This habitat may have contact with 'Offshore reefs' (MD2.51), 'Thanatocoenosis of corals, or Brachiopoda, or Bivalvia' (MD2.52), 'Offshore circalittoral detritic bottoms' (MD3.51), 'Offshore circalittoral mixed sediment' (MD4.51), 'Offshore circalittoral sand' (MD5.51), and 'Offshore terrigenous sticky mud' (MD6.51). When it develops on coralligenous outcrops or on deep banks in the circalittoral zone, it may be in contact with the habitat of coralligenous cliffs (MC1.51), with the habitats of coastal detritic bottoms (MC3.51, MC3.52), with the habitat of muddy detritic bottoms (MC4.51), and with the habitat of coastal terrigenous mud (MC6.51).

Related reference habitats

Facies with Scleractinia, also dominated by other species different from *Dendrophyllia* spp., can be found from the infralittoral to the bathyal zone. Scleractinians occur in the 'Algal-dominated infralittoral rock' (MB1.516a, MB1.516c, MB1.515b, MB1.516e), in the 'Invertebrate-dominated infralittoral rock' (MB1.524a), in the 'Infralittoral rock affected by sediment' (MB1.533), in the 'Invertebrate-dominated coralligenous' (MC1.517b, MC1.516c), in 'Semi-dark caves and overhangs' (MC1.534a, MC1.534b), in the 'Upper bathyal rock invertebrate-dominated' (ME1.515), in the 'Upper bathyal reefs' (ME2.513), in the 'Upper bathyal detritic sand' (ME5.518), in the 'Upper bathyal mud' (ME6.514), in the 'Lower bathyal rock' (MF1.513), and in the 'Lower bathyal reefs' (MF2.511).

Possible confusion

The facies dominated by dendrophylliid coral forests is easily distinguished by the large, distinct branched morphology and yellow to orange colour of their colonies and cannot be confused with any other habitat, including thanatocoenoses.

Typical species and associated communities

Dendrophyllia cornigera and *Dendrophyllia ramea* are arborescent species developing on a single trunk, then requiring smaller portions of hard substrate and enabling them to also settle on sub-outcropping regions mostly draped by sediments and on substrates covered by calcareous algae and shells in areas with moderate currents and turbidity. *D. cornigera* has branches and corallites irregularly arranged in colonies larger than 50 cm in height, with large polyps of 20-40 mm in diameter. It may locally form dense mono-specific aggregations on sedimentary detritic bottoms or develops in isolated colonies or small patches usually on rocks. *D. ramea* tends to form long branches on which the large terminal corallites are arranged quite regularly in two opposite rows. Unlike those of the congener *D. cornigera*, the lateral calices in *D. ramea* are quite different from the terminal calyx.

Communities associated with *Dendrophyllia* species are mainly characterized by large and erect sponges (e.g., *Axinella* spp.), encrusting sponges, serpulids, other cnidarians (mainly gorgonians, antipatharians or other small colonial scleractinians), large ceriantharians, bryozoans, crinoids, and tunicates. Crustacean isopods and numerous species of polychaetes are the main components of the vagile fauna, which find in the arborescent colonies a refuge and a suitable habitat. The associated fish assemblages includes many species of interest to fishery.

Conservation interest and ecological role

Animal forests promote morphological complexity and functioning of marine habitats. Long-lived and arborescent calcified Scleractinia act as marine ecosystem engineers and habitat formers, as they plays a significant role in benthic-pelagic coupling and generate three-dimensional space and habitat for many mobile invertebrates, thus enhancing biodiversity and the heritage value of the seascape. Many commercial species use this habitat for shelter, feeding, spawning and as nursery areas, often reaching high biomass and sizes. The calcification rates observed for *Dendrophyllia* spp. is around 0.7 mgCaCO3 g^{-1} d^{-1}.

Economic importance

Through its role in supporting high biodiversity, the facies with Scleractinia provides many ecosystem goods and services. It provides supporting services (i.e., habitat, biodiversity, nutrient cycling, water circulation and exchange, primary production, and resilience) necessary for the production of all other ecosystem services. It also provides provisioning services to humans, such as materials used by humans and genetic resources availability, habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms, regulating services (i.e., CO_2 and climate regulation, natural carbon sequestration and storage, waste absorption and biological control), information services in terms of scientific research (carbon cycle in the sea, biogeographic patterns, climate change studies), and cultural services through recreation, aesthetic enjoyment and inspiration. To date, the economic value of Scleractinia has not yet been assessed.

Vulnerability and potential threats

Arborescent Scleractinia are long-lived (over 10 years), slow growing and slow recruiting species and are poorly resilient to human pressures. They are threatened by pollution, sedimentation, sea water warming and deep-water fishing activities. The branching morphology of their colonies makes these assemblages particularly damaged by fishing gears, bottom trawling, anchoring, discarded/lost gears, dumping, and littering. They may represent a large proportion of fishing by-catch in Mediterranean fisheries. These species can also be harvested illegally. Scleractinians, such as other cnidarians, are sensitive to thermal anomalies. Filter feeders also suffer for the increase in the concentration of fine sediment and organic matter. Natural mortality events result in thanatocoenosis made by dead coral skeletons not uprooted from their original position and are mainly related to paleoclimatic changes, turbid currents or deep geothermal events linked to seismic phenomena.

Protection and management

The “deep-sea corals” habitat is reported on the list of priority habitats according to the SPA/BD protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention). *Dendrophyllia cornigera* and *D. ramea* are included in the Annex II “Endangered or threatened species” of the SPA/BD Protocol. *Dendrophyllia ramea* is classified as ‘Endangered’ while *D. cornigera* as ‘Vulnerable’ in the IUCN Red List of threatened species. All scleractinian coral species are listed in the Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). Furthermore, since corals may provide essential fish habitat for commercial fish and invertebrates, their protection should combine biodiversity conservation and fisheries management objectives according to the Ecosystem Approach (EcAp) to fisheries.

Suitability of the habitat for monitoring

Facies with Scleractinia, like other bioconstructors, are included within the guidelines for monitoring marine benthic habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The long-term persistence and easy recognition of this habitat make it particularly suitable for monitoring. The monitoring of this habitat is preferably performed through remote operated vehicles.

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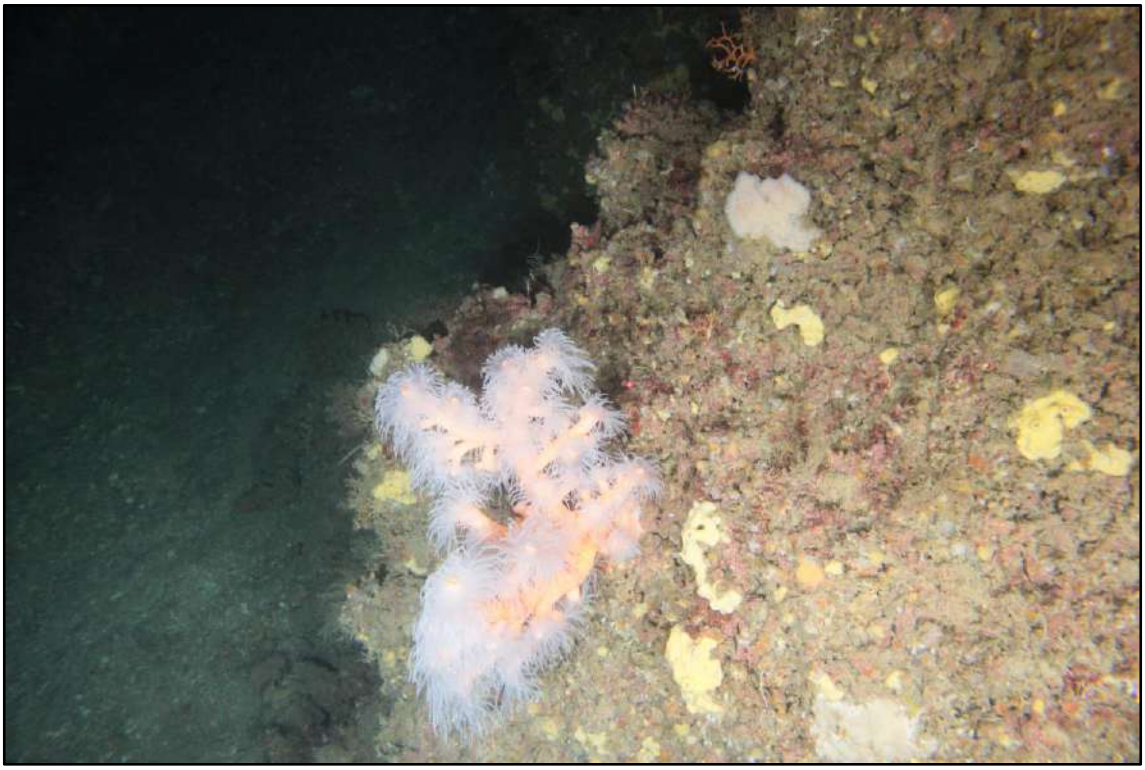
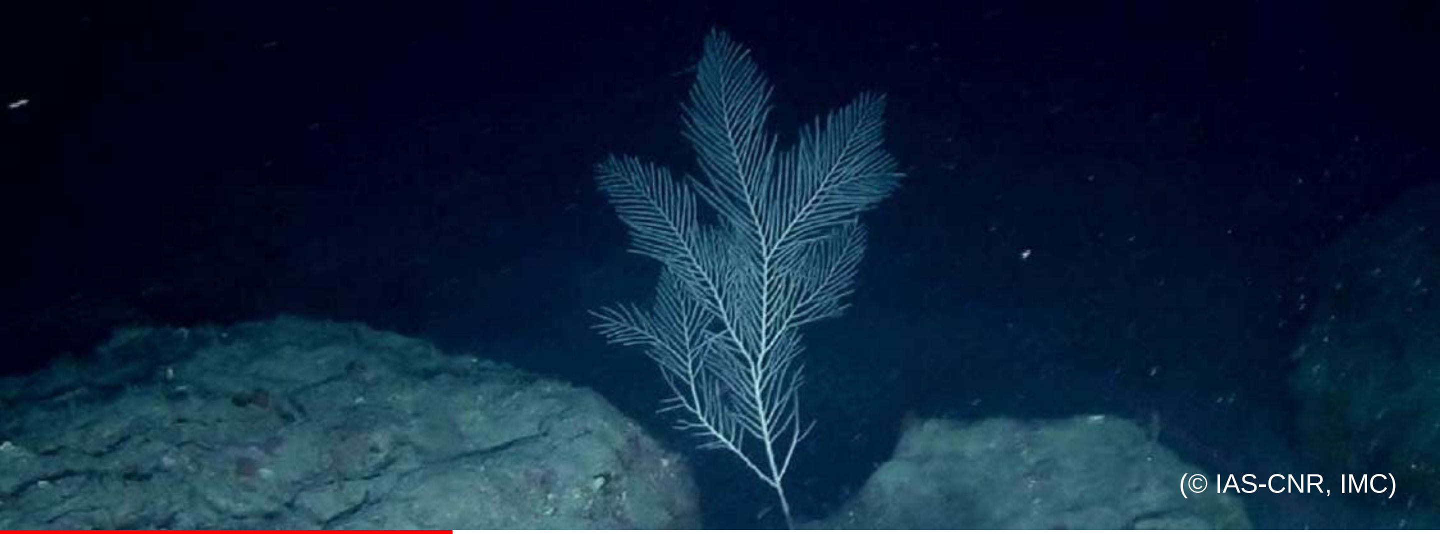
The yellow coral *Dendrophyllia cornigera* with sea urchins on incoherent detritic substrate (© S. Canese, ISPRA)



The yellow coral *Dendrophyllia ramea* on rock (© S. Canese, ISPRA)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Deep offshore circalittoral banks

Reference codes for identification:

- **BARCELONA CONVENTION: MD1.53**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral
Nature of the substratum	Hard (rock)
Depth range	70 m to 200 m
Position	Open sea
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 16°C
Suitability for monitoring	Yes

Author:
L. Piazzi

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CIRCALITTORAL
MD1.5 Offshore circalittoral rock
MD1.53 Deep offshore circalittoral banks

Description of the habitat

Deep offshore circalittoral banks are rocky shoals or soft mounds of variable surface that arise from deeper bottoms (both in the furthest part of the continental shelf and in the bathyal zone) to depths typically ranging from 70 to 200 m. The habitat can be highly variable depending on depth, bank morphology, surrounding bottoms and the presence of bioconstructions.

Geographic distribution

Deep offshore banks are described around most of the Mediterranean coasts, and mostly in the western part.

Associated habitats

Deep offshore circalittoral banks are included in the ‘Offshore circalittoral rock‘ (MD1.5). The habitat may have possible contact with ‘Offshore circalittoral detritic bottoms’ (MD3.51), ‘Offshore circalittoral sand‘ (MD5.5), and ‘Offshore circalittoral mud‘ (MD6.5). Associated habitats are ‘Facies with Antipatharia‘ (MD1.531), ‘Facies with Alcyonacea‘ (D1.532), and ‘Facies with Scleractinia‘ (MD1.533).

Related reference habitats

Offshore circalittoral banks can be related to ‘Invertebrate-dominated coralligenous’ (MC1.51b, c), ‘Coralligenous outcrops’ (MC1.52a), Coralligenous outcrops covered by sediment’ (MC1.52b), ‘Deep banks’ (MC1.52c), ‘Coralligenous platforms’ (MC2.51), ‘Offshore circalittoral rock invertebrate-dominated’ (MD1.51, MD1.52), ‘Upper bathyal rock invertebrate-dominated’ (ME1.51), ‘Lower bathyal rock’ (MF1.51).

Possible confusion

The habitat hosts assemblages that can be similar to the ‘Offshore circalittoral rock invertebrate-dominated‘ (MD1.51, MD1.52). The habitat can be distinguished because it is surrounded by deeper soft bottoms.

Typical species and associated communities

Different assemblages may be found depending on depth, bank morphology, surrounding bottoms and the presence of bioconstructions. The shallower banks (between 70-90 m) may host large and erect sponges (*Axinella cannabina, A. polypoides, Aplysina aerophoba, Haliclona mediterranea*), Alcyonacea (*Eunicella cavolini, E. singularis, Paramuricea clavata, Corallium rubrum, Alcyonum acaule*), bryozoans (*Pentapora fascialis*), and the gold coral *Savalia savaglia*. On the deeper banks it is also possible to find *Poecillastra compressa, Antipathella subpinnata, Ellisella paraplexauroides, Acanthogorgia hirsuta, Callogorgia verticillate*, and *Paramuricea macrospina*.

Conservation interest and ecological role

The deep offshore circalittoral banks support biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages.

Economic importance

The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. To date, the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. In particular, the habitat is threatened by fishing activities.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities (UNEP/MAP).

Suitability of the habitat for monitoring

The habitat has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). The ecological quality of the habitat shall also be assessed within the Marine Strategy Framework Directive. Several methods and ecological indices have recently been proposed to detect the ecological quality of the habitat. Monitoring is preferably conducted through remotely operated vehicles (ROVs).

Poecillastra compressa (left panel) and *Acanthogorgia hirsuta* (right panel)
(© IAS-CNR, IMC)

Callogorgia verticillata (© IAS-CNR, IMC)

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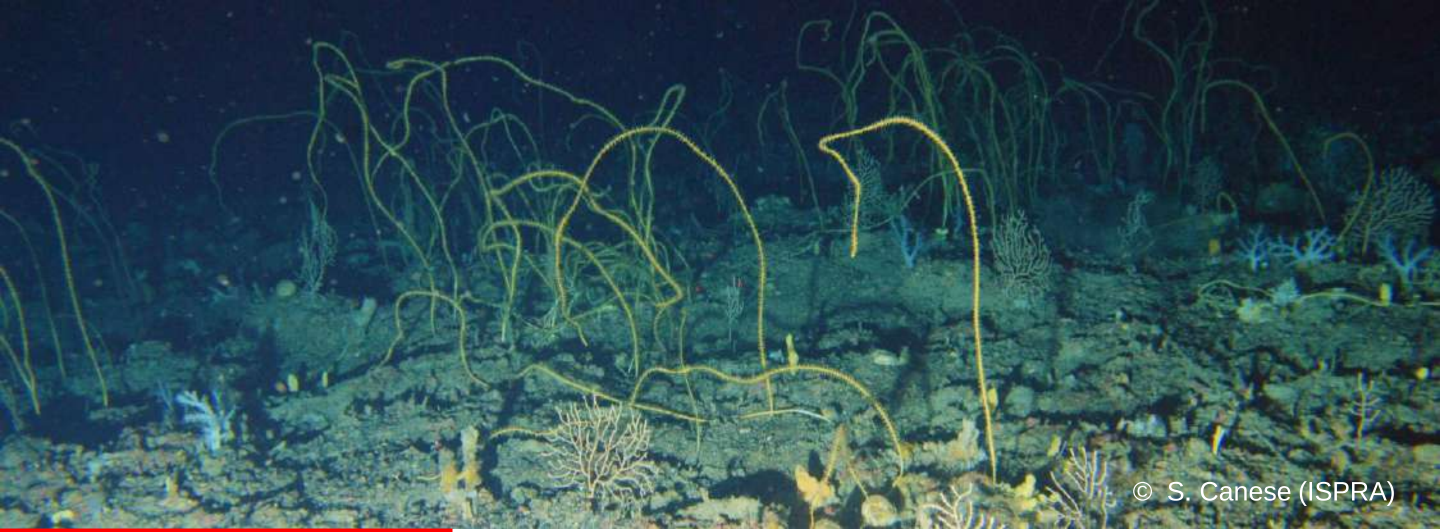
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Facies with Alcyonacea

Reference codes for identification:

- **BARCELONA CONVENTION: MD1.532**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral, circalittoral
Nature of the substratum	Hard (rock)
Depth range	70 m to 200 m
Position	Open sea (continental shelf, shelf edge)
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 16°C
Suitability for monitoring	Yes

Author:
M. Montefalcone

Photo credits:
C.N. Bianchi, M. Bo,
S. Canese (ISPRA)

OFFSHORE CIRCALITTORAL

MD1.5 Offshore circalittoral rock

MD1.53 Deep offshore circalittoral banks

MD1.532 Facies with Alcyonacea

Description of the habitat

This facies is a component of the deep offshore circalittoral banks, and is dominated by arborescent and long-lived alcyonacean species, such as the gorgonians *Callogorgia verticillata*, *Ellisella paraplexauroides*, *Eunicella* spp., *Paramuricea* spp., *Leptogorgia* spp., *Swiftia pallida*, and *Viminella flagellum*, the soft corals *Paralcyonium spinulosum*, *Nidalia studeri*, and *Chironephtya mediterranea*, and the red coral *Corallium rubrum.* This facies creates the habitat usually known as 'animal forests'. In some assemblages, soft corals reach high abundances, representing the main habitat forming species. The habitat mainly develops in the offshore circalittoral zone with extremely dim light conditions and at depths between 70 m and about 200 m, and close to the edge of the continental shelf. In the offshore circalittoral this facies can also be found in the 'Offshore circalittoral rock invertebrate-dominated' (MD1.513), also covered by sediment (MD1.523). This facies can also be found at shallower depths in the deep circalittoral zone, within the habitats of 'Deep banks' in the continental shelf rock (MC1.522c).

Geographic distribution

The facies with Alcyonacea can potentially be distributed all over the Mediterranean Sea from the circalittoral to the offshore circalittoral zone, where rocky substrates are present.

Associated habitats

Facies with Alcyonacea can be associated with the facies of sponges (small, large, and erect), Antipatharia, Scleractinia, Ceriantharia, Zoantharia, Polychaeta, Bivalvia, Brachiopoda, Bryozoa. The habitat may have contact with 'Offshore circalittoral detritic bottoms' (MD3.51), 'Offshore circalittoral mixed sediment' (MD4.51), 'Offshore circalittoral sand' (MD5.51), and 'Offshore terrigenous sticky mud' (MD6.51). When it develops on deep banks in the circalittoral zone, it may be in contact with the habitats of coralligenous (MC1.51, MC1.52a, MC1.52b, MC2.51), of coastal detritic bottoms (MC3.51, MC3.52), of muddy detritic bottoms (MC4.51), and of coastal terrigenous mud (MC6.51).

Related reference habitats

Some of the species found in this habitat (e.g., *Eunicella* spp., *Paramuricea* spp., *Leptogorgia* spp., and *Corallium rubrum*) can also be found in the habitats of moderately illuminated algal-dominated infralittoral rock (MB1.514b, MB1.514d), in lower infralittoral rock moderately illuminated (MB1.515e), in moderately illuminated invertebrate-dominated infralittoral rock sheltered (MB1.525a), in infralittoral rock affected by sediment (MB1.534), in the coralligenous (MB1.55) and semi-dark caves and overhangs (MB1.56) when they are in enclave in the infralittoral zone, in coralligenous outcrops (MC1.523a, MC1.523b), in semi-dark caves and overhangs (MC1.533a, MC1.533b), in coralligenous platforms (MC2.517), in coastal detritic bottoms (MC3.514, MC3.526), in muddy detritic bottoms (MC4.512), and in coastal terrigenous mud (MC6.511). Some other cold-water species (e.g., *Callogorgia verticillata*, *Swiftia pallida*, *Viminella flagellum, Ellisella paraplexauroides, Chironephthya mediterranea*, and *Nidalia studeri*) can also be found in the 'Upper bathyal rock invertebrate-dominated' habitat (ME1.51).

Possible confusion

Facies with Alcyonacea cannot be confused with any other habitat.

Typical species and associated communities

Gorgonians and soft corals are the typical species of this habitat. The yellow gorgonian *Eunicella cavolini* and the white gorgonians *Eunicella singularis* and *E. verrucosa*, *Leptogorgia sarmentosa* and *L. viminalis, Paramuricea clavata* and *P. macrospina* and the red coral *Corallium rubrum* colonize rocky bottoms from the circalittoral to the offshore circalittoral zone (and sometimes even up to the upper bathyal zone). See sheets MC1.514b, MC3.514, and MC3.526 for detailed descriptions of these species. More typical in the offshore circalittoral zone are the cold-water gorgonians *Callogorgia verticillata*, *Swiftia pallida*, *Viminella flagellum*, and *Ellisella paraplexauroides. Callogorgia verticillata* is characterized by fan-like colonies whose feathery branches resemble palm leaves; it is white-pink coloured and the colony can be up to more than 1 m in height and width. *Swiftia pallida* has a single main stem arising from a narrow base and is sparsely branched, with a colour varying from pink to red. It is a small sea fan, with a height that ranges between 8 cm to 20 cm; its polyps are mostly arranged alternately or irregularly on either side of the stem and branches. *Viminella flagellum* is a whip-like gorgonian characterized by unbranched colonies (or at most one or two branches) up to 1 m high, with a thinner basal diameter of the stem. Its colour varies from white to yellow-orange. *Ellisella paraplexauroides* forms big brick-red candlestick colonies, up to 2 m high. The branched colonies have thin, whip-like ramifications arising from a common short stem, heading parallel upwards and dividing dichotomously. Sometimes it may be unbranched or sparsely branched. It is a vulnerable gorgonian with an unusual restricted and uneven distribution, with isolated and extremely sparse colonies. The soft corals *Chironephthya mediterranea* and *Nidalia studeri* have been only recently discovered in the northwestern Mediterranean Sea. *C. mediterranea* has branched tree-like erect whitish colonies, with the stem attached to hard substrates. Branches are rigid and brittle due to the abundance of large and densely packed sclerites. Polyps are distributed along the entire length of the stem and branches, never restricted to terminal ends of branches, and oriented upwards and completely retractile into the calyces. Some solitary polyps may also be present on the main stem. *N. studeri* has a colony torch-like, a capitulum light orange in colour and dome-shaped and not distinctly projecting beyond the stalk. *Paralcyonium spinulosum* has a retractable trunk and its colour is whitish or translucent pinkish with conspicuous white sclerites; polyps are white and distributed over the entire length of the trunk. It may form highly dense monospecific facies on the continental shelf.

Communities associated with Alcyonacea are mainly characterized by sponges, serpulids, other cnidarians, bryozoans, and tunicates. Colonies of gorgonians are frequently covered by epibenthic organisms, such as the crinoid *Leptometra phalangium*, encrusting algae, bryozoans, hydroids, and ascidians. The parasitic zoanthid *Isozoanthus primnoidus* has been found associated with *Callogorgia verticillata.* Many nudibranch species can be found within the gorgonian forests, included the large and newly discovered species *Tritonia callogorgiae* found within *Callogorgia verticillata.* The anemone *Amphianthus dohrnii* seems to live exclusively on sea fans. Crustacean isopods and numerous species of polychaetes are the main components of the vagile fauna, which find in branched alcyonaceans a refuge and a suitable habitat. See further details on the communities associated with the habitats of the offshore circalittoral rock in the sheets MD1.51, MD1.52, and MD1.53, whist on the communities associated with Alcyonacea in the sheet MC1.514b.

Conservation interest and ecological role

Animal forests promote morphological complexity and functioning of marine habitats. Long-lived erect Alcyonacea act as marine ecosystem engineers and habitat formers, as they plays a significant role in benthic-pelagic coupling and generate three-dimensional space and habitat for many mobile invertebrates, thus enhancing biodiversity and the beauty of the seascape. *Eunicella singularis*, *Eunicella cavolini*, *Paramuricea clavata* and *Paramuricea macrospina* are endemic to the Mediterranean.

Economic importance

Through its role in supporting high biodiversity, the facies with Alcyonacea offers provisioning services to humans, such as materials and genetic resources availability, habitat services, due to the creation of a three-dimensional structure that amplifies the space available for marine organisms, and information services, in terms of scientific research and monitoring. *Corallium rubrum* is an important Mediterranean economic resource, and its populations have long been commercially exploited for jewellery since the ancient times (see also the sheet MC1.533a). Offshore circalittoral rocks and banks are important fishing areas. To date, the economic value of Alcyonacea has not yet been assessed.

Vulnerability and potential threats

Erect Alcyonacea are long-lived, slow growing and slow recruiting species and display a low resilience to human pressures. The branching morphology and the soft structure make these assemblages particularly damaged by fishing gears, bottom trawling, and anchoring. They represent a large proportion of fishing bycatch in Mediterranean fisheries. Alcyonacea are sensitive to entanglement by mucilage filaments and suffer for thermal anomalies. Severe diseases are triggered by a complex combination of pathogenic microbial and abnormally high seawater temperatures, and several mass mortality events have been recorded in the Mediterranean in coincidence with summer heat waves and the ongoing seawater warming trend. *Corallium rubrum* is a precious and target species that may be harvested illegally. Filter feeders also suffer for the increase in the concentration of fine sediment and organic matter.

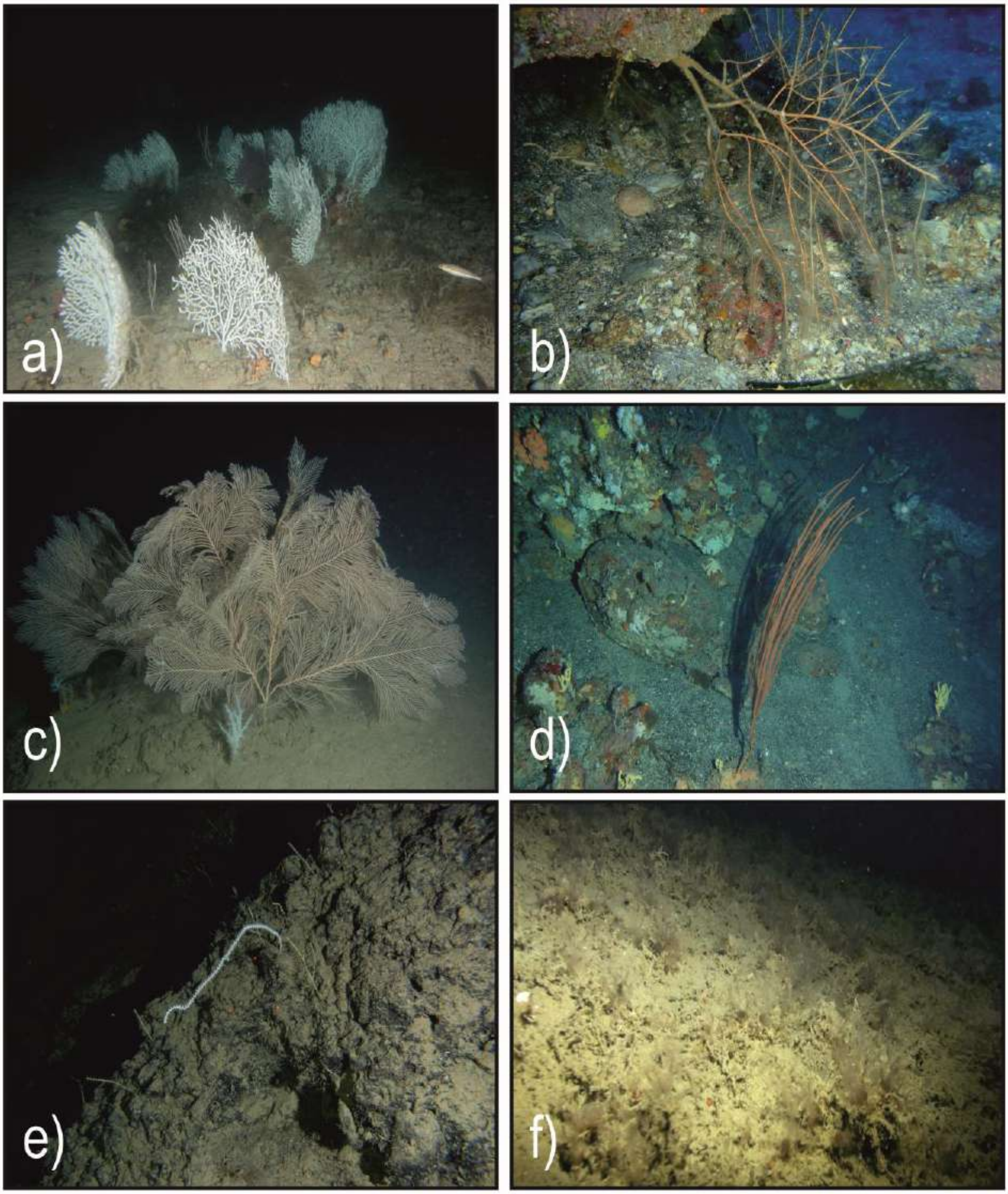
Protection and management

Among Alcyonacea only the red coral *Corallium rubrum* is included in the Annex II "Endangered or threatened species" of the Bern Convention, in the Annex III *"S*pecies whose exploitation is regulated" of the SPA/BD Protocol (Special Protected Areas and Biological Diversity in the Mediterranean, Barcelona Convention), and in the Annex V (species which are of interest to the European Union, of which the taking or exploitation of wild may be subject to management decisions) of the Council Directive 92/43/EEC (Habitats Directive). *Corallium rubrum* is also listed as "Endangered" in the IUCN Red List of threatened species and it is in the list of the Convention on International Trade in Endangered Species of wild flora and fauna (CITES). Nevertheless the growing awareness of the threats due to global warming and direct mechanical damages, no specific protection measures have been implemented yet for all the other Alcyonacea species. In order to preserve areas where animal forests are well developed and are still relatively well structured, the European Union has been committed in the establishment of special areas of conservation (SAC) for the Natura 2000 network.

Suitability of the habitat for monitoring

Facies with Alcyonacea are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The long-term persistence and easy recognition of this habitat make it particularly suitable for monitoring, and all methods proposed for monitoring coralligenous cliffs (see sheet MC1.51) can be effectively used also to monitor the facies with Alcyonacea.

This habitat may be particularly suitable for assessing specific pressures, such as mechanical damage, mucilage blooms, and climate change. For instance, the rate of necrosis of erect Alcyonacea is considered a useful indicator of climate-related stress. The monitoring of this habitat in deep waters is performed through remote operated vehicles.



The gorgonians *Eunicella verrucosa* (a), *Leptogorgia sarmentosa* (b), *Callogorgia verticillata* with the soft coral *Chironephtya mediterranea* (c), *Ellisella paraplexauroides* (d), *Viminella flagellum* and *Swiftia dubia* (e), and the soft coral *Paralcyonium spinulosum* (f) (a, f © M. Bo; b © S. Musumeci; c, d, e © S. Canese, ISPRA)

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To be added

CIRCALITTORAL

MD2.5 Offshore circalittoral biogenic habitat

MD2.51 Offshore reefs

Offshore reefs

Reference codes for identification:

- **BARCELONA CONVENTION: MD2.51**
- **EUNIS 2019: MD25**
- **EUNIS 2007: A5.6**
- **EC: 1170**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral
Nature of the substratum	Hard (rock)
Depth range	40 m to 200 m
Position	Open sea
Hydrodynamic conditions	Variable
Salinity	Between 36 and 39
Temperature	10 to 16°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:

Description of the habitat

Offshore reefs are biogenic habitats edified by different invertebrate taxa, such as scleractinians, bivalves, vermetids, and serpulids. They are mostly described for bathyal habitats but have been also found on the continental shelf until the shelf edge arising from soft bottoms at depths ranging from 40 m to the limit of the photic zone. The habitat may have a complex morphology hosting high biodiversity.

Geographic distribution

Offshore reefs are reported on most of the Mediterranean continental shelf, although they are considered quite rare.

Associated habitats

The habitat is included in the 'Offshore circalittoral biogenic habitat' (MD2.5). The habitat may have possible contact with 'Offshore circalittoral detritic bottoms' (MD3.51), 'Offshore circalittoral sand' (MD5.5), and 'Offshore circalittoral mud' (MD6.5). An associated habitat is the 'Facies with Vermetidae and/or Serpulidae' (MD2.511).

Related reference habitats

It is related with 'Thanatocoenosis of corals, or Brachiopoda, or Bivalvia' (MD2.52), 'with 'Offshore circalittoral rock invertebrate-dominated' (MD1.51, MD1.52), with 'Coralligenous platforms' (MC2.51), with 'Upper bathyal reefs' (ME2.51), and 'Lower bathyal reefs' (MF2.51).

Possible confusion

The habitat hosts assemblages similar to the 'Offshore circalittoral rock invertebrate-dominated' (MD1.51), but the offshore reefs are built by invertebrates with calcareous skeleton and arise both from hard and soft bottoms.

Typical species and associated communities

Offshore reefs may be built by different organisms, such as the scleractinians *Phyllangia americana mouchezii* and *Polycyathus muellerae*, Vermetidae, bivalves (*Neopycnodonte cochlear*) and Serpulidae (*Hydroides pseudo uncinata, Janita fimbriata, Serpula massiliensis*). Three additional scleractinian species, *Leptopsammia pruvoti*, *Caryophyllia inornata*, and *Hoplangia durotrix,* and the serpulids *Vermiliopsis infundibulum* and *V. labiata* may contribute to the reef construction. The associated assemblages mostly include Porifera, Bryozoa (e.g., *Schizomavella* spp., *Pentapora fascialis*, *Myriapora truncata*, *Adeonella calveti*, and *Chartella papyrea*), and Mollusca, while encrusting coralline algae may be present but to a lesser extent.

Conservation interest and ecological role

The offshore reefs support biodiversity by providing habitats, feeding grounds, recruitment, refuges and nursery sites for many invertebrates and fishes both at the juvenile and adult stages.

Economic importance

The habitat provide provisional (i.e., food, raw materials), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services to humans. To date, the economic value of the habitat has not been evaluated yet.

Vulnerability and potential threats

The main threats on the habitat are mechanical destruction (fishing, anchoring, and diving damages), pollution, sedimentation, spread of alien invasive species, bloom of benthic mucilage, and climate change. In particular the habitat is threatened by fishing activities.

Protection and management

The habitat have been included among the “special habitats types” according to the Habitat Directive (92/43/EEC) that should be monitored under the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Recently, the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea promoted protection and monitoring activities (UNEP/MAP).

Suitability of the habitat for monitoring

The habitat has been included as common indicator in the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). The ecological quality of the habitat shall also be assessed within the Marine Strategy Framework Directive. Several methods and ecological indices have recently been proposed to detect the ecological quality of the habitat. Monitoring is preferably conducted through remotely operated vehicles (ROVs).

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CIRCALITTORAL

MD3.5 Offshore circalittoral coarse sediment
MD4.5 Offshore circalittoral mixed sediment
MD3.51, MD4.51 Offshore circalittoral detritic bottoms

Offshore circalittoral detritic bottoms

Reference codes for identification:

- **BARCELONA CONVENTION: MD3.51, MD4.51**
- **EUNIS 2019: MD35, MD45**
- **EUNIS 2007: A5.15, A5.54**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral
Nature of the substratum	Soft (coarse, muddy sediment)
Depth range	70 m to 200 m
Position	Open sea
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 to 16°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:
S. Canese (ISPRA)

Description of the habitat

The habitats are distributed on the furthest part of the continental shelf and in offshore banks and it is characterised by soft bottoms with coarse organogenous/bioclastic sediment not or partially covered by mud.

Geographic distribution

The habitats are present throughout the Mediterranean Sea.

Associated habitats

The habitats are included in the ‘Offshore circalittoral coarse sediment’ (MD3.5) and ‘Offshore circalittoral mixed sediment’ (MD4.5). The habitat can have contact with ‘Deep offshore circalittoral banks’ (MD1.53) and ‘Offshore circalittoral rock invertebrate-dominated’ (MD1.51, MD1.52). Associated habitats are ‘Facies with Bivalvia’ (MD3.511, MD4.511), ‘Facies with Brachiopoda’ (MD3.512, MD4.512), ‘Facies with Polychaeta’ (MD3.513, MD4.513), ‘Facies with Crinoidea’ (MD3.514, MD4.514), ‘Facies with Ophiuroidea’ (MD3.515, MD4.515), and ‘Facies with Echinoidea’ (MD3.516, MD4.516).

Related reference habitats

‘Coastal detritic bottoms’ (MC3.51, MC3.52), ‘Infralittoral coarse sediment mixed by waves’ (MB3.51), ‘Infralittoral coarse sediment under the influence of bottom currents’ (MB3.52).

Possible confusion

The habitat could be confused with other soft bottoms, such as ‘Offshore circalittoral sand’ (MD5.51) or ‘Offshore terrigenous sticky muds’ (MD6.51). The presence of organogenous/bioclastic sediments is a distinctive character of the habitat.

Typical species and associated communities

The habitat is characterized by organisms of detritic, muddy and mixed soft bottoms. Many taxa are considered as characteristic of this habitat, such as Bivalvia (e.g., *Neopycnodonte cochlear*), Brachiopoda, Polychaeta, Crinoidea (e.g., *Leptometra phalangium*), Ophiuroidea, Echinoidea, Cnidaria (*Alcyonum* spp., *Cerianthus membranaceus*, *Funiculina quadrangularis*), and Porifera may be also widely distributed.

Offshore detritic bottoms host a highly diversified fish assemblages also of commercial interest (e.g., *Merluccius merluccius*, *Trisopterus* spp., *Phycis blennoides*, *Helicolenus dactylopterus*, *Capros aper*, *Macroramphosus scolopax*, *Lepidorhombus boscii*, *Scyliorhinus canicula*).

Conservation interest and ecological role

The habitat includes facies characterised by particular and ecologically important taxa. Soft bottoms banks host many fish of commercial value, and they are important fishing areas.

Economic importance

The habitat is an important fishing area, but to date its economic value has not been evaluated yet.

Vulnerability and potential threats

The mixed detritic bottoms may be altered by the increase of organic matter and pollutants that can act directly on the characteristic species of the assemblages. The habitat may be threatened by physical damage mostly caused by bottom trawling.

Protection and management

The habitat is not protected, and it is assessed as ‘Data Deficient’ by the European IUCN Red List.

Suitability of the habitat for monitoring

The macro-zoobenthos of Mediterranean soft bottoms is considered a useful tool in monitoring programs and impact evaluation studies and it has to be assessed under the European Directives. The habitat was mostly studied through the analysis of samples taken from box-corers or grabs. Moreover, the use of remotely operated vehicles may allow the study of epifaunal assemblages.

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Facies with the Bivalvia *Neopycnodonte* spp.

Reference codes for identification:

- **BARCELONA CONVENTION: MD3.511, MD4.511**
- **EC: 1170 (partim)**

LOCATION OF THE HABITAT

Zone	Circalittoral to upper bathyal
Nature of the substratum	Hard (rock), soft (coarse, sand, mud)
Depth range	25 m to 400 m
Position	Coastal, open sea (continental shelf, shelf edge, upper slope)
Hydrodynamic conditions	Moderate
Salinity	Between 36 and 39
Temperature	13 to 16°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Enrichetti

Photo credits:
S. Canese, ISPRA

OFFSHORE CIRCALITTORAL

MD3.5 Offshore circalittoral coarse sediment
MD4.5 Offshore circalittoral mixed sediment

MD3.51, MD4.51 Offshore circalittoral detritic bottom

MD3.511, MD4.511 Facies with the Bivalvia *Neopycnodonte* spp.

Description of the habitat

Bivalves are known to build up or contribute to biogenic reefs worldwide. The gryphaeid *Neopycnodonte cochlear* is widely distributed in the Mediterranean Sea, occurring from 25 m to about 400 m depth. Under mesophotic conditions (40-130 m, deep circalittoral, shelf edge and upper slope), *Neopycnodonte cochlear* creates massive aggregations on both horizontal and vertical seafloors, supporting the development of a rich benthic fauna. These reefs develop on both soft and hard substrates (including wrecks and other large metallic objects), in a wide array of sizes, with density of up to 1000 individuals m^{-2}.

Generally, this facies occurs over fragmented bedrock substrate, resulting in discrete clusters of *Neopycnodonte cochlear* surrounded by muddy or detritic flat bottoms. These bioconstructions may cover 0.5-5 m in lateral extension and up to 2 m in height. In other cases this facies occurs on vertical rocks, where it can develop in thick pinnacles or globose formations protruding perpendicularly with respect to the cliff for 0.5-1.5 m. These formations are often interconnected with one another to form a framework of high structural complexity, extending up to 450 m in length. Dead specimens of *Neopycnodonte cochlear* compose most of the bioconstructions, whereas living specimens occur onto the superficial layer in scattered clusters of a few individuals (6-20). *Neopycnodonte cochlear* specimens are generally irregularly arranged with respect to each other. The random orientation of the shells and the presence of point-like contacts determine the formation of an overall porous structure, whereas the contacts between larger surfaces favour the stability of the bioconstruction.

Geographic distribution

Oyster reefs engineered by *Neopycnodonte cochlear* have been reported, based on ROV observations from the Gulf of Lion, the Ligurian Sea, the Tyrrhenian Sea, the Ionian Sea, the Adriatic Sea, and the coasts of Lebanon in the Levantine Basin. In addition, data obtained from grabs and epibenthic hauls report large amount of *Neopycnodonte cochlear* valves from other Mediterranean sites, suggesting the existence of related reefs also in the Alboran Sea, Balearic Sea and Marmara Sea.

Associated habitats

This facies typically develops within ‘Offshore circalittoral detritic bottoms’ (MD3.51, MD4.51). It can be adjacent to or mixed with ‘Offshore circalittoral sand’ (MD5.51) and ‘Offshore terrigenous sticky mud’ (MD6.51). This facies can be surrounded or mixed with the same soft-bottoms habitats in the circalittoral and upper bathyal (MC3.51, MC4.51, MC5.5, MC6.51, ME3.51, ME4.51, ME5.51, and ME6.51). Occasionally, dense patches are found near or within habitats belonging to ‘Offshore circalittoral rock’ (MD1.5) and ‘Shelf platform rock’ (MC1.52). Brachiopoda (MD3.512), Polychaeta (MD3.513), Crinoidea (MD3.514), Ophiuroidea (MD3.515), and Echinoidea (MD3.516) can be associated in the community dominated by bivalves.

Related reference habitats

Neopycnodonte cochlear may be a component of other off-shore circalittoral and upper bathyal habitats. The following related reference facies are reported: ‘Facies with Bivalvia *Neopycnodonte* spp.’ (MD6.513, ME4.511, ME5.515, ME6.518).

Possible confusion

In comparison with the Mediterranean coralligenous reefs, *Neopycnodonte cochlear* bioconstructions generally lack in the major contributions of encrusting coralline algae and scleractinians as reef builders. *Neopycnodonte cochlear* can be easily distinguished from the congeneric *Neopycnodonte zibrowii* based on the size and type of aggregation (see also the sheet ME1.518) .

Typical species and associated communities

Several species contribute to structuring *Neopycnodonte cochlear* bioconstructions: cnidarians, serpulids and bryozoans participate in calcium carbonate deposition, whereas sponges bind shells together or erode the carbonate (boring species). Among the secondary structuring taxa, several scleractinians (e.g., *Caryophyllia* spp.) and *Corallium rubrum* (Annex III SPA/BD, Appendix III Bern, IUCN Red List EN) have been reported. Serpulids tubes encrust the outer portions of the bioconstruction as well as the reef interstices. In particular, spirorbid polychaetes exhibit specific adaptations to the dark crevices: they settle on the external edges of the living *Neopycnodonte cochlear* shells and the smooth inner parts of the dead specimens, playing a pioneering role in the community colonization patterns. Encrusting bryozoans (e.g., *Schizomavella* spp. and *Schizoporella* spp.) contribute to the compactness of the structure by forming thin crusts on the reef surface.

Sponges are mainly represented by several encrusting species covering large portions of the substrate. Erect forms are generally less represented, with only some exceptions (e.g., *Axinella* spp.). Occasionally, large epibenthic taxa including massive sponges and dense gorgonian populations are reported. Among the boring species, the sponge *Siphonodictyon infestum* play an important role as a bioeroder of the bioconstruction. In addition, the reef ’s crevices are also inhabited by *Hiatella* spp. bivalves, whereas red coralline algae are only sporadically reported. Fish fauna includes the species *Serranus cabrilla*, *Scorpaena scrofa* and *Conger conger*.

Conservation interest and ecological role

Oyster reefs are of paramount interest worldwide and have been included under different protection and management measures. For example, the European Union Habitat Directive define the habitat “1170 Reefs” as any geogenic or biogenic structure (including concretions, encrustations, and bivalve beds originating from dead or living animals) arising from the seafloor. *Neopycnodonte cochlear* reefs enhance heterogeneity and promote biodiversity, with up to 165 taxa observed including several protected species (e.g., *Axinella polypoides* and *Centrostephanus longispinus*).

Economic importance

Neopycnodonte cochlear reefs serve as habitat refuge for many organisms. As documented in the literature, this fauna also includes species of commercial interest like decapods and fishes (e.g., *Palinurus elephas* and *Scorpaena scrofa*). Thus, by promoting biodiversity, *Neopycnodonte cochlear* bioconstructions supply many ecosystem services for human society.

Vulnerability and potential threats

The ROV technology allowed identifying some potential threats to this habitat. Images of lost fishing gears directly entangling these reefs prove the direct impact of artisanal and recreational activities on these bioconstructions. Furthermore, abundant amounts of *Neopycnodonte cochlear* bycatch are commonly collected by trawlers and artisanal fishermen using nets contacting the seafloor. It is plausible that the extension of reefs within trawling fishing grounds has been reduced in time due to mechanical removal.

Protection and management

Further research is needed to better understand *Neopycnodonte cochlear* reefs and to expand our knowledge about their spatial distribution, associated biodiversity, potential threats and goods and services they may provide.

At present, the high biodiversity associated with *Neopycnodonte cochlear* reefs strongly advises for the enforcement of adequate management measures to ensure their protection. Following the European recommendations for ”1170 Reefs” in the Annex I of the Habitats Directive 92/42/EEC, these measures should include fishing restrictions. Habitats with *Neopycnodonte cochlear* have been listed in the Dark Habitats Action Plan.

Suitability of the habitat for monitoring

No monitoring protocol currently employs *Neopycnodonte cochlear* as target species. However, ROV surveys (under the Marine Strategy Framework Directive) and bycatch data (coming from scientific fishing surveys), as well as other scientific explorative programs, provide qualitative and quantitative data regarding the occurrence and abundance of this species, hence indirect information on the integrity of the habitat. Guidelines for inventorying and monitoring dark habitats, including this one, have been identified by RAC/SPA.

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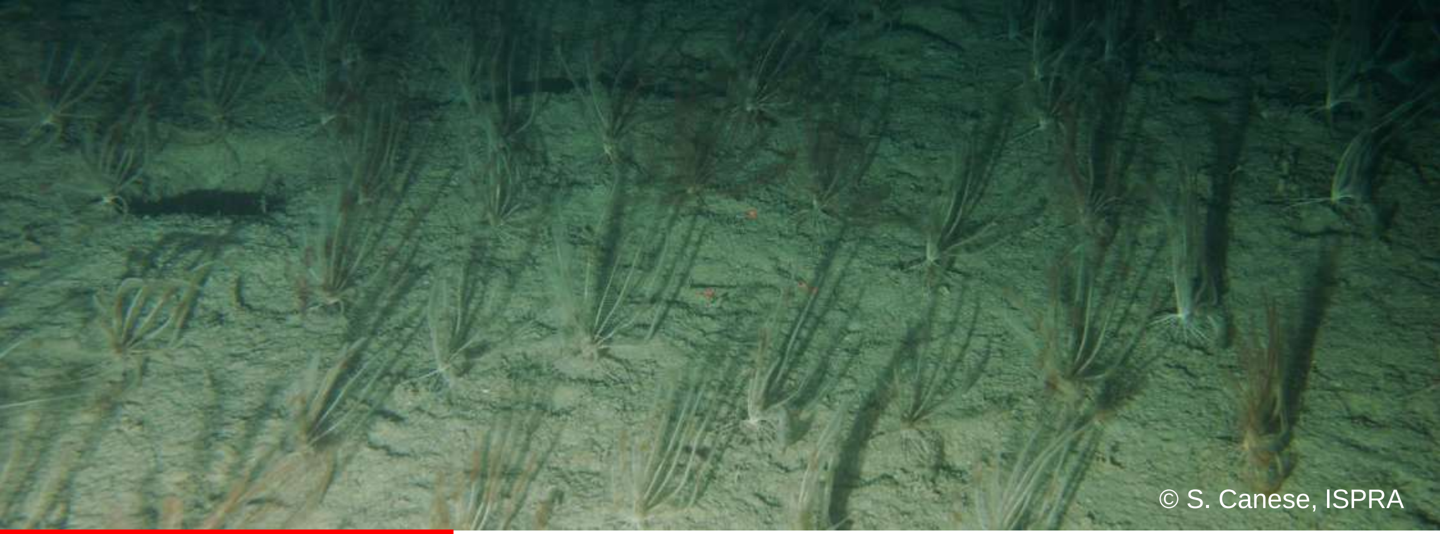
Isolated *Neopycnodonte cochlear* bioconstruction at 70 m depth in the Ligurian Sea (© S. Canese, ISPRA)

A dense population of *Neopycnodonte cochlear* on a wreck in the Ligurian Sea (© S. Canese, ISPRA)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Facies with Crinoidea

Reference codes for identification:

- **BARCELONA CONVENTION: MD3.514, MD4.514**
- **EUNIS 2019: MD4512**
- **EUNIS 2007: A5.472**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Hard (rock), soft (coarse, sand, mud)
Depth range	50 m to 1300 m
Position	Coastal, open sea (continental shelf, shelf edge, upper slope, canyons, seamounts)
Hydrodynamic conditions	Moderate
Salinity	Between 36 and 39
Temperature	13 to 16°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Enrichetti

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OFFSHORE CIRCALITTORAL

MD3.5 Offshore circalittoral coarse sediment
MD4.5 Offshore circalittoral mixed sediment

MD3.51, MD4.51 Offshore circalittoral detritic bottom

MD3.514, MD4.514 Facies with Crinoidea

Description of the habitat

The facies dominated by the crinoid *Leptometra phalangium* is considered by far one of the most characteristic of the Mediterranean detritic bottoms. This species occurs from 50 m to 1300 m depth, but its facies is generally reported between 100-300 m, thus occupying the deeper portion of the continental shelf, the shelf edge and the upper slope in dim light conditions. *Leptometra phalangium* is a semi-mobile suspension-feeder, normally stationary but able to move across the seabed or swim up into the water column if disturbed. Specimens can aggregate in patches that can extend for hundreds of meters and reach maximum densities of up to 50 individuals m^{-2}. These aggregations mainly occur on flat bottoms covered with coarse, organogenic, sandy to fine sediments, but they have also been reported over hard bottoms and erect, benthic organisms, including large sponges and anthozoans. The presence of this facies is generally associated with areas exposed to bottom currents that regularly carry high concentrations of suspended organic particles, like offshore shelf edge rocks, canyons, escarpments, and seamounts.

The crinoids of the genus *Antedon* are also known to create facies in the Mediterranean Sea, on a wide range of substrata including soft and (more frequently) hard bottoms. They generally occur shallower than 300 m depth, despite isolated records down to 930 m.

Geographic distribution

The facies with Crinoidea dominated by *Leptometra phalangium* has been widely reported from the Mediterranean Sea, including Alboran Sea, Balearic Sea, Gulf of Lion, Ligurian Sea, Tyrrhenian Sea, Sicily Channel, and Crete Island.

Associated habitats

This facies typically develops within circalittoral and offshore circalittoral detritic habitats (MC3.51, MD3.51, MD4.51) and upper bathyal soft bottoms (ME5.51, ME6.51). Within these habitats, it can be adjacent to or mixed with ‘Facies with Pennatulacea’ (MC3.515, MD6.511, ME5.512, ME6.512), ‘Facies with Polychaeta’ (MD3.513, MD6.512), ‘Facies with small sponges’ (ME6.511), ‘Facies with scleractinia’ (ME6.515), and ‘Facies with Ceriantharia’ (ME6.519).

As a vagile species, *Leptometra phalangium* can move near or over rocky and biogenic habitats, both in the offshore circalittoral (MD1.5, MD2.5) and upper bathyal (ME1.5, ME2.5), thus co-occurring within several other facies, including those dominated by scleractinians (ME1.515, ME2.513), antipatharians (ME1.513), and alcyonaceans (ME1.514).

Related reference habitats

The facies with Crinoidea dominated by *Leptometra phalangium* occurs in numerous habitats, including ‘Coastal detritic bottoms’ (MC3.519), ‘Upper bathyal rock invertebrate-dominated’ (ME1.517), ‘Upper bathyal detritic sand’ (ME5.513), and ‘Upper bathyal mud’ (ME6.516).

Possible confusion

Leptometra phalangium can be confused with crinoids of the genus *Antedon*, the latter being characterized by thicker arms, a larger number of pinnules and generally brightest colours. Furthermore, *Antedon* spp. generally occur shallower than *Leptometra phalangium*, mainly on hard or detritic bottoms, often associated to *Laminaria* beds. A third genus of Mediterranean crinoids is represented by *Hathrometra* sp., mainly living on rocks between 300 and 700 m depths. *Hathrometra* sp. is not known to form facies in the Mediterranean Sea.

Typical species and associated communities

The facies dominated by *Leptometra phalangium* is generally considered monospecific, but several associated species have ben reported. For example, the sea pen *Funiculina quadrangularis* (IUCN Red List VU), the polychaete *Lanice conchilega* and the cerianthid *Cerianthus membranaceus* accompany this facies on coarse sands, whereas on fine sands, the sea pen *Virgularia mirabilis*, the soft coral *Alcyonium palmatum*, and the sponge *Thenea muricata* have been reported. Crinoid beds are associated to high species richness of infaunal molluscs, particularly *Limopsis aurita*. The shrimp *Hippolyte leptometrae* lives in association with the crinoid. Cidarids and the holothurian *Parastichopus regalis* are frequently observed. In some cases, *Leptometra phalangium* facies have been also reported on firm bottoms, associated with large sponges, scleractinians, gorgonians and black corals.

Furthermore, *Leptometra phalangium* facies has been associated to several fishes, including the Mediterranean hake *Merluccius merluccius*, the poor cod *Trisopterus* sp., the greater forkbeard *Phycis blennoides*, the blackbelly rosefish *Helicolenus dactylopterus*, the red mullet *Mullus barbatus*, *Capros aper*, *Macroramphosus scolopax*, many gurnard species, the four-spot megrim *Lepidorhombus boscii*, and the catshark *Scyliorhinus canicula*.

Conservation interest and ecological role

Leptometra phalangium is a nearly-endemic Mediterranean species. Its aggregations are associated with high densities of benthopelagic fish, with high juvenile abundances, proving that this assemblage may play a crucial role in the life cycle of numerous fishes as a nursery area. The high densities of demersal species associated with this habitat is probably explained by the presence of the crinoids themselves, which favour the three-dimensionality and thus the heterogeneity of the sea-bottom. In certain conditions, this species may act as deposit-feeder, hence contributing to the bioturbation of the seafloor.

Economic importance

The fundamental role played by *Leptometra phalangium* facies in maintaining halieutic resources is widely documented in the literature. The deep-water rose shrimp *Parapenaeus longirostris*, the Mediterranean hake, the red mullet, the blue whiting *Micromesistius poutassou,* the curled octopus *Eledone cirrhosa,* and *Trisopterus minutus capelanus*, are reported among the most recurrent commercial species.

Vulnerability and potential threats

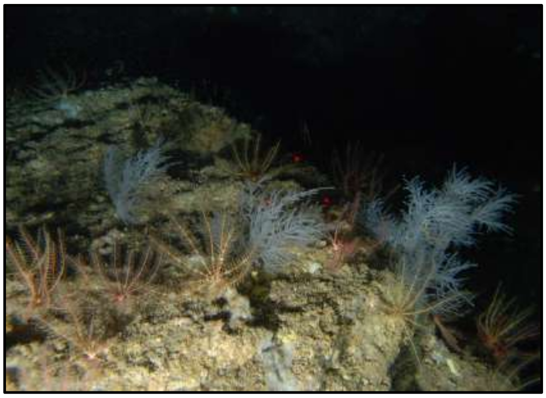
Leptometra phalangium is a fragile organism, easily destroyed by trawling. Studies on commercial catches reported the dominance of this species in the by-catch produced by the bottom trawling fleet in several areas of the Mediterranean Sea, with about 74000 individuals/115 kg collected per hour or 10490 individuals km^{-2}. The vulnerability of *Leptometra phalangium* populations to bottom trawling activities is also highlighted by their low recovering capacity, as reported from the Gulf of Lion, the Ligurian Sea and the Cretan continental shelf. The removal or damage of the individuals is not the only effect of trawling on this facies: modifications in terms of granulometry (related also to external input) and clogging may influence its re-establishment, similarly to changes in the hydrodynamic conditions.

Protection and management

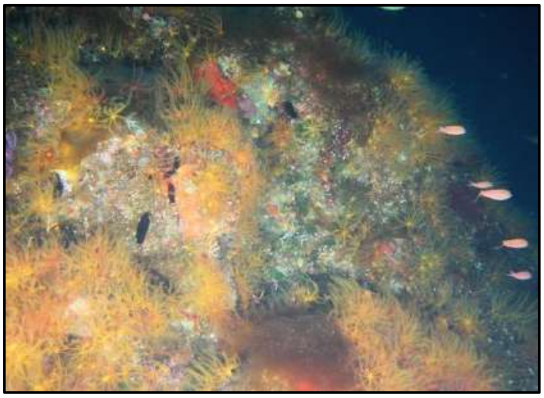
The wide distribution of this facies in many areas of the Mediterranean Sea has determined its inclusion in most habitat lists that deal with Mediterranean Sea environments. Furthermore, due to its vulnerability to bottom trawling activities and capacity to provide feeding, refuge or reproduction for commercial species, this habitat has been considered as a Sensitive Habitat (SH) relevant for fisheries, making any area with *Leptometra phalangium* beds a potential candidate site to become a Specially Protected Area of Mediterranean Importance (SPAMIs). Habitats with *Leptometra phalangium* have been listed in the Dark Habitats Action Plan.

Suitability of the habitat for monitoring

Leptometra phalangium density, estimated through underwater-video imagery, has been used, together with side-scan sonar acquisitions, to improve the quantitative estimation of trawling impacts. Similarly, biomass values obtained from fishing bycatch monitoring programs provide valuable information. Guidelines for inventorying and monitoring dark habitats, including this one, have been identified by RAC/SPA.



Leptometra phalangium facies on rocks inhabited by the black coral *Antipathella subpinnata*. St. Lucia Seamount (Ligurian Sea) © S. Canese, ISPRA



Antedon mediterranea facies on hard bottoms from Ponza Island (Tyrrhenian Sea) © M. Bo

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To be added

Offshore circalittoral sand

Reference codes for identification:

- **BARCELONA CONVENTION: MD5.51**
- **EUNIS 2019: MD55**
- **EUNIS 2007: A5.27**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral
Nature of the substratum	Soft (sand)
Depth range	70 m to 200 m
Position	Open sea
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 to 16°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:

CIRCALITTORAL

MD5.5 Offshore circalittoral sand

MD5.51 Offshore circalittoral sand

Description of the habitat

The habitat is distributed on the furthest part of the continental shelf and in offshore banks and it is characterised by soft bottoms with sand sediment.

Geographic distribution

The habitat is present throughout the Mediterranean Sea.

Associated habitats

The habitats are included in the ‘Offshore circalittoral sand’ (MD5.5). The habitat can have contact with ‘Deep offshore circalittoral banks’ (MD1.53), and ‘Offshore circalittoral rock invertebrate-dominated’ (MD1.51, MD1.52). Associated habitats are ‘Facies with Bivalvia’ (MD3.511, MD4.511), ‘Facies with Brachiopoda’ (MD3.512, MD4.512), ‘Facies with Polychaeta’ (MD3.513, MD4.513), ‘Facies with Crinoidea’ (MD3.514, MD4.514), ‘Facies with Ophiuroidea’ (MD3.515, MD4.515), and ‘Facies with Echinoidea’ (MD3.516, MD4.516).

Related reference habitats

‘Upper bathyal detritic sand’ (ME5.51).

Possible confusion

The habitat could be confused with other soft bottoms, such as ‘Offshore circalittoral mixed sediment’ (MD4.5) and ‘Offshore terrigenous sticky muds’ (MD6.51). The grain size of sediment can be used to distinguish the habitats.

Typical species and associated communities

Many taxa are considered as characteristic of this habitat, such as the sea pen *Virgularia mirabilis*, the soft coral *Alcyonium palmatum*, the sponge *Thenea muricata,* Bivalvia (e.g., *Neopycnodonte cochlear*), Brachiopoda, Polychaeta, Crinoidea (e.g., *Leptometra phalangium*), Ophiuroidea, Echinoidea. Offshore sand bottoms host a highly diversified fish assemblages also of commercial interest (e.g., *Merluccius merluccius*, *Trisopterus* spp., *Phycis blennoides*, *Helicolenus dactylopterus*, *Lepidorhombus boscii*).

Conservation interest and ecological role

The habitat includes facies characterised by particular and ecologically important taxa. Soft bottoms banks host many fish of commercial value, and they are important fishing areas.

Economic importance

The habitat is an important fishing area, but to date its economic value has not been evaluated yet.

Vulnerability and potential threats

The offshore sand bottoms may be altered by the increase of fine sediments, organic matter and pollutants that can act directly on the characteristic species of the assemblages. The habitat may be threatened by physical damage mostly caused by bottom trawling.

Protection and management

The habitat is not protected, and it is assessed as 'Vulnerable' by the European IUCN Red List.

Suitability of the habitat for monitoring

The macro-zoobenthos of Mediterranean soft bottoms is considered a useful tool in monitoring programs and impact evaluation studies and it has to be assessed under the European Directives. The habitat was mostly studied through the analysis of samples taken from box-corers or grabs. Moreover, the use of remotely operated vehicles (ROVs) may allow the study of epifaunal assemblages.

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To be added

Offshore terrigenous sticky mud

Reference codes for identification:

- **BARCELONA CONVENTION: MD6.51**
- **EUNIS 2019: MD651**
- **EUNIS 2007: A5.39**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral
Nature of the substratum	Soft (mud)
Depth range	70 m to 200 m
Position	Open sea
Hydrodynamic conditions	Weak
Salinity	Between 36 and 39
Temperature	10 to 16°C
Suitability for monitoring	Yes

Author:
L. Piazzi

Photo credits:

CIRCALITTORAL

MD6.5 Offshore circalittoral mud

MD6.51 Offshore terrigenous sticky mud

Description of the habitat

The habitat is distributed on the furthest part of the continental shelf, canyons and offshore banks and it is characterised by soft bottoms with muddy sediments.

Geographic distribution

The habitat is present throughout the Mediterranean Sea.

Associated habitats

The habitat is included in the ‘Offshore circalittoral mud’ (MD6.5). The habitat can have contact with ‘Deep offshore circalittoral banks’ (MD1.53) and ‘Offshore circalittoral rock invertebrate-dominated’ (MD1.51, MD1.52). Associated habitats may be ‘Facies with Pennatulacea’ (MD6.511), ‘Facies with Polychaeta’ (MD6.512), ‘Facies with Bivalvia’ (MD6.513), ‘Facies with Brachiopoda’ (MD6.514), and ‘Facies with Ceriantharia’ (MD6.515).

Related reference habitats

This habitat, and its associated communities, can be related to ‘Muddy detritic bottoms’ (MC4.51), ‘Coastal terrigenous mud’ (MC6.51), ‘Lower bathyal sandy mud’ (MF6.51), and ‘Abyssal mud’ (MG6.51).

Possible confusion

The habitat could be confused with other soft bottoms, such as ‘Offshore circalittoral sand’ (MD5.51) and ‘Offshore circalittoral mixed sediment’ (MD4.5). The presence of a muddy sediment is a distinctive character of this habitat.

Typical species and associated communities

The habitat is characterized by organisms of muddy soft bottoms. Many taxa are considered as characteristic of this habitat, such as Pennatulacea (e.g., *Pennatula* spp., *Virgularia mirabilis*), Polychaeta, Bivalvia (e.g., *Neopycnodonte* spp.), Brachiopoda, Ceriantharia (e.g., *Cerianthus* spp., *Arachnanthus* spp.). Offshore muddy bottoms host a highly diversified fish assemblages also of commercial interest (e.g., *Merluccius merluccius*, *Lophius budegassa*, *Lepidorhombus boscii*).

Conservation interest and ecological role

The habitat includes facies characterised by particular and ecologically important taxa and it is an important fishing area.

Economic importance

The habitat is an important fishing area, but to date its economic value has not been evaluated yet.

Vulnerability and potential threats

The mixed detritic bottoms may be altered by the increase of organic matter and pollutants that can act directly on the characteristic species of the assemblages. The habitat may be threatened by physical damage mostly caused by bottom trawling.

Protection and management

The habitat is not protected, and it is assessed as ‘Data Deficient’ by the European IUCN Red List.

Suitability of the habitat for monitoring

The macro-zoobenthos of Mediterranean soft bottoms is considered a useful tool in monitoring programs and impact evaluation studies and it has to be assessed under the European Directives. The habitat was mostly studied through the analysis of samples taken from box-corers or grabs. Moreover, the use of remotely operated vehicles (ROVs) may allow the study of epifaunal assemblages.

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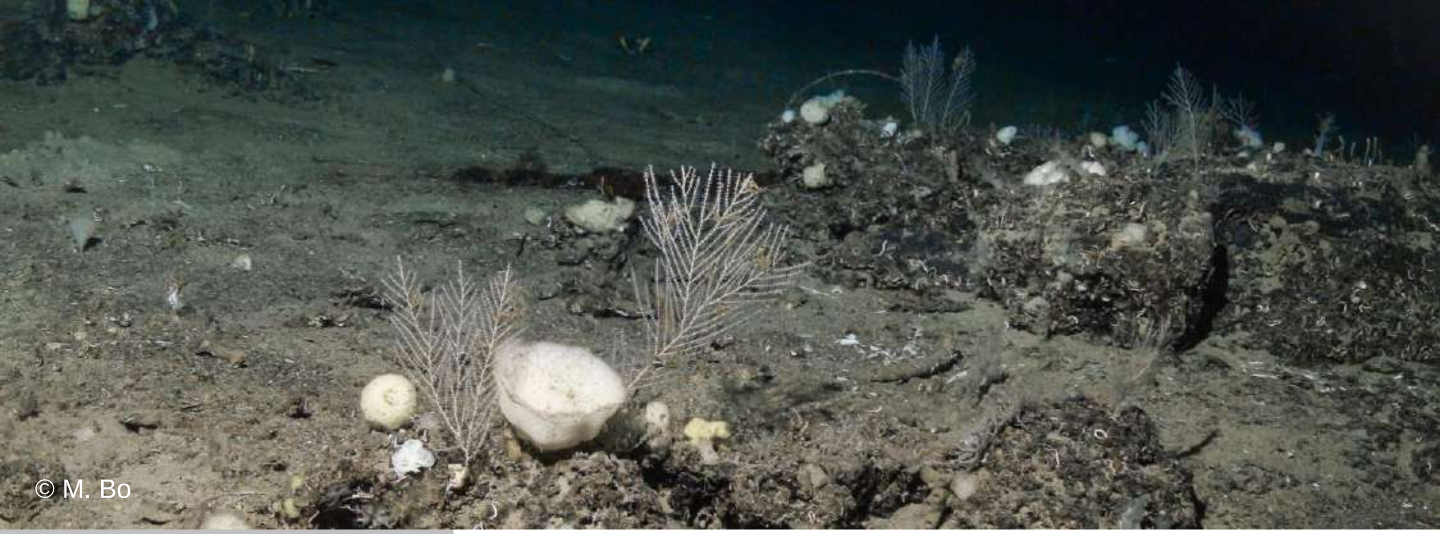

Upper bathyal rock invertebrate-dominated

Reference codes for identification:

- **BARCELONA CONVENTION: ME1.51**
- **EUNIS 2019: ME151**
- **EUNIS 2007: A6.1**

LOCATION OF THE HABITAT

Zone	Upper bathyal
Nature of the substratum	Hard (rock)
Depth range	200 m to 500 m
Position	Open sea (continental slope, topographic reliefs)
Hydrodynamic conditions	Moderate to strong
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Betti

Photo credits:
M. Bo, S. Canese, ISPRA

UPPER BATHYAL

ME1.5 Upper bathyal rock

ME1.51 Upper bathyal rock invertebrate-dominated

Description of the habitat

Below the continental shelf break, exposed hardgrounds are represented by offshore ridges, banks, highs, seamounts, and part of the flanks of the canyons fracturing the continental slope. They can be present as large isolated boulders, cliffs or terraces. Hardgrounds are usually variously silted, while fully outcropping rocks are mainly found in areas where high hydrodynamism reduces sedimentation. Rocks are often covered by a thick and uniform Fe-Mn crust. It is not uncommon the occurrence of patchy secondary substrates, as dead coral or bivalve frameworks, remains of paleo-biocoenoses. Type of substrate, inclination, degree of sedimentation and hydrodynamic conditions are the main factors influencing the benthic communities in this habitat together with recruitment. A certain degree of seasonality, mainly depending on the particles sinking, is observed.

Bathyal hardgrounds, being progressively rarer with depth, represent important sources of heterogeneity, usually turning into benthic diversity hot-spots and points of aggregations for mobile organisms, which tend to concentrate on and around them. Upper bathyal rocks are generally colonized by aggregations of different habitat-forming invertebrates (i.e. sponges, anthozoans, scleractinians, bivalves, barnacles), that, living or dead, strongly increase the tridimensionality of the primary substrate.

The general environment is characterised by a constant homeothermy of around 13-15°C starting around 300 m depth. The upper bathymetric limit is delimited by topography and generally corresponds to the shelf edge, around 200 m depth. The amount of light reaching the upper bathyal rock is lower than 1% of the incident light. The habitat is interested by the flow of the Modified Atlantic Water (MAW) and the Levantine intermediate Water (LIW). Local hydrodynamic turbulence over hardgrounds boosts the occurrence of facies dominated by filter-feeders.

Geographic distribution

This habitat is widespread in the entire Mediterranean Sea, both along the continental slopes (fractured by more than 800 steep canyons) and on topographic elevations scattered inside the basin, such as ridges, highs, banks and seamounts (these latter counting more than 250 structures). In terms of overall extent, 'Upper bathyal rock' is second to 'Upper bathyal mud' (ME6.51).

Associated habitats

This habitat is usually delimited at shallower depths by ‘Offshore circalittoral rock invertebrate-dominated (MD1.51), also covered by sediments (MD1.52), ‘Deep offshore circalittoral banks’ (MD1.53), offshore circalittoral thanatocoenoses (MD2.52), or soft-bottom habitats (MD3.51, MD3.52, MD5.51, MD6.51). Upper bathyal hardgrounds can be part of structures rising from lower bathyal depths, therefore bordering with “Lower bathyal rock’ (MF1.51). Usually they are surrounded by ‘Upper bathyal coarse sediment’ (ME3.5), ‘Upper bathyal mixed sediment’ (ME4.5), ‘Upper bathyal sand (ME5.5) or, more frequently, ‘Upper bathyal mud’ (ME6.5). The latter habitat can be found also in depressions or over plains on the rocky reliefs and may delimit their extension in the lower bathyal range. This habitat usually hosts vast aggregations of sessile habitat-forming species, creating ‘Facies with large and erect sponges’ (ME1.512), ‘Facies with Antipatharia’ (ME1.513), ‘Facies with Alcyonacea’ (ME1.514), ‘Facies with Scleractinia’ (ME1.515), ‘Facies with Cirripedia’ (ME1.516) and ‘Facies with the Bivalvia *Neopycnodonte* spp.’ (ME1.518). In addition, ‘Facies with small sponges’ (ME1.511), ‘Facies with Crinoidea’ (ME1.517), and ‘Facies with Brachiopoda’ (ME1.519) can be present.

Related reference habitats

The presence of both living and dead CWC frameworks on the rocky substrate can originate ‘Upper bathyal biogenic habitat’ (ME2.5) and upper bathyal thanatocoenoses (ME2.52). Finally, bathyal rock can be characterized by caves and ducts (ME1.52).

Possible confusion

Some species typical of the ‘*roche du large’* may extend in the upper bathyal. Sessile, carbonatic habitat-forming species (scleractinians and bivalves) often thrive in this habitat, thus the confusion with the habitats ‘Upper bathyal reefs’ (ME2.51) and ‘Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges’ (ME2.52) is possible. The extension, structure or status of the frameworks is the main differentiating aspect.

Typical species and associated communities

By enhancing the vorticity of currents, canyons and topographic reliefs are influenced by gyres, upwellings and downwellings having cascading effects on carbon fluxes, zooplankton concentrations, diversity and biomass of benthic and pelagic fauna. Cold-Water Corals (CWCs) such as *Dendrophyllia cornigera*, *Desmophyllum dianthus*, *Lophelia pertusa* (=*Desmophyllum pertusum*) and *Madrepora oculata* (all in Annex II SPA/BD, IUCN Red List EN) are typical inhabitants of this habitat. The scleractinian *Caryophyllia* (*Caryophyllia*) *calveri* can also be present. Black corals can form dense forests on the upper bathyal rock: *Leiopathes glaberrima* (Annex II & III SPA/BD, Annex III Bern, IUCN Red List EN), *Antipathes dichotoma*, *Parantipathes larix* and *Antipathella subpinnata* (all in Annex II & III SPA/BD, Annex III Bern, IUCN Red List NT; the latter only occasionally present in this depth range) are among the most conspicuous species of this habitat. Also, many alcyonaceans, such as *Acanthogorgia hirsuta*, *Dendrobrachia bonsai*, *Bebryce mollis*, *Swiftia pallida*, *Viminella flagellum*, and *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT) can form forests. The endemic hexactinellids *Farrea bowerbanki* and *Tretodictyum reiswigi*, and large demosponges (e.g., *Pachastrella monilifera*, *Poecillastra compressa*, *Sympagella delauzei*, *Haliclona (Haliclona) magna*, *Phakellia ventilabrum*, *Characella pachastrelloides*, *Stylocordyla pellita*), and encrusting ones (e.g., *Hexadella dedritifera*, *Hamacantha (Vomerula) falcula*, *Haliclona (Gellius) bioxeata*, *Rhabderemia* sp.) are among the most common organisms of this habitat, and some species can constitute facies. *Asconema setubalense* is a habitat-forming sponge, common in the Alboran Sea. Also, the bivalves *Neopycnodonte zibrowii* and *Spondylus gussonii* (both commoner in the lower bathyal), and the brachiopods *Gryphus vitreus*, *Megerlia truncata*, *Terebratulina retusa* and *Novocrania anomala* can form aggregations. Other benthic sessile organisms, such as serpulid worms, and bryozoans (e.g., *Exidmonea* sp.) are usually present. Many bathyal vagile invertebrates, such as molluscs (in particular the cephalopod *Pteroctopus tetracirrhus*), crustaceans (including the squat lobster *Munida tenuimana*, *Plesionika* spp., and *Palinurus mauritanicus*) and echinoderms (in particular the sea urchin *Cidaris cidaris*, crinoids and some sea stars, such as *Coronaster briareus*, *Peltaster placenta*) can be observed on invertebrate-dominated upper bathyal rock, together with benthic fishes, such as *Lophius* spp., *Helicolenus dactylopterus*, *Phycis blennoides*, *Conger conger*. Moreover, several bentho-nektonic

(*Hexanchus griseus*, *Merluccius merluccius* (IUCN Red List VU), *Pagellus bogaraveo, Pagellus acarne*, *Polyprion americanus*, *Centrolophus niger, Macroramphosus scolopax*, *Hoplostethus mediterraneus*, *Capros aper*, *Callanthias ruber*, *Epigonus* spp., and various macrourids), pelagic fishes and cetaceans tends to aggregate over seamounts or in canyons.

Conservation interest and ecological role

The upper bathyal is characterized by a high species richness, hosting both characteristic species and eurybathic ones. The fauna includes some nearly-endemic and endemic organisms, and a high occurrence of Atlantic species (many of boreal affinity), representing relatively recent entrances in the basin. The communities living in this habitat include rare species and many organisms that are still poorly studied. The aggregations of sessile invertebrates on upper bathyal hardgrounds are important deep-sea biodiversity hotspots, and are densely populated by a rich vagile and bentho-nektonic fauna, increasing the overall biomass of the area. Deep carbonate frameworks and animal forests provide niches, which boost biodiversity similarly to highly complex shallow-water environments, thanks also to the development of numerous biotic associations. The skeletal remains of numerous sessile species are persistent secondary hard substrates which contribute in guaranteeing temporal stability and environmental variability to the assemblages in this habitat. The occurrence of invertebrate-dominated rocks has an influence on the surrounding soft bottoms, in terms of diversity and biomass of epi and infauna. In addition, the highly populated hardgrounds of canyons and seamounts attract benthic and pelagic fishes. Finally, these complex ecosystems are known to enhance the pelagic-benthic coupling processes and the biogeochemical cycles occurring at these depths, hence they fully contribute to the functioning of the deep-sea.

Economic importance

Many species of crustaceans (e.g., *Palinurus mauritanicus*) and fishes (e.g., *Merluccius merluccius*, *Polyprion americanus*, *Lepidopus caudatus*, *Centrolophus niger*, *Lophius* spp., *Conger conger*, *Pagellus* spp.) of commercial interest live in this habitat. Many other valuable species regularly frequent it for feeding, spawning or as nursery site.

Vulnerability and potential threats

Upper bathyal hardgrounds are target of both artisanal and recreational fishing activities, and are only partially interested by bottom trawling. The three-dimensional facies may show high levels of damages (due to entanglement, eradication, breakage, size reduction). The physical destruction or selective removal of habitat-forming species leads to an homogenization of the seafloor, shifts in species composition towards fast-growing species, and ultimately alters the ecosystem functioning of this habitat and its productivity. The recovery ability of the communities to mechanical disturbances is reduced by the long life cycles and slow growth rates of some of the habitat-forming species, defining resilience in the order of decades or more. Abandoned, lost or otherwise discarded fishing gears (ALDFG) and associated accessories (e.g., disposable moorings, ropes), together with urban or maritime litter, are commonly seen on seamounts and along canyon flanks. Intensive recreational fishing effort may lead to the local extinction of slow growing, territorial fish species (e.g., *Polyprion americanus*) and a shift in target species. Mining activities, targeting hydrogenous Fe-Mn crusts and polymetallic sulphides exploited for base metals or for precious and high-tech metals, is likely to increase in the near future, as such exploratory mineral mining has already been conducted. Changes in the silting levels and input of pollutants, due to coastal activities, alter settling rates and the filter activity of benthic species. Increasing evidence is emerging towards the effects of global changes in the deep Mediterranean Sea: many CWCs, of Atlantic origin, are at their limit of thermotolerance in the basin, and are therefore particularly vulnerable to thermal alterations. In addition, higher temperatures increase deep-sea metabolism, thus exacerbating the effects of deep Mediterranean congenic food limitation.

Protection and management

Some measures have been identified to protect this habitat and the facies it hosts. Some species typically occurring on upper bathyal invertebrate-dominated rock are now included in lists of protection (IUCN, SPA/DB, Bern). All coral forests are identified as Vulnerable Marine Ecosystems (VMEs) in the FAO/GFCM International guidelines for the management of the deep sea fisheries in the high seas, representing Essential Fish Habitats (EFHs). The Mediterranean Action Plan of the Barcelona Convention included habitats dominated by habitat-forming species as part of the "Dark Habitats", which deserve protection. Mapping VMEs, such as the ones included in this habitat, is considered an essential step in the framework of environmental protection, as declared in the European Marine Strategy Framework Directive (2008/56/EC). Seamounts and canyons are considered priority biotopes under the European Commission Natura 2000 network. The implementation of protection measures through the creation of offshore Marine Protected Areas (MPAs) and Fisheries Restricted Areas (FRAs) are still poorly pursued mainly due to socio-economic constraints, lack of data and difficulties in controlling territories in international waters. At present, a FRA extending for about 4000 km^2 has been established in 2009 to protect the benthic habitat and the fishing resources in the Gulf of Lion canyon system (REC. GFCM/33/2009/1), part of a larger MPAs network. New proposals are emerging every year for this habitat thanks to scientific advancement and a larger consensus among stakeholders.

Suitability of the habitat for monitoring

Within the Marine Strategy Framework Directive (2008/56/EC) numerous ecological and biological parameters are employed to evaluate the environmental status of the hard-bottom benthic assemblages and describe the impact of anthropic activities in this habitat. Biodiversity (D1), integrity of the seafloor (D6), and sea floor litter (D10) are considered important descriptors to assess the status of this habitat and a major effort is currently in place to create distribution maps of VMEs and develop multi-parametric ecological indexes. Shared deep-sea essential ecological variables (DEEVs) have been defined to reach effective, long-term ecosystem-based management and monitoring strategies. General indications are given in the RAC/SPA guidelines for inventorying and monitoring of dark habitats in the Mediterranean Sea. A wide array of technologies are now available to investigate deep-sea ecosystems traditionally considered remote and difficult (e.g., ROVs, AUVs, fixed platforms acquiring physico-chemical parameters, continuous video and acoustic imaging, photomosaic techniques, and *in situ* environmental-DNA sequencing technologies) and benthic habitat modelling proved to be useful to obtain large-scale maps and help the decision-making process. Beside monitoring, an explorative effort is still necessary as only few rocky upper bathyal areas have been widely studied (e.g. Alboran Sea, NW Mediterranean Sea, Malta Escarpment, S Adriatic Sea).

The pink spiny lobster *Palinurus mauritanicus* and some narwal shrimps *Plesionika narval* (© S. Canese, ISPRA)

The fourhorn octopus *Pteroctopus tetracirrhus* (© S. Canese, ISPRA)

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Facies with large and erect sponges

Reference codes for identification:

- **BARCELONA CONVENTION: ME1.512**
- **EUNIS 2019: MC151G, MC1511**
- **EUNIS 2007: A4.1, A4.2, A4.261, A4.3**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Hard (rock, biogenic)
Depth range	90 m to 1000 m
Position	Open sea (continental shelf, shelf edge, slope, canyons, seamounts)
Hydrodynamic conditions	Moderate
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

Authors:
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UPPER BATHYAL

ME1.5 Upper bathyal rock

ME1.51 Upper bathyal rock invertebrate-dominated

ME1.512 Facies with large and erect sponges

Description of the habitat

Numerous large and erect sponges are known to form distinct facies on bathyal hard-bottoms. They can form monospecific facies or can be variously mixed between them and/or habitat-forming anthozoans.

The astrophorids *Pachastrella monilifera* and *Poecillastra compressa* have been widely reported from deep banks, canyons, escarpments and seamounts, where they generally form mixed assemblages on sub-horizontal highly silted hard bottoms between 90 and 980 m depth. In some areas these species create sponge grounds, reaching maximum sizes of 10-20 cm and densities of up to 50 individuals m^{-2}. Other massive sponges, including *Phakellia* spp., *Hamacantha (Vomerula) falcula*, *Haliclona (Halichoclona) magna*, *Erylus papulifer*, *Pachastrissa patologica* and *Tretodictyum reiswigi* (this latter possibly known down to 2644 m) may contribute to this assemblage or form separate facies. Some of these sponges reach considerable sizes, like *Phakellia* spp. (up to 25 cm) and *Haliclona (Halichoclona) magna* (up to 75 cm) and contribute to increase habitat complexity.

Two other bathyal sponge grounds dominated by demosponges are known from the Mediterranean Sea. *Stylocordyla pellita* is a 10-cm stalked sponge reported from 200 to 890 m depth. It is known to form dense aggregations on seamounts and escarpments (with density peaks of almost 100 specimens m^{-2}), developing both on flat and sloping silted hardgrounds and, less frequently, subfossil oyster and coral frameworks. Occasionally, this facies hosts other sponges, such as *Phakellia ventilabrum*. Another characteristic sponge ground is the one dominated by the massive, vase-shaped sponge *Characella pachastrelloides.* This aggregation is reported from a seamount between 410 m and 570 m, reaching densities of up to 3 individuals m^{-2}. It colonizes highly silted and flat hardgrounds also hosting numerous other massive sponges.

Hexactinellid sponges are also known to form facies on Mediterranean bathyal hard bottoms. *Farrea bowerbanki* can grows up to 60 cm, reaching high densities between 380 m and 990 m depth, on rocks and cliffs associated with canyons and seamounts. *Asconema setubalense* is a large vase-shaped sponge forming peculiar facies on highly silted sub-horizontal bottoms from 180 m to 500 m depth.

The lollipop sponge *Sympagella delauzei* (about 15-cm height) is generally associated with bathyal rocks and cold-water coral frameworks occurring from 180 m to 500 m depth.

Geographic distribution

Pachastrella monilifera and *Poecillastra compressa* assemblages are widely distributed in the western Mediterranean Sea; they are reported also from the Ionian Sea, Adriatic Sea and Aegean Sea. Sponge grounds dominated by *Stylocordyla pellita* and *Characella pachastrelloides* are reported from the Ligurian Sea, and the former species is also known from the Alboran Sea, Sicily Channel and the Aegean Sea.

Among hexactinellids, *Farrea bowerbanki* is known from the Balearic Sea, Ligurian Sea, Tyrrhenian Sea and the coasts of Lebanon. *Asconema setubalense* was initially reported from the Algerian coast and its facies results widely distributed within the Alboran Sea. *Sympagella delauzei* has been reported from the Alboran, Balearic and Tyrrhenian seas.

Associated habitats

The habitat dominated by large and erect sponges can be adjacent or mixed with the ‘Facies with small sponges’ (ME1.511), ‘Facies with large and erect sponges’ (ME1.512), ‘Facies with Antipatharia’ (ME1.513), ‘Facies with Alcyonacea’ (ME1.514), ‘Facies with Scleractinia’ (ME1.515), ‘Facies with Cirripedia’ (ME1.516), ‘Facies with Crinoidea’ (ME1.517), ‘Facies with Bivalvia’ (ME1.518), and ‘Facies with Brachiopoda’ (ME1.519).

Related reference habitats

This facies fully develops in the ‘Upper bathyal rock invertebrate-dominated’ (ME1.51), but it may be a component of the ‘Offshore circalittoral rock invertebrate-dominated’ (MD1.51, MD1.52), ‘Deep offshore circalittoral banks’ (MD1.53), ‘Offshore circalittoral biogenic habitat’ (MD2.5), ‘Upper bathyal biogenic habitat’ (ME2.5), ‘Lower bathyal rock’ (MF1.5) and ‘Lower bathyal biogenic habitat’ (MF2.5). In some areas, this facies can also extend on coarse detritic bottoms.

Possible confusion

ROV imaging-based techniques are often been proved to be inadequate for the identification of sponge species. Direct samplings allow to increase information on the species richness, species composition and characteristics of this deep-sea facies.

Typical species and associated communities

The typical species characterizing this facies are *Asconema setubalense*, *Characella pachastrelloides*, *Farrea bowerbanki, Hamacantha (Vomerula) falcula*, *Leiodermatium* sp., *Haliclona poecillastroides*, *Pachastrella monilifera, Phakellia* spp., *Poecillastra compressa*, *Stylocordyla pellita*, *Haliclona (Halichoclona) magna*, and *Sympagella delauzei*. Dictyoceratida e Agelasida may occur in the upper bathyal, especially in the eastern basin. Several other sponges are reported within this facies, including *Aaptos aaptos*, *Dictyonella* sp., *Erylus papulifer*, *Hexadella dedritifera*, *Haliclona mucosa*, *Geodia* sp., *Mycale* sp., *Pachastrissa pathologica*, *Podospongia loveni*, *Rhabderemia* sp., and *Tretodictyum reiswigi*.

Most common cnidarians include the gorgonians *Swiftia dubia, Callogorgia verticillata*, and *Bebryce mollis*, black corals (Annex II SPA/BD, Annex III Bern, IUCN Red List NT and EN), zoanthids and the scleractinians *Madrepora oculata*, *Lophelia pertusa* (= *Desmophyllum pertusum*), *Desmophyllum dianthus* and *Dendrophyllia cornigera* (Annex II SPA/BD, IUCN Red List EN). Associated fauna also include polychaetes (*Filograna* spp., *Sabella pavonina*, *Bonellia viridis*), crustaceans (*Munidopsis* spp., *Munida* spp., *Palinurus mauritanicus*), echinoderms (*Peltaster placenta*, *Cidaris cidaris*, *Echinus melo*) and brachiopods (*Gryphus vitreus*). Several fishes have been also reported, including *Callanthias ruber*, *Anthias anthias*, *Helicolenus dactylopterus*, *Notacanthus bonaparte*, *Merluccius merluccius (*IUCN Red List VU), *Lappanella fasciata*, *Phycis blennoides*, *Gaidropsarus granti*, *Aulopus filamentosus*, *Macroramphosus scolopax*, *Scorpaena* spp., and *Pagellus bogaraveo*.

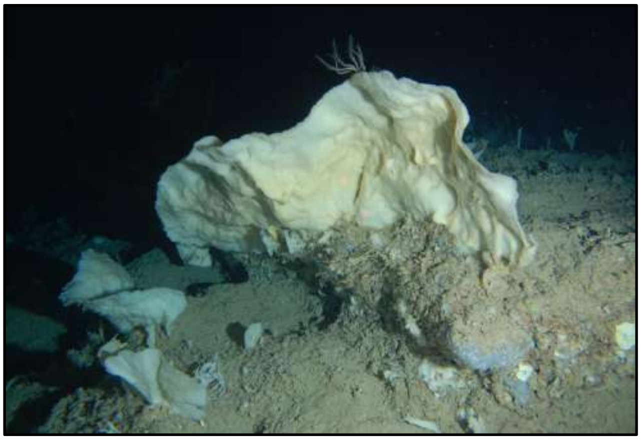
Conservation interest and ecological role

ROV explorations are revealing that sponges are an important component of deep-sea megabenthic communities, particularly on rocky bottoms. Due to their erect growth habit and tendency to create aggregations, this facies increases the three-dimensionality of the seafloor: small, erect species form a dense undergrowth among larger, massive sponges. Gorgonians, scleractinians and black corals often contribute in structuring these complex habitats in otherwise bidimensional environments often exposed to high sedimentation rates. As a result, sponge grounds attract numerous species of invertebrates and fishes leading to high biodiversity levels. Although less markedly than anthozoans, sponges themselves may represent a secondary substrate for other species, such as zoanthids, ophiuroids and amphipods. Sponges aggregations are also important elements in the deep-sea pelagic-benthic coupling. They are active filter feeders and, while exploiting the suspended organic matter, deep-sea sponge assemblages may also be affected by cidarid sea urchin grazing, overall playing a central role in organic matter and energy transfer from the pelagic to the benthic realm.

Economic importance

Bathyal hardgrounds where large and erect sponges occurs are often associated with several demersal fishes of commercial interest, including *Helicolenus dactylopterus*, *Merluccius merluccius*, *Phycis blennoides*, *Scorpaena* spp., and *Pagellus bogaraveo*. Furthermore, deep-sea sponge aggregations represent important biodiversity reservoirs and contribute to the trophic recycling of organic matter. Their biochemical potential remains still largely unexplored in the Mediterranean region. For these reasons they provide essential ecosystem services for the human society.

Pachastrella monilifera (left panel) and *Poecillastra compressa* with *Phakellia* sp. and *Madrepora oculata* (right panel) (© OCEANA)



Phakellia ventilabrum
(© OCEANA)

Characella pachastrelloides
(© M. Bo)

Vulnerability and potential threats

Mechanical impact and general habitat destruction (derived from either physical damage or pollution) represent the main threats to virtually all types of sponge aggregations. Bottom-fishing activities (e.g., longlines, bottom nets, benthic traps, trawling, etc.) are primary causes of mechanical damage. On hard bottoms, longlines, trammel nets and gill nets can be way more impacting than trawling activities. Trap or pot fishing may also damage sponge aggregations during the hauling operations. In addition to these direct impacts, sponges on hard bottoms may also suffer indirect impacts of chronic trawling activities through increased sediment loads enhancing clogging. The vulnerability of sponges to these sources of pressure may be different than that of anthozoans, but still received poor attention. Other causes of indirect stress could be represented by other industrial activities, such as dredging, oil and gas prospecting and exploitation, deep-sea mining, industrial pollution (e.g., red mud) and sea floor litter.

Protection and management

Sponge grounds are defined as aggregations of large sponges, dominating in size and abundance (and also often by the accumulation of skeletal remains on the seabed), that develop under certain environmental conditions to form structured habitat. The role of these aggregations as builders of complex three-dimensional habitats has often been recognized, but functional information regarding sponge biomass and fluxes of matter and energy have not been appropriately studied. Furthermore, very little is known about their reproductive biology, longevity and connectivity. This information is fundamental to fully understand the importance of sponge aggregations in marine ecosystems functioning and to plan proper conservation actions. Differently from the NE Atlantic, where sponge grounds are subjected to various forms of protection, no target action has been put in place in the Mediterranean Sea. The Food and Agriculture Organization (FAO) of the United Nations recognizes sponge grounds as Vulnerable Marine Ecosystems (VMEs), highlighting that the uniqueness and rarity of species and habitats, their functional significance, fragility, structural complexity and life history, limit their probability of recovery. The General Fisheries Commission for the Mediterranean Sea (GFCM) has adopted Fisheries Restricted Areas (FRAs) as a tool to protect VMEs (and related Essential Fish Habitats, EFHs) within the Mediterranean Sea. So far, deep sponge habitats are protected within the Gulf of Lion marine park network, including one FRA. The Mediterranean Action Plan of the Barcelona Convention on Biological Diversity included sponge grounds dominated by demosponges and hexactinellids as part of the so-called “Dark Habitats” and indicated these unique deep-sea habitats as potential indicators of Ecologically and Biologically Sensitive Areas (EBSAs). They can also be included in the EU Nature 2000 Network.

Suitability of the habitat for monitoring

While physical damage to sponge aggregations is relatively easy to identify at shallow depths through direct observations, their conservation status in the deep-sea is often hard to evaluate. However, modern technologies such as underwater acoustic profiling, ROVs, and photomosaic techniques are becoming increasingly used. ROV-Imaging, for example, allows to proper detect several quantitative parameters (e.g., specimens density, mean size, presence of litter) internationally recognized as good proxies for habitat monitoring. General indications are given in the RAC/SPA guidelines for inventorying and monitoring of dark habitats in the Mediterranean Sea.

Asconema setubalense
(© OCEANA)

Sympagella delauzei
(© OCEANA)

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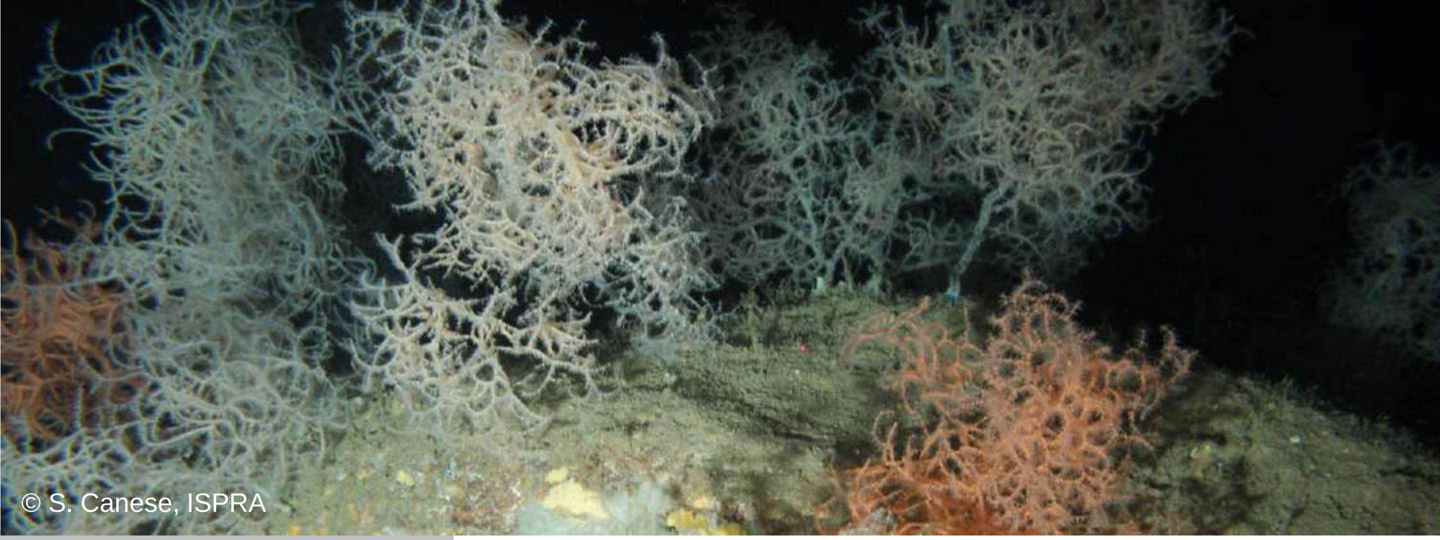
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Facies with Antipatharia

Reference codes for identification:

- **BARCELONA CONVENTION: ME1.513**
- **EUNIS 2019: ME1511, MF1511**
- **EUNIS 2007: A6.611**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Hard (rock, biogenic)
Depth range	80 m to 930 m
Position	Open sea (continental shelf, shelf edge, slope, canyons, seamounts)
Hydrodynamic conditions	Weak to strong
Salinity	Between 38 and 39
Temperature	13 to 15°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Betti

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UPPER BATHYAL

ME1.5 Upper bathyal rock

ME1.51 Upper bathyal rock invertebrate-dominated

ME1.513 Facies with Antipatharia

Description of the habitat

This facies, dominated by the arborescent black coral *Leiopathes glaberrima*, occurs mainly on sub-horizonal or gently sloping hardgrounds, never over-hanging. This species occurs as small, isolated patches or dense forests, monospecific or intermixed with other habitat-forming alcyonaceans and antipatharians. The largest forests are generally found on rocky reliefs (e.g. bench terraces, knolls, coral reef mounds), covering 50-100 m^2, exposed to moderate or strong currents and moderate silting levels. Here colonies can grow up to 200 cm high and 300 cm wide (usually around 60-100 cm), with basal diameters of up to 7 cm, and may show high densities (0.3-2.5 colonies m^{-2}, up to 8 colonies m^{-2}), with standing crops of few thousands of colonies. The dense canopy forms a highly three-dimensional environment.

The main factors driving the distribution and the structure of *Leiopathes glaberrima* forests are the availability of rock, dim light or darkness, currents, moderate to light inclination, moderate silting, trophic supply, biotic interactions with other habitat-formers, and fishing intensity.

Similarly to *Leiopathes glaberrima*, also *Antipathes dichotoma* shows a bathymetric optimum of distribution in the shelf and upper bathyal rocky habitats, however it never forms dense monospecific forests (on average 0.1 colonies m^{-2}, rarely up to 4 colonies m^{-2}). Small patches are known from pluri-specific forests intermixed with other antipatharians (*Leiopathes glaberrima*, *Parantipathes larix*, and *Antipathella subpinnata*) and gorgonians. The canopy formed by *Antipathes dichotoma* colonies is about 70-80 cm high (up to 130 cm). Colonies are generally branched, with a willow-like morphology, even if sparsely branched colonies or whip-like ones are known. Similarly to *Leiopathes glaberrima*, this species seems tolerate high silting levels. It has been recorded also on sub-vertical substrates.

Geographic distribution

Leiopathes glaberrima is an Atlanto-Mediterranean species. The greatest part of the global population is found in the Mediterranean basin, where this species is found throughout the area from about 110 m to about 790 m, but mainly between 150-400 m.

Forests are known from the Alboran Sea, western Mediterranean Sea, Sicily Channel, Ionian Sea, South Adriatic Sea, Aegean Sea and eastern Levantine basin, Rhodos, Crete and Israel. This facies is frequent along the shelf edge, canyons, ridges and seamounts' summits. The largest known populations are from SW Sardinia, southern Tyrrhenian Sea, Sicily Channel, and southern Adriatic Sea.

Antipathes dichotoma is also an Atlanto-Mediterranean species, with the majority of the populations found in the Mediterranean basin. It has been reported from 80 m to about 924 m with a similar geographic distribution to *Antipathella subpinnata* and *Parantipathes larix*, along most of the Mediterranean coasts, from the Alboran Sea to the Aegean Sea.

Other deep Atlantic black corals, still currently under taxonomic investigation, have been recently found in the western bathyal Mediterranean Sea, down to 2000 m depth, including species of the genera *Antipathes*, *Phanopathes* and *Parantipathes*.

Associated habitats

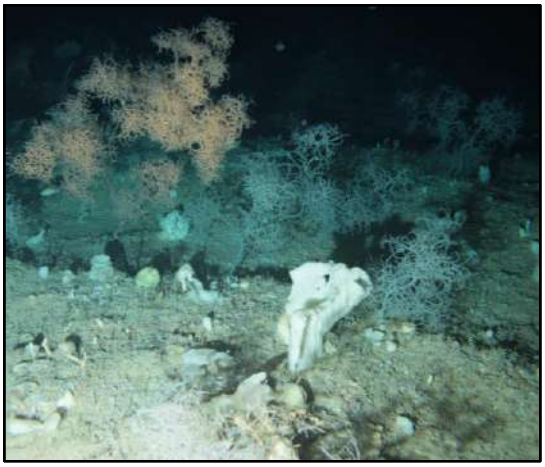
Facies with *Leiopathes glaberrima* are commonly found in the 'Upper bathyal rock invertebrate-dominated' (ME1.51) and 'Upper bathyal biogenic habitat' (ME2.5) as distinct forests, as well as intermixed or adjacent to facies with large and erect sponges (ME1.512), alcyonaceans (ME1.514), and scleractinians (ME1.515). The understory of the coral canopy, depending on the silt cover, may hosts facies with small sponges (ME1.511), small alcyonaceans (ME1.514), as well as scleractinians (ME1.515), cirripeds (ME1.516), crinoids (ME1.517), bivalves (ME1.518), and brachiopods (ME1.519). Adjacent detritic, mixed, sandy or muddy sediments commonly host 'Facies with Alcyonacea' (ME6.513), 'Facies with Pennatulacea' (MD6.511), 'Facies with Bivalvia' (MD6.513), and 'Facies with Ceriantharia' (MD6.515).

Related reference habitats

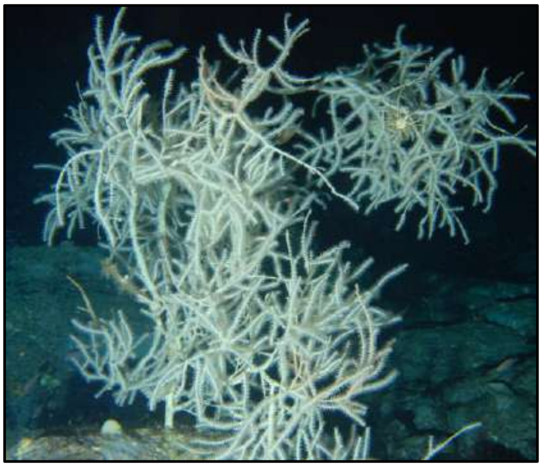
The 'Facies with Antipatharia' described here shares the same characteristics of the antipatharians-dominated habitats found on deep offshore circalittoral banks (MD1.531) and circalittoral deep banks (MC1.521c). Facies dominated by *Leiopathes glaberrima* and other black corals can be occasionally found also in ''Offshore circalittoral rock invertebrate-dominated' habitat (MD1.51).

Possible confusion

The facies dominated by *Leiopathes glaberrima* is easily distinguishable from both the forests of *Parantipathes larix* (bottle-brush morphology), from those of *Antipathes dichotoma* (characterized by opaque yellow, large polyps and long, loose flexible branches), and from those dominated by *Antipathella subpinnata* (densely branched, with smaller polyps), although the arborescent morphology of these latter two species may lead to mis-identification, especially from ROV images obtained from a certain distance. Antipatharian facies can develop intermixed with alcyonacean facies and/or white coral reefs, occasionally making the separation between these habitat difficult.



Rich sponge-dominated understory of a *Leiopathes glaberrima* forest (© S. Canese, ISPRA)



An arborescent colony of *Antipathes dichotoma* hosting the crab *Anamathia rissoana* (© S. Canese, ISPRA)

Typical species and associated communities

Forests of *Leiopathes glaberrima* (Annex II SPA/BD, Annex III Bern, IUCN Red List EN) may be monospecific or, as frequently happens in the Mediterranean Sea, are mixed with other antipatharians and gorgonians. This facies has been recorded on rocky outcrops together with *Antipathes dichotoma* (Annex II SPA/BD, Annex III Bern, IUCN Red List NT), *Parantipathes larix* (Annex II SPA/BD, Annex III Bern, IUCN Red List NT), *Antipathella subpinnata* (Annex II SPA/BD, Annex III Bern, IUCN Red List NT), the scleractinian *Dendrophyllia cornigera* (Annex II SPA/BD, IUCN Red List EN), large-sized gorgonians as *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Acanthogorgia hirsuta*, *Eunicella cavolinii*, *Viminella flagellum* and various small-sized alcyonaceans, such as *Villogorgia bebrycoides*, *Paramuricea macrospina*, *Swiftia dubia*, *Bebryce mollis*, *Corallium rubrum* (Annex III SPA/BD, Bern, IUCN Red List EN, Habitat Directive), *Muriceides lepida*. Among other filter-feeders are reported also *Pachastrella monilifera*, *Poecillastra compressa*, and *Asconema setubalense*, soft corals, such as *Paralcyonium spinulosum*, and bryozoans such as *Turbicellepora* spp. Mixed assemblages of *Leiopathes glaberrima* and white corals (*Madrepora oculata*, *Lophelia pertusa* (= *Desmophyllum pertusum*) and *Desmophyllum dianthus*) (all Annex II SPA/BD, IUCN Red List EN) have been reported in numerous localities. The giant barnacle *Pachylasma giganteum* (Annex II SPA/BD, Annex II Bern) has been observed in the same environment of *Leiopathes glaberrima* in the Sicily Channel. The rocks host also encrusting sponges, sea anemones, scleractinians (*Caryophyllia calveri*), nudibranchs, the echiurid *Bonellia viridis*, the brachiopod *Megerlia truncata*, serpulids, barnacles (*Verruca* sp.), and cemented bivalves (*Spondylus gussonii*). Various megafaunal species frequent the understory of this forest, such as the sea star *Peltaster placenta*, the sea urchins *Echinus melo*, *Cidaris cidaris* and *Stylocidaris affinis*, the crustaceans *Munida* sp., *Palinurus mauritanicus*, *Paromola cuvieri*, *Plesionika* spp., *Bathynectes maravigna*.

The arborescent skeleton of *Leiopathes glaberrima*, may represent a substrate for the development of numerous encrusting organisms, in particular hydroids, sponges, zoanthids (*Epizoanthus* sp.), bryozoans, stalked barnacles, and polychaetes living on the dead portions of the colonies. Occasionally it is possible to observe on the naked branchlets ophiuroids and crinoids, gastropods, bivalves and, more rarely, small anthozoans and scleractinians, such as *Desmophyllum dianthus*. No close symbiotic associations have been recorded with the living portions of the corals (which may produce a great amount of mucous when disturbed) with the exception of one or multiple pairs of the crab *Anamathia rissoana*.

Various fish species find a temporary refuge in the coral, such as *Hyporthodus haifensis*, *Anthias anthias*, *Aulopus filamentosus*, *Macroramphosus scolopax*, *Capros aper*, *Zeus faber*, *Lappanella fasciata*, *Scorpaena* sp., *Lepidopus caudatus*, *Pagellus bogaraveo*, *Phycis* spp., *Benthocometes robustus*, *Galeus melastomus*, *Trachurus* sp., and *Helicolenus dactylopterus, Polyprion americanus*. Numerous specimens of catsharks *Scyliorhinus canicula* are commonly observed in these forests, especially in the offshore circalittoral environments. This shark uses the ramifications of the black coral colonies to lay their eggs.

Conservation interest and ecological role

From an ecological point of view, black corals are considered ecosystem engineers, habitat-forming species able to create complex three-dimensional habitats, characterized by peculiar physico-chemical features promoting high levels of biodiversity and ecosystem functioning. The dense coral canopies, thanks also to resistant and flexible skeletons, occupy topographic reliefs subjected to complex hydrographic regimes such as those found on seamounts' summits, ridges, rocky outcrops and shoals that enhance the re-suspension of nutrients and the settling of large filter-feeders. Beside enhancing the three-dimensionality and biological heterogeneity of the environment and representing a refuge area for numerous vagile species, the canopies locally modify the surrounding bottom current flow, enhancing pelagic-benthic coupling, in terms of feeding (zooplankton and resuspended decayed organic) and larval entrapment. The long-term persistence of the colonies in the environment represent an important carbon sink on the seafloor. In addition to this, the coral branches are a suitable substrate for some shark species to lay eggs on, representing an important nursery habitat. Other species may use the forest for breeding and spawning areas. The effect of the forest in increasing energy transfer reflects also in the surrounding soft bottoms, increasing biodiversity and biomass of fauna at all levels.

The biocoenoses dominated by arborescent black corals is vertically stratified, meaning that within and below the canopy the forest hosts a diverse understory fauna, which in turn attracts numerous vagile predators form nearby areas. This is particularly evident in this facies considering the large size of *Leiopathes glaberrima*.

A unique aspect of this species is its extreme longevity (about 2000 years for a Sardinian colony 4 cm in basal diameter collected at about 200 m depth). This datum is particularly interesting since it suggests a millennial persistence of this facies, probably enhanced by the heterogeneity of the rocky seafloor representing a natural obstacle to bottom fishing. Slow growth rates seem not related to the colony height or basal diameter, while may vary among specimens and in accordance to numerous other parameters, such as locality and depth. A study conducted on a population in the Gulf of Mexico estimated 143 years for colonies about 35 cm high. Extreme longevity triggered the use of *Leiopathes* species as biological archives of paleoclimatic information and environmental indicators. In addition, this species is suspected to have a very long generation length based on its extremely slow growth rate with no information about the dispersal ability of its larvae, which, given the patchiness of the populations, is believed to be limited.

Economic importance

Historical data report occasional black coral collections in Mediterranean waters since Roman Ages. Traces of modern trade activity of black corals for jewellery in the Mediterranean basin have been found, mainly among France, Cyprus, Croatia and Morocco, even if no precise indication on the species is given. About 100-150 kg of what was identified as *Antipathes* sp. (presumably *Leiopathes glaberrima*) were collected between 1984 and 1987 at depths of about 500-600 m, south of the island of Gozo (Malta region), by means of destructive techniques used mainly for red coral exploitation. The thick basal, smooth stems of this species together with its tendency to occur in dense patches probably concurred in this exploitation attempt. Probably due to the fact that black coral forests are mostly out of scuba diving reach, that antipatharians are under CITES regulations (Ann. B), that the skeletons are not easy to manipulate, and that their profit values are lower than that of precious corals *sensu stricto*, at present, no traditional use, commerce or trade activity is known for Mediterranean species, besides local artisanal manufacturing with accidental bycatch fragments.

Numerous species of commercial interest frequent *Leiopathes glaberrima* and other black coral forests, making them an indirect target for a large part of the coastal artisanal and recreational fishermen and giving them an indirect economic importance.

Vulnerability and potential threats

With respect to anthropogenic threats, fishing activities (artisanal and recreational) represent the main source of declining for Mediterranean populations of *Leiopathes glaberrima* and other black corals. Longlining is generally practiced over deep untrawlable hardgrounds that are good habitats for coral forests, thus increasing the probability of coral bycatch, given also the catchability of the species, in terms of size, branching, density, as well as characteristics of the employed gear. Experimental longline fishing carried out between 500-600 m depth in the Ionian Sea using hooks targeting hake and blackspot seabream, reported antipatharians as the most frequently caught coral group. Fragments of *Leiopathes glaberrima* were abundant in the coral bycatch (approximatively 30 colonies per fisherman per year) and were usually associated with a high number of fish caught, suggesting a connection between the occurrence of coral aggregations and fish richness. Particularly high vulnerability has been reported from coral forests in the Malta region subjected to the fall of derelict ropes associated to the dolphin fish *Coryphaena hippurus* Fish Aggregating Devices (FADs). Their resistant skeleton enhances the entanglement and, if the colony is not uprooted, it may be broken or the entrapped line may cause wounds, which are successively colonized by fast-growing species, increasing the chances for the epibiosis to turn into necrosis and eventually mortality. Besides longlines, also benthic nets (trammel and gillnets) set in the proximity of the hardgrounds may result in entanglement, mechanical damage, sediment resuspension and clogging, finally leading to a reduction of tridimensionality, alteration of biogeochemical cycles, and ultimately loss of biodiversity. Coral forests may potentially be subjected to mass mortality events possibly related to deep bottom turbid currents, thermal anomalies or land pollution, but they can also be threatened by trawling silt resuspension, seafloor drilling activities for oil exploration or mining.

The recovery ability of black corals is triggered by their biological traits. Populations are naturally fragmented depending on the availability of substrate. All are considered longevous, slow-growing species with one spawning season per year (late summer) and an estimated minimum maturity age of various decades, corresponding to tall colonies, which generally represent a small percentage of the populations and have a higher catchability. Overall, resilience is low and this species should be considered sensitive and vulnerable.

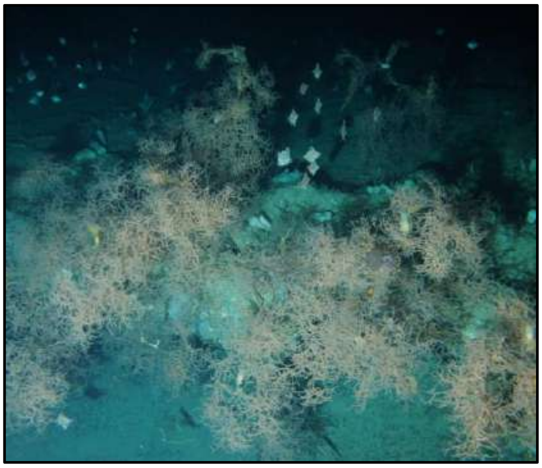
Protection and management

Coral aggregations have been internationally identified as special ecological features that require protection under the Convention of Biological Diversity. More specifically, "Coral Garden" habitats, as those formed by black corals on hardgrounds, are considered sensitive habitats, contributing to the formation of Vulnerable Marine Ecosystems (VMEs) potentially impacted by deep-sea fisheries. This is the reason why it has been recommended the establishment of Fisheries Restricted Areas (FRAs) where such VMEs are known to be or likely to occur in order to put into action an ecosystem-based fishery management of deep ecosystems, as recently carried out in the Gulf of Lion (REC. GFCM/33/2009/1), as part of a large network of protected areas. Other Mediterranean SCI host black corals (e.g., Seco de Los Olivos). So far, these species are not documented in any coastal Marine Protected Area (MPA), but the extension of the lower bathymetric limits of some areas may be able to include part of the known populations.

Black corals are included in CITES Appendix II, Annex III of Bern Convention, and Annex II of Barcelona Convention. There are some specific management initiatives to preserve the black coral resource, such as that operated by the Maltese government (black corals listed under Schedule VI of LN 311 of 2006). They have been assessed by IUCN in the Anthozoan Red List, and the Mediterranean Action Plan of the Barcelona Convention included black corals-dominated habitats as part of the so-called "Dark Habitats", which deserve protection. Management measures focused on the protection of the deep assemblages are challenged by the difficulties to control the fishing activities in Mediterranean international waters.

Suitability of the habitat for monitoring

Habitat-forming black corals are indicators of environmental status and their occurrence, density, degree of epibiosis, demography are important parameters obtained from ROV surveys, use to monitor biodiversity, seafloor litter and integrity in the context of the Marine Strategy Framework Directive (2008/56/CE). Monitoring may also be carried out by means of photogrammetry techniques and, remotely, by side scan sonar and multi-beam echosounder. General indications for inventorying and monitoring this habitat are given under RAC/SPA Dark Habitats Action Plan. Observations based on by-catch only may underestimate the longline impact, since corals may be lost during hauling or may be damaged *in situ*. Multi-parametric ecological indexes, based on MSFD protocols, have been developed to evaluate the status and pressures of hardbottom mesophotic megabenthic assemblages.



A dense forest of *Leiopathes glaberrima* frequented by schools of *Capros aper* (© S. Canese, ISPRA)

A mixed forest of antipatharians, gorgonians and sponges (© S. Canese, ISPRA)

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Facies with Alcyonacea

Reference codes for identification:

- **BARCELONA CONVENTION: ME1.514**
- **EUNIS 2019: ME1511, MF1511**
- **EUNIS 2007: A6.611**

LOCATION OF THE HABITAT

Zone	Upper bathyal
Nature of the substratum	Hard (rock, biogenic)
Depth range	200 m to 500 m
Position	Open sea (continental slope, topographic reliefs)
Hydrodynamic conditions	Moderate to strong
Salinity	Between 37 and 38
Temperature	Homeothermy around 13-15°
Suitability for monitoring	Yes

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UPPER BATHYAL

ME1.5 Upper bathyal rock

ME1.51 Upper bathyal rock invertebrate-dominated

ME1.514 Facies with Alcyonacea

Description of the habitat

Aggregations of erect alcyonaceans (also known as forests) constitute one of the most typical facies of the upper bathyal rocks. They are usually found on horizontal or sub-horizontal hardgrounds, both along the continental slope and on offshore reliefs subjected to various silting levels and moderate-strong currents that favour the growth of these passive filter-feeders. Facies have been observed also on more inclined surfaces and within crevices.

Fan-shaped (e.g., *Callogorgia verticillata*, *Acanthogorgia hirsuta*, *Villogorgia bebrycoides*, *Nicella granifera*) and bushy gorgonians (e.g., *Bebryce mollis*) are the main habitat-formers, but whip-like species (e.g., *Viminella flagellum*) and some soft corals (e.g. *Chironephthya mediterranea*, *Nidalia studeri*) can form dense aggregations as well. Alcyonaceans forests are often plurispecific. In this case, the ramifications of the largest species (e.g., *Callogorgia verticillata*, more than 1 m height) create the main canopy. Smaller gorgonians (e.g., *Bebryce mollis*, *Swiftia pallida*, *Muriceides lepida*, *Villogorgia bebrycoides, Dendrobrachia bonsai*) contribute to the complexity of the understory, together with other organisms such as soft corals, scleractinians, and massive sponges; nevertheless, all species can form monospecific patches. The facies with alcyonaceans can be intermixed with arborescent black corals and massive sponges, but in this case alcyonaceans tend to be the dominant component.

Most of the upper bathyal facies constituted by alcyonaceans are found on outcropping hardgrounds, but some species (e.g., *Acanthogorgia hirsuta*, *Bebryce mollis, Swiftia pallida, Villogorgia bebrycoides, Chironephthya mediterranea*, *Nidalia studeri*) can withstand high levels of sedimentation and extend their distribution on coral rubble, small pebbles and even coarse detritic bottoms in proximity to hardgrounds and coral bioconstructions. Alcyonacean facies are known also in proximity to cold seeps and mud volcanoes.

Geographic distribution

Alcyonacean forests are common on upper bathyal hardgrounds from the Alboran region to the Aegean Sea, with the majority of the records localized in the western and central basins. Besides few endemisms, Mediterranean deep alcyonaceans are also found in Atlantic waters, mainly in boreal localities.

Most of the typical habitat-forming species are characterized by wide depth ranges of occurrence, that often include the offshore circalittoral rock and shelf edge and the shallowest horizon of the lower bathyal realm. *Callogorgia verticillata*, one of the most common habitat-forming species, lives between 90 m and over 1000 m. It forms dense facies in the upper bathyal (up to 6 colonies m^{-2}) in the Alboran Sea, western basin, Sicily Channel, and southern Adriatic Sea, especially in canyons and on seamounts. The small-sized gorgonians *Bebryce mollis*, *Swiftia pallida*, and *Villogorgia bebrycoides* share a similar geographical distribution (with *Swiftia pallida* being the only gorgonian species reported from Lebanon): they have been reported from circalittoral depths (70-90 m) down to 850 m (up to 14 colonies m^{-2}). The whip gorgonian *Viminella flagellum* is known from 90 m to 500 m depth, forming dense aggregations (up to dozens of colonies m^{-2}) in the Alboran Sea, western basin, and Sicily Channel. This species is not known from the Adriatic and Aegean seas. *Muriceides lepida* and *Acanthogorgia* spp. (mainly *Acanthogorgia hirsuta*) show a similar geographic distribution, but a wider bathymetric occurrence, from 70-80 m to 1300-2180 m, respectively. Dense patches are known for these species (up to 12 colonies m^{-2}) on coral thanatocoenoses and rocky outcrops. *Dendrobrachia bonsai* is mainly known from the Alboran seamounts, western basin canyons and the Sicily Channel, mainly between the upper and lower bathyal (200-700 m). Colonies are generally sparse, but can be locally highly abundant, on coral thanatocoenoses, rocky walls and overhangs. *Nicella granifera* follows the same bathymetric distribution, but so far it has only been recorded on seamounts between the Alboran and the Balearic seas. Among soft corals, *Chironephthya mediterranea* is so far reported only from few locations in the Alboran Sea and western basin, between 90 and 400 m depth (up to 7 colonies m^{-2}). *Nidalia studeri* is known from the Alboran Sea, western basin, and the Ionian Sea, from 100 m to almost 350 m depth with locally dense patches (up to 50 colonies m^{-2}).

Associated habitats

This facies is widespread on ‘Upper bathyal rock invertebrate-dominated’ (ME1.51) and ‘Upper bathyal coarse sediment’ (ME3.5). The same habitats host facies of other habitat-forming species, such as ‘Facies with large and erect sponges’ (ME1.512), ‘Facies with Antipatharia’ (ME1.513), ‘Facies with Scleractinia’ (ME1.515), and ‘Facies with Bivalvia’ (ME1.518). In the Strait of Gibraltar, the Strait of Messina, and the Sicily Channel it can be found together with ‘Facies with Cirripedia’ (ME1.516). Finally, ‘Facies with small sponges’ (ME1.511), ‘Facies with Crinoidea’ (ME1.517), and ‘Facies with Brachiopoda’ (ME1.519) can be present in the same habitat. This facies can be intermixed or adjacent to ‘Upper bathyal biogenic habitat (ME2.5), in particular it can be found on coral thanatocoenoses and among white corals. The alcyonacean-dominated facies can be surrounded by soft bottoms such as ‘Upper bathyal sand’ (ME5.5) and ‘Upper bathyal mud’ (ME6.5) and the facies they contain.

Related reference habitats

This facies is usually found on ‘Upper bathyal rock invertebrate-dominated’ (ME1.51), but can extend also on coarse sediment (ME3.51), generating the ‘Facies with Alcyonacea’ (ME3.511). Some of the species typical of this facies can be found also on offshore circalittoral and shelf edge rocky habitats (MD1.51, MD1.52, MD1.53) and on the shallower horizon of ‘Lower bathyal rock’ (MF1.5).

A facies of *Swiftia pallida* on a silted hardground (© OCEANA)

Colonies of *Bebryce mollis* and *Nicella granifera* on dead corals (© OCEANA)

Possible confusion

Confusion with other facies is unlikely, nevertheless, some black corals, forming the ‘Facies with Antipatharia’ (ME1.513) can be mistaken with alcyonaceans based on ROV footage obtained from a certain distance. Taxonomic issues are reported with the identification of various alcyonacean species, based solely on ROV images.

Typical species and associated communities

Many gorgonians can form forests on upper bathyal hardgrounds and coarse sediments. *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Acanthogorgia* spp., *Swiftia pallida*, and *Viminella flagellum* are among the most common habitat-forming species. *Viminella flagellum* (IUCN Red List NT) usually forms small, but highly dense monospecific patches in sites characterised by high hydrodynamism and moderate sedimentation rates. Small-size gorgonians, such as *Bebryce mollis*, *Muriceides lepida*, *Villogorgia bebrycoides*, *Dendrobrachia bonsai*, and *Nicella granifera* can form facies as well, together with soft corals such as *Chironephthya mediterranea*, *Nidalia studeri*, and *Daniela koreni*. *Paramuricea clavata* (IUCN Red List VU), *Paramuricea macrospina*, *Eunicella cavolini* (IUCN Red List NT), *Eunicella verrucosa*, and *Corallium rubrum* (Annex III SPA/BD, IUCN Red List EN) are typical of shallow and/or mesophotic waters, but can occasionally contribute to plurispecific forests in the upper part of the continental slope. *Placogorgia* spp. gorgonians, typically inhabiting the lower bathyal, may occasionally extend in the upper bathyal.
Alcyonaceans forests are often interspersed with other sessile organisms, such as sponges (e.g., *Pachastrella monilifera*, *Poecillastra compressa*, *Haliclona bioxeata*, *Lycopodina hypogea*), hydrozoans (Lafoeidae, Plumulariidae), corallimorpharians, scleractinians (e.g., *Caryophyllia (Caryophyllia) calveri*, *Caryophyllia cyathus*, *Lophelia pertusa* (=*Desmophyllum pertusum*), *Madrepora oculata*, *Desmophyllum dianthus*) (the latter three Annex II SPA/BD, IUCN Red List EN), black corals (e.g., *Leiopathes glaberrima, Parantipathes larix*, *Antipathes* dichotoma, and *Antipathella subpinnata* (Annex II SPA/BD, Annex III Bern, IUCN Red List EN, NT, NT, NT, CITES Ann. B), brachiopods, and bryozoans. Colonies are often epibionted with hydrozoans, zoanthids (e.g., *Zibrowius primnoidus*), and anemones (e.g., *Amphianthus dohrnii*) and may host high numbers of ophiuroids and crinoids. The crab *Anamathia rissoana* is often found crawling on the branches of gorgonians and black corals. These forests host a rich associated vagile community, including echinoderms (*Cidaris cidaris*, *Peltaster placenta*), cephalopods, nudibranchs, and crustaceans (e.g., *Munida tenuimana*, *Paromola cuvieri*, *Plesionika* spp., the spiny lobster *Palinurus mauritanicus*). Many benthic fishes are found in the forests: *Scyliorhinus canicula*, *Phycis* spp., *Lophius* spp., *Helicolenus dactylopterus*, *Scorpaena* spp., *Conger conger*, are among the most common species. *Benthocometes robustus* is often observed hiding in *Callogorgia verticillata* branches with the head pointing downwards. Moreover, several bentho-nektonic and pelagic fishes (e.g., *Macroramphosus scolopax*, *Capros aper*, *Anthias anthias*, *Callanthias ruber*, *Pagellus* spp., *Polyprion americanus*) often aggregate on these forests.

Conservation interest and ecological role

Alcyonacean forests greatly increase the tridimensionality of the substrate, providing numerous microhabitats that sustain a rich (both in terms of diversity and biomass) associated fauna and therefore representing biodiversity hotspots in the upper bathyal realm. In addition, the communities living in this habitat include rare species and many organisms that are still poorly studied, hence representing important sources of undisclosed biological and ecological information. The physical presence of erect, branched, habitat-forming species reduces bottom current speed, enhancing larval entrapment, sediment and suspended particulate matter sedimentation. Therefore, forests are important links in the benthic-pelagic coupling and boost biogeochemical processes, hence contributing to the functioning of the deep-sea and its recovery. They also influence the surrounding soft bottoms, as poles of attraction, in terms of diversity and biomass of epi and infauna, and increase the environmental stability, offering an opportunity to coevolutionary processes and favouring the survivorship of fragile species. This habitat hosts slow-growing, longevous species, which have a paramount role from the conservation point of view and withhold important paleo-environmental information.

Economic importance

Many crustaceans (e.g., *Palinurus mauritanicus*) and fishes (e.g., *Lophius* spp., *Conger conger*, *Pagellus* spp., *Polyprion americanus*) of commercial interest live in this habitat. Many other valuable species regularly frequent this facies for spawning or as nursery site, attracted by the protection offered by the coral canopy and by the food availability.

Vulnerability and potential threats

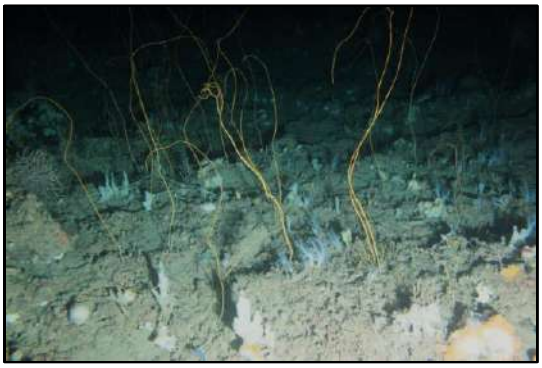
Sites hosting alcyonacean forests are elected targets of both artisanal and recreational fishing activities, mainly operated through longlines; on the other hand, trawling is occasional and more accidental over these areas due to the risk of losing the gear. Fishing activities do have a physical impact on these habitat-forming species. Gorgonians often show evidence of disturbance, including bottom lines and fishing nets entangled around the ramifications, high levels of tissue abrasions and epibiosis indicating prolonged contacts with fishing gears, necrosis, and broken branches. Some species, such as *Callogorgia verticillata*, are highly vulnerable due to the fragility of their skeleton, as demonstrated both by high levels of damaged colonies and by morphometric comparisons: specimens height/width ratio is halved in impacted areas. In addition, colonies can be eradicated from the seafloor by longlines entangled during fishing activities. Large and arborescent colonies are most easily entangled and detached by longlines, but small species, such as *Swiftia pallida* or *Villogorgia bebrycoides*, can be occasionally eradicated as well. The physical destruction or selective removal of structuring species causes the homogenization and simplification of the seafloor, the disappearance of the associated fauna, and ultimately alters the ecosystem functioning of deep benthic habitats. The recovery ability of the communities to mechanical disturbances is reduced by the longevity, late maturity and slow growth rates of some species, defining resilience in the order of decades or more. Abandoned, lost or otherwise discarded fishing gear (ALDFG), representing 80-90% of the total litter on offshore bathyal hardgrounds, are commonly observed on seamounts and along canyon flanks, mainly in concomitance with outcropping rocks hosting alcyonacean forests and other biogenic habitat. Due to the extremely slow degradation of nylon, lost gears may persist for a long time, accumulating on the seafloor, increasing sediment accumulation and covering wide areas, hence impeding the re-colonization for large anthozoans. Finally, trawling activities carried out nearby hardgrounds as well as other anthropic activities related to coastal modifications or deep disturbances (e.g., mining) can increase the silting rate ultimately increasing the risk of clogging the polyps of filter-feeding habitat-forming alcyonaceans and reducing the extension and density of the forests. Climate changes may pose a threat as well, despite still few evidences are available for this facies.

Protection and management

Various measures have been identified to contrast the general trends of impoverishment of this habitat. Some forest-forming species thriving at these depths are considered at different risk of extinction by IUCN, and few of them are now included in lists of protection, such as *Callogorgia verticillata*, *Viminella flagellum*, *Paramuricea clavata*, *Eunicella cavolini*, and *Corallium rubrum*. All coral forests are identified as Vulnerable Marine Ecosystems (VMEs) in the FAO/GFCM International guidelines for the management of the deep sea fisheries in the high seas, representing Essential Fish Habitats (EFHs). They meet al criteria for VMEs: fragility, low resilience, uniqueness, importance, high associated diversity, complexity, and services for the ecosystem. The Mediterranean Action Plan of the Barcelona Convention included habitats dominated by structuring species as part of the so called “Dark Habitats” which deserve protection. Mapping VMEs is considered an essential step in the framework of environmental protection, as declared in the European Marine Strategy Framework Directive (2008/56/EC). The implementation of protection measures through the creation of offshore Marine Protected Areas (MPAs), Sites of Community Importance (SIC) and Fisheries Restricted Areas (FRAs) with an active management plan are still poorly pursued mainly due to socio-economic constraints, lack of data and difficulties in controlling territories in international waters. A FRA has been established in 2009 to protect the benthic habitat and the fishing resources in the Gulf of Lion canyon system (REC. GFCM/33/2009/1), as part of a wider network of MPAs.

Suitability of the habitat for monitoring

Within the Marine Strategy Framework Directive (2008/56/EC) numerous ecological and biological parameters are employed to evaluate the environmental status of the hard-bottom benthic assemblages and describe the impact of anthropic activities in this habitat. Biodiversity (D1), integrity of the seafloor (D6), and sea floor litter (D10) are considered important descriptors of habitat quality and a major effort is currently in place to create distribution maps of VMEs and benthic habitat models (specifically those dominated by habitat-forming alcyonaceans), characterize the type and impact of seafloor litter, and define the fishing effort, providing useful management information. Recent studies, carried out by means of seafloor imagery, highlighted the presence of ALDFG and other litter on bathyal rocky seafloor, together with elevated rates of entanglement/eradication/breakage/size reduction of structuring species due to fishing activity; this information represents a useful baseline for the monitoring of the effects of direct anthropic impacts on this habitat. Alcyonacean forests are considered a good proxy to monitor the effects of fishing activities, because of their slow growth rate, their sessile erect habitus and their wide distribution. The use of tridimensional photogrammetry may help to characterize deep forests and monitor them in time.



Viminella flagellum and soft corals in the Sicily Channel (© S. Canese, ISPRA)

Colonies of the soft coral *Nidalia studeri* from Lipari Island (© OCEANA)

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Facies with Cirripedia

Reference codes for identification:

- **BARCELONA CONVENTION: ME1.516**
- **EUNIS 2019: ME151 (partim), MF151 (partim)**
- **EUNIS 2007: A6.611 (partim)**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Hard (rock, biogenic)
Depth range	80 m to 620 m
Position	Coastal, open sea (straits and channels)
Hydrodynamic conditions	Strong
Salinity	Between 37 and 38
Temperature	Homeothermy around 13°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Betti, J. Evans

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UPPER BATHYAL

ME1.5 Upper bathyal rock

ME1.51 Upper bathyal rock invertebrate-dominated

ME1.516 Facies with Cirripedia

Description of the habitat

The giant sessile barnacle *Pachylasma giganteum* is often found in association with the hydrocoral *Errina aspera* and cold-water coral (CWC) frameworks. It can colonize CWC thanatocoenoses, covering up to 25% of the available space with up to 40 individuals m^{-2}, but can also establish large populations on bare rocks, associated with encrusting sponges and solitary scleractinians. In this case, it generally occurs in clusters that cover large portions of the seafloor. Some individuals may occasionally overgrow others, giving a multi-layered assemblage. A second species of barnacle, *Megabalanus tulipiformis*, is often associated with these assemblages. While only a minor contributor to the habitat architecture when anthozoans (such as antipatharians and scleractinians) and other large sessile species are dominant, *Pachylasma giganteum* may become a habitat-former in the absence of competing species.

Geographic distribution

In the Mediterranean Sea, the barnacle *Pachylasma giganteum* is known from the Strait of Gibraltar (550-580 m on the sill), the Strait of Messina, and the Sicily Channel. The facies appears to be relatively frequent in the Strait of Messina and in Maltese waters.

Associated habitats

This facies is found mainly on 'Upper bathyal rock invertebrate-dominated' (ME1.51), but may extend also on 'Offshore circalittoral rock invertebrate-dominated (MD1.51) and 'Lower bathyal rock' (MF1.51). It can be found on CWC thanatocoenoses included in 'Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges' (ME2.52), and associated with 'Facies with Antipatharia' (ME1.513), 'Facies with Alcyonacea' (ME1.514) and 'Facies with Scleractinia' (ME1.515).

Related reference habitats

None.

Possible confusion

The two species can be distinguished from ROV by colour (*Megabalanus tulipiformis* has slightly pink plates) and size (*Pachylasma giganteum* can reach larger size, up to 5 cm in diameter).

Typical species and associated communities

Pachylasma giganteum is the typical species of the facies. It can be found associated with living and dead CWC frameworks. It can be found on rocks hosting the black coral *Leiopathes glaberrima* (Annex II SPA/BD, Annex III Bern, IUCN Red List EN), the gorgonians *Bebryce mollis*, *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List EN), other CWCs, including *Lophelia pertusa* (= *Desmophyllum pertusum*), *Madrepora oculata*, *Desmophyllum dianthus*, *Dendrophyllia cornigera* (all Annex II SPA/BD, IUCN Red List EN), *Javania cailleti*, hexactinellid sponges and the crab *Spinolambrus macrochelos*. In the Maltese area, *Pachylasma giganteum* was observed also growing on skeletons of *Leiopathes glaberrima* and seafloor litter. In the Strait of Messina, *Pachylasma giganteum* and *Megabalanus tulipiformis* frequently occur on stranded buoys detached by currents from fishing gears lost on the seafloor, together with *Miniacina miniacea*, *Errina aspera* (Annex II SPA/DB, Annex II Bern), *Coenocyathus cylindricus* and white corals, numerous serpulids, and bryozoans.

Conservation interest and ecological role

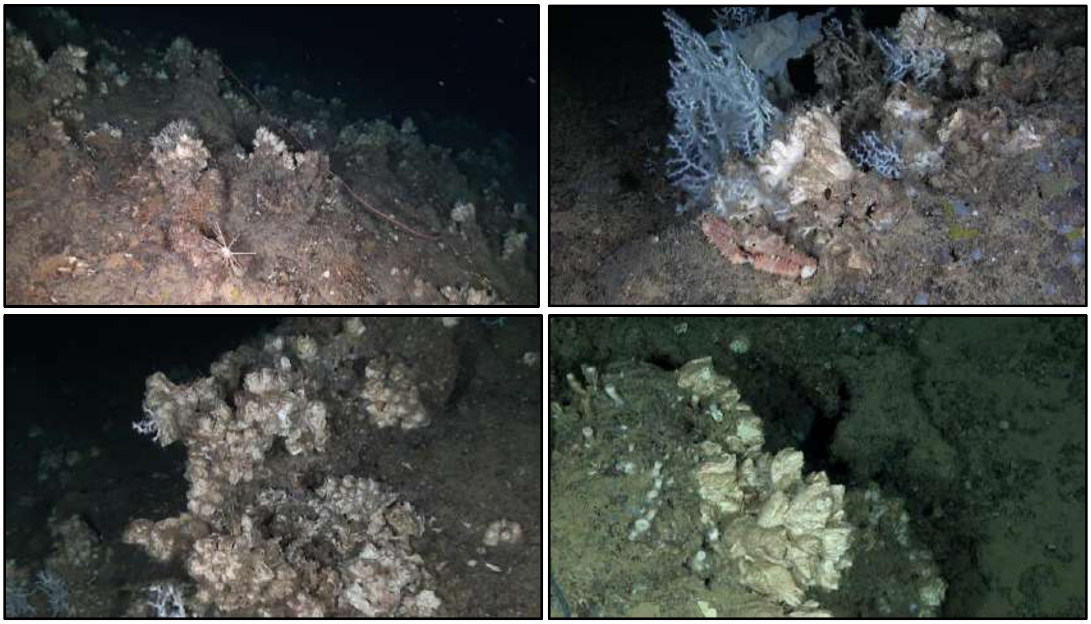
Erect sessile calcareous species such as *Pachylasma giganteum* are important habitat formers on the rocky substrata of the upper and lower bathyal zone, increasing the tridimensionality of the environment and therefore favouring high levels of biodiversity. The barnacle shell can record the neodymium isotopic composition of seawater, and therefore represents an important paleoceanographic tool.

Economic importance

None.

Vulnerability and potential threats

Fishing activities can directly impact this facies, through entangled trammel nets, gillnets, longlines, and lengths of nylon ropes. The Maltese population, in particular, is impacted by the discarded material coming from the *Coryphaena hippurus* fishing. No information is available on the fragility of the habitat-forming barnacle species or their life history traits.



Facies with the Cirripedia *Pachylasma giganteum* in Maltese waters (340-490 m). Aggregations are visible also close to *Madrepora oculata*. Nylon ropes can be observed entangled on the seafloor (© OCEANA, LIFE BaĦAR for N2K)

Protection and management

Pachylasma giganteum is included in Appendix II of the Bern Convention and in Appendix II of the SPA/BD. Both appendices include strictly protected species. No measures are in place at the moment to preserve this habitat, but deep-water engineering benthic invertebrate assemblages are listed in the RAC/SPA Dark Habitats Action Plan.

Suitability of the habitat for monitoring

No specific monitoring protocol currently employs habitat-forming cirripeds to evaluate the environmental status, however, scientific surveys suggest that occurrence and density of the target species may represent valuable parameters for monitoring. General indications are given in the RAC/SPA Guidelines for inventorying and monitoring of dark habitats in the Mediterranean Sea.

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Facies with the Bivalvia *Neopycnodonte* spp.

Reference codes for identification:

- **BARCELONA CONVENTION: ME1.518**
- **EC: 1170 (partim)**

LOCATION OF THE HABITAT

Zone	Upper to lower bathyal
Nature of the substratum	Hard (rock)
Depth range	230 m to 1300 m
Position	Open sea (continental slope, canyons, escarpments, seamounts)
Hydrodynamic conditions	Strong
Salinity	Between 37 and 38
Temperature	Homeothermy around 13°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Enrichetti

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UPPER BATHYAL

ME1.5 Upper bathyal rock
ME1.51 Upper bathyal rock invertebrate-dominated
ME1.518 Facies with the Bivalvia *Neopycnodonte* spp.

Description of the habitat

Although bivalve reefs are commonly considered as typical shallow-water habitats, fossil and living oyster-dominated habitats also occur at bathyal depths. The large deep-water oyster *Neopycnodonte zibrowii* was described in 2009 from the Azores archipelago, but it was already reported from the Mediterranean Sea as subfossil remain of the last glacial age.

Living and subfossil records suggest that, under favourable oceanographic conditions (i.e., sediment-protected areas exposed to high-nutrients currents), this species, in the Mediterranean basin, forms dense facies of 20 to up to hundreds individuals per square meter, with living specimens generally occurring between 350 m and 500 m depth. This facies thrives on vertical cliffs and underneath overhangs on seamounts, escarpments and in canyons. It has been also reported settled on coral thanatocoenoses and anthropogenic items, like shipwrecks, occasionally extending to the lower bathyal.

A typical feature of this species is that its larvae settle on live individuals or their remains, thereby forming multi-specimen stacks oriented in the same direction, resembling a pile of dishes.

Geographic distribution

Neopycnodonte zibrowii has an Atlantic-Mediterranean distribution. Living records from the Mediterranean Sea have been documented from Alboran Sea, Balearic Islands, Gulf of Lion, Corse, Sardinia, Sicilian Channel, and the Tyrrhenian Sea. Late Pleistocene subfossil records further extent this distribution both geographically (to Crete Island, eastern Mediterranean Sea) and bathymetrically (down to 1334 m).

Associated habitats

This facies typically develops within 'Upper bathyal rock invertebrate-dominated' (ME1.51) and it may also extend in the 'Lower bathyal rock' (MF1.51). It can be adjacent to or mixed with the 'Facies with small sponges' (ME1.511), 'Facies with large and erect sponges' (ME1.512), 'Facies with Antipatharia' (ME1.513), 'Facies with Alcyonacea' (ME1.514), and 'Facies with Scleractinia' (ME1.515). Occasionally it can be mixed with 'Upper bathyal biogenic habitat' (ME2.5), including 'Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges' (ME2.52).

Related reference habitats

Neopycnodonte zibrowii may be a component of other upper bathyal habitats, particularly a ‘Facies with Bivalvia *Neopycnodonte* spp.’ (ME2.514) is reported also in the ‘Upper bathyal reefs’ (ME2.51).

Possible confusion

Neopycnodonte zibrowii can be easily distinguished from the congeneric *N. cochlear*, thanks to the unusual morphology of the hinge line and the larger size (about 30 cm vs 4-5 cm). Furthermore, the habitats created by the two species occur at different bathymetrical ranges, with *Neopycnodonte zibrowii* often regarded as a distinct deep-sea relative of *Neopycnodonte cochlear* (see sheet MD3.511) with specific adaptations for upper bathyal depths.

Typical species and associated communities

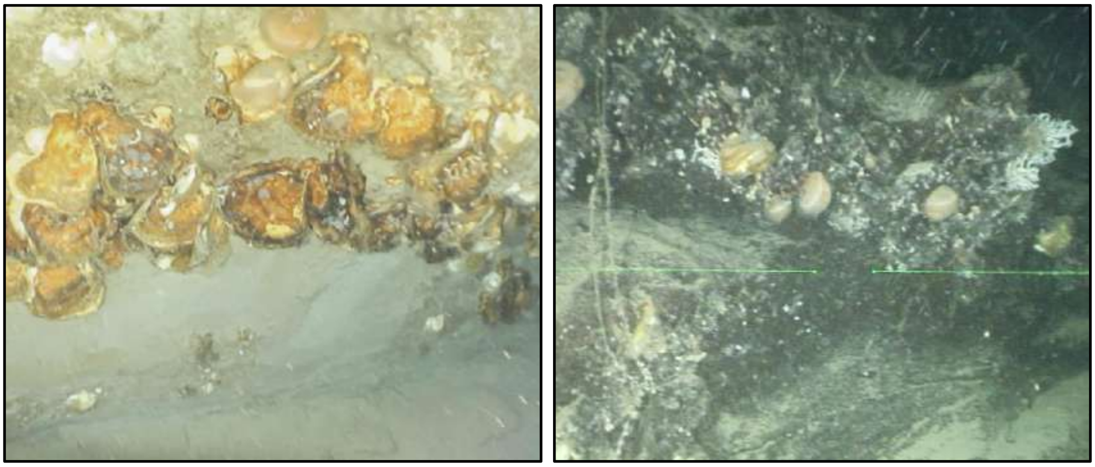
Neopycnodonte zibrowii often co-occurs with scleractinians, such as *Madrepora oculata*, *Lophelia pertusa* (= *Desmophyllum pertusum*), and *Desmophyllum dianthus* (Annex II SPA/BD, IUCN Red List EN). Several other organisms contribute to increase the overall complexity, including encrusting (e.g., *Desmacella inornata, Hexadella* sp.), boring, and massive sponges (e.g., *Phakellia* sp., *Spongosorites flavens*, *Rossella nodastrella*), the antipatharian *Parantipathes larix* (Annex II SPA/BD, Annex III Bern, IUCN Red List NT), the anemones *Amphianthus dohrnii* and *Protanthea simplex*, serpulid polychaetes, encrusting and erect bryozoans, and byssate (*Asperarca nodulosa*, *Delectopecten vitreus*) and cemented (*Spondylus gussonii*) bivalves. In the Dohrn Canyon, *Neopycnodonte zibrowii* coexists with cold-water corals and the bivalve *Acesta excavata*, creating a peculiar association only known from the Whittard Canyon in the North-eastern Atlantic Ocean. Fish fauna includes the species *Pagellus bogaraveo* and *Lepidopus caudatus*.

Conservation interest and ecological role

Neopycnodonte zibrowii lifespan can exceed 500 years, thus representing one of the longest-living non-colonial metazoan. Both living and subfossil aggregations enhance local heterogeneity and provide a suitable habitat for a diverse associated community of sessile, excavating, and mobile organisms, including protected species (e.g., scleractinians and black corals). Therefore these aggregations configure a well-defined deep-sea habitat deserving high-priority conservation.

Economic importance

This facies provides ecosystem services for the human society by promoting biodiversity. It acts as a refuge for several marine organisms, including demersal fishes and invertebrates of commercial interest.



Images of *Neopycnodonte zibrowii* from the Dohrn Canyon (Gulf of Naples). Left panel: vertical cliff of solid mud at 425 m. Right panel: rock coated by Mn-Fe oxides (437 m) hosting living *Madrepora oculata* colonies, *Acesta excavata* and *Neopycnodonte zibrowii.* Abandoned fishing gears are present (© ISPRA)

Vulnerability and potential threats

Potential threats for this habitat include mechanical damages by fishing gears (such as trammel nets, gillnets and longlines) and illegal dumping of garbage. Additional treats are represented by trawling, dredging and mining, despite direct evidences are not reported for the Mediterranean Sea.

Protection and management

Further exploration should improve our understanding of the biogeographic distribution of this recently-described species, which typifies an overlooked deep-water habitat. Within the European Union, this facies is included within the habitat “1170 Reefs”, defined as any geogenic or biogenic structure (including concretions, encrustations, and bivalve beds originating from dead or living animals) arising from the seafloor. Habitats with *Neopycnodonte zibrowii* have been listed in the Dark Habitats Action Plan. Another management option, already proposed or deployed in some Mediterranean sites hosting *Neopycnodonte zibrowii* (e.g., Gulf of Lion), is the creation of deep-sea marine protected areas.

Suitability of the habitat for monitoring

No monitoring protocol currently employs *Neopycnodonte zibrowii* as target species. However, ROV surveys (under the Marine Strategy Framework Directive) as well as other scientific explorative programs, provide qualitative and quantitative data regarding the occurrence, abundance and status of this facies. Guidelines for inventorying and monitoring dark habitats, including this one, have been identified by RAC/SPA.

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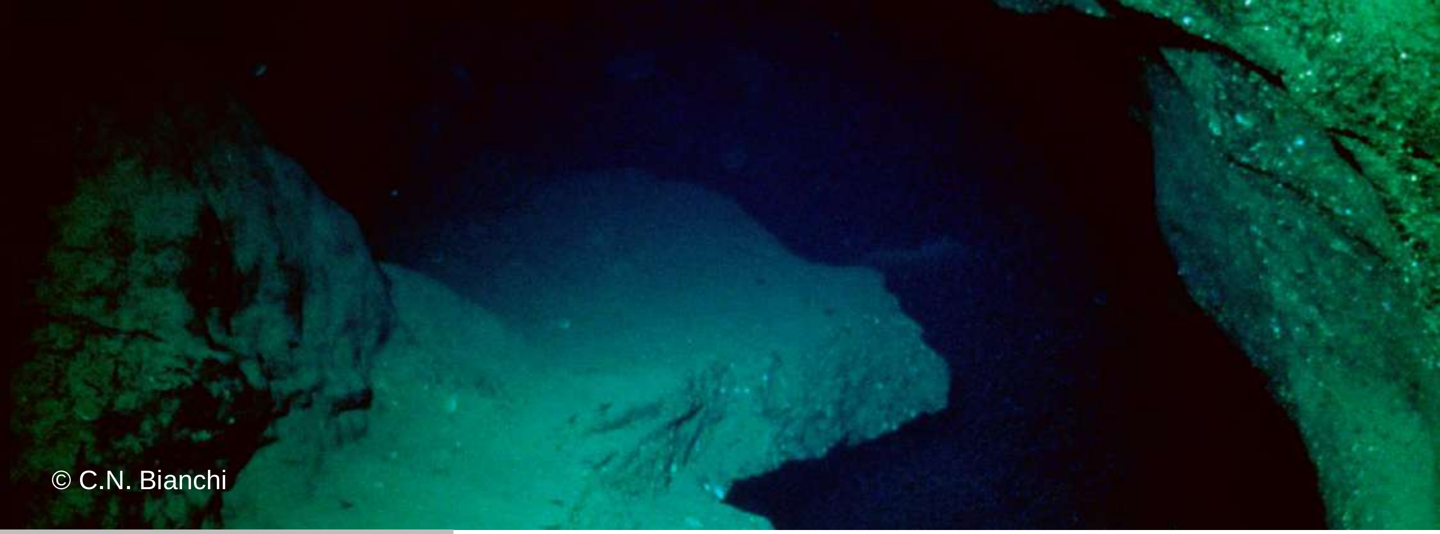
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UPPER BATHYAL

ME1.5 Upper bathyal rock

ME1.52 Caves and ducts in total darkness

Description of the habitat

In long blind-ended ('cul-de-sac') caves with comparatively narrow entrance, light penetration is rapidly reduced to values lower than 0.01% of the sea-surface levels. The decrease in ambient light depends not only on the distance from the entrance, but also on the topographic position considered (e.g., floor, walls, or roof) and the shape of the cavity. In the absence of light, photosynthetic organisms are excluded and the biological assemblages consist exclusively of animals, whose living is essentially conditioned by the supply of organic matter from outside. Thus, the main factor governing ecosystem functioning in dark caves is the confinement, a hydrodynamic notion essentially related to water exchange with the outside. Blind-ended caves are typically confined, and therefore trophically depleted; the fauna becomes rare, and the substratum cover by sessile species falls well below 50%. Similarly, a dramatic decrease of biomass occurs. Oligotrophy excludes organisms with high trophic demand and the sessile assemblage is composed mostly of non-massive sponges, scanty scleractinians, serpulids, bryozoans and brachiopods; organisms are small, encrusting rather than erected, and little coloured. Mobile animals (essentially fish and crustaceans) can be locally abundant. In the terminal and highly confined sections, biological cover can reach almost zero, originating the so-called 'empty quarter'. A black coating of iron and manganese oxides covers the walls and the calcified organisms. Water temperature and chemistry are more stable than outside, and sediment deposit is very fine. On the contrary, biological cover may remain at 100% in dark tunnels, where water renewal is significant, rock is not blackened and fine sedimentation reduced.

Geographic distribution

Dark caves are found throughout the Mediterranean. Rock constitutes over half of the Mediterranean coastline, and most rocky coasts, especially in karstic areas, are likely to include dark caves. More than 3,000 marine caves have been inventoried, mainly in northern and eastern areas; on the contrary, little information is available for North Africa. Most existing records correspond to shallow caves, with a water depth that rarely exceeds 20 m.

Associated habitats

Dark caves are typically in contact with the habitat of 'Semi-dark caves

Caves and ducts in total darkness

Reference codes for identification:

- **BARCELONA CONVENTION: MC1.52**
- **EUNIS 2019: ME152**
- **EUNIS 2007: A6.1 (partim)**
- **EC: 8330 (partim)**
- **CORINE: 11.26 (partim)**

LOCATION OF THE HABITAT

Zone	Bathyal (also in enclave in the infralittoral and circalittoral)
Nature of the substratum	Hard (rock)
Depth range	3 m to 200+ m
Position	Open sea
Hydrodynamic conditions	Weak (typically confined habitat)
Salinity	Between 36 and 39
Temperature	10 °C to 22 °C
Suitability for monitoring	Yes

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and overhangs' (MC1.53). In limestone rocks, the infiltration of rainwater through the karstic network creates the conditions for the development of the habitat of 'Brackish water caves or caves subjected to freshwater runoff' (MC1.53d).

Related reference habitats

Lack of light, environmental stability and food shortage create conditions similar to that of the deep sea, and thus bathyal and even abyssal species can be found in dark caves, especially in caves with descending profile that maintain constantly cool water (ca 10°C) in their terminal tracts. Analogies, therefore, may exist with the invertebrate-dominated facies of the 'Upper bathyal rock' (ME1.51), 'Lower bathyal rock' (MF1.51), and 'Abyssal rock' (MG1.51). Species thriving in dark caves may also be found in the crevices of the 'Coralligenous cliffs' (MC1.51), 'Coralligenous plaftorms' (MC2.51), 'Offshore circalittoral rock invertebrate-dominated' (MD1.51), and 'Offshore reefs' (MD2.51).

Possible confusion

Topographic location and lack of light, together with the scant presence of sessile fauna and black coating on rocks, make this habitat unmistakable. However, confusions are possible with the other cave habitats in the transitional zones.

Typical species and associated communities

Notwithstanding low abundance and biomass, species richness in dark caves is comparatively high. Among the most characteristic sessile species there are several sponges, including the ancestral taxon *Petrobiona massiliana* and the two deep-water species *Lycopodina hypogea* and *Oopsacas minuta*, known for a few caves only; the scleractinian coral *Ceratotrochus magnaghii*; the serpulids *Serpula cavernicola*, *Spiraserpula massiliensis, Filogranula annulata*, and many others occurring also in the bathyal or in the coralligenous; the brachiopod *Tethyrhynchia mediterranea*; the bryozoans *Harmelinopora indistincta*, *Crassimarginatella solidula*, cribrilinids and many others. The benthic chaetognath *Spadella ledoyeri* has been described from a dark cave. Although not exclusive to dark caves, several motile species may be abundant there, such as the mysids *Hemimysis speluncola*, *H. margalefi* and *Harmelinella mariannae*, the shrimp *Stenopus spinosus*, the crab *Herbstia condyliata*, and the fish *Grammonus ater*, among others. Some of these motile species play an important role in mitigating the oligotrophy by importing organic matter from the outside: swarm-forming mysids, for example, feed at night in the external environment but stay in the cave at day, releasing faecal pellets (which increase the internal trophic load) and being preyed by cave sessile carnivores, such as the sponge *L. hypogea*, the sea anemone *Halcampoides purpureus*, and cerianthids.

Conservation interest and ecological role

Dark caves represent extreme and unique habitats, inhabited by a specialized biota. Species living in dark caves exhibit peculiar adaptations to food shortage, allowing the exploitation of all possible resources, and resistance to starvation, which allows survival under an irregular and unpredictable food intake. Dark caves are refuges for ancestral taxa (such as the sponge *Petrobiona massiliana*). Absence of light and oligotrophy create the conditions for the occurrence of cryptic (crevicular) and deep-water species in dark caves, thus exemplifying the phenomenon of the so-called 'secondary stygobiosis'.

Economic importance

Dark cave ecosystems offer several services to humans. The most important are information services, especially for scientific research, as they constitute a comparatively accessible model or 'mesocosm' for the study of patterns and processes of deep marine ecosystems, which occupy over half the surface of our planet. Dark caves are also a source of inspiration and spiritual values, due to the fascination of cave diving for a restricted number of adepts. Provision services are represented by fishes and crustaceans of commercial interest that use marine caves as a day shelter. The monetary value of this habitat has not been assessed yet.

Vulnerability and potential threats

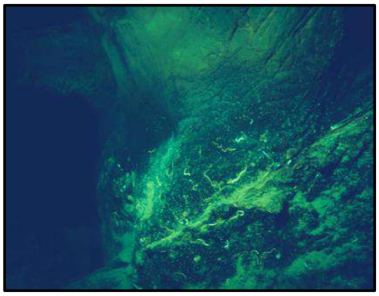
Resilience of the dark cave ecosystem is extremely low, so that perturbations can have long lasting effects. Organic or industrial contamination may lead to pronounced loss of biodiversity through the disappearance of many sensitive species thriving in dark caves. Coastal works (e.g., harbour construction) can increase the sediment load within the caves, with a detrimental effect on the biota. Global warming causes important changes in both the sessile and the motile components of the dark-cave community. Visitation by scuba divers, although limited because of the technical difficulty of cave diving, adversely affects the organisms either directly by contacts or indirectly by sediment resuspension and emission of exhaust air-bubbles.

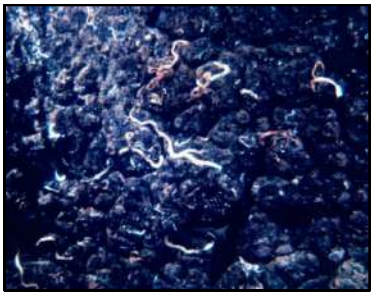
Protection and management

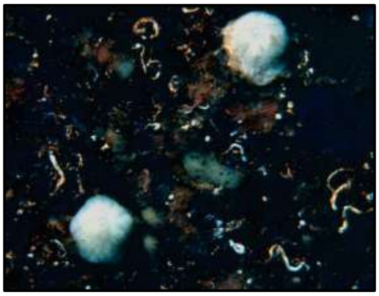
Dark caves deserve conservation priority because of their uniqueness. They include many rare, endangered, and protected species. The sponges *Petrobiona massiliana* and *Lycopodina hypogea* are included in the Annex II (Endangered and threatened species) of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. The former species is also listed in the Appendix II (Strictly protected fauna species) of the Bern Convention on the Conservation of European Wildlife and Natural Habitats. Marine caves are protected according to the Resolution no. 4 of the Council of Bern Convention (which listed them as endangered natural habitat type), by the Habitats Directive of the European Union, and by the Mediterranean Action Plan of the United Nations Environment Programme.

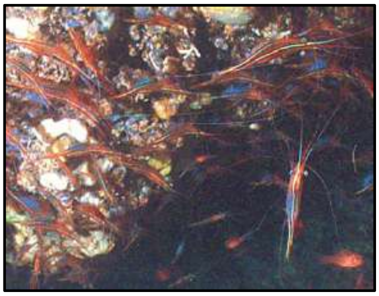
Suitability of the habitat for monitoring

Caves are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (included marine caves) in the Mediterranean Sea. However, examples of application are still limited, also because of the technical and safety problems linked to cave diving.


Black coating on rock
(© C.N. Bianchi)


Serpulidae on otherwise bare
rock (© C.N. Bianchi)


Petrobiona massiliana
(© C.N. Bianchi)


Plesionika narval
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Stenopus spinosus
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Grammonus ater
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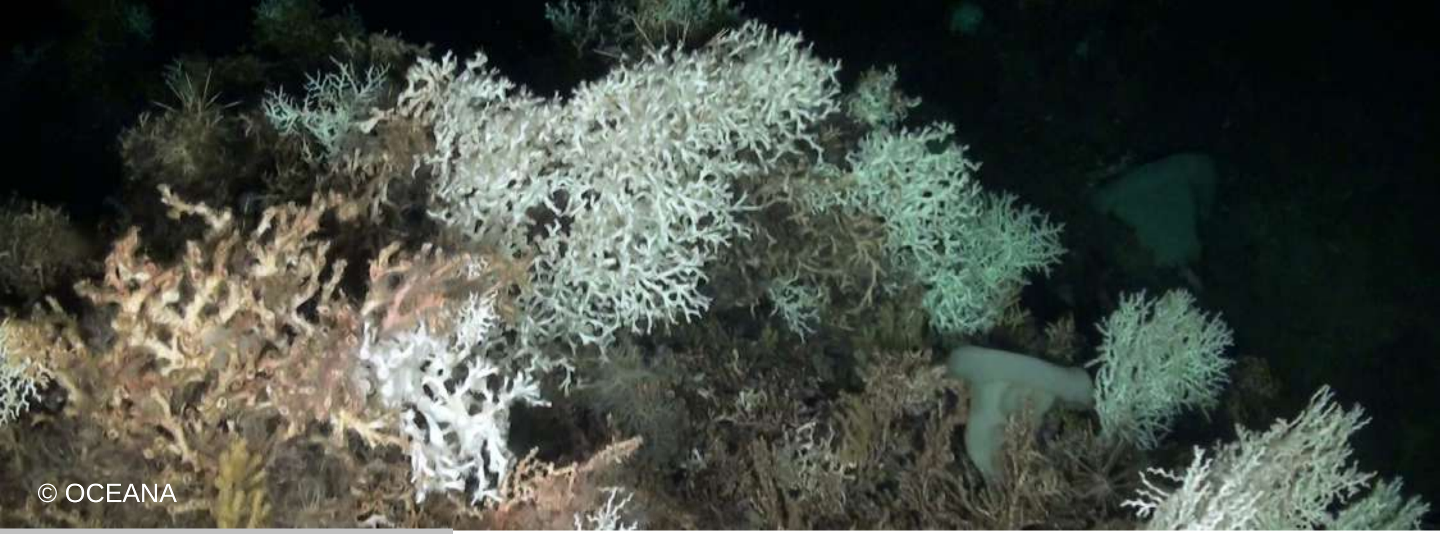
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Upper bathyal reefs;
Lower bathyal reefs

Reference codes for identification:

- **BARCELONA CONVENTION: ME2.51, MF2.51**
- **EUNIS 2019: ME25, MF25**
- **EUNIS 2007: A6.6**
- **EC: 1170 (partim)**

LOCATION OF THE HABITAT

Zone	Upper to lower bathyal
Nature of the substratum	Hard (rock, biogenic), soft (coarse, sand, mud)
Depth range	150 m to 1300 m
Position	Open sea
Hydrodynamic conditions	Variable
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

Authors:
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UPPER BATHYAL

ME2.5 Upper bathyal biogenic habitat
ME2.51 Upper bathyal reefs

MF2.5 Lower bathyal biogenic habitat
MF2.51 Lower bathyal reefs

Description of the habitat

In general terms, biogenic habitats are those created by the growth and architecture of particular species. They can be formed by an organism itself or its skeletal traces (as in the case of epifauna and epiflora), or they can derive from an organism’s activity (as in the case of burrowing infauna).

Deep-sea biogenic habitats, thriving in the upper and lower bathyal depth range, are a common source of biological heterogeneity both on hardgrounds and soft seafloors, where they increase the complexity of the primary substrate. They comprehend the so-called animal forests (aggregations of conspicuous individuals or colonies) as well as bioconstructions, namely living or dead tridimensional skeletal frameworks. These latter, in the Mediterranean Sea, are formed by a large number of different habitat-forming taxa, sharing the ability to form reef-like structures, namely carbonate or siliceous massive concretions produced by living individuals often growing over other conspecifics.

The most representative of these biogenic habitats, at times extending for kilometers and arising for various dozens of meters, is that formed by cold-water scleractinians, specifically *Madrepora oculata*, *Desmophyllum dianthus*, and *Lophelia pertusa* (= *Desmophyllum pertusum*), as well as the less conspicuous *Dendrophyllia cornigera*.

Sponges may also form important biogenic reef-like habitats, both with dense aggregations of small species (e.g., the hexactinellids *Tretodictyum reiswigi* and *Farrea bowerbanki*) as well as large and erect ones, partially growing over others’ skeletons (as in the case of the lithistid *Leiodermatium pfeifferae*). Bivalves of the genus *Neopycnodonte* include long-living species reaching large sizes and forming dense aggregations in numerous environments, from soft bottoms to vertical rocky terraces, from the continental shelf to the deep hardgrounds.

Lastly, also serpulids (particularly *Serpula vermicularis*) as well as brachiopods (e.g., *Gryphus vitreus*, *Megerlia truncata*) may form conspicuous bioconcretions or accumulations on bathyal rocks as well as within or nearby cold-water coral (CWC)-dominated habitats.

Deep biogenic habitats are dominated by filter-feeding organisms, which thrive in hydrodynamic turbulent areas. All these species are extensively present in the fossil and sub-fossil record of the basin and form wide thanatocoenoses, which are also important biogenic habitats, often co-occurring with their living counterparts.

Geographic distribution

Bathyal biogenic habitats, and particularly reef-like bioconstructions, are widespread in the entire Mediterranean Sea, both along the continental slopes (including shelf edge environments) and on topographic elevations, such as ridges, highs, banks and seamounts, with a larger frequency of occurrence in the Alboran Sea, western Mediterranean basin, Sicily Channel, central Mediterranean Sea, and the Aegean Archipelago. Despite some characteristic species of the biogenic habitats, such as *Desmophyllum dianthus*, are occasionally reported at 2500 m depth, actual facies are consistently known only down to 1300 m, with a higher occurrence in the upper bathyal. More widespread is the bathymetric occurrence of thanatocoenoses. Finally, while some biogenic facies are known from a large number of records (e.g., scleractinians, thanatocoenoses), others have a more limited distribution, at times including only few spots of occurrence (e.g., *Leiodermatium pfeifferae*, bathyal coral-serpulid frameworks, *Neopycnodonte zibrowii*).

Associated habitats

Bathyal reefs are mainly represented by ‘Facies with Scleractinia’ (ME2.513, MF2.511). They include also ‘Facies with small sponges’ (ME2.511), ‘Facies with large and erect sponges’ (ME2.512), ‘Facies with Bivalvia’ (ME2.514), ‘Facies with Serpulidae’ (ME2.515), and ‘Facies with Brachiopoda’ (ME2.516). These habitats can be found nearby or tightly intermixed together (as in the case of scleractinians and serpulids or sponges), as well as with other facies, including those thriving on ‘Upper bathyal rock invertebrate-dominated’ (ME1.51), ‘Lower bathyal rock’ (MF1.51), and thanatocoenoses (ME2.52, MF2.52). These habitats are often surrounded or intermixed by non-cohesive substrates (and the facies within), such as mixed sediment, detritic sand, and mud. Lastly, some of the bioconstructions found in the circalittoral (*Neopycnodonte cochlear*) (MD3.511) are also found in the upper bathyal.

Related reference habitats

From a structural point of view, ‘Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges’ (ME2.52, MF2.52) show similarities with the living biogenic reefs, and they may be partially intermixed. The associated fauna may also be partially shared.

Possible confusion

The distinction between ‘Upper bathyal reefs’ (ME2.51) and ‘Lower bathyal reefs’ (MF2.51) is fundamentally based on bathymetry, since the structure, a large part of the associated fauna and the functioning is very similar. Less clear is the distinction between the biogenic facies dominated by scleractinians and their counterparts occurring on bathyal rock, as often, also in this latter case, the facies is not characterized only by living colonies, but also by a distinct bioconstruction. Finally, the structural complexity of the ‘Facies with small sponges’ is not always immediately recognizable and the contribution of serpulids in terms of volume or coverage of the accretion is usually limited and overshadowed by that of structuring scleractinians.

Typical species and associated communities

Three-dimensional biogenic structures are associated to a rich variety of species, especially cold-water coral reefs are considered among the most complex hotspots of the deep Mediterranean Sea. A large part of the sessile and vagile associated megafauna of the biogenic habitats, both living and dead, is often shared. Besides the structuring species, other commonly observed species include the fan-like sponges *Poecillastra compressa* and *Pachastrella monilifera*, hydrozoans, zoanthids, and the habitat-forming anthozoans *Dendrophyllia cornigera* (Annex II SPA/BD, IUCN Red List EN), black corals (e.g., *Leiopathes glaberrima* and *Parantipathes larix* (Annex II SPA/BD, Annex III Bern, IUCN Red List EN, NT)), and alcyonaceans (e.g., *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Acanthogorgia hirsuta*, *Nicella granifera*, *Muriceides lepida*).

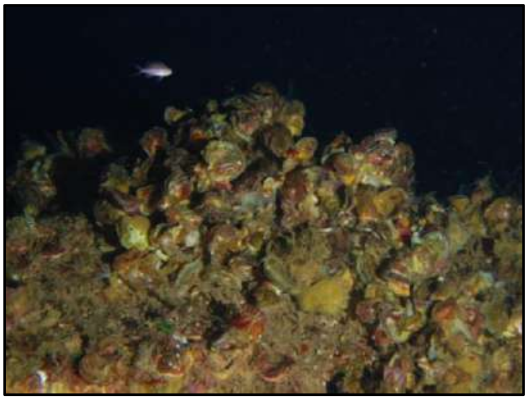
Also gastropods, serpulids, bryozoans, ascidians can be abundant and diverse. Numerous vagile species crawl above or within the bioconstructions, including many crustaceans (e.g., *Plesionika* spp., *Munida* spp., *Palinurus mauritanicus*, *Bathynectes maravigna* and *Paramola cuvieri*) and echinoderms (e.g., *Leptometra phalangium*, *Peltaster placenta*, *Cidaris cidaris*). Numerous fishes are attracted in this areas (e.g., *Pagellus bogaraveo*, *Lepidopus caudatus*, *Conger conger*, *Merluccius merluccius* (IUCN Red List VU), *Helicolenus dactylopterus*, *Galeus melastomus*).

Conservation interest and ecological role

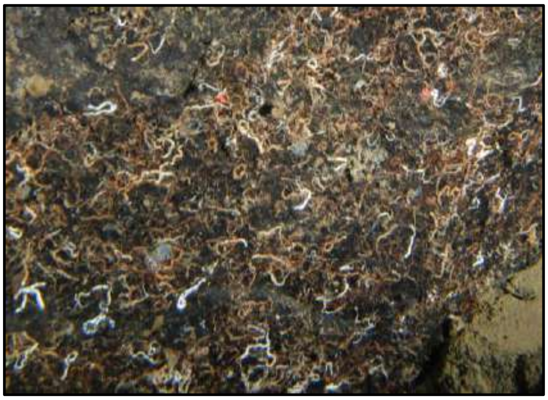
Ecosystem engineering species shape the surrounding physical-chemical environment and the resources therein. Habitat heterogeneity resulting from these structures influences the distribution of biodiversity at both local and regional spatial scales. Biogenic structures provide trophic niches, reproductive grounds and shelters for numerous vagile species, including fishes, crustaceans and molluscs, and harbour more biodiversity than surrounding habitats without biogenic habitats at comparable depths. A large part of the attractivity of biogenic habitats is derived from the size of the habitat-formers, being more significant with erect species forming arborescent canopies or primary frame builders. The biogenic structures decrease the current flow velocity, stabilize soft substrates, increase larval and organic matter entrapment. Hotspots of organic and inorganic matter processing contribute to an enhancement of the biogeochemical cycles (i.e., silicate and nitrogen). Smaller frame-builders provide additional hard substrata. Many structuring species forming bioconstructions are slow-growing, longevous species with low larval dispersal ability, which are life-history traits typical of vulnerable species. Other factors increase the importance of these ecosystems, including the occurrence of commercially important species and threatened species. Ultimately, the carbonate and siliceous long-lasting concretions remain in the fossil record and are a source of valuable paleo-environmental information.

Leiodermatium pfeifferae reefs from the Stone Sponge Seamount in the Balearic Sea (© OCEANA)

Dendrophyllia cornigera formation from Catifas, Alboran Sea (© OCEANA)



Neopycnodonte cochlear reefs from the Tyrrhenian Sea (© S. Canese, ISPRA)



Concretions of serpulid tubes on a bathyal rock (© S. Canese, ISPRA)

Economic importance

The most conspicuous biogenic habitats are home to numerous commercial fishes and invertebrates species, which here find a feeding area, as well as a spawning and nursery area, hence these environments are generally considered profitable fishing grounds, both for recreational and professional activities.

Vulnerability and potential threats

Potential threats for these habitats include mechanical damages by discarded or abandoned fishing gears and seafloor litter. Additional treats are represented by trawling, silting, dredging, drilling, pollution and mining, as well as anthropogenically-induced global climate changes.

Protection and management

Some primary frame builders are included in lists of protection, specifically cold-water coral scleractinians (Annex II SPA/BD, IUCN Red List EN, CITES Annex II). Many bioconstructions are considered Vulnerable Marine Ecosystems (VMEs) and some of them are recognized as Ecologically and Biologically Sensitive Areas (EBSAs) by the Convention on Biological Diversity. Within the European Union, they are considered under the habitat "1170 Reefs", defined as any geogenic or biogenic structure (formed by either dead or living animals) arising from the seafloor.

The Mediterranean Action Plan of the Barcelona Convention included biogenic habitats as part of the "Dark Habitats", which deserve protection. The General Fisheries Commission for the Mediterranean (GFCM) may establish deep-sea "Fisheries Restricted Areas" (FRA) over these habitats, mainly to protect Essential Fish Habitat" (EFH). Similarly, offshore Marine Protected Areas (MPA) and European Union's Natura 2000 protected areas, can be established to protect vulnerable communities.

Suitability of the habitat for monitoring

The availability of modern technologies (e.g. manned and unmanned underwater vehicles, acoustic imaging) allows scientists to characterize and map these sensitive deep-sea ecosystems using also non-destructive techniques. These habitats are suitable to monitoring activities following the Marine Strategy Framework Directive (2008/56/EC). They are also included within the monitoring guidelines requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention). The UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring dark habitats (biogenic habitats included) in the Mediterranean Sea. However, examples of application are still limited and are mainly focused on facies dominated by scleractinians.

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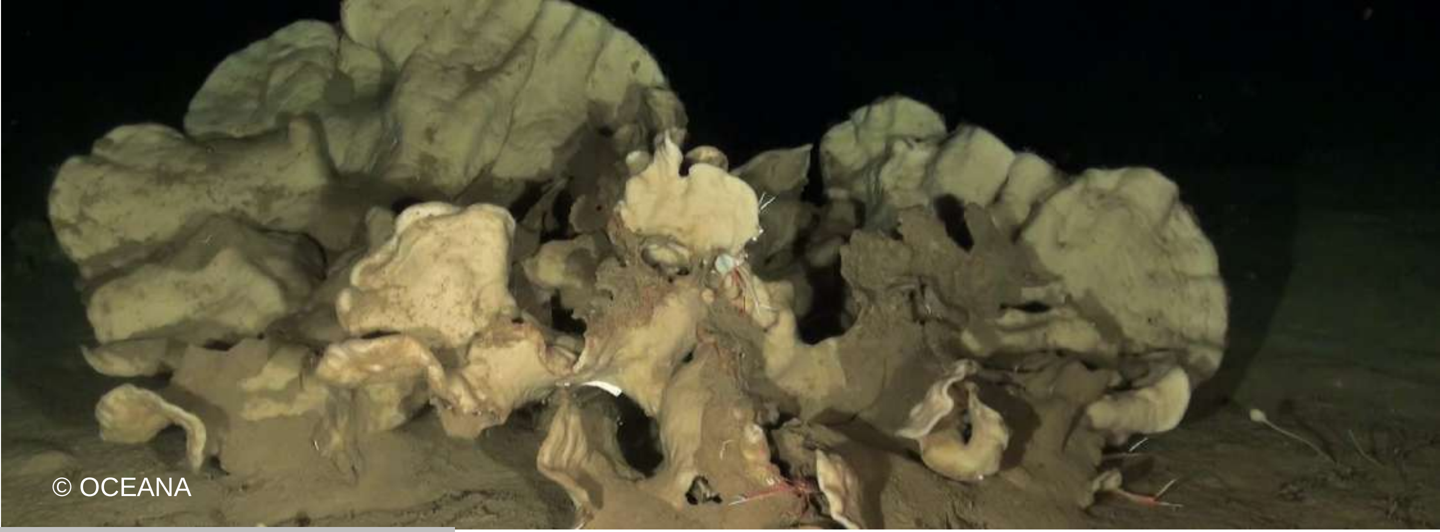
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Facies with large and erect sponges

Reference codes for identification:

- **BARCELONA CONVENTION: ME2.512**

LOCATION OF THE HABITAT

Zone	Upper to lower bathyal
Nature of the substratum	Hard (rock, biogenic)
Depth range	300 m to 800 m
Position	Open sea (continental slope, canyons, highs, seamounts)
Hydrodynamic conditions	Strong
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Enrichetti

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UPPER BATHYAL

ME2.5 Upper bathyal biogenic habitat
ME2.51 Upper bathyal reefs
ME2.512 Facies with large and erect sponges

Description of the habitat

“Lithistids” are a group of demosponges with different phylogenetic affinities, characterized by the presence of siliceous spicules welted together in a solid framework, that makes these sponges hard as stones (hence the common name of “rock sponges”). The skeleton generally persists after the sponge death, providing an available substrate for recruits and thus favouring the formation of complex, three-dimensional biogenic habitats. Lithistids were known to build impressive reefs in the Palaeozoic and Mesozoic oceans, but the living forms are currently considered relict species, mainly confined to bathyal habitats or shallow-waters caves.

In the Mediterranean Sea, *Leiodermatium* spp. records are associated with continental margins, canyons, and seamounts located between 300 m and 800 m. These records generally report few isolated specimens, with only one exception. Monospecific reefs built by *Leiodermatium pfeifferae* are reported from the Stone Sponge Seamount (SSS, Balearic Sea) at 800 m depth (upper horizon of the lower bathyal rock). Individuals grow as erect, intertwined, thick plates, reaching up to 80 cm in height and 100 cm in width, with density varying between 1 and 16 individuals m^{-2}. The accretive, clumped growth produces sponge mounds, estimated to reach heights of about 180 cm. Large densities are known also on the Mejean High (Ligurian Sea) between 380 m and 455 m.

Presence of hard substrate and food and silica availability probably affect the distribution and abundance of *Leiodermatium pfeifferae* facies. Intense siltation represents an essential factor, as this species presents specific adaptations to high silting levels.

Geographic distribution

In the Mediterranean Sea, *Leiodermatium* spp. records are reported from the Balearic Sea, the Ligurian Sea, the Tyrrhenian Sea, the Ionian Sea, and the Aegean Sea. *Leiodermatium pfeifferae* reefs are only known from the top of a seamount located in the Balearic Sea.

Associated habitats

This facies fully develops in the ‘Upper bathyal biogenic habitat’ (ME2.5) in the form of sponge reefs, however patches of individuals are present also within ‘Upper bathyal rock invertebrate-dominated’ (ME1.51) and extending to the 'Lower bathyal rock' (MF1.51). It can be adjacent or mixed with the 'Facies with small sponges' (ME2.511), 'Facies with Scleractinia' (ME2.513), 'Facies with Bivalvia' (ME2.514), 'Facies with Serpulidae' (ME2.515), and 'Facies with Brachiopoda' (ME2.516).

Related reference habitats

Leiodermatium spp. may be a component of the 'Upper bathyal rock invertebrate-dominated' (ME1.51), 'Lower bathyal rock' (MF1.5), and 'Lower bathyal biogenic habitat' (MF2.5). This facies share some ecological affinities with 'Facies with lithistid sponges' (MC1.531d).

Possible confusion

Leiodermatium lynceus and *Leiodermatium pfeifferae* are very similar species with largely overlapping bathymetrical and geographical distribution ranges. Some authors regard them as synonyms. Bathyal reefs of the lithistid *Neophrissospongia nolitangere*, which gives rise to large formations in the Atlantic Ocean and in Mediterranean shallow-water caves, are not known.

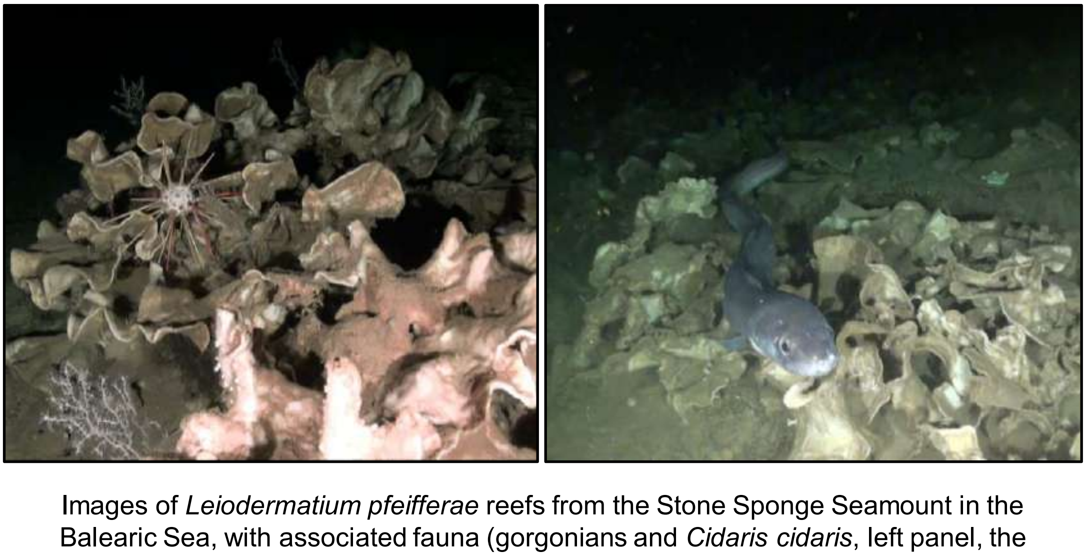
Typical species and associated communities

The living and dead remains of *Leiodermatium* spp. are often colonised by sessile organisms like hydroids, gorgonians, scleractinians, bryozoans, and more rarely, other sponges. In particular, the octocoral *Muriceides lepida* and the scleractinian *Desmophyllum dianthus (*Annex II SPA/BD, IUCN Red List EN) were reported from the Stone Sponge Seamount, together with a diverse vagile fauna dominated by fishes (e.g., conger eels *Conger conger*), crustaceans (e.g., *Aristeus antennatus*, *Munida* spp., *Bathynectes maravigna*) and echinoderms (e.g., *Peltaster placenta*, *Cidaris cidaris*).

In areas where *Leiodermatium pfeifferae* presents lower densities and does not form aggregations, the accompanying sponge community shows higher species richness, with *Stylocordila pellita*, *Pachastrella monilifera*, and *Tretodictyum tubulosum* among the most frequent associated sponges. In addition, *Leiodermatium pfeifferae* preferentially occupies heavily silted seafloors that are, in turn, avoided by the gorgonians *Bebryce mollis* and *Nicella granifera,* which dominate the outcropping rocks.

Conservation interest and ecological role

Lithistids were significant components of Palaeozoic and Mesozoic reefs and the most ancient remains of the genus *Leiodermatium* can be traced back to the Jurassic. In the modern oceans, lithistids were considered unable to develop aggregations, until the discovery, in 2015, of *Leiodermatium pfeifferae* reef-likes in the Mediterranean Sea. Thus, lithistid aggregations represent a unique living laboratory of inestimable naturalistic value. Furthermore, *Leiodermatium pfeifferae* aggregations form a dense and complex three-dimensional habitat, capable to attract a diverse vagile fauna dominated by fish and macroinvertebrates, also in areas characterized by strong silting.



Images of *Leiodermatium pfeifferae* reefs from the Stone Sponge Seamount in the Balearic Sea, with associated fauna (gorgonians and *Cidaris cidaris*, left panel, the conger ell *Conger conger*, right panel) (© OCEANA)

Economic importance

By promoting biodiversity, *Leiodermatium pfeifferae* aggregations provide ecosystem services for the human society. Among the marine organisms sheltering within this habitat, several commercial species occur, including demersal fishes (*Conger conger*, *Helicolenus dactylopterus*, *Polyprion americanus*) and crustaceans (e.g., *Aristeus antennatus*).

Vulnerability and potential threats

The architectural organization of *Leiodermatium pfeifferae* makes it particularly vulnerable to mechanical damage. Its large, erect, plate-like bodies result particularly susceptible to be impacted by demersal fishing gears, telecom cables, and devices targeting dredging, oil and gas prospecting, and deep-sea mining. The specimens that are broken and fall to the reef base have minimum survival chances due to clogging.

At present, the area hosting the lithistid reef-like formation recently discovered in the Mediterranean Sea is the target of an imminent plan for prospecting and exploitation of oil and gas.

Protection and management

Lithistid sponge aggregations represents unique habitats, with growing concerns over the need for effective and urgent preservation measures. They are recognized as Ecologically and Biologically Sensitive Areas (EBSAs) by the Convention on Biological Diversity. Furthermore, the Food and Agriculture Organization (FAO) of the United Nations recognizes sponge grounds as Vulnerable Marine Ecosystems (VMEs), highlighting that the uniqueness and rarity of species or habitat, functional significance, fragility and structural complexity, and life history, limit their resilience. Despite this, no high seas protected area has been currently designated to protect the Stone Sponge Seamount. *Leiodermatium* reefs have been listed in the Dark Habitats Action Plan.

Suitability of the habitat for monitoring

The availability of modern technologies (e.g., manned and unmanned underwater vehicles, acoustic imaging) allows scientists to study deep-sea ecosystems using non-destructive techniques. The status of lithistid aggregations can be assessed using parameters (e.g. specimens density and height, percentage of impacted individuals) easily extrapolated from video imaging. Furthermore, some indexes based on optical imagery have been developed, taking advantage of the availability of high-resolution underwater cameras, providing useful tools for monitoring deep-sea megabenthic communities.

Within the Marine Strategy Framework Directive, lithistids aggregations result suitable for monitoring with respect to Descriptor 1 ’biological diversity’, Descriptor 6 ‘seafloor integrity’ and Descriptor 10 ‘marine litter’ (and related impact parameters). Guidelines for inventorying and monitoring dark habitats, including this one, have been identified by RAC/SPA.

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Facies with Scleractinia

Reference codes for identification:

- **BARCELONA CONVENTION: ME2.513**
- **EUNIS 2019: ME151, ME1511, ME1512, ME1513, MF151, MF1511, MF1512, MF1513, ME25**
- **EUNIS 2007: A6.1, A6.611, A6.6, A6.61**
- **EC: 1170 (partim)**

LOCATION OF THE HABITAT

Zone	Upper to lower bathyal
Nature of the substratum	Hard (rock, biogenic), soft (mud, coarse, sand)
Depth range	180 m to 1100 m
Position	Open sea (continental slope, canyons, seamounts, geothermal areas)
Hydrodynamic conditions	Moderate to strong
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

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UPPER BATHYAL

ME2.5 Upper bathyal biogenic habitat

ME2.51 Upper bathyal reefs

ME2.513 Facies with Scleractinia

Description of the habitat

This facies is dominated by Cold-Water Corals (CWC) *sensu stricto*, namely deep-water azooxanthellate scleractinian (stony) corals found below ca. 200 m, forming bioconstructions. A bioconstruction is a complex framework in which colonial species grow over each others and over their skeletons creating a tridimensional habitat able to modify the surrounding physical and biogeochemical environment, persisting for long periods of time after the death of the animals, and ultimately enhancing the establishment of a distinct biocoenosis. The engineering species involved in this facies form the so-called 'white coral triad', and include the colonial species *Madrepora oculata* and *Lophelia pertusa* (= *Desmophyllum pertusum*) as well as the solitary species *Desmophyllum dianthus*. These species are able to create single facies or may variously co-exist. Other habitat-forming species may thrive intermixed or nearby the bioconstructions, including sponges, alcyonaceans, antipatharians, bivalves and serpulids.

In the Mediterranean Sea this facies is considered a relict of the cold fauna of the Quaternary period. At present, the white coral clumps only exist at appreciable depth, on hard substrata (rock or consolidated thanatocoenosis) along the edges of canyons or over topographic reliefs, where slope and seafloor heterogeneity sustain a significant hydrodynamic flux. The living parts of these clumps usually are reduced to the most distal part of the bioconstructions.

Corals occur as scattered colonies on variously inclined rocky substrata or as distinct frameworks over gently inclined seafloor forming either reefs or, more often in the Mediterranean context, carbonate mounds. Reefs are extensive and continuous ridge structures up to 20-km-long and 150-m-high, while mounds are generally elongated structures 25-50 m in height and 100-800 m across, often occurring in large numbers. In both cases, the flanks of the structures can be steep. At their base, the coral frameworks fade into loose frameworks, then they turn into coral rubble and finally into detritic and soft muddy bottom. Bioconstructions are covered by a veneer of coral thickets growing in an almost upright position, with the most intense coral growth observed on the up-current, exposed side. Downward-facing frameworks are known as well as capsized blocks, which continue to grow on the exposed side.

The living coral canopy is up to 70 cm high and 50 cm wide for *Madrepora oculata*, while colonies of *Lophelia pertusa* are generally smaller, and live portions rarely exceed 20 cm in size.

Apart from rocks and thanatocoenoses, living colonies can be found also on artificial structures (submarine cables, pipes, and iron wrecks) or, less frequently, they may settle on the denudated skeleton of persistent habitat-formers such as antipatharians. CWC, including white corals, have been reported also from fluid venting submarine structures in the Mediterranean Sea, including mud volcanoes and mud diapirs; CWC use these elevated structures as substrate and develop frameworks during periods of suitable environmental conditions.

Geographic distribution

The Mediterranean Sea is speckled with white corals occurrences except for most of the African coasts, which, however, is historically less explored. In terms of occurrence, *Madrepora oculata* and *Desmophyllum dianthus* are usually dominant in the upper bathyal frameworks with respect to *Lophelia pertusa*, more frequent in the lower bathyal depth range, despite they all show almost the same bathymetric range within the basin. All three species are distributed from the Gibraltar strait to the Aegean Sea, with only *Desmophyllum dianthus* found in the Levantine basin. This difference has been attributed to physiological differences of the two structuring species (e.g. growth rates, feeding ecology, metabolism, sensitivity to temperature changes, sensitivity to ocean acidification), particularly *Madrepora oculata* seems to exhibit a greater ability to grow in warmer waters than *Lophelia pertusa*.

Besides the sparse occurrences, at present, eight major "Provinces" have been identified in the basin, referring to geographically discrete areas (often many tens square kilometers wide) with an important deep-sea scleractinian presence. These include: 1) The Santa Maria di Leuca CWC Province, the first to be discovered and characterized. It is formed by coral mounds patchily distributed over an area of about 1000 km^2 ranging from 450 m to 1100 m. They host the white coral triad as well as the alcyonacean *Callogorgia verticillata* and are flourishing between 500 m and 700 m. 2) The southern Adriatic Sea CWC Province is represented by the Bari Canyon *Madrepora*-dominated build-ups, developing from 280 m to 600 m, and by the Montenegro *Madrepora*-dominated frameworks, developing on hardgrounds between 420 m and 1000 m. 3) The Sicily Channel CWC Province is represented by various sites located on escarpments, seamounts, and the flanks of volcanic islands, between 200 m and 1000 m. Particularly well structured, is the framework located South of Malta. 4) The South Sardinia CWC Province was recently identified off the southern coast of Sardinia in the Nora canyon, part of the Capo Spartivento canyon system. Its community is dominated by *Madrepora oculata* between 380 m and 460 m. 5) The Corsica Channel CWC Province is the most recently discovered area and one of the most pristine. Coral mounds, *Madrepora*-dominated, are 70 to 330 m long and up to 25 m high, and are distributed between 400 m and 430 m depth for a total coverage of about 5.3 km^2. 6-7) The Gulf of Lion CWC Provinces include the lush communities located between Cap de Creus and the Ligurian Sea (Levante Canyon), in the wide Catalan-Provençal-Ligurian canyon system. Here, the structuring species are mainly settled on the vertical and sub-vertical walls and include the shallowest populations of *Madrepora oculata* of the entire basin (180 m), found in the Cassidaigne Canyon together with *Corallium rubrum* (Annex III SPA/BD, IUCN Red List EN) and *Paramuricea clavata* (VU). 8) The Alboran Sea CWC Province includes massive reefs and mound formations over numerous topographic reliefs of the biogeographic regions, including also the Moroccan coasts. The white triad as well as numerous other habitat-formers (sponges, alcyonaceans and antipatharians) are found between 300 m and 700 m.

Recently, a distinctive CWC-bivalve biotope, including *Neopycnodonte zibrowii* and *Acesta excavata* (see sheets ME1.518, ME2.514) and characterized by numerous exclusive taxa, only shared with the Atlantic reefs, was discovered in the Gulf of Naples, within the Dohrn Canyon.

Occurrence, distribution and abundance of CWC species are strongly influenced by several abiotic factors (aragonite saturation, hydrodynamism, food supply, availability of suitable substrata, temperature, oxygen concentration). Mediterranean CWC are mainly influenced by the Levantine Intermediate Water (LIW), forming in the northern portion of the eastern Mediterranean Sea and flowing westward between 300 m and 600 m depth, the depth range where most of the flourishing deep communities are found. The LIW provides nutrition and oxygen to the coral communities, facilitates the larval transport and reduces the silting levels.

Associated habitats

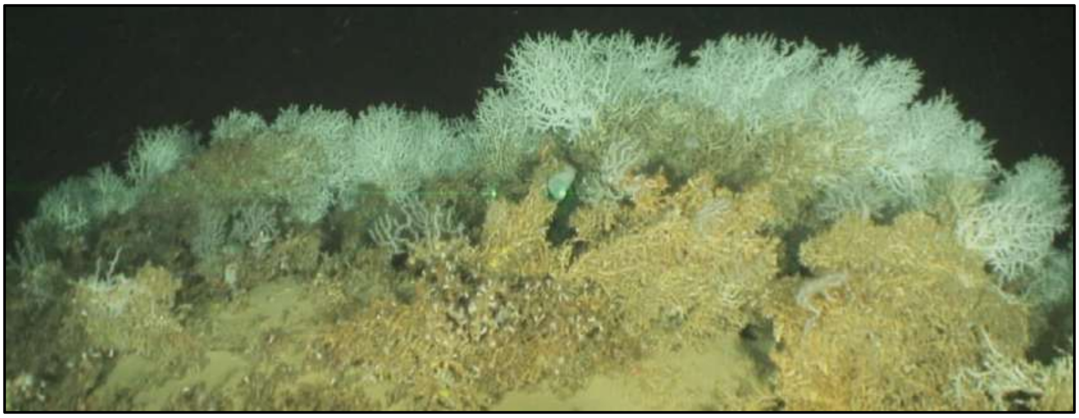
This facies is the most characteristic facies of the ‘Upper bathyal biogenic habitat’ (ME2.5), particularly ‘Upper bathyal reefs’ (ME2.51), but it can be found, although more scattered, also on ‘Upper bathyal rock invertebrate-dominated’ (ME1.51). Therefore, it can be found nearby or intermixed with facies of other habitat-forming species, such as ‘Facies with small sponges’ (ME1.511, ME2.511), ‘Facies with large and erect sponges’ (ME1.512, ME2.512), ‘Facies with Antipatharia’ (ME1.513), ‘Facies with Alcyonacea’ (ME1.514), ‘Facies with Crinoidea’ (ME1.517), ‘Facies with the Bivalvia *Neopycnodonte* spp.’ (ME1.518, ME2.514), ‘Facies with Serpulidae’ (ME2.515), and ‘Facies with Brachiopoda’ (ME1.519, ME2.516). In certain areas it can be found together with ‘Facies with Cirripedia’ (ME1.516).

A similar, although less diverse, setting of associated habitats is found in the lower bathyal range, where scleractinian-dominated facies (MF1.513, MF2.511) are found intermixed or nearby ‘Facies with small sponges’ (MF1.511), ‘Facies with Alcyonacea’ (MF1.512), as well as ‘Facies with chemosynthetic benthic species’ (MF1.514).

Finally, this facies can be found also within or nearby habitat dominated by thanatocoenoses, including consolidated and unconsolidated ones (ME2.52, MF2.52). In both depth ranges, the scleractinian frameworks area surrounded by various types of soft bottom habitats, including mud, sand and coarse sediment and the facies included within.

Related reference habitats

Various related reference habitats present overlapping characteristics to the facies described here within biogenic habitats, including ‘Facies with Scleractinia’ described for the upper bathyal rock invertebrate-dominated (ME1.515), for the upper bathyal detritic sand (ME5.518), for the upper bathyal mud (ME6.514), for the lower bathyal rock (MF1.513), and for the lower bathyal biogenic reefs (MF2.511).



Madrepora oculata mound from the Capraia Province (© ISPRA)

Lophelia pertusa and *Desmophyllum dianthus* (© S. Canese, ISPRA)

Madrepora oculata and *Desmophyllum dianthus* on a wreck (© G. Gay)

Possible confusion

The shape, size and colour of the white coral frameworks is generally very distinctive therefore no sources of confusion are generally present for this facies. The limits of this facies may be difficult to define in those sites characterized by a rich co-occurrence of habitat-forming species (alcyonaceans, antipatharians, scleractinians, sponges). Some identification issues between *Madrepora oculata* and *Lophelia pertusa* may arise from ROV footage taken at a certain distance from the seafloor. Similarly, issues to identify *Desmophyllum dianthus* from a certain distance may occasionally occur due to the large variety of other deep solitary scleractinians found in the bathyal zone, such as *Javania cailleti* on hardgrounds and *Caryophyllia smithii* var. *clavus* on certain soft bottoms. On the other hand, no possible confusion may occur with the peculiar aggregations of a deep, azooxanthellate *Madracis pharensis* recently found in the upper bathyal rocks of Lebanon.

Generally, no confusion is made between living and sub-fossil frameworks (either loose in the sediment, attached to rocky substrates or embedded in limestone). However, in the most structured provinces, the living and sub-fossil frameworks are greatly intermixed, being the sub-fossil ones the sustaining part of the bioconstruction.

Typical species and associated communities

Facies dominated by scleractinian frameworks are recognised as a key component of Mediterranean deep-sea ecosystems, but the knowledge of their associated biodiversity is still limited. A recent census reported that the combined biodiversity for Mediterranean CWC habitats and those of adjacent areas (Strait of Gibraltar-Gulf of Cádiz) includes ca. 520 species with a high contribution of sponges, polychaetes (each ca. 90 spp.), followed by cnidarians (ca. 80 spp.), bryozoans (ca. 75 spp.), crustaceans (ca. 60 spp.), molluscs (ca. 50 spp.), fishes (ca. 50 spp.), echinoderms (ca. 20 spp.), and brachiopods (7 spp.). Most species are not exclusively associated to the facies, but they benefit from the complex and diverse microhabitats provided by the bioconstruction, therefore are frequently found here. Some taxa are consistently found (e.g., the polychaetes *Eunice norvegica* and *Metavermilia multicristata*, the gastropod *Coralliophila richardi*, the bivalves *Asperarca nodulosa*, *Delectopecten vitreus*, *Spondylus gussonii*, and *Heteranomia squamula*).

With respect to the various taxonomic components, the assemblage is usually dominated by small and encrusting sponges including *Desmacella inornata* and *Sceptrella insignis*, and occasionally large massive species such as *Calthropella pathologica*, *Erylus papulifer*, *Poecillastra compressa*, and *Pachastrella monilifera*. Few boring species are known to mine the integrity of the frameworks with their bioerosive action (*Spiroxya levispira* and *Siphonodictyon infestum*). Within cnidarians, hydrozoans (e.g., *Acryptolaria conferta*, *Clytia linearis*, *Halecium labrosum*, the symbiont *Ectopleura* sp.) and especially anthozoans are very common, including scleractinians (e.g., *Stenocyathus vermiformis*, *Caryophyllia calveri*, *Dendrophyllia cornigera* (Annex II SPA/BD, IUCN Red List EN), and *Javania cailleti*), black corals (e.g., *Leiopathes glaberrima* (Annex II SPA/BD, Annex III Bern, IUCN Red List EN)), actinarians (e.g., *Amphianthus dohrnii*, *Protanthea simplex*, the boring species *Kadophellia bathyalis*), and alcyonaceans (e.g., *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Acanthogorgia hirsuta*, *Nicella granifera*, *Muriceides lepida*). Pennatulaceans and gorgonians (e.g., *Isidella elongata*, Annex II SPA/BD, IUCN Red List CR) are also common in nearby soft bottoms. Among polychaetes, beside the ubiquitous commensal eunicid *Eunice norvegica*, there are numerous serpulids (e.g., *Serpula vermicularis*) that play a role as secondary builders in CWC habitats (see sheet ME2.515).

While many bivalves are frequently present in numerous sites, few gastropods are commonly found (*Danilia tinei*, *Putzeysia wiseri*, and *Mitrella pallaryi*), some parasitic on the coral tissue. Among sessile taxa, also bryozoans (e.g., *Herentia hyndmanni*, *Scrupocellaria delilii*, and *Glabrilaria pedunculata*) and brachiopods are frequently observed in high densities (e.g., *Gryphus vitreus*, *Megerlia truncata*, *Terebratulina retusa*, and *Novocrania anomala*). Among crustaceans, the pandalids *Plesionika martia* and *Plesionika heterocarpus*, the anomurans *Munida intermedia* and *Munida tenuimana*, the xanthiid *Monadaeus couchii*, and the homoliids *Paramola cuvieri* and *Homola barbata* are commonly observed, together with the epibiont crab *Anamathia rissoana*. Numerous echinoderms occur in this facies (e.g., *Leptometra phalangium*, *Psolidium complanatum*, *Peltaster placenta*, *Ophiotrix fragilis*, *Cidaris cidaris*), as well as various fish species (*Pagellus bogaraveo*, *Conger conger*, *Helicolenus dactylopterus*, *Galeus melastomus*, and *Etmopterus spinax*).

The dead portions of the bioconstructions that are not covered by mud are hotspot of biodiversity thanks to the occurrence of numerous cavities (hosting cryptic macrofauna, such as gastropods and crustaceans) and the availability of inert denudated skeletons (enhancing the colonization by sessile and/or encrusting species, such as serpulids, cirripeds, bivalves, and sponges).

Conservation interest and ecological role

Mediterranean CWC habitats are structurally complex deep-sea ecosystems that form an intricate network of biogenic frames and interstices, providing trophic niches, spawning, nursery or shelter grounds for a large variety of organisms, including commercially important and threatened species. They provide a suitable substrate both for larval settlement and adult growth, adding to the number of available secondary hard substrates and increasing the overall tridimensionality of the habitat. Biological heterogeneity is enhanced also by the presence of other large, sessile, habitat-forming filter-feeders, which frequent areas with high hydrodynamic conditions and food supply.

The bioconstructions act as poles of attraction for the fauna, increasing the quantity and nutritional quality of the available organic matter and increasing the deposition of biogenic detritus also in the adjacent soft bottoms, which, gaining in complexity, host a higher faunal diversity. Similarly, the nearby coral rubble increases the occurrence of hard-bottom species also in predominantly incoherent environments.

In addition, CWC preserve in their aragonite skeletons important paleo-environmental information of the physico-chemical properties of the seawater in which they grew, which are used to obtain reconstructions of the past oceanographic deep environments and help define the geological and biogeographical history of the basin.

Economic importance

CWC habitats attract a rich fish fauna, including also commercial species, hence they are indirectly target of numerous fishing activities, both recreational and professional. Fish benefit from the shelter offered by the coral frameworks and also by the high density of zooplankton and benthic preys as well as organic detritus.

Several fish species use CWC habitats as a spawning area and nursery. Gravid individuals, egg masses and egg cases attached to corals or laid in the framework interstices demonstrate the relationship of many species with this environment for reproductive purposes.

Despite no clear positive relationship has been found between the diversity and abundance of fish fauna and the coral environments with respect to nearby mud-dominated habitat, some species may occur at higher densities or display larger sizes suggesting an actual benefit. A similar relationship has been observed also for some invertebrate commercial species, such as shrimps and cephalopods. Nevertheless, it is difficult to disentangle the influence of a higher fishing effort over incoherent seafloors and the actual effect of the increased habitat complexity and prey abundance typical of the frameworks.

Vulnerability and potential threats

Most CWC species, and specifically white corals, have been listed as vulnerable (due to their fragility, slow growth rates, low resilience and ecological role), as well as threatened as they are found in areas which are frequently the focus of resource exploitation (e.g. deep-sea fisheries, oil and gas prospections, mining) or are affected directly by other human activities (e.g., seafloor litter, pollution events). With respect to fishing practices impacting the coral frameworks, trawling activities are a major threat, since they may both mechanically impact the structures compromising their integrity and increase silting levels enhancing the clogging of the filtering structures. Similarly, longlines have a high chance of entanglement on these branched species. In addition, when lost or discarded, the gear (similarly to other plastic litter) collapse on the seafloor and may be dragged by bottom currents. The basal portions of the colonies, however, more resistant, reduce the traction of the gear, and the ability of living blocks to survive if capsized when not covered by mud, slightly reduce the physical vulnerability of this facies. Anthropogenically-induced global climate changes, including acidification, warming and salinification, are expected to have strong impacts on Mediterranean marine ecosystems and biodiversity also at great depths, especially on key calcifiers such as scleractinian CWC. In addition, information on the the spread of non-indigenous species (NIS) in the deep is so far very limited, hence scarcely predictable.

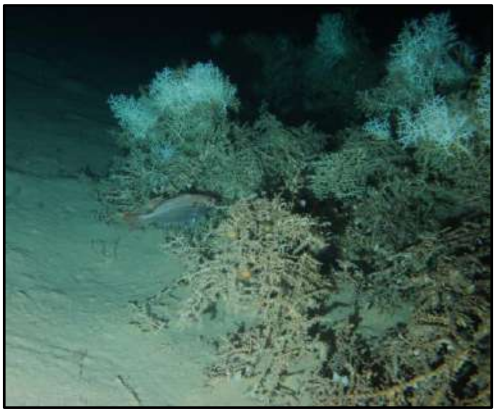
Protection and management

Some measures have been identified to protect scleractinian-dominated habitats. For instance, all three structuring species are included in lists of protection (Annex II SPA/BD, IUCN Red List EN, CITES Annex II) and the coral bioconstructions are recognized as Vulnerable Marine Ecosystems (VMEs) since 2008. Nonetheless, the management of this habitat is challenging. This is partly due to their remote location, impeding effective controls, as well as incomplete information on the diversity, occurrence, distribution, connectivity, resilience to disturbances of these environments, and socio-economic constraints. This data are key to the establishment of protected sites, such as offshore Marine Protected Areas (MPA) and European Union's Natura 2000 protected areas. CWC habitats can be recognized also as Essential Fish Habitat (EFH), which is important to establish deep-sea Fisheries Restricted Areas (FRA) as implemented by the General Fisheries Commission for the Mediterranean (GFCM). The Mediterranean Action Plan of the Barcelona Convention includes habitats dominated by white coral reefs as part of the "Dark Habitats", which deserve protection. In addition, the biotope formed by reef-forming scleractinians could be considered as "habitat type 1170 Reefs" under Annex I of the EC Habitats Directive 92/43/EEC. In this regard, measures shall be taken to maintain or restore the favourable conservation status for this facies, given also its significant economic importance.

At present, CWC frameworks in the Gulf of Lion canyon system and Santa Maria di Leuca, in the Ionian Sea, are protected by two Fisheries Restricted Areas (FRAs) (REC. GFCM/33/2009/1 and GFCM/2006/3, respectively). A Site of Community Importance (SCI) hosting white corals over the Chella bank (Seco de los Olivos) in Spain, was established in 2014. GFCM established also a permanent closure of the deep Mediterranean basin below 1000 m to benthic fishing gears (REC. GFCM/29/2005/1), which however leaves most of the CWC habitats, thriving between 200 and 800 m, entirely unprotected.

Canyons appear to act as natural shelters of CWC communities and a larger exploration and conservation effort should be dedicated to these environments. Similarly, seamounts and thanatocoenoses should also benefit from a larger research and protection effort.

Madrepora oculata and *Asconema setubalense* on the Seco de los Olivos (© OCEANA)



Madrepora oculata bioconstruction and *Pagellus bogaraveo* (© S. Canese, ISPRA)

Suitability of the habitat for monitoring

Deep coral reefs and mounds are suitable to monitoring activities following the Marine Strategy Framework Directive (2008/56/EC), specifically the descriptors biodiversity (D1), integrity of the seafloor (D6), and sea floor litter (D10). General indications for monitoring this habitat are given in the RAC/SPA Guidelines for inventorying and monitoring of dark habitats in the Mediterranean Sea. Bioconstructions can be mapped and characterized by means of remote systems (multibeam swath bathymetry, acoustic backscatter, side scan sonar), operated vehicles and underwater drop camera (video footage, photo stills), and CTD probes. In this ambit, predictive habitat mapping is increasingly considered as a reliable and efficient methodology to represent the complexity and extent of this facies on a large scale. Providing a full-coverage spatial perspective of habitat heterogeneity, is becoming an essential tool in science-based management of natural resources. The environmental status of this facies can be assessed through ecological multi-parametric indexes and photogrammetry targeting the morphometric structure of the population over time.

The use of the ‘province’ concept helps to identify situations exceeding occasional CWC occurrences and helps to narrow the areal of seabed meritorious of special attention for management and protection purposes.

Traditional sampling methods can still be used to collect samples, including trawls, dredges and cores. Computed tomography is used to disclose the presence of corals in the cores, to facilitate taxonomic identification of the species, and to elucidate their three-dimensional distribution and taphonomic aspects. Cores are used also to derive paleo-environmental information from geochemical signals. Similarly, radiocarbon dating is commonly used to trace the geologic history of the dead frameworks in relation to the environmental conditions.

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Facies with Serpulidae

Reference codes for identification:

BARCELONA CONVENTION: ME2.515

- **EUNIS 2019: ME25 (partim)**
- **EUNIS 2007: A6.6 (partim)**
- **EC: 1170 (partim)**
- **CORINE: 11.21 (partim)**

LOCATION OF THE HABITAT

Zone	Bathyal
Nature of the substratum	Hard (rock, biogenic)
Depth range	300 m to 600+ m
Position	Open sea
Hydrodynamic conditions	Bottom currents
Salinity	Between 36 and 39
Temperature	10 °C to 14 °C
Suitability for monitoring	Yes

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L. Beuck, C.N. Bianchi, MARUM (Center for Marine Environmental Sciences, University of Bremen), R. Sanfilippo, A. Vertino

UPPER BATHYAL

ME2.5 Upper bathyal biogenic habitat

ME2.51 Upper bathyal reefs

ME2.515 Facies with Serpulidae

Description of the habitat

The Serpulidae are a large (about 670 species in about 70 genera) family of sedentary polychaetes, inhabiting calcareous tubes, which they cannot leave. Tube calcium carbonate is in the form of both aragonite and calcite, in fairly constant ratio for each taxon. Tubes are cemented firmly to any hard substrate (in only few species tubes are free). Although in the majority of the species the tubes encrust the substrate for all their length, the distal part may eventually detach and grow erectly. Certain species in dense populations build tubes vertical to the substrate in clumps and cement the tubes to each other. This gives serpulids the capability of forming reef-life structures when densely settling. Despite the relative smallness of the individual tubes (rarely longer than 10 cm and wider than 1 cm), such reef-like structures may cover tens of m^2, with a layer more than 1 m thick. Most serpulids are considered to be ‘secondary frame builders’, filling crevices and cementing rubble in coral reefs and coralline algae bioconstructions. However, about 30 Recent serpulid species are known to form important aggregates, and may be regarded as ‘primary frame builders’. All of these aggregating species occur singly too and thus are not obligatorily constructional. Some species are able to reproduce asexually and thus may form small “pseudo-colonies”: these species, however, are not primary frame builders; major build-ups derive from larval gregariousness. Serpulid reefs are well known in the geological past, and phenomena of mass occurrence of Recent serpulid species have been reported from many sites. The main primary frame builders can be divided roughly into three groups, each occupying a major type of habitat and consisting of species that are morphologically (and probably phylogenetically) more similar to one another than to members of the other groups. The first group consists of taxa that form belts in the intertidal zone of open coasts. The second group is aggregating in quiet, enclosed embayments of normal salinity. The third group lives in brackish estuaries and lagoons. Only recently, significant serpulid aggregates have been described in the upper bathyal zone. They may grow from small hard substrates dispersed in the mud as three-dimensional clusters of multiple individuals, or be associated to cold-water coral reefs. Three types of coral-serpulid frameworks can be recognized based upon size and shape: bush-shaped frameworks 10-20 cm high; fan-shaped frameworks 15-35 cm high; and mitt-shaped frameworks 25-80 cm high. The abundance of serpulids increases with the size of the frameworks, which results from superimposition, overgrowth, and/or intergrowth of long-lived corals and several generations of serpulids. Occasionally, serpulid tubes become embedded within the coral skeleton. Adult serpulid tubes are up to 20 cm long, with only the first half encrusting, the distal half part growing erect. Serpulids appear to be the most representative coral skeletal epibionts in terms of species richness and abundance. They profusely encrust dead colonies/fragments or tissue-barren branches of living coral colonies but scarcely supply carbonate to the biogenic framework due to their comparatively small-size, acting as secondary builders. The coral-serpulid frameworks are widely scattered on the seafloor (generally spaced 0.5 m to a few meters) and may grow on extensive (mostly vertical to overhanging) rocks, boulders, and small hard substrates lying on the muddy bottom.

Geographic distribution

In the Mediterranean Sea, bathyal coral-serpulid frameworks have been described for the Southern Adriatic (Bari Canyon) only. Their possible occurrence in the Gulf of Lions needs confirmation.

Associated habitats

The facies with Serpulidae coexists with other bathyal habitats, either on rocky or sedimentary bottoms, such as ‘Facies with small sponges’ (ME2.511), ‘Facies with large and erect sponges’ (ME2.512), ‘Facies with Scleractinia’ (ME2.513), ‘Facies with Bivalvia’ (ME2.514), and ‘Facies with Brachiopoda’ (ME2.516).

Related reference habitats

The facies with Serpulidae greatly overlaps with the ‘Facies with Scleractinia’ (ME2.513) of the ‘Upper bathyal reefs’ (ME2.51). This habitat is related with the ‘Facies with Vermetidae and/or Serpulidae’ (MC1.518b, MC1.518c, MC2.51A, MD2.511) that develops in the circalittoral and offshore circalittoral zones.

Possible confusion

Clusters of serpulid tubes at bathyal depths, and their association with scleractinian corals, are a distinctive feature that should make this habitat easily distinguishable from other deep bioconstructed habitats.

Typical species and associated communities

The main serpulid species is *Serpula vermicularis*, which is responsible for the formation of the aggregates. The pseudocolonial serpulid *Filograna* sp. may form reticulate bushes up to 15 cm high around the tubes of *S. vermicularis* or on the muddy bottom. Other abundant serpulids include *Filogranula gracilis*, *Metavermilia multicristata*, *Vermiliopsis monodiscus*, *Bathyvermilia eliasoni*, and *Hyalopomatus madreporae*. Scleractinian corals in serpulid-coral frameworks are represented by *Madrepora oculata*, *Desmophyllum dianthus*, and – less frequently – *Lophelia pertusa* (= *Desmophyllum pertusum*) and *Dendrophyllia cornigera*. *S. vermicularis* clusters are colonized by hydrozoans, encrusting and erect sponges, sabellids, bryozoans (e.g., *Smittina cervicornis*), and ascidians; the largest aggregates are occasionally inhabited by ophiuroids. Large lobate sponges, mainly *Pachastrella monilifera* and *Poecillastra compressa*, are often associated to serpulid-coral frameworks.

Conservation interest and ecological role

In bathyal serpulid and serpulid-coral frameworks, *Serpula vermicularis* acts as ecosystem engineer, enhancing biodiversity through the production of additional hard substrata. Because of their rarity and important ecological function, *S. vermicularis* aggregations should be regarded as habitats of special conservation interest.

Economic importance

Serpulid-coral frameworks supply four kinds of ecosystem services. Regulating services consist in the stabilization of the sedimentary fans on bathyal slopes. Provisioning services are represented by food availability, as this facies offers protection and nursery to fishes and crustaceans of fishery importance. Habitat services are due to the creation of a three-dimensional space. Finally, information services reside in scientific research: bioconstructor skeletons act as climate records and their chemical composition give information about past water properties. Monetary evaluations of this habitat are still lacking.

Vulnerability and potential threats

The fragility of serpulid clusters and serpulid-coral frameworks makes them extremely vulnerable to the mechanical impacts caused by trawling. Lost fishing gears may entangle these bioconstructions. Deep sea disposal of waste (dredging, mining), research activities (seismic prospecting, sampling), and undersea prospecting (drilling, hydrocarbon exploitation, military activities) are further causes or damage. Ocean acidification may hamper the deposition of the carbonate structures of both serpulids and scleractinian corals.

Protection and management

Aggregations of *Serpula vermicularis* fall under the definition of 'biogenic reefs', and as such are included in the Annex I of the EU Habitat Directive. *Madrepora oculata*, *Desmophyllum dianthus*, and *Lophelia pertusa* are classified as 'Endangered' in the IUCN Red List. All scleractinian species are listed in Appendix II of CITES (Convention on International Trade in Endangered Species of wild flora and fauna). No specific protection measures for this habitat have been implemented yet.

Suitability of the habitat for monitoring

The communities of cold water corals (notably the facies with *Lophelia pertusa* or *Madrepora oculata*) are included within the guidelines for monitoring marine habitats in the Mediterranean, requested by the Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP, Barcelona Convention) to build a regional standardised monitoring system. The UNEP Regional Activity Centre for Specially Protected Areas of Tunis has published the guidelines for monitoring of dark habitats (cold water corals included) in the Mediterranean Sea. However, examples of application are still limited.

Serpula vermicularis branchial crown and operculum protruding from its tube (© L. Beuck)

Tube encrusting a worn coral fragment (© R. Sanfilippo)

Aggregated tubes growing vertically (© C.N. Bianchi)

Serpulid aggregate (© MARUM)

Distal ends of tubes intergrowing with *Madrepora oculata* (© A. Vertino)

Fan-shaped serpulid-coral aggregate (© MARUM)

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UPPER BATHYAL

ME2.5 Upper bathyal biogenic habitat

ME2.52 Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges

Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges

Reference codes for identification:

- **BARCELONA CONVENTION: ME2.52**
- **EUNIS 2019: ME1513, MF1513**
- **EUNIS 2007: A6.61**

LOCATION OF THE HABITAT

Zone	Upper bathyal
Nature of the substratum	Hard (rock, biogenic), soft (coarse, sand, mud)
Depth range	150 m to 2500 m
Position	Open sea (shelf edge, slope, canyons, seamounts)
Hydrodynamic conditions	Variable
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

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Photo credits:
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Description of the habitat

The exposed fossil or sub-fossil remains of megafaunal habitat-forming organisms can constitute thanatocoenoses, which represent conspicuous secondary hardgrounds in the deep-sea and may host aggregations of living habitat-forming species (e.g., sponges, alcyonaceans, black corals) and their associated fauna.

Among bathyal megafaunal thanatocoenoses, occurring both on hard and soft substrates with various inclination, there are those constituted by the white corals *Lophelia pertusa* (= *Desmophyllum pertusum*), *Madrepora oculate*, and *Desmophyllum dianthus*, which can produce both three-dimensional bioherms and loose or densely packed coral rubble fields, also close to living reefs. The bioclastic material constituting the thanatocoenoses can show various degrees of diagenetic processes, from sparse fragments to conglomerated micritic limestones, and can be partially or totally covered in Mn-Fe oxides. Also the yellow coral *Dendrophyllia cornigera* (and to a lesser extent *Dendrophyllia ramea*) forms wide thanatocoenoses of fragments or entire colonies in living position, mainly on sub-horizontal muddy or coarse seafloors.

Some species of large bathyal bivalves, such as *Neopycnodonte zibrowii*, *Acesta excavata*, and *Spondylus gussonii*, are responsible for thanatocoenoses on vertical or sub-vertical hardgrounds, often, but not exclusively, in association with the ones constituted by cold-water corals. The related *Neopycnodonte cochlear* can form thanatocoenoses on variously inclined hardgrounds and soft seafloors of the continental shelf and upper bathyal.

Other taxa are known to produce thanatocoenoses in the Mediterranean basin, even if with a more limited distribution. Among these there are the micriticised remains of fossil hexactinellids and the dead frameworks of living large reef-builder demosponges (*Leiodermatium pfeifferae*). Serpulids can occasionally form bathyal thanatocoenoses, and more often contribute with their calcified tubes to those dominated by cold-water corals. Finally, the valves of different species of brachiopods may produce patchy thanatocoenoses on vertical rocky walls or soft seafloors.

Geographic distribution

The current geographic and bathymetric occurrence of thanatocoenoses in the Mediterranean Sea derives from the wider distribution of habitat-forming cold-water species (and other taxa) during the Pleistocene glacial episodes. Overall, thanatocoenoses are mainly located between the deepest portion of the upper bathyal realm and the shallower horizon of the lower bathyal.

Thanatocoenoses of the three main frame-builder cold-water corals, *Lophelia pertusa* (= *Desmophyllum pertusum*), *Madrepora oculata* and *Desmophyllum dianthus*, are widely distributed, from the Strait of Gibraltar to the Sicily Channel, through the Ionian Sea to the Greek southern margin. In this latter area, an extensive investigation revealed the occurrence of distinct dead coral facies on deep steep topographies, including: i) *Neopycnodonte zibrowii*-*Desmophyllum dianthus*, ii) *Desmophyllum dianthus*-*Caryophyllia sarsiae*, iii) *Madrepora oculata*-*Lophelia pertusa*. All these framestones contain cavities hosting densely-packed fossilized macrofauna (e.g., foraminifera, scleractinians, stoloniferans, serpulids, gastropods, bivalves, brachiopods, bryozoans). On gentler substrates, unconsolidated skeletal sediments include: i) *Lophelia pertusa*-*Madrepora oculata* rubble, ii) *Dendrophyllia cornigera* rubble, iii) *Stenocyathus vermiformis* rubble, iv) *Caryophyllia calveri* rubble, and v) sediments with octocoral axes (isidid gorgonians, pennatulaceans axes). The bathymetric range of occurrence of coral thanatocoenoses in the Mediterranean Sea is wide (150-2500 m), but most of the records are located between 400 m and 1000 m. *Desmophyllum dianthus* thanatocoenoses on rocky hardgrounds have been observed down to 2500 m depth in French canyons and paleo-biocoenoses dominated by this species were identified close to the abyssal limit along the Malta Escarpment. This facies are known also from topographic reliefs in canyons and seamounts.

Dendrophyllia cornigera thanatocoenoses are mainly known from the western basin, from shelf edge areas (150 m) to more than 600 m depth, while dead *Dendrophyllia ramea* is reported from the Sicily Channel and eastern Mediterranean Sea at shallower depths. Dead *Neopycnodonte zibrowii* aggregations are found mainly in the western basin, but they are also known from Crete Island; they have been recorded mainly between 230 and over 1300 m. Thanatocoenoses of *Neopycnodonte cochlear* are commoner in the western basin, mainly confined in the offshore circalittoral realm. Other molluscs thanatocoenoses are widespread in the Mediterranean basin, mainly in association with cold-water corals. *Acesta excavata*, now extremely rare in the Mediterranean Sea, creates thanatocoenoses scattered in the basin from 180 to 1900 m. Thanatocoenoses of fossil hexactinellids are known below 1500 m in the Aegean Sea, while thanatocoenoses of *Leiodermatium pfeifferae* have been recorded at about 800 m over a seamount in the Balearic Sea. Thanatocoenoses of the serpulid *Spirobranchus triqueter* are known for the Creus Canyon, between 150 and 400 m.

Associated habitats

This habitat can be adjacent, intermixed or may be the substrate for most of the facies thriving on deep hardgrounds, such as offshore reliefs (MD1.5), or bathyal rocks (ME1.5, MF1.5). The most frequent coral thanatocoenoses are mainly found on soft bottoms from offshore circalittoral to bathyal depths (MD3.5, MD4.5, MD5.5, ME3.5, ME4.5, ME5.5, ME6.5, MF6.5).

Dense accumulations of conspicuous fragments of habitat-forming species (e.g., coral rubble, large bivalve shells) are included in this habitat, whereas smaller bioclastic components, as well as thanatocoenoses produced by whole macrofaunal organisms (e.g., foraminifera, small molluscs) are considered as components of coarse sediment (MD3.5, ME3.5), as they do not produce a structured habitat for associated megafauna. The dead portion of coral or bivalve reefs still including high densities of living specimens are considered in 'Offshore reefs' (MD2.51), 'Upper bathyal reefs' (ME2.51), or 'Lower bathyal reefs' (MF2.51), and related facies, depending on the depth range of occurrence.

Related reference habitats

Thanatocoenoses of corals, or Brachiopoda, or Bivalvia, or sponges are mainly represented in the upper bathyal depth range (ME2.52), as part of 'Upper bathyal biogenic habitat' (ME2.5), but they can be found also in the lower bathyal realm (MF2.52), as part of 'Lower bathyal biogenic habitat' (MF2.5); few species (e.g., *Dendrophyllia cornigera*, *Dendrophyllia ramea*, *Neopycnodonte cochlear*) are also present in the offshore circalittoral (MD2.52), as part of 'Offshore circalittoral biogenic habitat' (MD2.5).

Possible confusion

Thanatocoenoses facies include also those formed by foraminifera, benthic or planktonic gastropods, bivalves or fragments of carbonatic species in unlithified biogenic sediments, however since the conspicuous structuring elements (potentially offering substrate to living habitat-forming species) are missing, they are not taken into account here. The dead portion of living white coral frameworks or bivalve reefs is not considered here, but in the related sheets (see sheets ME2.513 and ME2.512, respectively).

Typical species and associated communities

Coral thanatocoenoses are the most complex structures in the Mediterranean bathyal realm, and they are usually abundantly colonised by a rich sessile fauna. The species observed in this habitat may occur also on bathyal hardgrounds and over dead portions of living reefs. Sponges include small or encrusting species (e.g., *Hexadella detritifera*, *Thrombus abyssi*, *Stylocordyla pellita*), and large massive ones, such as *Farrea bowerbanki*, *Tretodictyum reiswigi*, *Poecillastra compressa*, and *Pachastrella monilifera.* Hydrozoans are frequent, as well as gorgonians (e.g., *Acanthogorgia hirsuta*, *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Swiftia pallida*, *Muriceides lepida*, *Placogorgia* spp., *Dendrobrachia bonsai*), soft corals (*Scleranthelia musiva*, *Anthomastus* sp. in the Alboran Sea), zoantharians, stoloniferans, black corals such as *Leiopathes glaberrima* (Annex II SPA/BD, Annex III Bern, IUCN Red List EN, CITES Annex B), and other scleractinians (e.g. *Caryophyllia* spp., *Javania cailleti*, *Stenocyathus vermiformis*). Living specimens of framework-builders corals, such as *Lophelia pertusa* (= *Desmophyllum pertusum*), *Madrepora oculata*, *Desmophyllum dianthus*, *Dendrophyllia cornigera*, *Dendrophyllia ramea* (all in Annex II SPA/BD, IUCN Red List EN) may occur on thanatocoenoses. Most habitat-forming bivalves (e.g. *Neopycnodonte zibrowii*, *Acesta excavata*, *Spondylus gussonii*) can grow both on coral and on other bivalves thanatocoenoses, together with serpulids (e.g., *Neovermilia falcigera*, *Filogranula stellata*, *Vermiliopsis monodiscus*) and bryozoans (e.g., *Exidmonea atlantica*, *Tervia irregularis*). The high heterogeneity of thanatocoenoses (both bioherms and rubble) attract a very rich vagile fauna, mainly constitute by the crustaceans *Munida tenuimana*, *Palinurus mauritanicus*, *Plesionika* spp., *Paromola cuvieri*, and *Bathynectes maravigna*. Echinoderms (the sea urchin *Cidaris cidaris*, sea stars, crinoids, and ophiuroids) and molluscs (e.g., *Sepietta oweniana*) are common as well. Many fishes typically found on bathyal hardgrounds can be observed moving over thanatocoenoses; among the most commonly recorded are *Scyliorhinus canicula*, *Galeus melastomus*, *Etmopterus spinax*, *Conger conger*, different macrourids, *Chlorophthalmus agassizi*, *Hoplostethus mediterraneus*, *Helicolenus dactylopterus*, *Phycis blennoides*, *Scorpaena* spp., *Merluccius merluccius* (IUCN Red List VU), *Polyprion americanus*, and *Pagellus bogaraveo*.

Conservation interest and ecological role

Thanatocoenoses act as biogenic frameworks, constituting complex tridimensional structures that provide habitat, refuge, substrate and food to numerous species, both sessile and vagile. Moreover, this habitat often occur over soft seafloors, therefore this habitat hosts a richer (both in terms of diversity and abundance) associated sessile and vagile fauna in comparison to adjacent non cohesive substrates without the biogenic skeletal fragments. However, depending on the typology of the remains that constitute each thanatocoenosis, benthic assemblages can differ both in terms of species composition and abundance. The existence of this facies in a semi-enclosed temperate basin such as the Mediterranean Sea represents an important source of paleo-environmental information regarding the geologic and biologic history of the deep biogenic communities of the region over the last 40000 years. The comparison between past and present communities also provides information regarding the physiological tolerance limits of the species and give clues on possible future scenarios.

Economic importance

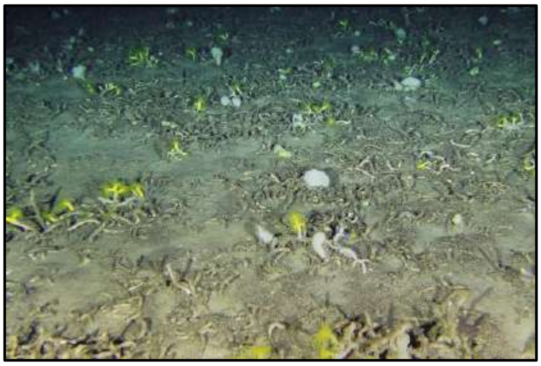
Many species of crustaceans (e.g., *Palinurus mauritanicus*) and fishes (e.g., *Merluccius merluccius*, *Polyprion americanus*, *Lepidopus caudatus*, *Lophius* spp., *Conger conger*, *Pagellus* spp.) of commercial interest live in this habitat, in particular in the upper bathyal realm. The commercial shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea* can be found on sandy mud in proximity to coral thanatocoenoses in the shallower horizon of the lower bathyal realm. Many other valuable species regularly frequent this habitat for feeding, spawning or as nursery site.

Vulnerability and potential threats

Trawling activities occurring in proximity to thanatocoenoses, targeting commercial shrimps, can compromise the integrity of the frameworks and damage the assemblages they sustain both directly (physical impact of the gears) and indirectly (increased resuspension and silting rates). Other fishing practices, both artisanal and recreational, can directly affect the thanatocoenoses. The physical destruction of the thanatocoenoses and the removal of the forests they sustain lead to an homogenization of the seafloor, a strong reduction of the associated communities, and ultimately to an alteration of the ecosystem functioning of this habitat and its productivity. Abandoned, lost or otherwise discarded fishing gears (ALDFG) and associated accessories (e.g., disposable moorings, ropes), together with urban or maritime litter, are commonly seen on seamounts and along canyon flanks, sometimes in concomitance with thanatocoenoses, and skeletal remains often represent accidental bycatch of both nets and longlines in these areas. Mining, drilling, and cables' positioning activities may represent sources of pressure for this habitat, both in terms of mechanical disturbance and alteration of the silting levels. Finally, increasing evidence is emerging towards the effects of global changes in the deep Mediterranean Sea (thermal stress, acidification, carbon fluxes).

Protection and management

No specific protection measures are in place to protect Mediterranean megafaunal thanatocoenoses and the aggregations they host. Nevertheless, most thanatocoenoses include portions of living reef systems as well as facies of habitat-forming species such as gorgonians or black corals, so they can be indirectly protected by the measures in place to manage the conservation of these habitats. Firstly, some species typically occurring on thanatocoenoses are now included in lists of protection (IUCN, SPA/DB, Bern). In addition, coral reefs in the Gulf of Lion canyon system and Santa Maria di Leuca, in the Ionian Sea, are protected by two Fisheries Restricted Areas (FRAs) (REC. GFCM/33/2009/1 and GFCM/2006/3, respectively), established by the General Fisheries Commission for the Mediterranean (GFCM), that ban dredges and bottom trawl activities in order to protect these ecosystems. The "deep-sea corals" habitat is also reported on the list of priority habitats according to the SPA/BIO protocol and fall within the EU Habitats Directive, Annex I habitat type (code 1170 Reefs). The Mediterranean Action Plan of the Barcelona Convention included habitats formed by thanatocoenoses of stony corals, molluscs, bryozoans, serpulids, and sponges as part of the so called "Dark Habitats" which deserve protection. The criteria of rarity, importance for life history stages of species, importance for threatened and endangered species/habitats, vulnerability, biological diversity and naturalness, make this ecosystem a Sensitive Habitat (SH). Due to the low resilience to mechanical pressure of the forests they sustain, these habitat are considered Vulnerable Marine Ecosystems (VMEs) in the FAO/GFCM's International guidelines for the management of the deep sea fisheries in the high seas. In this regard, in 2005, GFCM established a permanent closure of the deep Mediterranean basin below 1000 m to benthic fishing gears (REC. GFCM/29/2005/1), that may help preserving the deepest thanatocoenoses.



A *Dendrophyllia cornigera* thanatocoenosis on the Occhiali seamount (Ligurian Sea) (© M. Bo)

A glass sponge *Tretodictyum reiswigi* on a white coral thanatocoenosis on the Emile Baudot seamount (© OCEANA)

Suitability of the habitat for monitoring

Thanatocoenoses are suitable to monitoring activities following the Marine Strategy Framework Directive (2008/56/EC), specifically the descriptors biodiversity (D1), integrity of the seafloor (D6), and sea floor litter (D10). They can be mapped by means of remote sonar systems and operated vehicles and various ecological multi-parametric indexes are available to evaluate the environmental status of the epimegabenthic species living on the skeletal remains with respect to natural constraints and anthropic impacts. General indications are given in the RAC/SPA Guidelines for inventorying and monitoring of dark habitats in the Mediterranean Sea. Beside monitoring, an explorative effort is still necessary as only few bathyal hardgrounds, including thanatocoenoses, have been widely studied (e.g. Gulf of Lion, down to 2500 m). Traditional sampling methods are used to collect samples targeting the species composition of the fossil framestones. Radiocarbon dating is commonly used to trace the geologic history of the thanatocoenoses then correlated to the environmental conditions, which determined the death.

The white corals bioherm of Santa Margherita Ligure (Ligurian Sea) (© M. Bo)

The gorgonian *Callogorgia verticillata* on coral rubble (© OCEANA)

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Upper bathyal mud

Reference codes for identification:

- **BARCELONA CONVENTION: ME6.51**
- **EUNIS 2019: ME65, ME651**
- **EUNIS 2007: A6.5, A6.51**

LOCATION OF THE HABITAT

Zone	Upper bathyal
Nature of the substratum	Soft (mud, occasionally sandy mud)
Depth range	200 m to 500 m
Position	Open sea (continental slope, canyons, topographic reliefs)
Hydrodynamic conditions	Variable
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

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UPPER BATHYAL

ME6.5 Upper bathyal mud

ME6.51 Upper bathyal mud

Description of the habitat

The upper bathyal depth range is mainly characterized by a non-cohesive seafloor. Yellowish to blue-greyish clayey mud is the most widespread habitat in the whole basin. In the upper bathyal, mud is generally rather fluid, and not compact and may include a sandy component. The granulometric characteristics of the mud, its thickness and organic content are variable, influencing the distribution of the facies. The habitat typically shows high levels of bioturbation (e.g., burrows, tracks, sediment and faecal mounds). The general environment is characterised by a constant homeothermy of around 13-15°C starting around 300 m depth. The amount of light reaching the upper bathyal is lower than 1% of the incident light. The habitat is interested by the flow of the Modified Atlantic Water (MAW) and the Levantine intermediate Water (LIW).

Geographic distribution

Non-cohesive seafloors represent the most widespread habitat of the Mediterranean upper bathyal depth range in both basins. Deep rocky reliefs over seamounts, ridges and within canyons partially interrupts the extension of this habitat. Nevertheless, mud can be found also on hardgrounds as large patches of silt and a very thin layer of fluid mud is found along the flanks of canyons.

Associated habitats

This habitat is usually delimited at shallower depths by ‘Circalittoral mud sediment’ (MC6.5) and other soft bottom circalittoral habitats. Hardgrounds, such as ‘Circalittoral rock’ (MC1.5) and ‘Circalittoral biogenic habitat’ (MC2.5) can also be present. Upper bathyal mud encircling ridges and seamounts can border with ‘Offshore circalittoral mud’ (MD6.5) and other soft bottom offshore habitats, but mainly with ‘Offshore circalittoral rock’ (MD1.5) and ‘Offshore circalittoral biogenic habitat’ (MD2.5). At greater depths, this habitat usually continues in ‘Lower bathyal mud’ (MF6.5) or, more rarely, with ’Lower bathyal rock’ (MF1.5) or ‘Lower bathyal biogenic habitat’ (MF2.5). The upper bathyal mud can be fragmented by the presence of hardgrounds, such as ’Upper bathyal rock’ (ME1.5) and ‘Upper bathyal biogenic habitat’ (ME2.5), and other soft bottoms, such as ‘Upper bathyal coarse sediment’ (ME3.5), ‘Upper bathyal mixed sediment’ (ME4.5) and ‘Upper bathyal sand’ (ME5.5).

This habitat can host aggregations of soft bottom sessile cnidarians, such as ‘Facies with Pennatulacea’ (ME6.512), ‘Facies with Alcyonacea’ (ME6.513), and ‘Facies with Scleractinia’ (ME6.514). Other facies of sessile organisms present in this habitat are ‘Facies with Bivalvia’ (ME6.518), ‘Facies with Bryozoa’ (ME6.51B), and ‘Facies with giant Foraminifera’ (ME6.51C). In addition, ‘Facies with small sponges’ (ME6.511), ‘Facies with Crustacea Decapoda’ (ME6.515), ‘Facies with Crinoidea’ (ME6.516), ‘Facies with Echinoidea’ (ME6.517), ‘Facies with Brachiopoda’ (ME6.519), and ‘Facies with Ceriantharia’ (ME6.51A) can be observed.

Related reference habitats

This habitat, and its associated communities, can be related to ‘Offshore terrigenous sticky mud’ (MD6.51), ‘Lower bathyal sandy mud’ (MF6.51), and ‘Abyssal mud’ (MG6.51).

Possible confusion

‘Upper bathyal mud’ (ME6.5) is localized at shallower depths with respect to ‘Lower bathyal mud’ (MF6.5) and is generally described as more fluid, less compact, and with a sandy component. The faunistic components are also generally well distinguished from those found on the shelf muds. The fine granulometry distinguishes this habitat from other upper bathyal soft bottoms. ROV images do not always allow the correct identification of soft bottom categories.

Typical species and associated communities

Meiofauna (dominated by Nematoda) is a key component of the upper bathyal mud, together with infaunal macro- and megabenthos. Information are available also for deep-sea foraminifera and fungal communities. Macrofauna is generally dominated by polychaetes. Epimegafauna tends to be sparse and constituted mainly by mobile species such as crustaceans and echinoderms. Cnidarians are among the most common sessile and sedentary organisms, together with sponges. Aggregations of giant foraminiferans and bryozoans are also present. Fishes are second only to decapod crustaceans in terms of abundance and number of species in this habitat. The sharp decrease in organic carbon fluxes towards the Levantine basin explains the significant reduction in faunal abundance of the deep-sea benthic components on a latitudinal gradient. Spatial and temporal changes are observed in the communities characterizing this habitat and are mainly related to environmental and trophic gradients, and climatic oscillations.

This habitat can host forests of the gorgonian *Isidella elongata* (Annex II SPA/BD, IUCN Red List CR), as well as aggregations of cerianthariansand sea pens such as *Pennatula* spp., *Funiculina quadrangularis* (IUCN Red List VU), *Protoptilum carpenteri*, *Kophobelemnon stelliferum* and *Virgularia mirabilis*. Other sessile organisms, like giant foraminiferans belonging to the order Astrorhizida (tentatively identified as *Notodendrodes* sp. and *Pelosina* sp.), the sponges *Thenea muricata*, *Pheronema carpenteri*, and *Polymastia tissieri,* the anemone *Actinauge richardi*, the bryozoan *Kinetoskias* sp., the brachiopod *Gryphus vitreus*, and the ascidiacean *Dicopia antirrhinum* are observed and, in some cases, can create facies. Among infaunal macrofauna, polychaetes are frequent together with the ophiuroids *Amphiura* spp., the tusk shell *Antalis agilis*, and the cephalaspidean *Philine quadripartita*. Among vagile epifauna some of the most common decapod crustaceans are the crab *Paromola cuvieri*, the polychelid lobster *Polycheles typhlops*, the Norway lobster *Nephrops norvegicus*, the spiny lobster *Palinurus mauritanicus*, the shrimps *Plesionika* spp. and *Parapenaeus longirostris*, and different species of Anomura (e.g., *Munida* spp., *Pagurus prideaux*, *Pagurus alatus*). Other common mobile invertebrates are the gastropod *Aporrhais serresianus*, the heterobranchs *Tethys fimbria* and *Pleurobranchaea meckeli*, the cephalopods *Eledone cirrhosa*, *Bathypolypus sponsalis*, *Octopus salutii*, the polychaete *Hyalinoecia tubicola*, the holothurian *Parastichopus regalis*, the sea urchins *Cidaris cidaris* and *Brissopsis lyrifera*, the crinoids *Antedon mediterranea* and *Leptometra phalangium*, the asteroid *Anseropoda placenta*. Many benthic (e.g., *Scyliorhinus canicula*, *Raja clavata* (IUCN Red List NT), *Lepidorhombus boscii*, *Helicolenus dactylopterus*, *Chlorophthalmus agassizi*, and *Lophius budegassa*) and bentho-nektonic fishes (such as *Merluccius merluccius* (IUCN Red List VU), *Phycis blennoides, Benthocometes robustus*, *Gadiculus argenteus*, *Hoplostethus mediterraneus*, the grenadiers *Hymenocephalus italicus* and *Coelorinchus caelorinchus*) are also frequent.

Conservation interest and ecological role

The upper bathyal shows a high species richness, hosting both characteristic species and eurybathic ones. The fauna includes some nearly-endemic and endemic species, pre-Messinian relic species (of high historical value), and a high occurrence of Atlantic species (many of boreal affinity), representing relatively recent entrances in the basin. This habitat hosts aggregations of habitat-forming species (e.g. *Isidella elongata* and sea pens), which may be used as refuge, feeding or nursery areas and contribute in increasing the mobility and aggregation of species in this habitat. These complex ecosystems are known also to enhance the pelagic-benthic coupling processes and biogeochemical cycles occurring at these depths hence they fully contribute to the functioning of the deep-sea. Finally, the communities living in this habitat include rare species and many organisms that are still poorly studied. Overall, a greater diversity is observed in the upper part of the slopes with respect to deeper areas, with peaks in specific geomorphological features (e.g. canyons and seamounts).

Economic importance

Upper bathyal mud hosts many species of crustaceans (e.g., *Palinurus mauritanicus*, *Parapenaeus longirostris*, and *Nephrops norvegicus*) and fishes (e.g., *Merluccius merluccius*) of high commercial values. Trawling is the most common and widespread anthropic activity carried out in this habitat, especially in some canyon areas in the western basin, the Sicily Channel, the southern Adriatic Sea and the Aegean Sea.

Vulnerability and potential threats

Intensive deep-sea trawling (mainly targeting the Norway lobster *Nephrops norvegicus*, fishes and cephalopods) is responsible for overfishing of target species (reduction in abundance, size, number of sexually mature individuals), modifications of the silting rates and granulometry, habitat destruction, reduction in abundance of infaunal and epibenthic species collected as bycatch or discard (e.g. sharks, *Funiculina quadrangularis, Isidella elongata*), loss of biodiversity, changes in the trophic composition of the communities, and functioning of the ecosystem at all levels. Abandoned, lost or otherwise discarded fishing gears (ALDFGs) are also impacting the seafloor. The recovery ability of some communities to mechanical disturbances is reduced by the long life cycles and slow growth rates of some species, defining resilience in the order of decades or more.

Dumping activities (e.g., harbour sediments, industrial mineral residues, litter) and mining or drilling activities may also directly impact deep-sea muddy ecosystems. Coastal mudslides and fires can increase the supply of terrigenous sediment, organic matter and pollutants to the deep realm, thus affecting the characteristics of the bathyal mud and, ultimately, its biocoenoses. Increasing evidence is emerging towards the effects of global changes also in the deep Mediterranean Sea.

Protection and management

Various measures have been identified to contrast the general trends of impoverishments of this habitat. Some species typically occurring on upper bathyal mud are now included in lists of protection (IUCN Red List, SPA/DB). All coral forests, including soft bottom gardens of *Isidella elongata* and pennatulaceans, are identified as Vulnerable Marine Ecosystems (VMEs) and Sensitive Habitats (SHs) in the FAO/GFCM's International guidelines for the management of the deep sea fisheries in the high seas. The Mediterranean Action Plan of the Barcelona Convention included habitats dominated by structuring species as part of the so called “Dark Habitats” which deserve protection. Mapping VMEs, such as the ones included in this habitat, is considered an essential step in the framework of environmental protection, as declared in the European Marine Strategy Framework Directive (2008/56/EC). Finally, many researches focused on the development of more sustainable fishing gears and fishing tracking systems are now used to evaluate the large-scale fishing effort. The implementation of protection measures through the creation of offshore Marine Protected Areas (MPAs) and Fisheries Restricted Areas (FRAs) are still poorly pursued mainly due to socio-economic constraints, lack of data and difficulties in controlling territories in international waters. However, new proposals are emerging every year thanks to scientific advancement and a larger consensus among stakeholders. So far, two FRAs, banning demersal fishing activities, have been identified over habitats including upper bathyal mud to protect Essential fish habitats (EFHs) (Gulf of Lion, Jabuka/Pomo Pit), with other examples in shallower areas. The French FRA is part of a larger network of MPAs embracing also bathyal depths. Finally, it is worth mentioning the pluri-decennial closure to trawling, under regional law (L.R. 7.8.1990, n. 25, art. 9), of three gulfs in North Sicily (Catania, Patti, Castellammare), partially including upper bathyal mud and supporting the recovery of various commercial stocks.

Suitability of the habitat for monitoring

The outputs of large-scale, pluri-decennial scientific fishing campaigns (e.g., MEDITS, GRUND) are used to monitor trends of target species, bycatch and benthic discard over time and space. Within the Marine Strategy Framework Directive (2008/56/EC) biodiversity (D1), and integrity of the seafloor (D6) are considered important descriptors to assess the status of this habitat and a major effort is currently in place to create distribution maps of VMEs and ecological multi-parametric indexes to evaluate the environmental status of trawling fishing grounds based on the sensitivity of benthic mega-epifauna. Swept area ratios derived from VMS and AIS vessel control systems are used to quantify the intensity of fishery-induced abrasion on the seabed. Multibeam echo-sounding and side-scan sonar techniques are employed to evaluate trawl damages and extent and status of coral biocoenoses. Guidelines for inventorying and monitoring dark habitats, including those thriving on muddy bottoms, have been identified by RAC/SPA. From a larger perspective, a set of deep-sea essential ecological variables (DEEVs) among five scientific areas of the deep ocean (biodiversity, ecosystem functions, assessment of impact/risks, climate change, and conservation) have been identified to develop effective, long-term ecosystem-based management and monitoring strategies. In this regard, new technologies, able to work autonomously and continuously, represent the next frontier in deep-sea exploration and monitoring, and benthic habitat modelling proved to be useful to obtain large-scale maps and help the decision-making process in protection initiatives.

A facies of the bathyal sponge *Thenea muricata* (© OCEANA)

The spider octopus *Octopus salutii* (© OCEANA)

The grenadier *Coelorinchus caelorinchus* (© S. Canese, ISPRA)

Forest of the gorgonian *Isidella elongata* (© S. Canese, ISPRA)

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Facies with Pennatulacea

Reference codes for identification:

- **BARCELONA CONVENTION: ME6.512**
- **EUNIS 2019: ME6513**
- **EUNIS 2007: A6.513**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Soft (mud, sandy mud, detritic mud)
Depth range	40 m to 800 m
Position	Coastal, open sea (continental shelf, slope, canyons, seamounts)
Hydrodynamic conditions	Weak
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

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UPPER BATHYAL

ME6.5 Upper bathyal mud

ME6.51 Upper bathyal mud

ME6.512 Facies with Pennatulacea

Description of the habitat

The most representative facies with pennatulaceans of the upper bathyal mud is represented by aggregations of *Funiculina quadrangularis*, a whip-like sea pen, whitish-creamy in colour, and with a curved shape. Colonies are up to 2 m high, with approximately one quarter embedded in the sediment. This species has very specific habitat requirements and thrives on undisturbed, fluid mud and sandy mud (more rarely on detritic, coarse sand), mainly on the upper part of the continental slope (including canyons' head and flanks), but extending also in the deeper circalittoral shelf and lower bathyal. Aggregations may be characterized by sparsely or densely distributed colonies, with density generally varying between 0.05 and 1 colony m^{-2} (higher in small, pristine patches).

Additional sea pen aggregations, isolated or intermixed, can be found on detritic, sandy and/or muddy sediments and include *Pennatula rubra*, *Pennatula phosphorea*, *Pteroeides griseum*, *Veretillum cynomorium* (20-600 m), *Kophobelemnon stelliferum* (200-800 m), *Virgularia mirabilis* (20-400 m), and *Protoptilum carpenteri* (240-450 m). These species are smaller habitat-forming species (10-60 cm high) and many of them are capable of limited movements. The inclination of the slope may influence the occurrence of facies dominated by different pennatulaceans (lower slope for *Kophobelemnon stelliferum* and more important slope for *Funiculina quadrangularis*).

Geographic distribution

Funiculina quadrangularis is a cosmopolitan species, widely widespread in the Mediterranean region between 40 m and 800 m depth, being reported in the Alboran Sea, North African coasts, western Mediterranean Sea, Gulf of Lion and Corse Island, Ligurian and Tyrrhenian seas, Sicily Channel, Adriatic Sea and Ionian Sea, Aegean Sea, towards Lebanon, and including the Marmara Sea.

Kophobelemnon stelliferum is also a widely distributed species, mainly reported, in the Mediterranean Sea, from the western basin. Large facies (density up to 1.3 colony m^{-2}) are known so far from Santa Maria di Leuca (400-470 m) and in the Alboran Sea in the lower bathyal (500-860 m).

Protoptilum carpenteri is an Atlantic-Mediterranean species, seldomly reported in the basin (Santa Maria di Leuca and Tricase Canyon in the Ionian Sea, Balearic Sea, and Ligurian Sea). No dense facies is known of this species.

Virgularia mirabilis, *Pennatula* spp., *Pteroeides griseum*, and *Veretillum cynomorium* are widely distributed in the Mediterranean Sea and can be found in upper bathyal soft bottoms, however their bathymetric optimum of occurrence is generally located in the offshore circalittoral zone, hence they will be considered separately (MC3.515, Facies with Pennatulacea).

Associated habitats

The 'Facies with Pennatulacea' dominated by *Funiculina quadrangularis* (ME6.512) is typical of the 'Upper bathyal mud' (ME6.51) and can be found intermixed or adjacent to basically all upper bathyal mud facies, including those dominated by sessile and sedentary fauna such as small sponges (ME6.511), alcyonaceans (ME6.513), echinoids (ME6.517), brachiopods (ME6.519), ceriantharians (ME6.51A), bryozoans (ME6.51B), and giant foraminifera (ME6.51C), and those dominated by vagile fauna such as crustacean decapods (ME6.515). The facies can be adjacent also to small rocky environments scattered in the soft bottom dominated by scleractinians (ME6.514) and bivalves (ME6.518) or can surround 'Upper bathyal rock' (ME1.5). It may fade into upper bathyal habitats characterized by mixed sediment and detritic sand hosting, among others, 'Facies with Brachiopoda' (ME4.512, ME5.516). In the 'Upper bathyal detritic sand' (ME5.51) and the 'Lower sandy mud' (MF6.51), this facies can be adjacent or intermixed with similar facies to those reported in the 'Upper bathyal mud' (ME6.51).

Related reference habitats

This habitat is related to 'Facies with Pennatulacea' in the 'Upper bathyal detritic sand' (ME5.512) and to 'Facies with Pennatulacea' in the 'Lower bathyal mud' (MF6.514).

Possible confusion

Unlikely, however in the ROV footage, from a certain distance, colonies of *Funiculina quadrangularis* can be confused with the sea pen *Protoptilum carpenteri* (more reddish), *Virgularia mirabilis* (smaller, thinner, straighter, and retractile), or the whip gorgonian *Spinimuricea klavereni* (often branched and more flexuous).

Typical species and associated communities

The facies dominated by *Funiculina quadrangularis* (IUCN Red List VU) is generally associated with the infaunal gastropod *Aporrhais serresianus*. Other sea pens may occasionally be present (e.g., *Kophobelemnon stelliferum*, *Pennatula* spp., *Virgularia mirabilis*), as well as large soft-bottom hydrozoans (e.g., *Nemertesia antennina* and *Lytocarpia myriophyllum*). The surrounding soft bottoms are often colonised by cerianthids, the anemone *Actinauge richardi*, the sponge *Thenea muricata*, the brachiopod *Gryphus vitreus*, the polychaete *Lanice conchilega,* the bryozoan *Kinetoskias*, and the soft coral *Alcyonium palmatum*. The facies is frequented by the gastropod *Xenophora crispa*, the commercial cephalopod *Eledone cirrhosa*, the polychaete *Aphrodita aculeata*, and numerous crustaceans such as *Parapenaeus longirostris*, *Nephrops norvegicus, Aristeus antennatus*, *Alpheus glaber*, *Liocarcinus depurator*, *Medorippe lanata*, *Munida* spp., *Dardanus arrosor* (with the epibiont anemone *Hormathia alba*), *Solenocera membranacea*, and *Plesionika heterocarpus*. Numerous echinoderms are reported from this facies, such as *Gracilechinus acutus*, *Parastichopus regalis*, *Odontaster mediterraneus*, *Tethyaster subinermis*, *Hymenodiscus coronata*, and also *Leptometra phalangium*. A large variety of fish are reported from this facies, including *Lepidorhombus whiffiagonis*, *Helicolenus dactylopterus*, *Merluccius merluccius* (IUCN Red List VU), *Phycis blennoides*, *Trigla lyra*, *Chelidonichthys cuculus*, *Synchiropus phaeton*, and *Peristedion cataphractum*, as well as some sharks (e.g. *Scyliorhinus canicula*).

Kophobelemnon stelliferum aggregations can be found in soft bottom patches nearby hardgrounds together with *Cavernularia pusilla*, *Isidella elongata* (Annex II SPA/BD, IUCN Red List CR), *Funiculina quadrangularis*, molluscs, polychaetes (e.g., *Dasybranchus caducus*), crinoids, shrimps, and macrourid fishes.

Conservation interest and ecological role

Funiculina quadrangularis aggregations on bathyal mud increase benthic and demersal biomass and diversity through an increase in habitat heterogeneity, adding three-dimensional complexity to the habitat. *Funiculina quadrangularis* meadows are commonly frequented by commercially important crustacean species, in particular *Nephrops norvegicus* and *Parapenaeus longirostris*, triglids, and cephalopods (*Eledone cirrhosa*, *Illex coindetii* and *Todaropsis eblanae*). *Kophobelemnon stelliferum* was reported also within a *Merluccius merluccius* nursery. For all these reasons, this habitat is considered of high conservation value.

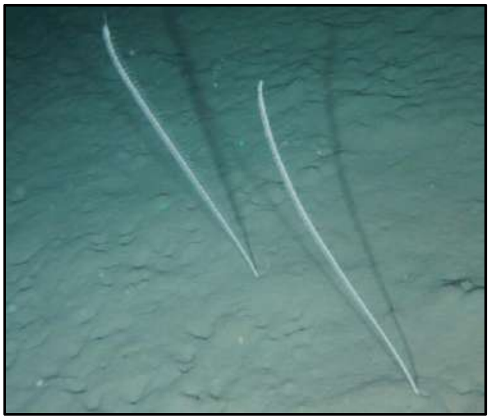
Economic importance

The economic importance of this facies is mainly linked to its role as a nursery area for several species including some of economic importance (e.g., *Merluccius merluccius*).

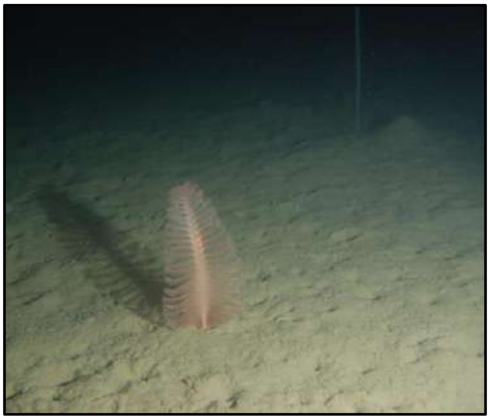
Vulnerability and potential threats

The main threat for this species in the Mediterranean Sea is the mechanical disturbance from bottom trawling. Populations, naturally patchy, become more fragmented under the mechanical action of the gear, and the colonies, characterized by a brittle axial rod and the inability to withdraw into the sediment, are uprooted or damaged. Taller colonies result more impacted. Bycatch wet weights of about 14 kg km^{-2} have been reported. Available information on the life traits of *Funiculina quadrangularis* support high total fecundity, prolonged oogenesis, and large oocytes suggesting lecithotrophic larvae with a survival time of some months. It has been inferred that this species reaches sexual maturity at 5-6 years, that it has a patchy recruitment, with isolated populations likely to be self-seeding, that is has slow growth and a long lifespan. These life traits support a high sensitivity of the species and a low resilience. However, studies conducted in the Gioia Canyon and in the Sicily Channel pointed out that relatively dense facies, with both adult and juvenile colonies, are known in areas characterized by moderate trawling effort suggesting that the relationship between trawling intensity and abundance is not straightforward for this species (and other sea pens), with respect to alcyonaceans living in the same habitat (e.g., *Isidella elongata*). Similarly, fishers' perception indicates an overall stable occurrence of *Funiculina quadrangularis* since the 1980s in the Adriatic Sea, with respect to other declining species (e.g. sponges, gorgonians, bivalves). In this regard, the relative flexibility of *Funiculina quadrangularis* colonies, their monopodial shape, their ability to bend prior the impact or to reinsert and right themselves when uprooted make this species less susceptible to trawling, if compared to brittle, branching gorgonians such as *Isidella elongata*.

It has been estimated that at least half of the potential habitat for this species has been affected in the last decades in the Mediterranean Sea and, considering that fishing activities causing the decline have not ceased, this species has been defined vulnerable (IUCN Red List VU). Major population declines have been observed in various trawling grounds (Adriatic Sea, Ligurian Sea, Gulf of Lion, Strait of Sicily, and Algeria) due to intensive trawling fisheries targeting *Parapenaeus longirostris* and *Nephros norvegicus*. Pristine dense patches are rare, mainly observed in untrawled areas, areas where trawling is forbade, or in the proximity of hardgrounds and coral mounds, which provide indirect protection.



Colonies of *Funiculina quadrangularis* on muddy bottom © S. Canese, ISPRA



Pennatula rubra and *Funiculina quadrangularis* on muddy bottom © S. Canese, ISPRA

Besides the removal of habitat-forming species and the long-term reduction and modification of the commercial stocks, bottom trawling has also other types of impact. The seafloor abrasion and sediment resuspension changes the granulometry, silting level, and distribution of organic matter with repercussions on the larval settling and patchiness of the species, the filtering ability of the polyps and their metabolic processes. Similar modifications are produced also by natural disturbances such as turbidite flows affecting populations colonizing canyons margins or mud accumulations along the flanks.

The removal of small infaunal invertebrates (i.e. bivalves, polychaetes, amphipods, gastropods) has influences on the functionality of the ecosystem because they burrow into sediments, mixing them, aerating the deeper layers and increasing rates of nutrient recycling by bioturbation and faecal deposition. Additional anthropic pressures are represented by oil, gas and mineral extraction, disposal of industrial waste, pollution, litter dumping, which can affect sediment composition and properties and, in turn, infaunal diversity.

Protection and management

The General Fisheries Commission for the Mediterranean (GFCM) identified the soft mud facies with the sea pen *Funiculina quadrangularis*, as a sensitive habitat and indicative of Vulnerable Marine Ecosystems (VMEs) as well as Essential Fish Habitats (EFHs). An adequate management measure to preserve this habitat and the fishing resources it hosts would be to create offshore protected areas, however, to date, sea pens and their associated habitats are not directly protected by any legislation and this species is not documented in any Marine Protected Area (MPA). However, *Funiculina quadrangularis* has been assessed by IUCN in the Anthozoan Red List, and the Mediterranean Action Plan of the Barcelona Convention included the sea pens habitats as part of the so-called “Dark Habitats”, which deserve protection. Two Fisheries Restricted Areas (FRAs), banning demersal fishing activities, have been identified over habitats including upper bathyal mud and facies with *Funiculina quadrangularis* to protect EFHs (Gulf of Lion, Jabuka/Pomo Pit). The French FRA is part of a larger systems of MPAs embracing also bathyal systems. Large areas of continental shelf, slope and seamounts, including mud habitat, have been proposed to be part of the Natura 2000 network, an ecosystem-based management strategy of marine resources and environments of the European Union. A transboundary large marine protected area (LMPA), specifically a no-trawl area, has also been proposed in the Adriatic Sea as a conservation tool able to trigger ecological, socio-economic and political benefits in an intensely-used marine region.

Suitability of the habitat for monitoring

Funiculina quadrangularis and other sea pens are indicators of environmental status and their occurrence, density, degree of epibiosis, and biomass are important parameters obtained from trawling campaigns and ROV surveys, monitoring biodiversity and integrity of the seafloor in the context of the Marine Strategy Framework Directive (2008/56/CE). General indications for inventorying and monitoring this habitat are given under RAC/SPA Dark Habitats Action Plan.

Bycatch thresholds limits are not in place in the Mediterranean Sea, in any case their efficiency has been debated especially for low weight habitat-forming species such as sea pens. Multibeam echo-sounding and side-scan sonar techniques are employed to evaluate occurrence of trawl scars, trawl damages and extent and status of the facies.

Facies of *Kophobelemnon stelliferum* in Algarrobo (Alboran Sea) (© OCEANA)

Kophobelemnon stelliferum and *Phycis blennoides* on muddy bottom (© OCEANA)

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Facies with Alcyonacea

Reference codes for identification:

- **BARCELONA CONVENTION: ME6.513**
- **EUNIS 2019: ME6515, MF6513**
- **EUNIS 2007: A6.514**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Soft (mud, sandy mud, detritic mud)
Depth range	110 m to 1850 m
Position	Open sea (continental shelf, canyons, gullies, seamounts, pockmarks)
Hydrodynamic conditions	Weak to moderate
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

Authors:
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UPPER BATHYAL

ME6.5 Upper bathyal mud
ME6.51 Upper bathyal mud
ME6.513 Facies with Alcyonacea

Description of the habitat

The facies dominated by *Isidella elongata* is the most representative habitat with alcyonaceans of the upper bathyal mud. *Isidella elongata* is a nearly-endemic, large-sized Mediterranean isidid (or bamboo coral), that may reach 70 cm in height and significant densities (up to 2300-2683 colonies ha^{-1}; up to 7 colonies m^{-2}) on compact mud covered by a film of fluid mud with little or no slope (3-20°). The colonies penetrate the mud thanks to a large basal root. The density of the aggregations and the abundance of the associated fauna is lower when the mud habitat fade into sandy mud. Bioturbation produced by large shrimps is an important phenomenon in this habitat. The biocoenosis is also well identified from the hydrological point of view being located at the limit of the zone of the Levantine Intermediate Waters (LIW), which is also rich in near-bottom zooplankton (copepods, euphausiids, and others). The species seems to prefer areas with low seasonal variations in terms of salinity and temperature. The facies is present along the offshore circalittoral, the continental slope and the bathyal plain, both in open plain areas and in the soft bottom near rocky elevations or dead coral mounds. Its sporadic occurrence close to diffuse fluid emissions from the seabed (pockmarks) could be related to local nutrient enrichment.

Geographic distribution

Isidella elongata is widely widespread in the Mediterranean region between 113-115 m (Malta, SW Sardinia) and 1819 m depth (France), but vast meadows are traditionally reported around 400-700 m depth. Facies are known from the Alboran Sea, North African coasts, western Mediterranean Sea (including Balearic islands), Gulf of Lion and Corse Island, Ligurian and Tyrrhenian Sea, Sicily Channel, S Adriatic Sea, eastern Ionian Sea, Aegean Sea, off the Southern coasts of Crete, Karpathos and Rhodes islands. It seems absent in the extreme Levantine basin.

Associated habitats

This facies dominated by *Isidella elongata* is typical of the 'Upper bathyal mud' (ME6.51) and can be found intermixed or adjacent to basically all upper bathyal mud facies, including those dominated by sessile and sedentary fauna such as small sponges (ME6.51), pennatulaceans (ME6.512), crinoids (ME6.516), echinoids (ME6.517), brachiopods (ME6.519), ceriantharians (ME6.51A), bryozoans

(ME6.51B), and giant foraminifera (ME6.51C), and those dominated by vagile fauna such as crustacean decapods (ME6.515). The facies can be adjacent also to small rocky environments scattered in the soft bottom dominated by scleractinians (ME6.514) and bivalves (ME6.518) or can surround ‘Upper bathyal rock’ (ME1.5). It may fade into upper bathyal habitats characterized by mixed sediment and detritic sand and hosting, among others, ‘Facies with Brachiopoda’ (ME4.512, ME5.516). In the ‘Upper bathyal detritic sand’ (ME5.51) and the ‘Lower sandy mud’ (MF6.51), this facies can be adjacent or intermixed with similar facies to those reported in the ‘Upper bathyal mud’ (ME6.51).

Related reference habitats

This habitat is related to ‘Facies with Alcyonacea’ in the ‘Lower bathyal mud’ (MF6.512). Potentially, a ‘Facies with Alcyonacea’ could be present also below 3000 m, in the ‘Abyssal mud’ (MG6.512), but no evidence so far support this. Instead, facies with alcyonaceans (e.g., *Isidella elongata* and *Spinimuricea klavereni*) are known from ‘Offshore circalittoral mud’ (MD6.5), but are not considered at present.

Possible confusion

Isidella elongata is easily recognized thanks to the typical alternation of white carbonatic internodes and brown organic nodes along the ramifications (hence the name bamboo coral). It has a candelabrum-shaped colony with a 45° inclination among the branches. Recently, two other soft-bottom isidids (*Acanella arbuscula* and *Acanella furcata*) have been identified in the Mediterranean basin between 190 and 1200 m (Balearic Sea, Ligurian Sea). Arrangement and shape of the sclerites (and partially the shape of the colony) are the taxonomic features that separate these species, limiting the possibility to discriminate them in the ROV footage. For this reason, it is not clear the quantitative contribution of these species to the *Isidella elongata* meadows, however, their ecological role can be considered comparable. Another isidid is known in the basin, but it is a small-sized, pinkish species living on lower bathyal rocks, *Chelidonisis aurantiaca*.

Typical species and associated communities

The *Isidella elongata* bathyal facies are known to be hotspots of biodiversity. The colonies themselves host numerous non-exclusive epibionts, including hydrozoans, the anemone *Amphianthus dohrnii*, the lepad *Scalpellum scalpellum*, the crab *Anamathia rissoana*, *Chlamys* bivalves, and polychaetes. Numerous sessile or vagile epifaunal invertebrates are observed between the colonies or nearby the forest, such as large foraminifera, the stalked sponges *Rhizaxinella pyrifera* and *Thenea muricata*, the large hydrozoan *Lytocarpia myriophyllum*, the pennatulaceans *Funiculina quadrangularis* and *Kophobelemnon stelliferum*, the bryozoan *Kinetoskias*, the decapods *Munida* spp. and *Dorhynchus thomsonis*, and the echinoderms *Ophiacantha setosa*, *Hymenodiscus coronata*, *Molpadia musculus*, *Penilpidia ludwigi*, *Mesothuria intestinalis*, and *Leptometra phalangium*. The mud surrounding the colonies hosts a rich infauna including the tusk shells *Antalis agilis* and *Entalina tetragona*, the bivalves *Abra longicallus* and *Cuspidaria rostrata*, the burrowing crab *Calocaris macandreae*. This is a favourable area for many mud-stirring deep shrimps (e.g. *Aristeus antennatus*, *Aristaeomorpha foliacea*, *Nephros norvegicus*, *Parapenaeus longirostris*, and *Plesionika martia*, *Plesionika acanthonotus*), which themselves are food for various cephalopods (*Rossia macrosoma*, *Bathypolypus sponsalis*, *Sepietta oweniana*, *Pteroctopus tetracirrhus*, *Octopus salutii*) and fishes.

Among these, some are quite frequent such as *Galeus melastomus*, *Scyliorhinus canicula*, *Chimaera monstrosa*, *Helicolenus dactylopterus*, *Chlorophthalmus agassizi*, *Notacanthus bonaparte*, *Phycis blennoides*, *Merluccius merluccius* (IUCN Red List VU), *Lophius piscatorius*, *Bathypterois dubius*, *Capros aper*, *Nezumia sclerorhynchus* and *Coelorinchus caelorhincus* (among other macrourids).

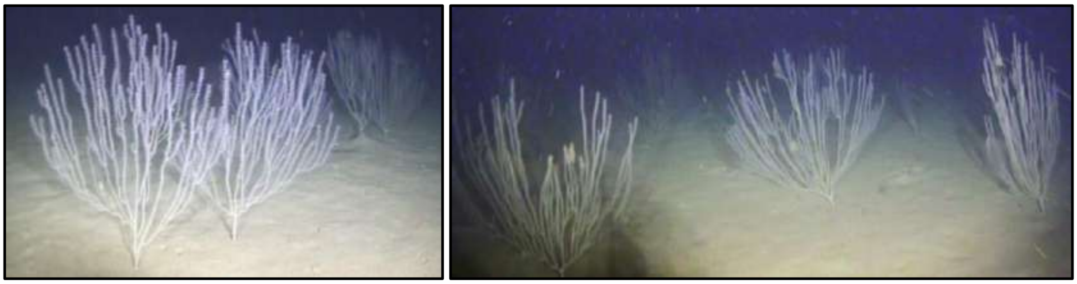
Conservation interest and ecological role

Isidella elongata is the most important habitat-forming species of the Mediterranean bathyal mud. The coral canopy influences the carbon flux rates, enhancing detritus accumulations with important implications for the bentho-pelagic food web. The colonies also increase the habitat complexity both in the benthic boundary layer and the sediments, enhancing heterogeneity, ultimately resulting in high species richness and biomass. Data coming from various studies suggest an overall diversity count of about 200 invertebrate species and 61 fishes. For these reasons this species greatly contributes to the functioning of the ecosystem. The fields of *Isidella elongata* are generally accompanied by a rich invertebrate ad fish fauna. The nature of the relationship between the corals and the fish fauna, however, is not always clear or stable and the ability of *Isidella elongata* to be a true habitat-former has been questioned: for example, while *Scyliorhinus canicula* and *Galeus melastomus* (and various cephalopods) are known to occasionally use the colonies to lay egg capsules, *Notacanthus bonaparte* is known to feed on the coral polyps, and *Benthocometes robustus* has been observed camouflaging among the ramifications, no exclusive species is known for this facies and most of them have been observed also in other environments (including rocky habitats) and probably they frequent the coral forests to take occasional advantage for protection, breeding and/or feeding. The co-occurrence may be explained by the fact that some species share common bathymetric ranges and ecological conditions with the coral. For example, some macrurid fish and pandalid shrimps (attracting many predators) may benefit, similarly to *Isidella elongata*, from wide soft bottoms, high food quality of sediment, and zooplankton aggregations enhanced by the slope geomorphological features. Nevertheless, some fish species show greater biomass and/or size differences within *Isidella elongata* facies compared to other areas where these facies is absent, and an overlap has been identified between healthy, complex canopies and spawning and/or nursery areas of commercial shrimps, cephalopods, *Phycis blennoides* and *Galeus melastomus*. While no significant difference in biodiversity was reported in a highly impacted site in the Catalan Sea, other studies highlighted a marked decrease in diversity in trawled areas respected to untrawled ones (e.g., Alboran Sea, Balearic Sea).

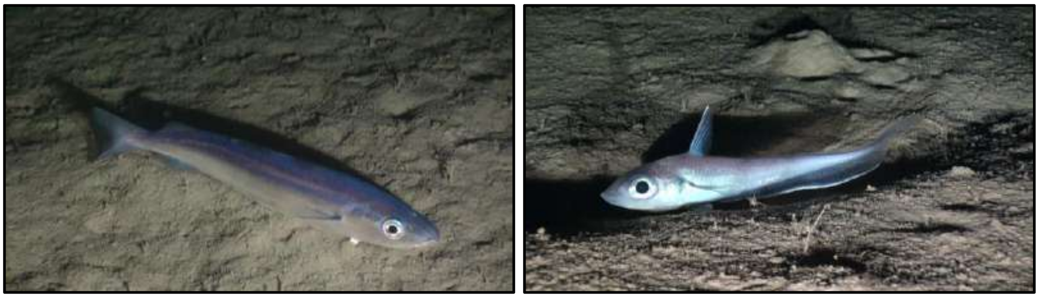
Little is known about important life history aspects of *Isidella elongata*, such as reproduction, dispersal and colonization patterns. However, based on data for other *Isidella* species (50-126 years, 0.1 mm year^{-1}, up to 400 years in other isidids), *Isidella elongata* is considered a slow growing and and exceptionally longevous species. For this reason, it is considered an important historical archive of ecological and biogeochemical information.

Economic importance

The species associated to the coral forests account for about 5% of all the income of professional fishery in the Mediterranean Sea (especially Italy and Spain). The target species include some high valuable crustaceans (*Aristaeomorpha foliacea*, *Aristeus antennatus*, and *Nephrops norvegicus*) as well as bony fish (*Merluccius merluccius*, *Micromesistius poutassou*, *Phycis blennoides*, *Lepidorhombus boscii*, *Helicolenus dactylopterus*, *Pagellus bogaraveo*). No uses are known for *Isidella elongata*, except for local artisanal jewellery made from bycatch fragments.



Isidella elongata meadow in SW Sardinia (© S. Canese, ISPRA)



Fish species observed within *Isidella elongata* meadows (*Micromesistius poutassou* and *Coelorinchus caelorhincus*) (© OCEANA)

Vulnerability and potential threats

Numerous elements support an exceptionally high vulnerability of *Isidella elongata*: the patchy aggregation, the size and fragility of the colonies, the life history traits of the species suggesting long recovery times (from a few decades to one century), and the fact that, differently from other habitat-forming species of bathyal mud, such as pennatulaceans, this isidid is not able to bend, it does not retract into the sediments and is not able to re-settle when swept away.

The main threat is represented by bottom trawling. The most relevant effect is the damaging and uprooting of the colonies. Due to this practice, bathyal meadows of *Isidella elongata* are now considered very rare, except made for areas difficult for trawling activities (e.g., small enclaves of colonies in shallow-water refuge areas protected by hardgrounds, areas nearby submarine cables, canyons, areas near CWC reefs) and poorly-exploited bathyal fishing grounds (e.g. Otranto Channel, Balearic Sea, SW Sardinia, NE Lipari). No evidence of pristine dense forests are known below 1000 m, even if it is plausible due to the trawling ban currently in place in the entire basin. Evidence of decline (biomass reduction of coral bycatch) was already observed in the 70-80s in the Ligurian and Sicilian trawling grounds suggesting a long-term impact on the pristine facies. The destructive potential of trawling is very high as demonstrated by the removal rate of colonies from a pristine forest found in 1994 off the Catalonian coasts that almost disappeared after approximately 15 years of fishing effort (the coral field was reduced to isolated colonies with a density of 0.9 colonies ha^{-1}). In areas exposed to higher trawling effort there is relatively high prevalence of small colonies, suggesting a removal of the larger, more catchable colonies. Dead, damaged or colonized colonies (e.g., the anemone *Amphianthus dohrnii* and the hydroid *Clytia linearis*) indicate stressful conditions for *Isidella elongata*. Beside habitat alteration, trawling also alters the silting rates causing the clogging of the non-retractile polyps and a disturbance in the zooplankton feeding activity, and influences the benthic trophic web, by momentarily increasing prey availability and ultimately leading to a reduction in the benthos production. Changes of sea-bottom morphology and sediment reworking due to fluid emissions could represent a cause of natural seafloor instability. Some authors suggested that the disappearance of *Isidella elongata* fields might have had implications on the spawning strategies of certain cephalopods.

Another fishing practice is known to cause damage to the *Isidella elongata* facies, and that is bottom long line fishing. Experimental long line seabream (*Pagellus* spp.) fishing carried out between 500 m and 720 m depth in the eastern Ionian Sea demonstrated that *Isidella elongata* colonies were frequent in the coral bycatch both living and dead, with an estimation of 130 live colonies caught per fisherman per year, with variations depending on the size of the hooks, the abundance and morphology of the colonies.

In addition to fishing impact, pollution and litter dumping on *Isidella elongata* facies are other important threats as well as other human activities, such as mineral extraction that favours, together with trawling activities and alteration of rivers run off, high silting levels.

Protection and management

The General Fisheries Commission for the Mediterranean (GFCM) identified the compact mud facies with the gorgonian *Isidella elongata*, as a sensitive habitat and indicative of Vulnerable Marine Ecosystems (VMEs) as well as Essential Fish Habitats (EFHs) on the basis of the functional significance, fragility, and structural complexity of the facies, as well its life history traits that limit the probability of recovery. To date, *Isidella elongata* facies are not directly protected by any legislation and have not been documented in any Marine Protected Area (MPA). However, *Isidella elongata* has been assessed by IUCN in the Anthozoan Red List as as critically endangered, it has been included in Annex II of the Barcelona Convention, and the Mediterranean Action Plan of the Barcelona Convention included isidid habitats as part of the so called “Dark Habitats”, which deserve protection. Two Fisheries Restricted Areas (FRAs), banning demersal fishing activities, have been identified over habitats including upper bathyal mud to protect EFHs (Gulf of Lion, Jabuka/Pomo Pit). The French FRA is part of a larger systems of MPAs, one of which (Parc Marine du Golfe de Lion) hosts an historical area with *Isidella elongata*. Large areas of continental shelf, slope and seamounts, including mud habitat, have been proposed to be part of the Natura 2000 network, an ecosystem-based management strategy of marine resources and environments of the European Union.

Suitability of the habitat for monitoring

The European Union (EU) has recently strengthened its environmental policies through the Marine Strategy Framework Directive (2008/56/CE), aiming to achieve a Good Environmental Status of the EU's marine waters. In line with these requirements, understanding the impact of fishing activities on VMEs is increasingly becoming a key scientific topic. *Isidella elongata* is an indicator of environmental status and its occurrence, density, degree of epibiosis, biomass, and basal diameter are important parameters obtained from trawling campaigns (although destructive) and ROV surveys, monitoring biodiversity and integrity of the seafloor. Bycatch thresholds limits are not in place in the Mediterranean Sea, in any case their efficiency has been debated especially for low weight habitat-forming species such as *Isidella elongata*. In addition, the absence of quantitative bycatch data prior the advent of intensive trawling, limits the definition of reference pristine values. Multibeam echo-sounding and side-scan sonar techniques are employed to evaluate the occurrence of trawl scars, trawl damages and extent and status of the facies. Radiometric dating of marine sediments and identification of skeletal remains in sediment cores have been used to evaluate the occurrence of *Isidella elongata* in areas prior trawling impact. General indications for inventorying and monitoring this habitat are given under RAC/SPA Dark Habitats Action Plan.

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UPPER BATHYAL

ME6.5 Upper bathyal mud

ME6.51 Upper bathyal mud

ME6.51B Facies with Bryozoa

Facies with Bryozoa

Reference codes for identification:

- **BARCELONA CONVENTION: ME6.51B**

Description of the habitat

Buguloid bryozoans may inhabit deep bathyal muds. One species belonging to the genus *Kinetoskias* (family Bugulidae) and tentatively identified as *Kinetoskias smitti* forms patchy aggregations on muddy seafloors. The colonies are whitish, small, thinly ramified, sustained by an elongated peduncle emerging directly from the mud to which they anchor thanks to thin, rhizoid filaments. Another unidentified yellow bryozoan, belonging to the family Candidae and not stalked, can be frequently found on bathyal muds. Given the fragility and small size of these species, and the difficulty to spot them even in ROV footage, this facies has been only recently identified in the Mediterranean basin.

Geographic distribution

Kinetoskias smitti is present on both sides of the Strait of Gibraltar; it appears to live deeper (2195-5223 m) on the Atlantic side than on the Alboran one (480 m). Facies of *Kinetoskias* cf. *smitti* are mainly known between 400 m and 650 m depth in the basin. The species was reported on the muddy seafloor between two seamounts East of Ibiza (Ses Olives and Ausias March), over the Emile Baudot Seamount, south of Formentera Island, and Malta. So far, all records of these soft-bottom bryozoans, are in the western Mediterranean Sea (mainly around the Balearic Islands) and Sicily Channel.

Associated habitats

This facies is present in the ‘Upper bathyal mud’ (ME6.51), but may extend over ‘Lower bathyal mud’ (MF6.5). Rarely it can be found near ‘Upper bathyal rock invertebrate-dominated’ (ME1.51). It is associated with ‘Facies with Alcyonacea’ (ME6.513), and in particular with aggregations of the isidid *Isidella elongata*. In the same environment can be found the ‘Facies with Pennatulacea’ (ME6.512), ‘Facies with Scleractinia’ (ME6.514), ‘Facies with Bivalvia’ (ME6.518), and ‘Facies with giant Foraminifera’ (ME6.51C). In addition, ‘Facies with small sponges’ (ME6.511), ‘Facies with Crustacea Decapoda’ (ME6.515), ‘Facies with Crinoidea’ (ME6.516), ‘Facies with Echinoidea’ (ME6.517), ‘Facies with Brachiopoda’ (ME6.519), and ‘Facies with Ceriantharia’ (ME6.51A) can be observed.

Related reference habitats

None.

LOCATION OF THE HABITAT

Zone	Upper to lower bathyal
Nature of the substratum	Soft (mud)
Depth range	300 m to 700 m
Position	Open sea (continental slope)
Hydrodynamic conditions	Weak
Salinity	Between 38 and 39
Temperature	Homeothermy around 13°C
Suitability for monitoring	Yes, but not applied

Authors:
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Possible confusion

None.

Typical species and associated communities

A species belonging to the genus *Kinetoskias*, tentatively identified *as Kinetoskias smitti*, and a Candidae are the typical species of the facies. Each *Kinetoskias* colony may represent a small island for hard bottom epibionts (such as serpulids), living on both the branches and the stalk. Giant foraminifera as *Pelosina* sp., tube polychaetes and Ampeliscidae amphipods, among others, can be observed nearby. Other species that may occur within this facies are the sponges *Cladorhiza abyssicola* and *Thenea muricata*, *Alcyonium palmatum* and *Pennatula* spp., and shrimps of the genus *Plesionika*. The habitat is frequented by various fish species such as *Chlorophtalmus agassizi*, *Helicolenus dactylopterus*, and *Phycis blennoides*.

Conservation interest and ecological role

The erect colonies represent a hard substrate for sessile and acrophilic organisms, thus enhancing macrobenthic biodiversity on a non-cohesive seafloor on a small-scale. No other information is available regarding the ecological role of these species.

Economic importance

The economic value of this habitat has not been assessed yet.

Vulnerability and potential threats

Upper bathyal muddy seafloors are widely exploited trawling fishing grounds. The studied *Kinetoskias* cf. *smitti* facies in the Balearic Sea were found on an untrawled seafloor, and resulted absent from an adjacent trawled area, confirming the removal effect caused by destructive fishing activities to the facies. No biological information is available for this species.

Protection and management

No form of protection targeting this facies are currently in place in the Mediterranean Sea. It would benefit from the protection of the forests constituted by the gorgonian *Isidella elongata*, a critically endangered species (IUCN), currently listed in Appendix II of the SPA/BD, and living in the same habitat. Bathyal facies with bryozoans are mentioned in the Dark Habitats Action Plan.

Suitability of the habitat for monitoring

General indications are given in the RAC/SPA Dark Habitats Guidelines.

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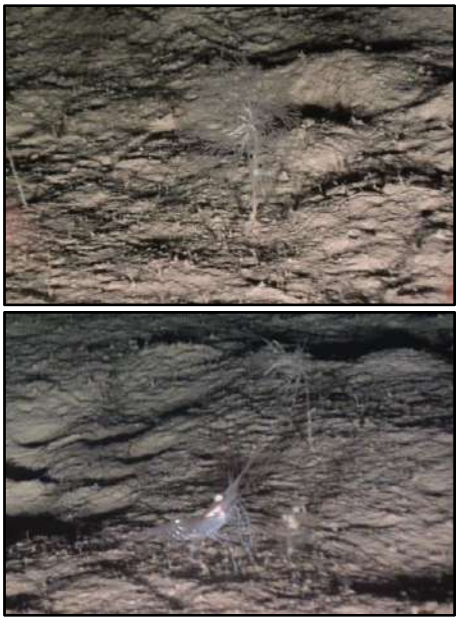

Specimens of *Kinetoskias* cf. *smitti*
from Ausias March Seamount
(© OCEANA)

Specimens of *Candidae* from
Formentera and Malta
(© OCEANA)


© S. Canese, ISPRA

Facies with giant Foraminifera

Reference codes for identification:

- **BARCELONA CONVENTION: ME6.51C**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Soft (mud, sandy mud, coarse, hydrothermal deposits)
Depth range	110 m to 950 m
Position	Open sea (continental slope, seamounts, hydrothermal vents)
Hydrodynamic conditions	Variable
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes, but not applied

Authors:
M. Bo, F. Betti

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UPPER BATHYAL

ME6.5 Upper bathyal mud
ME6.51 Upper bathyal mud
ME6.51C Facies with giant Foraminifera

Description of the habitat

Giant foraminifera belonging to the order Astrorhizida, and tentatively identified as *Notodendrodes* sp. and *Pelosina* sp. (*Pelosina* cf. *arborescens*), can create aggregations on upper to lower bathyal mud seafloors. Their erect habitus, up to about 6 cm in height, allows these species to live partially buried in the sediment and at the same time reach the turbulent benthic boundary layer, in which they extend long, thin and flexible branches. Test and stalk are sand-embedded. Ecological information regarding *Pelosina arborescens* are known only from the Baltic Sea, where the species is known to thrive at shallow depths, on soft bottoms characterized by low levels of bioturbation and anaerobic conditions, reaching densities of several thousand specimens m^{-2}. Dense patches as well as scattered individuals have been reported in the Mediterranean Sea. Astrorhizids have been observed also on lower bathyal rocks.

Patches of another giant agglutinated astrorhizid, *Spiculosiphon oceana*, are known in the basin at shallower depths between the shelf edge and the upper slope, and on seamounts. This stalked species, 4 cm high, displays a micro-predatory feeding strategy based on the employment of fragments of sponge spicules embedded in the test and stalk, similarly to carnivorous sponges. It is not permanently anchored to withstand the instability of the substrate on which it lives. It was reported on detrital sand and soft bottoms covered in authigenic Fe-rich precipitation, sulphur deposition and microbial mats typical of hydrothermal fields, close to non-effusive structures. It has been hypothesised that, in this environment, it exploits bacterial mats as trophic resource.

Geographic distribution

In the Mediterranean Sea, this facies is reported from two seamounts in the Ligurian Sea: Ulisse, at around 508 m (*Notodendrodes* sp.) and Janua, between 823 and 924 m (*Notodendrodes* sp., 877-924 m, and Astrorhizida, 823 to 924 m with maximum density at 823 m). The same facies, tentatively attributed to *Pelosina* sp., is present on the muddy seafloor between two seamounts East of Ibiza, in the Balearic Sea, between 480 m and 620 m depth. Dense patches of *Pelosina* cf. *arborescens* are known on bathyal muds in Lebanon and in the Aeolian Archipelago.

Spiculosiphon oceana is known from the Seco de Palos Seamount in the Balearic (153 m) and within the hydrothermal fields of the Pontine and Aeolian archipelagos (southern Tyrrhenian Sea) (116-204 m). Because of foraminiferans relatively small sizes and difficulty to be spotted in ROV footage, this facies probably remains undetected in many areas.

Associated habitats

The facies dominated by bathyal astrorhizids is present on 'Upper bathyal mud' (ME6.51) and may extend on 'Lower bathyal mud' (MF6.5). It can be associated with 'Facies with Alcyonacea' (ME6.513), and in particular with aggregations of the gorgonian *Isidella elongata*. In the same environment can be also observed the 'Facies with Pennatulacea' (ME6.512), 'Facies with Scleractinia' (ME6.514), 'Facies with Bivalvia' (ME6.518), 'Facies with Bryozoa' (ME6.51B). In addition, 'Facies with small sponges' (ME6.511), 'Facies with Crustacea Decapoda' (ME6.515), 'Facies with Crinoidea' (ME6.516), 'Facies with Echinoidea' (ME6.517), 'Facies with Brachiopoda' (ME6.519), and 'Facies with Ceriantharia' (ME6.51A) can be found.

Being present on seamounts and hardgrounds, habitats such as 'Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges' (ME2.52) and 'Upper bathyal rock invertebrate-dominated' (ME1.51) can be found in proximity to this facies.

Related reference habitats

The facies dominated by *Spiculosiphon oceana* is present also on 'Offshore circalittoral detritic bottoms' (MD3.51) and 'Upper bathyal detritic sand' (ME5.51).

Possible confusion

In the ROV footage, sand-agglutinating giant foraminifera may be mistaken for patches of tube polychaetes as *Spiochaetopterus* sp. (to which are sometimes intermixed).

Typical species and associated communities

The ROV footages alone do not allow for a certain identification of giant bathyal foraminiferans, while *Spiculosiphon oceana* has a distinctive morphology and so far is unique in the Mediterranean fauna. Currently the genus that are considered typical of the facies are *Pelosina* and *Notodendrodes* (in deeper waters) and *Spiculosiphon* (in shallower waters). Patches of *Pelosina* are frequented by *Helicolenus dactylopterus* and can be found together with *Dicopia antirrhinum*, *Gryphus vitreus* and ceriantharians. Within the patches of *Spiculosiphon oceana* were detected also scyphozoan polyps, encrusting sponges, and hydroids.

Conservation interest and ecological role

Overall not known. *Spiculosiphon oceana* has an affinity to intermediate stress conditions and studies highlighted its importance as a bio-indicator of recent ocean acidification processes related to hydrothermal activity.

Economic importance

The economic value of this habitat has not been assessed yet.

Giant foraminifera on Janua Seamount (© M. Bo)

Spiculosiphon oceana in the Panarea Hydrothermal complex (© V. Esposito)

Vulnerability and potential threats

Offshore circalittoral and bathyal soft bottoms are widely exploited trawling grounds. The occurrence of this facies on topographic discontinuities such as seamounts and hydrothermal vent fields contribute in reducing the degree of mechanical impacts inflicted by trawling.

Protection and management

No forms of protection targeting this facies are in place. It may indirectly benefit also from the institution of offshore protected areas dedicated to the conservation of Vulnerable Marine Ecosystems (VMEs) dominated by large habitat-forming species (e.g. the gorgonian *Isidella elongata*, a critically endangered species (IUCN), currently listed in Appendix II of the SPA/BD) as well as areas of geological importance.

Suitability of the habitat for monitoring

General indications are given in the RAC/SPA Dark Habitats Guidelines.

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Lower bathyal rock

Reference codes for identification:

- **BARCELONA CONVENTION: MF1.51**
- **EUNIS 2019: MF15, MF151**
- **EUNIS 2007: A6.1**

LOCATION OF THE HABITAT

Zone	Lower bathyal
Nature of the substratum	Hard (rock)
Depth range	500 m to 3000 m
Position	Open sea (continental slope, topographic reliefs)
Hydrodynamic conditions	Moderate to strong
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-14°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Betti

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M. Bo

LOWER BATHYAL

MF1.5 Lower bathyal rock

MF1.51 Lower bathyal rock

Description of the habitat

Hardgrounds of the lower bathyal realm share the same general traits of upper bathyal invertebrate-dominated rock; differently from this latter, however, they progressively decrease in occurrence and extent with depth. They are mainly represented by ridges, banks, highs, seamounts, and flanks of the canyons (or their deepest portion). They can appear as large isolated boulders, vertical cliffs or terraces. Rocks are usually silted, except for areas with high hydrodynamism and can be patchily covered by patchy secondary substrates, as dead coral or bivalve frameworks, remains of paleo-biocoenoses. When exposed, deep hardgrounds show a black coating of Fe-Mn oxides. Topographic and hydrodynamic factors control the distribution and structure of the benthic assemblages in this habitat.

The upper horizon of this zone can be considered a transitional area between the upper bathyal hardgrounds and the lower horizon, stretching below 1900 m. With respect to the upper bathyal invertebrate-dominated rock, this habitat is generally characterized by a progressive reduction in diversity and biomass of the benthic and demersal megafauna, with a partial shift to more bathyphilic species. Nevertheless, some habitat-forming species (mainly alcyonaceans and scleractinians) are able to colonize this habitat and create aggregations that, living or dead, increase the tridimensionality of the substrate and host a diverse associated and visiting fauna. The general environment is characterised by a constant homeothermy of around 13-14°C and total absence of light. The habitat is interested by the flow of the Levantine intermediate Water (LIW) and the Mediterranean Deep Water (MDW).

Geographic distribution

This habitat is widespread in the entire Mediterranean Sea, both along the continental slopes (fractured by more than 800 steep canyons) and on topographic elevations scattered inside the basin, such as ridges, highs, banks and seamounts (these latter counting more than 250 structures). In terms of overall extent, ‘Lower bathyal rock’ is second to ‘Sandy mud’ (MF6.51).

Associated habitats

This habitat is usually delimited at shallower depths by ‘Upper bathyal rock’ (ME1.5), soft bottoms (ME3.51, ME4.51, ME5.51, ME6.51) or, more occasionally, by ‘Upper bathyal biogenic habitat’ (ME2.5).

These hardgrounds can be parts of structures rising from abyssal depths, therefore bordering with the “Abyssal rock’ (MG1.51) habitat. More often, they rise from ‘Sandy mud’ (MF6.51) at lower bathyal depths. The latter habitat can be found also in depressions or over plains on the rocky reliefs and may delimit their extension in the abyssal range. Lower bathyal rock can be characterized by two important facies of habitat-forming species: ‘Facies with Alcyonacea’ (MF1.512), mainly represented by deep gorgonians, and ‘Facies with Scleractinia’ (MF1.513). The peculiar ‘Facies with chemosynthetic benthic species’ (MF1.514) can be present in concomitance with geochemical seepages from the crust. The ‘Facies with small sponges’ (MF1.511) can also be found.

Related reference habitats

The presence of both living and dead CWC frameworks on the rocky substrate can originate ‘Lower bathyal reefs’ (MF2.51) and lower bathyal thanatocoenoses (MF2.52). This habitat has affinities with the ‘Upper bathyal rock invertebrate-dominated’ (ME1.51) and with the “Abyssal rock’ (MG1.51).

Possible confusion

Confusion with other habitats in the same bathymetrical range is unlikely. Nevertheless, the difference between ‘Facies with Scleractinia’ (MF1.513), that can be present in this habitat, and both ‘Lower bathyal reefs’ (MF2.51) and ‘Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges’ (MF2.52), present in the habitat ‘Lower bathyal biogenic habitat’ (MF2.5) can be blurred, and depends on the extension, structure and status of the living and dead frameworks. Within the zone, at least two horizons are recognized, an upper (or ‘middle bathyal’, 500-1900 m, mainly along the continental slope) and a lower one (1900-3000 m, mainly on the bathyal plain), but boundaries may vary depending on the considered taxon and region.

Typical species and associated communities

Diversity and biomass of macro and megabenthic species living on and around hardgrounds are lower than what observed on upper bathyal rock and the trend with depth is a decreasing one. Species tend to be more scattered, except for highly turbulent areas (e.g., seamount summits, canyons) where currents enhance carbon fluxes, zooplankton concentrations, diversity and biomass of benthic and pelagic fauna. Many habitat-forming species typical of the upper bathyal rock can extend their distribution range down to 700-800 m, in the upper horizon of the lower bathyal environment.

Even though lower bathyal rocks are usually quite bare, they hosts some of the largest Mediterranean frameworks of scleractinians, *Desmophyllum dianthus*, *Lophelia pertusa* (= *Desmophyllum pertusum*, and *Madrepora oculata*, all in Annex II SPA/BD, IUCN Red List EN). Other anthozoans, such as the black corals *Leiopathes glaberrima* (Annex II & III SPA/BD, Annex III Bern, IUCN Red List EN), and *Parantipathes* sp., and the gorgonians *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Acanthogorgia hirsuta*, and *Placogorgia* spp. are usually present and can form facies. With respect to upper bathyal rock, this habitat shows a decrease of conspicuous sponges (the most typical species being *Tretodictyum reiswigi*, *Farrea bowerbanki*, *Pachastrella monilifera*, *Poecillastra compressa*), and a predominance of encrusting species (e.g., *Hamacantha* (*Vomerula*) *falcula*). The bivalves *Neopycnodonte zibrowii*, *Spondylus gussonii* and *Acesta excavata* can create dense aggregations. Other benthic sessile organisms, such as hydrozoans, scyphozoan polyps, the anemone *Kadophellia bathyalis,* zoanthids, stoloniferans, the scleractinians *Javania cailleti* and *Caryophyllia (Caryophyllia) calveri*, serpulid worms (e.g., *Vermiliopsis monodiscus*), *Bonellia viridis*, various gastropods, bryozoans, cirriped Verrucomorpha, and brachiopods are usually present. Many bathyal vagile invertebrates, such as molluscs and echinoderms (e.g., *Peltaster placenta*, *Cidaris cidaris*, *Gracilechinus acutus*) can be observed on lower bathyal rocks. Crustaceans are common and are dominated by squat lobsters (e.g., *Munida tenuimana*, *Munidopsis* sp.). The crabs *Paromola cuvieri* and *Bathynectes maravigna* are frequent in the upper horizon, while *Anamathia rissoana* is often associated with gorgonians and black corals. Typical fishes are *Etmopterus spinax*, *Helicolenus dactylopterus*, *Lophius* spp., *Cataetyx laticeps*, *Phycis blennoides*, *Notacanthus bonaparte*, *Facciolella oxyrhyncha*, *Nettastoma melanurum*, *Lepidion lepidion*, and various macrourids. Several bentho-nektonic and pelagic fishes tends to aggregate over seamounts or in canyons for spawning or feeding.

Conservation interest and ecological role

Data on lower bathyal rocks are still scarce at a basin-scale, with the majority of the information coming from the Alboran Sea, NW Mediterranean Sea, Malta Escarpment, and S Adriatic Sea. This means that while deep hardgrounds do withhold a high diversity including many rare species, potentially a large number of taxa are still to be disclosed, especially within macrofauna. The study of lower bathyal species gives important biological, physiological, ecological information regarding the adaptations to extreme environmental conditions, as well as clues into the evolution of the deep-sea fauna. The aggregations of habitat-forming anthozoans (scleractinians, antipatharians, alcyonaceans) increase the tridimensionality of the rocky seafloor both when living and dead, and provide niches enhancing species richness and attracting vagile fauna. Their occurrence influences also the surrounding soft bottoms, in terms of diversity and biomass of epi and infauna. Finally, these complex ecosystems are known to enhance the pelagic-benthic coupling processes and the biogeochemical cycles occurring at these depths, hence they fully contribute to the functioning of the deep-sea.

Economic importance

The lower bathyal hardgrounds host species of benthic crustaceans (e.g., *Palinurus mauritanicus*) and fishes (e.g., *Pagellus spp.*, *Lophius* spp., *Lepidopus caudatus*) of commercial interest, especially along the steep flanks of bathyal canyons and seamounts. Overall, fishing effort on these seafloors is greatly reduced with respect to upper bathyal rocks, due to greater technical difficulties to operate at growing depths.

Vulnerability and potential threats

Lower bathyal hardgrounds are only partially interested by artisanal and recreational fishing activities, mainly concentrated in the upper horizon, down to 800 m. The physical destruction or selective removal of habitat-forming species leads to an homogenization of the seafloor, shifts in species composition towards fast-growing species, and ultimately alters the ecosystem functioning of this habitat and its productivity. The recovery ability of the communities to mechanical disturbances is reduced by the long life cycles and slow growth rates of some of the habitat-forming species, defining resilience in the order of decades or more. Abandoned, lost or otherwise discarded fishing gears (ALDFG) and associated accessories (e.g., disposable moorings, ropes), together with urban or maritime litter, are commonly seen on seamounts and along canyon flanks.

Mining, drilling, and cables' positioning activities may represent sources of pressure for this habitat, both in terms of mechanical disturbance and alteration of the silting levels. Industrial pollution and litter dumping may be additional stress sources. Finally, increasing evidence is emerging towards the effects of global changes in the deep Mediterranean Sea (thermal stress, acidification, carbon fluxes).

Protection and management

Some measures have been identified to protect this habitat and the facies it hosts. Some species typically occurring on lower bathyal rocks are now included in lists of protection (IUCN, SPA/DB, Bern). All coral forests are identified as Vulnerable Marine Ecosystems (VMEs) in the FAO/GFCM International guidelines for the management of the deep sea fisheries in the high seas, representing Essential Fish Habitats (EFHs). The Mediterranean Action Plan of the Barcelona Convention included habitats dominated by habitat-forming species as part of the "Dark Habitats", which deserve protection. Mapping VMEs, such as the ones included in this habitat, is considered an essential step in the framework of environmental protection, as declared in the European Marine Strategy Framework Directive (2008/56/EC). Seamounts and canyons are considered priority biotopes under the European Commission Natura 2000 network. The implementation of protection measures through the creation of offshore Marine Protected Areas (MPAs) and Fisheries Restricted Areas (FRAs) are still poorly pursued mainly due to socio-economic constraints, lack of data and difficulties in controlling territories in international waters. At present, a trawling ban exists below 1000 m depth in the whole Mediterranean basin (1734091 km^2, REC. GFCM/29/2005/1). The same restriction is applied to the Eratosthenes Seamount (summit at 780 m) (14792 km^2, REC. GFCM/30/2006/3) and to part of the Gulf of Lion canyon system (4000 km^2, REC. GFCM/33/2009/1).

Suitability of the habitat for monitoring

Within the Marine Strategy Framework Directive (2008/56/EC) numerous ecological and biological parameters are employed to evaluate the environmental status of the benthic assemblages and describe the impact of anthropic activities in this habitat. A major effort is currently in place to create distribution maps of VMEs and develop multi-parametric ecological indexes. Shared deep-sea essential ecological variables (DEEVs) have been defined to reach effective, long-term ecosystem-based management and monitoring strategies. General indications are given in the RAC/SPA guidelines for inventorying and monitoring of dark habitats in the Mediterranean Sea. A wide array of technologies are now available to monitor deep-sea ecosystems going beyond traditional, time-consuming and expensive surveys, but their employment in Mediterranean lower bathyal and abyssal habitats is still scarce. Beside monitoring, an explorative effort is still necessary as only few rocky lower bathyal areas have been widely studied (e.g. French canyons, down to 2500 m).

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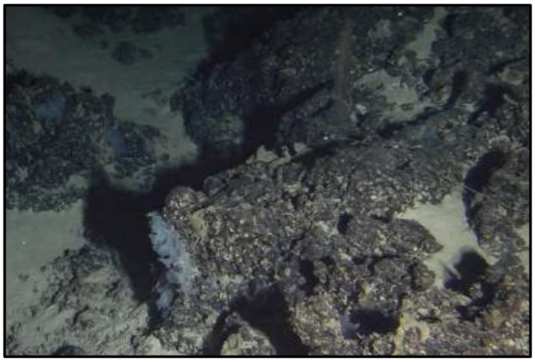
The crab *Paromola cuvieri* carrying a sponge on Janua seamount (© M. Bo)



The hexactinellid *Farrea bowerbanki* on Janua seamount (© M. Bo)

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Facies with Alcyonacea

Reference codes for identification:

- **BARCELONA CONVENTION: MF1.512**

LOCATION OF THE HABITAT

Zone	Lower bathyal
Nature of the substratum	Hard (rock)
Depth range	500 m to 2180 m
Position	Open sea (continental slope, topographic reliefs)
Hydrodynamic conditions	Moderate to strong
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C
Suitability for monitoring	Yes

Authors:
M. Bo, F. Betti

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LOWER BATHYAL

MF1.5 Lower bathyal rock
MF1.51 Lower bathyal rock
MF1.512 Facies with Alcyonacea

Description of the habitat

Aggregations of erect alcyonaceans (also known as forests) can be locally observed on lower bathyal horizontal or sub-horizontal hardgrounds subjected to moderate-strong currents that favour the occurrence of filter-feeders. They are found along the continental slope and on the summit or flanks of offshore reliefs.

Alcyonaceans forests in this depth range often form less developed canopies in terms of height and tridimensionality than those observed in the upper bathyal. The largest habitat-forming canopies are formed by fan-like gorgonians such as *Callogorgia verticillata* (more than 1 m high) or, more frequently, *Acanthogorgia hirsuta* and *Placogorgia* spp. (up to 60 cm high). Smaller species account for gorgonians such as *Dendrobrachia bonsai*, *Muriceides lepida*, *Nicella granifera*, *Bebryce mollis*, *Swiftia pallida*, *Chelidonisis aurantiaca*, and *Villogorgia bebrycoides*. Aggregations can be plurispecific and may host also black corals, scleractinians and massive sponges. Nevertheless, all species can also form monospecific patches. Some species (e.g. *Bebryce mollis*, *Swiftia pallida*, *Muriceides lepida*, *Acanthogorgia hirsuta*, *Placogorgia coronata*) can withstand high levels of sedimentation and extend their distribution on dead frameworks, coral rubble, small pebbles and even coarse detritic bottoms in proximity to hardgrounds and coral bioconstructions.

Geographic distribution

Alcyonacean forests are commonly found on lower bathyal hardgrounds from the Alboran region to the Aegean Sea. The majority of the records are localized in the western and central basins. Almost all species are found also in Atlantic waters.

Most of the aggregations are formed by species found also in the upper bathyal realm or offshore circalittoral (e.g., *Callogorgia verticillata*, *Bebryce mollis*, *Swiftia pallida*, *Villogorgia bebrycoides*, *Dendrobrachia bonsai*, *Nicella granifera*) and that can extend their occurrence in the shallower horizon of the lower bathyal, mainly down to 800 m. Few species (*Acanthogorgia hirsuta*, *Placogorgia* spp., *Muriceides lepida*, *Callogorgia verticillata*) can occasionally form aggregations down to 1000 m depth, with *Acanthogorgia hirsuta* and *Placogorgia* spp. known to form isolated patches down to 1800-2200 m depth.

Few species show a consistent preference for lower bathyal hardgrounds (e.g., *Placogorgia* spp., *Chelidonisis aurantiaca*).

Deep facies of *Callogorgia verticillata* are known between 650 m and 1000 m, particularly in the Alboran Sea and in the Sicily Channel (Malta). Similarly, aggregations of *Muriceides lepida* are reported between 700 m and 1100 m in the Blanes Canyon, Ibiza Channel and Sicily Channel (Malta). In the lower bathyal range, *Acanthogorgia* spp. (mainly *Acanthogorgia hirsuta*) show the widest distribution of all hardbottom alcyonaceans: the deepest record comes from the Canyon of Stoechade (France), however other populations (between 500 m and 1100 m) are known from the Gibraltar Strait, Alboran Sea (*Acanthogorgia hirsuta* and *Acanthogorgia armata* together), Blanes Canyon, Santa Maria di Leuca, and Sicily Channel (Malta). Few records of *Bebryce mollis* and *Swiftia pallida* are known between 500 m and 850 m from the Aeolian Archipelago and Santa Maria di Leuca. The latter species is reported also between 500 m and 600 m from Lebanon. Deep facies of *Muriceides lepida* (500-1100 m) are known from the Gibraltar Strait, Ibiza Channel, Blanes Canyon, northern Sicily, and Sicily Channel (Malta), while the deepest population of *Nicella granifera* (500-750 m) is reported from the Emile Baudot Seamount in the Balearic Sea. *Dendrobrachia bonsai*, known down to 690 m, can be the predominant species in areas of escarpments and canyons with a steep inclination in the Malta area.

Chelidonisis aurantiaca is a very rare species so far reported only from the summit of the Janua Seamount (Ligurian Sea) at 820-910 m. Facies of *Placogorgia* spp. are reported from 350 m to 1850 m (mainly between 800 m and 900 m), from Gibraltar to the Ligurian Sea, through the Sicily Channel to Santa Maria di Leuca.

Associated habitats

This facies can be found on ‘Lower bathyal rock’ (MF1.51) together with other facies of habitat-forming species, such as ‘Facies with small sponges’ (MF1.511) and ‘Facies with Scleractinia’ (MF1.513). In presence of hydrothermal seepage, ‘Facies with chemosynthetic benthic species’ (MF1.514) can be present as well. This facies can be intermixed or adjacent to ‘Lower bathyal biogenic habitat’ (MF2.5), in particular it can be found on coral thanatocoenoses and among white corals. The alcyonacean-dominated facies can be surrounded by ‘Lower bathyal mud’ (MF6.5) and the facies it contains.

Related reference habitats

Most of the species constituting this facies can also be found on rocks (ME1.514) and coarse sediments (ME3.511) in the upper bathyal realm. Few species typical of this facies, such as *Acanthogorgia hirsuta*, are known to reach great depths, and is therefore possible that their recorded bathymetrical distribution may extend in the abyssal realm (MG1.512), but no records are available, so far, on rocky environments below 3000 m in the Mediterranean Sea.

Possible confusion

On lower bathyal rock, confusion with other facies is unlikely. There may be taxonomic issues with the identification of some species from ROV images, including *Acanthogorgia hirsuta* and *Acanthogorgia armata*, *Villogorgia bebrycoides* and *Muriceides lepida*, *Placogorgia coronata* and *Placogorgia massiliensis*.

Dendrobrachia bonsai on a silted hardground (© OCEANA)

A forest of *Acanthogorgia hirsuta* (© OCEANA)

Typical species and associated communities

Lower bathyal hardgrounds are still poorly studied, and the level of knowledge tends to diminish with depth. The upper portion of the shallower horizon (down to 800 m) hosts the maximum megabenthic diversity of this depth range, and many gorgonians and soft corals typical of the upper bathyal realm can contribute to this facies: *Callogorgia verticillata* (Annex II SPA/BD, IUCN Red List NT), *Villogorgia bebrycoides*, *Swiftia pallida*, *Bebryce mollis*, *Muriceides lepida* are among the most common species. The red coral *Corallium rubrum* (Annex III SPA/BD, IUCN Red List EN), reaching its maximum abundance in the circalittoral realm, can be exceptionally found down to 1016 m in the Sicily Channel (Malta).

The lower bathyal facies dominated by alcyonaceans is intermixed with other sessile species, such as sponges (e.g., *Farrea bowerbanki*, *Characella pachastrelloides, Tretodictyum reiswigi*), hydrozoans, zoanthids, stoloniferans, scleractinians (e.g. *Lophelia pertusa* (= *Desmophyllum pertusum*), *Madrepora oculata*, *Desmophyllum dianthus*, all in Annex II SPA/BD, IUCN Red List EN), black corals (*Antipathes dichotoma*, *Parantipathes* spp., *Leiopathes glaberrima,* in Annex II SPA/BD, Annex III Bern, IUCN Red List NT, NT and EN, respectively), bivalves (e.g., *Spondylus gussonii*), brachiopods, and bryozoans (e.g., *Spondylus gussonii*). Colonies are often epibionted with hydrozoans, zoanthids (e.g., *Zibrowius primnoidus*), and anemones (e.g., *Amphianthus dohrnii*) and may host high numbers of ophiuroids. The crab *Anamathia rissoana* is often found crawling on gorgonians and black corals. A rich vagile fauna is often present in this facies: molluscs, echinoderms (e.g., *Peltaster placenta*, *Cidaris cidaris* in the shallower depth range) and crustaceans (mainly *Plesionika* shrimps, the squat lobster *Munida tenuimana* and the crabs *Paromola cuvieri* and *Bathynectes maravigna*) are common. Typical fishes are *Helicolenus dactylopterus*, *Lophius* spp., *Hoplostethus mediterraneus*, *Phycis blennoides*, *Notacanthus bonaparte*, *Facciolella oxyrhyncha*, *Pagellus* spp., *Lepidopus caudatus*, and *Lepidion lepidion.* The six-gills shark *Hexanchus griseus* may frequent these areas.

Conservation interest and ecological role

Data on lower bathyal alcyonaceans forests are still scarce, nevertheless alcyonacean forests greatly increase the tridimensionality of the substrate, providing numerous microhabitats that sustain a rich (both in terms of diversity and biomass) associated fauna and therefore representing biodiversity hotspots in the poorly-populated lower bathyal realm. In addition, the communities living in this habitat include rare species and many organisms that are still poorly studied, hence representing important sources of undisclosed biological and ecological information.

Forests are important links in the benthic-pelagic coupling and boost biogeochemical processes, hence contributing to the functioning of the deep-sea and its recovery. They also influence the surrounding soft bottoms, as poles of attraction, in terms of diversity and biomass of epi and infauna, and increase the environmental stability, offering an opportunity to coevolutionary processes and favouring the survivorship of fragile species. This habitat hosts slow-growing, longevous species, which have a paramount role from the conservation point of view and withhold important paleo-environmental information.

A patch of Chelidonisis aurantiaca on Janua Seamount (© M. Bo)

An aggregation of *Villogorgia bebrycoides*, soft corals and *Plesionika gigliolii* (© M. Bo)

Economic importance

Lower bathyal alcyonacean forests are more scattered and less populated than the ones found at shallower depths; this, together with greater technical difficulties for fishing boats to operate at growing depths, strongly reduces fishing effort on these seafloors with respect to upper bathyal forests. Nevertheless, some species of crustaceans (e.g., *Palinurus mauritanicus*) and fishes (e.g., *Pagellus spp.*, *Lophius* spp., *Lepidopus caudatus*) of commercial interest live in this habitat, mainly concentrated in the shallow horizon. In addition, other valuable species regularly frequent gorgonian forests for spawning or as nursery site, attracted by the protection offered by the coral canopies and the food availability.

Vulnerability and potential threats

The scattered distribution of hardgrounds and hence alcyonacean forests in the lower bathyal realm reduces the probability of mechanical injuries on this facies with respect to upper bathyal ones. Nevertheless, since maximum levels of diversity and abundances are concentrated in the upper horizon of this realm, this facies is still potentially vulnerable to fishing activities. The threats include entanglements, damages and eradication of the habitat-structuring species, and a consequent homogenization and simplification of the benthic habitat, the reduction of the biodiversity, and the alteration of ecosystem functioning. Large colonies are the most easily impacted by longlines, but small species can be eradicated as well. The recovery ability of the communities to mechanical disturbances is reduced by the long life cycles and slow growth rates of some species, defining resilience in the order of decades or more. Abandoned, lost or otherwise discarded fishing gear (ALDFG) are commonly observed on seamounts and along canyon flanks, mainly in concomitance with outcropping rocks often hosting alcyonacean forests and other biogenic habitat. Due to the extremely slow degradation of nylon, lost gears may persist for a long time accumulating on the seafloor and covering wide areas impeding the re-colonization for large anthozoans. Finally, trawling activities carried out nearby hardgrounds (at maximum 1000 m depth) as well as other anthropic activities related to coastal modifications or deep disturbances (e.g., mining) can increase the silting rate ultimately increasing the risk of clogging the polyps of filter-feeding habitat-forming alcyonaceans and reducing the extension and density of the forests. Climate changes may pose a threat as well, despite still few evidences are available for this facies.

Protection and management

Few alcyonacean species occurring at lower bathyal depths, *Callogorgia verticillata* and (exceptionally) *Corallium rubrum*, are considered at different risk of extinction by IUCN, and are included in lists of protection. All coral forests are identified as Vulnerable Marine Ecosystems (VMEs) in the FAO/GFCM International guidelines for the management of the deep sea fisheries in the high seas, representing Essential Fish Habitats (EFHs). They meet al criteria for VMEs: fragility, resilience, uniqueness, importance, diversity, complexity, and services of the ecosystems. The Mediterranean Action Plan of the Barcelona Convention included habitats dominated by structuring species as part of the so called “Dark Habitats”, which deserve protection. Mapping VMEs is considered an essential step in the framework of environmental protection, as declared in the European Marine Strategy Framework Directive (2008/56/EC). The implementation of protection measures through the creation of offshore Marine Protected Areas (MPAs), Sites of Community Importance (SIC), and Fisheries Restricted Areas (FRAs) are still poorly pursued mainly due to socio-economic constraints, lack of data and difficulties in controlling territories in international waters. At present, a trawling ban exists below 1000 m depth in the whole Mediterranean basin (1734091 km^2, REC. GFCM/29/2005/1). The same restriction is applied to the Eratosthenes Seamount FRA (summit at 780 m) (14792 km^2, REC. GFCM/30/2006/3) and to the FRA localized within the Gulf of Lion canyon system (4000 km^2, REC. GFCM/33/2009/1) embracing also lower bathyal environments.

Suitability of the habitat for monitoring

Within the Marine Strategy Framework Directive (2008/56/EC) numerous ecological and biological parameters are employed to evaluate the environmental status of the hard-bottom benthic assemblages and describe the impact of anthropic activities in this habitat.

Biodiversity (D1), integrity of the seafloor (D6), and sea floor litter (D10) are considered important descriptors of habitat quality and a major effort is currently in place to create distribution maps of VMEs and benthic habitat models (specifically those dominated by habitat-forming alcyonaceans), characterize the type and impact of seafloor litter, and define the fishing effort, providing useful management information. Recent studies, carried out by means of seafloor imagery, highlighted the presence of ALDFG and other litter on bathyal rocky seafloor, together with elevated rates of entanglement/eradication/breakage/size reduction of structuring species due to fishing activity; this information represents a useful baseline for the monitoring of the effects of direct anthropic impacts on this habitat. Alcyonacean forests are considered a good proxy to monitor the effects of fishing activities, because of their slow growth rate, their sessile erect habitus and their wide distribution. The use of tridimensional photogrammetry may help to characterize deep forests and monitor them in time. Finally, besides monitoring activities, explorative campaigns are still required to better evaluate extension and composition of lower bathyal alcyonacean forests, especially below 1000 m, considering that they are greatly under-studied.

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To be added

Facies with chemosynthetic benthic species

Reference codes for identification:

- **BARCELONA CONVENTION: MF1.514**

LOCATION OF THE HABITAT

Zone	Offshore circalittoral to lower bathyal
Nature of the substratum	Hard (rock), soft (mud)
Depth range	200 m to 2800 m
Position	Open sea (continental shelf, slope, bathyal plain, and seamounts)
Hydrodynamic conditions	Weak
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-15°C; higher values close to thermal seepage
Suitability for monitoring	Yes

Authors:
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LOWER BATHYAL

MF1.5 Lower bathyal rock

MF1.51 Lower bathyal rock

MF1.514 Facies with chemosynthetic benthic species

Description of the habitat

Chemosynthesis-based communities are constituted by dense aggregations of benthic organisms specialized in living in proximity to cold seeps, mud volcanoes, hydrothermal vents but also fall carcasses, sunken wood, and reducing bottoms. Cold seeps are marine seafloor ecosystems that develop around seepages of methane, hydrogen sulphide and other hydrocarbons at ambient or slightly higher temperatures. These seepages can sometimes remain stagnant in brines. Mud volcanoes are cold seeps occurring on soft bottoms, characterized by a concurring eruption of water, mud or slurries. Hydrothermal vents, resulting from volcanic activities, are constituted by seepage or venting of geothermally heated (60°C - 460°C) waters, rich in metals and minerals, most notably sulphides; they can be found on hardgrounds, and the mineral deposits produced by their emissions can concur in creating new hard substrates. The collapse of non-cohesive seafloors following geothermic emissions can produce pockmarks, that increase the heterogeneity of the seafloor and consequently diversity and abundance of benthic species. Chemosynthetic Archaea and Bacteria, the latter both free-living and endosymbionts of metazoans, are dominant in these environments. The facies is mainly constituted by bacterial mats (e.g., *Beggiatoa*), and aggregations of specialized bivalves and siboglinid worms.

Geographic distribution

This facies is present in correspondence to deep-sea (mainly at lower bathyal depths) cold seeps, mud volcanoes and hydrothermal vents in the whole Mediterranean Sea, being more frequent in the eastern basin. A recent study identified 18 main bathyal cold seeps-associated sites and they are found in: the Alboran Sea (Alboran mud volcanoes), the central Adriatic Sea (Pomo/Jabuka), along the southern coasts of Sicily (Gela basin pockmark field), in the Marmara Sea, in front of Egypt (river Nile fan), and in different localities of the eastern basin, namely Anaximander and Olimpi mud volcanoes, Eratosthenes Seamount, and the Israel continental margin. The main hydrothermal vents facies are located on the Marsili and Palinuro seamounts (southern Tyrrhenian Sea), and on the Kolumbo and Santorini craters (Aegean Sea).

Mediterranean pockmarks have been reported from the Catalan margin, Aegean, Levantine and Ionian seas. Bacterial chemoautotrophy is also reported on the brine-seawater interface of Mediterranean deep hypersaline anoxic basins (DHABs) (see sheet MG6.51 'Abyssal mud'), but no specific facies were observed. Siboglinid worms of the genus *Lamellibrachia* were observed also on two shipwrecks: one found at 490 m in the southern Tyrrhenian Sea and one at 2800 m South-East of Crete. Here, symbiotic chemosynthetic bacteria may rely on the degradation of the organic substrates of the ships and their loads.

Associated habitats

Facies with chemosynthesis-based species are mainly found on 'Lower bathyal rock' (MF1.51) and 'Lower bathyal mud' (MF6.5), nevertheless, they may be found also at upper bathyal depths. The presence of cold seeps, mud volcanoes or hydrothermal vents is the main condition for the presence of this facies. Shallower water chemosynthetic communities (<200 m) in the Mediterranean basin associated with hydrothermal and cold seep situations share some traits with their deep water counterparts.

Related reference habitats

None.

Possible confusion

No confusion can be made with this habitat. Chemosynthetic microbial consortia can be found also on the brine-seawater interface of DHABs, but they do not constitute nor sustain a specific facies.

Typical species and associated communities

This facies is constituted by mats of chemosynthetic bacteria, such as *Beggiatoa*, that form the core of the trophic structure on the facies. A diverse megafauna lives off the chemosynthetic bacteria either eating them directly or harbouring them in their bodies (endosymbiotic or episymbiotic relationships) hence benefiting of the organic compounds the bacteria produce. The main representative of the typical megafauna are siboglinid worms of the genera *Siboglinum* and *Lamellibrachia* (exceeding 1 m of tube length and often creating large aggregations of several hundreds specimens), and Bivalvia belonging to the families Lucinidae (e.g., *Myrtea amorpha*, *Lucinoma kazani*), Vesicomyidae (e.g., *Isorropodon perplexum*), Mytilidae (e.g., *Idas modiolaeformis*), Thyasiridae (e.g., *Thyasira striata*), and Solemyidae. Sponges (e.g., *Rhizaxinella pyrifera*), cnidarians, other annelids, and crustaceans (in particular the ghost shrimps of the genus *Calliax*, and the crab *Chaceon mediterraneus*) can live in close proximity of the seepages. After the cessation of the emissions, exumed metanogetic carbonates may provide hard substrates suitable to larvae settlement of Cold-Water Corals (CWCs) and other hard bottoms sessile organisms. Finally, this facies results unique also at lower size-scale, since the meiofaunal community (nematodes) appears different from non-chemosynthetic areas.

Conservation interest and ecological role

The present facies is constituted by a unique community of highly specialized species able to live in an extreme environment. Most of the megafaunal species typical of this facies are exclusively found in these environments. Also meiofauna results particularly abundant and characterized by a different composition in proximity of mud volcanoes. In general, the abundance and richness of the fauna associated with these ecosystems are higher than in surrounding deep-sea areas. Therefore, their conservation is of extreme importance.

Economic importance

This facies is found in areas characterized by chemosynthetic activities, which can hold an economical interest for hydrocarbon extraction and ore mining. Moreover, thermophile and hyperthermophile bacteria show a great potential for biotechnological applications; some bacteria from hydrothermal deep-sea vents are able to biosynthesize innovative exopolysaccharides that might find biochemical applications in the near future.

Vulnerability and potential threats

Chemosynthetic habitats are exposed to various anthropogenic stressors, such as hydrocarbon extraction, ore mining, and trawling. Fishing activities might impact these habitats also through abandoned fishing gears, as recorded in the pockmark area in the Gela basin. These systems might show an important variability in terms of pH and oxygen concentration, so that their associated fauna is likely to tolerate shifts in these variables related to global change.

Protection and management

The evaluation of potential anthropogenic threats to these habitats resulted in recommendations for the establishment of Marine Protected Areas. At present, candidates are deep-sea mud volcanoes such as the Olympic and Anaximander fields, and the Pomo/Jakuba Pit (General Fisheries Commission for the Mediterranean (GFCM) recommendation: 41/2017/3) in the western basin. The Nile Delta cold hydrocarbon seeps have been recently enclosed in a Fisheries Restricted Area (FRA) established by GFCM (REC. GFCM/30/2006/3): a permanent prohibition to use towed dredges and bottom trawl nets is in place since 2006 over an area of 6042.6 km^2. Similar restrictions are in place over the Eratosthenes Seamount for a total area of 14791.6 km^2 (REC. GFCM/30/2006/3). Following the GFCM recommendation, the EU prohibited the use of towed dredges and trawlers at depths beyond 1000 m by creating a deep-water FRA (REC. GFCM/29/2005/1), which protects par of the deeper sites. The Mediterranean Action Plan of the Barcelona Convention included habitats with chemosynthetic phenomena as part of the so called “Dark Habitats” which deserve protection.

Suitability of the habitat for monitoring

No specific guidelines are available for monitoring this facies, which is still poorly known. Nevertheless, general indications are given in the RAC/SPA Guidelines for inventorying and monitoring of dark habitats in the Mediterranean Sea. Sampling activities include acoustic technologies (e.g., multibeam and side-scan sonar) to identify the habitats and CTDs probes to obtain information on the water features. Sediment and meiofaunal samplings, ROVs explorations and collection of megabenthic organisms also provide valuable information on the diversity and functioning of these ecosystems.

Sulphide deposits on the Marsili Seamount (© G. Gay)

Photo

Legend (© N. Surname)

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LOWER BATHYAL

MF6.5 Lower bathyal mud

MF6.51 Sandy mud

Description of the habitat

The lower bathyal depth range is characterized by vast areas of clayey muddy seafloors. Differently from the upper bathyal mud, the lower bathyal one results mostly firm and compact. The granulometry and thickness of the sediment is not homogeneous, and, locally, areas with sandy mud or fluid mud can occur, even if they are more common in the upper bathyal. Pockmarks of geothermic origin increase the heterogeneity of the bottom and consequently diversity and abundance of benthic species. The general environment is characterised by a constant homeothermy of around 13-14°C and total absence of light. The habitat is interested by the flow of the Levantine intermediate Water (LIW) and the Mediterranean Deep Water (MDW).

Geographic distribution

Mud represents the main habitat of the lower bathyal depth range and shows a basin-scale extent. Seamounts, ridges and canyons partially interrupts this habitat, given the occurrence of deep rocky reliefs. Nevertheless, mud can also occur as large patches on deep hardgrounds.

Associated habitats

This habitat is usually delimited at shallower depths by ‘Upper bathyal mud’ (ME6.5). ‘Upper bathyal rock’ (ME1.5), ‘Upper bathyal biogenic habitat’ (ME2.5), ‘Upper bathyal coarse sediment’ (ME3.5), ‘Upper bathyal mixed sediment’ (ME4.5) and ‘Upper bathyal sand’ (ME5.5) might also be present. At greater depths, this habitat is delimited by ‘Abyssal mud’ (MG6.5). The lower bathyal sandy mud can be fragmented by the presence of ‘Lower bathyal rock’ (MF1.5) or ‘Lower bathyal biogenic habitat’ (MF2.5). Close to geothermic activities, ‘Facies with chemosynthetic benthic species’ (MF1.514) can also be occasionally observed. This habitat can host facies dominated by sessile cnidarians, such as ‘Facies with Alcyonacea’ (MF6.512) and ‘Facies with Pennatulacea’ (MF6.514). Both these facies are typical of the upper bathyal but can extend into the lower bathyal realm. Facies with small sponges’ (MF6.511), ‘Facies with Echinoidea’ (MF6.513), and ‘Facies with bioturbations’ (MF6.515) can also be found.

Sandy mud

Reference codes for identification:

- **BARCELONA CONVENTION: ME6.51**
- **EUNIS 2019: MF65, MF651**
- **EUNIS 2007: A6.5, A6.51**

LOCATION OF THE HABITAT

Zone	Lower bathyal
Nature of the substratum	Soft (mud, locally sandy)
Depth range	500 m to 3000 m
Position	Open sea (continental slope, canyons, bathyal plain, topographic reliefs)
Hydrodynamic conditions	Variable
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-14°C
Suitability for monitoring	Yes

Authors:
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Related reference habitats

This habitat, and its associated communities, can be related to ‘Offshore terrigenous sticky mud’ (MD6.51), ‘Upper bathyal mud’ (ME6.51), ‘and Abyssal mud’ (MG6.51).

Possible confusion

At lower bathyal depths, this habitat is the sole among non-cohesive ones, therefore the confusion with other habitats is unlikely. ‘Lower bathyal mud’ (MF6.5) is localized at deeper depths with respect to ‘Upper bathyal mud’ (ME6.5) and is generally described as more compact and less fluid. Within the zone, at least two horizons are recognized, an upper (or ‘middle bathyal’, 500-1900 m, mainly along the continental slope) and a lower one (1900-3000 m, mainly on the bathyal plain), but boundaries may vary depending on the considered taxon or region.

Typical species and associated communities

The trend in biodiversity and abundance decreases progressively with depth and partially from West to East, mainly following the trophic gradient of the basin. Overall, the lower bathyal range hosts a lower number of species with respect to the upper bathyal with differences occurring between canyons and deep-water coral areas (considered more diverse in terms of megafauna) with respect to open slopes. Spatial and temporal changes are observed in the communities characterizing this habitat and are mainly related to environmental and trophic gradients, and climatic oscillations.

Meiofauna (dominated by Nematoda) is a key component of the ecosystem, together with infaunal macro- and megabenthos. Epifauna tends to be sparser and poorer in terms of species than in the upper bathyal, and constituted mainly by mobile organisms, that tends to be more frequent nearby silted hardgrounds. This habitat can host forests of the gorgonian *Isidella elongata* (Annex II SPA/BD, IUCN Red List CR), as well as aggregations of sea pens (including the vulnerable *Funiculina quadrangularis* (IUCN Red List VU)). Giant foraminiferans, the anemone *Actinauge richardi*, different species of Ceriantharia, the brachiopod *Gryphus vitreus* and the ascidiacean *Dicopia antirrhinum* are frequently observed. Among sponges, *Hyalonema* (*Cyliconema*) *thomsonis* can be locally abundant and *Cladorhiza abyssicola* can be observed. Among infaunal macrofauna, polychaetes are the dominant group (e.g., *Nothria maremontana*, *Laubieriopsis brevis*); the ophiuroids *Amphiura filiformis* and *Amphilepis norvegica* are also common as well as bivalves (e.g., *Abra longicallus*). Decapod crustaceans are the dominant vagile epimegafaunal organisms, the most common species being the crabs *Geryon longipes* and *Paromola cuvieri*, the polychelid lobster *Polycheles typhlops*, the shrimps *Aristeus antennatus* (commoner in the western basin)*, Aristaeomorpha foliacea* (commoner in the eastern basin)*,* and *Pasiphaea* spp., and different species of Anomura. Predominance of *Acanthephyra eximia*, *Nematocarcinus exilis*, and *Stereomastis sculpta* is observed in the lower horizon. Other common mobile invertebrates are the cephalopod *Bathypolypus sponsalis*, the holothurians *Molpadia musculus*, *Pseudostichopus occultatus*, *Mesothuria intestinalis* and *Penilpidia ludwigi*, the sea urchins *Cidaris cidaris* and *Brissopsis lyrifera*, and the sea stars *Ceramaster grenadensis*, *Hymenodiscus coronata*, and *Odontaster mediterraneus*. Many benthic (e.g., *Galeus melastomus*, *Helicolenus dactylopterus* and *Lophius* spp.) and bentho-nektonic fishes (e.g., *Etmopterus spinax* (IUCN Red List NT), *Dalatias licha*, *Centroscymnus coelolepis*, *Lepidion lepidion*, *Mora moro*, *Nettastoma melanurum*, *Bathypterois dubius*, *Alepocephalus rostratus*, the grenadiers *Hymenocephalus italicus*, *Nezumia* spp., *Coelorinchus caelorinchus*, and *Coryphaenoides guentheri*) are also frequent.

Conservation interest and ecological role

Deep-sea ecosystem processes play a key role in global functioning of the planet. These functions are largely dependent upon deep-sea biodiversity. The communities living in this habitat include rare species and many organisms that are still poorly studied and whose role still need to be fully understood. The lower bathyal mud, extending throughout the Mediterranean basin, is a source of important ecosystem services (e.g., carbon storage), fundamental to guarantee the functioning of the deep-sea and climate in general. This habitat hosts aggregations of habitat-forming epifaunal species (e.g., *Isidella elongata* and sea pens), which may be used as refuge, feeding or nursery areas and contribute to increasing

The mobility and aggregation of species in this habitat. This habitat is also characterized by a large variety of scavengers and deposit-feeders, attracting numerous predators and participating at the bioturbation of sediments together with a rich infauna.

Economic importance

In the Mediterranean Sea trawling effort is at its highest in the offshore circalittoral and upper bathyal zones, however specific fishing grounds are known in the lower bathyal zone (upper horizon) down to 800 m depth targeting decapod crustaceans (red shrimps, *Aristeus antennatus* and *Aristaeomorpha foliacea*) and fishes (e.g., *Lophius* spp.) of high commercial values. Some canyon systems (e.g., Liguria, Gulf of Lion) and seamount areas, the Sicily Channel, the Balearic islands, and the Ionian Greek area are highly exploited trawling fishing grounds.

Vulnerability and potential threats

Trawling can have can have numerous impacts on the sea bottom, including stock impoverishment, alterations to the seafloor morphology, sediment resuspension, increased bottom-water turbidity, epibenthos mortality, decrease in organic matter content, altered nutrient cycles, and alteration of the benthic biodiversity. Trawled areas exhibit significant low densities of habitat-forming species and a striking impoverishment of habitat complexity and diversity. These species are characterized by slow growth rates and high longevity, therefore are poorly resilient and particularly vulnerable to anthropic impacts. Plastic debris funnelled by canyons or lost over shipping routes and abandoned, lost or otherwise discarded fishing gears (ALDFGs) are also common in these areas.

Dumping activities (e.g., harbour sediments, industrial mineral residues, litter) and mining or drilling activities may also directly impact deep-sea muddy ecosystems. Large accumulations of plastic litter are known from deep canyon areas. Increasing evidence is emerging towards the effects of global changes also in the deep Mediterranean Sea.

Protection and management

In 2005, the General Fisheries Commission for the Mediterranean (GFCM) established a permanent closure of the deep Mediterranean basin below 1000 m to benthic fishing gears (REC. GFCM/29/2005/1). The Fisheries Restricted Area (FRA) includes part of the lower bathyal habitat, and its objective is to protect deep-sea habitats and resources. A FRA was established in 2009 also over part of the Gulf of Lion canyon system including lower bathyal mud habitats (REC. GFCM/33/2009/1). The French FRA is part of a larger network of MPAs embracing the bathyal depths. Control is a major issue for offshore, vast FRAs; it can be achieved through the employment of fishing tracking systems (AIS, VMS). Other protection measures are known: some species occurring on lower bathyal mud are included in lists of protection (IUCN Red List, SPA/DB). All coral forests, including soft bottom gardens of *Isidella elongata* and pennatulaceans, are identified as Vulnerable Marine Ecosystems (VMEs) and Sensitive Habitats (SHs) in the FAO/GFCM's International guidelines for the management of the deep sea fisheries in the high seas. The Mediterranean Action Plan of the Barcelona Convention included habitats dominated by structuring species as part of the so called "Dark Habitats" which deserve protection.

The bathyal holothurian *Mesothuria intestinalis* on Emile Baudot Seamount (© OCEANA)

The carnivorous sea squirt *Dicopia antirrhinum* (© OCEANA)

Suitability of the habitat for monitoring

The outputs of large-scale, pluri-decennial scientific fishing campaigns (e.g. MEDITS, GRUND) are important to monitor species trends over time and space. This is particularly true for the upper horizon of the lower bathyal mud habitat, with only experimental trawling activities carried out below 1000 m (especially in the Catalan and Balearic seas). Within the Marine Strategy Framework Directive (2008/56/EC), a number of descriptors have been identified to assess the the quality of this habitat and a major effort is currently in place to evaluate the distribution and environmental status of VMEs based on species sensitivity. VMS and AIS vessel control systems are used to quantify the intensity of fishery-induced abrasion on the seabed. Multibeam echo-sounding and side-scan sonar techniques are employed to evaluate trawl damages and extent and status of coral biocoenoses. Guidelines for inventorying and monitoring dark habitats, including those thriving on muddy bottoms, have been identified by RAC/SPA. Deep-sea essential ecological variables (DEEVs) have been identified to develop effective, long-term ecosystem-based management and monitoring strategies. In this regard, new technologies, able to work autonomously and continuously, represent the next frontier in deep-sea exploration and monitoring.

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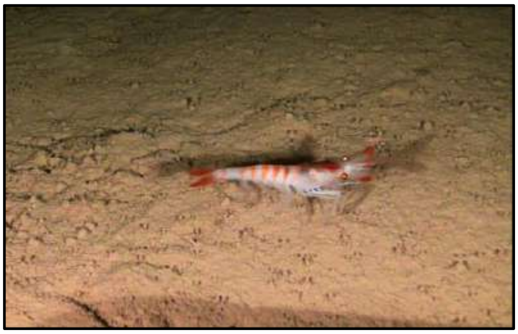
The bathyal fish *Nettastoma melanurum* (© OCEANA)



The commercial shrimp *Aristeus antennatus* (© OCEANA)


© M. Bo

Abyssal rock

Reference codes for identification:

- **BARCELONA CONVENTION: MG1.51**
- **EUNIS 2019: MG15**
- **EUNIS 2007: A6.1**

LOCATION OF THE HABITAT

Zone	Abyssal
Nature of the substratum	Hard (rock)
Depth range	3000 m to 5270 m
Position	Open sea (topographic reliefs)
Hydrodynamic conditions	Weak
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-14°C
Suitability for monitoring	Not known

Authors:
M. Bo, F. Betti

Photo credits:
M. Bo

ABYSSAL

MG1.5 Abyssal rock

MG1.51 Abyssal rock

Description of the habitat

The abyssal depth range is almost exclusively characterized by a homogeneous muddy seafloor, constituted by fine-grained, silt-clay terrigenous and biogenic sediments. Nevertheless, scattered hardgrounds constituted by abyssal seamounts and ridges, or the exposed basal portion of topographic elevations that reach the bathyal realm, are present. Because of the high rates of sedimentation of silt and marine snow, most of the abyssal rocks are heavily silted, thus exposed rocks are even scarcer.

The general environment is characterised by a constant homeothermy and a complete lack of ambient light. The habitat is interested by the flow of the Mediterranean Deep Water (MDW) and currents are generally weak. High pressure, darkness, low food availability and relative homogeneity of the seafloor lead to low species diversity and low abundance of individuals with depth.

Abyssal rocky substrates represent the least known habitat of the Mediterranean Sea, but it is possible to hypothesize that some benthic or demersal species found on the lower horizon of the lower bathyal rock can extend also at these depths.

Geographic distribution

In the Mediterranean Sea, hardgrounds below the bathymetry of 3000 m are scarce, and occur only in the Tyrrhenian and Ionian abyssal basins. Specifically, 13 seamounts in the Tyrrhenian Sea and 11 seamounts in the Ionian Sea rise deeper than 3000 m; 9 of these elevations are completely included in the abyssal domain. The bases of the two Victor Hensen Hills are the deepest hardgrounds known in the Mediterranean basin, rising from 4090 and 3960 m depth, respectively.

Associated habitats

Abyssal rocks are almost never considered in the biological literature. They are believed to be poorly colonized, nevertheless it is possible that some lower bathyal gorgonians can reach abyssal depths, thus creating ‘Facies with Alcyonacea’ (MG1.512). Other facies that are likely to develop on abyssal rocks are ‘Facies with small sponges’ (MG1.511), ‘Facies with Polychaeta’ (MG1.513), and ‘Facies with Crustacea (Amphipoda, Isopoda, Tanaidacea)’ (MG1.514).

Abyssal rocks are scattered in the much wider ‘Abyssal mud’ (MG6.51); mud can be often found on depressions or plains of the rocky edifices, that are usually heavily silted.

Related reference habitats

Most abyssal hardgrounds reach the lower bathyal realm, thus constituting ‘Lower bathyal rock’ (MF1.51).

Possible confusion

This habitat includes all the hardgrounds below the 3000 m isobath, therefore the confusion with other habitats is unlikely. Some authors use 2500 m as the upper bathymetric boundary of this habitat. The existence of a true abyssal realm, hence a true abyssal fauna, in the Mediterranean Sea has been questioned, mainly in relation to the deep homeothermy and the geographic separation represented by the Gibraltar Sill.

Typical species and associated communities

No information are available for Mediterranean abyssal rocks. Sampling efforts are mostly confined to muddy seafloor, due to easier dredging conditions. The Cold-Water Coral *Desmophyllum dianthus* and the alcyonacean *Acanthogorgia hirsuta* have been observed down to 2500 m and 2180 m, respectively, so they both can be potentially present also in the abyssal realm. Paleo-biocoenoses dominated by *Desmophyllum dianthus* were identified close to the abyssal limit along the Malta-Siracusa Escarpment. Sponges (e.g., the hexactinellid *Tretodictyum reiswigi*, reported at 2644 m) and serpulid polychaetes could also be part of the abyssal fauna. Benthic and bentho-nektonic fishes observed in the abyssal realm (the macrourid *Coryphaenoides mediterraneus,* the tripod fish *Bathypterois dubius*, and the brotula *Cataetyx laticeps*) may potentially frequent these hardgrounds or their close surroundings.

Conservation interest and ecological role

Based on the available information, currently it is not possible to speculate on ecological and conservation aspects. The occurrence of few abyssal endemisms or highly adapted species, that can potentially frequent this habitat, increases the intrinsic value of the species and the habitat itself. Bathyal and abyssal living and dead faunas provide valuable information to understand the geologic and biogeographic history of the basin.

Economic importance

No industrial exploitation of Mediterranean abyssal resources is in place.

Vulnerability and potential threats

The deep-sea biota is generally characterized by slow growth rates and late maturation; thus, species are particularly vulnerable to all impacts and could show a limited resilience. Climate-induced changes (e.g., deep-water warming, formation of new deep water, food limitation, acidification) and human activities (e.g., seafloor litter, chemical pollution) might impact the structure, function and biodiversity of abyssal ecosystems.

Protection and management

In 2005, the General Fisheries Commission for the Mediterranean (GFCMA) established a permanent closure of the deep Mediterranean basin below 1000 m to towed dredges and trawl nets (REC. GFCM/29/2005/1). The Fisheries Restricted Area (FRA) covers 1.734.091 km^2, it includes all abyssal habitats, and its objective is to protect deep-sea habitats and resources. Control is a major issue for this offshore, vast FRA.

Suitability of the habitat for monitoring

No monitoring protocol is currently in place in this habitat. The feasibility of monitoring programs at these depths would benefit from next-generation, non-destructive technologies able to work autonomously. A mapping of the distribution and extent of this habitat is a priority.

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Abyssal mud

Reference codes for identification:

- **BARCELONA CONVENTION: MG6.51**
- **EUNIS 2019: MG65**
- **EUNIS 2007: A6.5**

LOCATION OF THE HABITAT

Zone	Abyssal
Nature of the substratum	Soft (mud)
Depth range	3000 m to 5270 m
Position	Open sea (abyssal plain, reliefs)
Hydrodynamic conditions	Weak
Salinity	Between 38 and 39
Temperature	Homeothermy around 13-14°C
Suitability for monitoring	Not known

Authors:
M. Bo, F. Betti

Photo credits:
RAMOGE 2018, T. Linley

ABYSSAL

MG6.5 Abyssal mud

MG6.51 Abyssal mud

Description of the habitat

The abyssal depth range is almost exclusively characterized by a homogeneous muddy seafloor, constituted by fine-grained, silt-clay terrigenous and biogenic (foraminiferal chalk) sediments. These derive from hemipelagic settling and from turbiditic currents funnelled by canyons. The abyssal plain is mainly ‘‘featureless’’, but low topographic reliefs (up to 35 m high), pockmarks and trenches increase the heterogeneity of the seafloor and consequently the local diversity and abundance of benthic species. The general environment is characterised by a constant homeothermy and a complete lack of ambient light. The habitat is interested by the flow of the Mediterranean Deep Water (MDW), and currents are generally weak. High pressure, darkness, low food availability and relative homogeneity of the seafloor lead to low species diversity (except for Bacteria and Archaea) and low abundance of individuals with depth. The relative homogeneity of the Mediterranean abyssal environment is interrupted by nine deep hypersaline anoxic basins (DHABs), derived from the re-dissolution of Messinian evaporites after exposition to seawater due to tectonic activity, and located in the Ionian abyssal basin. These brine lakes represent polyextreme environments, with salt concentration up to 7-10 times higher than those of seawater.

Geographic distribution

Four deep basins (DB) exceeding 3000 m occur in the Mediterranean Sea (Tyrrhenian DB, Ionian DB and two Levantine DBs, the Rhodes and Herodotus basins separated by the Mediterranean Ridge). The arched Hellenic Trench system extends along the northern edges of the Ionian and Rhodes basins. Abyssal mud is the main habitat of the abyssal depth range, extending to the maximum recorded depth of about 5270 m in the Calypso Deep (Ionian Sea). This habitat represents around 13% of the Mediterranean surface. It can be interrupted by abyssal rock, which includes the exposed portion of the deepest seamounts.

Associated habitats

This habitat is the bathymetric prosecution of the ‘Lower bathyal mud’ (MF6.5). It can be fragmented by the presence of ‘Abyssal rock’ (MG1.51). On abyssal mud are likely to develop ‘Facies with small sponges’ (MG6.511), ‘Facies with Alcyonacea’ (MG6.512). ‘Facies with Polychaeta’ (MG6.513), ‘Facies with Crustacea (Amphipoda, Isopoda, Tanaidacea)’ (MG6.514), and ‘Facies with bioturbations’ (MG6.515).

Related reference habitats

This habitat, and its associated communities, can be partially related to ‘Offshore terrigenous sticky mud’ (MD6.51), ‘Upper bathyal mud’ (ME6.51), and ‘Lower bathyal sandy mud’ (MF6.51).

Possible confusion

Below 3000 m depth this habitat includes all soft bottom seafloors, therefore the confusion with other habitats is unlikely. Other vast deep plains are reported as abyssal (e.g., Algero-Balearic) even if bounded by the 2600-2855 m isobaths. Different scientific disciplines may use different bathymetric boundaries. The existence of a true abyssal realm (and relative fauna) in the Mediterranean Sea has been questioned.

Typical species and associated communities

Due to the recent recolonization of the basin after the Messinian Salinity Crisis, the homeothermy of the Mediterranean deep waters, and the presence of the Gibraltar sill that limits the entrance of deep-water Atlantic species, the Mediterranean abyssal realm shows a very low degree of endemism and a general low diversity compared to the Atlantic fauna at similar depths. No cold-water stenothermal species are known, and no well characterised facies of abyssal mud are reported. The macrobenthos is constituted by a large number of eurybathic species, and only few true bathophilic species. Meiofauna is dominated by Nematoda, while macrofauna is mainly represented by polychaetes. Some benthic megafaunal organisms are recurrent in the literature: in particular, the shrimp *Acanthephyra eximia* is the dominant scavenging crustacean. Other crustaceans typically found in this habitat are the endemic geryonid crab *Chaceon mediterraneus*, and the shrimps *Nematocarcinus exilis*, *Robustosergia robusta*, and *Deosergestes corniculum*. The red shrimp *Aristeus antennatus*, typical of the lower bathyal depth range, has been reported also in the abyssal zone. The holothurian *Pseudostichopus occultatus* and the asteroid *Hymenodiscus coronata* are also observed. The polychaetes *Aphelochaeta marioni*, *Uschakovius enigmaticus* and *Lacydonia laureci* are known as principal components of abyssal macrofauna, together with few crustaceans, mainly represented by Cumacea (such as *Makrokylindrus longipes* and *Bathycuma brevirostre,* known for the shallower portion of the depth range), Amphipoda, Isopoda and Tanaidacea. Habitat-forming sessile organisms are not known for the abyssal soft seafloors, however, the low number of observations carried out in this depth range and the occurrence of some alcyonaceans and pennatulaceans in the lower bathyal zone prevent from confirming, so far, that this benthic component is truly missing. Benthic and bentho-nektonic fishes are rare: the macrourid *Coryphaenoides mediterraneus* is often the dominant or sole fish species collected. Other reported species are the tripod fish *Bathypterois dubius* and the brotula *Cataetyx laticeps*. Hypersaline anoxic basins host a highly specialized microbic community, including chemosynthetic bacteria on the brine-seawater interface; metazoans (e.g., nematodes (*Daptonema* spp.), crustaceans, cnidarians, bryozoans, and loriciferans) have been observed from sediments edging the haloclines. Loriciferans are the only metazoans reported to inhabit the anoxic DHAB brines and their ability to survive their entire lifecycle in the absence of oxygen has been investigated.

Conservation interest and ecological role

The communities inhabiting the vastity of the Mediterranean abyssal mud plains are still poorly known; nevertheless, evidence support the fact that this habitat is both a reservoir of biodiversity at all levels and a source of important ecosystem services (e.g., carbon storage), fundamental to guarantee the functioning of the deep-sea and climate in general. The occurrence of few abyssal endemisms increases the intrinsic value of these species and the habitat hosting them.

Economic importance

No industrial exploitation of Mediterranean abyssal resources is in place. Prokaryotes and fungi of DHABs hold great potential for biotechnological applications.

Vulnerability and potential threats

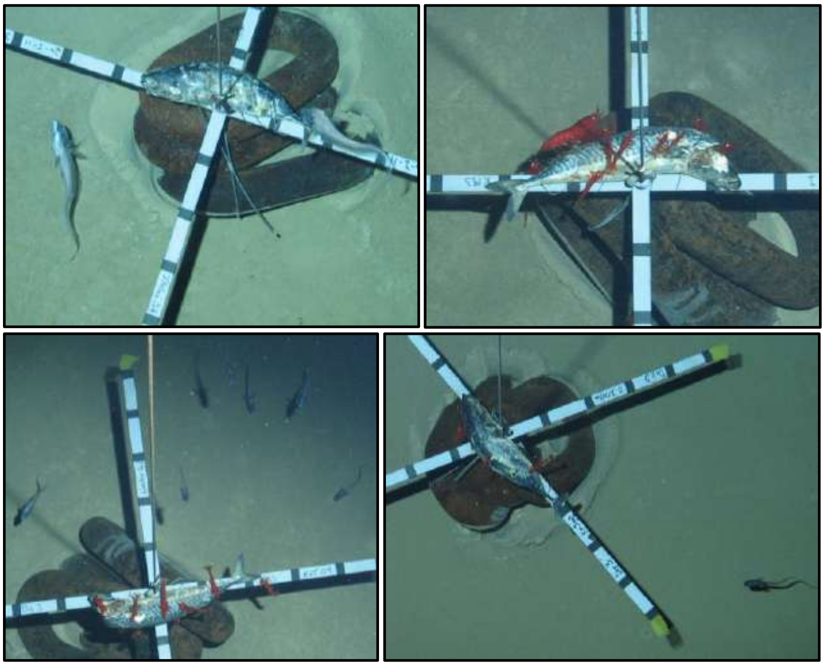
Deep-sea biota is characterized by slow growth rates and late maturation; thus, species are particularly vulnerable to all impacts and could show a limited resilience. Climate-induced changes (e.g. deep-water warming, formation of new deep water, food limitation, acidification) and human activities (e.g. sea floor litter, chemical pollution) might impact the structure, function and biodiversity of abyssal ecosystems.

Protection and management

In 2005, the General Fisheries Commission for the Mediterranean (GFCMA) established a permanent closure of the deep Mediterranean basin below 1000 m to towed dredges and trawl nets (REC. GFCM/29/2005/1). The Fisheries Restricted Area (FRA) covers 1.734.091 km^2, it includes all abyssal habitats, and its objective is to protect deep-sea habitats and resources. Control is a major issue for this offshore, vast FRA.

Suitability of the habitat for monitoring

No monitoring protocol is currently in place in this habitat. The feasibility of monitoring programs at these depths would benefit from next-generation technologies able to work autonomously.



Demersal bait-attending fauna from the western and eastern abyssal Mediterranean Sea, including the macrurid *Coryphaenoides mediterraneus* and the shrimp *Acanthephyra eximia* (3396 m, 4203 m, 4200 m, 5100 m). No signs of burrowing or grazing animals can be observed (© T. Linley, University of Aberdeen, Eurosites/KM3NeT Projects)

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Annex I. Complete list of the Mediterranean benthic marine habitat types

Updated classification of benthic marine habitat types for the Mediterranean region (from SPA/RAC-UN Environment/MAP, 2019a). In bold are the habitats included in the updated reference list of marine habitat types (from SPA/RAC-UN Environment/MAP, 2019b).

LITTORAL

- MA1.5 Littoral rock
  - **MA1.51 Supralittoral rock**
    - MA1.511 Association with Cyanobacteria and lichens
    - MA1.512 Association with Ochrophyta
    - MA1.513 Facies with Gastropoda and/or with Chthamalidae
  - **MA1.51a Supralittoral euryhaline and eurythermal pools**
  - **MA1.51b Wracks of dead leaves of macrophytes**
  - **MA1.52 Midlittoral caves**
    - MA1.521 Association with encrusting Corallinales or other Rhodophyta
  - **MA1.53 Upper midlittoral rock**
    - **MA1.531 Association with encrusting Corallinales creating belts**
    - MA1.532 Association with Bangiales or other Rhodophyta, or with Chlorophyta
    - MA1.533 Facies with Bivalvia
    - MA1.534 Facies with Gastropoda and/or with Chthamalidae
  - **MA1.54 Lower midlittoral rock**
    - **MA1.541 Association with encrusting Corallinales creating belts**
    - **MA1.542 Association with Fucales**
    - MA1.543 Association with algae (algal belts), except Fucales and encrusting Corallinales
    - **MA1.544 Facies with *Pollicipes pollicipes***
    - **MA1.545 Facies with Vermetidae**
    - MA1.546 Facies with Bivalvia
    - MA1.547 Facies with Gastropoda
  - **MA1.54a Midlittoral euryhaline and eurythermal pools**
- MA2.5 Littoral biogenic habitat
  - **MA2.51 Platforms of encrusting Corallinales**
  - **MA2.52 Reefs of *Sabellaria* spp.**
  - **MA2.53 Reefs of Vermetidae**
  - **MA2.54 Banks of dead leaves of macrophytes (banquettes)**
- MA3.5 Littoral coarse sediment
  - **MA3.51 Supralittoral coarse sediment**
    - **MA3.511 Association with macrophytes**
  - **MA3.51a Deposit of dead leaves of macrophytes**
  - MA3.51b Beaches with slowly-drying wracks
  - **MA3.52 Midlittoral coarse sediment**
    - **MA3.521 Association with indigenous marine angiosperms**
    - MA3.522 Association with *Halophila stipulacea*
  - **MA3.52a Deposit of dead leaves of macrophytes**
- MA4.5 Littoral mixed sediment
  - **MA4.51 Supralittoral mixed sediment**
    - **MA4.511 Association with macrophytes**
  - **MA4.51a Deposit of dead leaves of macrophytes**
  - MA4.51b Beaches with slowly-drying wracks
  - **MA4.52 Midlittoral mixed sediment**
    - **MA4.521 Association with indigenous marine angiosperms**

- MA4.522 Association with *Halophila stipulacea*
- **MA4.52a Deposit of dead leaves of macrophytes**

MA5.5 Littoral sand
- **MA5.51 Supralittoral sand**
  - **MA5.511 Association with macrophytes**
- **MA5.51a Deposit of dead leaves of macrophytes**
- MA5.51b Beaches with slowly-drying wracks
- **MA5.52 Midlittoral sand**
  - **MA5.521 Association with indigenous marine angiosperms**
  - MA5.522 Association with *Halophila stipulacea*
  - MA5.523 Facies with Polychaeta
  - MA5.524 Facies with Bivalvia
- **MA5.52a Deposit of dead leaves of macrophytes**

MA6.5 Littoral mud
- **MA6.51 Supralittoral mud**
  - **MA6.511 Association with macrophytes**
- MA6.51a Beaches with slowly-drying wracks under glassworts
- **MA6.52 Midlittoral mud**
- **MA6.52a Habitats of transitional waters (estuaries and lagoons)**
  - **MA6.521a Association with halophytes or marine angiosperms**
  - MA6.522a Habitats of salinas

INFRALITTORAL

MB1.5 Infralittoral rock
- **MB1.51 Algal-dominated infralittoral rock**
- **MB1.51a Well illuminated infralittoral rock, exposed**
  - **MB1.511a Association with Fucales**
  - MB1.512a Association with photophilic algae (except Fucales, encrusting Corallinales and Caulerpales)
  - **MB1.513a Association with encrusting Corallinales creating belts**
  - **MB1.514a Association with *Caulerpa prolifera***
  - MB1.515a Association with non-indigenous Mediterranean *Caulerpa* spp.
  - **MB1.516a Facies with zooxanthellate Scleractinia**
  - MB1.517a Facies with Bivalvia
  - MB1.518a Facies with Echinoidea on encrusting Corallinales (barren ground)
- **MB1.51b Moderately illuminated infralittoral rock, exposed**
  - MB1.511b Association with encrusting Corallinales
  - **MB1.512b Association with *Caulerpa prolifera***
  - MB1.513b Association with non-indigenous Mediterranean *Caulerpa* spp.
  - MB1.514b Facies with Hydrozoa
  - **MB1.515b Facies with azooxanthellate Scleractinia**
- **MB1.51c Well illuminated infralittoral rock, sheltered**
  - **MB1.511c Association with Fucales**
  - MB1.512c Association with photophilic algae (except Fucales, encrusting Corallinales and Caulerpales)
  - MB1.513c Association with encrusting Corallinales
  - **MB1.514c Association with *Caulerpa prolifera***
  - MB1.515c Association with non-indigenous Mediterranean *Caulerpa* spp.
  - **MB1.516c Facies with zooxanthellate Scleractinia**
- **MB1.51d Moderately illuminated infralittoral rock, sheltered**
  - MB1.511d Association with encrusting Corallinales
  - **MB1.512d Association with *Caulerpa prolifera***

- MB1.513d Association with non-indigenous Mediterranean *Caulerpa* spp.
- **MB1.514d Facies with Alcyonacea**

- **MB1.51e Lower infralittoral rock moderately illuminated**
    - **MB1.511e Association with Fucales**
    - **MB1.512e Association with Laminariales (kelp beds)**
    - **MB1.513e Association with *Caulerpa prolifera***
    - MB1.514e Association with non-indigenous Mediterranean *Caulerpa* spp.
    - **MB1.515e Facies with Alcyonacea**
    - **MB1.516e Facies with azooxanthellate Scleractinia**
- **MB1.52 Invertebrate-dominated infralittoral rock**
- **MB1.52a Moderately illuminated infralittoral rock, exposed or sheltered**
    - **MB1.521a Association with *Caulerpa prolifera***
    - MB1.522a Association with non-indigenous Mediterranean *Caulerpa* spp.
    - MB1.523a Facies with small sponges
    - **MB1.524a Facies with azooxanthellate Scleractinia**
    - **MB1.525a Facies with Alcyonacea**
- **MB1.53 Infralittoral rock affected by sediment**
    - MB1.531 Facies with small sponges
    - **MB1.532 Facies with large and erect sponges**
    - **MB1.533 Facies with Scleractinia**
    - **MB1.534 Facies with Alcyonacea**
    - MB1.535 Facies with Ascidiacea
    - MB1.536 Facies with Bivalvia
    - **MB1.537 Facies with endolithic species**
- **MB1.54 Habitats of transitional waters (estuaries and lagoons)**
    - **MB1.541 Association with marine angiosperms or other halophytes**
    - **MB1.542 Association with Fucales**
- **MB1.55 Coralligenous (enclave of circalittoral)**
- **MB1.56 Semi-dark caves and overhangs**

MB2.5 Infralittoral biogenic habitat

- **MB2.51 Reefs of Vermetidae**
- **MB2.52 Reefs of *Sabellaria* spp.**
- **MB2.53 Reefs of *Cladocora caespitosa***
- **MB2.54 *Posidonia oceanica* meadow**
    - **MB2.541 *Posidonia oceanica* meadow on rock**
    - **MB2.542 *Posidonia oceanica* meadow on matte**
    - **MB2.543 *Posidonia oceanica* meadow on sand, coarse or mixed sediment**
    - MB2.544 Dead matte of *Posidonia oceanica*
    - **MB2.545 Natural monuments/Ecomorphoses of *Posidonia oceanica*** (fringing reef, barrier reef, stripped meadow, atoll)
    - **MB2.546 Association of *Posidonia oceanica* with *Cymodocea nodosa* or *Caulerpa* spp.**
    - **MB2.547 Association of *Cymodocea nodosa* or *Caulerpa* spp. with dead matte of *Posidonia oceanica***

MB3.5 Infralittoral coarse sediment

- **MB3.51 Infralittoral coarse sediment mixed by waves**
    - **MB3.511 Association with maërl or rhodoliths**
- **MB3.52 Infralittoral coarse sediment under the influence of bottom currents**
    - **MB3.521 Association with maërl or rhodoliths**
- MB3.53 Infralittoral pebbles
    - MB3.531 Facies with *Gouania willdenowi*

MB4.5 Infralittoral mixed sediment

- MB5.5 Infralittoral sand
    - MB5.51 Fine sand in very shallow waters
        - MB5.511 Facies with Bivalvia
    - **MB5.52 Well sorted fine sand**
        - **MB5.521 Association with indigenous marine angiosperms**
        - MB5.522 Association with *Halophila stipulacea*
        - MB5.523 Association with photophilic algae
    - **MB5.53 Fine sand in sheltered waters**
        - **MB5.531 Association with indigenous marine angiosperms**
        - MB5.532 Association with *Halophila stipulacea*
        - **MB5.533 Association with *Caulerpa prolifera***
        - MB5.534 Association with non-indigenous Mediterranean *Caulerpa* spp.
        - MB5.535 Association with photophilic algae (except Caulerpales)
        - MB5.536 Facies with Bivalvia
        - MB5.537 Facies with Polychaeta
        - MB5.538 Facies with Crustacea Decapoda
        - **MB5.539 Facies with *Tritia* spp. and nematodes in hydrothermal vents**
    - **MB5.54 Habitats of transitional waters (estuaries and lagoons)**
        - **MB5.541 Association with marine angiosperms or other halophytes**
        - **MB5.542 Association with Fucales**
        - MB5.543 Association with photophilic algae (except Fucales)
        - MB5.544 Facies with Polychaeta
        - MB5.545 Facies with Bivalvia
- MB6.5 Infralittoral mud
    - **MB6.51 Habitats of transitional waters (estuaries and lagoons)**
        - **MB6.511 Association with marine angiosperms or other halophytes**

CIRCALITTORAL

- MC1.5 Circalittoral rock
    - **MC1.51 Coralligenous cliffs**
    - **MC1.51a Algal-dominated coralligenous**
        - MC1.511a Association with encrusting Corallinales
        - **MC1.512a Association with Fucales or Laminariales**
        - MC1.513a Association with sciaphilic algae (except Fucales, Laminariales, encrusting Corallinales, and Caulerpales)
        - MC1.514a Association with non-indigenous Mediterranean *Caulerpa* spp.
    - **MC1.51b Invertebrate-dominated coralligenous**
        - MC1.511b Facies with small sponges
        - **MC1.512b Facies with large and erect sponges**
        - MC1.513b Facies with Hydrozoa
        - **MC1.514b Facies with Alcyonacea**
        - MC1.515b Facies with Ceriantharia
        - **MC1.516b Facies with Zoantharia**
        - **MC1.517b Facies with Scleractinia**
        - **MC1.518b Facies with Vermetidae and/or Serpulidae**
        - **MC1.519b Facies with Bryozoa**
        - MC1.51Ab Facies with Ascidiacea
    - **MC1.51c Invertebrate-dominated coralligenous covered by sediment**
        - See MC1.51b for examples of facies
    - **MC1.52 Continental shelf rock**
    - **MC1.52a Coralligenous outcrops**

        MC1.521a Facies with small sponges
        MC1.522a Facies with Hydrozoa
        MC1.523a Facies with Alcyonacea
        MC1.524a Facies with Antipatharia
        MC1.525a Facies with Scleractinia
        MC1.526a Facies with Bryozoa
        MC1.527a Facies with Polychaeta
        MC1.528a Facies with Bivalvia
        MC1.529a Facies with Brachiopoda
    MC1.52b Coralligenous outcrops covered by sediment
        See MC1.52a for examples of facies
    MC1.52c Deep banks
        MC1.521c Facies with Antipatharia
        MC1.522c Facies with Alcyonacea
        MC1.523c Facies with Scleractinia
    MC1.53 Semi-dark caves and overhangs
    MC1.53a Walls
        MC1.531a Facies with sponges
        MC1.532a Facies with Hydrozoa
        MC1.533a Facies with *Corallium rubrum*
        MC1.534a Facies with Scleractinia
        MC1.535a Facies with Zoantharia
        MC1.536a Facies with Bryozoa
        MC1.537a Facies with Ascidiacea
    MC1.53b Roof
        See MC1.53a for examples of facies
    MC1.53c Detritic bottom
        See MC3.51 for examples of facies
    MC1.53d Brackish water caves or caves subjected to freshwater runoff
        MC1.531d Facies with lithistid sponges
MC2.5 Circalittoral biogenic habitat
    MC2.51 Coralligenous platforms
        MC2.511 Association with encrusting Corallinales
        MC2.512 Association with Fucales
        MC2.513 Association with non-indigenous Mediterranean *Caulerpa* spp.
        MC2.514 Facies with small sponges
        MC2.515 Facies with large and erect sponges
        MC2.516 Facies with Hydrozoa
        MC2.517 Facies with Alcyonacea
        MC2.518 Facies with Zoantharia
        MC2.519 Facies with Scleractinia
        MC2.51A Facies with Vermetidae and/or Serpulidae
        MC2.51B Facies with Bryozoa
        MC2.51C Facies with Ascidiacea
MC3.5 Circalittoral coarse sediment
    MC3.51 Coastal detritic bottoms
        MC3.511 Association with Laminariales
        MC3.512 Facies with large and erect sponges
        MC3.513 Facies with Hydrozoa
        MC3.514 Facies with Alcyonacea
        MC3.515 Facies with Pennatulacea
        MC3.516 Facies with Polychaeta (*Salmacina*-*Filograna* complex included)

        - MC3.517 Facies with Bivalvia
        - **MC3.518 Facies with Bryozoa**
        - **MC3.519 Facies with Crinoidea**
        - MC3.51A Facies with Ophiuroidea
        - MC3.51B Facies with Echinoidea
        - MC3.51C Facies with Ascidiacea
    - **MC3.52 Coastal detritic bottoms with rhodoliths**
        - **MC3.521 Association with maërl**
        - **MC3.522 Association with *Peyssonnelia* spp.**
        - **MC3.523 Association with Laminariales**
        - **MC3.524 Facies with large and erect sponges**
        - MC3.525 Facies with Hydrozoa
        - **MC3.526 Facies with Alcyonacea**
        - **MC3.527 Facies with Pennatulacea**
        - MC3.528 Facies with Zoantharia
        - MC3.529 Facies with Ascidiacea
- MC4.5 Circalittoral mixed sediment
    - **MC4.51 Muddy detritic bottoms**
        - MC4.511 Facies with Hydrozoa
        - **MC4.512 Facies with Alcyonacea**
        - **MC4.513 Facies with Pennatulacea**
        - MC4.514 Facies with Polychaeta
        - MC4.515 Facies with Ophiuroidea
        - MC4.516 Facies with Ascidiacea
- MC5.5 Circalittoral sand
- **MC6.5 Circalittoral mud**
    - **MC6.51 Coastal terrigenous mud**
        - **MC6.511 Facies with Alcyonacea and Holothuroidea**
        - **MC6.512 Facies with Pennatulacea**
        - MC6.513 Facies with Gastropoda

OFFSHORE CIRCALITTORAL

- MD1.5 Offshore circalittoral rock
    - **MD1.51 Offshore circalittoral rock invertebrate-dominated**
        - MD1.511 Facies with small sponges
        - **MD1.512 Facies with large and erect sponges**
        - **MD1.513 Facies with Alcyonacea**
        - **MD1.514 Facies with Antipatharia**
        - **MD1.515 Facies with Scleractinia**
        - MD1.516 Facies with Ceriantharia
        - **MD1.517 Facies with Zoantharia**
        - MD1.518 Facies with Polychaeta
        - MD1.519 Facies with Bivalvia
        - MD1.51A Facies with Brachiopoda
        - **MD1.51B Facies with Bryozoa**
    - **MD1.52 Offshore circalittoral rock invertebrate-dominated covered by sediment**
        - See MD1.51 for examples of facies
    - **MD1.53 Deep offshore circalittoral banks**
        - **MD1.531 Facies with Antipatharia**
        - **MD1.532 Facies with Alcyonacea**
        - **MD1.533 Facies with Scleractinia**
- MD2.5 Offshore circalittoral biogenic habitat

- **MD2.51 Offshore reefs**
  - **MD2.511 Facies with Vermetidae and/or Serpulidae**
- **MD2.52 Thanatocoenosis of corals, or Brachiopoda, or Bivalvia**
  - See MD1.51 for examples of facies

MD3.5 Offshore circalittoral coarse sediment

- **MD3.51 Offshore circalittoral detritic bottoms**
  - **MD3.511 Facies with Bivalvia**
  - MD3.512 Facies with Brachiopoda
  - MD3.513 Facies with Polychaeta
  - **MD3.514 Facies with Crinoidea**
  - MD3.515 Facies with Ophiuroidea
  - MD3.516 Facies with Echinoidea

MD4.5 Offshore circalittoral mixed sediment

- **MD4.51 Offshore circalittoral detritic bottoms**
  - See MD3.51 for examples of facies

MD5.5 Offshore circalittoral sand

- **MD5.51 Offshore circalittoral sand**
  - See MD3.51 for examples of facies

MD6.5 Offshore circalittoral mud

- **MD6.51 Offshore terrigenous sticky mud**
  - **MD6.511 Facies with Pennatulacea**
  - MD6.512 Facies with Polychaeta
  - **MD6.513 Facies with Bivalvia**
  - MD6.514 Facies with Brachiopoda
  - MD6.515 Facies with Ceriantharia

UPPER BATHYAL

ME1.5 Upper bathyal rock

- **ME1.51 Upper bathyal rock invertebrate-dominated**
  - ME1.511 Facies with small sponges
  - **ME1.512 Facies with large and erect sponges**
  - **ME1.513 Facies with Antipatharia**
  - **ME1.514 Facies with Alcyonacea**
  - **ME1.515 Facies with Scleractinia**
  - **ME1.516 Facies with Cirripedia**
  - **ME1.517 Facies with Crinoidea**
  - **ME1.518 Facies with Bivalvia**
  - ME1.519 Facies with Brachiopoda
- **ME1.52 Caves and ducts in total darkness**

ME2.5Upper bathyal biogenic habitat

- **ME2.51 Upper bathyal reefs**
  - ME2.511 Facies with small sponges
  - **ME2.512 Facies with large and erect sponges**
  - **ME2.513 Facies with Scleractinia**
  - **ME2.514 Facies with Bivalvia**
  - **ME2.515 Facies with Serpulidae**
  - ME2.516 Facies with Brachiopoda
- **ME2.52 Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges**
  - See ME1.51 for examples of facies

ME3.5 Upper bathyal coarse sediment

- **ME3.51 Upper bathyal coarse sediment**
  - ME3.511 **Facies with Alcyonacea**

ME4.5 Upper bathyal mixed sediment

- **ME4.51 Upper bathyal mixed sediment**
  - **ME4.511 Facies with Bivalvia**
  - ME4.512 Facies with Brachiopoda

ME5.5 Upper bathyal sand

- **ME5.51Upper bathyal detritic sand**
  - ME5.511 Facies with small sponges
  - **ME5.512 Facies with Pennatulacea**
  - **ME5.513 Facies with Crinoidea**
  - ME5.514 Facies with Echinoidea
  - **ME5.515 Facies with Bivalvia**
  - ME5.516 Facies with Brachiopoda
  - **ME5.517 Facies with Bryozoa**
  - **ME5.518 Facies with Scleractinia**

ME6.5 Upper bathyal mud

- **ME6.51 Upper bathyal mud**
  - ME6.511 Facies with small sponges
  - **ME6.512 Facies with Pennatulacea**
  - **ME6.513 Facies with Alcyonacea**
  - **ME6.514 Facies with Scleractinia**
  - ME6.515 Facies with Crustacea Decapoda
  - **ME6.516 Facies with Crinoidea**
  - ME6.517 Facies with Echinoidea
  - **ME6.518 Facies with Bivalvia**
  - ME6.519 Facies with Brachiopoda
  - ME6.51A Facies with Ceriantharia
  - **ME6.51B Facies with Bryozoa**
  - **ME6.51C Facies with giant Foraminifera**

LOWER BATHYAL

MF1.5 Lower bathyal rock

- **MF1.51 Lower bathyal rock**
  - MF1.511 Facies with small sponges
  - **MF1.512 Facies with Alcyonacea**
  - **MF1.513 Facies with Scleractinia**
  - **MF1.514 Facies with chemosynthetic benthic species**

MF2.5 Lower bathyal biogenic habitat

- **MF2.51 Lower bathyal reefs**
  - **MF2.511 Facies with Scleractinia**
- **MF2.52 Thanatocoenosis of corals, or Brachiopoda, or Bivalvia, or sponges**
  - See MF1.51 for examples of facies

MF6.5 Lower bathyal mud

- **MF6.51 Sandy mud**
  - MF6.511 Facies with small sponges
  - **MF6.512 Facies with Alcyonacea**
  - MF6.513 Facies with Echinoidea
  - **MF6.514 Facies with Pennatulacea**
  - MF6.515 Facies with bioturbations

ABYSSAL

MG1.5 Abyssal rock

- **MG1.51 Abyssal rock**
  - MG1.511 Facies with small sponges
  - **MG1.512 Facies with Alcyonacea**
  - MG1.513 Facies with Polychaeta
  - MG1.514 Facies with Crustacea (Amphipoda, Isopoda, Tanaidacea)

MG6.5 Abyssal mud

- **MG6.51 Abyssal mud**
  - MG6.511 Facies with small sponges
  - **MG6.512 Facies with Alcyonacea**
  - MG6.513 Facies with Polychaeta
  - MG6.514 Facies with Crustacea (Amphipoda, Isopoda, Tanaidacea)
  - MG6.515 Facies with bioturbations