MAPPING OF BENTHIC ROCKY SHORE HABITATS OF THE ALGERIAN COAST (SOUTH-WESTERN MEDITERRANEAN)

Lamia Bahbah, Bilel Bensari, Khadidja Chabane, Halima Seridi, Simone Mariani, Enric Ballesteros

Abstract: This study is the first large-scale mapping of supralittoral, mediolittoral and upper infralittoral benthic rocky substrate habitats of the Algerian coast. It is a first step to fix the lack of cartographic information and general knowledge of coastal marine habitats in Algeria. 2D digital habitat mapping was carried out along 450 km of coastline using CAT-LIT methodology. We also provide a reference database of the coastal marine habitats of the Algerian coast, named "List of ALGerian MARin HABitats". Natural rocky coastlines are the dominant typological category in the area. The coastline studied is highly diverse in terms of habitats, since 35 benthic habitats were identified. Supralittoral benthic communities are dominated by barnacle *Euraphia depressa* and the lichen *Verrucaria amphibia*. Barnacles (*Chthamalus* spp.) and the red alga *Rissoella verruculosa* occupy the upper mediolittoral zone, while habitats dominated by the red algae *Ellisolandia elongata* and *Lithophyllum byssoides* characterize the lower mediolittoral zone. The upper infralittoral fringe is dominated by *Ellisolandia elongata* and rockweed *Ericaria selaginoides* in exposed shores or by *Gongolaria barbata* in sheltered areas. These habitats represent the core habitats of the littoral zone of Algeria. Anthozoans *Astroides calycularis* and *Actinia equina* are common in the infralittoral zone. Ulvales are abundant in Algiers Bay indicating polluted waters.

Keywords: Cartography, Macroalgae, Marine Habitats, Coastal Ecosystems

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Introduction

In spite of the many definitions in the literature (see [19]), here we define the habitat as a natural system characterized by its own environmental conditions and the assemblages of organisms that inhabit it at definite, albeit dynamic, spatial and temporal scales. Coastal areas exhibit strong gradients of environmental conditions which continuously keep most species within their tolerance limits. In many coastal areas, this feature helps the recognition of different arrays of habitats dominated by one or several species of benthic organisms.

Habitat classifications aim to define habitats in a coherent way, thus allowing their comparison across different geographical regions or periods. As for marine habitats, several classifications and typologies have been established in Europe and North America, such as ZNIEFF-mer, CORINE biotopes, Natura 2000, EUNIS, CMECS, and LPRE. Thanks to the newest digital mapping techniques [17] and the existence of habitat typologies, the responses of coastal habitats to environmental disturbances, for instance, whether natural or anthropogenic, can be better on at different geographical scales

In Algeria, the classification of marine habitats was nonexistent, and knowledge about the marine and coastal environment remained very poor. The present study aims at: 1) Establishing the first reference framework for coastal rocky substrate habitats from the Algerian coast; 2) creating detailed maps of these habitats at a scale of 1:1500 using the catenas method from CAT-LIT (see the Materials and Methods session and [19]); 3) and assessing the relationships between them through network analysis.

Materials and Methods

Study Area

The geographical area covered by this study corresponds to the central Algerian coast (Figure 1). It includes four cities from east to west: Boumerdes, Algiers, Tipaza, and Chlef. The study area extends from Cap Djenet in the east (Boumerdes) to Cap Tenes in the west (Chlef), encompassing approximately 450 km of coastline. The coastal geomorphology consists of a succession of cliffs, rocky and sandy bays, scattered with rocky promontories and beaches. The study region includes the bays of Zemmouri, Algiers, and Bou Ismail, with several river mouths. Additionally, there is a major commercial port (Algiers Port) and 11 fishing ports.

Data Collection

The "Algerian Marine Habitats" (ALG-MAR-HAB) is based on widespread typologies such as CORINE Biotopes and EUNIS, as well as the LPRE classification. In situ identification of dominant benthic habitats was conducted over a period of three years (2016-2021). Information on dominant species, substrate type, accompanying species, wave exposure, bathymetric level, substrate mode, and topography was recorded at each site. More concretely, the environmental characteristics considered for habitat classification included:

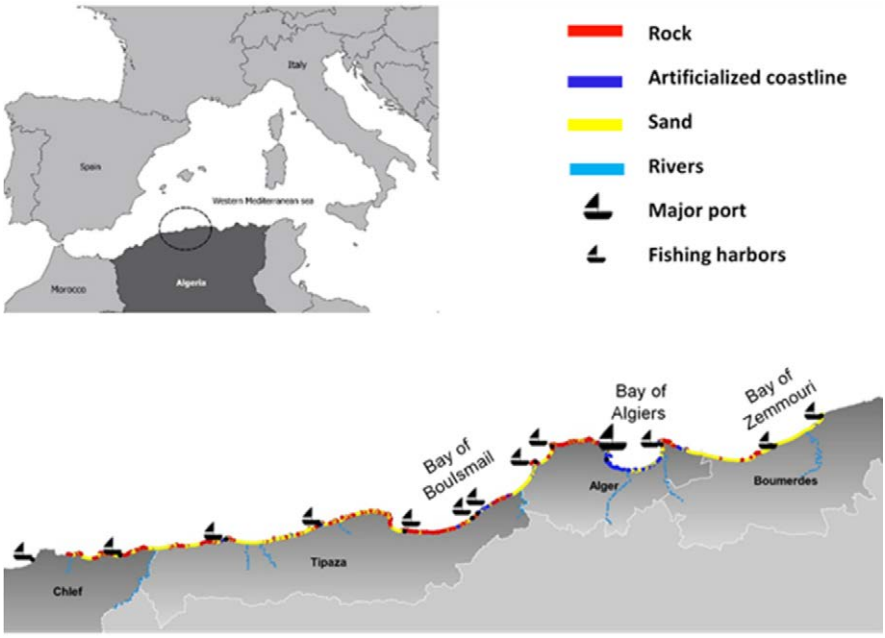

Figure 1 – Geographical Positioning of the Study Area.

- *Substrate type*: Rocky, sandy, muddy, gravel.
- *Bathymetric level*: Three zones were considered in this study:
  - Supralittoral Zone: More or less regularly-wetted, never-submerged.
  - Mediolittoral Zone: Intermittently-submerged.
  - Infralittoral Zone: Almost permanently submerged.
- *Wave exposure*: sheltered, moderately exposed, or exposed.
- *Substrate topography*: "plateaus", caves, overhangs, hollows and ridges, tide pools.

Habitat Mapping

This approach includes both data collection from the field and data entry into digital databases. Data collection consisted in mapping the rocky littoral habitats while steering along the coastline on a small boat. Where the access by boat was challenging, mapping was done directly from the shore on foot or by snorkeling. Prior to the characterization of the different habitats, (see [19]), we mapped different horizons or belts dominated by a specific organism or organisms and recorded this information on a paper map (A4 format). The scale was set at 1:1500, and the mapped coastal sectors measured at least 10 meters, except for some horizons from specific environments (e.g., caves, rock pools), where the sampling unit was scaled to the area they occupied, and the exact position recorded by GPS, applying the WGS84 reference system. The data was recorded *in situ* using orthophotos.

To validate the identification of uncertain species we collected samples for the identification in the laboratory. The entire sampling process took place over three months, from May to August 2018-2021, during the peak in the annual development period of algae.

The task of recording all the horizons in a particular spot was much simplified by using the catena methodology from [19]. Our methodology, in fact, draws inspiration from the CAT-LIT method ("CATenas" and "LITtoral"), modified and adapted to the Algerian coast. First, we needed to clarify the definition and differentiation of these operational units (the horizons and the catenas), the equivalence or overlap between existing terms, and the hierarchical relationships to establish a classification as unambiguous as possible (Figure 2).

Horizons: Subdivisions into bands defined by the dominant species in terms of biomass, cover, or number of individuals.

Catenas: Defined here as a series of horizons linked by their topographical occurrence, i.e., their position along the vertical axis, extending from the upper level of the supralittoral zone (about 50 cm on protected shores to over 10 m on more exposed shores) down to 1 m depth. The number of horizons in each sector varies from one to nine.

Figure 2 – Explanatory Image of Operational Units for Data Classification

An alphanumeric code was assigned to each catena, as shown in Annex 01, where each uppercase letter often refers to a group of similar catenas sharing characteristic horizons. For example, catenas A1 and A2 belonged to the same group because the horizons of the red alga *Rissoella verruculosa* and the brown alga *Ericaria selaginoides* were present in both, but they differed due to the dissimilarity in other horizons. This classification aims to conduct a precise study

of the distribution of benthic habitats and facilitate the introduction of data into the GIS.

Digital mapping was developed using Geographic Information System (GIS) techniques with the QGis 3.12.3 program. The projected coordinate system was the WGS84. Digital mapping was carried out at a scale of 1:1500. Data were entered into a digitized linear vector, representing the central Algerian coastline. The digitized coastline was created from the most recent satellite imagery (2018) of the coastline.

As described above, each catena comprises several horizons, and each horizon could correspond to one or more habitats, most of which are described by the three classifications used: LPRE, EUNIS, and CORINE. Thus, the link between each catena and its corresponding horizons was stored in one table. Additionally, correspondences between horizons and habitats were stored in a third table. Finally, to have each habitat on a specific line segment, the habitat table was joined and connected to the line attribute table through a common field: HORIZON.

In summary, in QGis, after clicking on the "Information on a line segment" button, the corresponding catena, substrate, and segment length are displayed. Furthermore, by clicking on the Catena_Habitats link icons, the relevant horizons and their correspondences with different habitats (ALG-MAR-HAB, LPRE, EUNIS, and CORINE) are shown.

Data Analysis

Once the digital mapping is completed, a series of analyses can be performed directly from the project in QGIS 3.12.3. Firstly, general information such as the extent of substrate types, of the horizons and the catenas, and then the habitats (see below) can be easily obtained through queries. Secondly, the percentage cover of each habitat can be calculated relatively to the approximately 210 km of rocky shore. On the other hand, the percentage cover of each substrate type can be calculated relative to the total length of sampled coastline.

A network illustrating the relationships between rocky habitats (i.e. the number of times paired habitats coincided in the catenas) was visualized using the Gephi 0.8.2 beta program [8]. Each of the identified habitats was placed as a neighboring node by the Fruchterman-Reingold algorithm [11], before enhancing visualization using Gephi tools.

Results

Coastal Benthic Habitat Mapping

The mapping conducted is a 2D digital cartography of the horizons found along a coastline and grouped into different catenas. An excerpt of the mapping results is presented in Figure 3. It depicts approximately 6 km of the coastline with different line colors and labels for each Catena. By clicking the "identify" button, the habitats contained within each Catena are shown, along with the substrate type and the length of the segment occupied by that habitat. The list of existing catenas is provided in Annex 1.

By utilizing the same orthophotos both in the field and for digital mapping (Figure 3), we ensured a high level of consistency between the digital map data and the field-mapping values.

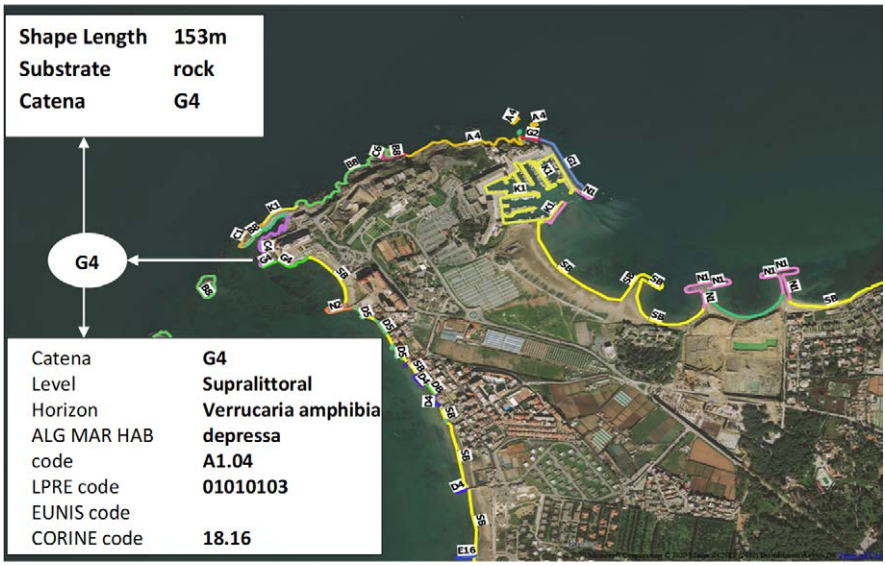

Figure 3 – Representation of the coastline showing different colors and labels for each Catena in QGIS.

Coastal Morphology

The most common substrate type along the studied coast was the natural rocky substrate (NHC), extending over 166.73 km of coastline. This was distributed between low coast (130.55 km; 28.11 %) and high rocky coast (cliffs; 36.20 km; 7.79 %). Furthermore, soft bottom represented 31.15 % of the coast. Artificial rocky coastline occupied a significant stretch, dominated by breakwaters (developed area) with 23.9 % and ports with 8.93 %. Concrete dykes represented less than 1% of the coast (Figure 4).

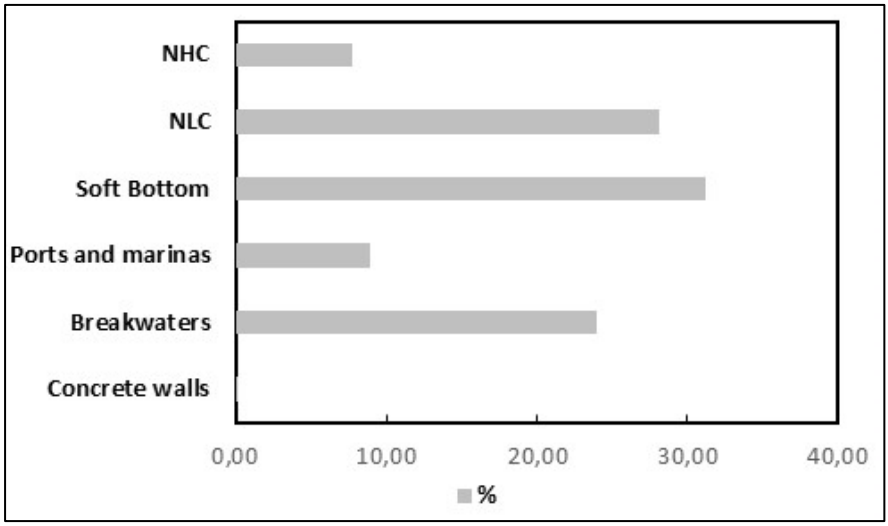

Figure 4 – Frequency of different mapped substrate types. NHC: Natural High Rocky Coastline, NLC: Natural Low Rocky Coastline.

Distribution of Benthic Habitats

We used 35 different horizons dominated by one species or different species guilds. These horizons corresponded to as many habitats in our final typology (see Annex 2).

Figure 05 shows the pattern of habitat abundance, calculated from the line lengths of each horizon, converted into percentages. None of the habitat studied exhibited a uniform distribution across the entire vertical gradient, with no habitat spanning all three zones. Some habitat show a narrow vertical distribution, like *Euraphia depressa*, *Rissoella verruculosa*, Trottoir, *Ericaria selaginoides*. Conversely, other habitats spread over a broader vertical range but with varying abundance, such as *Chthamalus* spp., *Ralfsia verrucosa*, *Lithophyllum* spp., *Gelidium* spp., *Halopteris scoparia*, *Mytilus galloprovincialis*, *Ellisolandia elongata*, and *Cystoseira compressa*.

The supralittoral rock is dominated by barnacle *Euraphia depressa* with lichen *Verrucaria amphibia* and some *Chthamalus* spp. The upper mediolitoral zone is defined by the habitat of *Chthamalus* spp. of the red alga *Rissoella verruculosa*. The lower mediolittoral rock is mainly populated by red alga *Ellisolandia elongata* and some mediolittoral algae forming carpets, and the upper infralittoral rock is covered whether by *E. elongata*, different photophilic algae and canopy-forming algae (*Ericaria selaginoides* and *Cystoseira compressa* in exposed coasts and *Gongolaria barbata* in sheltered coasts. (Figure 6).

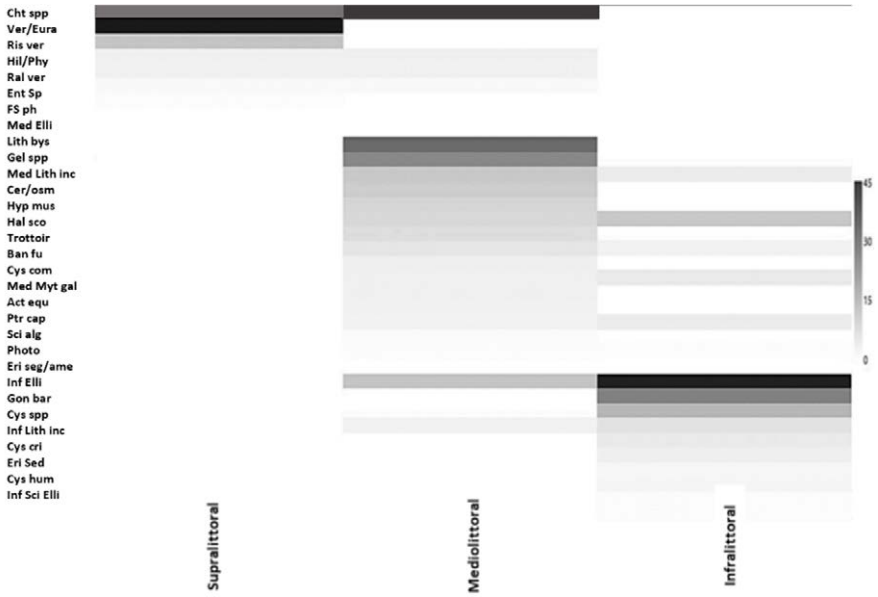

Figure 5 – Diagram illustrating the abundance (in percentage) of habitats along the vertical gradient of littoral zones.

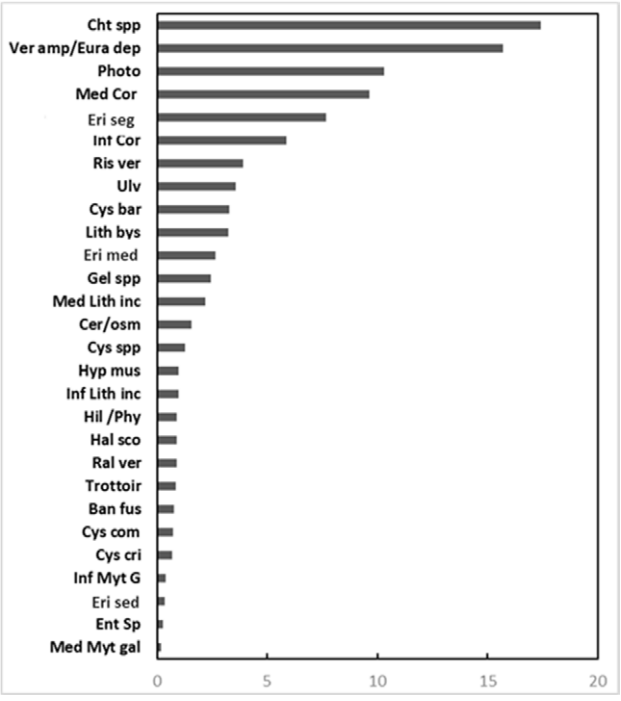

Figure 6 – Frequency of the most common habitats on rocky shores.

Habitat relations in the catenas

The diagram represented in Figure 7 depicts the degree of connection among the rocky habitats. It consists of a cloud of nodes of different sizes arranged in a decreasing gradient from the center to the edges, connected by links whose thickness depends on the degree of connectivity (the larger the link, the thicker the line). The most co-occurring habitats, such as *Verrucaria amphibia-Euraphia depressa* (Ver amp/Eura dep), *Chthamalus* spp. (Cht spp), and the mediolittoral habitat *Ellisolandia elongata* (Med Elli), are located in a central hub with larger node diameters (in brown) and thicker links between them. They are nearly ubiquitous but not connected to freshwater springs (FS ph). The orange nodes located near the center correspond to frequent habitats such as Ulvales (Ulv), photophilic algae (Photo), and infralittoral *Ellisolandia* (Inf Elli). The most frequent fucoids are *E. selaginoides/ amentacea* (Eri Seg/amen) in orange), while the less frequent ones are represented by small yellow nodes at the upper end of the diagram (*Cystoseira humilis, Ericaria sedoides, Ericaria crinita*). The least connected habitats are Freshwater Springs (FS ph), *Ulva* sp. (Ent Sp), and they are also the least frequent habitats.

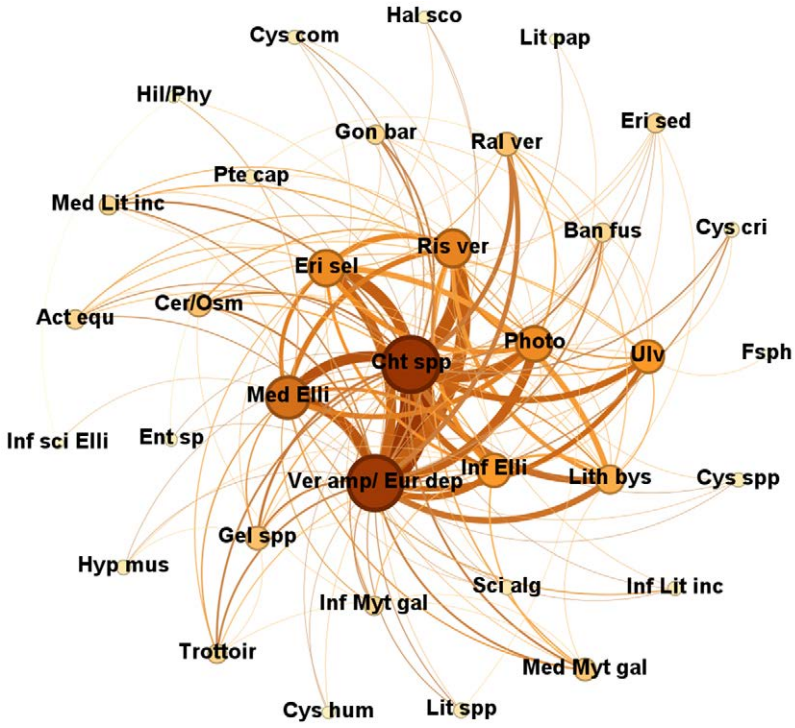

Figure 7– Network of the rocky habitats used for analysis. The habitat codes are listed in Table 2, along with the number of connections between them. The diameter of the nodes and the color darkness are relative to the degree of connections.

Table 2 – Habitat codes ranked by the number of connections between them.

COMMUNITY	CODE	Degree of CONNECTION
***Chthamalus* spp.**	Cht spp	33
Verrucaria amphibia – Euraphia depressa	Ver amp/Eura dep	33
Mediolittoral *Ellisolandia elongata*	Med Elli	26
Infralittoral *Ellisolandia elongata*	Inf Elli	24
Rissoella verruculosa	Ris ver	22
Photophilic algae	Photo	21
Ericaria selaginoides/amentacea	Eri sel	19
Ulvales	Ulv	19
Lithophyllum byssoides	Lith bys	17
Gongolaria barbata	Cys bar	15
Ralfsia verrucosa	Ral ver	14
***Ceramiales/Osmundea* spp.**	Cer/Osm	13
***Gelidium* spp.**	Gel spp	11
Lithophyllum incrustans	Med Lith inc	11
Hypnea musciformis	Hyp mus	11
Mediolittoral *Mytilus galloprovincialis*	Med Myt gal	10
***Hildenbrandia* sp./*Phymatolithon* sp.**	Hil /Phy	10
"Trottoir"	Trottoir	10
Bangia fuscopurpurea	Ban fus	9
Halopteris scoparia	Hal sco	9
Actinia equina	Act equ	7
Infralittoral *Mytilus galloprovincialis*	Inf Myt gal	7
Ericaria sedoides	Eri Sed	7
Cystoseira compressa	Cys com	6
Sciaphilic algae	Sci alg	5
Infralittoral *Lithophyllum incrustans*	Inf Lith inc	5
Pterocladiella capillacea	Ptr cap	5
Ericaria crinita	Eri cri	4
***Cystoseira sensu lato* spp.**	Cys spp	4
***Ulva* sp.**	Ent Sp	4
***Lithophyllum* spp.**	Lit spp	4
Cystoseira humilis sensu lato	Cys hum	3
Lithophyllum papillosum	Lith pap	3
Freshwater soringsq Photophilic algae	FS ph	1
Infralittoral sciaphilic *Ellisolandia elongata*	Inf Sci Elli	1

Discussion

Here we show the first map of the littoral habitats from the Algerian coast. In the first phase of this study 35 habitats were identified along the rocky coastline of the study area. The resulting set, distributed across the supralittoral, mediolittoral, and infralittoral zones, represented the dominant macrophytes and various sessile

filter-feeding animals (mainly barnacles, mussels, bryozoans, and corals) from the study coast.

The habitats dominated by *Euraphia depressa* and *Verrucaria amphibia*, *Chthamalus* spp., and *Ellisolandia elongata* are almost ubiquitous. The subset of habitats formed by *Ericaria selaginoides/amentacea, Lithophyllum byssoides, Rissoella verruculosa,* and photophilic algae appears to be the most frequent after the first group. While these habitats are a measure of the extent of the mediolittoral and infralittoral rocky substrate influenced by moderate to strong waves (ALG-MAR-HAB, LPRE) and high light intensity, their presence of these habitats is evidence of good environmental quality [2]. However, the habitat of artificial coasts such as ports and marinas, spans over a significant portion of the studied coastline (57 km). This distribution allows for an assessment of the harbor walls colonized by organisms adapted to highly fluctuating environmental conditions or those that are very abundant due to a lack of effective competitors on poorly colonized substrates [19].

According to [3] and [21], climate-induced changes in distribution areas have influenced the evolution of a complex formed by three closely related *Ericaria* species which are a key element of Mediterranean and Atlantic seaweed forests experiencing demographic decline. The *E. selaginoides* complex, consisting of *E. tamariscifolia*, *E. amentacea*, and *E. mediterranea*, has indistinct boundaries, and natural hybridization is suspected [21]. Therefore, the term *Ericaria E. selaginoides/ amentacea* is here used to avoid confusion.

Cystoseira sensu lato forests are among the most important structural species in the Mediterranean, creating complex habitats essential for biodiversity and ecosystem functioning. Over recent decades, Mediterranean populations of *Cystoseira* s.l. have generally declined due to anthropogenic pressures [5]; [20]; [7]; [6]; [9]; [22]; [4]; [27]; [25]; [18]; [26]. Our study reveals that *Cystoseira* s.l. forests still exist in various areas along the Algerian coast, in both exposed conditions (*Ericaria selaginoides* complex*, Cystoseira compressa,*) and sheltered conditions (*Gongolaria barbata*, *Cystoseira foeniculacea,* and *Ericaria crinita).*

Biogenic concretions ("trottoir") such as those formed by the red *alga Lithophyllum byssoides* and platforms created by the algae *Neogoniolithon brassica-florida* and the gastropod *Dendropoma lebeche* (vermetid reefs) have been described in only a few locations along the Mediterranean coast. These species are sensitive to coastal disturbances (e.g., surface pollution, trampling) and serve as good indicators of sea level changes [13]; [14]; [15]; [16]; [10]. However, along the rocky coasts surveyed in this study, these bioconcretions were observed throughout the western region. The vermetid reefs appear to be better developed in areas such as Ténès, Beni Haoua, Sidi Ghiles, and Gouraya compared to the Tipaza coast.

Other species, however, thrive in polluted environments and are nitrophilic, tolerating high concentrations of nitrates and phosphates. For instance, Ulvales are frequently found in the Bay of Algiers, with *Ulva lactuca* and *Ulva rigida* being particularly prevalent. These species are considered reliable indicators for assessing eutrophication levels in marine ecosystems [12].

Among the identified habitats, some have no correspondence with other known typologies, such as the association with *Ericaria sedoides.* Notably, this species is also found in Sicily and Tunisia [1], [23]. Additionally, the habitat of mediolittoral caves with *Actinia equina* and *Astroides calycularis* stands out. The anthozoan *Astroides calycularis* has a limited distribution confined to the western Mediterranean, owing to its temperature tolerance [28] and preference for unpolluted environments [24]. In our study, this species was found in the mediolittoral zone, whereas other classifications indicate its presence starting only from the infralittoral zone. [24] provide evidence for the presence of this species from depths as shallow as 0 meters.

Apart from being the most abundant and frequent alga, the red coralline *Ellisolandia elongata* (mediolittoral and infralittoral), shows the highest degree of connections in the network and creates a central hub of connections with other habitats (Figure 7). This is not the case for other specific habitats, such as the mediolittoral cave habitat dominated by *Hildenbrandia rubra* and *Phymatolithon lenormandii*, and the freshwater spring habitat dominated by Ulvales, which both have a very modest number of connections and are rather unconnected to the rest of the network.

The habitat distribution and cover shown in this study will establish an important baseline, something that was lacking for the coast of Algeria. This "starting point" will allow the assessment of the evolution of these habitats and the effects of natural and human-induced disturbances in the study area. The evolution of the different assemblages and their responses to potential impacts, both in the short and the long term, will serve to detect changes in the shore and to investigate their causes.

Conclusion

The ALGMARHAB represents a unique and precise mapping and a comprehensive cartography about the spatial distribution of coastal habitats in Algeria. The use of catenas to map shoreline habitats has proven to be very practical and relevant, enabling the creation of detailed maps.

The ALGMARHAB list has been outlined and is ready to be expanded in the future as a tool for marine habitats monitoring and management. It will represent an invaluable tool to assess changes in habitat distribution and relate them with both natural and anthropogenic pressures.

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Annex 1 – Correspondence between catenaries and Horizons.

Code	N	Community
A1	1	Verrucaria amphibia – Euraphia depressa
A1	2	Chthamalus spp.
A1	3	Rissoella verruculosa
A1	4	Lithophyllum byssoides
A1	5	Hypnea spp
A1	6	Ericaria selaginoides
A1	7	Infralittoral Ellisolandia elongata
A2	1	Verrucaria amphibia – Euraphia depressa
A2	2	Chthamalus spp.
A2	3	Rissoella verruculosa
A2	4	Lithophyllum byssoides
A2	5	Mediolittoral Ellisolandia elongata
A2	6	Mediolittoral Mytilus galloprovincialis
A2	7	Ericaria selaginoides
A2	8	Infralittoral Ellisolandia elongata
A3	1	Verrucaria amphibia – Euraphia depressa
A3	2	Chthamalus spp.
A3	3	Rissoella verruculosa
A3	4	Lithophyllum byssoides
A3	5	Ericaria selaginoides
A3	6	Infralittoral Ellisolandia elongata
A4	1	Verrucaria amphibia – Euraphia depressa
A4	2	Chthamalus spp.
A4	3	Rissoella verruculosa
A4	4	Mediolittoral Ellisolandia elongata
A4	5	Ericaria selaginoides
A4	6	Photophilic algae
A5	1	Verrucaria amphibia – Euraphia depressa
A5	2	Chthamalus spp.
A5	3	Rissoella verruculosa
A5	4	Lithophyllum byssoides
A5	5	Ericaria selaginoides
A5	6	Infralittoral Ellisolandia elongata
A5	7	Ericaria sedoides
B1	1	Verrucaria amphibia – Euraphia depressa
B1	2	Chthamalus spp.
B1	3	Rissoella verruculosa
B1	4	Ulvales
B1	5	Ceramiales/Osmundea spp.
B1	6	Ericaria selaginoides
B1	7	Lithophyllum byssoides
B1	8	Actinia equina
B2	1	Verrucaria amphibia – Euraphia depressa
B2	2	Chthamalus spp.
B2	3	Rissoella verruculosa
B2	4	Ulvales
B2	5	Ericaria selaginoides
B2	6	Lithophyllum byssoides
B2	7	Actinia equina
B3	1	Verrucaria amphibia – Euraphia depressa
B3	2	Chthamalus spp.
B3	3	Rissoella verruculosa
B3	4	Lithophyllum byssoides
B3	5	Hypnea spp
B3	6	Ericaria selaginoides

Code	N	Community
B3	7	Infralittoral Ellisolandia elongata
B4	1	Verrucaria amphibia – Euraphia depressa
B4	2	Chthamalus spp.
B4	3	Rissoella verruculosa
B4	4	Ericaria selaginoides
B4	5	Infralittoral Ellisolandia elongata
B4	6	Photophilic algae
B5	1	Verrucaria amphibia – Euraphia depressa
B5	2	Chthamalus spp.
B5	3	Rissoella verruculosa
B5	4	Lithophyllum byssoides
B5	5	Mediolittoral Ellisolandia elongata
B5	6	Ericaria selaginoides
B6	1	Verrucaria amphibia – Euraphia depressa
B6	2	Chthamalus spp.
B6	3	Rissoella verruculosa
B6	4	Ericaria selaginoides
B6	5	Infralittoral Ellisolandia elongata
B6	6	Gongolaria barbata
B7	1	Verrucaria amphibia – Euraphia depressa
B7	2	Chthamalus spp.
B7	3	Rissoella verruculosa
B7	4	Lithophyllum byssoides
B7	5	Ericaria selaginoides
B7	6	Infralittoral Ellisolandia elongata
B8	1	Verrucaria amphibia – Euraphia depressa
B8	2	Chthamalus spp.
B8	3	Rissoella verruculosa
B8	4	Mediolittoral Ellisolandia elongata
B8	5	Cystoseira compressa
C1	1	Verrucaria amphibia – Euraphia depressa
C1	2	Chthamalus spp.
C1	3	Rissoella verruculosa
C1	4	litophyllum incrustans
C1	5	Mediolittoral Ellisolandia elongata
C1	6	Infralittoral Ellisolandia elongata
C2	1	Verrucaria amphibia – Euraphia depressa
C2	2	Chthamalus spp.
C2	3	Rissoella verruculosa
C2	4	Trottoir
C2	5	Mediolittoral Ellisolandia elongata
C2	6	Infralittoral Ellisolandia elongata
C3	1	Verrucaria amphibia – Euraphia depressa
C3	2	Chthamalus spp.
C3	3	Rissoella verruculosa
C3	4	Lithophyllym byssoides
C3	5	Mediolittoral Ellisolandia elongata
C3	6	Algues sciaphiles
C4	1	Verrucaria amphibia – Euraphia depressa
C4	2	Chthamalus spp.
C4	3	Rissoella verruculosa
C4	4	Mediolittoral Ellisolandia elongata
C4	5	Infralittoral Lithophyllum incrustans
C5	1	Verrucaria amphibia – Euraphia depressa
C5	2	Chthamalus spp.
C5	3	Hildenbrandia sp

Code	N	Community
C5	4	Rissoella verruculosa
C5	5	litophyllum sp
C6	1	Verrucaria amphibia – Euraphia depressa
C6	2	Chthamalus spp.
C6	3	Rissoella verruculosa
C6	4	litophyllum incrustans
C6	5	photophilic algae
D1	1	Verrucaria amphibia – Euraphia depressa
D1	2	Chthamalus spp.
D1	3	Rissoella verruculosa
D1	4	Mediolittoral Ellisolandia elongata
D1	5	Photophilic algae
D2	1	Verrucaria amphibia – Euraphia depressa
D2	2	Chthamalus spp.
D2	3	Rissoella verruculosa
D2	4	Ceramiales/Osmundea spp.
D2	5	Infralittoral Ellisolandia elongata
D3	1	Verrucaria amphibia – Euraphia depressa
D3	2	Chthamalus spp.
D3	3	Rissoella verruculosa
D3	4	Infralittoral Ellisolandia elongata
D3	5	Mediolittoral Mytilus galloprovincialis
D4	1	Verrucaria amphibia – Euraphia depressa
D4	2	Chthamalus spp.
D4	3	Rissoella verruculosa
D4	4	Infralittoral Ellisolandia elongata
D4	5	Photophilic algae
D4	1	Verrucaria amphibia – Euraphia depressa
D4	2	Chthamalus spp.
D4	3	Rissoella verruculosa
D4	4	Mediolittoral Ellisolandia elongata
D4	5	Mediolittoral Mytilus galloprovincialis
D4	6	Infralittoral Mytilus galloprovincialis
D4	7	Infralittoral Ellisolandia elongata
D5	1	Verrucaria amphibia – Euraphia depressa
D5	2	Chthamalus spp.
D5	3	Rissoella verruculosa
D5	4	Ulvales
D5	5	Ceramiales/Osmundea spp.
D5	6	Infralittoral Ellisolandia elongata
D6	1	Verrucaria amphibia – Euraphia depressa
D6	2	Chthamalus spp.
D6	3	Rissoella verruculosa
D6	4	Mediolittoral Ellisolandia elongata
E1	1	Verrucaria amphibia – Euraphia depressa
E1	2	Chthamalus spp.
E1	3	Lithophyllum byssoides
E1	4	Mediolittoral Ellisolandia elongata
E2	1	Verrucaria amphibia – Euraphia depressa
E2	2	Chthamalus spp.
E2	3	Trottoir
E2	4	Mediolittoral Ellisolandia elongata
E3	1	Verrucaria amphibia – Euraphia depressa
E3	2	Chthamalus spp.
E3	3	Trottoir
E3	4	Ericaria selaginoides

Code	N	Community
E3	5	Infralittoral Ellisolandia elongata
E4	1	Verrucaria amphibia – Euraphia depressa
E4	2	Chthamalus spp.
E4	3	Trottoir
E4	4	Gelidium spp
E4	5	Mediolittoral Ellisolandia elongata
E4	6	Ericaria selaginoides
E5	1	Verrucaria amphibia – Euraphia depressa
E5	2	Chthamalus spp.
E5	3	Trottoir
E5	4	Mediolittoral Ellisolandia elongata
E5	5	Mediolittoral Mytilus galloprovincialis
E5	6	Infralittoral Ellisolandia elongata
E6	1	Verrucaria amphibia
E6	2	Chthamalus spp.
E6	3	Lithophyllum byssoides
E6	4	Ericaria selaginoides
E6	5	Photophilic algae
E7	1	Lithophyllum byssoides
E7	2	Mediolittoral Ellisolandia elongata
E7	3	Ericaria selaginoides
E7	4	Infralittoral Ellisolandia elongata
E8	1	Verrucaria amphibia
E8	2	Chthamalus spp.
E8	3	Lithophyllum pustulatum
E8	4	Photophilic algae
E9	1	Verrucaria amphibia – Euraphia depressaEuraphia depressa
E9	2	Chthamalus spp.
E9	3	Bangia sp
E9	4	Lithophyllum byssoides
E10	1	Verrucaria amphibia – Euraphia depressaEuraphia depressa
E10	2	Chthamalus spp.
E10	3	Lithophyllum byssoides/lichenoides
E10	4	Mediolittoral Ellisolandia elongata
E10	5	Photophilic algae
E11	1	Chthamalus spp.
E11	2	Lithophyllum incrustans
E11	3	Ericaria selaginoides
E11	4	Photophilic algae
E12	1	Infralittoral Lithophyllum incrustans
E13	1	Infralittoral Lithophyllum incrustans and mesophyllum sp
E14	1	Mediolittoral Ellisolandia elongata
E14	2	Infralittoral Lithophyllum incrustans
E15	1	Verrucaria amphibia – Euraphia depressa
E15	2	Chthamalus spp.
E15	3	lithophyllum incrustans
E15	4	Hildenbrandia sp
E15	5	corrallianales /ulvales/laurencia
E15	6	Gongolaria barbata
E16	1	Verrucaria amphibia – Euraphia depressa
E16	2	Chthamalus spp.
E16	3	litophyllum incrustans
E16	4	Hildenbrandia sp
E16	5	corrallianales /ulvales/laurencia
F1	1	Verrucaria amphibia – Euraphia depressa
F1	2	Chthamalus spp.

Code	N	Community
F1	3	Ralfsia verrucosa
F1	4	Lithophyllum spp
F1	5	Corrallinales
F2	1	Verrucaria amphibia – Euraphia depressa
F2	2	Chthamalus spp.
F2	3	Ralfsia verrucosa
F2	4	Lithophyllum byssoides
F2	5	Mediolittoral Ellisolandia elongata
F3	1	Verrucaria amphibia – Euraphia depressa
F3	2	Chthamalus spp.
F3	3	Ralfsia verrucosa
F3	4	Lithophyllum byssoides
F3	5	Mediolittoral Ellisolandia elongata
F3	6	Ericaria selaginoides
F4	1	Verrucaria amphibia – Euraphia depressa
F4	2	Chthamalus spp.
F4	3	Ralfsia verrucosa
F4	4	Mediolittoral Ellisolandia elongata
F4	5	Ericaria selaginoides
F4	6	Photophilic algae
F5	1	Verrucaria amphibia – Euraphia depressa
F5	2	Chthamalus spp.
F5	3	Ralfsia verrucosa
F5	4	Mediolittoral Ellisolandia elongata
F5	5	Pterocladiella capillacea
F5	6	Photophilic algae
F6	1	Verrucaria amphibia – Euraphia depressa
F6	2	Chthamalus spp.
F6	3	Ralfsia verrucosa
F6	4	Lithophyllum incrustans
F6	5	Photophilic algae
F7	1	Verrucaria amphibia – Euraphia depressa
F7	2	Chthamalus spp.
F7	3	Bangia fuscopurpurea
F7	4	Ralfsia verrucosa
F7	5	Ulvales Infralittoral
F7	6	Infralittoral Ellisolandia elongata
F8	1	Verrucaria amphibia – Euraphia depressa
F8	2	Chthamalus spp.
F8	3	Ralfsia verrucosa
F8	4	Ulvales
F8	5	Mediolittoral Ellisolandia elongata
F8	6	Photophilic algae
F9	1	Verrucaria amphibia – Euraphia depressa
F9	2	Chthamalus spp.
F9	3	Bangia fuscopurpurea
F9	4	Ralfsia verrucosa
F9	5	Ulvales Infralittoral
F9	6	Infralittoral Ellisolandia elongata
F10	1	Verrucaria amphibia – Euraphia depressa
F10	2	Chthamalus spp.
F10	3	Ralfsia sp/litophyllum
F10	4	Photophilic algae
F10	5	Ericaria selaginoides
F10	6	Infralittoral Corrallina elongata
F10	8	Halopteris scoparia

Code	N	Community
F10	9	Infralittoral corallinales
G1	1	Chthamalus spp.
G1	2	Gelidium spp
G1	3	Corallinales
G2	1	Verrucaria amphibia – Euraphia depressa
G2	2	Chthamalus spp.
G2	3	Gelidium spp
G2	4	Corallinales
G2	5	Photophilic algae
G3	1	Verrucaria amphibia – Euraphia depressa
G3	2	Chthamalus spp.
G3	3	Mediolittoral Ellisolandia elongata
G3	4	Ericaria selaginoides
G3	5	Photophilic algae
G4	1	Verrucaria amphibia – Euraphia depressa
G4	2	Chthamalus spp.
G4	3	Mediolittoral Ellisolandia elongata
G4	4	Ericaria selaginoides
G4	5	Photophilic algae
G5	1	Verrucaria amphibia – Euraphia depressa
G5	2	Chthamalus spp.
G5	3	Mediolittoral Ellisolandia elongata
G5	4	Cystoseira spp
G5	5	Photophilic algae
G6	1	Verrucaria amphibia – Euraphia depressa
G6	2	Chthamalus spp.
G6	3	Gelidium spp
G6	4	Hypnea musciformis
G6	5	Infralittoral Ellisolandia elongata
G7	1	Chthamalus spp.
G7	2	Ceramiales
G7	3	Ulvales
G7	4	Infralittoral Ellisolandia elongata
G8	1	Verrucaria amphibia – Euraphia depressa
G8	2	Chthamalus spp.
G8	3	Ulvales
G8	4	Infralittoral Ellisolandia elongata
G9	1	Verrucaria amphibia – Euraphia depressa
G9	2	Chthamalus spp.
G9	3	Infralittoral Ellisolandia elongata
G10	1	Chthamalus spp.
G10	2	Ulvales
G10	3	Mediolittoral Ellisolandia elongata
G10	4	Photophilic algae
G11	1	Verrucaria amphibia – Euraphia depressa
G11	2	Chthamalus spp.
G11	3	Bangia fuscopurpurea
G11	4	Ulvales
G11	5	Gelidium spp
G11	6	Mediolittoral Ellisolandia elongata
G11	7	Photophilic algae
G12	1	Verrucaria amphibia – Euraphia depressa
G12	2	Chthamalus spp.
G12	3	Ceramiales/Osmundea spp.
G12	4	Mediolittoral Ellisolandia elongata
G12	5	Infralittoral Mytilus galloprovincialis

Code	N	Community
G12	6	Infralittoral Ellisolandia elongata
G13	1	Mediolittoral Ellisolandia elongata
G13	2	Ericaria selaginoides
G13	3	Photophilic algae
G14	1	Mediolittoral Ellisolandia elongata
G14	2	Ericaria selaginoides
G14	3	Photophilic algae
G15	1	Mediolittoral Ellisolandia elongata
G15	2	Infralittoral Lithophyllum incrustans
G16	1	Gelidium spp
G16	2	Mediolittoral Ellisolandia elongata
G16	3	Cystoseira compressa
G16	4	Photophilic algae
G17	1	Barren rock
G17	2	Mediolittoral Ellisolandia elongata
G17	3	Infralittoral Ellisolandia elongata
G18	1	Corallinales
G18	2	Cystoserira sedoises
G19	1	Verrucaria amphibia – Euraphia depressa
G19	2	Chthamalus spp.
G19	3	Ulvales
G19	4	Mediolittoral Ellisolandia elongata
G20	1	Corallinales
G20	2	Gongolaria barbata
G21	1	Mediolittoral Ellisolandia elongata
H1	1	Hildenbrandia sprandia sp./Phymatolithon sp.
H1	2	Mediolittoral Ellisolandia elongata
H1	3	Infralittoral Ellisolandia elongata
H2	1	Hildenbrandia sprandia sp./Phymatolithon sp.
H2	2	Mediolittoral Ellisolandia elongata
H2	3	Infralittoral sciaphilic Ellisolandia elongata
H3	1	Bangia fuscopurpurea
H3	2	Red algae
H3	3	Photophilic algae
H4	1	Verrucaria amphibia – Euraphia depressa
H4	2	Chthamalus spp.
H4	3	Bangia fuscopurpurea
H4	4	Ulvales
H4	5	Infralittoral Ellisolandia elongata
I1	1	Ericaria selaginoides
I1	2	Photophilic algae
I2	1	Barren rock
I2	2	Photophilic algae
I2	3	Gongolaria barbata
I3	1	Verrucaria amphibia – Euraphia depressa
I3	2	Chthamalus spp.
I3	3	Enteromorpha sp
I3	4	Gongolaria barbata
I3	5	Halopteris sp
I4	1	Gravel
I4	2	Gongolaria barbata
I5	1	Verrucaria amphibia – Euraphia depressa
I5	2	Chthamalus spp.
I5	3	Cystoseira humilis
I5	4	Photophilic algae
I6	1	Verrucaria amphibia – Euraphia depressa

Code	N	Community
I6	2	Chthamalus spp.
I6	3	Ericaria crinita
I6	4	Photophilic algae
I7	1	Chthamalus spp.
I7	2	Cystoseira compressa
I8	1	Verrucaria amphibia – Euraphia depressa
I8	2	Chthamalus spp.
I8	3	Ericaria selaginoides
I9	1	Verrucaria amphibia – Euraphia depressa
I9	2	Chthamalus spp.
I9	3	Ulvales
I9	4	Ceramiales
I9	5	Hypnea sp
I9	6	Gongolaria barbata
I10	1	Verrucaria amphibia – Euraphia depressa
I10	2	Chthamalus spp.
I10	3	Ericaria crinita
I11	1	Verrucaria amphibia – Euraphia depressa
I11	2	Chthamalus spp.
I11	3	Ulvales
I11	4	Ericaria crinita
I14	1	Verrucaria amphibia – Euraphia depressa
I14	2	Chthamalus spp.
I14	3	Ulvales
I15	1	Verrucaria amphibia – Euraphia depressa
I15	2	Chthamalus spp.
I15	3	Photophilic algae
I16	1	Mediolittoral rock pools with Ulvales
I16	1	Infralittoral Mytilus galloprovincialis
I17	1	Photophilic algae Infralittoral
J1	1	Posidonia oceanica
J2	1	Cymodocea nodosa and Zostera noltii
K1	1	Barren rock
L1	1	Sea urchin overgrazing
M1	1	Freshwater sources Photophilic algae
N1	1	Mediolittoral and infralittoral of Ports et marinas
N2	1	Mediolittoral and infralittoral of artificialized coast
O	1	Soft-bottom

Annex 2 – The benthic habitats found along the coast studied, corresponding to the EUNIS, CORINE and LPRE typologies.

Stage Level	Habitat	Alg-Mar-Hab Code	Lpre Code	Corine Code	Eunis Code
Supralittoral	Cyanobacteria and lichen association	A1.01	01010102		A1.42
Supralittoral	Facies with *Melarhaphe neritoides, Euraphia depressa* and *Chthamalus* spp	A1.02	01010103		A1.161
Supralittoral	Facies with *Verrucaria* sp.	A1.03	01010103	18.16	
Supralittoral	Freshwater spring in supralittoral rock	A1.04	010102	18.18	
Supralittoral	Cuvettes with variable salinity	A1.05	0101102	18.17	A1.42
Supralittoral lower	Facies with *Patella* spp. & *Chthamalus* spp.	A1.06	02010214	18.1311	A1.112
Mediolittoral/ High hydrodynamic	Facies with *Patella* spp. & *Chthamalus* spp	A2.01.01.01	02010214	18.1311	A1.112
Mediolittoral/ High hydrodynamic	Association with *Lithophyllum byssoides* TROTTOIR	A2.01.01.02	02010115	18.132	A1.141
Mediolittoral/ High hydrodynamic	Belt of *Neogoniolithon brassica-florida*	A2.01.01.03	02010226	18.112	A1.134
Mediolittoral/ High hydrodynamic	Association with *Corallina elongata*	A2.01.01.04	02010227	18.111	
Mediolittoral/ High hydrodynamic	Association with *Gellidium* spp	A2.01.01.05	02010311	18.127	A1.233
Mediolittoral/ High hydrodynamic	Association with *Rissoella verruculosa*	A2.01.01.06	02010215	18.1313	A1.133
Mediolittoral/ High hydrodynamic	Facies with *Bangia atropurpurea*	A2.01.01.07	02010220	18.1316	A1.131
Mediolittoral/ High hydrodynamic	Facies with *Mytilus galloprovincialis*	A2.01.01.08	02010224	18.113	
Mediolittoral/ High hydrodynamic	Association with Ceramiales	A2.01.01.09	0201011202	18.125	
Mediolittoral/ High hydrodynamic	Facies with vermets *Dendropoma lebeche*	A2.01.01.10	02010226	18.112	
Mediolittoral/ Moderate hydrodynamic	Facies with photophilic red algae	A2.01.02.01			A1.12
Mediolittoral/ Moderate hydrodynamic	Association with *Polysiphonia* spp	A2.01.02.02	02010219	18.1315	
Mediolittoral/ Moderate hydrodynamic	Association with *Padina pavonica* et *Halopteris scoparia*	A2.01.02.03	0201021303		
Mediolittoral/ Moderate hydrodynamic	Association with *Ralfsia verrucosa*	A2.01.02.04	02010216	18.1314	
Mediolittoral/ Moderate hydrodynamic	Facies with *Rissoela verruculosa*	A2.01.02.05	02010215	18.1313	A1.133
Mediolittoral/ Moderate hydrodynamic	Facies with *Lithophyllum papillosum*	A2.01.02.06	02010226	18.112	
Mediolittoral/ Moderate hydrodynamic	Facies with *Lithophyllum byssoides*	A2.01.02.07	02010115	18.132	A1.141
Mediolittoral/ Moderate hydrodynamic	Facies with *Corallina elongata*	A2.01.02.08	02010227	18.111	
Mediolittoral/hy Moderate hydrodynamic	Facies with *Ulva rigida*	A2.01.02.09	0201231	18.126	A1.341

Stage Level	Habitat	Alg-Mar-Hab Code	Lpre Code	Corine Code	Eunis Code
Mediolittoral/ Moderate hydrodynamic	Facies with Vermets *Dendropoma lebeche*	A2.01.02.10	02010226	18.112	
Mediolittoral/ Moderate hydrodynamic	Facies with *Hypnea* sp	A2.01.02.11	02010235	18.111	
Mediolittoral/Sheltered	Belt with *Nemoderma* sp	A2.01.03.01	02010308	18.122	
Mediolittoral/Sheltered	Association with *Lithophyllum incrustans*	A2.01.03.02	02010309	18.124	
Mediolittoral cave	Mediolittoral caves with *Lithophyllum byssoides*	A2.01.04.01.	02010225	18.121	A1.141
Mediolittoral cave	Mediolittoral caves with *Hildenbrandia rubra et Phymatolithon lenormandii*	A2.01.04.02.	02010404	18.14	A1.44B
Mediolittoral cave	Mediolittoral caves with *Lithophyllum* spp	A2.01.04.03.	02010309	18.124	
Mediolittoral cave	Mediolittoral caves with *Actinia equina* et *Astroides calycularis*	A2.01.04.04.			
Mediolittoral cave	Mediolittoral caves with *Actinia equina*	A2.01.04.05.			
Mediolittoral basins	Encrusting algae and sea urchins	A2.01.05.01	02010404	18.15	
Mediolittoral basins	Association with *Cystoseira* spp	A2.01.05.02	02010405	18.16	
Mediolittoral basins	Association with vermets	A2.01.05.03	02010406	18.17	
Mediolittoral basins	Association with Ulvales	A2.01.05.04	02010407	18.18	
Mediolittoral basins	Association with Dictyotales	A2.01.05.05	02010408	18.19	
Mediolittoral basins	Association with *Codium* spp	A2.01.05.06	02010409	18.20	
Upper infralittoral	Association with *Ericaria selaginoides*	A3.01.01.01	030102210	11.2411	
Upper infralittoral	Association with *Sargassum vulgare*	A3.01.01.02	0301030511		
Upper infralittoral	Association with *Sargassum spp*	A3.01.01.03	0301011702		
Upper infralittoral	Association with *Cystoseira barbata/Cystoseira foeniculacea*	A3.01.01.04	0301030601		
Upper infralittoral	Association with *Cystoseira compressa*	A3.01.01.05	0301030508		
Upper infralittoral	Fucales forests	A3.01.01.06	03010116		
Upper infralittoral	Association with *Ericaria crinita*	A3.01.01.07	030103050	11.24131	
Upper infralittoral	Association with *Cystoseira sedoides*	A3.01.01.08			
Upper infralittoral	Facies with Dictyotales	A3.01.01.09	0301021603		
Upper infralittoral	Association with *Padina pavonica*	A3.01.01.10	0301021701		
Upper infralittoral	Association with *Dictyopteris polypodioides, Zonaria tournefortii*	A3.01.01.11	0301021601		
Upper infralittoral	Association with *Halopteris scoparia*	A3.01.01.12	030103070	11.24141	A3.331
Upper infralittoral	Photophilic algae in the absence of fucales	A3.01.01.13	030103070	11.24141	A3.331

Stage Level	Habitat	Alg-Mar-Hab Code	Lpre Code	Corine Code	Eunis Code
Upper infralittoral	Association with *Codium* spp	A3.01.01.14	03010218		
Upper infralittoral	Association with *Colpomenia sinuosa*	A3.01.01.15	0301030711		
Upper infralittoral	Association with *Ulva* spp	A3.01.01.16			
Upper infralittoral	Facies with *Mytilus* spp	A3.01.01.17	03010502		
Upper infralittoral	Facies a *Plocamium cartilagineum*	A3.01.01.18	0301022301	11.24182	
Upper infralittoral	Association with *Pterocladiella capillacea*	A3.01.01.19	0301022303	11.24183	A3.334
Upper infralittoral	Association with *Corallina elongata* et algues photophiles	A3.01.01.20	0301022202	11.24121	A3.135
Upper infralittoral	Association with *Corallina elongata*	A3.01.01.21	0301022302	11.24182	
Upper infralittoral	Overgrazed facies with encrusting calcareous algae and sea urchins	A3.01.01.22	03010115		A3.131
Upper infralittoral	Facies with *Lithophylum incrustans*	A3.01.01.23	0301030901	11.24142	A3.131
Upper infralittoral	Association with *Lithophyllum* spp. and *Mesophyllum* spp	A3.01.01.24	03010114		
Upper infralittoral	Facies with *Asparagopsis armata/Taxiformis*	A3.01.01.25	0301022205		
Upper infralittoral	Facies with *Grateloupia lanceola*	A3.01.01.26	0301021401		
Upper infralittoral	Sciaphilic algae	A3.01.01.27	03010411		
Roche artificielle	Managed coastline (decimetric blocks)	A4.01			J4.5
Roche artificielle	Ports and marinas coast	A4.02	070108	89.11	J4.5
Seagrass meadows	*Posidonia oceanica* meadow	A5.01	030512	11.34	A5.535
Seagrass meadows	*Zostera noltii* meadow	A5.02	0305130105		
Seagrass meadows	*Cymodoceae nodosa* meadow	A5.03	03051301041	11.331	A5.53132
Seagrass meadows	*Posidonia oceanica* death mattes	A5.04	03051203	16.1123	A2.13