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A new classification scheme of European cold-water coral habitats: implications for ecosystem-based management of the deep sea

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Abstract :

Cold-water coral (CWC) habitats can form complex structures which provide refuge, nursery grounds and physical support for a diversity of other living organisms, but despite their ecological significance, CWCs are still vulnerable to human pressures such as fishing, pollution, ocean acidification and global warming

Providing coherent and representative conservation of vulnerable marine ecosystems including CWCs is one of the aims of the Marine Protected Areas networks being implemented across European seas and oceans under the EC Habitats Directive, the Marine Strategy Framework Directive and the OSPAR Convention. In order to adequately represent ecosystem diversity these initiatives require a standardised habitat classification that organises the variety of biological assemblages and provides consistent and functional criteria to map them across European Seas (Howell 2010). One such classification system, EUNIS, enables a broad level classification of the deep sea based on abiotic and geomorphological features. More detailed lower biotope-related levels are currently under-developed, particularly with regards deep-water habitats (>200 m depth).

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This paper proposes a hierarchical CWC biotope classification scheme that could be incorporated by existing classification schemes such as EUNIS. The scheme was developed within the EU FP7 project CoralFISH to capture the variability of CWC habitats identified using a wealth of seafloor imagery datasets from across European seas and oceans. Depending on the resolution of the imagery being interpreted, this hierarchical scheme allows data to be recorded from broad CWC biotope categories down to detailed taxonomy-based levels, thereby providing a flexible yet valuable information level for management. The CWC biotope classification scheme identifies 81 biotopes and highlights the limitations of the classification framework and guidance provided by EUNIS, the EC Habitats Directive, OSPAR and FAO; with limited categories for identifying and classifying these CWC habitats.

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1. Introduction

1.1 Cold-water coral habitats

Due to the high biodiversity associated with coral-dominated habitats and their ecological significance as physical support, refuge or nursery area for other living organisms; interest in cold-water corals (CWC) has grown significantly throughout the last two decades (e.g. Freiwald et al. 2004; Bryan and Metaxas 2007; Henry and Roberts 2007; O'Hara et al. 2008, Roberts et al. 2009). Because of their vulnerability to fishing activity (Rogers, 1999; Fosså et al. 2002; Roberts 2002; Grehan et al. 2005; Waller et al. 2007), a number of CWC habitats were earmarked for conservation. In 2004, '*Lophelia pertusa* reefs', 'coral gardens', 'carbonate mounds' and 'sea-pen and burrowing megafauna communities' were considered as 'threatened or declining' under the Oslo-Paris Convention for the Protection of the Northeast Atlantic (OSPAR Agreement 2004-6). In 2007, cold-water coral reefs and several types of coral gardens came under the definition of the 'Reefs' habitat listed in Habitats Directive (92/43/EEC) Annex I and in 2009, CWCs habitats were listed as Vulnerable Marine Ecosystems (VMEs) by the United Nations General Assembly (UNGA Resolution 61/105 and FAO, 2009).

CWC habitats typically occur in areas with geomorphological elevations, entirely or partly created by azooxanthellate frame-building coral species, known as CWC reefs, banks and mounds according to their size, shape and composition (e.g. Freiwald et al. 2004, Roberts et al. 2009). They are widespread along the NE Atlantic margin, at shelf breaks and on the upper continental slope (De Mol et al. 2002; Freiwald et al. 2004; Roberts et al. 2009),

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typically found in areas of pronounced topographic relief such as the slopes of banks, submarine canyons, and seamounts (Genin et al. 1986; Frederiksen et al. 1992; MacIsaac et al. 2001; Auster et al. 2005; Davies et al. 2014, 2015) associated with hard substrate (Freiwald et al. 1999; Bryan and Metaxas 2007). Recent studies have shown the presence of cold-water coral habitats in Mediterranean deep-sea environments, occurring on the top and flanks of coral-formed or coral-topped relief (e.g. Vertino et al. 2010, Rosso et al. 2010, Savini and Corselli, 2010, Savini et al. 2014, Lo Iacono et al. 2015, Savini et al. 2016) as well as along escarpments and canyon walls (e.g. Freiwald et al 2009, Sanfilippo et al. 2012, Gori et al. 2013, Taviani et al. 2011, 2015). In order to take an ecosystem-based approach to managing deep-sea environments and achieve an ecologically-coherent network across biogeographic regions, it is essential that we develop and structure our understanding of the variety and distribution of benthic habitats or biotopes. Biotopes represent distinct biological assemblages associated with certain environmental factors such as substratum and depth (Dahl 1908).

Combining habitat maps originating from national and international programmes is necessary, but this can only be done harmoniously if standardised terminology exists. To date deep-sea maps produced by different projects / countries cannot be combined because of a lack of an agreed deep-sea classification system and recognised and agreed definitions of mapping units.

1.2 **Habitat classification schemes as a mapping prerequisite**

A premise to biotope mapping is having a systematic inventory and consistent descriptions of the biological assemblages to be used as mapping units. Habitat classification schemes are instrumental to these exercises as they present the diversity of biological units to be mapped in a structured and systematic way, ensuring consistency, repeatability and comparability between maps from different regions.

1.2.1. The EUNIS classification

A range of marine habitat classification schemes which are applicable to the deep sea exist, and include (i) those that are top-down schemes with a predominantly geological basis (e.g. Greene et al. 1999) and (ii) those that are hierarchical, nested, and aim at ultimately resolving biotopes, such as the European Nature Information System (EUNIS).

EUNIS is a European hierarchical habitat classification scheme that was designed to facilitate and standardise data collection and description of terrestrial, freshwater and marine

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environments across Europe. Developing such standards in a balanced and comprehensive way throughout the diversity of environments is vital to allow continuity of data when producing habitat maps. Within the marine category (split from terrestrial environments at level 1), the deep seabed is discriminated at level 2 (A6) and subsequently divided into zones on the basis of substrate (level 3) and benthic assemblages (level 4). Topographically-based deep-sea habitat complexes such as seamounts and canyons are also included in level 3, but would be more appropriately placed at higher hierarchical levels. EUNIS currently fails to provide as much detail for deep-water habitats (>200 m) as it does for shallow-water habitats (Galparsoro et al. 2012; Tempera et al. 2013).

1.3 **Deep-sea environments**

The first effort to describe seabed assemblages for use in the mapping of the broad deep-sea areas off the European shores is traditionally attributed to Le Danois (1948), who worked on the basis of dredged samples in the Bay of Biscay. More recently, with the dissemination of *in situ* still and video imagery as a method of sampling the benthos, descriptions of deep-sea benthic assemblages have advanced more rapidly (e.g. Laubier and Monniot 1985; Howell et al. 2010; Vertino et al. 2010, Tempera et al. 2013; Davies et al. 2014, 2015; De Leo et al. 2014). However, these efforts are still restricted to smaller areas within national waters and a comprehensive biogeographical coverage remains to be completed.

This paper contributes to refining existing classification schemes by hierarchically organising the diversity of CWC biotopes inventoried under project CoralFISH using seafloor imagery from the Northeast Atlantic and Mediterranean.

2. **Methods**

2.1 **CoralFISH project**

The CoralFISH project ran between 2008 and 2013 by a consortium of 17 institutes and small/medium enterprises from 11 countries receiving co-funding from the 7th Framework Programme. Its objective was to assess the interaction between CWCs, fish and fisheries in order to develop monitoring and predictive modelling tools for ecosystem-based management in the deep waters of Europe and beyond.

In its scope, six target areas spread out over the Northeast Atlantic Ocean and the Mediterranean Sea were studied: Northern Norway – eastern Norwegian Sea, Iceland, Porcupine Seabight / Rockall Trough, Bay of Biscay, Azores and the Ionian sector of the Mediterranean Sea.

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Figure 1. Schematic representation of the six regional study areas of the CoralFISH project; their location is here referred to the corresponding European marine ecoregion, as defined from the Report of the ICES Advisory Committee on Fishery Management and Advisory Committee on the Ecosystem, 2004. The six study areas are located; (1) offshore south Iceland (ecoregion A); (2) offshore Norway (ecoregion D); (3) offshore western Ireland (Porcupine Bank and Seabight, and Rockall Trough; ecoregion E); (4) offshore western France (Bay of Biscay, ecoregion G); (5) offshore Italy and Greece in the Eastern Mediterranean sea (Northern Ionian sea, ecoregion I) and (6) in the Azores archipelago (ecoregion K).

2.2 **Habitat classification scheme**

2.2.1 Cold-Water Coral habitat identification

A CWC habitat was defined where a coherent suite of conspicuous epibenthic organisms including CWCs (as defined by Roberts et al. 2009) extended throughout a minimum estimated area of 25 m^2 (as observed by underwater cameras). Generally, the individual habitats catalogued: (i) were repeatedly observed in multiple seafloor photos or along a video footage stretch representing an area $\geq 25\ m^2$ and (ii) showed similar dominant species compositions in different locations. Areas with a high along-track turnover rate in dominant species were interpreted as transitional habitats and avoided in establishing typical species compositions.

The analyses spanned seven major physiographic provinces between 200 and 3,300 m depth, as explained below.

Imagery sources ranged from old discoloured slides from the late 1960's or aged VHS footage from the early 1990's to high-definition (full-HD) video and high-resolution digital photography from the early 2010's with resolutions as high as 3072x2304 pixels (additional details can be found in Vertino et al. 2010; Savini et al. 2014; Rengstorf et al. 2014; Van den Beld et al. this issue; Arnaud-Haond et al. this issue).

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Geological classification

Following Harris et al. (2014) standardised geomorphological classification of the ocean seafloor were used for each level 3 biotope. Within the physiographic provinces investigated by the CoralFISH project, 7 major physiographic provinces were identified: 1. Continental shelf, 2. Continental slope, 3. Continental rise, 4. Abyssal hills and mountains (seamounts), 5. Volcanic islands (including upper bathyal hill on island slope), 6. Oceanic banks and plateau (Banks rises and plateau), 7. Abyssal plains (basin areas – on abyssal zone).

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In all of the physiographic provinces investigated, CWC were associated with different geomorphic units. The terminology used to define geomorphic units was aimed at indicating (*Sensu* Harris 2011, which recognises the importance of seafloor geomorphology in understanding the distribution of benthos) the main geomorphic features and substrate types which typify the locations in which CWC biotopes are known from the literature and/or characterised in the six CoralFISH study areas, as described below. Most of the terms used are also reported in standardised classification of ocean basins (although no official agreement exist between scientists in using the most appropriate terms for the different situations – MIM partnership, *in press*; Dove et al. 2016), for example the ones reported by the International Hydrographic Organisation (IHO, 2008) or by Harris et al. 2014 (Geomorphology of the oceans). Geomorphic units used in our work include *Carbonate mounds*, *Canyon systems*, *Mass-movement deposits* and *Submarine glacial landforms* that represent the major submarine landforms characterising the surveyed regions in the six CoralFISH study areas. In addition, *Bedrock and escarpments* were also considered to refer to those regions dominated by erosive processes or hard substrate or mixed sediments (including volcanic substrates forming volcanic cones or other volcanic landforms); whereas those region of the bathyal plane that do not belong to common submarine landforms and are covered by soft sediment, were indicate as *Smooth and featureless slope regions*.

2.2.2 Habitat classification

The main factors taken into consideration in the habitat classification proposed were:

(i) the dominant species or group of species.

(ii) type of substrate, with the two main categories separating hard substrate (including mixed substrate and consolidated mud) and soft substrate; in particular cases, boulder habitats and vertical walls are also discriminated given the major changes in species and environmental conditions associated with them.

(iii) the presence of coral framework (three-dimensional structure created by in-place scleractinians whose skeletons are in mutual contact and/or merged), with subordinate classes distinguishing alive or completely dead framework, the complexity of the 3D structure and the level of colonisation by other groups;

Some additional CWC habitats known from literature but not necessarily encountered in CoralFISH study areas were included with indication of sources, to provide a fully

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comprehensive classification scheme.

The majority of the terminology used in Table 1 follows the CoralFISH glossary for underwater video analysis of European CWC habitats.

2.2.3 Taxonomical identification

Emphasis was given to conspicuous habitat-building organisms and main characteristic species when establishing biotopes and the species composition list. Given the limitations in the resolution provided by many imagery sources, generally only taxa >10 cm were identified. Where voucher specimens were not collected, the authors' taxonomical expertise and macroscopic correspondence to specimens in reference collections, or to referenced *in situ* taxa images, were used to establish the best taxonomic identification (i.e. high level of certainty to a given taxonomic level) of the organisms observed in the imagery. Despite the fact that non-calcified hydrozoans are not traditionally considered as corals, the habitats some of them form (e.g. order Leptothecata) share structural (and possibly functional) similarities with gorgonian gardens. They have thus been included in the definition of corals used in the CoralFISH glossary (Beuck et al. *in prep*) and the biotopes they structure integrate our classifications scheme.

2.2.4 Correspondences with others classifications

Wherever possible, correspondence of habitats to the following were achieved (i) Habitats Directive, (ii) OSPAR list of threatened and/or declining species and habitats, (iii) the EUNIS classification, and (iv) FAO/NEAFC Vulnerable Marine Ecosystems (VMEs) (ICES Advice 2013, Book 1). As the FAO categories for VMEs are limited the NEAFC proposed VMEs were used.

Coral gardens are defined in the scope of the OSPAR Convention as a relatively dense aggregation of colonies or individuals of one or more coral species. Following the CoralFISH glossary (Beuck et al. *in prep*), coral gardens can also be dominated by frame-building scleractinian species but differ from coral frameworks and reefs because coral skeletons are not in mutual contact and do not form large three-dimensional carbonate structures. Where no established criteria or statistical analyses were provided, assemblages were identified as "potential coral garden".

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3. Results

The CWC habitats were classified into three biotope levels (Table 1): Biotope L1 is characterised by the dominant group of taxa and structure (e.g. reef, framework, rubble) or the dominant group of taxa and substrate typology (soft, mixed, hard); Biotope L2 is characterised by the dominant group of taxa, structure and density measure (e.g. dense or loosely-packed framework), substrate and presence of colonisation by other species and Biotope L3 is characterised by the dominant subgroup of taxa (defined at genus or species level where possible), structure and/or substrate and/or secondary group of taxa (colonisation) and, where relevant, geoform. Biotope level relates to varying levels in taxonomic resolution, with level 1 being a low resolution category and 3 being a higher resolution category. Sixteen level 1 biotopes, 25 level 2 and 81 level 3 categories were identified (See Table 1). For some categories it was unclear if there was a placement for the corresponding categories under the listed habitats, in these instances, it was labelled as unclear (See Suppl Table 1).

The majority of these habitats correspond to habitats listed in directives and conventions: 66 fall under the OSPAR list of priority habitats, 62 under the Habitats directive and 71 fit the VME categories established by NEAFC. All 81 habitats could be classified using the substrate classification level in EUNIS, but only 9 corresponded to existing EUNIS biotopes (See Suppl (Guillamount et al. 2016) for full CWC habitat classification and Suppl Table 1 for comparison with other habitat classification scheme and listed habitats). Note that the CMECS (Coastal and Marine Ecological Classification Standard) system developed by NOAA has been included in the Supple table 1 to allow comparison with the CoralFISH Scheme, and also to illustrate a more comprehensive scheme than the current European models. As it is not a European-based system, it will not be discussed within this paper. For each biotope, associated metadata are given in the CWC catalogue (Suppl), with a full list of the physiographic province and geomorphic unit each biotope is associated with throughout the CoralFISH study area given in the Suppl Table 2.

4. Discussion

The large diversity of biotopes identified at different resolution levels demonstrates that not only imagery from recent expeditions but also historical photographic datasets represent

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valuable sources of information for deep-sea bionomy, even in situations where the original purpose of the surveys was not biotope recognition (e.g. geological exploration expeditions from the late 1960's up to the 1990's).

4.1 Listed habitats

The various initiatives list only three habitats which relate to those biotopes described in the CoralFISH CWC scheme: cold-water coral reefs (OSPAR, Habitats Directive and VME), coral gardens (OSPAR, Habitats directive and VME), and seapen communities (OSPAR and VMEs). These categories are widely used from an operational point of view (i.e. policy making) to give weight to habitats of conservation concern, and the CoralFISH CWC classification scheme presented here highlights a lack of taxonomic details that are of concern for the effectiveness of these categories. For example, under OSPAR, coral gardens are defined as ‘a habitat which has a relatively dense aggregation of individuals or colonies of one or more coral species which can occur on a wide range of soft and hard substrates’ (OSPAR 2010). In the context of hard substrate this habitat has been described as being dominated by gorgonian, stylasterid and/or antipatharian corals (ICES 2007) and can develop on exposed bedrock, boulders or cobbles (Roberts et al. 2009). The OSPAR definition of coral gardens is very broad, and the habitat in terms of biodiversity and densities of associated species can vary with region, hydrography, topography, substrate and depth (OSPAR 2010). To adequately protect such habitats, better criteria (including examples of coral garden habitats) are required to allow appropriate assessment and discrimination of the distinct habitat types embedded in this category (Bullimore et al. 2013).

The working definitions of listed habitats are restricted and vague. While some biotopes clearly adhere to those described under listed habitats, e.g. *Lophelia pertusa* reefs (1.1.1 in the proposed CoralFISH scheme) to ‘Biogenic reef’ (Annex I, Habitats Directive), ‘*Lophelia pertusa* reefs’ (OSPAR), and ‘deep-sea *L. pertusa* reefs’ (EUNIS); the placement of many others under these schemes is unclear. For example, when *Madrepora oculata* is the dominant reef-building coral none of the listed categories provides a good fit. Under the Habitats Directive only *L. pertusa* is mentioned, OSPAR only acknowledges the species as characteristic of the *Lophelia* dominated reefs and EUNIS can only be used if we take the unspecific level of ‘communities of deep-sea corals’.

4.2 Classification schemes

Existing habitat classification schemes are not adequate to support representative protection

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of vulnerable deep-sea biotopes such as those formed by cold-water corals. For example, under EUNIS, 'Bioherms' (large biological structures, formed by e.g. corals or sponges) are not split up despite many authors reporting distinct assemblages associated with different bioherm zones [e.g. mostly live coral on coral mound summit; mostly dead framework and coral rubble on the flanks and surrounding seafloor; as described by Mortensen et al. (1995), Pfannkuche et al. (2004), Wienberg et al. (2008), Roberts et al. (2009), Vertino et al. (2010) Davies et al. (2015)]. Additionally, in the EUNIS deep-sea bioherm section (A6.6) only one coral biotope is considered: Deep-sea *Lophelia pertusa* reefs. This does not reflect the range of deep-sea CWC bioherm biotopes identified by the CoralFISH inventory.

An objective, comprehensive and representative classification scheme using consistent terminology is required for describing the diversity of such habitats found across European seas. The CoralFISH CWC biotope classification scheme (i) addresses the shortcomings of other schemes, (ii) represents the regional variation of cold-water coral habitats and (iii) can be related to habitats listed in EU Directives and international Conventions.

The CoralFISH CWC classification scheme is compatible and could be included with CWC biotopes discrimination at EUNIS levels 4 to 6 - a proposal that is consistent with the perspective of the upcoming EUNIS revision (Doug Evans, unpublished data). It is assumed that at EUNIS level 3 deep-sea habitats are divided on the basis of substrate, which has been endorsed as a valid factor for deep-sea habitat classification (Howell 2010).

In addition, unlike other classification schemes, the CoralFISH CWC classification subdivides scleractinian bioherms into live/dead reef, live/dead coral framework and rubble zones (*sensu* Mortensen et al. 1995) - an important feature given that these zones are known to vary in associated biodiversity (e.g. Jensen and Frederiksen 1992; Mortensen et al. 1995; Freiwald et al. 2002, Rosso et al. 2010, Spezzaferri et al. 2013). The reef-building coral species are also distinguished, providing a better discrimination of these biotopes than OSPAR, which only accounts for *Lophelia pertusa* reefs and neglect other dominant species, for example the widely distributed *Madrepora oculata* (Arnaud-Haond et al. this issue) that is the dominant frame-building species in the Mediterranean (Vertino et al. 2014 and reference therein). This is important from a conservation point of view and promotes the integration of improved representativeness into MPA networks.

4.3 Data resolution

Due to technical constraints and the high cost associated with deep-sea research, it is not

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feasible to collect full-coverage biological data (Diaz et al. 2004). For instance, approaches used for mapping shallow-water habitats based on satellite imagery are not applicable to the deep sea. Instead, the vast inaccessible area involved requires broad-scale sub-sampling and modelling accompanied by nested fine-scale surveys.

The methods used to acquire data determine the taxonomic resolution that may be achieved by subsequent analyses. The proposed hierarchical scheme allows data of varying resolutions to be represented. Given that resolutions of imagery datasets being interpreted vary greatly between equipment type, the CoralFISH scheme allows results to be recorded from broad cold-water coral categories down to finer detailed biotope level, thereby providing a flexible yet valuable information level for management.

The CWC habitat classification scheme provides much needed habitat descriptions which ought to be included into existing schemes such as EUNIS. At a nature conservation level, the results are instrumental to identify biotope occurrences that require protection under the Habitats Directive (reefs) and the OSPAR Convention (coral gardens, scleractinian reefs, seapens and burrowing megafauna communities, deep-sea sponge aggregations).

It should be noted that statistical methods (e.g. multivariate cluster analysis) were not employed to describe all level 3 biotopes. Undertaking a fully-quantitative analysis of deep-sea data is still very time-consuming due to the faunal complexity of many deep-sea habitats. Frequently it is also taxonomically-limited, as living specimens morphology is poorly documented for many species, which makes their visual identification difficult.

As the datasets explored during CoralFISH were broad and varied, such methods were not feasible for the entire dataset. Analytical methods may aggregate data at a resolution that is not ecological significant, i.e. too small a unit, thus employing a non statistical approach allows expert judgement to be employed. Despite this, the hierarchical system which has been put into place still allows the inclusion of subsequently-defined biotopes when robust quantitative data and statistical analysis are available.

Finally, it must be emphasised that a detailed description of epibenthic assemblages requires further dedicated collections of voucher specimens and continued taxonomy research, preferably including molecular barcoding, on multiple animal groups which remain either unknown to science or visually irresolvable. Besides identification of organisms forming biotopes, further exploration of the deep-sea will potentially reveal biotopes not listed in the CoralFISH classification scheme, since the majority of the deep-seafloor still remains

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unexplored.

Conclusion

The analyses of a wide variety of imagery datasets from the Northeast Atlantic and Mediterranean within the project CoralFISH showed that the range of cold-water coral (CWC) biotopes is currently very poorly represented in the EUNIS classification system.

In order to address this, a new comprehensive hierarchical scheme is proposed incorporating this additional detail so that it can be readily embedded into the existing deep-sea EUNIS level 4-6. The proposed hierarchy is flexible in accommodating habitat data with different taxonomic resolutions, allowing occurrences from broad CWC biotope classes down to detailed taxonomy-based categories. This more detailed description and classification of CWC biotopes will facilitate the identification of biotope occurrences requiring protection under the Habitats Directive (reefs) and the OSPAR Convention (coral gardens, scleractinian reefs, seapens and burrowing megafauna communities). The proposed classification scheme will also aid environmental economists engaged in the mapping and assessment of ecosystem goods and services (cf. MAES, 2014).

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Table 1: CoralFISH cold-water coral biotope classification scheme. The hierarchical scheme is set over three levels: biotope L1 incorporates dominant group of taxa and structure or the dominant group of taxa and substrate, biotope L2 incorporates dominant group of taxa, structure, density measures, substrate, and biotope L3 includes dominant subgroup of taxa, structures and/or substrate and/or secondary taxa groups and where relevant, geoform.

BIOTOPE - LEVEL 1 (dominant group of taxa, structure and/or substrate)	**BIOTOPE - LEVEL 2 (dominant group of taxa, structure, density and/or substrate)**	**BIOTOPE - LEVEL 3 (dominant subgroup of taxa, structure and/or substrate and/or secondary taxa, geoform)**	**FINAL CODE**
1. CW Scleractinian Reef	1. CW Scleractinian Reef	1. *Lophelia pertusa* Reef	1.1.1
		2. *Madrepora oculata* Reef	1.1.2
		3. Mixed *Madrepora oculata* and *Lophelia pertusa* Reef	1.1.3
		4. *Lophelia pertusa* and/or *Madrepora oculata* Reef with dense *Aphrocallistes*	1.1.4
		5. *Lophelia pertusa* and/or *Madrepora oculata* Reef with dense free swimming Crinoids	1.1.5
	2. Colonised CW Scleractinian Reef	1. *Lophelia pertusa* Reef Colonised by *Primnoa* sp. and Plexauridae	1.2.1
		2. CW Scleractinian Reef Colonised by Antipatharians and/or Gorgonians	1.2.2
	3. Loosely-packed CW Scleractinian Framework with Soft Substrate	1. Loosely-packed *Lophelia pertusa* and/or *Madrepora oculata* Framework with Soft Substrate	1.3.1
	4. Colonised Loosely-packed CW Scleractinian Framework with Soft Substrate	1. Loosely-packed *Lophelia pertusa* Framework Colonised by *Primnoa* sp. and Plexauridae	1.4.1
		2. Loosely-packed *Lophelia pertusa* and/or *Madrepora oculata* Framework with Soft Substrate Colonised by Antipatharians	1.4.2
		3. Loosely-packed *Solenosmilia variabilis* Framework with Soft Substrate Colonised by Gorgonians	1.4.3
	5. Predominantly dead CW Scleractinian Reef	1. Isolated *Madrepora oculata-Lophelia pertusa* colonies on Framestones/Rudstones	1.5.1.
		2. Isolated *Madrepora oculata-Lophelia pertusa* colonies on predominantly dead and low coral framework	1.5.2

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	6. Dead CW Scleractinian Reef	1. Dead *Lophelia pertusa* and/or *Madrepora oculata* Framework with Brisingids	1.6.1
2. CW Scleractinian Rubble			2
3. Colonial CW Scleractinians or Stylasterids on Hard Substrate	1. Densely-packed CW Scleractinian Framework on Hard Substrate	1. Dense *Lophelia pertusa* Framework on Vertical Wall	3.1.1
		2. Dense *Solenosmilia variabilis* Framework on Vertical Wall	3.1.2
		3. Dense *Eguchipsammia* Framework on Hard Substrate	3.1.3
	2. Colonised CW Scleractinian Framework on Hard Substrate	1. *Solenosmilia variabilis* Framework on Vertical Wall Colonised by Gorgonians	3.2.1
		2. *Solenosmilia variabilis* Framework on Vertical Wall Colonised by Ascidians	3.2.2
	3. Loosely-packed to Isolated colonies of CW Scleractinians on Hard Substrate	1. Isolated Colonies of *Lophelia pertusa* on Hard Substrate	3.3.1
		2. Isolated Colonies of *Madrepora oculata* on Hard Substrate (Vertical wall)	3.3.2
		3. Isolated Colonies of *Madrepora oculata* and *Lophelia pertusa* on Hard Substrate	3.3.3
		4. Isolated Colonies of *Madrepora oculata* and *Lophelia pertusa* on Hard Substrate with Euplectellidae	3.3.4
		5. Isolated Scleractinians Colonies on Boulders	3.3.5
		6. *Dendrophyllia cornigera* on Hard Substrate/Mixed Substrate	3.3.6
		7. *Enallopsammia rostrata* on Hard Substrate	3.3.7
	4. CW Stylasterids on Hard Substrate	1. *Errina dabneyi* and Sponges on Exposed Rocky Edges	3.4.1
		2. *Crypthelia* sp. on Hard Substrate	3.4.2
	5. Dead CW Scleractinian Framework on Hard Substrate	1. Dead *Madrepora oculata*-*Lophelia pertusa* Framework on Hard Substrate	3.5.1

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4. Solitary CW Scleractinians on Hard Substrate	1. Solitary CW Scleractinians on Hard/Mixed Substrate or Compact Mud	1. *Vaughanella* sp. on Hard Substrate Covered by Soft Substrate	4.1.1
		2. Solitary caryophyllids on Mixed Substrate	4.1.2
5. CW Alcyoniina on Hard substrate	1. CW Alcyoniina on Hard/Mixed Substrate or Compact Mud	1. *Anthomastus* sp. on Hard/Mixed Substrate or Compact Mud	5.1.1
		2. Nephtheidae on Hard/Mixed Substrate or Compact Mud	5.1.2
6. CW Antipatharians and/or Gorgonians on Hard Substrate	1. CW Antipatharians on Hard/Mixed Substrate or Compact Mud	1. Antipatharians on Hard Substrate	6.1.1
		2. *Antipathes dichotoma* on Hard Substrate with intense sedimentation	6.1.2
		3. *Leiopathes glaberrima* on Boulders	6.1.3
	2. CW Gorgonians on Hard/Mixed Substrate or Compact Mud	1. *Iridogorgia* sp. and other Gorgonians on Hard/Mixed Substrate	6.2.1
		2. *Chrysogorgia* sp. and *Acanella* sp. on Hard Substrate	6.2.2
		3. *Viminella flagellum* on Hard/Mixed Substrate	6.2.3
		4. *Viminella* sp. and *Dentomuricea* sp. on Hard/Mixed Substrate	6.2.4
		5. *Isidella elongata* on Hard/Mixed Substrate or Compact Mud	6.2.5
		6. *Narella* cf. *versluysi* on Hard Substrate	6.2.6
		7. *Primnoa resedaeformis* on Hard/Mixed Substrate or Compact Mud	6.2.7
		8. *Acanthogorgia* spp. and Large Primnoids on Hard/Mixed Substrate	6.2.8
		9. *Dentomuricea* sp. on Mixed Substrate	6.2.9
		10. *Swiftia pallida* on Hard/Mixed Substrate or Compact Mud	6.2.10
		11. Plexauridae spp. on Hard/Mixed Substrate	6.2.11
		12. *Paragorgia arborea* on Hard/Mixed Substrate	6.2.12

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		13. Unidentified white coiled whip coral on Hard/Mixed Substrate	6.2.13
		14. cf. *Victorgorgia josephinae* on Hard/Mixed Substrate	6.2.14
7. Mixed CWC on Hard Substrate	7.1. Mixed CW Corals on Hard/Mixed Substrate or Compact Mud	1. Isolated colonies of Scleractinians, Antipatharians and Gorgonians on Hard/Mixed Substrate or Consolidated Mud	7.1.1.
		2. Isolated Colonies of Scleractinians, Antipatharians and Gorgonians on Hard Substrate Covered by Soft Substrate	7.1.2.
		3. *Primnoa* sp., Plexauridae and *Lophelia pertusa* on Hard Substrate	7.1.3.
		4. *Candidella imbricata*, *Lophelia* and various other Corals on Hard Substrate	7.1.4.
		5. *Paragorgia johnsoni*, *Anthomastus* sp. and Stylasterids on Hard Substrate	7.1.5.
		6. *Primnoa resedaeformis* and *Lophelia pertusa* on Vertical Wall	7.1.6.
		7. *Candidella imbricata* and *Leptopsammia* cf. *formosa* on Hard Substrate	7.1.7
8. Mixed CWCs and Sponges on Hard substrate	8.1. Mixed CWCs and Sponges on Hard/Mixed Substrate or Compact Mud	1. *Lophelia pertusa*, Alcyoniina, Encrusting and Glass Sponges on Mixed Substrate	8.1.1.
		2. Large sponges and Isolated Scleractinian colonies on Hard/Mixed Substrate or Compact Mud	8.1.2.
		3. Stylasterids, Primnoids, Alcyoniina and Large Sponges on Hard Substrate	8.1.3.
		4. Antipatharians, Short Sponges and Sparse Large Sponges on Hard Substrate	8.1.4.
		5. *Anthomastus* sp. with Lamellate Sponges and *Gorgonocephalus* on Hard Substrate	8.1.5.
		6. *Callogorgia verticillata*, *Asconema setubalense* and Demosponges on Hard Substrate	8.1.6.
9. Colonial Scleractinians on Soft Substrate	9.1. CW Colonial Scleractinians on Soft Substrate	1. Isolated Colonies of *Lophelia pertusa* and *Madrepora oculata* on Soft Substrate	9.1.1.
10. Solitary Scleractinians on Soft Substrate	10.1. CW Solitary Scleractinians on Soft Substrate	1. Solitary Caryophyllids and Xenophyophores on Soft Substrate	10.1.1.
		2. Flabellidae on Soft Substrate	10.1.2.

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11. Gorgonians on Soft Substrate	11.1. CW Gorgonians on Soft Substrate	1. *Radicipes* sp. on Soft Substrate	11.1.1.
		2. *Callogorgia verticillata* on Soft Substrate	11.1.2.
		3. *Acanella* sp. on Soft Substrate	11.1.3.
		4. *Acanella arbuscula* and *Lepidisis* sp. on Soft Substrate	11.1.4.
		5. *Acanella arbuscula* and Unidentified Branched Coral on Soft Substrate	11.1.5.
12. Mixed CWCs on Soft Substrate	12.1. Mixed CWCs on Soft Substrate	1. *Thouarella* sp. and Seapens on Soft Substrate	12.1.1.
13. Mixed CWCs and Sponges on Soft Substrate	13.1. Mixed CW Corals and Sponges on Soft Substrate	1. *Acanella arbuscula* and *Hyalonema* spp. on Soft Substrate	13.1.1.
14. CW Seapens on Soft Substrate	14.1. CW Seapens on Soft Substrate	1. *Funiculina quadrangularis* and Burrowing Megafauna on Soft Substrate	14.1.1.
		2. cf. *Halipteris* sp. on Soft Substrate	14.1.2.
		3. *Kophobelemnon stelliferum* on Soft Substrate	14.1.3.
		4. *Pennatula* spp. on Soft Substrate	14.1.4.
		5. *Distichoptilum gracile* on Soft Substrate	14.1.5.
15. CW Hydrarians on Hard/Mixed Substrate	15.1. CW Hydrarians on Hard/Mixed Substrate	1. Hydrarians (cf. fam. Sertulariidae) on Hard Substrate	15.1.1.
16. CW Hydrarians on Soft Substrate	16.1. CW Hydrarians on Soft Substrate	1. *Lytocarpia myriophyllum* on Soft Substrate	16.1.1.

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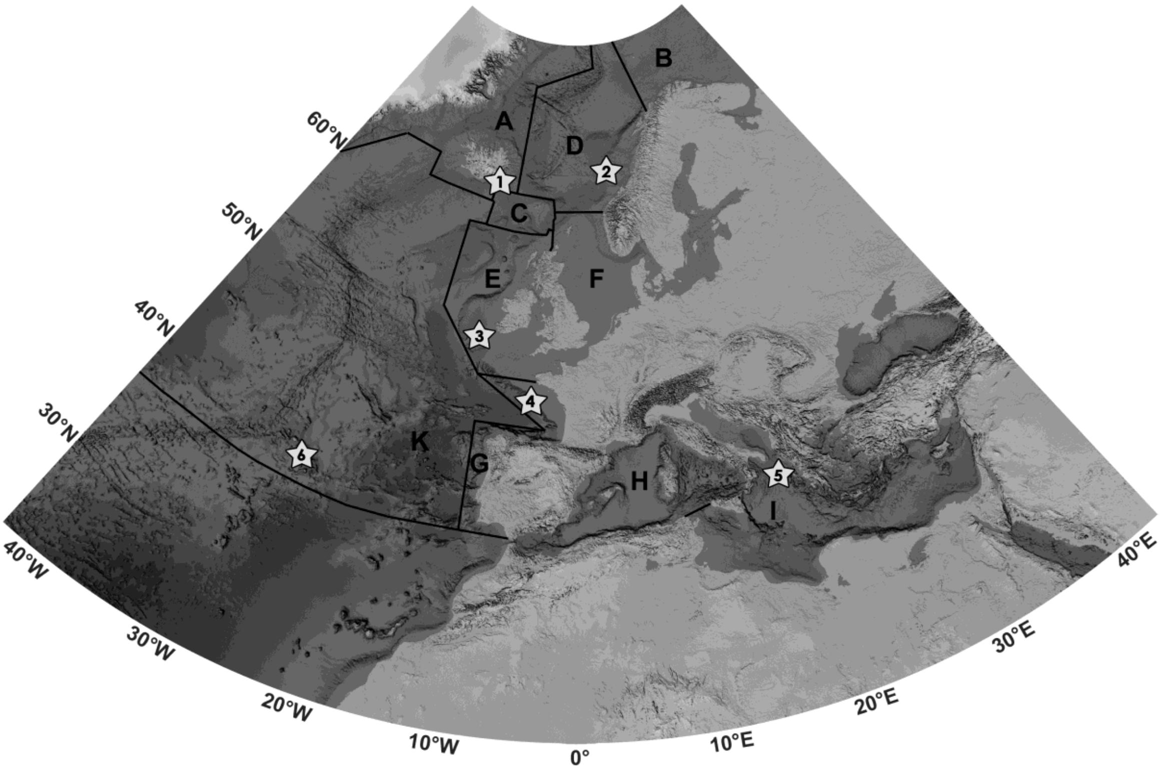

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