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Abstract Volume

HELSINKI

VELMU surveys underwater biodiversity in the Baltic Sea

VELMU
The Finnish Inventory Programme for the Underwater Marine Environment

VELMU's objective is to survey marine habitats in Finnish waters and give an overview of species occurrence.

VELMU's objective is to survey the marine habitats in Finnish waters, generate an overview of species occurrence, and develop a management system for data collected on the benthic marine environment. The information is needed, for instance, in assessing the status of threatened species and natural habitats, and in support of marine spatial planning. Marine biodiversity is affected by a number of activities, from wind power production to fishing.

The VELMU programme is

- enhancing knowledge of the marine environment by producing an overview of the occurrence and distribution of the most important habitat types and species in Finland's marine waters;
- collating existing research data into a database;
- promoting the exchange of information between institutions engaged in marine biodiversity research and making biological, geological and physical data more easily available; and
- establishing a web-based resource for marine environment information, including a map service.

VELMU surveys both abiotic and biotic elements of the marine environment, in other words, both the geological properties of the sea floor and the species and habitats.

From scuba diving to remote sensing

A variety of methods are used to inventory the marine environment, from scuba diving to remote sensing and modelling. Geological survey methods include echo sounding and bottom sampling. Selected physical and chemical measurements, including water turbidity, temperature and salinity, are included in some field surveys. Methods for biological inventories include underwater video photography, sampling of the bottom fauna and dive transects.

A white plate and scoop are used to survey fish spawning and larval areas in shallow shore areas with submerged vegetation, a seine net is used in waters with sand and gravel bottoms, and in open waters, Gulf ichthyoplankton samplers attached to the bow of a boat are used. Remote sensing methods such as aerial photography and satellite imagery are used, for example, in the planning of surveys and mapping of habitats in shallow areas.

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The GeoHab 2011 Conference

Marine Geological and Biological Habitat Mapping

3–6 May, 2011

Geological Survey of Finland, Espoo

Edited by Aarno Kotilainen and Anu Kaskela

Preface

The Geological Survey of Finland (GTK) with cooperating partners (Metsähallitus SYKE, and Alleco Oy) wish you all welcome to the GeoHab 2011 conference in Espoo, Finland, May 2011.

This is the first time the GeoHab is held in Finland, by the Baltic Sea. Conference will bring together more than 120 scientists, decision makers, and university students from about 25 countries, from Baltic Sea region and around the world, which all have a passion for submarine habitat mapping.

The scientific themes of the GeoHab 2011 include:

- Habitat mapping of shallow seas
- Scale and variability in habitat distribution and diversity
- Geo-bio interactions
- Advances in optical remote sensing of marine habitats

94 abstracts in this volume include oral presentations and poster presentations. All abstracts are printed in alphabetical order of the first author. We would like to thank all authors for their contribution to this abstract volume. We hope that the final result meets the expectations of the authors. We would also like to thank all our sponsors. The success of GeoHab meeting in attracting world-wide participation is largely dependant on your goodwill.

The first official GeoHab conference was held in Moss Landing, California in 2002, after several preparatory meetings in Norway and Canada in 2001. Since then, GeoHab conferences have been held in Australia (Hobart), Ireland (Galway), Canada (Sidney), United Kingdom (Edinburgh), New Caledonia (Noumea), the United States (Sitka), Norway (Trondheim) and New Zealand (Wellington).

Welcome to Espoo, Helsinki Metropol, Finland

Aarno Kotilainen and Anu Kaskela,
On behalf of the organizing committee

Contents

Utilizing physical parameters for predicting shipworm *Teredo navalis* spreading in the Baltic Sea. The WreckProtect Project

Zyad Al-Hamdani[1], Christin Appleqvist[2], Per Jonsson[2] and Jon Havenhand[2]

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Wooden structures such as shipwrecks were adequately preserved in the Baltic Sea from shipworm attacks for centuries. The low sea water temperate and low salinity kept these wooden artefacts safe from the attacks of the wood borers (such as *Teredo navalis*), thus saving an important part of the national heritage from destruction and eventual lost.

Recently there had been new reports on the shipworm *Teredo navalis* attack on shipwrecks. The spatial distribution of these reports is extending from the Kattegat to the southern part of the Baltic Sea. The WreckProtect project (EU 7th FP funded project) investigates the ecological properties of this wood borer and establishes their physiological tolerance to salinity and temperature. Modelled datasets for salinity, temperature and oxygen were acquired form DHI/Denmark using their MIKE-3 Model. These datasets represent the monthly average of the upper 9meter of the water column as well as the near seabed layer and cover the years 1980–2008 (hindcast) and 2009–2020 (predicted). A "Teredo Scenario" that represents the minimum tolerance limits for the shipworm adults to reproduce and the larvae to metamorphosis was established.

A GIS model was build using the "ModelBuilder" to visually elaborate the spatial extension of the "Teredo scenario" over the given period of time. A spreading model was also used to investigate the dispersal extension of the shipworm in the Baltic Sea. The risk of the shipworm spreading is presented for the hindcast period as well as for the predicted period.

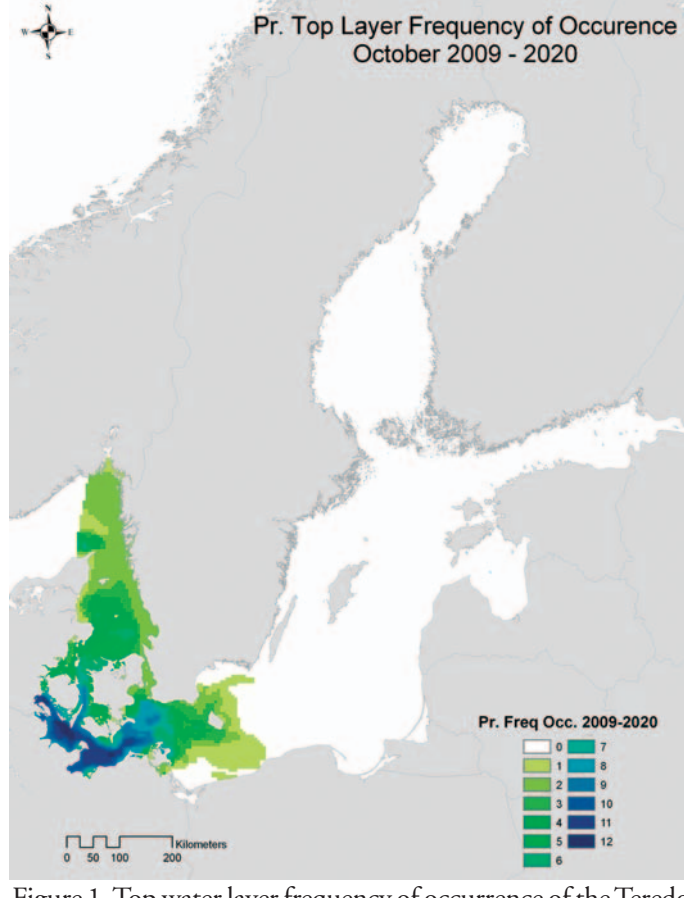

Figure 1. Top water layer frequency of occurrence of the Teredo Scenario.

Geographic Distribution of Natant Decapod Shrimps in the Ross Sea, Antarctica

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This study used new field data and environmental modelling of the distribution of natant decapod crustaceans to identify what environmental variables most influenced their distribution and predict their distribution in the Ross Sea, Antarctica. Six species were recorded, namely *Nematocarcinus lanceopes, Chorismus antarcticus, Notocrangon antarcticus, Pasiphaea scotiae, Pasiphaea sp.and Lebbeus sp*. The geographic distribution of *N. lanceopes* and *N. antarcticus* was predicted from samples of 59 individuals collected at 19 locations between 280 and 2300m depth during the New Zealand IPY-CAML research voyage (TAN0802) in 2008. The Maximum Entropy (MaxEnt) species distribution modelling techniques was used for the data analysis. Environmental data layers had 0.05° spatial resolution and comprised of distance from shore, bathymetry, rugosity, ice coverage, bottom temperature, bottom salinity, current speed, and chlorophyll concentration in summer months. The predicted distributions of the species were mapped and validated using additional data on the species distributions from the SCAR-MarBIN, Australian Antarctic Division data portal, Smithsonian Antarctic Marine database and literature. The most important environmental variables influencing the species distributions were rugosity and bathymetry for *N. lanceopes,* while bottom temperature and chlorophyll concentration in summer months contributed most to the distribution of *N. antarcticus*. Effects of spatial resolution in modelling were also investigated with a comparison between the models generated with environmental layers having different spatial resolutions.

Sedimentary processes and habitats on a shallow strandflat bank, Lopphavet, southern Barents Sea

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Norway's major seabed mapping programme (MAREANO) aims to investigate the physical, biological and environmental status of the seabed offshore Lofoten and in the Southern Barents Sea. Results are continuously published on www.mareano.no. Multibeam (bathymetry and backscatter) data, samples and video data were acquired in 2010 on the near-shore continental shelf in outer Lopphavet.

This study focuses on a shallow (20–200 m water depth) strandflat bank named Alangstaren located between Tromsøflaket and the coastline. The bank represents an unusually large, submerged part of the Norwegian mainland (to the southwest) comprising Palaezoic and Precambrian bedrock. On all other sides it is bordered by glacial troughs eroded by ice streams, and deep glacial lineations occur on the surface of the bank. The Norwegian Coastal Current is strong in this area (maximum velocity over 0.50 cm/s). It comes from the southwest and turns clockwise around the bank.

The shallowest areas of the bank mainly comprise bedrock covered by kelp forest. On the sea floor between the kelp leaves we find common sea stars (*Asterias rubens*), bushy bryozoans, worms living in calcareous tubes (Sepulidae polychaeta), and red algae.

The kelp forest reaches down to 37 m depth. Seaweeds and high density fauna cause the multibeam backscatter to exhibit lower values than those expected for bedrock. Deep depressions in the bank are filled by sediments (coarse sand to boulders). Current and wave ripples are common on the sediment surfaces. Rippled scour depressions occur on bank slopes, with coarse sediments in depressions and rippled sand between depressions. Mud and sandy mud are deposited in deeper water areas, indicating a drop in current velocity. The change in sediment type seems to occur between 150 and 200 m water depth. A sea bottom covered by several hundred brittle stars per square meter was discovered.

This bank is very different from other banks in the MAREANO area, such as Malangsgrunnen and Sveinsgrunnen, which comprise sedimentary bedrock covered by a succession of coarse grained till that is being eroded by strong ocean currents. The strandflat bank occurs at depths similar to the banks built of glacial material, but has a much more undulating and uneven topography. Very little sedimentation occurs and the depositional environment is similar to the near-coast depositional environment.

The differences in morphology and sedimentary processes lead to different habitats at similar depths, demonstrating that widely different habitats can occur in the same depth intervals. The links between habitats and sedimentary processes will be discussed, with emphasis on landscape forming processes and biology.

Mapping the coastal benthic fauna of south of Portugal using two statistical techniques

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In the South Coast of Portugal, the Marine Ecological Reserve extends to 30 metres depth. The biological knowledge about the area is scarce and the urgent need to create tools for sustainable coastal management led to the mapping of an experimental area.

Side scan survey and ground truthing were conducted to identify the main sedimentological categories present. Benthic fauna was sampled in rocky areas with underwater visual census and using a beam trawl in soft bottom areas.

Two statistical techniques were used to create maps using the sampling points, Generalized Additive Models (GAM) and geostatistical kriging. The results were compared between the two techniques.

Both models provide a clear view of the biological distribution patterns sampled.

The same pattern of distribution was obtained, with the two models showing the rocky areas with higher densities than the soft bottom areas, however the GAM model provides a wider range of values with higher maximum and lower minimum.

Multibeam echosounder seabed mapping of the Tauranga Bridge Marina, New Zealand

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Tauranga Harbour is a mesotidal lagoon located within the Bay of Plenty, New Zealand, and is subject to an ongoing maintenance dredging program to remove mud deposits coming from various sources in the catchment. At the southern end of the commercial port, the Tauranga Bridge Marina was built adjacent to the bridge causeway, with 500 floating concrete berths, enclosed by concrete floating breakwaters. It is proposed to convert these floating breakwaters into solid ones to stop waves entering the marina. This is expected to influence tidal circulation around the Tauranga bridge causeway, and potentially affect sedimentation and marine habitats. The region is an important source of kai moana (seafood) for local iwi, and is a source of juvenile shellfish for the large beds located on the flood tidal delta and surrounding channels.

To investigate the impacts of the solid breakwaters, a sediment transport modelling study and a habitat-mapping survey using acoustic mapping techniques will be undertaken. The overall goal of the mapping part of this project is to identify and locate the different seabed facies and features within the study site, which may be affected by the sediment transport potentially resulting from the future construction.

The acoustic mapping survey will be performed using a Kongsberg-Simrad EM3000 multibeam echosounder. The backscatter data from this system will be used for habitat mapping, while its accurate depth data will be used for sediment transport modelling. An underwater camera and seabed sampling will then be used to ground-truth the morphologies identified from the acoustic backscatter analysis.

The first part of this presentation will discuss the aim and objectives of data acquisition for habitat mapping in the Tauranga Harbour. The second part of this presentation will introduce the planned methodology for processing backscatter data into a habitat map, using previous projects to show the expected results.

Geomorphological classification of cold water coral seabed (Bay of Biscay – NE Atlantic)

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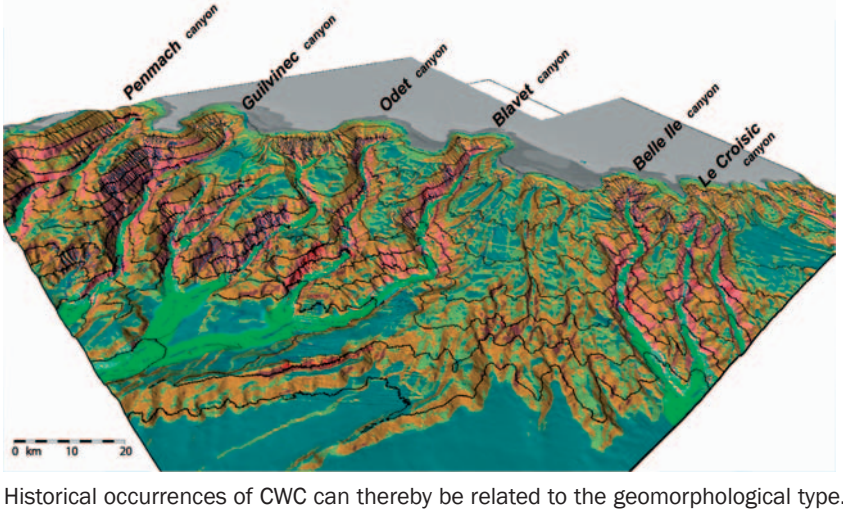
Cold water corals (CWC) are declared vulnerable ecosystem by several international organizations. In European waters, tools to assess the impact on fisheries and the effectiveness of protected areas are lacking. European CoralFISH project aims to study the interaction between CWC, fish and fisheries through an ecosystem-based approach. One of the objectives is to provide a comprehensive characterization of CWC habitats based on geophysical and ground-truthing data.

All along the northern margin of the Bay of Biscay, the succession of interfluves and deep canyons has shaped the passive margin. More than 130 canyons are organized into 8 large drainage networks. The complex hydrology (geostrophic and tidal currents, swells, internal waves) and the vast canyons systems play an important role in determining benthic habitat distribution and development. The link between the particular morphology and occurrences of Cold Water Corals, their full extent and spatial patterns were poorly known. Recently acquired MultiBeam EchoSounder data for four areas from the shelf break down to depths of ~ 3000 m. provide new insights. The four accurate Digital Terrain Models (15 to 25 m grid spacing) have been available in their high resolution version since the BOBGEO and BOBGEO2 surveys (October 2009 and July 2010).

A classification methodology based on the combination of several morphological attributes is applied on DTM. Attributes derived from DTM and used to initiate the automated classification are local slopes at different scales, residual bathymetry, drainage network and distances to the thalwegs. It allows delineating the *megageoform*s and next delineating smaller scale geoforms thanks to a specific morphological analysis. M*eso-geoforms* such as canyon beds and banks, falls, escarpments, flanks, crests, and other as mounds present in the interfluve areas will be defined together with the method(s) for automatic identification from the DTM attributes. The corresponding codes of the Coastal and Marine Ecological Classification Standard are also considered.



Historical occurrences of CWC can thereby be related to the geomorphological type.

Study of *Maërl* facies from southern Italy and relevant acoustic signal from Chirp and Side Scan Sonar.

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Coralline red-algae are one of the most important carbonate sediment contributor in the benthic communities of Mediterranean area. They represent one of the most productive ecosystems in temperate regions.

Several types of assemblages and seafloor features have been described so far, due to the high heterogeneity of coralline growth-forms, distributed from the intertidal down to 160 m water depth (wd), from *corniche* to *maërl* to coralligenous build-ups.

Many benthic habitats, for example the coralligenous framework, have three-dimensional structure that serve as shelter and provide storm protection by buffering wave action along coastlines.

Furthermore, carbonate facies like *maërl* are considered highly-biodiversity spots and are protected by European laws.

In European waters, *maërl* occur throughout the Mediterranean and are patchily distributed along the Atlantic coast. *Maërl* represents an important fraction of the coastal detritic biocoenosis. Light, salinity and temperature seem to be the main environmental factors influencing the distribution of this facies.

Maërl sediments are characterized by accumulations of calcareous free-living non-geniculate coralline algae, referred to as "rhodoliths", and they develop and accumulate on soft bottoms influenced by laminar currents, producing characteristic calcareous deposits which constitute major sources of carbonate sediment.

Phymatolithon calcareum (Pallas) W.H. Adey & D.L. McKibbin and *Lithothamnion corallioides* (P.L. & H.M. Crouan) P.L. & H.M. Crouan are the main European *maërl* forming species.

The areal definition and the investigation of these environments are fundamental scientific topics with strong implications for resource management and preservation policies.

We collected acoustic data (by means of Side Scan Sonar and Chirp-Sub bottom profiler) of *maërl* beds from Cilento peninsula, Tyrrhenian sea and 4 grab samples.

Acoustic data have been processed in order to define the related echo-facies in the framework of literature models and the main features of the acoustic response. Grain size analyses of the biogenic sediments and identification of the benthic associations and carbonate producers have been performed.

A precise relationship between the identified coralline facies and its acoustic response is here proposed, in order to improve the detection and spatial delimitation of these biogenic carbonate deposits and high biodiversity spots.

Multiple methods, maps, and management applications: purpose made maps in support of Ocean Management

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The establishment of multibeam echosounders (MBES) as a mainstream tool in ocean mapping has facilitated integrative approaches towards nautical charting, benthic habitat mapping, and seafloor geotechnical surveys. The inherent bathymetric and backscatter information generated by MBES enables marine scientists to present highly accurate bathymetric data with a spatial resolution closely matching that of terrestrial mapping. Furthermore, developments in data collection and processing of MBES backscatter, combined with the quality of the co-registered depth information, have resulted in the increasing preferential use of multibeam technology over conventional sidescan sonar for the production of benthic habitat maps. A range of post-processing approaches can generate customized map products to meet multiple ocean management needs, thus extracting maximum value from a single survey data set.

Based on recent studies over German Bank off SW Nova Scotia, Canada, we show how primary MBES bathymetric and backscatter data, along with a variety of supplementary data (i.e. *in situ* video and stills, seismic etc.), was processed using a variety of methods to generate a series of map products. Surficial geological maps were generated for the area using conventional interpretation techniques (i.e. expert interpretation utilizing all available geospatial data sets). These provide contextual information on seafloor geo-morphological conditions, relevant to marine engineering, resource management and other geological related applications. Methods conventionally used for classification of multispectral data were also tested for classification of the MBES data set to produce seafloor maps summarizing broad bio-physical characteristics of the seafloor (i.e. Benthoscape maps). These types of map products are of value for use in many aspects of marine spatial planning. In addition, species-specific habitat maps were generated from the MBES data by applying novel species distribution modeling (SDM) methods to spatially predict habitat for species of commercial interest. We present an example of scallop habitat maps generated in this way, which offer tremendous promise for use in fisheries management.

Through the process of applying multiple methods to generate multiple maps for specific management needs, we demonstrate the efficient use of survey data sets to maximize the benefit to a wide number of potential end users.

Predictive modelling of benthic assemblages: performance of modelling techniques in a Baltic-wide perspective

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Development and application of various statistical techniques and GIS tools, the progress of predictive species/habitat distribution models has rapidly increased in ecology. Such models are useful in biogeography, conservation biology, climate change research, and habitat or species management. A wide array of statistical techniques, with different purposes and data requirements, is available for fitting data and predictive species modelling. When data is available on the presence of a potential target variable (but not absences), methods such as geographic and climatic envelopes utilise multivariate methodology and machine learning to predict the presences and absences (occurrence). These methods generally perform poorer than models based on occurrence data. Nevertheles, modern methods based on the data of presences only, (e.g. Maximum entropy – MAXENT) are able to fit more complex functions between the response and predictor variables, and generally outperform the other presence only methods. When occurrence and/or quantitative (such as per cent cover, species diversity or biomass) data is available of a target variable, a multitude of methods can be applied, including, generalized linear and additive models (e.g. GLM, GAM, Multivariate adaptive regression splines – MARS), machine learning methods (e.g. Random forest – rF), and Bayesian methods.

In this research we aim to compare the performance of several types of models (GAM, MARS, rF, MAXENT and Kriging) on two type of data, occurrence and quantitative, in order to arrive at recommendations for cost-efficient and precise modelling practices to be used in spatial planning in the marine environment. The response variables are chosen typical Baltic Sea benthic species belonging to vegetation, invertebrates and fishes. The sets of predictors differ per response variable according to the species ecology and conditions of the study area. The data is randomly split into train and test sets, where model calibration is performed on train set, while validation is made on both, train and test sets. The performance of an empirical model is measured on the basis of several different methods and criteria. These involve the per cent correct classification of observations, its capacity to correctly identify presences or absences (area under the curve – AUC) and the precision of quantitative predictions (determination coefficient – r^2 and root mean squared error – RMSE) of continuous variables.

In the results we have obtained that in general all modeling methods perform well, but there are some differences in the performance of species models among study areas, responses and data quality. These differences are analyzed and discussed in presentation.

Seafloor classification of a gully system offshore the island of Sylt (NW Germany)

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In September 2010 an area extending approximately 1 km east-west and 3km north-south offshore the north-frisian island of Sylt was mapped with the multibeam system EM710, installed onboard the research vessel FS Heincke. In addition data from a Reson Seabat-8125 multibeam system, two sidescan sonar systems (Imagenex YellowFin and Benthos 1624), and the ECHOplus seabed classification system are available. Ground truthing was done by a regular grid of sedimentological and benthic sampling at 45 stations. The goal was to perform a seafloor classification based on the EM710 multibeam data, and to compare and calibrate the different sonar systems and their classification approaches.

The area with water depths ranging from 12 to 18m showed a system of sinuous gullies with an east-west orientation. In the southern part of the area, where the water depths are shallowest, patchy depressions and plateau-like structures were observed. The backscatter intensity of the EM710 multibeam data was higher in the gullies and in the depressions in comparison with the elevated areas. High backscatter intensities corresponded to coarse-grained sands, whereas low backscatter intensities corresponded to fine to medium-grained sands. The benthic samples of these two distinct acoustic facies were clearly different.

To perform and evaluate an automated classification of the multibeam depth and backscatter data, a software tool was developed. It allows reading and writing of the gridded bathymetry and backscatter data in netCDF format, and applies a moving box filter to both datasets. Inside the box filter various parameters are calculated, e.g. the mean value, a percentile, and the standard deviation. The object-oriented design of the software enables an easy extension with other parameters. The calculated values from the moving box are used as observations for a cluster analysis. Here the k-means algorithm is applied. The result of the clustering is the classified map and various scatter plots of the box filter values. In addition, the software allows loading grain size analysis data from Excel sheets. The grain size data, e.g. gravel, shell debris, sand and mud content are analysed using a hierarchical clustering. The seafloor samples can then be plotted with different symbols according to their sediment class in a Folk ternary diagram and in the maps at the sample locations. Finally, the match between sediment classes and acoustic classes can be evaluated.

The automated classification of the EM710 geoacoustic dataset of the survey area is then compared with the result of the ECHOplus seabed classification, the analysis of the benthic samples, and the class maps resulting from the analysis of the sidescan sonar data with the Quester Tangent QTC software suite.

Advances in broad-scale habitat mapping for the UK and Europe

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Acquiring sufficient full coverage acoustic data and biological ground-truthing for widespread direct mapping of seabed habitats at a European scale would be prohibitively expensive and take many years. There is now an implicit requirement for continuous mapping that can be applied across European regions as part of the Initial Assessments for the Marine Strategy Framework Directive. Transnational marine spatial planning and information-based management need to be informed by the best-available data if they are to achieve long-term sustainable use and management of the marine environment and its resources. There is therefore a clear need to create full coverage maps by predicting seabed habitats.

EUSeaMap and UKSeaMap 2010 are two projects that provide such maps. EUSeaMap (www.jncc.gov.uk/EUSeaMap) is a European Commission (EC) funded project, under the initiative to build a European Marine Observation Data Network (EMODnet), that has produced broad-scale predictive habitat maps for over 2 million square kilometres of seabed covering four geographic areas of the European seas: Celtic, North, Baltic and western Mediterranean seas. UKSeaMap (www.jncc.gov.uk/UKSeaMap) has developed a map for the UK continental shelf that is being used to help guide the selection of a network of ecologically coherent Marine Protected Areas. Both projects have built on similar methods applied in the North-western Atlantic through MESH, in the Baltic through BALANCE and in the UK through the Irish Sea Pilot Project and UKSeaMap 2006. A suite of environmental variables, which form the basis of the models, have been developed and improved, and made publically available. Biological data have been incorporated into the modelling process, through the development of ecologically-relevant thresholds. All the models are structured to allow ready update of the maps, as new higher quality data become available in the future. Presented here is an overview of the improvements made in datasets, as well as a focus on the quantitative and qualitative methods developed to assess and illustrate spatially the confidence associated with the maps.

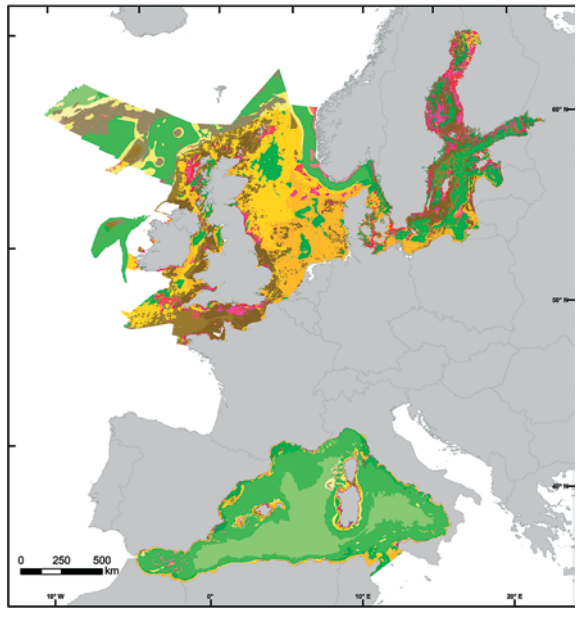

Figure 1. Harmonised seabed habitat map across the EUSeaMap regions.

Modelling wrack deposits

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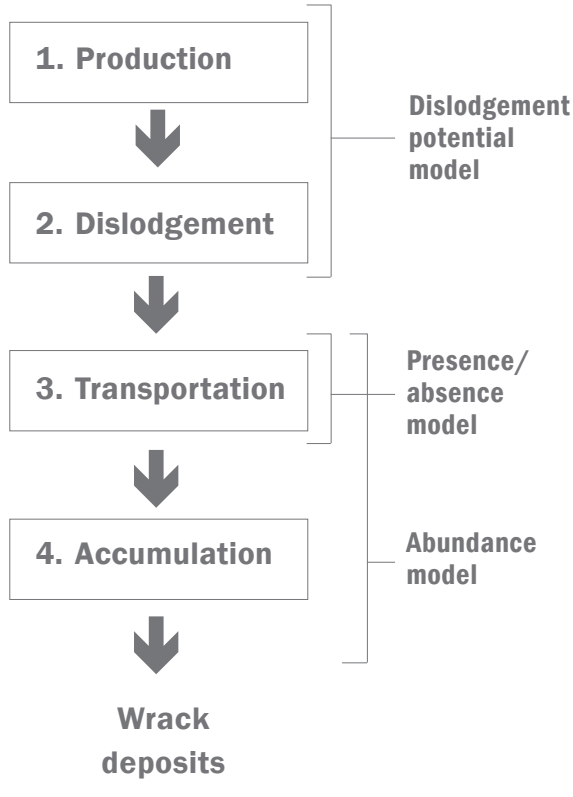
Wrack deposits, phytodetritus deposited on the shore, constitute a vital nutrient subsidy at the interface between marine and terrestrial ecosystems. By using spatially explicit modelling, we demonstrate how the distribution and abundance of bladder wrack (*Fucus vesiculosus*) deposits can be predicted.

We envision four processes that determine the distribution of wrack deposits: 1) production of algae; 2) dislodgement of algae; 3) transportation of drift algae and debris; 4) accumulation at the shoreline.

The aim of this study was to analyse and model each of these steps in order to predict the deposits of bladderwrack *Fucus vesiculosus* along the shores of Gräsö island in the southern Bothnian Sea. The first two steps were integrated into a dislodgement potential model, describing the spatial distribution of bladderwrack on the seafloor in the study area. The results of this model were then used as input to step three where a presence-absence model was constructed to investigate where drift algae are washed ashore. The dislodgement potential model was also used as input to the abundance model of wrack deposits in step four, yielding information on where beach cast detritus accumulate.

For modelling wrack deposits at the shoreline, two innovative environmental variables were used as predictors. Dislodgement potential was calculated as the sum of the % cover of Fucus inside a certain radius. Bay indices were calculated by placing points every 10 meters along the coastline of Gräsö and creating 8 radiating lines from each point. The lines were then cut using the coastline. For every point, the length of the remaining lines were calculated and used as a bay index.

Results show that the probability of finding beach cast detritus was larger on points and headlands, which are more exposed to waves and closer to algal production areas. However, wrack is sequentially transported further into small bays and sheltered areas in the vicinity where large amounts of bladderwrack accumulate. These results are important for the continued research on the impact of nutrient flow across ecosystem boundaries, particularly marine subsidies to the littoral environment.



Predicting the Distribution of Benthic Habitats for Environmental Impact Assessment: Examples from Industry

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Creating inventories of marine resources at the scale and resolution required for environmental impact assessments, monitoring change, and for developing policy and management strategies is one of the challenges we face for supporting sustainable ocean management.

Limited funding for research organisations often restricts the spatial extent and/or the amount of data that can be investigated. This results in either high resolution information over small areas, or sparse information over larger areas. While industry typically has significantly larger budgets, full coverage benthic habitat surveys can still be cost prohibitive. The consequence is uncertainty around what biota is actually present, and therefore, uncertainty around how much impact a development may have on the environment.

Recently, industry proponents in Western Australia have made use of predictive habitat modelling approaches to produce full coverage, the high resolution maps of the distribution and composition of benthic habitats across large spatial extents (369 km^2 – 3,700 km^2). The approach centres on the collection of high resolution bathymetry data (e.g. multibeam or LiDAR data) and presence/absence data for the different substrate and biota present (collected using underwater video systems). Modelling is then used to define the relationships that exist between the observed distribution of the different substrate and biota, and a series of environmental metrics derived from the bathymetry data (e.g. topographic complexity and characteristics of the seabed in the local neighbourhood). These relationships are then used to predict and map, with quantified accuracy, the distribution and percent cover of biota types across the entire area for which bathymetry data exist.

In addition to providing detailed baseline information about the existing environment to support environmental approvals, predictive modelling and mapping provides other benefits. Project footprints like pipeline corridors and berth and wharf infrastructure can be overlaid on habitat maps to identify areas where the habitat may be lost or impacted. When dredging activities are required, dredging footprints and the outputs from sediment plume modelling can be used in conjunction with biologically relevant 'thresholds' (e.g. sediment loads, water turbidity, or light availability) to identify areas where sensitive biota may be impacted or influenced by dredging activity.

Through the use of predictive modelling, regulatory authorities have a much more comprehensive picture of what is present, and what the likely impacts from a development may be. This level of information has not previously been available and provides greater confidence in the outcomes of the environmental impact assessment process.

Angular response supervised classification and image segmentation for benthic biological habitat discrimination

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Angular response from multibeam echosounder (MBES) has the potential to be used for benthic habitat characterization by preserving full angular variation from different seabed habitats, whilst backscatter imagery provides fine spatial resolution for the construction of habitat characterisation maps. In this study we demonstrated how benthic biological habitat distribution maps can be generated through combination of angular response and backscatter imagery. We combine supervised classification of angular response data and image segmentation techniques. We compare the (1) three classifiers; Maximum Likelihood Classifier (MLC), Decision Trees (DT) and Support Vector Machine (SVM), (2) variations in use of angular response data (average angular response at specific angular domain or full angular response of backscatter curve), (3) three image segmentation levels. We observed that overall accuracy and Kappa coefficients varied between classification methods, number of variables used and between different segmentation levels; for biotic class the overall accuracies from 66.9 % to 85.2 %, Kappa coefficient values from 0.47 to 0.76 and for substratum class the overall accuracies from 67.3 % to 82.8 %, Kappa coefficient values from 0.48 to 0.71. Random Forest decision tree showed the highest accuracy both for biotic and substratum habitats (overall accuracy = 85.2 %, Kappa = 0.76 for biotic habitats and overall accuracy = 82.8 %, Kappa = 0.71 for substratum) compare to other classifiers. Irrespective of classification method, number of variables and segmentation levels, Invertebrate habitat showed the highest accuracy, while Mixed Brown algae/ Invertebrates and Mixed Red/Invertebrate achieved the lowest accuracy. By using pairwise test statistic of two error matrices, the classification accuracies were found to be not significantly affected by the number of variables and the segmentation levels applied.

Origin and evolution of Macquarie Ridge Complex seamounts

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The Macquarie Ridge Complex is a 1600 km-long bathymetric ridge comprised of many discrete, elevated seamounts as it varies in depth from 150–1500 m below sea-level along its axis, and coincides with the Australia-Pacific plate boundary south of New Zealand. Tectonic plate reconstructions predict that the plate boundary evolved from a mid-ocean ridge spreading centre to an obliquely convergent plate boundary over the last 40 Myr. While the tectonic history of the plate boundary has been the focus of numerous studies, the geological origin and evolution of the ridge seamounts remains poorly understood. In this study we present new high-resolution multibeam, photographic and petrologic data from ten seamounts of the Macquarie Ridge Complex.

Underwater towed-camera investigation and epibenthic sled sampling of the seafloor reveal that seamounts originated as mid-ocean ridge volcanoes comprised of basaltic lava flows. Bathymetry and backscatter mapping reveals that this oceanic crust has since been sheared, accreted, uplifted and exhumed during (the last 10 Myr of) transform and convergent relative plate motion at the plate boundary. This deformation has given rise to elongate, plate boundary-parallel seamount morphologies. Three of the seamounts are characterized by broad summit plateaus, which were formed by wave erosion when their ridge sections were exposed to the sea surface and have since subsided.

While the seamounts are of a volcanic origin, they are manifest now as the result of tectonic and geomorphic processes. Understanding the geological origin and evolution of Southern Ocean seamounts is crucial for producing a framework for studies of the biological diversity and distribution of benthic ecosystems between Antarctica and New Zealand.

Using geological datasets to guide predictive bottom-up biotope modelling: an example from the southern North Sea

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The coastal zones of the United Kingdom are an important economic and environmental resource. However, competing pressures in these zones, from renewable energy development, aggregate extraction and fishing, poses an increasing threat to many habitats defined under the EU Habitats Directive. Between 2008 and 2011, a comprehensive study was undertaken assessing a 3,300 km^2 area off the east coast of East Anglia for its geological, biological and archaeological significance.

Comprehensive geological, geophysical and hydrodynamic datasets were acquired and analysed, and a series of 1:100,000 maps produced detailing sea-bed sediment distribution, sea-bed geomorphology, wavecrest density, dominant grain size distribution and sorting. This regional geological assessment provided the underpinning baseline onto which the distribution of 14 mapped biotope classes, gained from the analysis of discrete sampling, was placed. This was then passed through five models to produce a bottom-up regional predictive habitat classification, based on the interplay between different faunal assemblages with sediments, bedforms, bedform wavelengths, backscatter intensity and deviation, suspended particulate matter and tidal strength. The models used were multilogistic regression, maximum likelihood, neural learning, Decision Tree Analysis and maximum entropy.

The results suggested that this bottom-up approach utilising significant geological variables can work very well, revealing subtle, localised differences in distribution patterns across biota, with the flexibility to assess the specific impact of sediment type, suspended sediment, tidal strength etc on a particular biotope assemblage. It also indicated that the model output could be used as a predictive tool where survey data is limited. However, it is acknowledged that this method doesn't currently allow for comparison between surveys and regions at a national level.

The modelling results have shown that this method can create ecologically relevant habitat units that best represent the relationships between macrofauna and their benthic environment, even on a localised scale. Macrofaunal assemblages could be mapped relative to the specific environmental factors found to be influential in their distribution, thereby providing flexibility when assessing not only the impact of an environment on target species, but also in identifying the areas where the combination of geological and biological factors could imply a habitat under threat.

Assessing Seabed Processes with Relevance to Offshore Renewable Energy Installation in the Irish Sea

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The Irish Sea is a shallow, formerly glaciated, continental shelf consisting of a series of deeps in the south which presently experience high energy regimes to relatively benign mudbelts in the north. As such, the area has been recognized as having the potential to develop a number of sites for offshore renewable energy installations in both the wind and tidal sector.

Therefore, in September 2009 the Irish Sea Marine Assessment (ISMA) was undertaken by University College Cork (UCC), the Geological Survey of Ireland (GSI) and an industrial partner to investigate areas within the east Irish Sea potentially suitable for offshore renewable energy installations. During the course of the assessment research surveys were carried out with the intention of building a reliable geological model for the study area. Data sets collected during the surveys include seismics, bathymetry, acoustic backscatter and seabed current velocities data as well as sedimentary and biological samples.

Initial analyses of sedimentary bedforms particle size distributions in surface sediments indicate a marked decrease in current velocities from the southern end to the northern end of the study area. These observations are furthermore supported by acoustic backscatter pattern (groundtruthed by sediment samples and underwater video camera transects). Eventually, a combination of these data sets will be used in creating sediment facies distribution maps for the study area as well as determining sedimentary processes on the seabed.

Constraining a good geological model of an area is essential in both siting offshore installations as well as assessing the potential environmental impact of these installations. The ISMA datasets provide broad baseline parameters of relevance to siting offshore renewable energy devices and their environmental impacts. They also facilitate further studies focused on more site specific factors (e.g. scour, hydrodynamic and sediment transport interactions and ecosystem response). In this way, through a carefully designed seabed mapping exercise, we hope to develop adequate data collection protocols for sustainable offshore renewable energy development.

Characterizing Wave and Current Stress on the Sea Floor of the U.S. Atlantic Continental Margin for Coastal and Marine Spatial Planning

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The United States recently initiated a process for Coastal and Marine Spatial Planning (CMSP) to determine how offshore areas can be sustainably used and protected[1]. This study seeks to improve our understanding of sediment movement on continental margins and to inform the CMSP process by developing metrics of seafloor disturbance caused by bottom shear stress, a force exerted on the seabed by the combined action of waves and currents. Bottom stress can resuspend sediment, scour around objects on the seafloor such as anthropogenic installations, and impact plants and animals that live on or in the ocean floor. Bottom stress thus affects the use of the seafloor and in part defines the benthic environment, influencing ecosystems and habitat. In this study, bottom stress is computed from near-bottom currents and wave-orbital velocities using a bottom boundary layer model. The bottom currents are extracted from 3D regional ocean circulation models operated as part of the U.S. Integrated Ocean Observing System (IOOS)[2] and the near-bottom wave-orbital velocities are calculated from a surface-wave model (two wave models are being evaluated; WAVEWATCH III[3] and COAWST[4]). The spatial resolution of these models is approximately 5 km. Our goal is to calculate multi-year time series of bottom stress and develop statistics to describe the strength, spatial distribution, temporal variability, and relative importance of various causes of bottom stress over the continental margin of the U.S. Preliminary results for the Middle Atlantic Bight, an area offshore of the northeastern United States being considered for wind-power development, show that relatively high stress in shallow water near the coast is associated with surface waves whereas high stresses over Nantucket Shoals are caused by tidal currents. Relatively low stresses were found over a region of fine-grained sediment west of Nantucket Shoals and in the topographic low of the Hudson Shelf Valley.

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[1] *http://www.whitehouse.gov/administration/eop/oceans*

[2] *http://www.ioos.gov/*

[3] *http://polar.ncep.noaa.gov/waves/index2.shtml*

[4] *http://woodshole.er.usgs.gov/operations/modeling/COAWST/index.html*

Can meso-scale geomorphology be used as a surrogate to map benthic assemblages?

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To implement ecologically representative networks of Marine Protected Areas, biologically meaningful maps are required to inform managers on the distribution and diversity of habitats. The use of large topographical features such as seamounts, banks and submarine canyons as a megahabitat landscape, have been used and proven useful for broad scale mapping over large areas. Whilst broad scale mapping may adequately represent some habitats, others are not distributed at the same spatial scale and thus require a different approach. To adequately represent the biology it is necessary to understand the distribution of habitats at a data acquisition level, or fine-scale, which can be related to, typically more generalised, broad scale maps that cover a wider geographic area. Relationships between biological assemblages and geomorphological features at a mesohabitat scale have been reported, e.g. cold-water coral reefs associated with mound features, although the link between geomorphology and biological communities is still unclear.

Two seabed surveys were undertaken in 2007 and 2009 to acquire multibeam and ground-truthing data from Anton Dohrn Seamount, Rockall Bank and the SW Approaches canyon system (UK). Still images were quantitatively analysed and community analysis used to group benthic assemblages and define fine-scale biological mapping units. Mapping units were used in conjunction with multibeam bathymetry and its derived layers to map assemblages across meso-habitats and compare between different mega-habitats. Meso-scale geomorphology proved more useful for mapping benthic assemblages on the Seamount and Bank than in the Canyons.

The use of meso-scale geomorphology as a tool for mapping benthic assemblages across three different megahabitat features will be discussed.

Mapping of moraine ridges and associated habitats in the eastern Baltic Sea

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Underwater moraine ridges in the coastal waters of the eastern Baltic Sea have been mapped in depths of 9–20 m using traditional combination of side scan sonar and multibeam echosounder. Underwater drop videocamera and diving surveys were carried out for the groundtruthing purposes and visual inspection of features. Two geomorphologically distinct types of underwater ridges have been recorded: i) 4 to 5 m height small-scale (10–100 m^2) steep and elongated ridges, always distributed perpendicularly to the coastline and typically clustered within distinct groups; and ii) larger scale (up to 200 m width and 1.5 km length) approx. 10 m height elongated ridges of relatively gentle slope and distributed parallel to the coastline.

The substrate type, slope and other physical characteristics have been used in order to obtain geomorphological classification of the area. Such classification combined with biological thresholds (photic depth, exposure etc.) is used for further study of distinct seabed units, which have different biological importance. These units will be shortly discussed in a context of EUNIS habitat classification and Habitat Directive Annex I habitat types.

Marettimo Shelf (Egadi Islands, Italy): a non-tropical carbonate platform from the Mediterranean Sea

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The Marettimo Island is the westernmost island of the Egadi archipelago, located west of Sicily. It is mainly constituted by calcareous rocks and is surrounded by a shelf which was the object of accurate studies carried out during the surveying for the geological mapping of the area. The surveying was carried out by means of SideScanSonar, ROV and grab sampling.

Close to the coast the calcareous rocks characterizing the island crop out on the seabottom or are covered only by a thin veneer of sediments. The main part of the shelf extends toward southeast, gently dipping till -110 m at an average slope of 1°. It is bordered on the northeast and southwest by two NNW-SSE trending active canyons, which draw sediments from the shelf and favour slope instability causing the withdrawal of the shelf break that runs at a depth between 100 and 110 m.

The shelf is characterized by intense currents that generate a marked turn-over of water, supplying nutrients and allowing oxygenation. They determine prevalently coarse carbonate sedimentation and originate different sedimentary structures. In the eastern sector of the shelf megaripples and sand-waves (heigth of 1.5–3 m, wavelength up to 20 m) are widespread. All deposits are of biogenic origin; their texture and composition vary according to hydrodynamics, type of substrate (soft or hard), depth and light penetration, which due to low turbidity of water reaches more than -40 m.

Biogenic sands dominate the shelf sedimentation; they are formed by a microassociation composed mostly by benthic forams, with planktic forams as a minor component, and a macroassociation composed mainly by bivalves and at a lesser extent by gastropods.

Rhodoliths are abundant over a large area of the shelf, where they constitute the main component of sediments; the maerl and praline facies (*sensu* Peres & Picard, 1964) represent the coarser (gravel) fraction of the biogenic sedimentation.

Posidonia oceanica grows following the patterns of sediments accumulation; in the study area it is distributed preferably close to the coast on the sediments covering the substrate. It plays a role in the sedimentary processes, capturing sediments and reducing wave energy; together with other plants, it also influences the composition of living assemblages that rely on them for shelter and nutrition.

Coralligenous build-ups are present in small patches, surrounded by the debris they originate. Other organisms such as sponges, corals, echinoderms, bryozoans and coelenterates were found living on and within the seafloor or as a minor fraction of the deposits.

A new habitat map of the British part of the English Channel

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Worldwide, the oceans and marginal seas are under increasing pressure from human activities and there is an ever greater need for good habitat maps, both to underpin environmental and socio-economic impact assessments and to help in the development of effective management measures that will contribute to our responsible stewardship of the marine environment and the sustainable use of its resources. The development of habitat mapping is now driven more by specific policy needs than our innate desire to explore our world. For example, the European Union's Marine Strategy Framework Directive requires better habitat maps than exist at present to support assessments of the status of the seabed and the proportion of each habitat significantly affected by human activities. We report on methodological developments that can be applied to provide better predictive habitat maps.

We present a case study to develop an improved habitat map for the British part of the English Channel. At its heart is a more realistic representation of seabed substrate types than has been available in standard seabed sediment maps. We have used geostatistical predictions and terrain modelling techniques, validated against observational data sets, to map seabed substrates and used this to model the distribution of rock and sediment habitats according to the EUNIS (European Union Nature Information System) classification.

We applied a hybrid spatial prediction model to map sediment composition using both spatial autocorrelation and correlation with auxiliary predictors (bathymetry and derivatives thereof, wave and tidal shear stress, etc.). The proportion of sand, mud and gravel were then analysed to classify the sediments according to Folk textural classes and the EUNIS habitat schema.

Morphologically distinct bedrock outcrops were extracted from a detailed bathymetric data set (30 m by 30 m bins). Several measures of rugosity were tested using a training data set for their ability to discriminate between rock and non-rock. The Vector Ruggedness Measure was selected for use, applying a cut-off value to discriminate flat from rugged terrain. The latter class included subaqueous dunes and sandbanks which were subsequently separated from rock outcrops.

The sediment predictions and the bedrock layer were unified to yield a substrate map. This layer was finally intersected with modelled biological zones (infralittoral, circalittoral and deep circalittoral) and hydrodynamic energy at the seabed to derive the EUNIS habitat model.

A fine scale habitat map of a highly heterogeneous shallow archipelago near Tvärminne, Finland

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The archipelago area near the small coastal town of Tvärminne, Finland, has been the site of numerous studies relating to marine biology and biodiversity in the Baltic Sea, due to the long history of a biological research station located there. Up to now, however, there has not been an accurate map available of the submarine nature values in the area. We selected this well known area as the site for a pilot study with the first ever application of a multibeam echosounder survey specifically designed to map benthic habitats in Finnish waters, that was performed in 2007. An approximately 2 sq km area of the archipelago was surveyed with full cover multibeam in minute detail (approximately 20 cm precision) and this was used to make a detailed substrate map (1:500) corresponding to the biologically relevant surface layer of the substrate. The survey area is highly convoluted and shallow with a depth range from the waterline of the many islands down to 45m, adding to the challenging nature of the survey. The same area was sampled using both ROV video and a Van Veen grab sampler to gain information on communities of both epibiota and infauna.

The seafloor surrounding Tvärminne was found to be highly heterogeneous. A clay basin is interrupted by outcrops of bedrock and boulders and different sized patches of sand and gravel. Gyttja clay has accumulated in places in sheltered depressions and also the deepest part of the study area. Each of these substrates house specific biological communities. The archipelago gradient with varying exposure to wave action, from very sheltered to exposed, adds another dimension to the environment governing the distribution of habitats in the area. The species compositions in the inner sheltered habitats, more prone to the effects of eutrophication, showed a clear difference from that in the outer more exposed habitats of the same substrate and depth characteristics. Here we present the resulting detailed habitat map, and descriptions of the communities associated with the different habitats.

Developing a GIS-based method for automated marine landscape classification

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As part of the ongoing regional, multidisciplinary seabed mapping program MAREANO (www.mareano.no), marine areas in North Norway have been mapped at a landscape level. Landscapes, in this context, are broad-scale, non-overlapping, full-coverage areas with a uniform surficial appearance. Landscape classes constitute one level in Norway's hierarchical nature-type classification system ('Naturtyper i Norge (NiN)') which is being developed across both terrestrial and marine areas.

This study and earlier work in the MAREANO program represent the first attempts to map marine landscapes in the region. This process has been assisted by the availability of high-quality multibeam bathymetry data which have been acquired and assimilated through MAREANO. To help overcome subjectivity in the classification of marine landscapes we have developed a standardized method of landscape classification based on analyzing bathymetry data through a systematic approach. The classifi cation is done in a GIS using the combinations of quantitative terrain descriptors including slope, curvature and neighborhood focal statistics, similar to methods frequently applied in terrestrial landscape mapping.

The classification method aims to identify individual landscape types based on the statistical properties of the bathymetry data. Our assumption is that the geomorphological differences between landscape classes result in different statistical properties of the quantitative terrain descriptors. This means that, through the selection of appropriate terrain descriptors and cut-off values, the classification process can be automated. The result is an objective, repeatable classification. Key terrain descriptors in distinguishing landscape types include *relative relief*, which identifies the range of depth values in a 1 km^2 neighborhood and is used to differentiate between flat and hilly areas, and the *bathymetric position index*, which indicates whether a particular location is higher or lower than its neighbors.

So far the method has been applied to a 100 000 km^2 area off North Norway, the geomorphology of which is topographically diverse and spans water depths from 0 to 2800 m. Seven different landscape classes have been identified through our analysis: Strandflat, continental slope, canyons, marine valleys, fjords, deep sea plain, and continental shelf plains. The completed landscape maps, together with other results from MAREANO, are publicly available at www.mareano.no.

Landscape maps such as these are valuable in their own right for environmental management and further scientific research. One important application within MAREANO is the use of the landscape maps in the development of benthic habitat maps for the offshore region (another level in the NiN nature type hierarchy). Marine landscape classification will continue as MAREANO progresses, with the refinement of the approach presented here if needed. Although developed for Norway our approach should be applicable to other regions where appropriate data are available.

Sensitivity Mapping; Setting New Standards for Marine Environmental Monitoring in Norway

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When Norwegian Energy companies are planning and executing development in areas with possible sensitive or red-listed marine fauna (e.g. sand eel spawning grounds, deep sea coral reefs, honeycomb-worm reefs, or sponge beds), it does not pass unnoticed. The Norwegian Climate and Pollution Agency generally demand visual mapping of the seabed habitats within the anticipated influential area of the activities. The demand for visual habitat surveys has grown substantially over the last years, and methods are becoming increasingly standardised. By combining visual methods with traditional sediment sampling, the stage is set for a modern approach to environmental monitoring offshore, and the availability of new types of environmental data is booming. Two case studies of applied visual techniques in combination with traditional standardised sediment surveys are presented; a habitat assessment of sand eel sediment preferences and visual mapping of sponge bed assemblages, both in relatively shallow areas destined to be subject to drilling activities.

The energy companies and their hired subcontractors often have different practices when it comes to planning and executing visual habitat surveys, and it is desirable to establish a common approach and a set of rules. With experiences from visual mapping for the petroleum industry, in areas with deep water corals and benthic communities dominated by large sponges, a Norwegian guideline for conducting standardised visual surveys is being developed. Standardised methods and equipment requirements not only provide quality assurance, but also secures high-quality data that offers new insight into the seabed communities. The combined data give a more holistic approach to the evaluation of the habitat sensitivity in an area prior to development, and provide new knowledge on any environmental effects on the sensitive fauna groups. The following case studies show how a combination of mapping techniques gives new meaning to what would otherwise be traditional baseline surveys.

Case 1: Sand eel habitat assessment

Sensitive fauna: Sand eel (*Ammodytes*)

Methods: Sidescan bathymetry, visual mapping (ROV) and sediment sampling

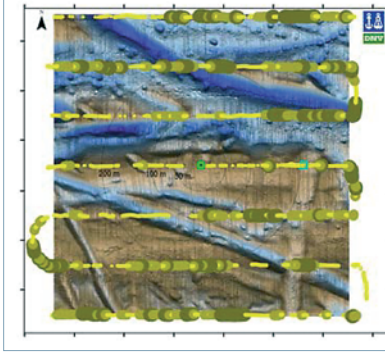
Result: Substrate composition, and spatial patterns in area with preferred habitat for sand eel established

Case 2: Mapping of sponge assemblages and associated fauna

Sensitive fauna: Longlived sponge communities

Methods: Multibeam sonar, visual mapping (ROV), sediment sampling

Result: Hi-resolution sponge distribution data, discovery of a new type of sponge-softbottom fauna associations, substrate preferences for sponge communities at a small scale



Benthic habitat mapping: concerns using a combined approach (acoustic, sediment and biological data)

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Near-shore benthic biotopes, in the 2-30 meters depth range, were analyzed and mapped using a combination of biological, sedimentary and acoustic data. The surveyed area comprehended approximately 270 km^2, along the southeast coast of Portugal. The acoustic data was acquired with a single beam ground discrimination system (QTC VIEW, Series V), connected to a dual frequency echo sounder (50 and 200 kHz). Sediment grain-size and macrofaunal community data were obtained by grab sampling in 88 sites. The sedimentary and the biological data were submitted to classification and ordination analysis (PRIMER v6). The acoustic data obtained with the two frequencies were analysed individually with the QTC IMPACT (v3.4) software and classified into acoustic classes. The affinity groups obtained with the three datasets were mapped using a Geographic Information System. The sedimentary characteristics of the study area identified an inshore-offshore pattern with sands ranging from very fine to very coarse, revealing a sediment distribution in the near-shore shelf comprised by two main areas; a very fine/fine sand area up to 7-10 m depth and a very coarse/coarse sand area offshore. Following the sedimentary pattern, the biological data showed an inshore-offshore pattern, identifying two main biological assemblages: fine/very fine and coarse/very coarse sand communities. Furthermore, the results showed that the biological pattern clearly reflect the hydrodynamic conditions of the area, from highly hydrodynamic shallow depth to the calmer deeper areas. Accordingly, at shallow areas species richness and densities were lower than at deeper depth. The acoustic data identified the prevailing biosedimentary gradients along the inshore-offshore direction. Overall, the results obtained showed that the acoustic system was able to identify two main areas based on sediment grain size, which are in close relationship with the two main biological communities.

This study indicates the importance of combining several layers of information in order to increase the spatial resolution of the main biotopes distribution (validating the acoustic data) and detail their sub-divisions (ground-truth sampling). Furthermore, the present work reveals that designing ground-truth samples on the basis of the acoustic diversity data is conditioning the ability of the biological data to "speak" for itself. Generally, acoustics is used as a mean to optimize ground-truth sampling. This will only be reasonable if acoustics are able to capture all the essence of biotope heterogeneity. If this is not the case, special attention should be given when using broad scale methods (acoustic remote sensing) devoted to biotope mapping.

Interpretation of benthic stereo imagery using 2D and 3D features in an active learning framework

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Benthic mapping programs that collect optical imagery produce vast, rapidly growing volumes of data. The onerous, time consuming nature of human data interpretation makes detailed classification of complete datasets infeasible. Consequently, automated techniques are required for efficient and effective analysis. Machine learning algorithms are useful for image-based interpretation and can generally be broken into supervised classification and unsupervised clustering techniques. Supervised classification techniques generally still require substantial human input in the form of human-labelled examples. Unsupervised clustering techniques do not require labelled examples for training, however, without a human in the loop, there are no guarantees that the clusters will represent information that is relevant to end users. These unsupervised techniques are useful for providing a good start at examining patterns and structure in the data (see Figure 1), which makes focusing in on subsets very easy. It also provides a sensible initialisation point for an active learning framework, in which computer algorithms can be used to query and learn from a human oracle in a way that maximises the usefulness of the labels that are obtained, while at the same time minimising the amount of human effort (see Figure 2).

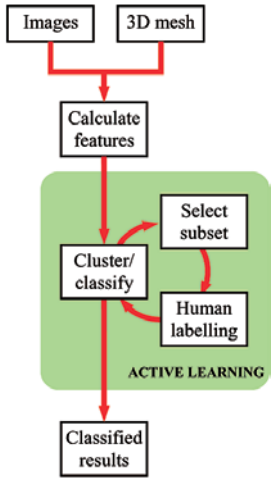

Figure 2 – Active learning framework for minimising human effort, while maximising the usefulness of human labels.

The results of machine learning algorithms largely depend on the features that are used to describe the imagery. Features need to be selected that capture some of the semantic content of the images. Most attempts at automated image-based classification use features extracted from monocular images to derive descriptors, which are limited by the 2D nature of the images and lack any notion of scale. Indices such as rugosity, slope and aspect are often used as a proxy for marine biodiversity and can be calculated from the bathymetry. Autonomous underwater vehicles (AUVs) capable of high precision navigation and equipped with stereo cameras can recover bathymetry at fine resolutions over relatively large, contiguous extents of seafloor, beyond diver depths. Our approach uses stereo imagery to interpret the data based on visual appearance and 3D structure at multiple scales to distinguish habitat types.

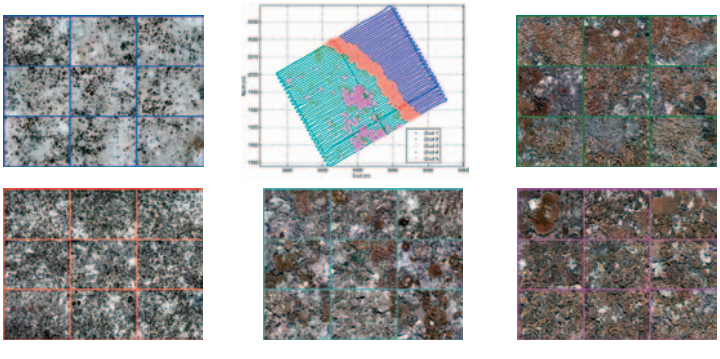

Figure 1 – Clusters from a dense AUV grid (50m×75m, 9,831 stereo image pairs) completed in Scott Reef off Western Australia. Clustering was performed using a variational Dirichlet process (VDP) technique that automatically determines the number of clusters. The VDP found 5 distinct clusters using a combination of 3D features for rugosity and slope calculated at multiple scales, and appearance features for colour and texture. Cluster 1 contains sand (dark blue), cluster 2 contains fine branching coral (green), cluster 3 contains rubble (red), cluster 4 seems to contain mostly dead coral (light blue) and cluster 5 contains large plate-like coral (pink).

We present a rationale for a combined unsupervised / active learning framework to analyse large sets of benthic imagery, as well as results from the main components of the system. These include unsupervised clustering based on image appearance and 3D structure features, and an interactive training approach that produces high classification performance with reduced human input.

Problems of investigating the bottom of large shallow lagoons for the needs of habitat classification – example of the Vistula Lagoon

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During the last sixty years, in the Vistula Lagoon, a number of investigations directed at characterising the biological environment of this specific water body were carried out. Due to its specifics, especially the small depth, the low transparency of water and the high percentage of bottom covered by mud deposits, as a rule these investigations were limited to a small part of the Lagoon, or, if they were carried out over the whole water body, they were based on a regular measurement grid, which was not representative of the complexity of the investigated area.

Since the maritime administration is planning to increase the economic use of the Vistula Lagoon, it became necessary to carry out complex environmental investigations, including the classification of the bottom habitats of the Lagoon.

The Maritime Institute in Gdansk carried out acoustic investigations of the Vistula Lagoon bottom in Summer and Autumn of 2010 in order to determine fish spawning habitats in the investigated area.

The paper describes the problems encountered during sonar investigations. Problems related to the significant limitation of the horizontal reach of sonar sets resulted mainly from the small average depth of the water body, and therefore to the risk of damage by underwater obstacles, in that fishing nets, the acoustic hardness of the bottom deposits, local thermocline occurrence due to the inflow of fresh water to the lagoon and finally submerged vegetation, which covers about 80 % of the Vistula Lagoon banks.

In effect of the sonar measurements, on the basis of the obtained sonar mosaic, habitat areas were determined according to the EUNIS classification up to level 3, areas of occurrence of submerged and reaching above water surface vegetation, and basing on two types of determinations, a detailed determination of spawning areas in the Vistula Lagoon was achieved.

These investigations will form the basis for the assessment of impact of future infrastructural investments on the ichthyofauna environment of the Vistula Lagoon.

Defining scale and variability in habitat distribution as a function of biological-geological interactions from optical imagery

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Recent advances in continuous optical imaging of the seafloor using high resolution cameras, as in the HabCam system, is allowing acquisition of an unprecedented amount of biological-geological information over a variety of spatial and temporal scales. Image informatics is being used in both human and automated modes to extract data from optical surveys for the description of habitat and community structure. However, the interpretation of biological-geological interactions is strongly scale dependent necessitating scale-sensitive multivariate analyses. An approach to developing a habitat feature set is described by combining geomorphological substrate features extracted from imagery and interpreted by humans (e.g., mud, sand, gravel, cobble, boulder) with features extracted by machine vision (e.g., rugosity, fractal index, surface area) along with bathymetry (e.g., depth, slope) and biological components such as species assemblages. The feature set is then interpreted along a continuum of spatial scales from cm's to 100 km's in multivariate space to evaluate scales where gradients from one type of association or habitat transition to another. Boundaries are then established at transitions to demark polygons of similar habitat. The approach is similar to a technique in image processing known as hierarchical segmentation providing statistical rigor to boundary creation. Additional features such as acoustic backscatter intensity or benthic shear stress may be added as availability presents itself. The result is a habitat map defined by associations between elements of the feature set and the spatial scale at which they change. An example data set and analysis is provided from repeated HabCam surveys in the Stellwagen Bank National Marine Sanctuary.

Process-Driven Characterization and Mapping of Sedimentary Habitats within the Basque continental shelf (Bay of Biscay)

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The process-driven benthic habitat mapping approach (Kostylev and Hannah, 2007) is based on the ecological theory that relates species life history traits to the properties of the environment, transforming the maps of the physical environment into a map of benthic habitat types. The habitat template for benthic habitat mapping aggregates the sets of environmental factors into two axis: (i) the 'Disturbance' axis, which reflects the intensity of habitat alteration or destruction; and (ii) the 'Scope for Growth' (SfG) axis, which describes the amount of energy available for growth and reproduction.

It was found a significant correlation between taxon composition and environmental conditions at the stations studied (RELATE; $\rho = 0.376$, $P<0.001$). The best correlation between environment and taxa was given by a combination of 5 environmental parameters (BIOENV; $\rho = 0.419$ and a significance level of 0.01), which were found to be: mean grain size, sediment resuspension index, annual chlorophyll concentration, annual mean temperature and annual minimum temperature. It was also found that associations between environmental conditions and taxon composition were weaker when environmental variables were considered individually. Sediment resuspension index and mean grain size showed higher correlation ($\rho = 0.340$ and $\rho = 0.331$ respectively); meanwhile annual mean temperature, annual chlorophyll concentration and annual minimum temperature showed lower correlation ($\rho = 0.248$; $\rho = 0.174$ and $= 0.157$ respectively). According to the process-driven theory, both the mean grain size and the resuspension index, were classified as the factor reflecting the Disturbance, meanwhile annual mean chlorophyll concentration, annual mean temperature and annual minimum temperature were as the factor reflecting the Scope for Growth. Then, the environmental variables were transformed into the scope for growth and disturbance axis using linear scaling and equal weights in an additive model.

This method reduces multiple environmental variables to the major selective forces responsible for defining the life history traits of species and as shown in this study – types of benthic communities. The resulting habitat map for the Basque coast shows a continuum of environments, where the gradients arise naturally from the data layers. Mapping the combination of SfG and Disturbance allows the estimation of the potential scale of impacts of different types of human activities on seabed habitats, and their recovery capacity. Moreover, the resulting map will be used in the implementation of the European Marine Strategy Framework Directive, in relation to the seafloor integrity descriptor.

Reference:

Kostylev, V.E. and C.G. Hannah, 2007. Process-Driven Characterization and Mapping of Seabed Habitats. Mapping the Seafloor for Habitat Characterization: Geological Association of Canada, Special Paper 47, p. 171-184. B. J. In Todd, and Greene, H.G., eds (Eds.). pp.

Predicting the distribution of benthic biotopes by conditional inference in the Koster Fjord area (Sweden)

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The designation of the Koster Fjord Marine National Park, off the West coast of Sweden, has prompted investigation into the biological composition of its seabed environment, including the spatial patterns of biota, to aid in marine spatial planning. To this end, spatially-explicit modelling was conducted whereby a suite of environmental attributes available as GIS, full-coverage layers were used to predict the occurrence, on a pixel by pixel basis, of benthic biotopes, as derived from point-source underwater imagery.

Spatially-explicit predictive models are widely used for estimating variables such as the presence of a feature of interest in unsurveyed locations, so that full-coverage maps of e.g. various components of biodiversity can be cost-effectively produced. Inevitably though, what is ultimately delineated on the map is dependent on the choice of methods and other parameters. In this paper, we report on the model used in this project and the predictions obtained, while focusing on the importance of quantifying accuracy and understanding error. Given the specific needs that the map product is expected to fulfil, our goal was to achieve maximal agreement between predictions and reality (which comes at the expense of the ability to explain patterns) subject to using methods as automated and repeatable as possible.

The model used was a conditional inference tree ensemble (conditional random forest), a data-driven, machine-learning technique virtually new to the field of ecology. The algorithm outperformed other decision tree-based methods (classification and regression trees, random forests) in terms of sensitivity and specificity.

Model predictions were checked against a custom-built measure of "dubiousness", calculated at polygon level. The final model's overall prediction error was also examined beyond the simple reporting of its magnitude (which was 28 %): incorrectly classified cases were looked into in depth in an effort to further qualify the inadequacy of the predictions. This analysis led to additional insights and increased confidence in the model.

A total area of 456 km^2 was modelled. Biotope classes included: deep, hard substrate communities with erect sponges, brachiopods, and tube-dwelling pollychaetes (272 km^2); hard substrate communities of intermediate depths featuring soft corals and solitary stony corals (110 km^2); communities associated with the reef-forming, cold water coral *Lophelia pertusa* (12 km^2); and soft sediment communities, associated with the presence of sea feathers, and the (highly valued) Norway lobster (over 40 km^2). A preliminary quantitative assessment of representativeness of the National Park was successfully carried out.

Biological Highlights from the Regional Environmental Characterisation (REC) Programme

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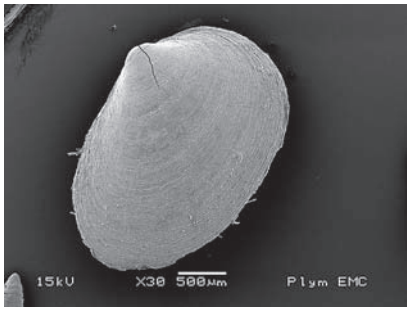
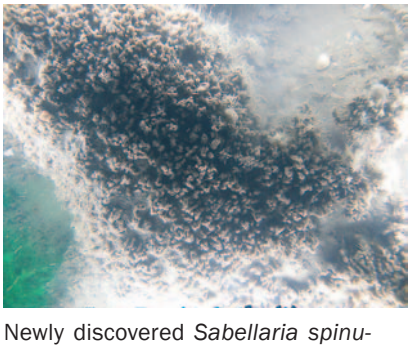
Since 2003, the Department for Food and Rural Affairs (Defra) has funded six broad scale marine mapping projects covering the South Coast, Eastern English Channel, Outer Thames Estuary, East Coast and Outer Humber Regions. The aim of these surveys was to acquire data of the highest quality possible to enable broadscale characterisation of the seabed habitats, their biological communities and potential historical assets within the regions. These projects have resulted in huge scientific advances across a number of disciplines. Some of the biological highlights include the presence of extensive *Sabellaria spinulosa* reefs off the east Anglian coast, apparent northerly range extensions in both native and alien species and the discovery of extensive black bream nests off the South Coast. These advances demonstrate both the scientific worth of seabed mapping on this scale and their contribution towards marine planning and conservation.



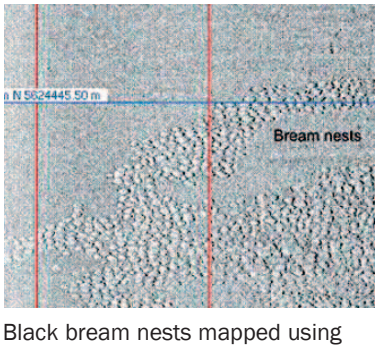
The second record of *Coracuta obliquata* in Britain

The most northerly record of *Crepidula fornicata* in Britain

The most northerly record of *Rissoides desmaresti* in Britain



Newly discovered *Sabellaria spinulosa* reefs in the southern North Sea



Black bream nests mapped using side-scan sonar

Bryozoan found at new depths

Habitat Mapping of the Shallow Inland Salish Sea – San Juan Archipelago, Pacific Northwest United States

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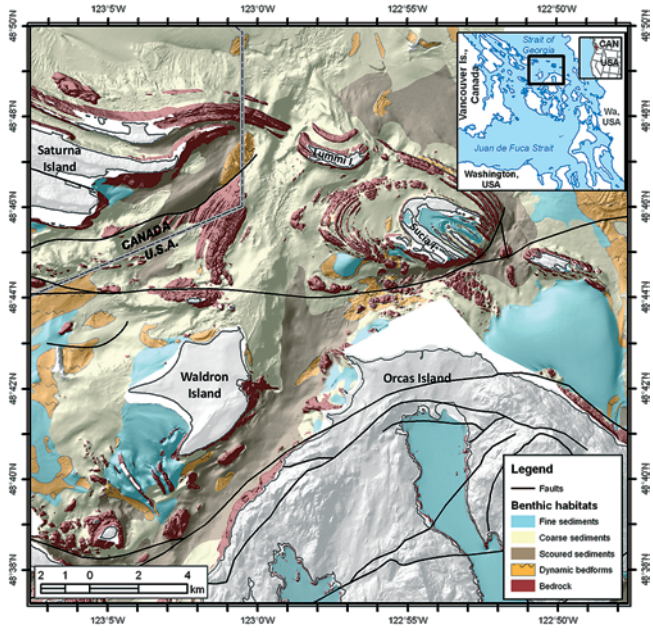
The Salish Sea lies in a tectonically active region, overlying the Juan de Fuca subduction zone, and has been extensively glaciated. Results of this combination of present-day and historical geological processes are expressed in deformed (faulted and folded), differentially eroded bedrock outcrops and relatively deep (~300 m) current scoured fjords. A variety of significant potential marine benthic habitat types ranging from sheer rock walls to rock rubble aprons to cobble–pebble pavements to erratic boulders to dynamic bedforms to mud-filled bays and sounds are found in this setting. Modern day oceanographic processes such as strong tidal flows and freshets further complicate this estuarine sea.

Extensive mapping using multibeam echosounder (MBES) bathymetry and backscatter data collected at a 200 % coverage along with 3.5 kHz subbottom seismic reflection profiles of the Salish Sea in and around the San Juan Archipelago, Washington State, USA and southern Georgia Strait, British Columbia, Canada has taken place for the past 15 years and resulted in the construction of highly detailed and comprehensive potential habitat maps. Fisheries management agencies, regional and local marine resources committees, and the local interested citizenry are using these maps, now being published by the Geological Survey of Canada, to evaluate and manage a variety of ecological resources. Of particular interests are the habitats for commercial and recreational groundfish, such as lingcod (*Ophiodon elongatus*) and rockfish (*Sebastes* spp.), and forage fish such as Pacific sand lance (PSL, *Ammodytes hexapterus*). In addition to habitat characterization, we are using the detailed MBES data and seismic reflection profiles to identify and map seafloor geohazards such as active faults and landslides. Methods and results of this mapping exercise will be presented.



Coastal Zone Planning: A Geophysical Classification of Inlets to Define Ecological Representation

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Selection of candidate sites for designation as Marine Protected Areas in coastal waters still involves many arbitrary choices. Analysis of candidate sites, according to a combination of geophysical and ecological criteria, can lead to the recognition of representative coastal areas, and potentially reduce the arbitrary nature of these decisions. In coastal areas, estuaries have long been classified according to their geophysical properties. Bays and coves are at least as diverse in character, yet existing classifications are dependent largely upon description of the benthic communities themselves and take little advantage of existing hydrographic and digital information. This classification of coastal marine inlet types designed to represent specific community types including α and β-diversity patterns. The classification is based on GIS analysis of existing digital hydrographic and geophysical data and was applied to Nova Scotia's Atlantic shoreline. On Nova Scotia's Atlantic Shoreline, inlets fall into 11 recognizable inlet types that are related to selected species, groups of species and community types. Of these inlet types only one is sufficiently protected according to the International Union for Conservation of Nature's conservation target of at least 10 %.

Annotating optical images from ROVs or drop-frames in Vulnerable Marine Ecosystems studies

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The attention to Vulnerable Marine Ecosystems (VME) in the deep-sea has increased in the last few decades for several reasons, such as fishery and oil exploration activities. Marine Protected Area networks have to be developed and techniques to investigate the seafloor, such as acoustic survey techniques and optical remote sensing, play an important role in this. Image footage from Remotely Operated Vehicles (ROVs) or towed camera is a very good method to analyse and compare abundances and compositions of large epifaunal species in several deep-sea areas. This is particularly well adapted in the case of vulnerable habitats dominated by corals or sponges, as it is less destructive than a trawl sampling. The developing of standardized image annotations becomes an important goal. However, due to availability of historical data, technical reasons or budget limitations, teams are often confronted with the use of various imagery sources and have to develop methodologies for optimizing these data.

Within the European fp7-funded project CoralFISH, IFREMER (France) has developed a program (COVER) which promotes the standardization of annotation but keeps a large degree of flexibility. A methodology has been proposed to CoralFISH partners and improved in cooperation; it is based on common knowledge tables with a hierarchical structure where necessary. These tables have been defined taking existing references such as EUNIS, CMECS, Worms Register into consideration.

Cover is able to visualise and synchronise different types of videos and still images. The snapshot generator allows frame grabs to be made at regular time or distance interval. These frame grabs can be used for statistical analysis. The annotation interface has configurable components linked with the knowledge tables: keyboard shortcuts, buttons, combo lists, and sliders. It is also possible to enter comments. The user can organize items by blocks following thematic annotations like substrate type, benthic habitat/communities, taxa and anthropogenic impacts. This interface can be adapted to the needs of the area, the type and quality of images.

Some features of Cover will be introduced into the existing software Adelie (IFREMER).

Vulnerable Marine Ecosystems of the Bay of Biscay (NE Atlantic)

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European and international regulations have been recently reinforced to limit the negative effects of anthropogenic activities on Vulnerable Marine Ecosystems (VMEs). This has induced raising needs for the development of more detailed habitat classifications, distribution maps and evaluations of the ecological status of these VMEs. The optical remote sensing of the deep seafloor plays an important role in this.

Cold-water coral reefs and deep-sea sponge grounds are known to occur in the Bay of Biscay since the beginning of the 20th century. From 1996 to 2010, 12 campaigns using Remotely Operated Vehicles, submersibles or towed cameras have been conducted on the canyons and the open slope of the Bay of Biscay with collections of videos and still images. Most of the images have been acquired along transects crossing bathymetric lines over a depth range of 180–2000 m. Until 2008, most of the campaigns have been designed for halieutical or geological purposes; the more recent ones focus on VMEs.

The first results from image analysis have allowed the identification of various habitats dominated by coral or sponges. *Lophelia pertusa* and *Madrepora oculata* compound mixed reefs occurring until 1100 m depth in association with a large variety of antipatharian, some gorgonians and hexactinellids sponges. Coral rubble and areas of trawl impacts have also been recognised. The stony coral *Enallopsammia rostrata* occurs as a dominant species on vertical cliffs around 1500 m. Some localised areas of hard bottom substrate are colonised by demosponge beds or by coral gardens.

On the soft sediment, the two main pennatulid habitats are dominated by *Kophobelemnon* and by *Funiculina quadrangularis* (in association with burrowing megafauna). Bamboo fields are also well represented on the soft bottom with *Acanella arbuscula* or others Isididae, some times associated with stalked sponges. The sponge grounds with *Pheronema carpenteri* are present in various localities.

These results have been compared with the habitat definitions mentioned in regulatory texts, existing classification schemes and scientific publications from others areas along the North East Atlantic.

Substrate classification from marine geological information

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The Geological Survey of Sweden (SGU) has developed superficial substrate maps from available marine geological information in Swedish sea areas. The maps show nine different classes of substrates, which are based on the EUNIS-classification scheme. The classes are defined through Factor analyses on 2 900 visual seabed-observations described according to the EUNIS-terminology. The seabed-observations are quite evenly geographically distributed in Swedish sea areas. A direct translation from the geological nomenclature and marine geological map to the EUNIS-classification and superficial substrate map gave best results. The two modelling methods, Generalized Regression Analysis and Spatial Prediction (GRASP) and Classification and regression trees (CART), using the input variables; marine geological map, bathymetry, wave exposure, bottom current and visual observations gave poorer results when validating the produced substrate maps. This may be due to the fact that more errors being introduced by using bathymetry-, wave exposure- and bottom current-data of less good quality and resolution.

In addition, mobility maps have been developed showing the coarsest grain size, according to the EUNIS grain size scale, which erode (become mobile) within different areas due to the effect from wind-induced waves. A comparison between the developed mobility maps and estimates of mobility from 415 visual observations shows a significant relationship, although there are indications that the calculated values sometimes are low. This could be due to the lack of bottom current data and that the calculations are based on average wind conditions.

In conclusion, the method of using direct translations from geological nomenclature and SGU marine geological maps to EUNIS-classification and superficial substrate maps were found to give the best results and are therefore employed here. Substrate maps will continuously be produced in areas SGU surveys in the future. The marine geological maps show the original deposited material and reflect past and present hydrodynamic processes such as bottom currents, wave exposure, sediment-erosion, -transportation and -deposition as well as bathymetry.

GeoHab Atlas of seafloor geomorphic features and benthic habitats – synthesis and lessons learned

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This paper presents a broad synthesis and overview based on 57 case studies accepted for publication in the "GeoHab Atlas of seafloor geomorphic features and benthic habitats" (the Atlas). The case studies covered areas of seafloor ranging from 0.15 to over 1 million km^2 (average of 26,600 km^2) and a broad range of the geomorphic feature types. The mean depths of the study areas ranged from 8 to 2,375 m, with about half of the studies on the shelf (depth <120 m) and half on the slope and at greater depths. Mapping resolution ranged from 0.1 to 170 m (mean of 13 m). There is a relatively equal distribution of studies among the four naturalness categories: near-pristine (n = 17), largely unmodified (n = 16), modified (n = 13) and extensively modified (n = 10). In terms of threats to habitats, most Authors identified fishing (n = 46) as the most significant threat, followed by pollution (n = 12), oil and gas development (n = 7) and aggregate mining (n = 7). Anthropogenic climate change was viewed as an immediate threat to benthic habitats by only three authors (n = 3).

Water depth was found to be the most useful surrogate for benthic communities in the most studies (n = 17), followed by substrate/sediment type (n = 14), acoustic backscatter (n = 12), wave-current exposure (n = 10), grain size (n = 10), seabed rugosity (n = 9) and BPI/TPI (n = 8). Less useful surrogates were water properties (temperature, salinity, DO; n = 0) and sediment sorting (n = 1). A range of analytical methods were used to identify surrogates, with ARC GIS being by far the most popular method (23 out of 44 studies that specified a methodology).

Of the many purposes for mapping benthic habitats, four stand out as being preeminent: 1) to support government spatial marine planning, management and decision-making; 2) to support and underpin the design of marine protected areas (MPAs); 3) to conduct scientific research programs aimed at generating knowledge of benthic ecosystems and seafloor geology; and 4) to conduct living and non-living seabed resource assessments for economic and management purposes. Out of 57 case studies, habitat mapping was intended to be part of an ongoing monitoring program in 24 cases, whereas the mapping was considered a one-off exercise in 33 cases. However, out of the 33 one-off cases, the Authors considered that their habitat map would form the baseline for monitoring future changes in 24 cases. This suggests that governments and regulators generally view habitat mapping as a useful means of measuring and monitoring change. In terms of the perceived clients and users of habitat maps, most Authors considered marine conservation to be the biggest user (n = 45), followed by the fishing industry (n = 24), government regulators (n = 12), the scientific community (n = 9), the tourism industry (n = 8), navigation (n = 6), other industry (eg. deep sea minerals, wind farms, etc. n = 6), oil and gas industry (n = 5) and aggregate mining (n = 4). However, the overwhelming majority of habitat surveys were funded by government or government funded agencies/institutions (n = 49) with only minor funding from private industry (n = 7) or non-government organisations (n = 4).

A gap analysis (i.e. geomorphic features and habitats not included in the case studies) illustrates that whereas shelf and slope habitats were well represented in the case studies, estuarine and deltaic coastal habitats plus deep ocean (abyssal – hadal) environments were described in only a few case studies. Geographically, about half of the case studies were from waters around western Europe whilst the margins of the continents of Africa, Asia and South America were not represented in any case study. Given the intense pressures facing benthic habitats and broad regional differences in ecosystems, species and habitats, future case studies from these regions should be specifically sought for the future editions of the Atlas.

The use of the Maximum Entropy Model Maxent in Biological Assemblage Mapping

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The need for comprehensive habitat maps to enable effective management of the marine environment is growing. The use of acoustic survey using multibeam, coupled with biological sampling or 'ground truthing', provides a means to map the distribution of biological assemblages (biotopes) over wide areas by inferring some relationship between the observed communities and the acoustic signal. Historically, this inference has been made manually using a rule based approach. However, the relationship between biotopes and multibeam data and its derived layers, can be formalised using a modelling approach. We present a method of mapping using biological community analysis coupled with maximum entropy modelling using the freely available software Maxent. Biological community analysis is undertaken on data extracted from video and image ground truthing in order to describe distinct biological assemblages. Video transects are mapped using the newly defined biological assemblages and point shapefiles created for each biotope. Multibeam bathymetry is used to derive layers of slope, rugosity, bathymetric position index, aspect and curvature in ArcGIS 9.3. Multibeam bathymetry, back scatter and video and image ground truthing are interpreted to produce substrate and geomorphology shapefiles in ArcGIS. Shapefiles are converted to rasters and all layers clipped and regridded to be of equal size, grid cell size and grid alignment as required for input into Maxent software. Individual biotope presence data are formatted as csv files for input into Maxent. Models of the distribution of each biotope are produced sequentially and maps of probability of presence throughout the study area are produced. For each biotope probability maps are converted to presence / absence maps using an appropriate threshold. Individual biotope maps are merged and adjusted using expert ecological knowledge to produce a single complete biotope map for the area of interest. The positive and negatives of this approach are discussed.

Explore Different Approaches of Processing Backscatter Angular Response Curves for Seabed Mapping

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The aim of the study was to explore different approaches of feature selection, extraction and reduction from backscatter angular response curves for a relatively complex seabed. The study area is located at Point Cloates along the coast of central Western Australia, where water depths range from 6 to 200 m. The region is characterised by areas of bedforms, flat sandy seabed, and coral reefs. A Simrad EM3002 300 kHz sonar system was used to collect multibeam data across an area of 281 km^2 in 2008. The angular response curves were derived separately for port and starboard by applying a series of radiometric and geometric correction to the raw data and averaging every 100 pings along the ship track. Seabed sediment texture was characterised from 90 samples that were analysed for grain size properties (percentage gravel, sand, and mud) and classified into six sediment classes. Co-located towed-video transects from the survey were used to identify areas to be classified as rocky seabed.

Four approaches of processing the angular response curves have been explored. The first approach used all effective beam angles (4° to 51°) with a manual feature selection method in the modelling process. The second approach used principal component analysis to condense the 48 variables into four (explaining 99 % of the data variance). The third approach extracted nine parameters from two domains of the angular response curves including slope, intercept, orthogonal distance and mean. The fourth approach derived continuum-removed angular response curves.

Probability Neural Network was used as the classifier. The classification results show that the continuum removal approach performed the best with an overall accuracy of 73 % when classifying the seven seabed classes (Figure 1). Merging the six sediment classes into four improved the performance of all approaches. The best performing approach with five seabed classes is the first approach (80 % accuracy). The visual assessment of the prediction maps shows generally similar spatial patterns among these approaches. As expected, complex spatial patterns were predicted at the inner-shelf area where reefs and mounds mixed with different sediment types. In summary, using backscatter angular response curves can satisfactorily classify relatively complex seabed. Different approaches can and should be used to extract the most useful information from angular response curves for the better prediction of seabed types and interpretation of the predictions.

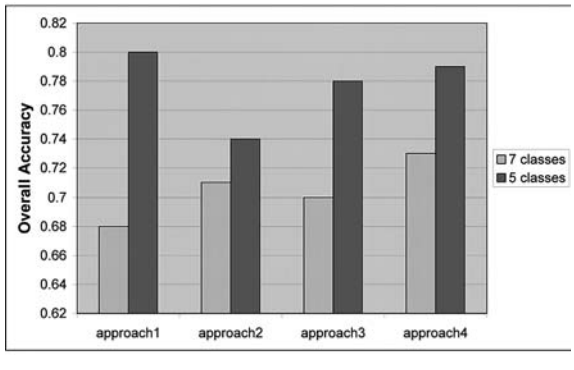

Figure 1: Overall Accuracies of the Seabed Classification.

Modeling species distributions in GIS for coastal zone management

Martin Isaeus

AquaBiota Water Research

Marine species distribution modeling (SDM) has recently became a tool for producing layers for management purposes, while earlier the method was mainly used in research. In Sweden the first two projects using SDM for large scale map production for detailed coastal zone management was recently finalized. The areas were Östergötland county and Västernorrland county, situated in the Baltic Proper and Bothnian Sea respectively. A large effort was put into improvement of environmental layers to enhance model performance. This included digitizing of historic depth measurements and physical oceanographic modeling. GAM statistics were used to model distributions of phytobenthic species or groups in 25 m resolution in both areas, and in the second area also benthic fauna were modeled. Antropogenic disturbance and pollution layers were developed and used, which improved the modeling significantly. All species predictions were validated using independent field data. In close cooperation with managers criteria for mapping areas of marine biological significance based on species predictions were developed.

Presently modeling projects are performed in four more counties, and these projects will be finalized 2013 to 2015. The modeling approach has been extended to include also fish recruitment areas, and distribution of adult fish.

The project was performed by AquaBiota Water Research in cooperation with county administration boards in Östergötland and Västernorrland, Norrköping municipality, Swedish Maritime Administration, and Swedish Geological Survey. Both projects were funded by the Swedish Environmental Protection Agency.

Geological model as basis for raw material- and habitat mapping, Danish North Sea

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In the summer of 2010 GEUS carried out, in cooperation with Orbicon A/S, a combined raw material mapping and habitat mapping program of a significant portion of the Danish section of the North Sea. The mapping was tendered by the Danish Nature Agency as part of the government's general raw material mapping, and as an input for the implementation of the EU Marine Strategy Framework Directive. The purpose of the raw material mapping is to provide a general overview of distribution, volumes and composition of available raw material resources in the Danish waters, whereas the habitat mapping seeks to identify, describe and map the distribution of the dominant habitat types.

The mapping procedure comprised a combination of bathymetric single beam echo sounding, side scan sonar seabed mapping and shallow seismic profiling of acoustic units. Ground truthing included vibrocores, grab samples and video collected by Remotely Operated Vehicle (ROV). Substrate type mapping is part of the seabed mapping task because seabed sediments are the habitats of marine benthic biomass. Understanding sediment distribution is important for mapping the distribution of marine life.

The presentation will focus on a geological model as background for evaluation of potential raw material resources in specific stratigraphical units ranging from pre-Weichselian deep channel deposits and Weichselian meltwater deposits to drowned coastal deposits and sand waves.

Besides the potential raw material resources a close relationship is observed between the geological units and the seabed biotopes.

A number of additional parameters (e.g., photic zone depth, salinity, temperature) influence the distribution of habitat types, but the close link between the till deposits on Jyske Rev and the stone reef nature type (Natura 2000 code 1170) is obvious, as well as giant sand ridges and the sand bank nature type (Natura 2000 code 1110). The mapping of the giant sand ridges as sand bank habitat type has been compared with information of distribution of sand eel fishing grounds in the Jyske Rev–Lille Fiske Banke area and a nearly perfect match is found to the distribution of the geological unit giant sand ridges interpreted as sand bank habitat type.

Fine-scale information on submarine moraines – Airborne LiDAR survey in the Kvarken Archipelago, the Baltic Sea

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Kvarken Archipelago – a UNESCO World Heritage site – is located in the northern Baltic Sea. The Kvarken Archipelago is a unique, shallow (0–25 m) brackish water area. The variety of moraine formations combined with continuous land uplift (8.0–8.5 mm/year) serve as an example of ongoing geological and biological processes and ecosystem development in time and space. Washboard-like De Geer moraine fields are specific feature of the Kvarken Archipelago. Approximately over 30 % of Finnish seawater areas are shallower than 20 meters. These shallow areas, especially the shoaly, fragmented areas, like the Kvarken Archipelago, are very difficult to operate and survey by boat. Generally, the existing data from these areas is not adequate to support sustainable use of marine resources.

We have tested airborne laser scanning system (Light Detection And Ranging, LiDAR) in ULTRA project to provide information on bathymetry and seafloor structure from shallow water areas. The method was tested in the Kvarken Archipelago, where the object was to study moraine formations at the seafloor. We have compared LiDAR data with acoustic survey data. BLOM kartta Oy did airborne LiDAR survey in the Kvarken area in the summer of 2009. Acoustic-seismic surveys within the area were carried out in 2007 by Geological Survey of Finland. Here we will discuss the area, where the seismic and LiDAR data overlap.

On the basis of our study, the airborne LiDAR is an effective tool for providing detailed information on the shallow water bathymetry, structure and morphology of seafloor. The used Hawk Eye laser scanning system gathered bathymetry data up to -14 meters deep. The produced topography model shows a series of small, parallel and elongated features at the seafloor, which characterize the whole area.

Finnish Scientific Diving Steering Association

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Suomen tutkimussukelluksen ohjausyhdistys ry. – Finnish Scientific Diving Steering Association (FSDSA) is a special interest group for the professional scientific divers. FSDSA addresses the matters of health and safety of scientific divers, and is the issuing authority of European Scientific Diver (ESD) and Advanced European Scientific Diver (AESD) qualifications in Finland. Full members must be individuals holding an (A)ESD qualification, but supporting membership can be admitted to any individual, institute or company.

FSDSA is a founding member of the European Scientific Diving Panel (ESDP) of the European Science Fund's Marine Board (ESF-MB). ESDP aims to advance and promote scientific diving across Europe. This is achieved by creating a pan-European framework that encourages the best practise and co-operation between marine scientists, promoting the (A)ESD-standard, advising in the establishment of national committees where they do not exist, organizing meetings, conferences and workshops, developing an European database of scientific divers, etc.

Scientific diving is a valuable and cost-effective tool in underwater research and mapping, which greatly extends the possibilities of ship-based monitoring techniques. Skilled scientific divers deliver data of greater quality than remote methods, reach places not accessible from the surface and have less effect on the fragile surroundings. Scientific diving supports underwater science through efficient and targeted sampling, quantitative survey and observation, in situ measurement, impact studies, ecological analyses, evaluation of new techniques, mapping underwater areas, profiling subtidal geology/geochemistry and accurate deployment/retrieval of underwater apparatus. The divers have proven to be indispensable in research of for example shallow coastal habitat, vertical walls and caves.

Occupational scientific diver training in Finland was established in 1994. The rigorous learning goals aim to exceed the minimum requirements of the AESD certificate. The course, offered by Luksia vocational school, runs in modules scattered over a 1.5-year period and the students are oriented either in the field of natural sciences or archaeology. No previous diver training is needed, but the participants are expected to have undergone academic studies of the suitable field.

For more information contact the president of FSDSA Pirkko Kekäläinen (pirkko.kekalainen@gmail.com) or visit the following websites:
FSDA http://www.tutkimussukellus.net
ESDP http://www.scientific-diving.eu/
ESF-MB http://www.esf.org/research-areas/marine-sciences/marine-board-panels/scientific-diving-and-the-esdp.html

Mapping habitats and macrophyte species on extremely shallow and diverse soft bottoms

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In situ data collection is necessary when collecting the first information from a new area. Remote-sensing techniques do not work well underwater when it comes to biological habitat mapping and species composition. Some sections of the Bothnian Bay Archipelago Natura 2000 conservation area (Perämeren saaret -natura-alue) have been established well over ten years ago but almost nothing is known of their underwater nature. Basic species composition studies and biological habitat mapping were conducted in two different areas of the conservation area during two consecutive field seasons. Both study areas are shallow land-upheaval islands but the other one is on the outer islands in the open sea (Krunnit conservation area) and the other one near the mainland (Kraaseli area). Salinity is between 1–2 per mil. Vascular plant vegetation does not reach deeper than about 4–5 m in these areas because of the tannic acid that dyes the water dark brown. This means that most of the densest vegetation lies in the very shallow water depth, mainly between 0.1 m – 1 m.

Mapping was done with a drop-down video camera and an aquascope. Some of the areas were too shallow for boats and scuba diving but both the biodiversity and the number of threatened directive species were very high on these areas. Higher species diversity and more biomass were found in the sheltered areas near the mainland islands and the species composition was slightly different between the two study sites. Also the Habitats Directive (Annex I) habitats can be derived from this data set. This is important for the management purposes.

Time consuming and expensive in situ habitat and species mapping are the only way to start mapping a new underwater area, especially a shallow one, if the purpose is to reveal the species composition. Remote-sensing techniques and modeling can be used on larger scale studies and maybe even on some biological habitats studies, but the only way to study the distribution and the abundance of certain important species is to go to the place and see for yourself.

Geomorphological Map is Base of Study of Biogeosenosis Distribution in Troms III Area, the Barents Sea

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Bathymetrical and geo-morphological maps of the sea bottom can be used while studying bottom deposits and communities of benthic organisms. They help to determine the current condition of the sea bottom, to outline the major "geomorphological traps", to reveal a typical litho-dynamic conditions and paths of sediments flows. They are a necessary basis for forecasting environmental changes under the conditions of a changing climate.

The Barents Sea is being affected for a long time by trawling fishery, and now it plays a key role in the development of oil and natural gas extraction on shelf. Economic activities influence on coastal-shelf zones in Arctic regions requires especially careful study.

At the Barents Sea, I collected samples of surface sediments in cruise during the period from 24th July until 15th August 2010, on the board of research vessel "G.O. Sars", the Institute of Marine Research, Norway (MAREANO project), in different parts of the Barents Sea on depths from 200 to 1500 m, in places with various rates of sediment accumulation.

The bottom sediments and living organisms inhabiting them (benthos) play an important indicative role while estimating the condition of marine ecosystems. Bottom sediments are capable of accumulating and storing the information on the status and change of geochemical, dynamic, climatic, neo-tectonic environmental conditions, the processes of mass transferring, including those caused by man-caused impact. Benthos is stable over time, characterizes local situation in the area; it is capable of representing the changes of an ecosystem retrospectively.

The seas studied by us differ in many ways: in the isolation degree, in the features of hydrological mode, in various oceanic masses, and also in level of anthropogenic impact. However, basic processes in bottom sediments are universal and, hence, during their research we can trace, first, various natural and anthropogenic factors, and secondly, to make the forecasts of changes in the ecological conditions of marine ecosystems.

Due to increasing pressures on marine ecosystems benthic communities are changing (size, density, changes in species, etc) as well as bottom sediments (changes in grain size, mineralogical and chemical composition.

In this project in the process of studying benthos we determine the following characteristics: biomass, numbers, biodiversity as well as spatial distribution of benthic communities (biocenoses), depending on the geomorphological characteristics of the seabed. Research of these marine ecosystem components is a tool for creating the Integrated Management Plan of the seas.

Ferromanganese concretion fields – unknown habitat in the Baltic Sea?

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Ferromanganese (FeMn) deposits are found at the seafloor in the Atlantic Ocean, the Indian Ocean, and the Pacific Ocean, as well as in the Baltic Sea. FeMn deposits have well known economical importance, but their role e.g. in the internal loading of nutrients and their ecological significance as a habitat, is poorly known.

We show the results of the MESA project that aims to reveal information on the character of the seafloor that is covered by FeMn –concretions, their elemental content, and clarify their ecological significance as a habitat. The field investigations were conducted in the Gulf of Finland (GoF) (in 2008), and in the Archipelago Sea (AS) (in 2010), the northern Baltic Sea, using various acoustic-seismic investigation and sediment sampling methods (Box corer), and video observations. Both study areas, the GoF and AS are relatively shallow (average depth of approximately 35/37 and 23 meters, respectively) with rocky islands and islets. The variable seafloor topography characterizes both areas. The seafloor is a patchy combination of various substrates like bedrock, moraines (till), gravel and sand, clays of different ages as well as soft mud.

In the AS, a total of 32 sites were sampled from water depths between 9 and 83 meters, and in the GoF, 31 sites were sampled from water depths between 9 and 61 m. Different type of FeMn –concretions (e.g. spherical, discoidal and plates) were found at the seafloor of the water depths of 11–58 m in the AS, and 9–61 m in the GoF (Fig. 1). Silty clayey (glacial and post glacial clay) seafloor was fully or partly covered with 1–3 cm thick FeMn plates in the water depths of 10–60 m in the AS and 40–60 m. Areal coverage of the FeMn plate rich seafloor is ~41 % and ~9 % in the AS and GoF study areas, respectively. These FeMn concretion fields provide hard substrate for the seafloor fauna and flora, perhaps comparable to reef. This habitat is poorly known and studied in the Baltic Sea so far.

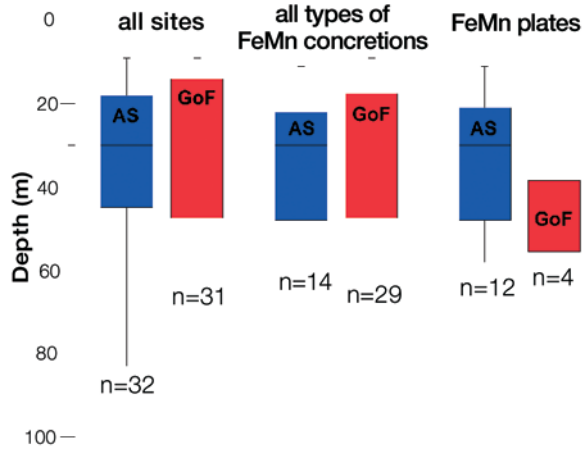

Figure 1. Depth distribution of all study sites (left), sites where FeMn concretions were found (middle), and sites covered with FeMn plates (right). Blue bars indicate the Archipelago Sea (AS) and red bars the Gulf of Finland (GoF) sites. N= the number of sites/samples in each category.

Mapping of seabed landscapes of Polish EEZ – first step for habitat classification

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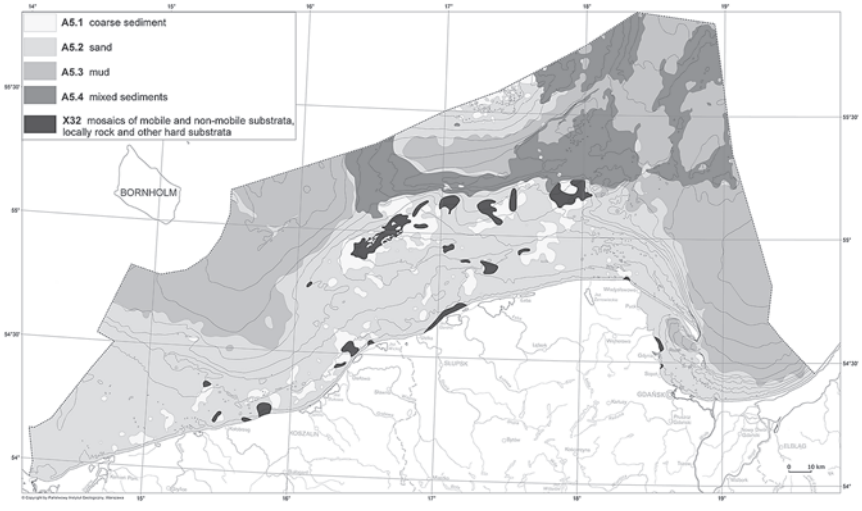
The Polish Maritime Areas (PMA) are generally shallow, and depths in excess of 100 m are only found in the central part of the Gdansk Basin. A wide belt of shallows (less than 30 m) extends for nearly 20 km along the coast from Pomeranian Bay to the Hel Peninsula and to Vistula Spit in the Gulf of Gdansk. The habitats were designed based on the Geological Map of the Baltic Sea Bottom (1:200 000) elaborated by Polish Geological Institute (1989–1993) which cover 30 533 km^2 of PMA. 18 sediment classes, ranging from clay to coarsest gravel and boulders and anthropogenic deposits, distinguished on the map of surface sediments, were simplified to EUNIS III category.

At the third level of the EUNIS habitat classification system, which is based on sediment description, five habitats in PMA are distinguished: A.5.1, A.5.2, A.5.3, A.5.4 and X.32.



A.5.1 – coarse sediments (gravel and coarse sand), which comprise a small surface area throughout the coastal zone, and are also found on Slupsk Bank and to the east of it, Stilo Bank and on the shallow most part of Southern Middle Bank.

A.5.2 – sand is distributed in a wide strip from the west that encompasses the Pomeranian Bay, the slopes of Slupsk and Southern Middle Banks, through the Czolpino Shallow to the east. There is a narrower strip of sand extending along the Hel Peninsula and the Gulf of Gdansk.

A.5.3 – Mud comprising fine material beneath a grain size of 0.063 mm. Within Polish EEZ, these are deposited in the southern part of Bornholm Basin, on the northern slope of Slupsk Furrow, Gdansk Basin and southern part of East-Gotland Basin.

A.5.4 – Mixed sediments comprising sand, mud and gravel. These are noted on the seabed elevation (troughs) between Bornholm Basin and Slupsk Furrow as well as between Slupsk Furrow and Gdansk and East-Gotland Basins. Mixed sediments occur also on southern slope of Slupsk Furrow and on foot of East-Gotland Basin slopes.

X.32 – Mosaic sae bed and locally hard bottoms includes areas comprising cobbles and boulders and associated with patches of sand and gravel, and occasionally outcrops of till or clay. This type of habitat occurs in the near-shore zone close to cliffs and in the northern part of the Slupsk Bank and its extension to the east.

Pattern analysis of natural and artificial hard bottom substrata in the Polish Marine Area (PMA)

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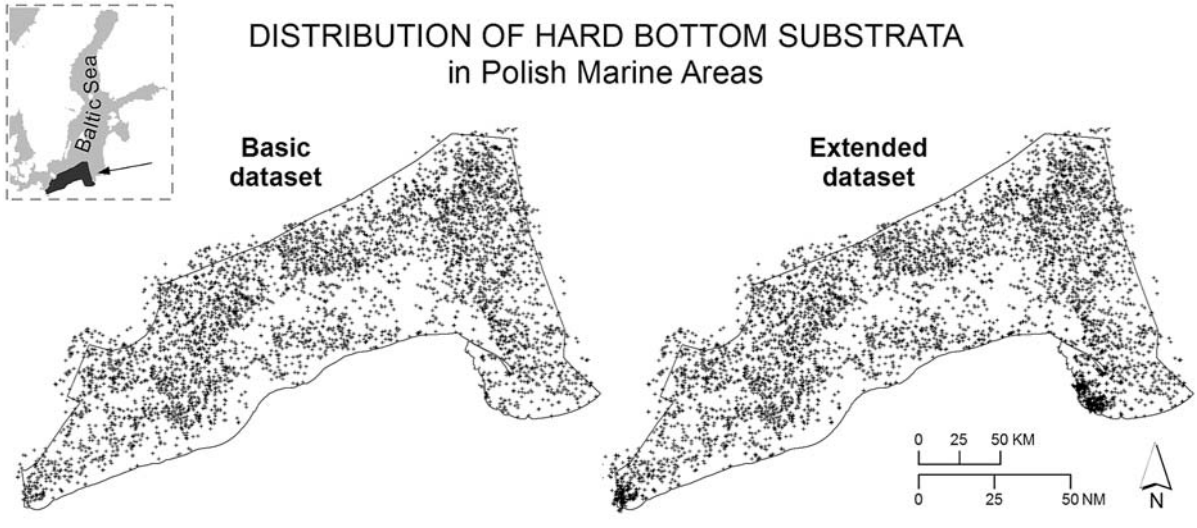
The aim of the research is to identify various components of spatial point patterns (e.g., departure from randomness, scale and strength of the pattern) by using real data sets of bottom object occurrences. A range of methods, including both first order tests (nearest neighbour index, Diggle's G and F functions) and second order tests (Ripley's K-function, L and neighbourhood density functions) are applied. In order to combine data (geographic coordinates of hard bottom substrata of all kinds and sizes, rocks and stones, wrecks and wreckage ground, ammunition, obstructions, and others) gleaned from different sources, data preprocessing is required. Supervised data generalisation is used to overcome the problem of non-uniform data coverage as well as data repetition. Confirmed duplications of object positions are excluded. Spatial statistics are calculated for two sets of data, basic and extended, including 4943 and 6122 objects respectively. While the event distribution in the basic set is generally homogeneous over the PMA, the extended set is characterised by much higher data concentration in the vicinity of Polish major harbour approaches of Gdansk and Szczecin. Fulfilling the fundamental assumption of spatial stationarity of the pattern, the PMA (32 534 km^2) is divided into several smaller regions with areas ranging from 3 360 km^2 to 10 209 km^2. Finally, spatial statistics are calculated for the set of 12 configurations of input parameters, regarding two datasets and nine regions. In most cases results confirm the clustered nature of the pattern. Nevertheless the null hypothesis of random bottom object distribution at the local scale cannot be rejected.



FINMARINET – a joint effort to combine multiple data sources to produce information on marine habitats

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FINMARINET, 'Inventories and planning for the marine Natura 2000 network in Finland', a four-year research project launched in 2009, is financed by the European Union's LIFE+ programme and it forms a part of the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). The project collects information to be utilised in nature conservation and marine spatial planning. In the project, seabed topography (surface features and depth contours), structure and biota is mapped, alongside with the occurrence of underwater habitats. Some underwater habitats, including reefs and sandbanks, are of particular interest of also the European Union Habitats Directive.

In the FINMARINET research areas, the geological mapping of seabed topography and substrate is carried out alongside the biological surveys of habitat types and their flora and fauna. Mapping methods include underwater video recordings, SCUBA diving, acoustic survey methods and sampling of the seabed biota. Already existing data is combined with data gathered during the project, and utilised in the modelling of underwater habitat and species distribution.

In deeper offshore areas, habitat surveys are based on the video recordings of the sea floor, utilising a Remotely Operated Vehicle (ROV) that is steered from a survey vessel. In shallower areas, data is produced on the bottom characteristics and species occurrence utilising diving and underwater video recording from small boats. The bottom sampling of biota also forms a vital element of research activity within the project. By using state of the art satellite based Geographic Information Systems (GIS) methods and statistical modelling the gathered material is combined with existing data on the physical characteristics of the target areas. In this way, information on species distribution and their habitats can be obtained even in areas where no inventories have been conducted.

In FINMARINET, underwater mapping is being performed in and around seven marine Natura 2000 sites along the entire Finnish coastline. The project is coordinated by the Finnish Environment Institute (SYKE), with four associated beneficiaries: the Geological Survey of Finland (GTK), Metsähallitus Natural Heritage Services, Åbo Akademi University and the University of Turku.

Regional substrate classification of Cook Strait, New Zealand, from textural image analysis of backscatter data

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A comprehensive EM300 (32 kHz) multibeam survey of Cook Strait, New Zealand (~8500 km^2) is used to generate a regional substrate classification map over a wide range of water depths, seafloor substrates and geological landforms using an automated mapping method based on the textural image analysis of backscatter data. We used the SonarScope® software to process the data, including signal corrections from sensor bias, specular reflection compensation and speckle noise filtering aiming at attenuating the effects of recording equipment, seafloor topography, and water column. This is required in order to obtain an image with a strongly attenuated specular reflection. Image segmentation of the merged backscatter and bathymetry layer is constrained using shape, compactness, and texture measures. The number of classes and their spatial distribution are statistically identified by employing an unsupervised fuzzy c-means (FCM) clustering algorithm to sediment samples, independent of the backscatter data. Classification is achieved from the overlay of the FCM result onto a segmented image and attributing segments with the FCM class.

Four classes are identified and uncertainty in class attribution is quantified by a confusion index layer. Validation of the classification map is done by comparing the results with the sediment and structural maps. The calibrated Backscattering Strength (BS) is used to provide information on the physical characteristics of the seafloor and emphasise acoustic class separation, as it is a good indicator of the sediment grain size and provide a first-order interpretation of the substrate composition.

The method combines multibeam data with physical seabed data in a complementary analysis to seeking correlations between datasets using object-based image analysis and unsupervised classification. Texture within these identified classes is examined for correlation with typical backscatter angular responses for mud, sand and gravel. The results show a first order correlation between each of the classes and both the sedimentary properties and the geomorphological map. This quantitative first order correlation between the seabed substrate and the MBES data is a first for Cook Strait at a regional scale. The correlation with the backscatter angular response is still in its infancy but has great potential in enabling the quantitative mapping of the seafloor.

The method acknowledges the application of imprecise and/or uncertain data through the integration of different approaches: analytical modelling (fuzzy classification), spectral classification (segmentation), and spatial analysis (boundaries). The next logical step in this methodology is to combine physical and biological data collected across the Cook Strait region to assess the validity of the classes and distinct habitats.

Seascapes of Eastern Brazil Continental Shelf

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The continental shelf off eastern Brazil is a high-energy, tropical, low-acommodation, narrow shelf characterized by a reduced terrigenous sediment influx. Shelf width can be as narrow as 5 km and shelf break is located between the 45–50 m depth. This paper presents an integration of sediment texture and composition, bathymetric and sonographic (sub-bottom and side-scan) data compiled during the last five years (Figure 1). This dataset allowed us for the first time to adequately evaluate the seascapes present at this region.

Seascape types and spatial distribution in the study area is strongly controlled by the long-term subaerial exposure of the entire shelf during most of the Quaternary, since shelf break is located at just 45–50 m. This favored extensive fluvial incision of the shelf surface with rivers emptying in the upper slope, directly connected to submarine valleys and canyon. When the shelf was flooded during high-stands sedimentation resumed. As a result, the outer shelf (20–50 m depth) is characterized by a gravelly thin cover of rhodoalgal sediments (encrusting coralline algae with subordinate amounts of foraminifera and molluscs) on a hard (karstic) substrate. The inner shelf (<20 m) is dominated by terrigenous sandy sediments. Mud accumulation is controlled by the distribution of topographic lows on the shelf, which coincide with major incised valleys and canyon heads.

This spatially comprehensive dataset when integrated to benthic data, fisheries and other human activities (e.g. oil exploration, effluent disposal) will improve surrogacy and environmental management. In fact the outer shelf with the rhodalgal sediment cover, hard bottoms and canyon-controlled upwellings is already extensively exploited for its demersal resources by the local fisheries.

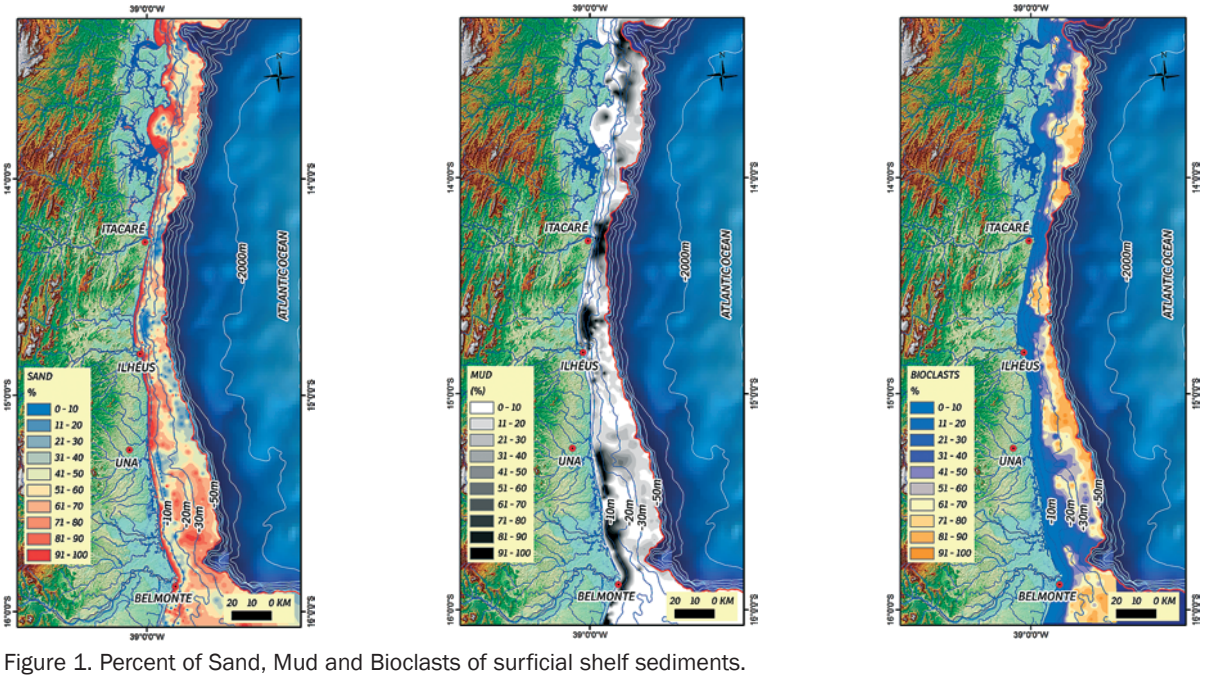

Figure 1. Percent of Sand, Mud and Bioclasts of surficial shelf sediments.

Acoustic mapping and ground truthing analysis used for the modelling of benthic habitats in the Kattegat, Denmark

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The Kattegat is located in the transition zone between the Baltic Sea and the North Sea (Figure 1). It forms a relatively protected environment with minor tidal effect. The present structure of the southern Kattegat including the study area reflects its tectonic and glacial history. The relatively shallow seabed can be regarded as a drowned glacial landscape. Deeply incised valleys are most likely remnants of a river system draining the Kattegat to the north during the late glacial period. The valleys cut into the surrounding seabed of glacial and late glacial sediments. The distribution of reef habitats is directly linked to the complex deglaciation history and shoreline displacement of the Kattegat during the late Weichselian period. After its maximum extension, the late Weichselian ice sheet retreated toward the northeast leaving a series of recessional ice border stages behind forming morphological elements at the sea floor. The presence of these elements is attributed to the distribution of the reefs habitats in Kattegat.

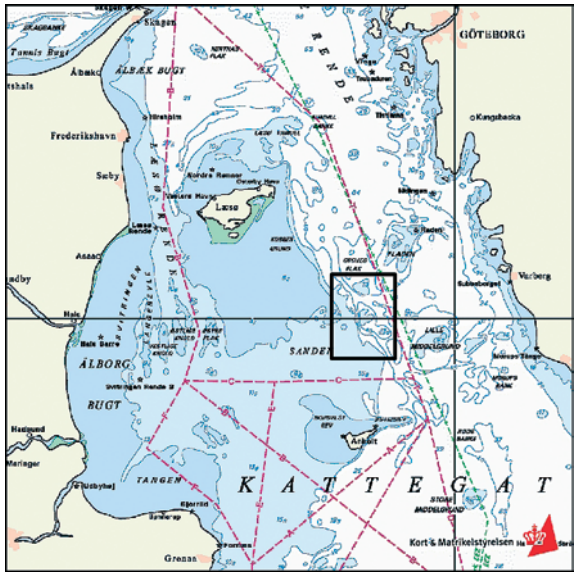

Figure 1. The study area in the Kattegat, Denmark.

Multibeam sonar, digital sidescan sonar and seismic sub-bottom profiler combined with ground truthing have been used to construct detailed images of the sea floor and the shallow geology within the study area. The resulting maps constitute the geological basis for the preparation of habitat maps and modelling of hard bottom habitats

The present knowledge of the biological components inhabiting the geological features of the seabed in open waters is derived from small spots with a scale ranging from a core samplers to a relatively short transects of diver investigation or video inspection. Each of those small bits of information is often subjected to different but important structuring factors operating both on spatial scales from centimetres to many kilometres as well as in time varying from hours (storm events) to years. This study identifies key biological habitat elements suitable to describe reef habitats in a robust manner in a given space and time. The concept underlying this approach is that certain habitat characteristics are needed to host specific species, assemblages or communities.

The results of the acoustic mapping have been combined with two different predictive models describing important key biological elements characterizing hard bottom habitats and presented on GIS maps. Habitat maps combining important geological and biological features as demonstrated in the present case study will be a very valuable and operational tool for large scale spatial planning and management of offshore resources.

Geo-acoustic characterization and habitat distribution in the Chella Bank (Eastern Alboran Sea – SW Mediterranean)

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This study focuses on the characterization of morphostructures and related benthic habitats detected and mapped in the Chella Bank, also referred as "Seco de los Olivos", a seamount located offshore the coast of Almería, in the Eastern Alboran Sea (SW Mediterranean). The Chella Bank is one of the selected areas of the LIFE-INDEMARES Project (www.indemares.es), aimed to contribute to the protection and sustainable use of biodiversity in the Spanish seas through the identification of valuable areas for the Natura-2000 Network. This study is based on a comprehensive compilation of acoustic data (swath-bathymetry, backscatter and parametric echosounder), seismic data (Sparker) and video images acquired during successive surveys. The Chella Bank is a Neogene age volcanic seamount located along the upper slope of the Almeria Margin, characterized by a sub-circular shape and covering an area of 100 km^2 within a depth range of 70 to 700 m. High-resolution swath-bathymetric mapping reveals three main large scale (hundreds of m scale) morphological features on the Chella Bank: a round shaped flat top volcanic edifice surrounded by two steep ridges, located to the west and east of the edifice. The top consists of an irregular central area, from 76 m to 130 m depth, with local relieves and terraces, partly corresponding to carbonate relict bioherms formed in shallow environments during the Last Glacial Maximum. Two main ridges range in depth from 160 m to 600 m and are composed of small crests and subcircular peaks. The physiographic complexity, current circulation and geological composition of the seafloor represent the main constraining factors in the distribution of benthic habitats of the area. The rocky outcrops of the top are characterized by a high biodiversity and provide the substratum for extensive deep-sea gorgonian assemblages, mostly *Callogorgia verticillata* and *Viminella flagellum*. Small patches of living stony corals (*Madrepora oculata*) are also present at the top. Biodiversity strongly decreases along the peaks and crests of the western and eastern ridges, composed of hard massive steep bedrock and corresponding to habitats mostly dominated by the presence of hat-shaped glass sponges *Fakelia ventilabrum*. Video surveys revealed the presence of cold water coral frameworks, mainly consisting of *Lophelia pertusa* (mostly dead), forming a 2 km long linear morphostructure, rising up to 60 m above the surrounding seafloor. We acknowledge funding from the Spanish National Project EVENT (CGL2006-12861-C02-02).

An integrated biological-geological approach for the management of renewable marine resources: the COMSOM Project

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The exploitation of renewable marine resources by bottom trawling is one of the major sources of damage to benthic communities and habitats. Thus, there is an urgent need for developing the ecosystem indicators of disturbance based on robust data to achieve efficient fishery management strategies and minimise fishing impact on ecosystems. A comprehensive biological and geo-acoustical dataset is essential to relate potential changes in the structure and composition of benthic communities and the degree of habitat disturbance to gradients of fishing effort. In the context of COMSOM Project (CTM 2008-04617 and CTM2008-04206-E), aiming to define new strategies for the management of fishery resources, we adopted an integrated biological and geological approach in the study of trawling disturbance in the Mediterranean. To achieve this objective four coastal areas subjected to different degrees of trawling efforts have been selected over the Mediterranean continental shelves: two areas in the western Mediterranean (Cap de Creus and Murcia, Spain), one area in the central Mediterranean (northern Tyrrhenian, Italy) and one area in the eastern Mediterranean (Ionian Sea, Greece). Each area is located between 40 and 70 m depth and is mainly characterised by soft-bottoms and by sporadic rocky outcrops. The study areas were surveyed with geo-acoustic methodologies (Sidescan Sonar, Multibeam) and ROV to characterise the physical attributes and define the distribution of benthic habitats. A 2m-beam trawl and a Van Veen grab were used to collect benthic fauna and a CTD to record hydrographical variables. The benthic habitats, mapped combining biological and geological information (density of indicator species in each area, sediment distribution and geomorphology), have been contrasted with the different levels of fishing effort within each area. These data allowed identifying different habitats and communities subjected to variable trawling intensity. For example, the heaviest fished areas are composed by muddy sediments with the high abundance of mobile invertebrates and lack of the habitat forming species. Mapping the areas subjected to different trawling intensities will provide a valuable tool for detecting habitat and community degradation, this point being essential for the spatial planning of fishing activities. In this context, the obtained results will bring an invaluable opportunity to proof the feasibility of a seascape integrated approach in the study of benthic habitats and in the management of marine ecosystems exploited by fishing activities.

From Research to Reality; Geocoder's Past, Present and Future

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Geocoder was introduced several years ago as a detailed backscatter processing application. As a product of research from the Center for Coastal and Ocean Mapping (CCOM), many of the participants in CCOM's Industrial Associates program released commercial implementations of the research code within a short time. Research code is not always commercially viable, however, and many commercial vendors are now dealing with some of the same limitations of the original code base. While new processing techniques can move an industry forward, building a complete application that exploits new algorithms and is both usable and useful is no simple feat.

This paper describes a re-implementation of the capabilities of the Geocoder algorithm core, in an application toolbox that is designed from the ground up to be flexible, modular, and user configurable. The design distils out Geocoder's core algorithm components and marries them with a modern commercially tested architecture that covers the efficient IO as well as full exploitation of multi-core and multi-CPU environments. This new scheme has the potential to change the way that further research is done by providing a user-controlled plug-in architectural framework that can be used to extend (or replace) the capabilities of Geocoder.

Comparing towed and baited underwater video techniques for assessing temperate marine fishes

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Accurate estimates of fish species occurrence are important to any species' assessments and distribution model. With increasing emphasis on non-destructive sampling, underwater video techniques are commonly used without a thorough understanding of their advantages and disadvantages. This study compared data collected from baited remote underwater stereo-video systems (stereo BRUVS) and towed-video systems to determine; (1) the differences between these video techniques in terms of fish assemblages, functional groups (i.e. pelagic carnivore, epibenthic carnivore/omnivore or herbivore) and observability (i.e. conspicuous or cryptic), and (2) what impact do these two techniques have on the interpretation of spatially-explicit, predictive models. We found stereo BRUVS and towed-video techniques recorded very different assemblages, functional groups and observability categories across structurally complex benthic biological habitats (i.e. macroalgae dominated habitats). However, as the habitat complexity became less (e.g. seagrass and areas with no visible macro-biota) both techniques appeared to provide similar fish assemblage information. We also found considerable differences in the predicted extents of habitat suitability between the two video techniques.

Large-scale acoustic seabed characterization for *Nephrops* habitat and other environmental studies in the Porcupine Bank, Ireland

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Shallow geophysical data acquired during the Irish National Seabed Survey (2000–2002; www.infomar.ie) have been used in this study to characterise over 50,000 km² of the Porcupine Bank's seafloor (NE Atlantic, Ireland). Multibeam backscatter parameters have been analysed with the aid of existing ground-truthing to delineate large-scale geological boundaries from the top of the Bank (150 m) to the 500 m isobaths. In general, the multibeam backscatter response within the study area can be grouped in two large regions: high amplitude levels on the Bank's Ridge (150 m to 200 m water depth) are associated to hard substrate and gravel dominated facies; and low backscatter levels between 200–500 m are associated to a smooth gradient of fine-grained sediments. Part of this area, in the southern slopes between 320 m and 550 m, constitutes suitable mud habitat for the burrowing decapod *Nephrops norvegivus* (or Dublin Bay prawn). The spatial extent, of the fishery targeting *Nephrops* (in excess of 10,000 km²) has been identified using integrated Vessel monitoring systems (VMS) and logbook data. The backscatter derivative maps over the Nephrops area shows a large recognisable pattern that largely correlates with the VMS spatial extent. Detailed spatial and swath analysis of multibeam backscatter within this region is used to constrain some of the geoacoustical properties related to sediment properties. The primary control over the backscatter variability within the Nephrops region is sediment grain-size related parameters, primarily the depth decreasing sand fraction which defines the most shallowest depth habitat boundary. However, some seafloor spatial morphological indices also contribute to the backscatter response and might aid in characterising the seabed features (such as burrow density). This information can be used to improve the assessment and management of the *Nephrops* stock in the Porcupine Bank and other similar environments.

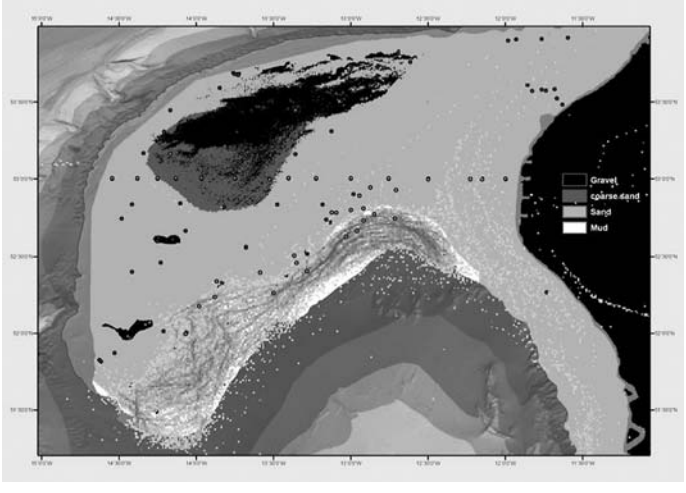

Figure 1. Porcupine Bank seabed geology map (GSI, 2010). Nephrops distribution on the southern part largely coinciding with the mud dominated facies (white). Black dots depicting ground-truthing sites

Mollusc associations from a cold-water coral environment (Apulian margin, S Italy)

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A quantitative study by means of multivariate analysis was carried out on molluscs yielded by 8 small cores, up to 40 cm long, recovered in 2010 (CoralFISH EU-FP7 Project) along the Apulian margin off Santa Maria di Leuca (S Italy), 525 to 784 m depth. The mainly silty seafloor of this area is characterized by mound-like and elongated topographic features (50–300 m wide and up to 25 m high) whose upper part is generally colonized by cold-water coral communities.

Shells were picked from 31 core levels and then identified – when possible – to species, revealing a diverse fauna including 79 benthic taxa (37 Bivalvia, 3 Scaphopoda, 39 Gastropoda) out of 112 recognized in the area by sorting 24 contextually recovered box-corer samples. The dominant taxon is the small infaunal bivalve *Kelliella miliaris*; among other relevant elements, *Abra longicallus*, *Notolimea crassa* and *Alvania cimicoides* are also mud-related, while *Heteranomia squamula*, *Delectopecten vitreus*, *Asperarca nodulosa* and *Bathyarca pectunculoides* thrive on hard substrates.

The multivariate analysis (clustering, MDS) was conducted on a 79 species x 29 samples abundance matrix, defining three groups (A to C); they were analyzed in terms of the dominance and similarity contributions of species and proved to belong to different habitats as regards bottom type and relationships with corals. A and B are quite homogeneous; the former is restricted to coral mound tops and appears to be related to coral branches or rubble, while the latter is found both in inter-mound areas and on the mound upper flanks and links to a frankly muddy seafloor.

Conversely, group C is heterogeneous and interpreted as transitional; the MDS dispersion of its levels led to perform a second step analysis on a reduced matrix. This revealed at least three different transitional stages (C2 to C4) between coral rubble and mud habitats. C3, found at or near mound tops just below mud-related faunas, appears closer to group A; C4, mostly represented at the NE base of mounds, is more similar to B; C2 occurs quite randomly and includes a mixed fauna.

The mollusc groups and stages studied herein match quite well with both macrohabitats and thanatofacies recognized in the area by means of bottom samples and submarine video surveys (APLABES Project, HERMES Project).

Modelling the potential impact on local fish stocks and habitat use by post-breeding aggregations of foraging Great Cormorants (*Phalacrocorax c. sinensis*)

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The Great Cormorant (*Phalacrocorax c. sinensis*) is a large-sized fish eating bird, breeding in dense colonies. The Finnish breeding population was established in 1996, and since then the numbers have grown to c. 16 000 pairs. Following the increase, the species has gained the status of being a problem for local, small-scale fisheries. However, the body of published information on the use of different fish species, and the potential of local cormorants to affect fish stocks on a regional level, are still poorly understood. In particular, as Cormorants are present in Finnish coastal waters for an extended period prior- and post-breeding, and dietary analyses have been done in breeding colonies, there is a need to address issues of total potential fish consumption. This need is clearly coupled with a need to estimate the extent of foraging areas.

We observed feeding flocks of Cormorants off the Hanko Peninsula, southern Finland, throughout the post-breeding season in 2006–2008. The positions of the feeding flocks were entered on sea charts and later into a GIS. The numbers of birds were recorded as long as the Cormorants were present each year. This allows for a tentative calculation of fish removed by the birds over the post-breeding season.

We used the presence-only modelling method Maxent to model the potential feeding areas of the cormorant in a c. 400 km^2 water area around the Hanko peninsula. The models are based on the presence records of feeding cormorant flocks (2006: 63, 2007: 31, 2008: 25) from the three years (model learn sets). We used five predictor rasters for the models (resolution 25 x 25 m): depth, slope, exposure, distance to sandy substrate and distance to gravelly substrate. We run Maxent with default settings for each year, using the other two years as test sets.

The models for all 3 years are reliable according to the AUC values, which ranged between 0.88 and 0.93 for the test sets. As the models preformed similarly, we chose the model for 2007 for further study. The variable contributions were: distance to gravel (41 %), exposure (30.1 %), distance to sand (19 %), depth (5.5 %) and slope (4.4 %). We divided the Maxent probability raster into 3 classes: 0–20 % probability (unsuitable feeding areas), 20–50 % (marginal feeding areas) and > 50 % (main feeding areas). The total extent of the main feeding areas is 27 km^2 (6.1 % of the total area). Thus, Cormorants use a fairly small area (of the total available) for foraging.

Using underwater video for quantitative coverage assessments: what is the influence of a human error?

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Coverage estimation is one of the most common tasks in underwater video analysis. In spite of emerging automatic image analysis techniques, the manual (visual) treatment of video data remains a routine approach in the treatment of underwater video material. That makes inevitable a certain level of subjectiveness (uncertainty) which may affect the accuracy of the results, especially if video material is being treated by different operators.

In our studies, we are using a simple mechanistic approach to analyze underwater video, which helps to reduce the influence of human error. A video sequence is divided into manageable (e.g. 90 sec) sections, each being considered as a separate/ independent sample. The time interval of ca. 90 sec is chosen based on the theoretical knowledge of human ability to maintain focused attention while estimating visual features and our own experience in underwater video analysis since early 1990s. A sample is further subdivided into 3 equal sub-samples (ca. 30 sec); the coverage of a feature (e.g. bottom sediment, algae or animal colonies) is estimated for each subsample and then calculated as a mean for the entire sample. Such division of a sample into 3 sub-samples helps to level the possible errors of visual analysis.

To evaluate the robustness of the approach we tested it on a group of Biology/Ecology Master students who had no previous experience in underwater video analysis. The paper examines the level of uncertainty while estimating the coverage of various features by different operators and discusses the ways to minimize the subjectiveness.

Ecological Gymnastics – Combining a top-down and bottom-up approach to Biotope Modelling

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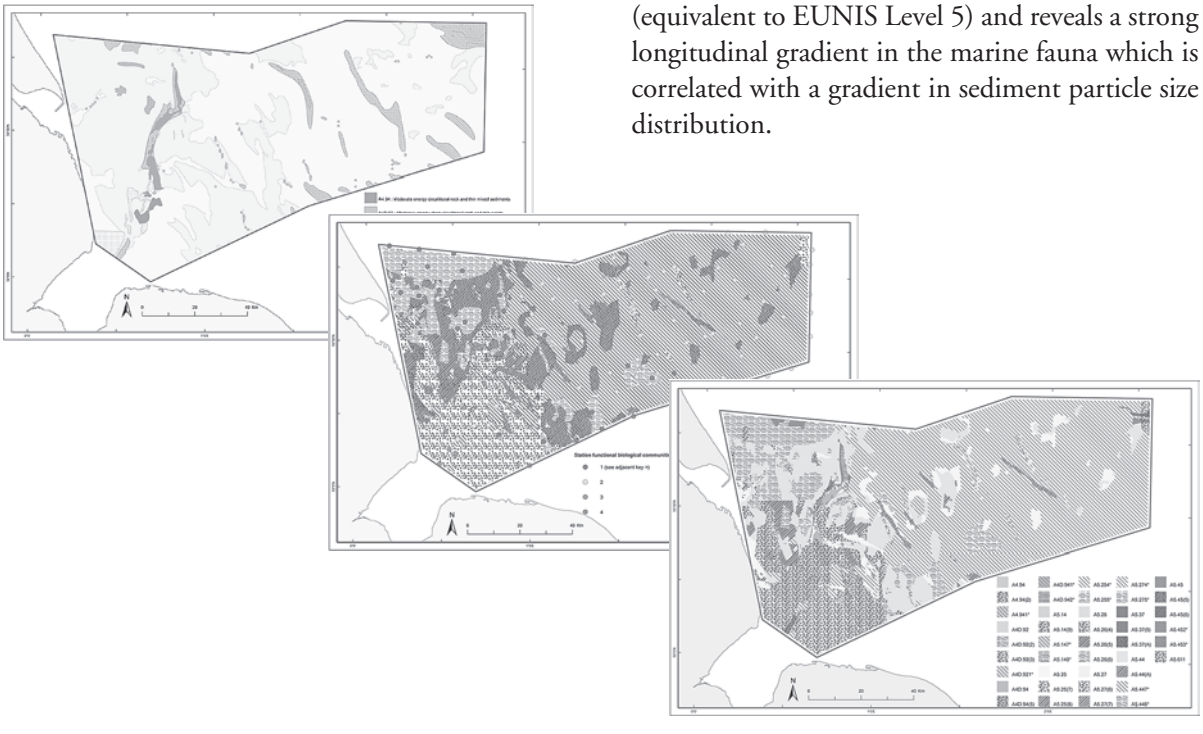
A Regional Environmental Characterisation (REC) survey of the Outer Humber region was commissioned by the British Government in 2008, through the Marine Environmental Protection Fund (MEPF). The primary objective of this survey was to produce a broad scale characterisation of seabed habitats, to facilitate the development of an ecologically coherent network of Marine Protected Areas (MPAs) and provide a broader spatial context to development specific Environmental Impact Assessments (EIAs). It is anticipated that this broad-scale characterisation will also be used in future marine planning.

Previous biotope mapping efforts on this scale have utilised either a top-down approach to biotope modelling, adhering strictly to the hierarchical classification scheme proposed by EUNIS or have employed a bottom-up approach whereby modelling is driven by the recorded distribution of biological communities. Here we present an alternative whereby the advantages of both methods are combined to produce an accurate and comprehensive biotope model. The combined biotope model was constructed using some of the most up-to-date environmental data and animal-sediment relationships derived from statistical analyses and expert judgement. The model predicted a total of 26 biotopes (equivalent to EUNIS Level 5) and reveals a strong longitudinal gradient in the marine fauna which is correlated with a gradient in sediment particle size distribution.



Better Benthic Monitoring through Machines: Robotics and machine learning supporting repeatable surveys and analysis

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Australia's Integrated Marine Observing System (IMOS) has a strategic focus on the impact of major boundary currents on continental shelf environments, ecosystems and biodiversity. To support an improved understanding of natural, climate change, and human-induced variability in shelf environments, the IMOS Autonomous Underwater Vehicle (AUV) facility has been charged with generating physical and biological observations of benthic variables that cannot be cost-effectively obtained by other means. Starting in 2010, the IMOS AUV facility began collecting precisely navigated benthic imagery using AUVs at selected reference sites on Australia's shelf. This observing program capitalizes on the unique capabilities of AUVs that will allow repeated visits to the reference sites, providing a critical observational link between oceanographic and benthic processes. In 2010 benthic reference sites were established in Western Australia, Tasmania, SE Queensland and New South Wales (NSW), in collaboration with groups from the University of Tasmania, the University of Western Australia, the University of NSW, CSIRO, AIMS, the Tasmanian Aquaculture and Fisheries Institute, the Sydney Institute for Marine Science and the NSW Department of Climate Change and Water.

This presentation covers the relevant capabilities of the AUV facility, the design of the IMOS benthic sampling program, and preliminary results from the 2010 surveys around Australia that established a baseline for future surveys. We also report on some of the challenges and potential benefits to be realized from a benthic observation system that collects several TB of geo-referenced stereo imagery a year. This includes semi-automated image analysis and classification, visualization and data mining, change detection and characterisation, and coordinating and enabling collaborative analysis for marine scientists across the country.

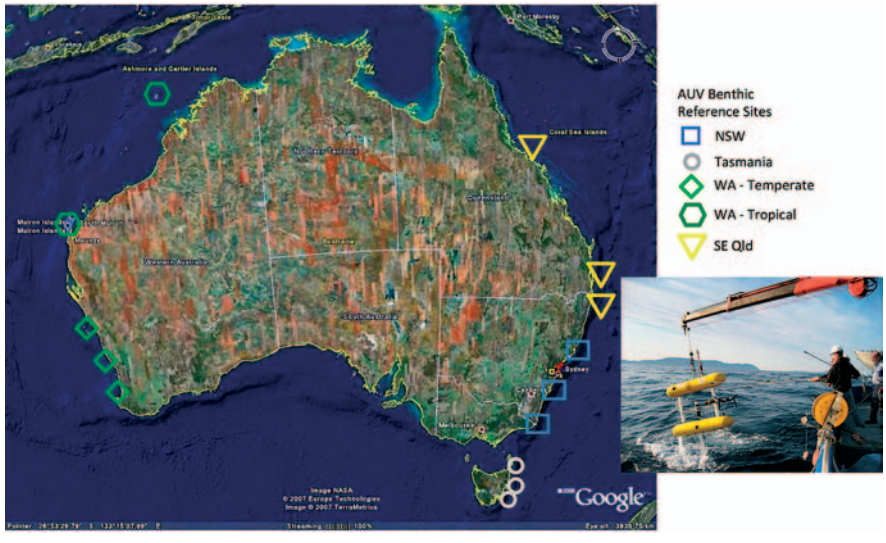

Figure 1. Proposed AUV Benthic reference sites. Most have been visited by the end of 2010. Inset: AUV recovery in Tasmania.

MeshAtlantic: Mapping Atlantic Area seabed habitats for the better marine management

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Member States and the European Commission are alike dramatically lacking information about the marine environment to properly design their policies and apply their legislation, namely the Habitat Directive and the Marine Strategy Framework Directive. The MeshAtlantic project is aimed at promoting the production and use of harmonised seabed habitat maps covering the Atlantic Area (AA). In order to reach this goal, the project will adapt and enhance previous achievements from projects MESH and EUSEAMAP and bring the AA onto equal footing with other European regions. The key outputs of the project will be three different sets of maps harmonized across the area through the EUNIS habitat classification. These maps are primarily (i) those which already exist, but need enhancement and harmonization, (ii) detailed bespoke maps covering a limited set of Natura 2000 sites – including some transnational ones – as well as (iii) a broad-scale modelled map resulting from the collation of readily available data layers. By collating and processing this knowledge, MeshAtlantic intends to serve the community at large and contribute towards Marine Spatial Planning and Ecosystem-Based Management. Based on a multifaceted communication plan, that includes making the outputs freely accessible online through an interactive webGIS portal, the project will collaborate with and serve a community of marine environment users (managers, fishermen, NGOs) working towards a sustainable use of the marine space and its resources.

Integrating time-series hydroacoustics and video observations for detecting changes in benthic habitats

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The ability to quantify change in marine benthic habitats must be considered a key goal of marine habitat mapping activities. Changes in distribution of distinct suites of benthic biological species may occur as a result of natural or human induced processes and these processes may operate at a range of temporal and spatial scales. It is important to understand natural small scale inter-annual patterns of change in order to separate these signals from potential patterns of longer term change. Work to describe these processes of change from an acoustic remote sensing stand point has thus far been limited due to the relatively recent availability of full coverage swath acoustic datasets and cost pressures associated with multiple surveys of the same area. This paper describes the use of landscape transition analysis as a means to differentiate seemingly random patterns of habitat change from systematic signals of habitat transition at a shallow (10–50 m depth) 18 km^2 study area on the temperate Australian continental shelf between the years 2006 and 2007. Supervised classifications for each year were accomplished using independently collected high resolution (3 m cell-size) multibeam echosounder (MBES) and video-derived reference data. Of the 4 representative biotic classes considered, signals of directional systematic changes were observed to occur between a shallow kelp dominated class, a deep sessile invertebrate dominated class and a mixed class of kelp and sessile invertebrates. These signals of change are interpreted as inter-annual variation in the density and depth related extent of canopy forming kelp species at the site, a phenomenon reported in smaller scale temporal studies of the same species. The methods applied in this study provide a detailed analysis of the various components of the traditional change detection cross tabulation matrix allowing identification of the strongest signals of systematic habitat transitions across broad geographical regions. Identifying clear patterns of habitat change is an important first step in linking these patterns to the processes that drive them.

Development and application of broad scale habitat maps in European waters

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EUSeaMap was a two-year EU project funded by DG-MARE as part of the preparatory actions for the European Marine Observation Data Network (EMODNET). One of the project aims is to produce a broad scale habitat maps for the Baltic, the Celtic and the North Seas as well as the western Mediterranean basin. The project utilised the accumulated experience from previous initiatives (e.g. INTERREG projects MESH, BALANCE) and enhanced that with new modelling techniques and improved input layers. The existing marine landscape maps of BALANCE and the habitat map of the MESH projects were improved and seamlessly merged and extended to other marine regions such as the Mediterranean.

Full coverage mapping and ground truthing is both time consuming and very costly, therefore using the available datasets with improved methodology and GIS technique for producing the broad-scale habitat maps is highly favourable. The produced digital map is available at www.jncc.gov.uk/EUSea Map to stakeholders to download and the data will be available for the public.

Examples of the potential use of EUSeaMap broad-scale habitat maps for the Baltic, North and the west Mediterranean Seas are presented. These examples will demonstrate how these maps can be applied to support an ecosystem-based approach to management of human activities within the European Seas. Special focus is placed on how these maps can be used to support the implementation of the Marine Strategy Framework Directive (MSFD), maritime spatial planning and to describe the representativeness of the Marine Protected Area networks in the Mediterranean.

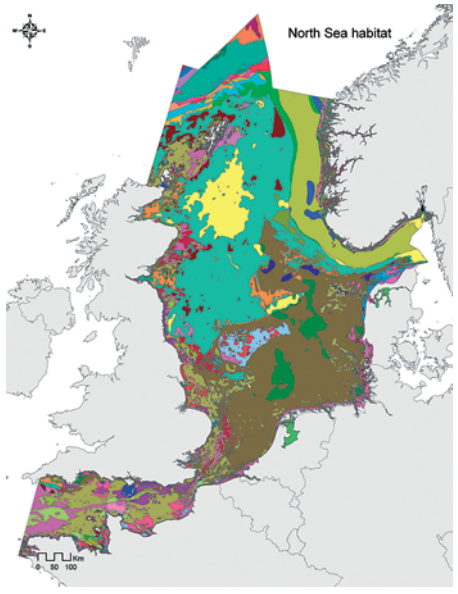

Figure 1. North Sea habitat map.

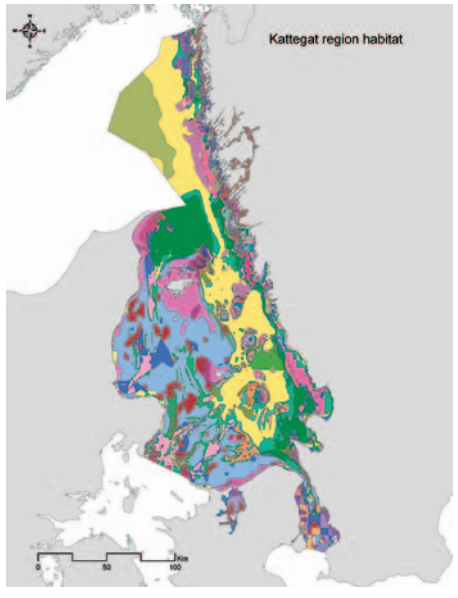

Figure 2. Baltic Sea habitat map, without the Kattegat.

Modelling and Mapping Seabed Biotopes in the Southern Irish Sea

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Seabed habitat maps have a variety of uses in marine management and conservation. However, to date, fully ground truthed seabed mapping surveys have only been carried out in a limited number of areas, due in part to the expense of running these types of surveys. In order to address the information gaps in the short term the HABMAP (HABitat MAPping for conservation and management of the southern Irish Sea) project was set up to develop a predictive modelling tool that would enable the distribution of benthic biotopes to be mapped in areas of the southern Irish Sea where survey data is absent. The project was initially part funded through the INTERREG IIIa programme and was a collaborative venture between organisations in both Wales and Ireland.

The project collated physical and biological datasets in a GIS, and used these to develop a model to predict biological community type. Maps were produced for individual biotopes, and a confidence assessment method was developed to highlight areas where predicted distributions were likely to be more or less accurate. The biotope maps were then combined in to a single layer within a GIS – this covered the full extent of the study area. Any overlapping biotope distributions were ranked according to their confidence values, so that the most likely biotope to be found in each area was shown visually on the final map. Survey data (multibeam echosounder bathymetry plus ground-truthing) was collected as part of the HABMAP project to help validate the modelled outputs.

First results of marine habitat mapping of the Russian part of the Baltic Sea

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In the past, geological and geomorphic study and mapping, as well as biological research, were undertaken both in the south-eastern Baltic and the eastern Gulf of Finland. However, these data were never compared with benthic biological data. The first attempt of joint analysis of geological and biological diversity was recently made by ABIO RAS, VSEGEI and ZIN RAS.

The Russian sector of the south-eastern Baltic Sea includes 11,633 km^2 within part of the Gdansk Basin and adjacent shallow-water areas and lagoons. The area represents a diversity of geomorphic features from the relatively deep plain of the Gdansk Deep (80–110 m depth) and its gentle slope to a shallow-water erosion plateau and coastal lagoon plains. Smaller geomorphic features such as banks, sand ridges, sand waves, valleys, etc., are found in the study area. The bottom sediment varies from silty-clayey mud within the Gdansk Deep to coarse-grained sediment in adjacent shallow-water coastal areas. Two broad groups of benthic habitats are soft-sediment bottoms (89 % of surface area) and hard substrate (11 %). Benthic faunal assemblages on hard substrata vary in terms of species diversity and abundance, but are dominated by sessile suspension-feeders (blue mussels, barnacles, hydroids, bryozoans), whereas soft bottom assemblages are dominated by selective and non-selective deposit-feeders (bivalves, polychaetes). Biodiversity and biomass reach maximum values on hard substrates located between 10–25 m water depth; benthos have been absent from depths >83 m in recent years due to oxygen depletion.

In the eastern Gulf of Finland the first attempt at marine habitat mapping was done for two shallow water areas – part of the northern near-shore zone of Kurortny District and an area within Vyborg Bay. These areas differ very much in geological and sedimentological features and benthic organisms distribution. The near-shore zone of Kurortny District is characterized by freshwater to oligohaline conditions with short-term salinity increases following upwellings and inflows; the depth where wave action impacts bottom sediments extends down to 4–5 m depth. Different marine habitat areas were found within very shallow near-shore areas. Dense vegetation of green filamentous algae *Cladophora glomerata* occurs on the surface of the near-shore submarine terrace (zebra mussel and colonial hydroid polype *Cordylophora* and *Cladophora glomerata*), terrace slope and submarine accumulation plain (where macrozoobenthos is represented by *Chironomidae* and *Oligochaeta*). The area of Vyborg Bay is characterized by variable and mosaic distribution of bottom relief forms and surface sediment types. These factors together form a pattern of living benthic assemblages. The study was funded by RFBR grant 11-05-01093-0a.

Nordic Network for Marine Inventories and Modeling

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Marine inventories and habitat mapping of sea areas have taken place in the Baltic Sea and along the Norwegian coast during the past 10 years. In each country, this work has been done differently, largely depending on existing background data and national research traditions. The studied marine environments vary largely, shifting from fully marine deep waters outside Norway to a variety of brackish-water environments in the Baltic Sea, including exposed and homogenous coastlines and scattered sheltered archipelago areas. Therefore different methodologies and approaches are required. So far co-operation between the countries has taken place in a variety of projects, e.g. the successful BALANCE-project ("Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning" 2005–2007). However, there is a continuous need for discussions and harmonizing, to create habitat maps that can efficiently be used in a regional management framework, e.g. within HELCOM or OSPAR.

Within our Nordic network we bring together Nordic (Finnish, Swedish, Norwegian and Danish), Estonian and Lithuanian expertise to discuss progress and eventual drawbacks in marine inventory work and spatial modeling. The aim is to learn together by arranging work shops, PhD-courses, student exchange between laboratories and by distributing information electronically.

Our Nordic Network for Marine Inventories and Modeling (http://nordforskmimo.webs.com/) is funded for three years (Sept 2009- Sept 2012) by NordForsk.

Rhodolith facies distribution on the Pontine Islands Shelf

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The rhodolith distribution along the continental shelf of the Pontine Islands (Tyrrhenian Sea, Italy) was investigated by Side Scan Sonar data interpretation (460 km^2), ROV images observation (68 ROV films) and analysis of algal samples (49 grabs). This study provides an estimate of abundance and distribution of the different rhodolith growth forms and identifies the most abundant rhodolith-forming coralline species. More than 800 living rhodoliths were collected at 49 stations (on a total of 235 stations) located in a bathymetric range of 40–110 m.

The most abundant morphological groups were prâlines (50 % of the specimens) and unattached branches (41 % of the specimens); "boxwork" rhodoliths were only 9 % of the specimens. In the study area prâlines and unattached branches were registered in shallower water (40–80 m of depth) than "boxwork" rhodoliths (abundant from 80 to 110 m of depth); this bathymetric distribution is related to the different hydrodynamic conditions necessary for the development of such morphological groups. Prâlines generally had a columnar structure (55 % of the prâlines), even if laminar (20 % of the prâlines) and fruticose (25 % of the prâlines) structures were also present. The bathymetric distribution of these different structures is also related to hydrodynamic conditions as follows: columnar and laminar prâlines are abundant from 40 to 70 m depth, whereas branched structures prevail from 70 to 80 m depth. The major components of the coralline algal association are: *Lithothamnion minervae* Basso, *Lithothamnion valens* Foslie, *Spongites fruticulosus* Kützing, *Lithophyllum racemus* (Lamarck) Foslie, *Lithophyllum incrustans* (Philippi) and *Phymatolithon calcareum* (Pallas) W.H. Adey et D.L. McKibbin. The comparison between Side Scan Sonar data (covering the shelf area) and rhodoliths distribution highlights that rhodoliths are mostly related to the high backscatter sonar facies, and are associated to sediments mainly made up of coarse skeletal grains. As confirmed by ROV images, such areas with abundant rhodoliths are mainly distributed in the saddle connecting Ponza and Palmarola and in NW Palmarola, whilst they lack in the Eastern side of Palmarola and Ponza Islands. In some cases (saddle between Palmarola and Ponza, E Palmarola, S part of the saddle between Ponza and Zannone) rhodoliths are associated with coarse grained sediment patches corresponding to prevailing high backscatter areas.

Catching the moment: data collection, modeling and mapping of herring spawning grounds at the exposed Baltic Sea coast

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The spawning period of the Baltic herring *Clupea harengus membrans*, which is commercially important fish species in the Baltic Sea, is rather short and its beginning is barely predictable. Unfavorable conditions of the exposed Lithuanian coast with poor underwater visibility (often <1m) and small size of herring eggs (<2 mm) leave no opportunity to use any remote sensing technique for the detection of the spawning grounds. The only reliable method was SCUBA diving during spring (April-early May) in cold turbid Baltic waters and collecting data manually. The herring is known for variability in choosing spawning ground depending on local factors and conditions. Based to prior knowledge we hypothesized that in the Lithuanian coastal waters herring spawning grounds are associated with red alga *Furcellaria lumbricalis*. To test that underwater survey was performed during 2009–2010 seasons at 96 diving stations distributed along potential herring spawning grounds. Divers recorded herring eggs presence or absence, collected samples, described habitats and made video documentation. Multibeam and Side Scan sonars were used to obtain data on bathymetry and bottom sediments.

Collected data revealed that spawning takes place not only at stones covered by the *Furcellaria,* but also at another red alga *Polysiphonia* and even at bare stony substrate. Moreover, the presence of the *Furcellaria* does not guarantee presence of the spawning grounds. However, there are some indications that substrate type plays significant role in the eggs survivability during nursing period. The depth is an important factor and varies from 4 to 10 meters. Spawning grounds are extremely patchy (the occurrence of herring eggs changes several times in just a few hundred meters), but it seems that general pattern remains during different seasons. Apart from substrate and depth bottom morphological features could be one of the main factors determining selection of particular spawning grounds by herring.

Bayesian probability based Maximum Entropy model was used to predict potential spawning grounds due to great patchiness of spawning grounds and constrains in data collection *in situ*. The resulted probability map of herring spawning grounds distribution in Lithuanian coastal waters was in a good correlation with the *in situ* observations.

Multi-scale mapping of cold-water coral habitats on the Ionian margin (Mediterranean sea)

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The present work reports the main results obtained from acoustic investigations carried out at different spatial scales within the Mediterranean Santa Maria di Leuca (SML) Cold-Water Coral (CWC) province (south eastern Italy – northern Ionian Sea).

The SML coral area, over 800 km^2 in extension, is located along the Apulian continental slope between 400 and 1000 m water depth, and represents the largest occurrence of a live CWC community so far known in the Mediterranean sea. It has been investigated by national (i.e. APLABES) and European (i.e. EU-FP6 Hermes and EU-FP7 CoralFISH) projects, that collected acoustic data (over more than 1700 km^2 survey area) along with video observations (performed by work class ROVs) and sediment samples.

Three different scales of data sets are presented and discussed: (1) a small scale morphobathymetric map (1/1000000) that resolves the regional geomorphology of the Apulian plateau; (2) a detailed medium scale morphobathymetric map (1/40000) obtained from multibeam data acquisition and (3) large scale morphobathymetric and backscattering maps (1/1000) obtained at different representative sites, where video-data, microbathymetry (by ROV-based multibeam surveys) and/or high resolution side scan sonar mosaics have been collected. The small scale map (provided from the Gebco Digital Atlas) shows that the SML CWC province is located along the upper slope of the gently south-eastward dipping Apulian continental margin and that the large-scale morphology of the area is affected by a strong tectonic control. The multibeam data set was used to produce a medium scale morphobathymetric map (from DTM at 40 m grid size), in which several geomorphic processes are recognized (i.e.: broad slope erosion, sediment sliding, block tilting and collapse and downslope mass movements) superimposed on the regional large-scale morphology. Video investigation and sediment samples documented CWCs occurrences along a bathymetric gradient varying between 500 and 900 m depth (1) within a large mass-movements and mass-transport deposition area, where coral-mounds occur, (2) on sparse debris deposits diffused along the eroded western flank of a prominent ridge, where drift sedimentation also occurs, and (3) on firm and hard grounds outcropping at the top of narrow ridges and fault scarps that characterise the western sector of the mapped area. Two large scale maps well show the fine-scale morphology of coral mounds, revealing a number of features indicative of active benthic current and its interaction with coral distribution at these representative sites.

The role of geomorphology in determining the occurrence of CWC habitats on the northern Ionian margin is investigated.

Seabed Mapping in a Tropical Shelf: The Case Study of MacroHabitats in the Abrolhos Bank, Brazil

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The coastal and marine environments are composed of a mosaic of ecologically interconnected ecosystems that support a high diversity of habitats. Seabed habitat mapping is a very important tool that underlies the discussion and decision making for management of marine ecosystems.

The Abrolhos Bank is the most important coral formation in South Atlantic, recognized by UNESCO as World Natural Heritage and classified as a priority area for biodiversity conservation.

Produced with the use of geo-technologies and integration between methods and methodologies, a seabed habitat mapping was proposed and carried out along this important region. Between the years 2007 and 2010, more than 3000 km of side-scan sonar images (Edgetech 4100, 100–500 kHz) (Figure 01A) were collected, with the purpose of mapping the sea macrohabitats distributed along the continental shelf of the Abrolhos Bank. In order to correlate them with the information of the seabed (Figure 01B), a database was compiled using information from various data bank sources (National Oceanographic Data Bank of Brazil, Geological Survey of Brazil) and obtained through the use of Remotely Operated Vehicle (ROV, Seabotix LBV 150S). For integration and visualization of data, a Geographic Information System (GIS) was used.

A macrohabitats scheme was developed and classified according to morphological and textural characteristics of the seabed. Three major macrohabitats domains were recognized in the scale of the entire Abrolhos Bank (51,000 km ²). The most representative spatial scale domain was the group *Maerl* (48 %), represented by rhodolith beds and biogenic gravel. *Unconsolidated* sediments (sand and mud), was second with more representative area (35 %). The *Reef* domain has been classified by the morphological and texture changes of the seabed, increasing three-dimensionality and thus generating a more complex habitat. With 17 % of the mapped area, the *Reef* domain is no less important than the others because it is composed of complex ecosystems that support a high diversity of habitats, with an arrangement that has a dynamic role in the support of many associated biological communities. The mapping of marine macrohabitats (Figure 01C) allows an important discussion to improve conservation and management policies in Abrolhos. The results presented herein are the first attempt to understand and to recognise the distribution of different seabed types and habitats. So far, most studies over the area have been restricted to the portion of coastal and shallow waters (< 20 m), leaving an important gap in habitat mapping along offshore areas.

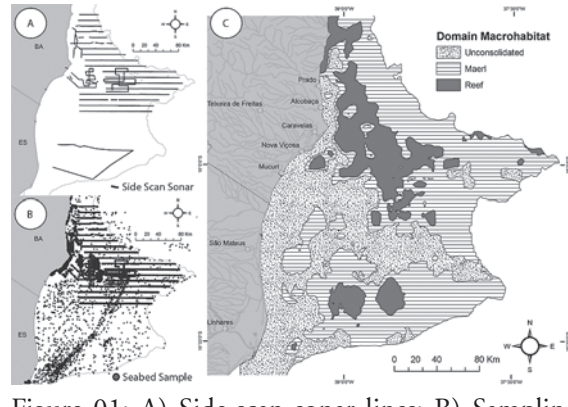

Figure 01: A) Side-scan sonar lines; B) Sampling spots; C) Mapping area.

Quantitative assessment of habitat services based on modelling of fish feeding grounds

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Benthic macrofauna is widely known as being one of the most important food sources for higher trophic levels in marine ecosystems. Large Baltic fish species such as cod or flounder feed on the wide spectra of benthic animals such as isopods *Saduria entomon*, bivalves *Macoma balthica, Mytilus edulis, Mya arenaria* and even relatively small polychaete worms and gammarids.

This study was aimed at the delineation of optimal feeding grounds for Baltic cod, flounder and burbot in Lithuanian economic zone (~ 7 000 km^2). The contents of 1425 fish digestive tracts were analysed to identify food sources of bentophagous fish species and to estimate occurrence and importance of food items in the diet. The distribution and biomass of macrofauna species (food items) were modelled using random forest regression modelling technique based on the statistical relationships between the species distribution and fundamental characteristics of benthic habitats (orbital velocity, bottom current velocity, near-bottom oxygen, salinity, sediments, thermocline and halocline areas etc.). Data on the distribution of benthic macrofauna species for model development were obtained from 640 benthic samples taken in 224 stations. After model calibration and validation the biomass prediction for each benthic species was performed in grid size of 100 x 100 m.

Overlay of GIS layers representing the biomass distribution of food item (weighted according to occurrence and importance in the diet) resulted in the distribution map of gross biomass of food items for selected fish species and then was used to delineate optimal fish feeding grounds. Additionally, the accuracy assessment of modeled distribution of food items was used to increase the confidence of overall assessment for decision making.

Mapping spatial natural heritage evidence: identifying opportunities for deployment of marine renewable energy technologies in Wales

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The Countryside Council for Wales (CCW) is the Government's statutory advisor on sustaining natural beauty, wildlife and the opportunity for outdoor enjoyment in Wales and its inshore waters.

CCW is committed to working strategically with regulators and developers to support the deployment of marine renewable energy devices in locations, and using technologies, that avoid significant adverse environmental impacts. To facilitate this, GIS-based evidence layers have been produced for natural heritage resources that are likely to be affected by marine renewables.

The marine renewable energy sector is at a very early stage of development and, to date, only a handful of pilot devices have been deployed in UK waters. There is therefore a great deal of uncertainty about their environmental effects, so the focus for CCW has been on providing evidence about resources that are most likely to be affected: diving birds, marine mammals, seabed habitats and Wales' seascapes.

Geographic information layers have been developed for these natural heritage resources, which CCW believes should be taken into account when planning or searching for suitable locations for the deployment of marine renewables. Some of the evidence layers provide information on the distribution and extent of key natural heritage resources and highlight the breadth of natural heritage interests that need to be taken into account in strategic planning processes. Other layers provide an assessment of the risks to, or vulnerability to the impacts of, key natural heritage resources from the development of the marine renewable energy sector in Wales. These 'interpreted layers' are important in facilitating an understanding for the risks that marine renewable device deployment may pose to natural heritage.

This mapping work is specifically designed to complement and support work within government that will guide the location of marine energy development to locations that maximise the use of the energy resource, whilst avoiding significant adverse environmental impacts. The information will help to ensure that the environmental risks of development are reduced and that the uncertainties faced by developers in obtaining consent for projects are minimised.

The Application of Predictive Species Modelling Using Multibeam Echosounder Data, Geological Interpretation, and Biological Video Observations to Map the Distribution of Vulnerable Marine Ecosystems

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The need for improved management of our marine environment is growing internationally, specifically the momentum to establish networks of marine protected areas (MPAs) for the conservation of threatened species and habitats. One of the criteria by which MPAs are selected includes the protection of habitats and species that have been identified as rare, sensitive, functionally important, and threatened and/or declining. The practical implementation of such networks requires an understanding of the distribution of these species and habitats with the main problem being the lack of detailed distribution data, e.g. maps. Predictive modelling provides a method by which continuous distribution maps can be produced from limited sample data.

The UK Deep-Sea MPA Project[1] uses Maxent predictive modelling to model the distribution of vulnerable marine ecosystems (VMEs) across Hatton Bank, George Bligh Bank, East Rockall Bank, Anton Dohrn Seamount and Rosemary Bank located to the west of the Scottish mainland; and Wyville–Thomson Ridge, and two areas within the Faroe–Shetland Channel located to the north of the Scottish mainland. The model was constructed using multibeam bathymetry data, interpreted sea-bed sediment and sea-bed geomorphology[2], and derived layers of bathymetric position index, rugosity, slope and aspect. VME presence / absence records were obtained from video observations[3].

Sea-bed sediment and geomorphology layers were interpreted from a combination of multibeam bathymetry and its derived layers including its backscatter response. Unfortunately, the quality of the backscatter data was not sufficient to be used in an automated classification which may reflect sea-bed sediment variations across an area an objective way. The sea-bed sediment data were ground-truthed using existing British Geological Survey samples and the acquired photographic sample images.

Videos were reviewed and VMEs were mapped and linked to the navigational data from the USBL on the camera system, such that the location of each VME was recorded and then plotted in ArcGIS 9.3.

The model performed well with results showing that the sea-bed sediments and geomorphology layers are the most important variables in the model followed by BPI, slope, rugosity and depth. Probability maps for the distribution of VMEs were produced. These maps will contribute to the development of a network of MPAs for the UK deep-sea area.

[1] *Project joint between the University of Plymouth and British Geological Survey. Data were acquired during the Strategic Environmental Assessment Surveys carried out in 2005 and 2006, and during the Joint Nature Conservation Committee funded Special Area of Conservation Survey (Anton Dohrn Seamount and East Rockall Bank) in 2009. The SEA surveys were paid for by the UK Department of Trade and Industry (now the Department of Energy and Climate Change www.offshore-sea.org.uk) and Defra (Department of Environment, Food and Rural Affairs www.defra.gov.uk/).*

[2] *Interpretation carried out by the British Geological Survey as part of its ongoing regional mapping programme (MAREMAP).*

[3] *Interpretation and Maxent modelling carried out by University of Plymouth.*

Harmonised geological maps of the European seas – the EMODNET-Geology project

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The European Marine Strategy Framework Directive has been implemented in order to allow a more holistic and multidisciplinary approach to the management of Europe's seas and oceans. In support of this legislation the European Commission has initiated the European Marine Observation and Data Network (EMODNET) to assemble existing but fragmented and inaccessible marine data and to create interoperable, contiguous and publicly available information layers which encompass whole marine basins.

EMODNET is being created from a network of existing and developing European observation systems linked by a data management structure covering all European coastal waters, shelf seas and surrounding ocean basins. The marine departments of the European Geological Surveys form the partnership of the EMODNET-Geology project, part of a suite of EMODNET pilot studies that also cover marine chemistry, marine biology, marine habitats and hydrography. The project will share methodologies and technologies with One Geology and OneGeology-Europe (1G-E) in order to deliver the EMODNET integrated geological map products through both the One Geology/1G-E portals so providing geoscientific information for the seas around Europe to the One Geology system.

EMODNET-Geology will adopt those standards implemented in One Geology including the use of GeoSciML as well as other open web service technologies including OGC, WMS, WFS etc. EMODNET-Geology will have a distributed map service with each of the work packages delivering a specified layer which will include seafloor geology, seabed sediments, mineral resources and geological events such as submarine slides and earthquakes.

Further information about the EMODNET project can be found at: http://ec.europa.eu/maritimeaffairs/eu-marine-observation-data-network-mission_en.html.

How to identify biogenic reefs from statistics of backscatter

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MMT has during a long time worked with habitat identification using geophysical information and with further ground truthing for verifying the data. Backscatter, together with side scan sonar and bathymetry, is the main geophysical information sources for both identifying areas of interest for further ground truthing and interpret the extension of the habitat. The most common way of using backscatter data is to identify substrates with different hardness by displaying the mean signal strength. From the experience of habitat classification there has been a need for extracting more information from the data. Rugosity and variance were tested for two ground truthed areas where Sabellaria reefs and Modiolus reefs were found. FMGeocoder were used to investigate if information from the signal strength can be used not only to identify areas of different hardness but also if biogenic reefs can be identified with the variance value of the signal. The idea is that the variance must be larger the more complex the substrate is due to the scattering effect. Together with the mean value biogenic reefs can be identified with a higher confidence. Rugosity is also a way to identify the complexity of the substrate as is known. In FMGeocoder the rugosity can be calculated in two different ways both through ARA and through the statistics tool. The two different tools calculate in slightly different ways which also can be detected in the results from the Modiolus reef where the reef was detected using ARA but not when using the statistics tool. The Sabellara reef could not be detected using rugosity calculations but were clearly detected using variance calculations. The conclusion of this can be that different types of biogenic reefs need different type of calculations to be able to detect them in a more comprehensive way using backscatter data.

Predictive habitat modelling in support of management: the use of species distribution models for assessing marine protected area networks

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By 2010, an ecologically coherent network of well-managed marine protected areas was to be implemented in the North-East Atlantic and the Baltic Sea. The aim of the network is to maintain favourable conservation status of selected habitat types and species according to the European Union Habitats Directive. The Natura 2000 network in marine areas constituted the basis for this network and included, in the coastal areas of the Baltic Sea, several habitat types that are important spawning and feeding grounds for ecologically important fish species. Thus, by including functional fish habitats the network may, in addition to the rare species in the directive, support many of the common species that are central to the ecological functioning of the area.

Based on predictive distribution models of a coastal fish assemblage and associated habitats, we present a spatially explicit assessment of two important components of the ecological coherence of marine protected area networks; representativity and connectivity, in a 30 000 km^2 archipelago area. Representativity measures the proportion of each conservation feature that is protected whereas connectivity assesses the spatial configuration of the network.

In total, 3.5 % (11 km^2) of the assemblage habitat was protected and 48 % of the potentially connected habitats were included in the marine protected area network. Visually communicated using maps, the assessment explicitly identified geographical areas where the network should be improved to ensure ecological coherence. Assessments of ecological coherence are scale dependent and the presented approach is modifiable according to different management units or dispersal distances of the species and habitats under consideration.

Tools for visualising and communicating the results to stakeholders and policy makers in the process of working towards ecological coherence should be of broad interest as marine protected area networks are being implemented. These types of map-based assessments of the strengths and weaknesses of evolving marine protected area networks are also highly needed in adaptive management.

Spatial and Environmental Predictors of Species Richness in Tropical Seabed Ecosystems

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Species richness is a key biodiversity metric widely used to estimate biodiversity gain or loss and assist in conservation planning and management. Studies of marine systems typically focus on only one or a few taxonomic groups and the groups chosen often vary among studies. Consequently, it is not possible to understand the performance of predictors of species richness across taxonomic groups. Using a taxonomically comprehensive data set including 14 taxa of seabed fauna from 6 phyla on the Great Barrier Reef, Australia, we tested the performance of a suite of environmental and spatial predictors of species richness using boosted regression trees. We identified groups of taxa similarly related to predictor variables and ranked all variables based upon the number of taxa for which they are significant predictors. We then tested the predictive power of these variables and compared variable importance between taxonomic groups. Sediment composition was the most important predictor of species richness for all but one taxonomic group. Other predictors consistently important across taxonomic groups included bottom stress, depth and distance to coast. We show that the power of spatial and environmental variables to predict species richness patterns is high, explaining up to 61 % of the deviance for some taxa.

Deep-sea biotope diversity: an illustrated catalogue for the Azores (NE Atlantic)

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Portugal's marine jurisdiction around the Azores archipelago (NE Atlantic) presently totals almost 1 million km^2. In case the Portuguese continental shelf extension claim is accepted, this area is expected to grow to more than 2.8 million km^2.

Video archives at the University of the Azores and the Portuguese Task Group for Maritime Affairs (EMAM) were investigated to catalogue the deep-sea megafaunal assemblages occurring in this vast region. This poster condenses the diversity identified so far, their horizontal and vertical ranges, as well as geomorphological structures they are found upon. Over 26 distinct facies dominated by corals, sponges, bivalves, crinoids, sea-urchins or holothurians are presented that occur from 150 m to 3,500 m depth. Many of them typify biotopes of conservation importance such as coral gardens, scleractinian reefs, deep-sea sponge aggregations or hydrothermal vents but cases of sensitive assemblages that currently are not protected (e.g., xenophyophore aggregations) are also included, along with less exuberant, though more extensive facies such as bioturbated abyssal muds and sparse corals on barren rocks.

This inventory contributes to the development of the deep-sea sections of the EUNIS habitat classification system and identifying a representative suite of Mid-Atlantic Ridge biotopes in need of protection.

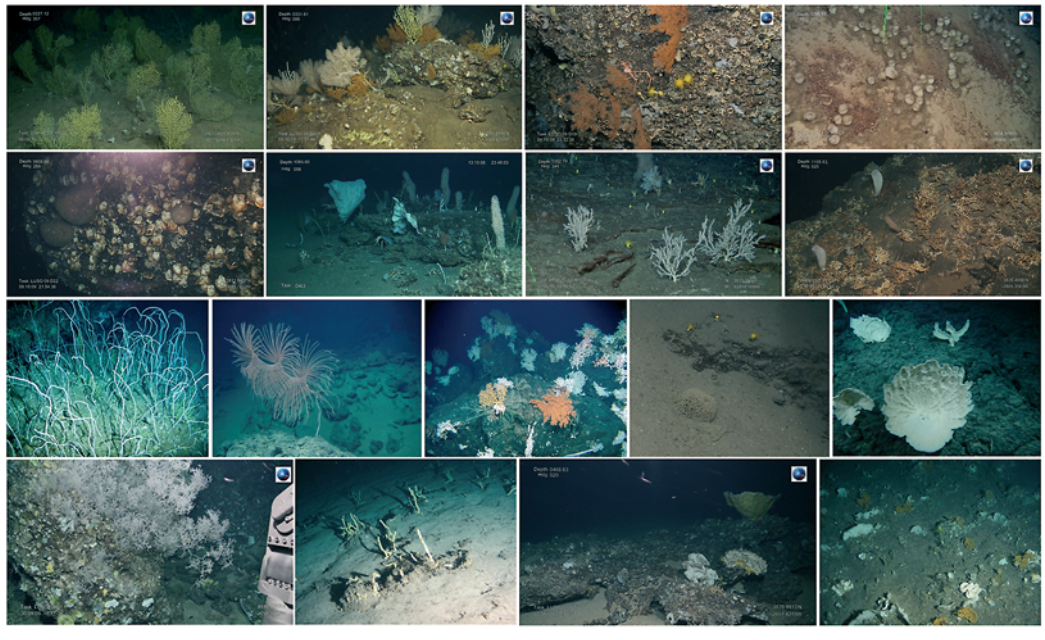

Figure1: Examples of deep-sea facies found in the Azores. (Image credits: EMAM; DOP/UAz; GreenPeace© Gavin Newman; SEAHMA)

Habitat mapping in extreme deep sea environment: geosphere–biosphere interaction in deep anoxic basins

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The recent exploration of the Mediterranean Ridge area has resulted in the discovery of some of the most extreme deep-sea environments, characterized by peculiar geochemical and physical condition. Tyro Basin was the first deep sea, hypersaline brine-filled, anoxic depression found. This and subsequent structures were named "hypersaline anoxic basins", having total dissolved salts as high as 500 g/L and sulphide content upto 20 mM/L.

The origin of these structures is morphologically connected to the compressive regime of the Mediterranean Ridge, due to the African plate subducting beneath Eurasia. The brine composition and physical characteristics are mainly due to the dissolution of underlying Messinian evaporites.

The brines are characterized by the absence of oxygen, the presence of high concentrations of H_2S and CH_4, and by an extremely sharp seawater/brine interface, thus with a strong density contrast. This interface is a hotspot for a large variety of mostly redox-controled strong bacterial activity.

In the last years, different projects have dealt with with the study of those basins. The work has focussed on the reconstruction of drastic composition changes of the water column, the evaluation of the anoxia trends and of the chemical elements concentration, and more recently, thanks to the technical innovations on seafloor mapping, to a progressively more accurate characterization of the shape and structure of the seabed.

In the last three years, the Milan–Bicocca University has been responsible for geophysical data acquisition and analysis in the EU Moccha Project (Multidisciplinary study of continental/ocean climate dynamics using high-resolution records from the eastern Mediterranean), whose cruises (Doppio 2008, Macchiato 2009, Ristretto&Lungo 2010–11) allowed the collection of information (Multibeam Echosounder Simrad EM302) on several target areas at the Mediterranean Ridge. The processing and elaboration of the geophysical data allowed a highly detailed and extended morpho-bathymetric characterization of Urania, Atalante, Discovery, Bannock, Medee, Kryos, and Thetis anoxic basins.

The coupling of new geophysical information with the biotechnological results of EU BIODEEP Project (Biotechnologies from the Deep: EU Community 2001–2004), also coordinated by Milan–Bicocca University, will be presented in this work as a first approach to a "Habitat Mapping" definition on the extreme anoxic basin environment, suggesting a methodology for subsequent studies on the same area.

Mapping cold seep habitats using AUV mounted acoustic and optical devices

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Cold seeps with associated carbonate crusts are uncommon, but potentially important habitats with special faunas. These habitats have received little attention in Norwegian waters, because of their scarcity and the challenges involved in studying them. New technologies involving acoustic and optical devices mounted on AUV's, together with the ability of multibeam echosounders to collect and process water column data have opened new possibilities.

The study area is in the glacial depression Hola, located 15 km off the coast of Vesterålen, North Norway, at c. 200 m water depth. This depression is famous for its coral reefs, exceeding a number of 200. In 2007, a gas plume was detected using a single beam echosounder, and a slab of carbonate crust was observed on video. The sediments are dominated by sand, with coarser areas of gravel to boulders.

For the study, we used the multibeam echosounder EM710 (bathymetry and water column data), the HUGIN 1000 AUV and a small ROV. The HUGIN 1000 was equipped with a 400 Khz sidescan sonar, multibeam echosounder, a methane sniffer, salinity and temperature meters, and a high speed black&white camera. The ROV was equipped with video recording and still image equipment, and a grip arm for collecting samples.

With the EM710, we were able to prove that gas plumes are present in the area. Several short surveys indicate that the emissions of gas are periodical, and may be related to tide water cycles. The sidescan data from HUGIN allowed identification of several anomalous areas close to the locations where gas plumes were observed. The photos provided by HUGIN (one every second) gave us a continuous 7–10 m wide transect of the seabed, and showed several areas with irregular, up to 1 m wide dark slabs. The EM710 data demonstrated that these areas represent small, 1–2 m high mounds, up to 100 m in diameter. The carbonate crust retrieved with the ROV will be used for geochronologic profiling which hopefully will allow the assessment of venting rates over time.

Figure, left: Carbonate crust slabs on the seafloor, overgrown by sponges. Figure, right. The HUGIN AUV was used for collecting detailed sidescan sonar data and photos along sections.

MAREANO – an integrated programme for marine mapping in Norway

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The MAREANO programme maps bathymetry, sediment composition, habitats and biotopes, biodiversity, as well as pollution in the seabed in Norwegian coastal and offshore regions. The area encompasses continental shelf, slope and deep water zones and includes many extreme habitats including shelf-edge canyons and submarine slides. MAREANO is coordinated by the Institute of Marine Research, in collaboration with the Geological Survey of Norway and the Norwegian Hydrographic Service. MAREANO fills knowledge gaps related to seabed conditions and biodiversity defined in The Integrated Management Plan for the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands presented by the Government in 2006.

In 2010, MAREANO mapped 16 000 km^2 in terms of geology and biology, and 7 000 km^2 of multibeam bathymetry. The total budget was 60 millon Norwegian kroner, equivalent to 7.740 million Euros. The results from MAREANO were reported to the Government, as part of the Integrated Management Plan process. A popular scientific book (in Norwegian) was also presented.

Highlights in 2010 include mapping of the Røst Reef – presumably the world's largest known coral reef. This reef is situated on the shelf edge c. 100 km west of Lofoten, an area known for its beautiful mountains and rich fishing grounds. The reef complex is situated in a 4 000 year submarine slide complex. The large parts of the reef is well preserved, possibly because the very rugged submarine slide terrain has made it impossible to use bottom trawls in the area. This provides an interesting link between geological processes, biological features and human interaction.

For further information and results see the MAREANO website www.mareano.no.

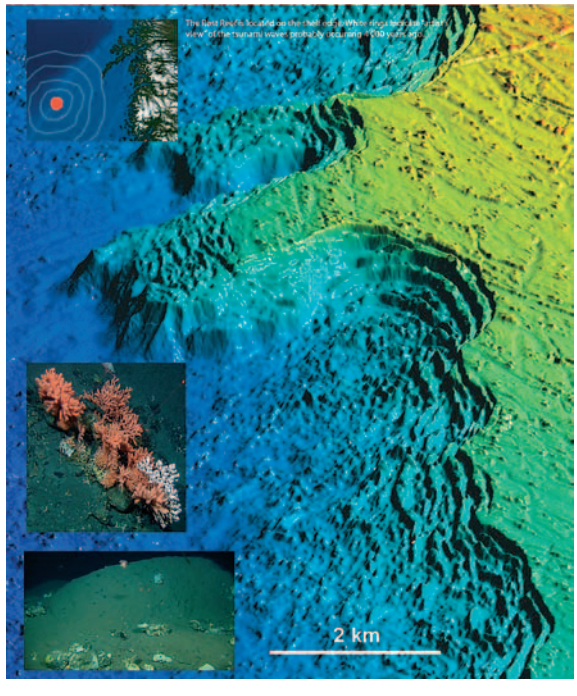

Figure: 3D model of the Røst Reef.

Multivariate statistical analysis of cold-water coral distributions in relation to seabed topography

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Paragorgia arborea (*P. arborea*) and *Primnoa resedaeformis* (*P. resedaeformis)* are the two most abundant and widely distributed large cold-water gorgonian corals in the North Atlantic Ocean. Both gorgonian assemblages can provide significant habitat for numerous invertebrate species. Both are slow growing and fragile species that are vulnerable to the damage of human activities, such as fishing and oil exploration. Direct benthic habitat mapping work is restricted to the remoteness. Therefore, understanding the environmental controls on distribution and further modeling the cold-water coral species distribution is important in assessing anthropogenic impacts and conservation management.

The topographic features may influence the cold-water coral distribution indirectly by governing the current regimes to concentrate the nutrient and larvae. However, the quantitative relationship between cold-water coral distribution and terrain features is far from well known. In this study, we focused on dense living gorgonians (*P. arborea* and *P. resedaeformis*) identified by video surveys from Jago dives of Polarstern ARK XXII/1a expedition (2007) at the three study sites on Norwegian Margin: Røst Reef, Sotbakken Reef and Traena Reef.

The seabed topography was quantitatively described by a suite of multiscale terrain parameters with ecological relevance. A series of statistical methods, including summary statistics, distribution statistics, ecological niche factor analysis and correlation analysis, were applied to investigate the quantitative relationship between coral (*P. arborea* and *P. resedaeformis*) distribution and topography at the three study sites. The distribution pattern of both species and global area on these terrain variables were statistically analyzed. The curvature (mean curvature, plan curvature and profile curvature) and BPI (bathymetry position index) at analysis scales 90 m and 170 m were found as key terrain variables and were strongly correlated at the three geographically distinctive study sites. Almost all of both species were found on topographic highs at Traena Reef and Sotbakken Reef. However, at Røst Reef, a lot of both species were observed in low-lying area at the analysis scales 30 m, 90 m and 170 m, which might emphasis the more importance of the rugged seabed topography at Røst Reef in influencing the nutrient concentration.

Developing maps from acoustic and groundtruth data that portray seabed features, substrates, and processes as a basis for habitat and biotope mapping

Page C. Valentine

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The seabed exhibits a suite of mappable attributes that include topography, substrate backscatter intensity, sediment texture and mobility, seabed features (bedforms, gravel pavements, boulder ridges, living structures), and water temperature, among others. Such physical information is used to define and map habitats, places where biological assemblages live. Following recent usage, a physical habitat and the biological elements that live there is called a biotope. Effective ecosystem management requires maps that show the distributions of habitats, biotopes, and individual species of interest. The level of habitat resolution that can be achieved depends on the quality and quantity of available physical data. Ideally, the approach to mapping biotopes is to first map habitats based on physical parameters and second, describe the species resident in each habitat. Practically, physical data are generally less time consuming to collect and analyze than biological data. Where biological data are not available, habitat mapping can still proceed and provide a basis for future biological collecting and biotope definition. Mapping geological substrates and seabed processes at high resolution (10s of meters) is key to understanding where species live and why they live there.

For the Stellwagen Bank region off Boston, MA, a suite of five seabed maps have been produced to show the aspects of the physical environment. These maps (1:25,000) are based on multibeam sonar data (bathymetry, backscatter intensity), video and still photo images, and sediment sampling and grain size analysis. They document a wide range of physical settings that include rippled mobile coarse-grained sand in shallow water (35–50 m), gravel pavements and boulder ridges, steep slopes of mixed sediment, and immobile muddy fine-grained sand in deep water (80–180 m). The maps show habitats in various combinations of topography, seabed ruggedness, boulder ridges, acoustic substrates, geologic substrates, dominant grain size distributions, and the geographic limits of sediment mobility (based on bedforms) and sediment deposition (based on mud content). A goal of habitat and biotope mapping is to provide information for use in predicting the distribution of species and assemblages in areas where habitats are mapped but biological data are sparse. In the map area, four Atlantic cod biotopes are defined by the association of cod with boulders in four mappable habitats, including: boulder ridges; boulders in mobile coarse-grained sand; boulders on pebble gravel pavement; and boulders on pebble gravel with a partial veneer of muddy sand.

Standardisation and Harmonisation in Seabed Habitat Mapping: How can a geological data infrastructure project contribute?

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Seabed habitat mapping is mostly based on the assumption that the ecological value of an area can be represented by its abiotic characteristics (substrate type, topography and energy regime). Within this realm geological and geophysical data are crucial, as are their derivatives. For end-users it is not always clear what data exists, and when compiling data from various sources, problems arise on how to harmonise the data. More standardised archiving of data is needed, as also more standardised approaches on how to deal with the data. Geo-Seas, a FP7 pan-European e-infrastructure for geological and geophysical data is addressing this need, both at the data level, as well as by the development of new data products and services. In this respect, Geo-Seas targeted 'Seabed Habitat Mapping' as a field where the standardisation and harmonisation of geological data can lead to better mapping products. Sediment and terrain characterisation is focussed on, respecting applications on a regional (>500 m), medium- (50 m) to fine-scale (<5 m).

In relation to the sediment characterisation, emphasis is put on improving sediment databases. Instead of working with derived parameters such as the median grain-size and/or silt-clay percentage, the full grain-size distribution curve data will be made available. As such parameters can be calculated on the fly; multiple users can derive the most relevant parameters for their use (e.g. resource evaluations or fisheries habitat mapping). Further, the better classification of gravel/boulders/rocks is aimed at. Recommendations will be provided on the use of multibeam backscatter data for sediment classification. Cross-fertilisation of Geo-Seas and the EMODNET-Geology and EUSeaMap (DG MARE) projects is foreseen.

Terrain characterisation has gained considerable importance in the mapping and modelling of habitats. However, calculation and classification of terrain variables is still subject of discussion. More standardised approaches will be proposed with recommendations on: (1) Identifying geomorphological structures with ecological significance, and suitable for use in habitat mapping in European waters; (2) Demonstrating how such structures can be identified using terrain characterization; (3) Investigating how different resolution of bathymetry data affects the terrain characterisation, with case studies demonstrating successful and unsuccessful classification at various scales (5 m, 50 m, 500 m); and (4) Providing recommendations for the resolution and formats of bathymetric data to be used for habitat mapping.

Soft substratum biodiversity hotspots in shallow waters, the role of sediment dynamics and anthropogenic influence?

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Mapping the extent of seabed habitats and their characterization becomes increasingly important within a European context. Within the European Marine Strategy Framework Directive anthropogenic impacts need weighing against the habitat types with the aim of maintaining the integrity of the seafloor. This is particularly challenging in the Belgian coastal zone, where anthropogenic influence is high and where mud to fine sands prevail. Disposal of dredged material is common practice and influences both suspended and bedload transport. The main disposal ground is situated at the edge of an ebb tidal delta. Disposal activities take place in a tidal channel, at the end of which hotspots of biodiversity occur. Beam trawling is intense in these areas.

Fine-scale mapping has been procured, using very high resolution multibeam echosounding (300 kHz; 1*1m). Full-coverage imagery was obtained, as also, along selected lines, repetitive measurements to study bedform dynamics, as also the stability of the biodiversity hotspots. Hull-mounted Acoustic Doppler Current Profiling (ADCP) revealed insights into the current structure during 13hrs tidal cycle. Ground-truthing comprised of sediment and biological sampling, point-based and along transects.

Multibeam imagery allowed direct visualization of the habitat of some macrobenthos species. At the end of the tidal channel, the dense aggregations of the tube worm *Owenia fusiformis* were inferred. Sediment dynamics are here intensified, confirmed by the presence of medium dunes, composed of fine sands. Outside of this influence zone, another hotspot of biodiversity was mapped: the dense fields of the razor blade *Ensis directus*, being the most important invasive species in Belgian waters. Higher up the slope of the ebb tidal delta, a fine patchy structure was revealed, likely corresponding with the dense aggregations of the tube worm *Lanice conchilega*. Both *O. fusiformis* and *L. conchilega* are considered important ecosystem engineers for Belgium. Biological zonation is further studied along the sampled transects. Analyses of these will likely provide valuable information on ecosystem functioning on a very local scale.

The repetitive surveys, in combination with ADCP measurements, revealed the importance of the tidal channel as transport pathway of sediment, larvae, and nutrients. Nutrient supply is likely enhanced, because of the vicinity of the disposal ground. However, the interplay with the dynamics of the ebb tidal delta is yet unclear. Satellite imagery, with a high spatial and temporal resolution, is targeted for this purpose, as also sediment transport modelling. It is aimed at demonstrating the role of sediment processes in the dynamics of benthic communities; hence the latter also being vulnerable to changing physical parameters.

Acknowledgements

Research is conducted within the Belgian Science Policy (Belspo) projects QUEST4D (*QUantification of Erosion and Sedimentation patterns to Trace natural versus anthropogenic sediment dynamics*; Belspo SD/NS/06B), and EnSIS (Ecosystem Sensitivity to Invasive Species; Belspo SD/NS/09A). Results are reported as case study for fine-scale habitat mapping within the EU-FP7 project Geo-Seas on Geological and Geophysical Data Infrastructure, Work package 'Seabed Habitat Mapping'.

A proposed biotope classification system for the Baltic Sea

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The Baltic Sea Action Plan (BSAP) proposes that an international biotope classification system should be developed for the Baltic Sea by the year 2011. Such a classification system is needed for marine spatial planning and for the reporting to the EC Directives, including the upcoming Marine Strategy. It is further needed for the identification of valuable and threatened biotopes in the Baltic Sea, presently addressed by the Project for Completing the HELCOM Red List of Species and Habitats/ Biotopes.

We have compiled existing habitat classification systems and evaluated how a Baltic biotope classification can build on these previous efforts. In parallel, we have analysed field data from the phytobenthic zone of Finland and Sweden in order to identify important habitats. Based on the outcome from the compilation of existing systems and analyses of field data, we propose which environmental factors that should be used for the upper levels of the classification, the criteria and classes for these factors and the hierarchical organization of the factors. Finally, lower-level biotopes defined by biology have been added from existing habitat classifications and from the analyses of Swedish and Finnish samples.

We present a draft version of a Baltic biotope classification based on the HELCOM Red list of biotopes (1998), and aim to update the classification to lower levels adding biological features. The ambition has been to create a classification that meets the needs of the Baltic region and reflect major features of the Baltic ecosystem. At the same time, the aim has been to enable smooth transfer of the Baltic units to the European habitat classification system EUNIS. The proposed biotope classification therefore represents a compromise classification between an independent Baltic classification and EUNIS, as both should be consistent in terms of structure.

The proposed biotope classification presented here is not fully covering the diversity of biotopes in the Baltic Sea. It provides the first step towards a full biotope classification system, but further work involving experts from all parts of the Baltic Sea are needed to complete the classification geographically and structurally.

Lidar – a remote sensing technique for improving the accuracy of spatial modelling in coastal areas.

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Lidar (light detection and ranging) has emerged as a potential tool for mapping macrovegetation and bottom substrates in shallow coastal areas. By sending out two laser pulses, one hitting the sea surface and one hitting the sea floor, the bottom depth can be calculated from the time interval between them. The technique collects highly accurate bathymetric data from 0.2 m depth down to 2 x secchi depth – a depth interval where detailed bathymetric information is often missing. In the Baltic Sea, many species of macroalgae and phanerogams have their main distribution within this depth interval, making lidar data a potentially important contributor when building spatial distribution models of these habitats.

Within two projects, ULTRA and EMMA, a lidar survey was conducted in the archipelago of Rönnskär, approximately 40 km west of Vaasa at the coast of Finland, in September 2009. One of the studies in this area compared the predictive accuracy of models based on bathymetric data from nautical charts with models based on bathymetric data from lidar. Models for nine different responses were built using data from 661 stations where the macro vegetation and bottom substrate had been estimated and classified with a drop video camera. 289 stations were left out from the model building step to allow an independent validation of the predictions derived from the models. Both model performance and their predictive ability (maps) were improved for 8 out of 9 responses when using lidar data instead of nautical chart data. The positioning of the lidar data is highly accurate, leading to requirements for biological data with similar positioning quality. Biological data with high positioning quality are hard to come by, making it difficult to examine the full potential of bathymetric lidar data for habitat mapping.

Recent Seafloor Habitat Mapping in Brazil includes Bathymetric LiDAR Reflectance Imagery

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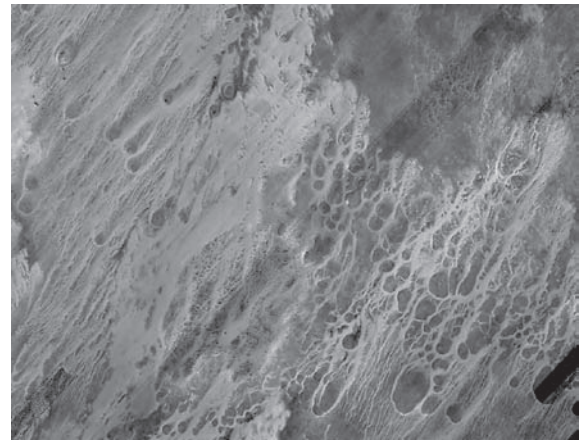
An agency of the Geological Survey of Brazil has been conducting a seafloor mapping program of regions of the Brazil coastline in recent years based of sampling, bathymetric and Side-Scan Sonar surveying.

The Companhia de Pesquisa de Recursos Minerais (CPRM) is a state-owned company that carries out the functions of the Geological Survey of Brazil, under the auspices of the Ministry of Mines and Energy. Its mission is to "produce and divulge the basic geological and hydrological knowledge required for sustainable development in Brazil."

CPRM has recently added airborne LiDAR bathymetry (ALB) to augment their program. This added information provides contiguous elevation data from the offshore depths, across the shoreline and along an onshore corridor of coastal topography. This provides a unified data set to fill in the near-shore gap between the inshore edge of vessel-based survey data and the shoreline.

In addition to the continuous coastal zone elevation data from ALB, the return from each laser beam is recorded as a wave form, which can be processed to yield an image of the underwater terrain. The example below is from the CPRM project.



Early results are now being processed and assessed. One objective is to design a ground truth data acquisition plan specifically to support interpretation of this newly added data source.

We will present the progress of the CPRM program in Brazil and preliminary examples and interpretations of the seafloor reflectance imagery.

Review of Geological Mapping in the Lithuanian Water Area

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The bottom topography and sedimentation of the Baltic Sea have been explored for more than a hundred years. During the last 30 years, local marine investigations have expanded to wide marine area and on the basis of the data collected, regional geological mapping at various scales has been initiated.

The first complex geological investigation in Lithuanian waters was accomplished in 1982–1989 during the national program of geological mapping of the Eastern Baltic Sea. Set of maps including geological, geomorphological, bottom sediments, geochemical, etc., at a scale of 1:200 000 were compiled.

In 1992, the Lithuanian Institute of Geology (GI) and Lithuanian Geological Survey (LGT) initiated a program of geological mapping in Lithuanian waters. In 1993–1996, geological and geophysical investigations and mapping of Lithuanian waters in the Klaipeda–Sventoji area were carried out. Geological and geomorphological maps (scale 1:50 000) were compiled. In 1997–1999, investigations were continued in the Klaipeda–Nida area, but due to lack of financial support were stopped in 2000 and realization of the entire program was cancelled.

The joint Lithuanian–Swedish project "Geobalt", aimed at geological mapping of the central part of the Baltic Sea, started in 1994. Regional bathymetric and bottom sediment maps of the Baltic Sea at a scale of 1:500 000 were published in 1998.

In 1999–2004, The LGT, in collaboration with Institute of Geology and Geography (GGI) and the Universities of Vilnius (VU) and Klaipeda (KU), compiled a digital geological atlas of the Lithuanian coast. The atlas contained geological, geomorphological and anthropogenic load maps of the coastal zone including shallow waters and shore at a scale of 1:5 000.

In addition to the regional geological mapping, many local geological, geophysical, geochemical, underwater and archaeological investigations in the south-eastern part of the Baltic Sea were accomplished. Papers in geology, sedimentology, paleogeography, etc., were published. However, researchers from different scientific fields have very limited geological information about the sea bottom of the Lithuanian Exclusive Economic Zone (EEZ). In the last decade, a number of hydroacoustic investigations in shallow part of Lithuanian waters were done (Fig. 1). The data obtained by these hydroacoustic investigations will be the basis for detailed geological and biological studies, marine spatial planning and geological mapping.

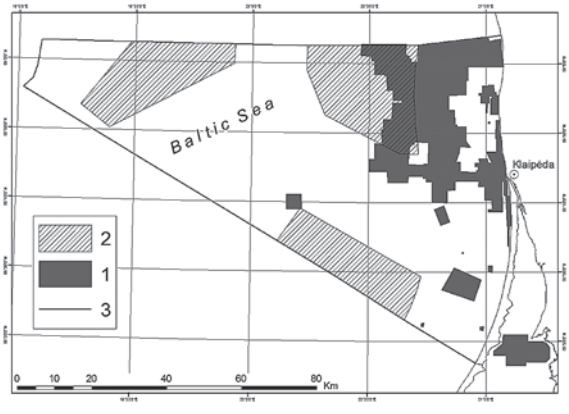

Figure 1. Map of hydroacoustic investigations in Lithuanian waters. 1 – investigated area, 2 – area of future investigation, 3 – boundary of the Lithuanian EEZ.

Ferromanganese concretions as microhabitats in the Gulf of Finland

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Large and dense (0.5-50 kg m^{-2}) Fe/Mn-concretion deposits cover about 10 % of the bottom surface of the Gulf of Finland. Concretions are from millimetres up to centimetres in size and their concentrations of Fe and Mn are high (27 % and 5 % DW respectively). Also other elements such as P, Ca, Si, Zn, Ni, Cu and As are found in high quantities. Due to their geochemical properties, concretions may have significant effect on the cycling of Fe, Mn and P in the Baltic Sea. Spherical concretions, formed from alternating Fe and Mn layers, are porous, fragile and their interior is often hollow. The physical and chemical characteristics indicate that concretions themselves may serve an excellent site for microbial life. To test this hypothesis, we investigated microbial diversity in concretions and tested if micro-organisms present in concretions are able to oxidize Mn and Fe. Microbial diversity was studied using epifluorescence microscopy and DNA-based methods such as cloning of community 16S rRNA-gene and sequencing. Mn-oxidation was studied in bottle incubation units and Fe-oxidation in gradient tubes where the availability of oxygen, Na-acetate as carbon source and temperature were controlled. Our results demonstrated that concretions host diverse bacterial community with an average density of 6.7 x 10^7 cells g^{-1} DW. The sequencing studies showed that one third of the cloned sequences were related to uncultured, unclassified bacteria and half of the cloned sequences were affiliated to Proteobacteria. The closest matches to the sequences found from the concretions of the Gulf of Finland were obtained from ocean crust, sediments and e.g. from Fe-oxidizing biofilms and contaminated sites. Microbes extracted from the concretions enhanced the oxidation of Mn and the experimental conditions favoured enrichment of bacteria such as *Sphingomonas*, *Pseudomonas* and *Bacillus*. Fe-oxidation experiment was carried out in vials with FeS and oxygen gradient. Bacterial growth and oxidized layer of Fe was observed only in those inoculates where concretion suspension was alive (Fig. 1). The phylogenetic affiliation of these likely Fe-oxidizing bacteria is yet to be resolved. Our studies have shown that an individual concretion forms a microcosm which is colonized by diverse and mostly unknown prokaryotes. In addition we have demonstrated that microbes hosted by concretions oxidize Mn and Fe which supports the view that the formation of concretions is biogenous.

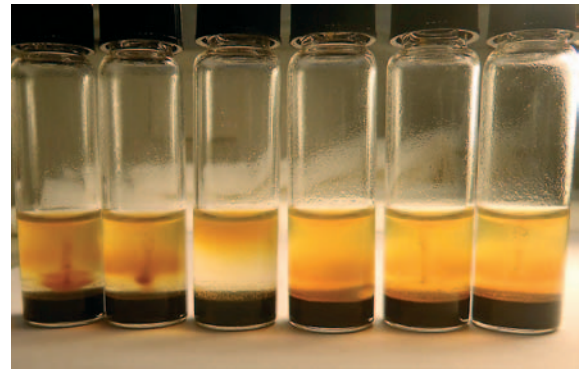

Figure 1. Bacteria from Fe/Mn concretions grow as layers in opposing gradients of FeS (black bottom plug) and oxygen with and without added Na-acetate (1 mM) respectively (tubes 1 & 2 from left). Tubes 3 & 4 are uninoculated controls with and without Na-acetate. Tubes 5 & 6 are killed inoculates with and without Na-acetate.

The Seabed Sediment Mapping Programme in the German Baltic Sea (1994–2011)

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On behalf of BSH the seabed sediments of the German Baltic Sea have been mapped by IOW from 1994 until 2010. The mapping is based on old and new grab samples that underwent granulometric analyses. The derived statistical parameters *median* and *sorting* were used for the classification of gravel, sand, silt and clay. Further sediment types comprise lag sediments, glacial clay, boulders and peat.

During the mapping programme the classification scheme and the interpolation methods were improved after gaining more practical experience over the years. Consequently, the complete dataset is being harmonized for the whole mapping area in 2011 and will be available via the GeoSeaPortal of BSH by the end of the year.

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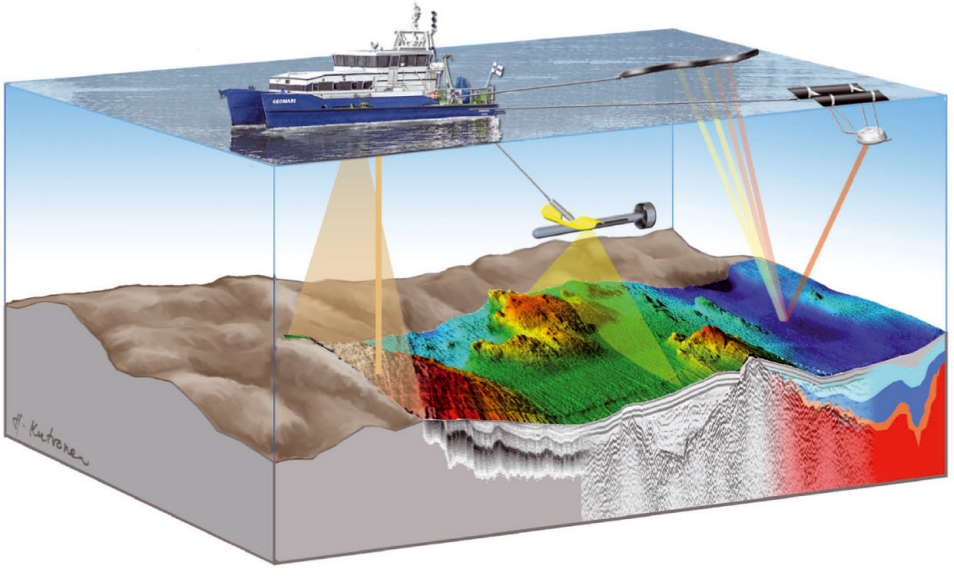
The Geological Survey of Finland (GTK) is an internationally oriented geoscience research and contract services agency. GTK produces and disseminates geological information for industry and society to promote the systematic and sustainable use of crustal resources and the national geological endowment. GTK serves as Finland's national geoscientific information centre and participates actively in international research and project work.

GTK plays a vital role in providing findings of applied and fundamental research, developing innovative ways to acquire and use geoinformation, and applying its geoscience expertise to industry needs and the wider community within the minerals, energy, land use and construction sectors. Research activities at GTK are currently coordinated through six programs. Marine Geology and Global Change is one of the research programs.

The main research methods include a wide variety of marine acoustics and seafloor sampling, as well as modern sedimentological and geochemical analysis and modeling. Marine geological mapping and research provide information that can be used e.g. in more effective marine spatial planning, planning seafloor constructions (e.g. pipelines, cables, harbors) and to detect environmental risks, as well as for preparing and adapting the impacts of global warming in the Baltic Sea area.



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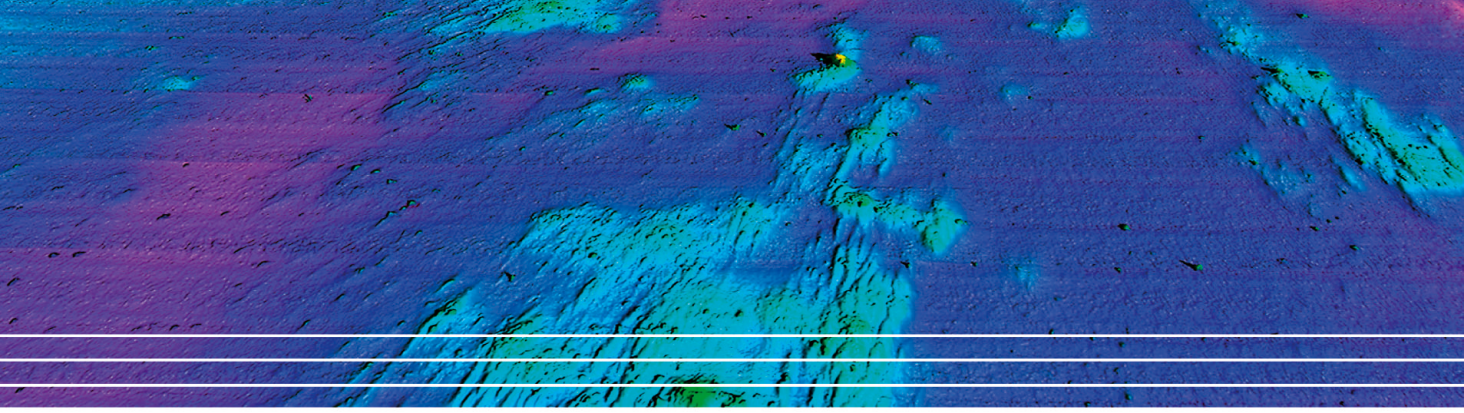

The GeoHab 2011 Conference

Marine Geological and Biological Habitat Mapping

3 - 6 May, 2011

Geological Survey of Finland, Espoo

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GEOHAB Marine Geological and Biological Habitat Mapping

Cover image: Image is based on multibeam echo-sounding data from the Kvarken Archipelago, the Baltic Sea. Image by Kimmo Alvi and Jyrki Hämäläinen, GTK.

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