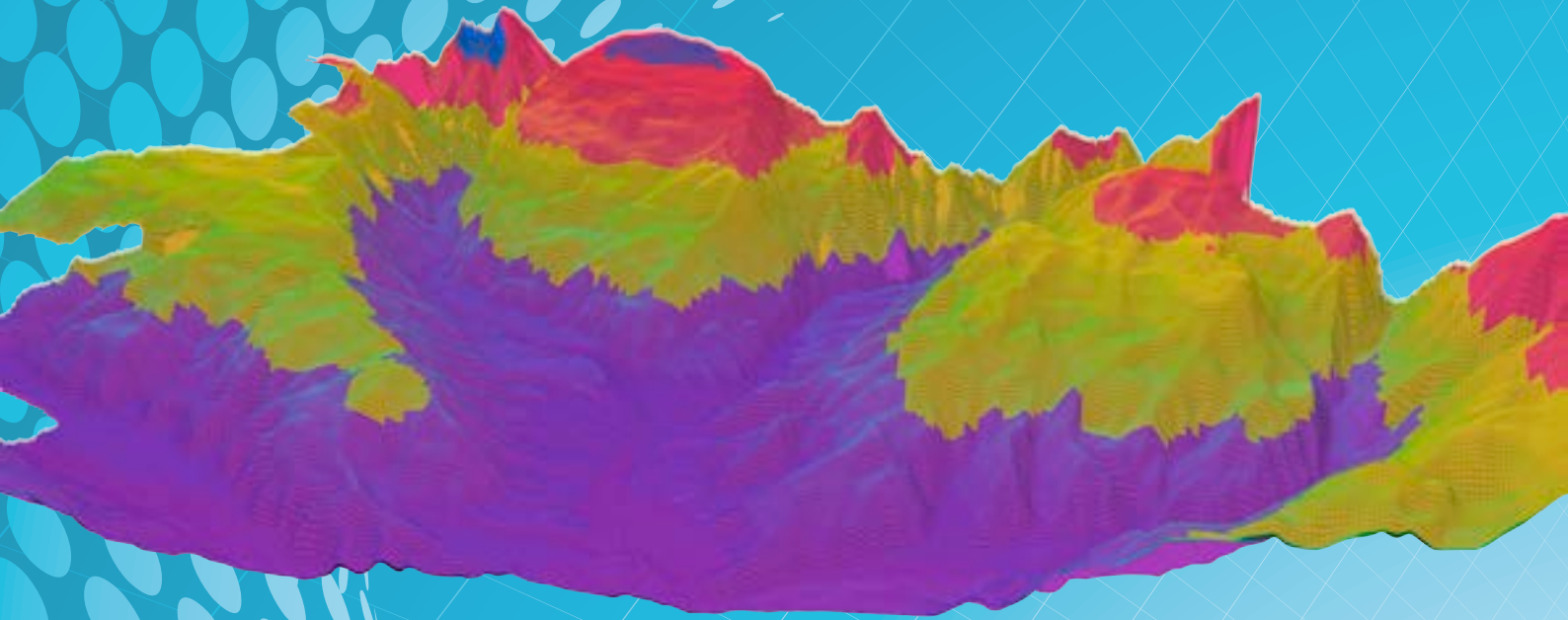# EUSeaMap:
A broad-scale physical habitat map for European Seas

A rocky reef teeming with life in the Tyrrhenian Sea, West Mediterranean.

Table of contents

1 Introduction

EUSeaMap is a project aiming to produce a broad-scale seabed habitat map covering all European Seas in a consistent way[1]. In its first phase (2009–2012) over two million square kilometres of European seabed were mapped, across four regions: the Baltic Sea, Greater North Sea, Celtic Seas and Western Mediterranean Sea (Figure 1). EUSeaMap, also known as EMODnet Seabed Habitats, is part of a wider family of projects within the European Marine Observation and Data Network (EMODnet) initiative. It is funded by the European Commission's Directorate-General for Maritime Affairs and Fisheries (DG MARE), with the primary aim to support the requirements of the Marine Strategy Framework Directive (MSFD[2]). The EMODnet project has been extended as part of the DG MARE 2020 Marine Strategy framework.

In the second phase of EUSeaMap (2013–2016, dashed areas in Figure 1) the coverage will be extended to all European seas and the existing maps improved.

EMODnet

❝ *The main purpose of EMODnet is to unlock fragmented and hidden marine data resources and to make these available to individuals and organisations (public and private), and to facilitate investment in sustainable coastal and offshore activities through improved access to quality-assured, standardised and harmonised marine data*❞ **(www.emodnet.eu).**

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[1] Using the EUNIS classification system (European Nature Information System), **http://eunis.eea.europa.eu/habitats.jsp)**
[2] Marine Strategy Framework Directive: Directive 2008/56/EC on establishing a framework for community action in the field of marine environmental policy.
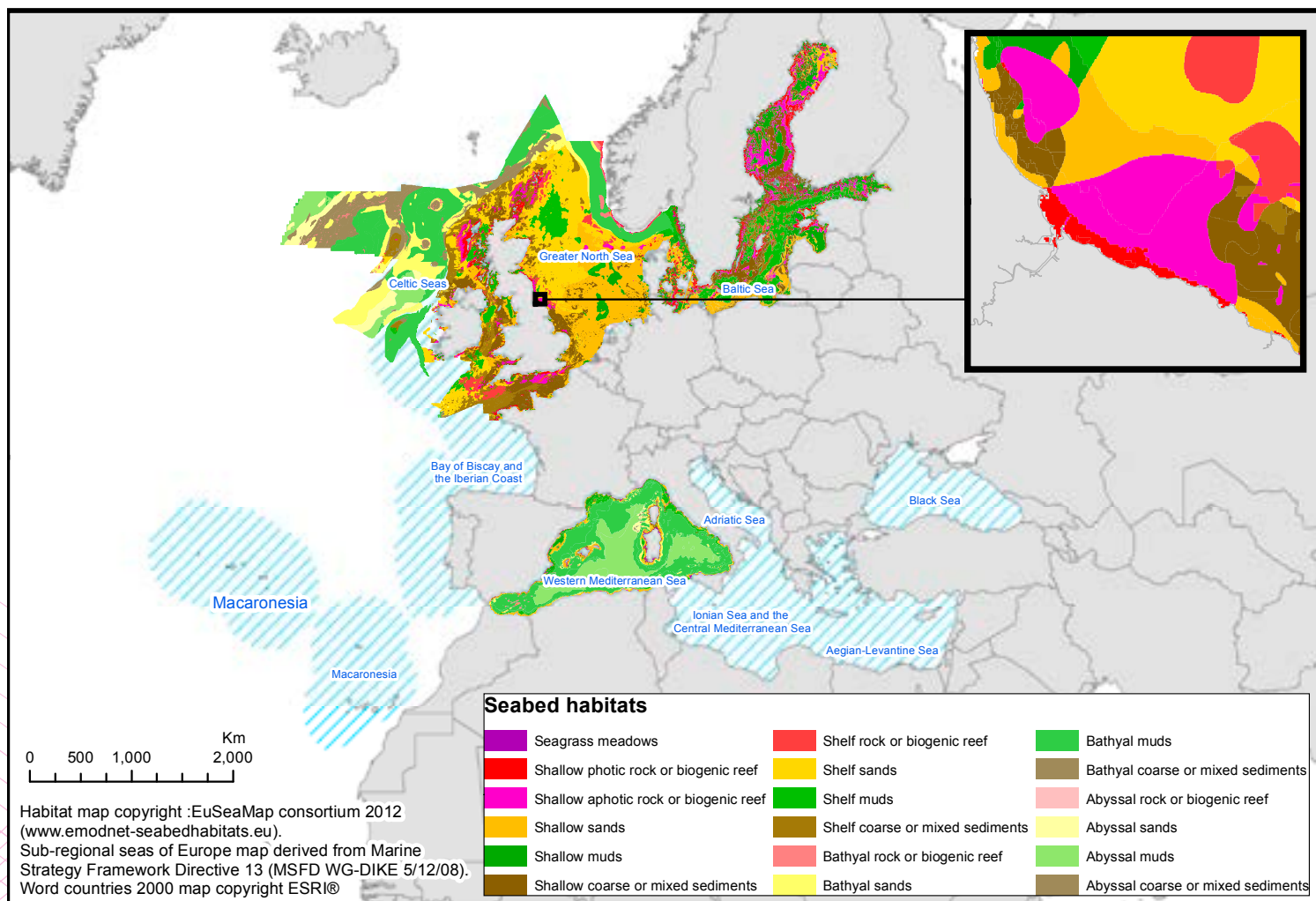
Seabed habitats

Seagrass meadows	Shelf rock or biogenic reef	Bathyal muds
Shallow photic rock or biogenic reef	Shelf sands	Bathyal coarse or mixed sediments
Shallow aphotic rock or biogenic reef	Shelf muds	Abyssal rock or biogenic reef
Shallow sands	Shelf coarse or mixed sediments	Abyssal sands
Shallow muds	Bathyal rock or biogenic reef	Abyssal muds
Shallow coarse or mixed sediments	Bathyal sands	Abyssal coarse or mixed sediments

Habitat map copyright :EuSeaMap consortium 2012
(www.emodnet-seabedhabitats.eu).
Sub-regional seas of Europe map derived from Marine
Strategy Framework Directive 13 (MSFD WG-DIKE 5/12/08).
Word countries 2000 map copyright ESRI®

Figure 1 Overview of the EUSeaMap broad-scale map coverage in 2012 and areas to be covered by the EUSeaMap Phase 2.

EMODnet provides access to data and mapping products from the following themes: bathymetry, geology, physics, chemistry, biology, human activities and seabed habitats. EUSeaMap delivers the seabed habitat theme and is a primary user of many of the harmonised data layers produced by other EMODnet partners, such as the harmonised substrata, bathymetry and seabed biology datasets.

2 Benefits of a European broad-scale seabed habitat map

In order to most benefit from the potential offered by the European marine basins in terms of growth and employment, and to protect the marine environment, we need to know more about the seafloor. European Directives, such as the MSFD, call for a full-coverage seabed habitat map of all European seas. In general, habitat maps are very costly and time consuming to produce from survey. The creation of a detailed habitat map involves first surveying the seafloor with sonar equipment and collecting samples or photos of the seabed. These data are then analysed and integrated to generate a map.
It can take several years from planning a survey to completing a detailed map. By contrast, a more time- and cost-efficient way to meet the need for a full-coverage habitat map is to use low-resolution maps and models to predict seafloor habitat types.

EUSeaMap provides the community with a comprehensive, free and ready-to-use map, harmonising mapping procedures and fostering a common understanding among seabed mappers in Europe. The EUSeaMap methods are repeatable and ensure that the predictive maps can continue to be improved in the future.

Figure 2 Examples from the EUNIS hierarchy. Using continuous physical data habitats can be modelled to EUNIS Level 3 for rocky environments (right) and EUNIS Level 4 for sedimentary environments (left). Predicting higher Levels (5 and 6) would require large amounts of biological community data from sampling.

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❙❙ In 2014–2015 the European Topic Centre on Biological Diversity plans to update the marine section of the EUNIS habitat classification. Outcomes from EUSeaMap will inform this development highlighting gaps or inconsistencies.❙❙

A common hermit crab (*Pagurus bernhardus*) on a bed of Maerl (*Lithothamnion glaciale*) in a Scottish sea loch.

Europe's marine habitat classification

The European Nature Information System (EUNIS) classifies habitats on a seven-tier hierarchical scale developed by the European Environment Agency. The upper levels of the marine classification of EUNIS are primarily defined using abiotic variables (substrate, depth, etc.) which are categorised in a way that is relevant to the biological communities they support. Having separated marine habitats at Level 1 (EUNIS code: A), Level 2 identifies eight broad marine habitats based on depth and substrate type, permanent or non-permanent water cover, ice-cover and characteristics of the pelagic water column (EUNIS codes: A1 – A8, Davies et al., 2004). Level 3 habitats are further classified based on criteria involving abiotic variables such as the actual substrate nature (e.g. rock, coarse sediment, sand, etc.), energy levels (moderate, high, low energy) as well as temperature, light, salinity and plant cover. Differentiations between habitats based on the components of the biological communities begin to appear at Level 4 in rocky environments (e.g. A3.11: Kelp with cushion fauna and foliose red seaweeds; Figure 2). However the inclusion of biological communities at Level 4 is not universal across the system. Figure 2 shows that in sediment environments Level 4 uses only physical information, e.g. A5.35: circalittoral sandy mud.

2.1 Examples of application of EUSeaMap

- **MSFD Assessment:** Predicted habitat maps produced by EUSeaMap were a key base layer for the 2012 MSFD Initial Assessment of marine ecosystems. In Italian national waters, for example, EUSeaMap was used to outline where the MSFD predominant habitats occur, where detailed information was lacking. The EUSeaMap broad-scale habitat map was central in the HARMONY project[3], which developed tools for harmonisation of the MSFD initial assessment in the eastern parts of the Greater North Sea sub-region.

- **Benthic Habitat Monitoring:** EUSeaMap has been used at the UK-wide scale to begin to develop monitoring options for benthic habitats as part of the UK Marine Biodiversity Monitoring Research and Development Programme[4]. The habitat maps can be overlain with maps of human pressures in order to develop sampling designs that focus monitoring effort on those habitats most at risk from human activities. The habitat maps form an integral part of the strategic approach to developing integrated monitoring options for UK benthic habitats.

- **Marine Protected Areas:** In the UK and in France EUSeaMap has been used for national Marine Protected Areas (MPA) identification and in Natura 2000[5] reporting as an aid where no survey data are available. EUSeaMap has also been used in the UK in reviewing the developing MPA network, where it was used to provide the predicted area of each broad-scale habitat within a given biogeographic region. The area of a broad-scale habitat type afforded protection by MPAs within each region was compared to the total predicted area for the habitat type within each region, as derived from EUSeaMap, which was a valuable analysis to review the progress of developing an ecologically coherent network of MPAs.

- **Species distribution modelling:** Some of the layers produced by EUSeaMap and EMODnet (energy, substrate and bathymetry) will be used to model habitats preferred by some small cetaceans (harbour porpoises) in the Baltic Sea. The work on harbour porpoise conservation will be done in the framework of the SAMBAH[6] (Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise) project involving all European countries around the Baltic Sea.

- **Marine planning:** EUSeaMap outputs were used as data sources during the creation of the UK's first marine plan[7], which was finalised in 2013 for the East of England inshore and offshore area. EUSeaMap biological zones and energy map layers were combined with a local seabed substrate model to create a new map of broad-scale habitats in this area. Where more-detailed habitat maps were available, these were preferentially selected if they were created using both remote sensing and ground truthing data.

[5] Natura 2000 is the centrepiece of EU nature & biodiversity policy: http://ec.europa.eu/environment/nature/natura2000/index_en.htm
[6] SAMBAH project (Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise), www.sambah.org
[7] East of England Marine Plans: http://www.marinemanagement.org.uk/marineplanning/areas/east.htm

Brittle stars and crustose communities on rock, Solan Bank, Scottish Continental Shelf. © JNCC

◀◀ *EUSeaMap products have been used for assessing and reporting the status of European seas, designing ecologically coherent Marine Protected Area networks, species distribution modelling, establishing monitoring programmes for seabed habitats and informing marine planning.*◀◀

3 Principles behind making broad-scale seabed habitat maps

Owing to the practical problems and high costs associated with direct mapping of the seabed, particularly in deep areas, coupled with the vastness of the area being mapped, a fundamental principle in the creation of such an ambitious map is that of Connor et al. (2006):

❮❮ *[it is] recognised [that there is] strong correlation between environmental parameters and ecological character, such that mapping* **environmental parameters** *in an* **integrated manner** *can successfully be used to produce ecologically relevant maps.* ❮❮

In other words, it is possible to produce a 'predictive map' of expected seabed-habitat types by combining a series of proxy measurements, such as water depth and light levels amongst others, using statistical analysis and Geographical Information System modelling.

Principal drivers for seabed habitat distributions include the type of seabed substrate (rock, mud, mixed sediment, etc.), depth, light availability and the energy of water movements. To describe the variation in environmental conditions with depth, EUNIS divides subtidal habitats into zones: Infralittoral, Coastal Circalittoral (or Circalittoral), Deep Circalittoral and Deep Sea (Figure 3). In EUSeaMap, it was decided to further subdivide the Deep Sea zone into, bathyal (in the Atlantic bathyal is further divided into upper slope, upper, mid and lower bathyal) and abyssal zones, following scientific literature and recognising the diversity of these huge areas.

Another factor that can be fundamental in driving habitat types is the degree of exposure to wave and water-current energy (Figure 5). For some more enclosed basins other parameters, such as salinity, oxygen levels and temperature of water at the seabed are also considered to be fundamental for habitat mapping.
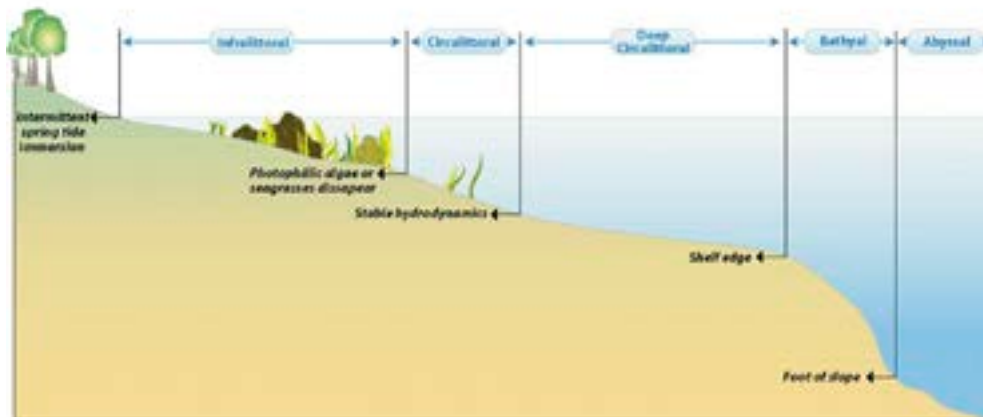
Figure 3 The division of marine sublittoral habitats into biological zones.
©MESH Atlantic Blue Box, 2013.

Figure 4 Deep Sea rocky habitats from the North East Atlantic Ocean, Antohn Dohrn SeaMount

Figure 5 Examples of an exposed rocky habitat and a more sheltered muddy habitat from the North East Atlantic.

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4 Generating the maps

During the first phase of EUSeaMap (2009–2012), a consistent methodology was developed to take into account the diverse range of seabed habitats found in different regions.

The first step is to acquire the best-available spatial data for several environmental variables. This includes data provided by EMODnet Geology and Bathymetry projects (See EMODnet box). The data are organised and harmonised into pixelated images divided into classes (Figure 6 and Figure 7). These data can be combined by 'layering' the data in GIS to create a combined output describing the habitat (Figure 6). The principal input layers are the type of seabed substrate and the biological zones. Depending on the basin, layers of hydrodynamic energy levels, salinity and/or temperature are also produced. For example the hydrodynamic energy layer is divided into 'Low', 'Medium' and 'High' classes.

Angelshark *(Squatina squatina)* resting camouflaged on the seabed. Canary Islands, East Atlantic Ocean.
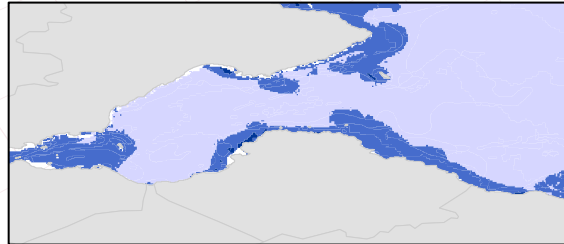
© Alex Mustard/naturepl.com
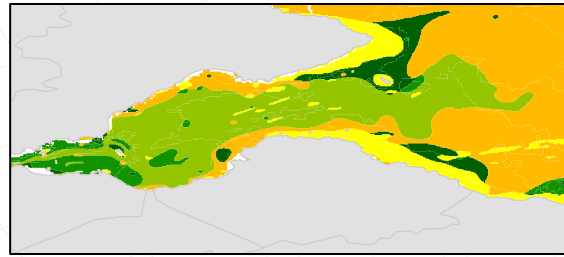
Seabed Substrate
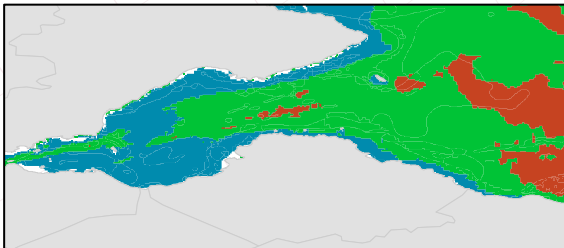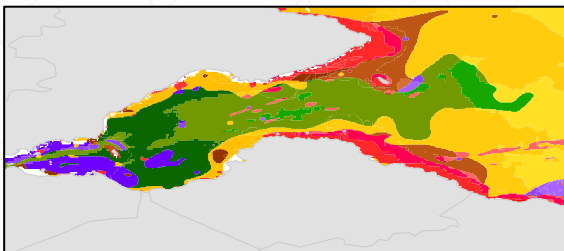
+

Energy level at the seabed

+

Biological Zones

=

EUNIS broad-scale Habitats

Figure 6 Illustration of how a predictive habitat map can be created by 'layering' data in GIS.

Encrusting sponges and Devonshire cup corals *(Caryophyllia smithii)* on large boulders, Solan Bank, Scottish Continental Shelf

The EUSeaMap model was developed in ESRI™ ArcGIS ModelBuilder and can be saved and executed multiple times, which ensures that the systems are repeatable and easily updated when new layers or methodologies are available.

As well as careful evaluation of contributing data, and refining statistical methods for its interpretation, during EUSeaMap Phase 1 it was necessary to define meaningful thresholds for likely changes in habitats: in each input layer

these are used to define the boundaries between classes, where the change in the physical conditions reaches a critical point that defines an expected change in habitat type (at the map-scale adopted in EUSeaMap, 250mx250m blocks). For example, the infralittoral zone is the area of the seabed where photosynthetic algae is able to grow (Figure 8 and Figure 9). In EUSeaMap, a threshold proportion of light reaching the seabed was used to define the lower boundary of the infralittoral zone.
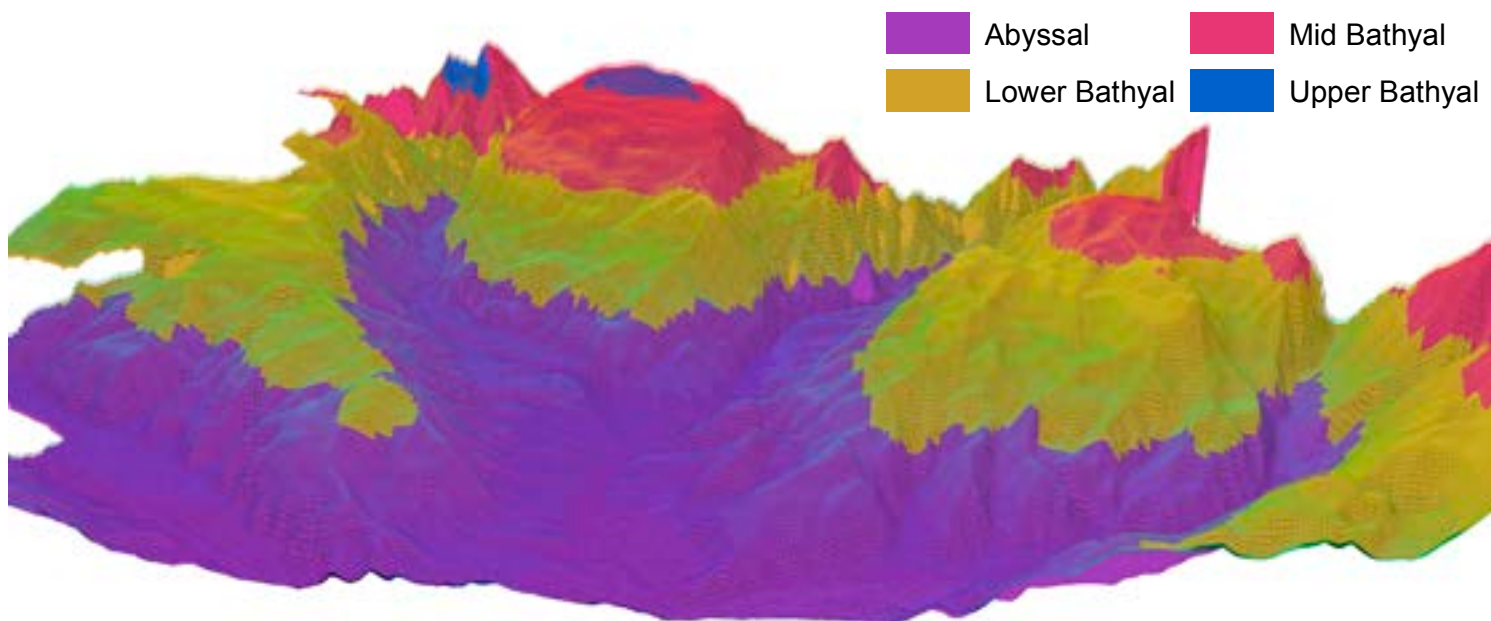
Figure 7 Example of an input layer: The modelled biological zones layer used in EUSeaMap phase 1 to predict seabed habitats. Input layers are also useful per se and are available online through the EUSeaMap web portal.

Figure 8a The amount of light reaching the seabed affects the distribution of life in the Atlantic Ocean. Example of a habitat of the infralittoral zone, dominated by photosynthetic organisms.

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Figure 8b Habitat of the circalittoral zone, where light is scarce and animal life rather than plant life dominates.

© JNCC
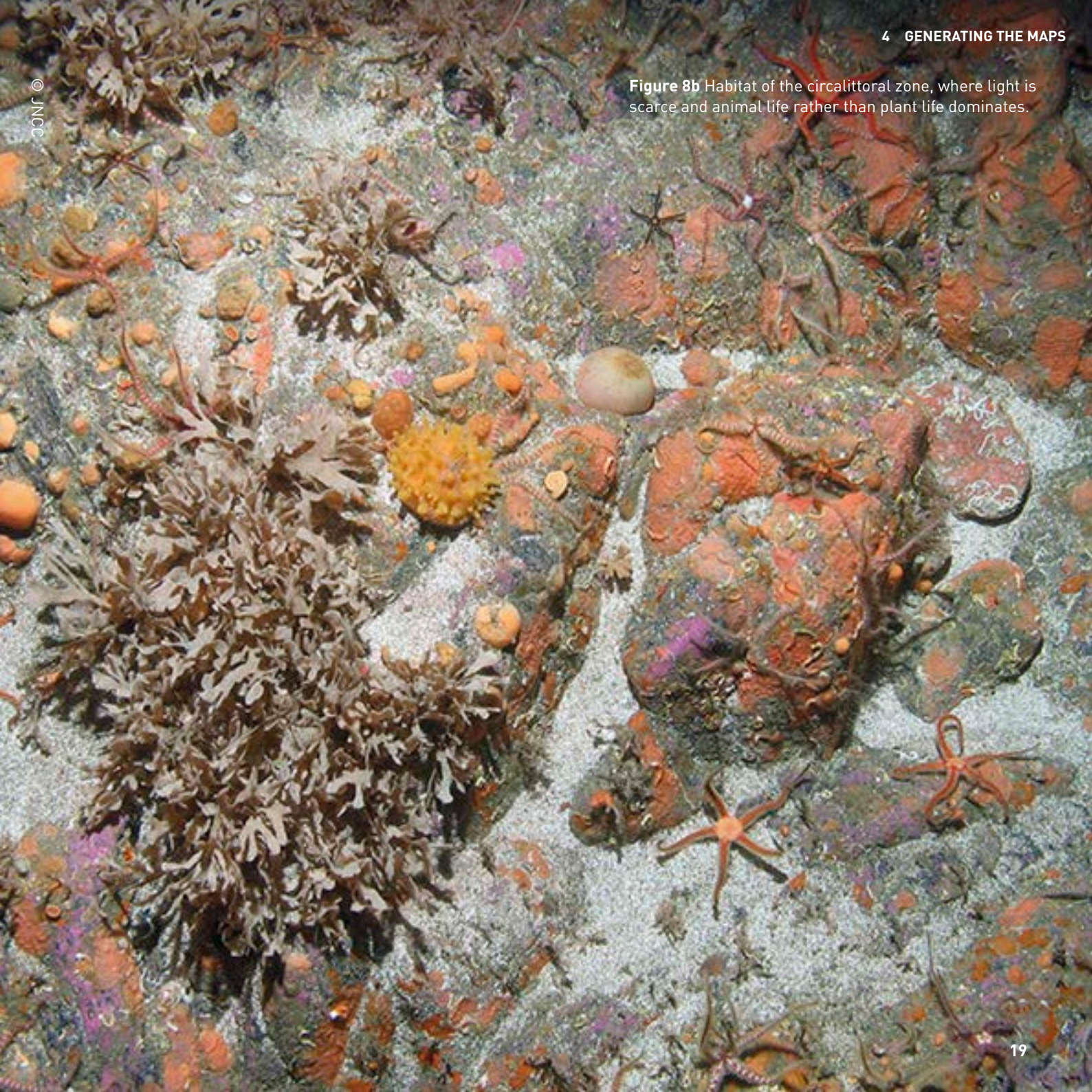
Biogeographic differences: similar light conditions to those in Figure 8 in a different basin.

Figure 9a *Posidonia oceanica* seagrass beds support a rich habitat in the infralittoral zone of Mediterranean Sea.

Figure 9B Mediterranean coralligenous communities in the circalittoral zone.

5 Products

Region-specific maps – Regional-specific maps are available to end users at 250m resolution (see an example in Figure 10), which roughly correspond to a 1:500,000 scale. Although there is a need to produce a harmonised map across the regions, harmonising necessarily loses some of the region-specific data. More-detailed maps are possible, owing to the specific conditions relevant to each region.

A3.1: Atlantic and Mediterranean high energy infralittoral rock
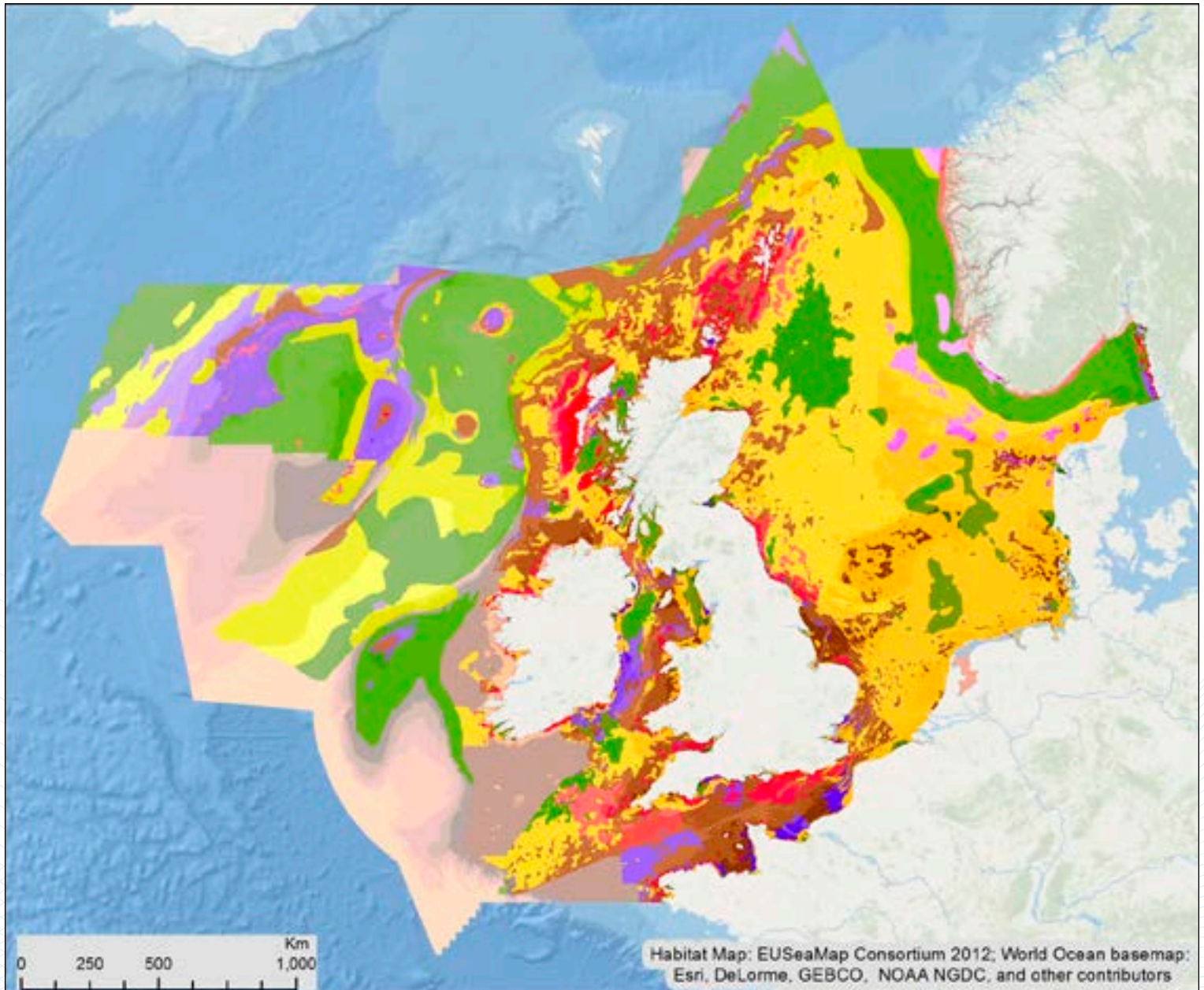
A3.2: Atlantic and Mediterranean moderate energy infralittoral rock

A3.31: Silted kelp on low energy infralittoral rock with full salinity

A5.43: Infralittoral mixed sediments

A5.13: Infralittoral coarse sediment

A5.23: Infralittoral fine sand or A5.24: Infralittoral muddy sand

A5.33: Infralittoral sandy mud or A5.34: Infralittoral fine mud

High energy infralittoral mixed hard sediment

Moderate energy infralittoral mixed hard sediment

Low energy infralittoral mixed hard sediment

A4.11: Very tide-swept faunal communities on circalittoral rock or A4.13: Mixed faunal turf communities on circalittoral rock

A4.2: Atlantic and Mediterranean moderate energy circalittoral rock

A4.31: Brachiopod and ascidian communities on circalittoral rock

A5.44: Circalittoral mixed sediments

A5.14: Circalittoral coarse sediment

A5.25: Circalittoral fine sand or A5.26: Circalittoral muddy sand

A5.35: Circalittoral sandy mud or A5.36: Circalittoral fine mud

High energy circalittoral mixed hard sediment

Moderate energy circalittoral mixed hard sediment

Low energy circalittoral mixed hard sediment

A4.12: Sponge communities on deep circalittoral rock

A4.27: Faunal communities on deep moderate energy circalittoral rock

A4.33: Faunal communities on deep low energy circalittoral rock

A5.45: Deep circalittoral mixed sediments

A5.15: Deep circalittoral coarse sediment

A5.27: Deep circalittoral sand

A5.37: Deep circalittoral mud

Deep circalittoral mixed hard sediment

Upper slope rock or reef

Upper slope mixed sediment

Upper slope coarse sediment

Upper slope sand and muddy sand

Upper slope mud and sandy mud

Upper slope mixed hard sediment

Upper bathyal rock or reef

Upper bathyal mixed sediment

Upper bathyal coarse sediment

Upper bathyal sand and muddy sand

Upper bathyal mud and sandy mud

Mid bathyal rock or reef

Mid bathyal mixed sediment

Mid bathyal coarse sediment

Mid bathyal sand and muddy sand

Mid bathyal mud and sandy mud

Lower bathyal rock or reef

Lower bathyal mixed sediment

Lower bathyal coarse sediment

Lower bathyal sand and muddy sand

Lower bathyal mud and sandy mud

Abyssal rock or reef

Abyssal mixed sediment

Abyssal sand and muddy sand

Abyssal mud and sandy mud

High energy infralittoral seabed

Moderate energy infralittoral seabed

Low energy infralittoral seabed

High energy circalittoral seabed

Moderate energy circalittoral seabed

Low energy circalittoral seabed

Deep circalittoral seabed

Upper slope seabed

Upper bathyal seabed

Mid bathyal seabed

Lower bathyal seabed

Abyssal seabed

Figure 10 The Greater North Sea and Celtic Seas predicted habitats map (Version 2012) as an example of the modelled map of seabed habitats.

Harmonised broad-scale habitat map –
A single harmonised broad-scale habitat map is currently available for the Baltic Sea, the Western Mediterranean Sea, the Greater North Sea and the Celtic Seas (Figure 1). Its coverage is being extended to all European seas by 2016. The habitats in this map are consistent between basins and approximately correspond to the MSFD 'predominant habitats'.

Confidence maps – Each habitat map has several associated 'confidence maps', which reflect our levels of confidence in the data layers that have been used to construct the final predicted habitat map. These are important to enable the variation in quality and resolution of the input data layers to be visually reflected. Combining the data in a meaningful way for the purposes of predictive mapping is a highly complex process, given that there is variation in:

- **Thematic scale –** different areas of the maps are described to different levels of the EUNIS classification hierarchy – those areas that are mapped to less-detailed levels have fewer sources of error;

- **Spatial scale –** high resolution data are available in some cases, but are predominantly coarser farther offshore;

- **When the data were collected –** depending on the variability in the parameter, older data may be less reliable;

- **Method of data collection –** different techniques provide different error margins in their recording;

- **Reliability of data interpretation –** the input data layers are modelled; the quality of these depends on the quality of the modelling technique and density of validation points;

- **Ease of defining threshold values for environmental parameters to enable mapping of biologically-relevant boundaries –** some habitat definitions are easier to link to environmental parameters than others and the amount of biological data available to properly define threshold values of environmental parameters varies.

A review of the source layers (involving quantitative and qualitative assessments, resolution, age and data source quality) is performed when there are adequate data and metadata available.

Dead man's fingers (*Alcyonium digitatum*), red seaweeds (Rhodophyta) and crustose coralline algae (Corallinaceae) on Solan Bank Reef, Scottish Continental Shelf.

6 Making data available: the web portal

EUSeaMap products and reports are all available through an interactive online mapping portal: **http://www.emodnet-seabedhabitats.eu.**

The interactive mapping portal (or 'webGIS') is a free resource for viewing and downloading seabed habitat maps as well as input data layers such as energy, depth and light penetration (when these are freely available). All layers can be exported using the Web Map Service (WMS) to personal desktop GIS applications or to other web mapping portals. Information can also be downloaded as ready-to-use maps (Figure 12), in pdf format for example, or in GIS format to be easily overlaid with users' datasets.

Metadata describing the file content is provided with the files following INSPIRE directive[8] standards. With EUSeaMap Phase 2, not only new predictive habitat maps will be made available through the web portal, but also detailed habitat maps derived from survey data in European Seas will be collated and uploaded online, following on from work in previous projects such as MESH[9] and MESH Atlantic[10].
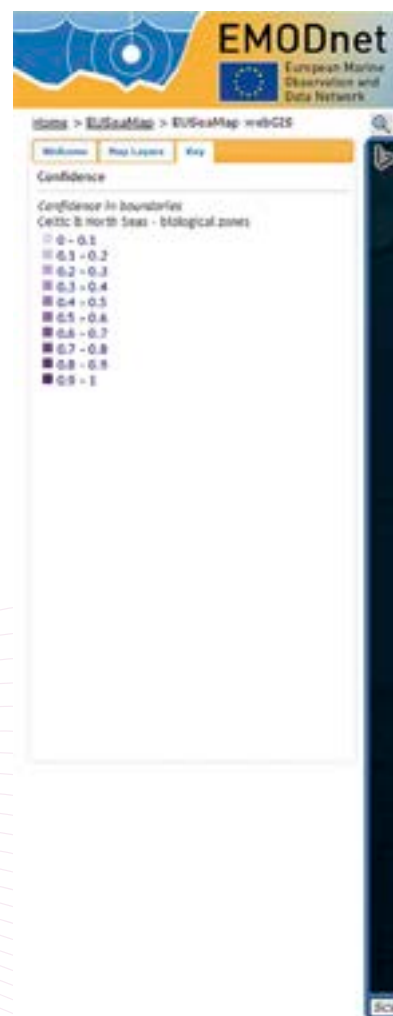
[8] INSPIRE: European Directive 2007/2/EC.
[9] Development of a framework for Mapping European Seabed Habitats (MESH), **http://www.searchmesh.net**
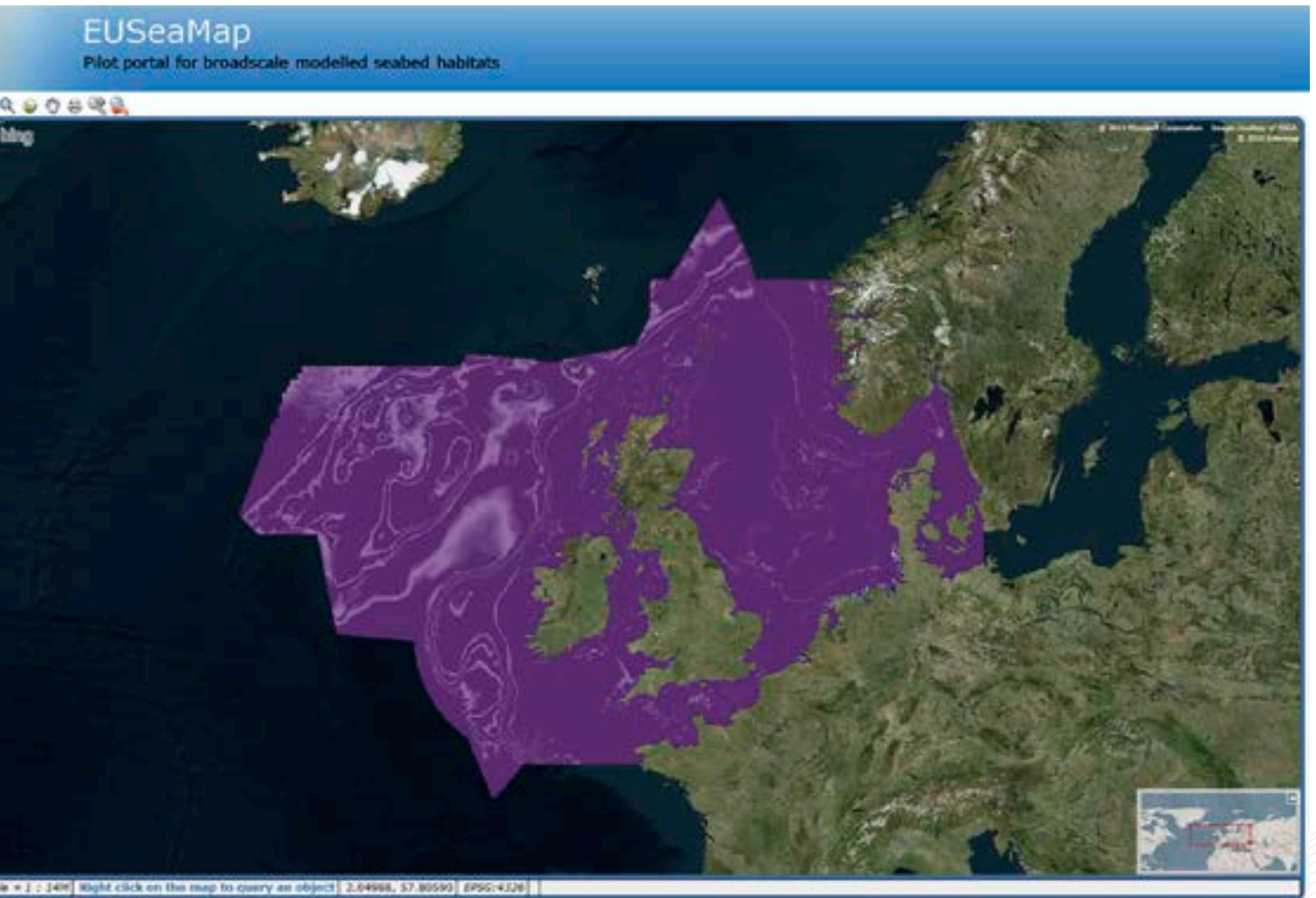[10] Mapping Atlantic Area Seabed for Better Marine Management (MESH Atlantic), **http://www.meshatlantic.eu/**

Figure 11 A screen grab from the interactive web portal showing a confidence map for the EUSeaMap phase 1 area.

Legend:
- 0-10 m
- 10-50 m
- 50-150 m
- 150-450 m
- 450-1000 m
- 1000-2000 m
- 2000-3500 m
- >3500 m

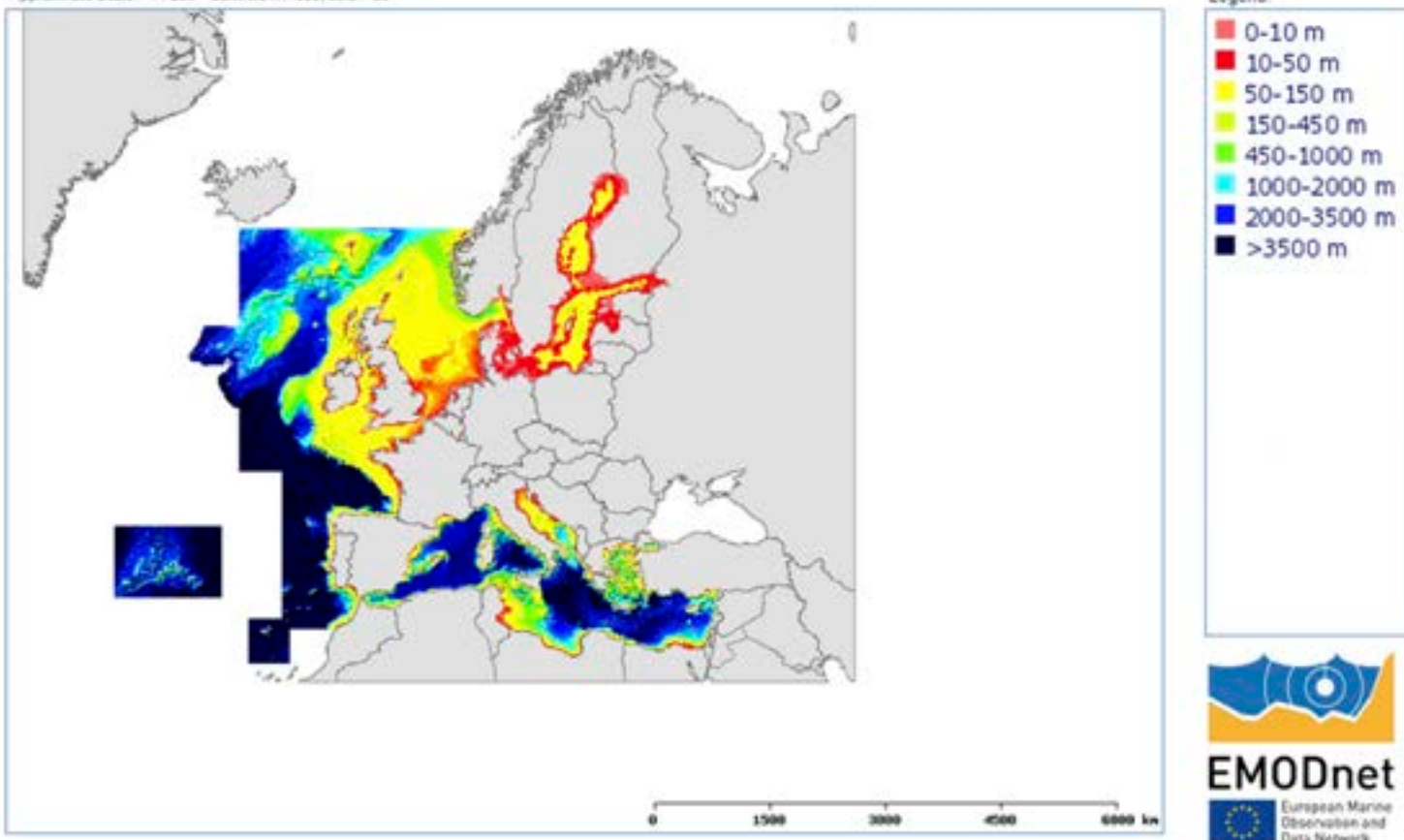EMODnet
European Marine
Observation and
Data Network

Figure 12 Example of a ready to use map downloaded from the EUSeaMap webGIS portal.

EUSeaMap is free of charge to users. An interactive web portal allows users to view and query the data, and enables those with GIS software to interrogate the data further.
http://www.emodnet-seabedhabitats.eu

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Seabed survey on board the RV CEFAS Endeavour – EUSeaMap phase 2 will collate available local maps derived from surveymapping and share these online.

7 The future of EUSeaMap

European Strategy – In the framework of **Marine Knowledge 2020**, EMODnet Phase 3 (2017–2020) has plans to set up a mechanism whereby the comprehensive pan-European broad-scale map would be updated as blocks of new source data become available, either within member states or regionally. Over 20 M€ were invested in EMODnet Phase 2 and this figure is likely to increase several folds in EMODnet Phase 3.

Improving resolution – Modelled maps have been made so far with a low level of detail (broad-scale), because the underlying data are low resolution. When the resolution of the source layers increases, the production of enhanced modelled habitat maps will be achievable and possibly at the same spatial scale as some surveyed maps.

Combined approach – Maps made from in-situ, often detailed, biological and substrate data, as well as acoustic/optical information, might lack information on energy level or depth zones. Applying the EUSeaMap modelling approach at small scales for those areas with more survey data available will produce more accurate habitat maps.

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Red Starfish (*Echinaster purpureus*) on a reef, Balearic Sea, West Mediterranean Sea.

8 The EUSeaMap partnership

The Partnership comprises government agencies and research institutions with proven national and international expertise in marine seabed mapping and modelling.

In EUSeaMap Phase 1 a consortium of seven partners from five countries joined together led by the UK Government's nature conservation advisor (JNCC).

JNCC (UK Government's nature conservation advisor)

Ifremer (The French national institute for marine research)

IEO (Spanish national oceanographic institute)

ISPRA (Italian institute for environmental protection and research)

Natur Vårds Verket (Swedish Environmental Protection Agency)

DHI (International consulting and research organisation, former Danish Hydraulic Institute)

Danish Ministry of the Environment, Agency for Spatial and Environmental planning.

A consortium of nine partners is working together to deliver EUSeaMap Phase 2, under the leadership of French research institute Ifremer.

Ifremer (The French national institute for marine research)

JNCC (UK government's nature conservation advisor)

IEO (Spanish national oceanographic institute)

ISPRA (Italian institute for environment protection and research)

Hellenic Centre for Marine Research (National laboratory of Greece on oceanography and marine research)

NIVA (Norwegian Institute for water research)

GeoEcoMar (Romanian national research and development institute for marine geology and geoecology)

IOBAS (Institute of Oceanology, Bulgarian Academy of Sciences)

DCE (Aarhus University's central unit for knowledge exchange within the areas of nature, environment, climate and energy, in Denmark)

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An octopus *(Octopus vulgaris)* living in a shallow rocky reef. Tyrrhenian Sea, West Mediterranean Sea

10 Acknowledgements

© Eleonora Manca.

Grey seal (*Halichoerus grypus*) swimming amongst kelp, Northern North Sea.

Spiny seahorse (*Hippocampus guttulatus*) sheltering in a
Zostera marina seagrass meadow, Eastern English Channel.

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