MESH
MAPPING EUROPEAN SEABED HABITATS

The MESH Blue Book

A summary of achievements
of the MESH Project

Contents

Foreword

Back in 2002, JNCC and a consortium of like-minded organisations applied to the EC INTERREG Programme to fund a project on seabed habitat mapping. To justify our application we stated:

The current situation whereby mapping activities are undertaken on a local or regional basis, and cannot be collated in a consistent manner at national or international levels, presents a considerable obstacle to the management of the productive waters of the north-east European continental shelf. This can only be overcome by transnational co-operation, which in turn promotes consensus.

We stated this with the intention that:

...mapping practitioners and end-users will become fully aware of the available information, its importance in environmentally-sound management and planning.

Six years and over €8 million later, the MESH Project has achieved successful transnational cooperation to deliver standardised seabed habitat maps and internationally agreed standards and protocols to help future marine mapping initiatives.

Over subsequent years, the state of the marine environment has attracted significant attention in terms of the impact of human activities and climate change. EU policy already recognises the need for urgent action. In October 2007, the EC published its action plan for an integrated maritime policy for the EU. It stated: *The seas are Europe's lifeblood. Europe's maritime spaces and its coasts are central to its well-being and prosperity…The cumulated effect of all [human] activity is leading to conflicts of use and to the deterioration of the marine environment that everything else depends upon."* In December 2007, the EU and the European Parliament adopted the Marine Strategy Directive that requires Member States to *take necessary measures to achieve or maintain Good Environmental Status by 2020", and* develop marine strategies that *will apply an ecosystem-based approach to the management of human activities… to enable the sustainable use of marine goods and services by present and future generations."* Marine issues will clearly dominate the European policy agenda for the coming decade. Successfully meeting these policy challenges will require comprehensive spatial information on seabed resources at a European level.

The MESH Project achieved exactly what it set out to do - develop a ***framework*** for Mapping European Seabed Habitats. However, some of the basic challenges remain:
- much of the seabed lacks detailed habitat maps; and,
- integrating this information with existing and improved knowledge about the human impacts on the marine environment and their effects on marine biodiversity.

MESH Partners encourage other EU countries to take-up the products of the project, to contribute to the growing mapping resource which the MESH project started, and ensure all information gets utilised appropriately in this generation s custodianship of the marine environment.

If society is to better understand marine ecosystems, then there is a clear need to continue collaborative mapping work. In addition, there is a need to change the way people work by encouraging the greater and more creative use of spatial data in addressing today s and future environmental challenges.

JNCC and the other partners will continue to promote the use of outputs from the MESH Project, and assist those who are working towards the sustainable management of European Seas.

Deryck Steer
Managing Director, JNCC, UK

Cover Images
Left: Rocky reef habitat. A diverse animal community on a deep-sea rocky reef (' Crown Copyright, UK)
Middle: An aerial photograph of Les Abers, Brittany (' Ifremer)
Right: A multibeam bathymetric sonar image of sand waves off Ireland (' Marine Institute)

The MESH Blue Book – a synopsis

A Blue Book is intended to act as a guide and a source of reference to the subject matter. This *MESH Blue Book* summarises the key achievements of the MESH Project, including its main outputs and how they can help the key European and national marine policy and management initiatives such as the aim to deliver the sustainable use of marine goods and services by present and future generations (Article 1, EU Marine Strategy Framework Directive). It will help readers understand how the MESH Project can help their work and answer the question Where do I find its products?

Developing a Framework for Mapping European Seabed Habitats (MESH) was a four year project involving twelve partners from five north-west European countries led by the UK s Joint Nature Conservation Committee (JNCC), with the financial support from the EC s INTERREG IIIB Programme for north-west Europe; it finished in January 2008. The MESH partnership brought together technical habitat-mapping skills, expertise in data management, and proven practical experience in the use of seabed-habitat maps for environmental management and policy development within national regulatory frameworks. Such a blend of expertise, with a focus on regional, national and international level delivery was essential to effectively deliver the end products in a readily useable format.

The MESH project set out to establish a framework for mapping marine habitats by developing internationally agreed protocols and guidelines for seabed habitat mapping and generating the first compiled marine habitat map for north-west Europe. The project covered the entire marine areas of Ireland, the UK, Netherlands, Belgium and France from the Belgian border to southern Loire on the Atlantic Coast; an area that reflects the geographical scope of the INTERREG IIIB financial instrument and does not imply any desire to exclude other EU countries from the process or products.

MESH set out to achieve this goal by:
- compiling, standardising and quality testing the available seabed habitat mapping information to provide the first seabed habitat maps for north-west Europe;
- developing habitat modelling techniques to predict the distribution of habitats for areas with no existing information;
- producing a set of internationally agreed and practically tested protocols and standards for habitat mapping to support future mapping programmes;
- disseminating the key results via a project website that includes a state of the art web-mapping system, providing ready access to the project information for a wide range of end-users; and
- building a network of stakeholders with an interest in seabed mapping to better understand their end needs, to encourage the supply of relevant data and to encourage the improved use of the mapping information in policy development and environmental management.

The following pages describe how the MESH Project successfully delivered its goal, creating in the process a wealth of products that will help anyone with an interest in seabed habitat mapping, be they someone developing marine policy, someone trying to manage human activities in a sustainable manner, or a technical specialist who has to actually create a map of an area of seabed.

Partners

|	
JOINT NATURE CONSERVATION COMMITTEE	**Joint Nature Conservation Committee (JNCC)**
UNIVERSITEIT GENT	**Ghent University**
Ifremer	**Ifremer**
Marine Institute	**Marine Institute**
WAGENINGEN IMARES / ALTERRA WAGENINGEN UR	**IMARES**
TNO	**TNO – Netherlands Organisation for Applied Scientific Research**
Cefas	**Centre for Environment, Fisheries and Aquaculture Science (CEFAS)**
afbi Agri-Food and Biosciences Institute	**Agri-Food and Biosciences Institute**
NATURAL ENGLAND	**Natural England**
ENVISION	**Envision Mapping Ltd**
national museum wales / amgueddfa cymru / Noddir gan Lywodraeth Cynulliad Cymru Sponsored by Welsh Assembly Government	**Amgueddfa Cymru – National Museum Wales**
British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL	**British Geological Survey (BGS)**

Rocky reef habitat (' JNCC)
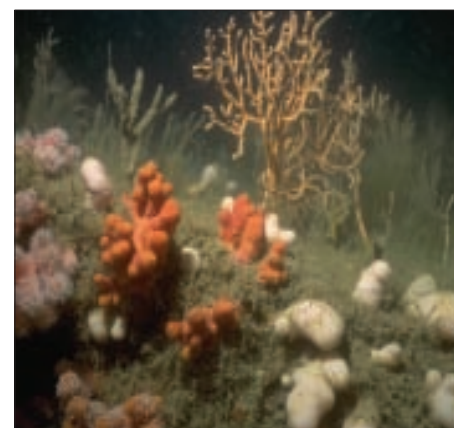
Key achievements

What does the MESH Project offer users?

The MESH Project Partners delivered a range of key transnational products, supported by a large number of specific or individual outputs, from survey reports to case studies. All products are available through the MESH website in our *Product Library* (**www.searchMESH.net/Products**). The *key products* are grouped under the following themes that are described in detail later in this document:

Generating maps —over 1,000 data sets were reviewed by the MESH Project Partners to build a library of available information stored in the *MESH metadata catalogue*. From these maps, we created the first *collated and harmonised map of seabed habitats* for north-west Europe. *Habitat prediction models* were developed either to fill the gaps where existing survey data were not available, or to help understand the distribution of specific habitats using survey data. We developed the *MESH Confidence Assessment Tool* to determine the quality of these maps, showing the results as *Confidence Maps*.

Setting standards — existing protocols and standards for marine surveys were collected and their suitability for seabed mapping evaluated by a group of international experts prior to being published as a *Review*. To help set standards for future surveys and improve the comparability of their products, MESH Project Partners pooled their expertise to produce the *MESH Guide to Habitat Mapping*. Important products presented through the *MESH Guide* are the *MESH Recommended Operating Guidelines* (ROGs) for field survey equipment and the *MESH Scoping Tool*. To aid and promote the common interpretation of acoustic and optical seabed images we initiated the *MESH Catalogue of Seabed Signatures*, showing how a range of habitats appear to different sensing and sampling instruments.

New field studies — testing the suitability of the material presented through the *MESH Guide* to the practical field situation was a key aim of the MESH Project. Over 70 *new field surveys* were completed during the project ranging from studies of the shore and adjacent shallow waters to a survey of very deep submarine canyons on the edge of the continental shelf, over 400 km out to sea. All these studies were recorded in the *MESH Survey Database*.

Mapping data online —from the outset, the MESH Project set out to deliver mapping data directly to our end-users; our products had to be publicly available at no cost to the end-user. We created an interactive mapping system — the *MESH webGIS* linked to databases to provide additional descriptive data about the maps. The *MESH Metadata Catalogue* describes all the datasets and maps collated by the project. Over 2,800 images of the seabed are available through the *MESH webGIS* to help the user visualise the structure and marine life on the seabed at selected locations.

Communicating results — it was vital to the success of the project that its products and outputs met the requirements of the wider technical, scientific and policy stakeholder communities. The project established a *Stakeholder Network* with the details stored in the *MESH Stakeholder Database*. Partners delivered over 350 presentations to conferences and meetings, and published over 20 reports and papers in the scientific literature. Our main results were presented at the *MESH Conference* held in Dublin Castle in March 2007, attended by over 200 people from more than 20 countries around the world. A portfolio of *Case Studies* was compiled both from MESH Partners and stakeholders showing the practical application of habitat maps in marine environmental management.

Future strategy - after consulting with our key stakeholders via meetings and *Stakeholder Workshops*, we developed the *MESH Follow-on Strategy* suggesting how seabed habitat mapping may be taken forward into the future to meet emerging challenges. It deals with maintaining and enhancing the existing MESH Products, and how we propose to explore new avenues for using habitat maps in a research and policy framework.

Why map seabed habitats?

Marine habitat mapping combines biological data from discrete seabed observations with remotely-sensed images to create a habitat map. Marine mapping has a long history dating back many centuries when explorers set out to chart the world's oceans in search of new worlds. Mapping habitats on the seabed (both inter-tidal and subtidal areas) is a relatively new industry that has made great strides over the past decade due to our increased technological ability to image the seabed. Many organisations worked in this field with the result that a variety of 'standards' were created, the maps spoke different 'languages' in terms of the way they described the seabed habitats, maps emanated from 'local' studies of small geographic areas and, most frustratingly, they were locked away in dusty archives so not available for use by others resulting in many areas being re-mapped at significant expense.
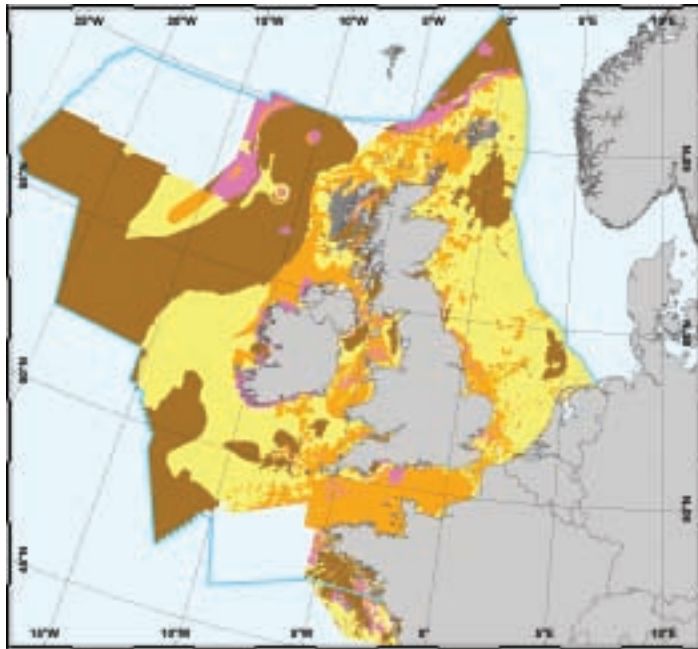
The first transnational seabed sediment map for NW Europe

Emerging European marine policy that aims to improve the state of the marine environment, manage human activities to reduce their impact and ultimately deliver international commitments on sustainable development requires a strong evidence base on seabed resources. Seabed habitat maps are one essential piece of evidence but the maps must be consistent in language and format so they can be compared and combined to offer appropriate geographic coverage to underpin planning and management of human activities.

Examples of key policy and management challenges where the outputs of the MESH Project are directly relevant include:

- **Implementing the ecosystem approach in practice**: this policy underpins the recently agreed EU Marine Strategy Framework Directive. Due to the MESH Project, we have a better basis for describing the seabed - a key component of the ecosystem, for several of the 'Marine Sub-Regions' for which marine strategies will be developed. The MESH Project provides new modelling approaches to 'fill in' the gaps between actual survey data.

- **Addressing multiple use and pressures including through the development of measures such as marine spatial planning**: the MESH Project has provided much improved information on the spatial distribution and the quality of seabed habitats and explored how this, combined with equivalent data on human activities, is essential to deliver effective spatial planning and management of the marine environment - see the section on Case studies.

- **Delivering international obligations to protect seabed habitats**: the outputs of the MESH Project provide a sounder basis for considering conservation measures at a broad level, e.g. working towards a network of Marine Protected Areas under the OSPAR Convention, and also at the individual site level with surveys of potential Special Areas of Conservation — see section on the MESH Canyons Cruise.

The MESH Project delivered a framework and the necessary tools to help deliver this evidence base. This *MESH Blue Book* describes how the project's outputs can support your work.

Case study: mapping shellfish beds

Surveys in the Dutch Wadden Sea showed that sidescan-sonar imaging is an effective tool for mapping shellfish beds, even in extremely shallow water environments. Digital processing and pattern recognition techniques were able to delineate the edge of the bed, and estimate the density of shellfish.

Intertidal sediment sampling (' IMARES)

Seabed habitat mapping – a background

It is important to understand that a habitat map is a visual product that is the culmination of a complex process that involves the expert interpretation of data. Maps are designed to pass on specific messages to the map user. For many, maps are pieces of art to be admired, but to others, they form an essential part of a toolset to solve complex problems in the natural environment. Unfortunately, these two extremes become somewhat blurred when users trying to solve problems do not have an understanding of maps beyond the concept of art . Remember that maps are **one** truth and not **the** truth: compare the maps of the Dutch continental shelf made for engineers and for biologists. Different map makers will produce differing maps of the same feature, unless they agree to use the same datasets and to follow the same protocols.

A map created for engineers showing broad percentage mud content of sediment
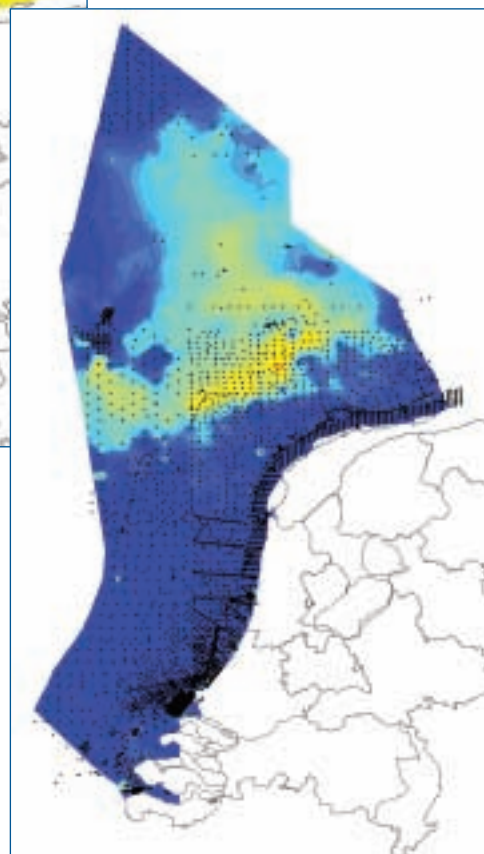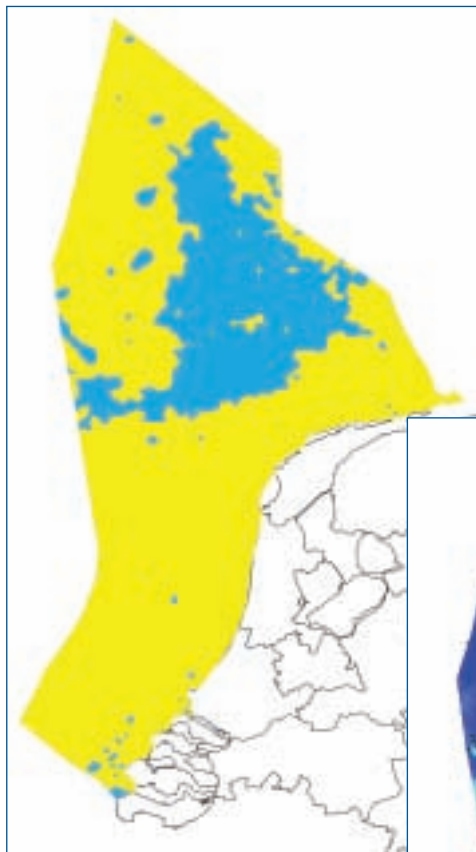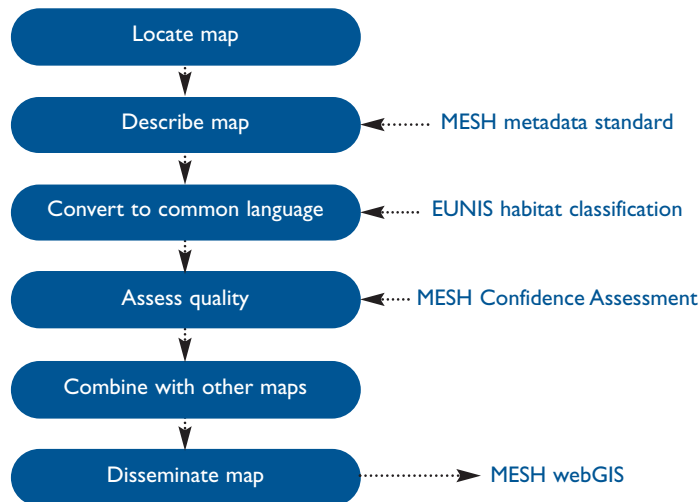
A map created for biologists showing detailed percentage mud content of sediment

Societal demands for marine resources for consumption (fish), construction (aggregates), energy and space (shipping and recreation) have risen sharply over past decades. Technological advances have supported such demand, generally by exploiting marine ecosystems further and further away from the coast. Our need for accurate spatial data has similarly increased. Habitats maps provide a fundamental layer for strategic and spatial planning to assist the sustainable use of marine resources. They also underpin the implementation of the ecosystem approach to management of human activities to help protect marine ecosystems and facilitate State of the Seas assessments. The importance of spatial information is clearly recognised in the plans for marine spatial planning and an European Atlas of the Seas in the EC Maritime Strategy Action plan.

Generating maps

Seabed maps are a valuable resource because the data upon which they are based are expensive to collect and time-consuming to interpret. This makes them relatively rare commodities; therefore it is vital that maximum value can be extracted from a data resource, both at the time of collection and into the future. Re-mapping an area because a previous study was hidden from other users results in a significant waste of scarce resources that could be used to collect new data from previously un-mapped areas.

Building maps from existing data

Locate map

Describe map ·········◄ MESH metadata standard

Convert to common language ◄······· EUNIS habitat classification

Assess quality ◄····· MESH Confidence Assessment

Combine with other maps

Disseminate map ············► MESH webGIS

Process used by MESH Partners to create standardised maps from exisiting data

Using existing data

Depending upon your need for a seabed habitat map, it may not be necessary to commission a new survey campaign — existing maps or new maps created using models may meet your requirements. The MESH Project developed the MESH Scoping Tool to help assess your needs. It also brought together existing maps with tools to help describe and display them, and modelling techniques to generate new maps that predict the distribution of seabed habitats using physical environmental data.

Locating & describing existing data

MESH Project Partners located existing seabed habitat maps in north-west Europe held by very many organisations in disparate archives in a wide range of formats. They highlighted two technical obstacles to the goal of generating a unified seabed habitat map for north-west Europe. Firstly, lack of a common and practical set of terms to describe data resources, and secondly, the lack of a common file format for sharing seabed habitat maps. In overcoming these obstacles, the MESH Project defined a new metadata standard and Data Exchange Formats (DEFs) specifically for application to seabed habitat maps.

Metadata are high-level information that describes a data set, giving information about its characteristics and provenance. For example, metadata records *Who, What, When, Where, How* and *Why* data were collected and maps were made. The MESH metadata standard was developed to record specific information that describes seabed habitat mapping studies. Over 1,000 studies from five countries (Belgium, France, Ireland, Netherlands and UK) were described by the MESH Partners, and the descriptions made publicly available in the searchable *MESH Metadata Catalogue* (**www.searchMESH.net/metadata**), also linked to the *MESH webGIS* to map the location of a study.

Data Exchange Formats (DEFs) define the characteristics of data to be exchanged between parties by clearly stating the recipients requirement. The MESH Project defined DEFs for the different types of data involved in seabed habitat mapping. The MESH DEFs helped the exchange of seabed mapping data between individuals or organisations and the MESH Project. They are available for download from the MESH website (**www.searchMESH.net/DEF**) and offer a standard format for future data to make its exchange easier and thereby maximise its value to others.

Seabed sediment sample (' Cefas)
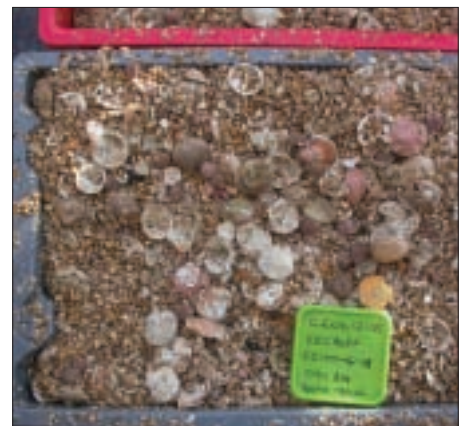
"This is considered to be the first multi-criteria, systematic, confidence assessment methodology of its kind to be produced for marine habitat mapping"

The ICES (International Council for the Exploration of the Seas) Working Group for Marine Habitat Mapping

Standardising maps

Existing seabed habitat maps described by the MESH Partners were derived from a diverse range of studies, many of which used different languages (i.e. habitat classification schemes) to describe the seabed. Asking questions across a range of such maps about the occurrence and extent of habitats of interest is impossible without first converting all the maps to a common language . The MESH Project calls this process of converting habitat classes from one classification system to another *translation'* and focused on translating maps to a European standard known as the EUNIS classification scheme (European Nature Information System: **eunis.eea.europa.eu**). Over 250 maps were translated from their original habitat classes to their corresponding EUNIS habitats using expert judgement by the MESH Partners.
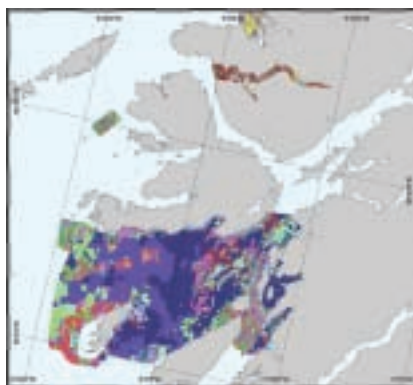
Original habitat maps have their own colour schemes
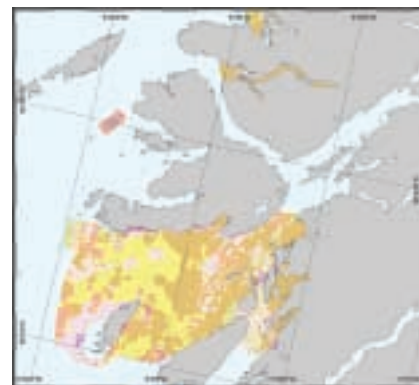
Habitat maps were standardised to the EUNIS scheme

Assessing the quality of a map

Users want to know the quality of a habitat map, particularly if they have to use it for important decisions that may have significant socio-economic consequences. The MESH Project developed a confidence assessment system to give users a measure of the suitability of maps in the management of natural resources. A multi-criteria approach facilitates the determination of *map confidence* based around three central themes:

1. How good is the remote sensing?
2. How good is the ground truthing?
3. How good is the interpretation?

These themes follow the MESH principle that habitat maps are created through the interpretation of remote sensing data together with ground truthing data. Historical maps can be as easily assessed as contemporary maps. Each theme has a series of questions relating to the various factors that affect user-confidence in a map. Maps can be scored using the information held for that study in the MESH metadata catalogue. The scheme was developed into the interactive **MESH Confidence Assessment Tool** that is available on the MESH website (**www.searchMESH.net/confidence**).

Overlapping maps showing different habitats for the same area

Overlapping maps have different MESH Confidence scores

A screenshot of the interactive *MESH Confidence Assessment Tool*

Combining maps

A key output of the MESH Project was a habitat map for north-west Europe based on the EUNIS classification scheme, derived from existing maps, displayed on the MESH webGIS and made available for distribution to third parties. Once the existing (source) maps were translated to the EUNIS scheme, they were combined to create a single layer. On occasion, some of the original source maps overlapped, meaning that several interpretations were available within the area of overlap, which was not desirable. In this case we chose to classify the habitats in the area of overlap using the source map that had the highest score in the MESH Confidence Assessment Tool.

Overlapping sections of maps with the lower confidence score removed


Sonar image of the seabed (' AFBI)
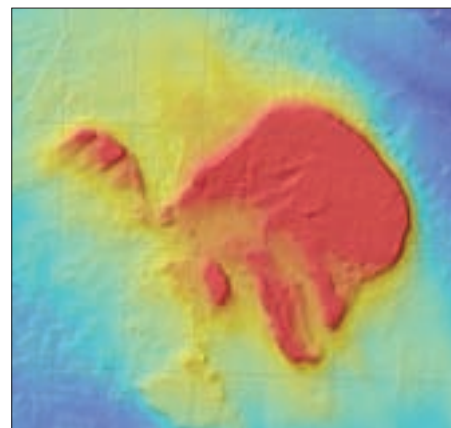
Habitat modelling

There are simply no detailed habitat maps available for much of the seabed of north-west Europe. The MESH Project developed modelling approaches to predict the distribution of seabed habitats over these large gaps using the physical characteristics of the seabed such as the sediment type and the depth. The same modelling approach was used to create two different types of map: maps showing the likely occurrence of EUNIS habitats and maps showing the distribution of more broadly defined marine landscapes.

EUNIS habitats in the MESH area

Our knowledge of the distribution of EUNIS habitats in north-west Europe is extremely patchy, because much of the area has not been subject to habitat mapping studies or surveys. However, the potential distribution of EUNIS habitats can be predicted by models based on environmental variables known to be important in defining these habitat types. The MESH Partners worked together to create transnational environmental datasets (bathymetry, sediments, energy) on which to base a prediction of EUNIS habitat across the MESH area. These data sets are significant products in their own right and could not have been created without the opportunity for transnational cooperation offered by the MESH Project.
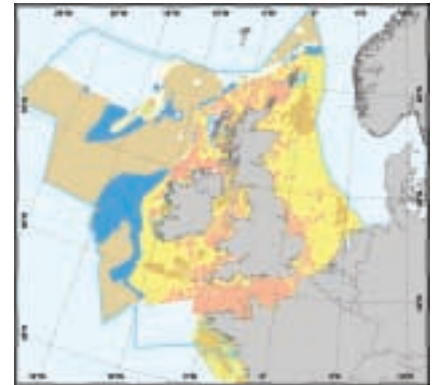
Predicted distribution of EUNIS habitats for the MESH area

National marine landscape maps

Maps showing detailed habitat types are either not suitable or frequently not available for some applications, such as planning at a regional sea scale, where more general descriptions of the seabed are possible in the form of marine landscapes, i.e. the sub-sea equivalent of terrestrial landscapes (a mix of topography and broad habitats) such as heathland, valley, forest or mountain with which we are all familiar. Marine landscape maps of national waters were created by the Belgian, Dutch, French and UK Partners. National maps were created because the size of the national territories varies and it was more appropriate to produce maps at the scale most relevant to each country. Nevertheless, MESH Partners collaborated to use a common modelling approach throughout, with the final maps created at the most appropriate scale and resolution of the marine landscape type.
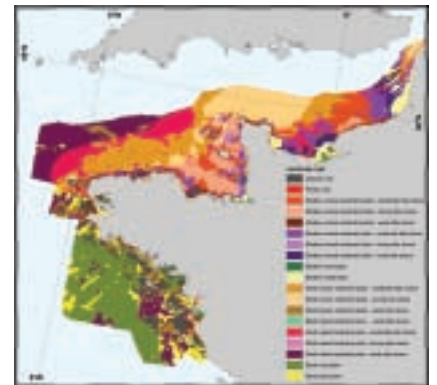
A marine landscape map for northern France

Predicting the distribution of single habitats and species

MESH Partners developed a range of models to help understand the distribution of specific habitats or species. These models generate maps showing the relative suitability of different areas of seabed for a particular species or habitat. Such a model can be useful in determining which environmental factors have the most influence on species or habitat distribution, and help to show where new mapping studies should be targeted, particularly those concerned with species and habitats of conservation interest.


A habitat suitability map for communities on the Belgian Continental Shelf

Field studies

MESH surveys

MESH Project Partners completed a wide range of field studies during the project, ranging from surveys of new areas to surveys in challenging environments (such as the MESH Canyons Cruise), to surveys that tested familiar equipment in unfamiliar situations (using sidescan sonar for mapping mussel beds in very shallow water). Practical experience gained from these surveys contributed to the *MESH Guide*, and all the results are available in the Products Library of the MESH website (**www.searchMESH.net/products**), including one or more reports on each of the surveys.

Samples of seabed sediments are collected by box corer.
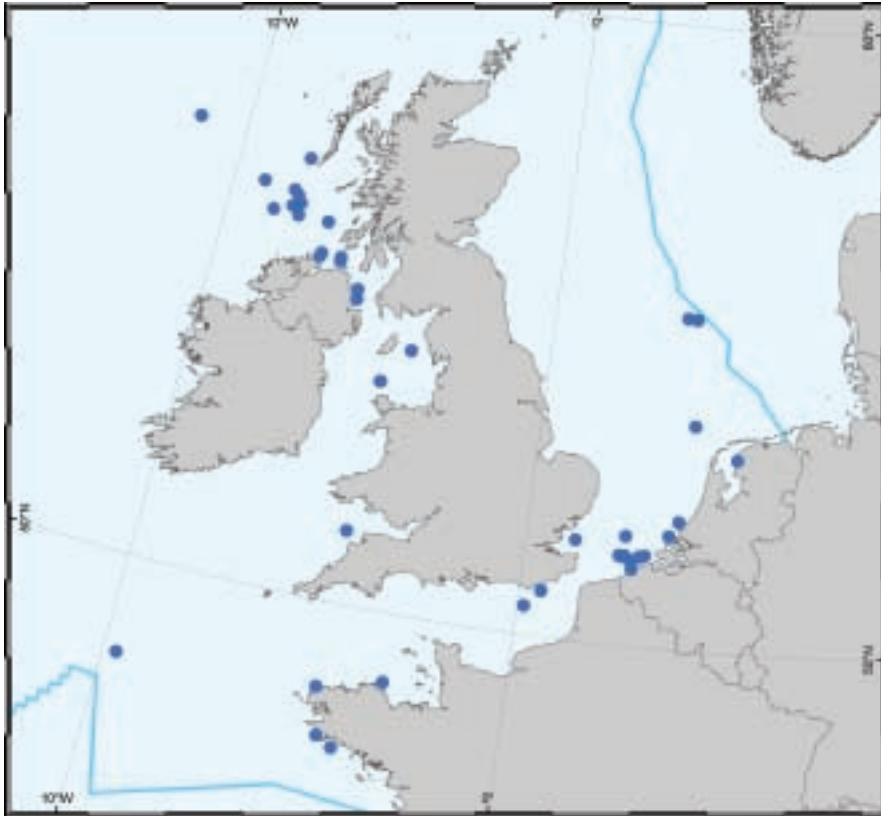
The location of new surveys completed by the MESH Project Partners

MESH Project Partners completed over 70 field surveys in all five countries of north-west Europe.
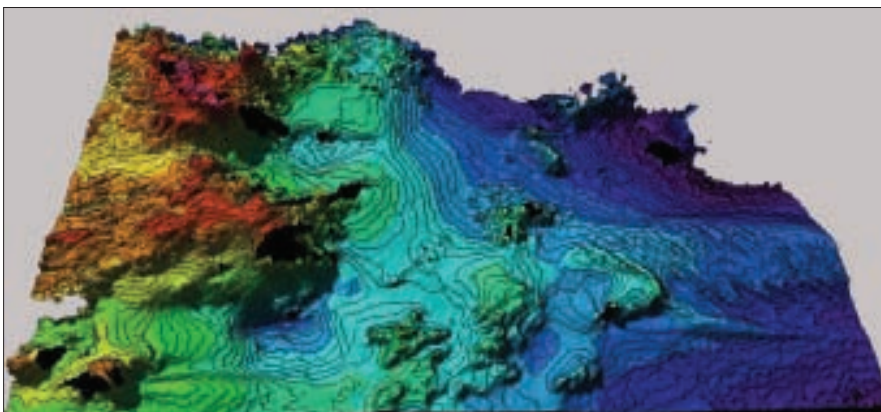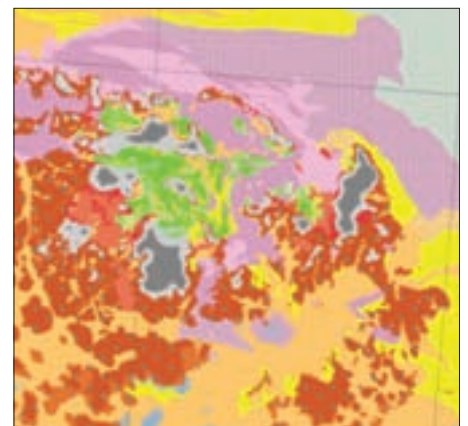

A digital terain model of Tregor, Brittany based on a LiDAR image (' Ifremer)
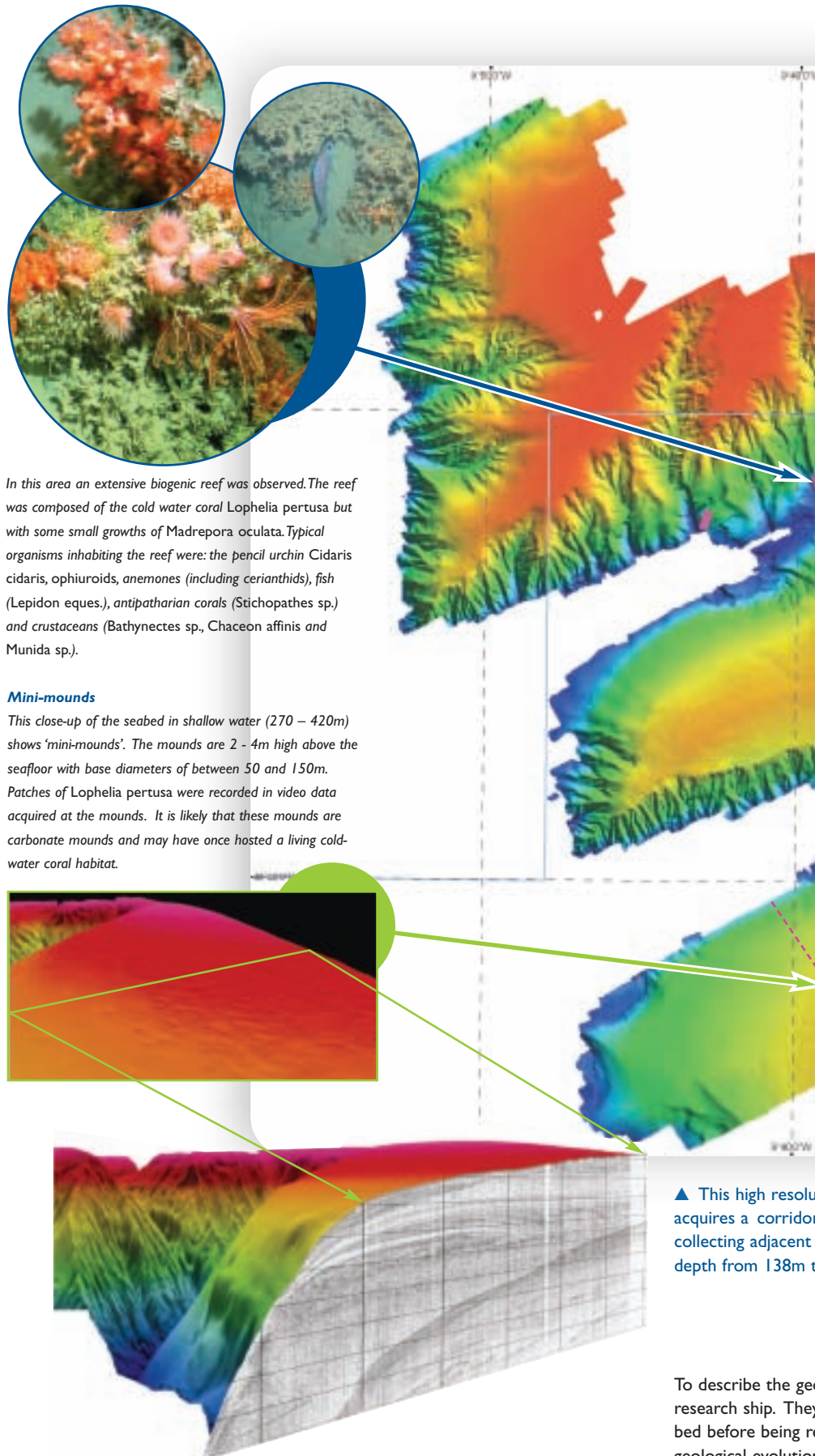
Seabed habitat map (' Ifremer)

Exploring the geology & the canyons in

In June 2007, the MESH Project completed a survey of some submarine canyons that cut into the edge of the continental shelf in the SW Approaches, an area located approximately 320km southwest of UK. During a 15 day cruise aboard the *RV Celtic Explorer*, the MESH team acquired high resolution sonar and seismic data of the seabed, together with video images of the biological communities. They mapped both the surface topography and geological structure under the seabed, and investigated the biological communities within the canyon system to assess whether the area met the criteria to be designated a Special Area of Conservation (SAC) under the EC Habitats Directive. The cruise also tested the advice developed for the *MESH Guide*, to provide a proof of concept of the advice from the planning stage to the final maps.

On the biological section of the cruise, a high resolution deep water camera was lowered to the seabed to c 1,000m. The seabed of the canyons consisted of fine muddy sands at the head, with the epifauna characteris and featherstars. Cold water coral reefs were discovered on the canyons flanks. Some data suggested forme to the top of the canyons, similar to those found on the edge of the Irish continental shelf.

In this area an extensive biogenic reef was observed. The reef was composed of the cold water coral Lophelia pertusa *but with some small growths of* Madrepora oculata. *Typical organisms inhabiting the reef were: the pencil urchin* Cidaris cidaris, *ophiuroids, anemones (including cerianthids), fish (*Lepidon eques.*), antipatharian corals (*Stichopathes sp.*) and crustaceans (*Bathynectes sp., Chaceon affinis *and* Munida sp.*).*

Mini-mounds
This close-up of the seabed in shallow water (270 – 420m) shows 'mini-mounds'. The mounds are 2 - 4m high above the seafloor with base diameters of between 50 and 150m. Patches of Lophelia pertusa *were recorded in video data acquired at the mounds. It is likely that these mounds are carbonate mounds and may have once hosted a living cold-water coral habitat.*

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capture video and still images at depths down to a
by seapens, soft corals, anemones, sea cucumbers,
r coral mounds were present on the seabed adjacent
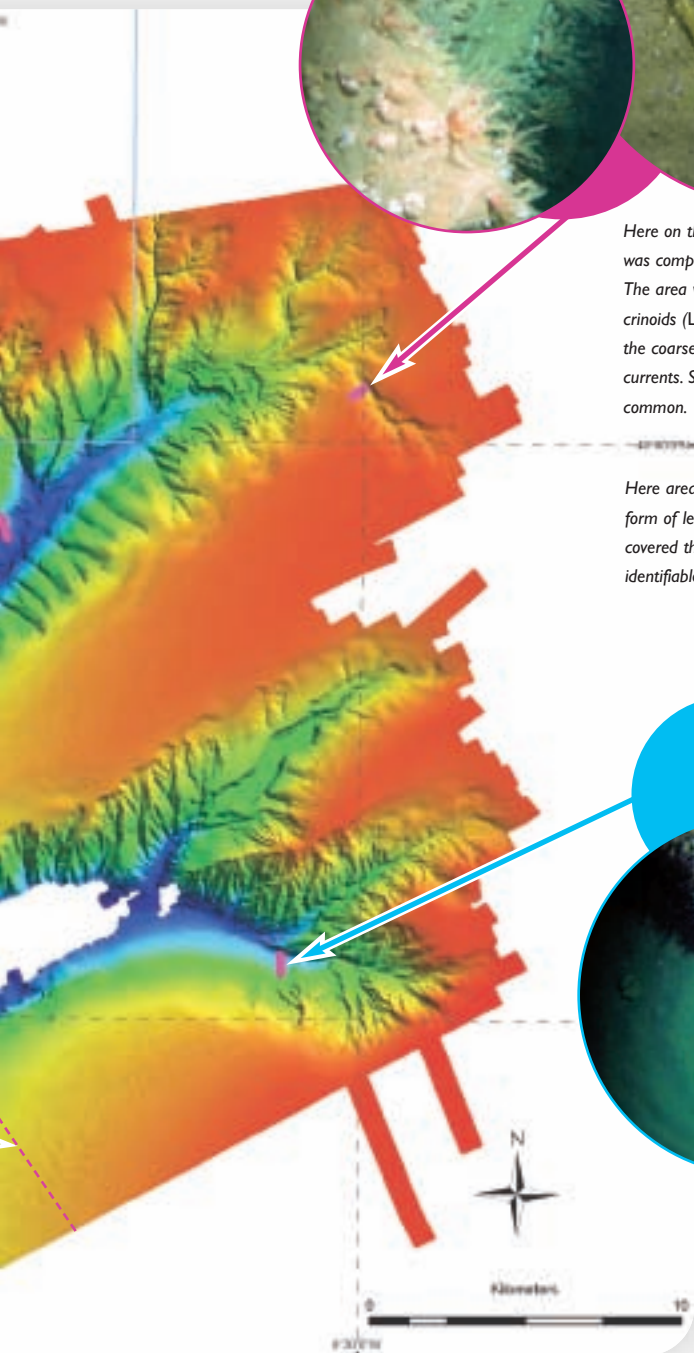
*Here on the steep slopes of the tributary the seabed
was composed of coarse sand and mixed sediments.
The area was dominated by dense aggregations of
crinoids (Leptometra celtica), which together with
the coarse nature of the substrate suggests active
currents. Squat lobsters (Munida sp.) were also
common.*

*Here areas of bedrock were observed and took the
form of ledges or terraces. A veneer of sediment
covered the bedrock and few fauna were
identifiable. However, anemones are clearly visible.*

tion topographic image of the seabed was collected using a multibeam bathymetry system. This system
of data on the depth to the seabed below the boat which allows large areas to be covered quickly. By
corridors of data a complete picture of the shape of the canyons was revealed. The canyons varied in
o 1,165m and showed a complex network of tributary valleys feeding into the head of the main canyons.

ological structure below the seabed, two different frequency seismic systems were towed behind the
y emitted sound waves that were reflected both by the seabed and the sedimentary layers below the sea
ecorded by an array of hydrophones, also towed behind the ship. The data gathered showed the complex
n of the canyon system, revealing periods of intense erosion and deposition.

Setting standards

A core objective of the MESH Project was the establishment of a common set of standards and protocols for marine habitat mapping to ensure that future local, regional and national mapping initiatives are compatible and can be used to build and maintain integrated habitat maps for the seas of north-west Europe. The *MESH Guide to Marine Habitat Mapping* was developed to pass on to others the cumulative experience and wisdom gathered during the project. The *MESH Guide* involved reviewing the existing application of remote sensing and direct sampling techniques and, where necessary, amending or developing these for specific application to seabed habitat mapping. The standards and protocols required information on the operation of equipment, the conduct of surveys and the interpretation of data. New field surveys tested the standards and protocols to ensure they offered appropriate advice. The final stage was to set out a common approach for turning the data into maps.

The *MESH Guide* describes the processes involved in creating a seabed habitat map

Review of existing standards and protocols

Many of the survey and sampling techniques used in habitat mapping were initially designed for other purposes, each of which has its own set of standards and protocols. Standards apply to data and ensure consistent data quality. Protocols apply to methods and ensure consistency in survey methodology and data interpretation. The *MESH Review of Standards and Protocols* examined existing standards and protocols with a view to highlighting those that could be adopted immediately, and identifying the major areas where further development was required.

For each technique the MESH Review of standards and protocols provides:

A review of the technique
The general principles of operation
Descriptions of the systems available

Existing Standards & Protocols for:
 Data acquisition
 Data processing
 Data interpretation
Its provenance and current usage
A summary and recommendations

The reviews were grouped into four broad themes:

Remote sensing techniques - for shoreline & shallow water surveys such as airborne techniques including LiDAR, CASI and aerial photography, and satellite imaging.

Acoustic systems - remote imaging techniques for deeper water surveys using acoustic systems such as multibeam sonar, sidescan sonar, Acoustic Ground Discrimination Systems (AGDS), 3D seismics and sub-bottom profiling.
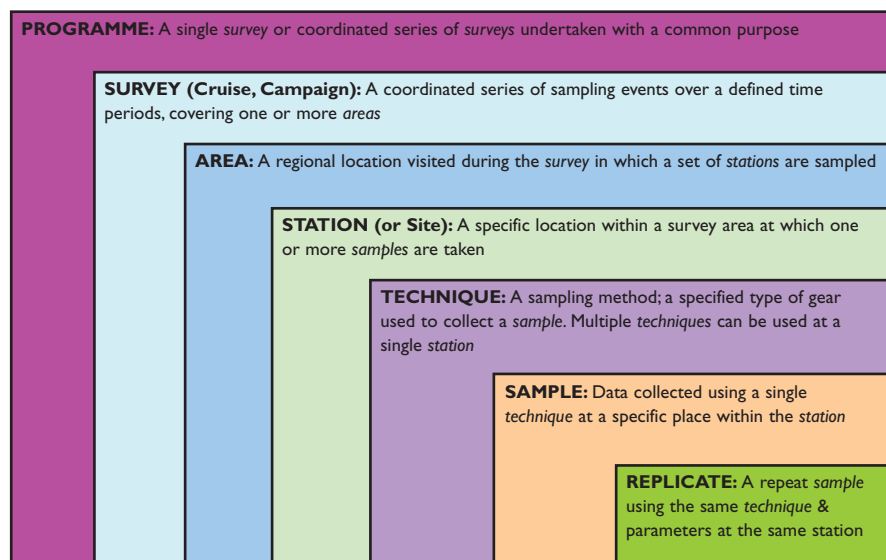
In-situ sampling techniques - for ground-truthing of remote data including diver surveys, grabs sampling, trawling and dredging.

Video and imaging techniques - including camera sledges, ROVs, drop cameras and sediment profile imagery (SPI).

The *MESH Review of Standards and Protocols* can be downloaded from the Product Library on the MESH website (**www.searchMESH.net/Default.aspx?page=1442**)

Collecting quality assured data

Producing effective maps requires quality assured data interpreted in a standard manner. The *MESH Review* process concluded that it would be counter productive to be too prescriptive about the way in which certain types of survey equipment were used; surveyors need to be able to tweak their equipment as best suits the prevailing conditions at the time of survey. It was more important to capture information about how the system was set up and how it was used, as this knowledge is critical to the subsequent interpretation of the data. Such survey metadata describes *Where*, *When*, *How* and *Why* a survey was done; information that is crucial in assessing the quality of the resulting data. The confidence that can be placed in the final map is largely dependant on an understanding of the quality of the data that has been used to make the map.

PROGRAMME: A single *survey* or coordinated series of *surveys* undertaken with a common purpose

SURVEY (Cruise, Campaign): A coordinated series of sampling events over a defined time periods, covering one or more *areas*

AREA: A regional location visited during the *survey* in which a set of *stations* are sampled

STATION (or Site): A specific location within a survey area at which one or more *samples* are taken

TECHNIQUE: A sampling method; a specified type of gear used to collect a *sample*. Multiple *techniques* can be used at a single *station*

SAMPLE: Data collected using a single *technique* at a specific place within the *station*

REPLICATE: A repeat *sample* using the same *technique* & parameters at the same station

Survey data are organised into a heirarchy for easy recording

Seabed Signatures Catalogue

This catalogue provides a reference collection of seabed images showing how a habitat appears to a variety of sensing or sampling techniques. It will help everyone recognise the particular signature of a habitat and so promote a standard interpretation of similar images. It also helps to show how some techniques are better at imaging certain habitats than others. The seabed signatures catalogue is available as an interactive website (**www.rebent.org/mesh/signatures**) that currently shows images of 33 habitat types found in the north-west Europe region. To encourage wider participation, we encourage anyone to submit new images of existing habitats and to generate entries for new habitats that are not already covered.

An example page from the *MESH Seabed Signatures* catalogue showing different images of the same habitat


MESH webGIS: study areas

MESH Guide to Marine Habitat Mapping

The *MESH Guide to Marine Habitat Mapping* describes the processes and decisions required to deliver a comprehensive, fit for purpose, quality assured seabed habitat map. It provides simple explanations and detailed, practical, step-by-step assistance through the mapping process giving users all the information required to ensure **consistency and compatibility** between seabed habitat maps. It is an indispensable resource for anyone associated with habitat mapping since it describes the whole process from project planning and scoping, through the field work, to producing and using the final maps.
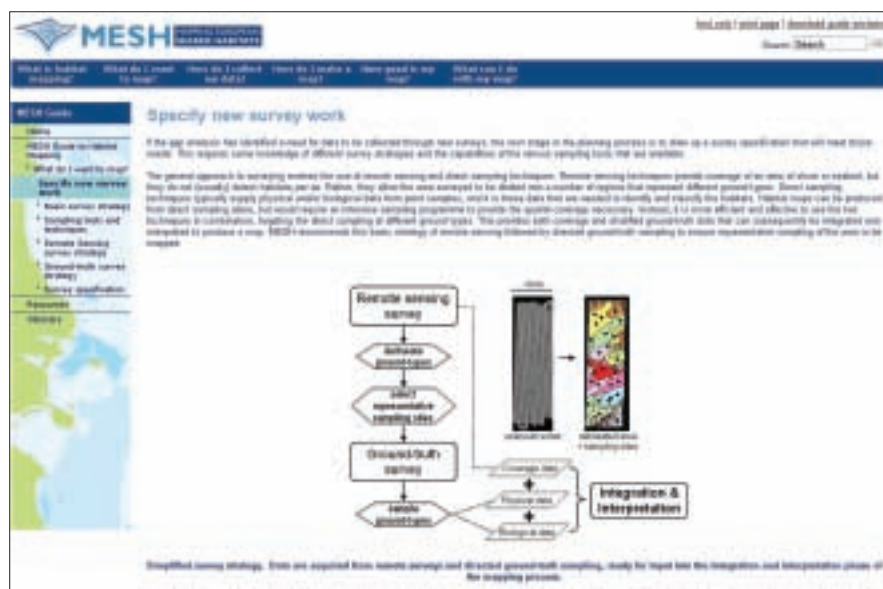
The *MESH Guide to Habitatal Mapping* is an easy to use, interactive website

The *MESH Guide* is available through the MESH website (**www.searchMESH.net/mapping-guide**). Over 250 web pages are full of advice, extensively illustrated with pictures and a series of tools, templates and texts available for download from a resource library. It is extensively linked to other sources of information throughout the website and presents the *MESH Recommended Operating Guidelines* (ROGs), interactive tools such as the *MESH Scoping Tool*, and a comprehensive library of resources. A printed summary with the full site on a DVD are available for offline use. Each section has a hierarchical structure where the top level explains the key principles in simple terms and the subsequent levels offering greater technical detail as the user navigates down the guide.

Producing the *MESH Guide* was an enormous collaborative effort across the partnership - it pools our collective knowledge to offer users an in-depth understanding of seabed habitat mapping. The *MESH Guide* is a very significant transnational product and a valuable addition to seabed habitat mapping.

Recommended Operating Guidelines

Most of the techniques used by habitat mappers were designed for other survey disciplines, often having well established standard operating procedures (SOPs). Following the MESH review of existing standards and protocols, it was apparent that some techniques needed new guidance on their specific application to habitat mapping: the *MESH Recommended Operating Guidelines* (ROGs) describe how best to use each technique in a marine habitat mapping context.

These guidelines are not intended to be prescriptive; instead they allow techniques to be adapted to suit local needs. They reflect operational experience of the MESH Partners and aim to provide a common protocol for the use of each technique and to ensure that the data collected have acceptable quality and are compatible with similar data from other surveys.

Specially designed survey vessels are essential for efficient data collection (' AFBI)

Intertidal & shallow mapping	Subtidal mapping	Ground truth data subtidal collection
Aerial photography	AGDS	Box Coring
Airborne Digital Imagery	Sidescan Sonar	Sediment Profile Imagery (SPI)
LiDAR	Single beam echo sounder	Trawls and Dredges
Satellite Imagery	Sub bottom Profiling (Chirp)	Video
	Swath Bathymetry	
	3D Seismic imagery	

The *ROGs* are a significant output from the project towards helping improve the consistency between the products of future seabed habitat mapping studies.

MESH Scoping Tool

To help users design a mapping programme to meet their requirements, the *MESH Guide* provides an interactive Flash$^{¤}$ animation — the *MESH Scoping Tool* (see: **www.searchMESH.net/default.aspx?page=1931**). It guides the user through a series of prompts asking them to consider the purpose of their survey, what factors that will affect the amount of survey effort required and how different survey and environmental conditions will affect the suitability of various survey tools that may be available. A summary table highlights one or more potential survey strategies and provides guidance based on an analysis of the choices made. The *MESH Scoping Tool* aims to ensure that each element of a mapping programme is properly balanced so that the final maps meet the user s expectations.

MESH webGIS: seabed sediments

The interactive *MESH Scoping Tool*

Type of Organisation	Percentage of Stakeholder network
Government	28
Private company	18
University	16
Research Institute	13
Industry	7
NGO	6
Education	6
Other	6
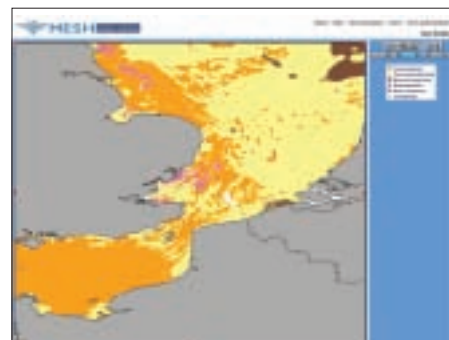
Communicating results

A project is only successful if its products are actually used and valued by stakeholders. Changing behaviour is essential to ensure the wider use of new products since people naturally tend to use familiar, tried and tested tools in their work.

The MESH Project Partners put considerable effort into engaging with others in the wider scientific, policy, planning and technical communities, together with the general public, to incorporate their expertise and ideas into project outputs and to keep them informed of the work and results of the project. Project results were presented at international conferences including GeoHab and CoastGIS and to groups such as the IUCN, EU Commission, European Environment Agency, OSPAR, and the European Nature Conservation Symposium. Partners have published many papers in peer reviewed journals and articles in magazines and newsletters.

At an early stage, a communication strategy prioritised who needed to be contacted and identified the most effective approach. A key part of this strategy was to design a project website to disseminate results and feedback on the project and generate a mapping tool — *MESH webGIS* to display the habitat maps.

Stakeholder engagement

Through hundreds of presentations, attendance at conferences, interacting with stakeholders at meetings and through the website, the MESH Partners built up a network of contacts interested in seabed habitat mapping. The *MESH stakeholder database* contains over 1,700 contacts from 44 countries encompassing all relevant industry, government and private sectors, from specialist habitat mappers to data providers, spatial and environmental managers, scientists and policy makers. In total, nearly 900 organisations were regularly engaged with the project before it finished in January 2008 through newsletters (all the newsletters are available to read on the website) and mail updates. Feedback provided by this wide range of people was extremely valuable for guiding the project s final outputs towards products that would meet the needs and requirements of the marine habitat mapping community. Each Partner took responsibility for communication with, and disseminating information and results to, interested organisations in their respective countries.

Each Member State organised and hosted a *Stakeholder Workshop* on the use and need for habitat maps in spatial planning and environmental management. The workshops allowed in-depth discussion on specific topics of interest and, as well as raising the profile of MESH, provided invaluable feedback from people on a more personal level. The presentations to and the outcomes from each national meeting, together with a summary report drawing together common views, are available through the project website — each report reflecting the priorities and interests of that particular region.

MESH website

The MESH website (**www.searchMESH.net**) is the easiest way to access and download the wealth of products generated over the four years of the project. Quick links are provided from the home page to the *MESH Guide to Marine Habitat Mapping, MESH Mapping System* and the *Product Library*. Initially the website described the project's work and supported internal communication between the Partners via a private extranet area. Later, entrance portals to the early versions of the *MESH webGIS* and *MESH Metadata Catalogue* were added. Finally, the whole website was completely redesigned at the end of the project to act as a delivery system for the key products and outputs.

The website is organised around the *Product Library* which is divided into the different elements of habitat mapping — planning, field work, modelling, producing maps, which effortlessly leads to your area of interest. The *MESH webGIS* and the *MESH Metadata Catalogue* are linked together into a single area — the MESH Mapping System. Providing easy access to maps and protocols is essential to help bring about the improvements in the consistency of mapping surveys and contribute to spatial planning and management initiatives which underpin the goal of the MESH Project. The website still provides comprehensive background information on the origin of the MESH project, its history and how it was organised, together with a *Guide to seabed mapping for non-scientists.*

Finally, the MESH website also acts as a forum for promoting habitat mapping so that other groups can link up with the project and, ideally, add their data to the existing libraries. At the end of the project in January 2008, the website was receiving over 35,000 page visits and 3,500 new visitors a month.

The MESH Project website presents all the key products

Case study: Habitat mapping in the Wadden Sea
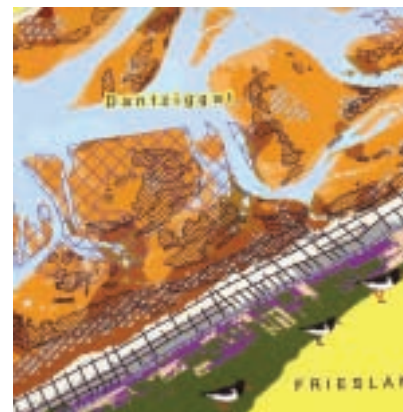
The Netherlands stakeholder meeting reviewed a habitat map for the Wadden Sea which included salt marshes, areas where mussel or cockle beds occurred in recent years and areas where large numbers of birds roost at high tide.

The maps are being used for policy and management decisions on the location of pipelines, other human activities and conservation areas. Image © IMARES

MESH webGIS: seabed images
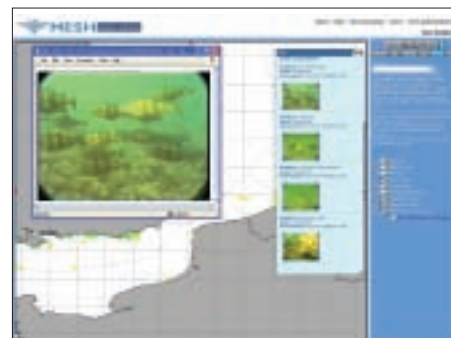
| Collated data available online	Number
Studies listed in metadata catalogue	1,066
Study locations shown on MESH webGIS	467
Seabed habitat maps shown on MESH webGIS	250
Of these, maps translated to EUNIS	170
Acoustic images of the seabed	31
Seabed photos	2,784
National landscape maps	4

MESH mapping system

Two key outputs of the MESH Project have been combined to create the MESH Mapping System area of the website: the *MESH webGIS* shows the maps whilst the *MESH Metadata Catalogue* provides detailed descriptions of these maps, and other sources of data located by the project Partners.

MESH webGIS

The *MESH webGIS* (**www.searchMESH.net/webGIS**) is an online interactive mapping system that is one of the more accessible and visual deliverables from the project. Giving people access to standardised maps and data were central aims of the MESH project and the website now contains over 1,000 studies from which you chose the location, content and scale. The *MESH webGIS* is a simple and easy to use mapping application displaying habitat maps in a standard form together with other data layers important to seabed habitat mapping. Data are grouped into themes to help users find the information they require: habitats, marine landscapes, sediments, bathymetry, boundaries and images. Users can query maps to find out further information about the habitats either at a single location or for an area, create printable reports describing the habitats in the area, and link to the *MESH Metadata Catalogue* to find detailed background information about each study. The *MESH webGIS* also includes an image catalogue allowing you to click on the map to reveal images of the seabed at that location, and links to the UK s National Biodiversity Network website which gives a list of species recorded in a user-selected area.

The *MESH webGIS* can also deliver data directly to a desktop GIS system via a live link, so allowing users to overlay their own data onto the MESH maps or other web mapping services such as Google Earth. The final version of the application was launched in January 2008 - it is publicly available at no cost to the user requiring only a simple registration to obtain the login details. At the end of project in January 2008, the *MESH webGIS* had over 600 registered users.
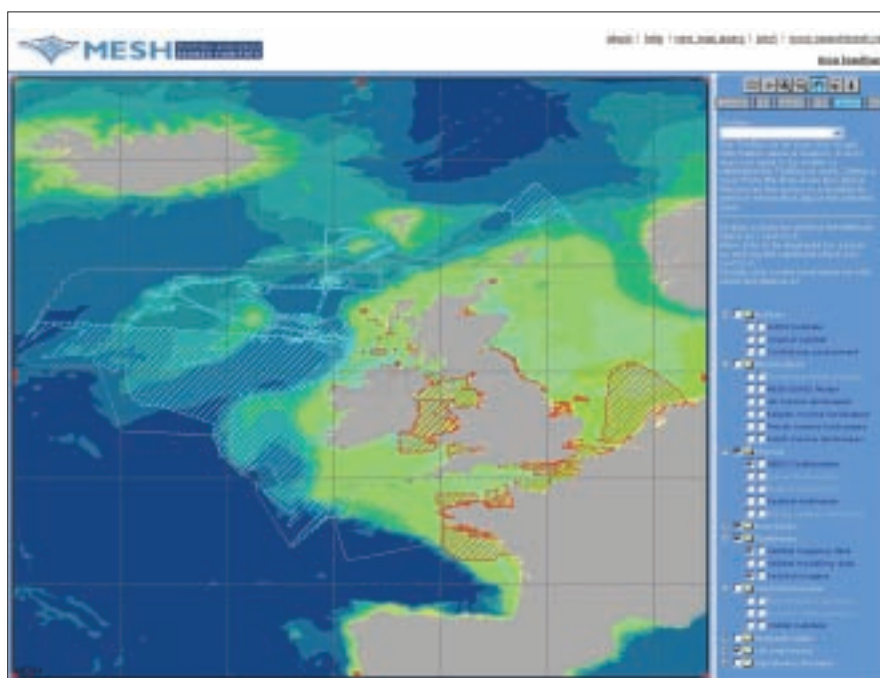
Users can select data layers to view on the *MESH webGIS*

MESH Metadata Catalogue

The online *MESH Metadata Catalogue* (**www.searchMESH.net/metadata**) is a regularly-updated reference library containing descriptions of over 1,000 studies around north-west Europe. Users can interrogate the database to search for studies by country, region, type of habitat classification scheme or data theme. Where the actual habitat mapping data are available, the catalogue provides a link to the *MESH webGIS* so that users can view the area covered by a particular study in conjunction will all other studies. To facilitate data exchange and promote collaborative working, the MESH Project also developed a metadata standard specific to seabed habitat mapping that remains compliant with the recognised international standard for metadata (ISO 19115). Spreadsheet templates supported by a guidance document are available from the MESH website for any users wishing to describe their studies in a suitable manner that they can be incorporated into the existing catalogue.

MESH case studies

Illustrating the importance of having good spatial habitat maps for sustainable marine resource planning and development was a key aim of the MESH Project. The MESH Partners put together a portfolio of case studies that show how maps were used to tackle real problems. These case studies show:

- Examples of spatial planning or decision making where good habitat data were available; and
- The wider use of habitat mapping in environmental or conservation management.

These case studies provide examples from all the countries involved in the MESH Project and cover topics such as sand extraction, spatial planning for tidal stream energy, environmental assessment and monitoring for aggregate extraction, identifying Special Areas of Conservation (SACs), using new technology for detecting biogenic reefs, and multiple use zoning and assessment of human pressures. Visit the MESH website to match your particular field of interest to an example from the large selection of the case studies available to download.

Technical workshops

To ensure the all the outputs from the MESH Project incorporate the most up-to-date thinking, the project Partners used a number of technical workshops to bring together mapping experts from across Europe and North America. These experts could advise on the cutting edge technical thinking, help capture best practice, and give direction and priority to some aspects of the project s work. Workshops were used to target specific techniques and produce high quality, peer reviewed, guidance and standards. The first workshop considered mapping protocols and standards and culminated in the *MESH Review of Standards and Protocols*. Reports are available from the workshop on the use of sonar backscatter data, the Video Working Group meetings, an Intercalibration Workshop on intertidal and shallow subtidal mapping, and a deepwater subtidal mapping workshop (see: **www.searchMESH.net/Default.aspx?page=1914**).

Sharing knowledge during the MESH Intercalibration Workshop, Brest, France (' JNCC)
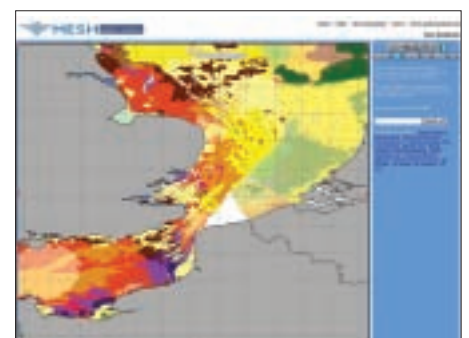
The MESH Project conference

The MESH Project held an international conference in Dublin Castle, Ireland on 14-15 March 2007 to share results and promote the MESH achievements to the wider marine scientific, policy and management communities. The conference attracted over 200 delegates from 20 countries around the world and clearly demonstrated the benefits of transnational partnerships and sharing of expertise. The conference proceedings were published by JNCC together with a DVD containing the posters and presentations, including that of the keynote speaker - Professor Gary Greene (Moss Landing Laboratories, USA). An electronic version of the proceedings is available to download from the MESH website, along with the contents of the DVD (**www.searchMESH.net/conference**).

Case study: Marine Protected Areas the French Spatial Approach

Seabed habitat maps from the MESH Project helped The French Marine Park Authority work toward a coherent network of MPA's in France. The maps mobilised existing data into a useable format, provided a starting point for discussion, aided rational diagnosis in debates, and helped integrate conservation priorities. Maps will also be used in the future to organise new surveys and field sampling programmes. Image © Ifremer

MESH webGIS: marine landscape maps

MESH follow-on strategy

In addition to the wide range of activities undertaken during the course of the project, a key aim was to establish how the outputs from the MESH Project could be maintained and developed beyond the end of the project. The MESH partnership was keen from the outset to establish a foundation for seabed mapping both across the five MESH countries and beyond to other parts of Europe.

This has been achieved through:
- Publishing the *MESH Guide* to promote the production of high quality and consistent habitat mapping data into the future.
- Building capacity and expertise within each MESH country to collate, process and aggregate seabed maps into standard formats and classifications.
- Developing standard *Data Exchange Formats* for new habitat maps and mechanisms to add these data to the existing MESH data bank.
- Ensuring the *MESH website* and *MESH webGIS* facility will be maintained at JNCC beyond the end of the project, offering the opportunity to add further data to improve the quality of existing maps or to extend its geographic coverage beyond north-west Europe.

Feedback received from external users of the MESH Products, particularly the *MESH webGIS*, has indicated a clear need to maintain and continue to develop the maps produced during the project. Partners in each of the MESH countries are developing various ideas on how this can be achieved. These have been summarised in the MESH follow-on strategy on the website. How this will be achieved in each country varies depending on national mechanisms and funding arrangements. For instance:
- Ireland will continue its seabed mapping through the national INFOMAR programme (**www.marine.ie/home/services/surveys/seabed/**) led by the Marine Institute and the Geological Survey of Ireland.
- In France, IFREMER coordinates or contributes to a number of mapping initiatives, including the REBENT programme, which will continue to benefit from MESH products and generate further standard maps.
- The UK has established a national seabed survey coordination group, which will promote the production of seabed maps to MESH standards.

A number of other European countries have expressed interest in following MESH standards and expanding its geographic scope. Additionally the European Commission and European Environment Agency are considering ways to build upon MESH to develop seabed maps across European Seas to contribute to the EC Marine Strategy and the European Atlas of the Seas proposal from the EC Maritime Strategy. Initial ideas include harmonising the maps from north-west Europe (the MESH area) and the Baltic Sea (from the INTERREG BALANCE project) and expanding the broadscale mapping to the Mediterranean Sea. At the global scale, the MESH Project is included in the UN Atlas of the Oceans (**www.oceansatlas.org**)

Seabed mapping is clearly very high on the European marine agenda. The MESH Project successfully established a framework that can be further developed as required to meet the needs of stakeholders as they continue to tackle the challenges of managing human activities to protect the marine environment. The MESH Project offers a range of products to help implement the ecosystem approach to management and thereby deliver the sustainable development agenda for Europe s seas.

David Connor
MESH Project Leader

Acknowledgements

The MESH Project Partners could not have achieved their goals without the management and financial support of their host organisations, and the financial support from the EC INTERREG IIIB Programme for north-west Europe. The Partners wish to acknowledge the staff in the NWE Secretariat in Lille for their support and assistance over the four years of the project.

The MESH Steering Group provided valuable advice and direction during the project, including the suggestion that the Project produces an executive summary — this *MESH Blue Book*.

A number of organisations outside the MESH Partnership provided support to assist the Partners deliver their commitments under the project. These sponsors are listed in the panel to the right.

MESH Partnership

The 12 organisations that made up the MESH Partnership were:

The Joint Nature Conservation Committee (JNCC) is the statutory adviser to Government on UK and international nature conservation. Its work contributes to maintaining and enriching biological diversity, conserving geological features and sustaining natural systems. JNCC were the Lead Partner for the MESH Project.
Website: **www.jncc.gov.uk**

Ghent University is one of the most important institutions of higher education and research in the Dutch-speaking part of Europe. It distinguishes itself as a socially committed and pluralistic university in a broad international perspective, open to all students, regardless of their ideological, political, cultural or social background. Website: **www.rcmg.ugent.be**

Ifremer is the National French institute for marine research. Ifremer contributes, through studies and expert assessments, to knowledge about the ocean and its resources, monitoring of marine and coastal zones and the sustainable development of maritime activities. Website: **www.ifremer.fr**

The **Marine Institute** is the Irish national agency responsible for Marine Research, Technology Development and Innovation. Website: **www.marine.ie**

Wageningen IMARES specialises in strategic and applied marine ecological research. Website: **www.wageningenimares.wur.nl/UK**

TNO is a Dutch institution which aims to apply scientific knowledge to strengthening the innovative power of industry and government. Website: **www.tno.nl**

Cefas is an internationally renowned scientific research and advisory centre working in fisheries management, environmental protection and aquaculture. Website: **www.cefas.co.uk**

Agri-Food and Biosciences Institute (AFBI) (formerly DARD) is a public body based in Northern Ireland and one of the world's leading providers of scientific research and services to government, non-governmental and commercial organisations. Website: **www.afbini.gov.uk**

Natural England (formerly English Nature) is a UK Countryside Agency working for people, places and nature to conserve and enhance biodiversity, landscapes and wildlife in rural, urban, coastal and marine areas. Website: **www.naturalengland.org.uk**

Envision Mapping Ltd is a private consultancy and research company with specialist expertise in environmental mapping, management and data services. Website: **www.envision.uk.com**

The National Museum Wales (NMW) is an independent chartered body and a registered charity. It aims to develop, care for, study and encourage access to its collections for the benefit of society in perpetuity. Website: **www.museumwales.ac.uk**

The British Geological Survey (BGS) is a public sector organisation responsible for advising the UK government on all aspects of geoscience as well as providing impartial geological advice to industry, academia and the public. Website: **www.bgs.ac.uk**

Sponsors

INTERREG IIIB

DEFRA

FPS Economy, SMEs, Self-employed and Energy

Belgian Science and Policy

Delft Cluster

Région Bretagne

Direction Régionale de l'environnement de Bretagne

Front cover (left hand image): this photograph was produced as part of a reef survey commissioned by DEFRA/JNCC within the context of the UK Department of Industry's continuing programme of Strategic Environmental Assessment. The survey of areas of potential reef was to provide information to support the implementation of the EU Habitats Directive in UK offshore waters.

MESH webGIS: EUNIS habitat maps with metadata

Maps showing the distribution of animal and plant communities on the seabed — known as habitat maps, are essential for the wise marine management of human activities to deliver sustainable development.

The *Mapping European Seabed Habitats* (MESH) project tackled the challenge to produce a comprehensive framework to ensure future mapping work could operate in a consistent, quality assured manner to create maps that are fit for purpose.

This Blue Book summarises the key achievements of the MESH Project, describing its main outputs and suggesting how they can help the key European marine policy initiatives that aim to deliver the sustainable use of marine goods and services by present and future generations .