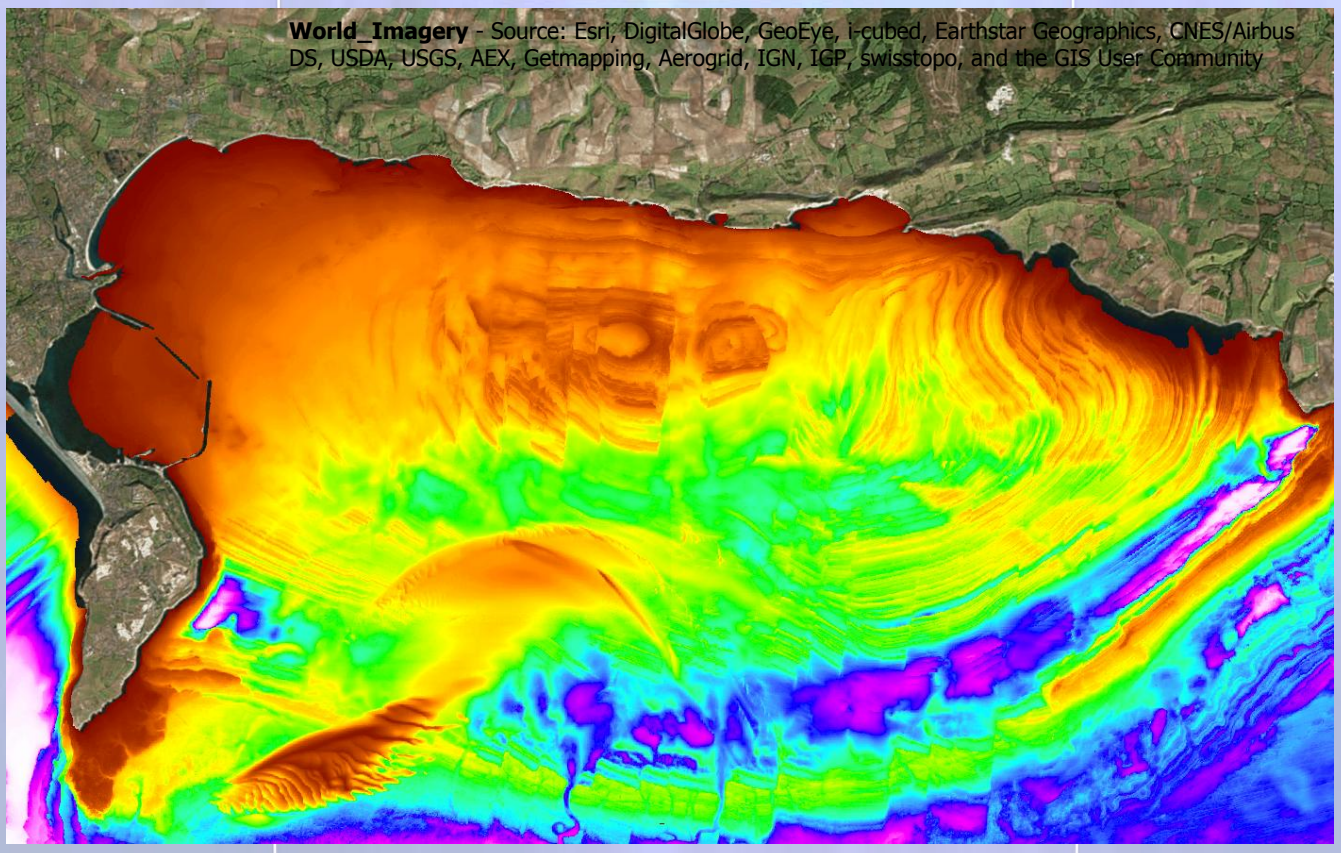
GEOHAB

Marine Geological and Biological Habitat Mapping

Marine Environment Mapping and Interpretation – from the Coast to the Deep Ocean.

Abstract Booklet



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2nd to 6th May 2016

WINCHESTER, UNITED KINGDOM

http://www.geohab2016.org

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Markus Diesing (Centre for Environment, Fisheries & Aquaculture Science, UK)
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Program

Monday 2nd May 2016

Workshop

08:30	Registration	
	Interpretation of Marine Environments using Object Based Image Analysis (OBIA)	
09:30	Introduction to the workshop	
09:40	Markus Diesing	Application of OBIA to marine datasets
10:00	Nils Erik Jørgensen	eCognition software
10:15	Tim Le Bas	RSOBIA toolbar
10:30	Tea and Coffee	
11:00	Simeon Archer	Mapping coral reef habitats in the British Virgin Islands
11:15	Evangelos Alevizos	Influence of threshold selection on classification results in rule-based seafloor sediment classification using OBIA
11:30	Nicole J. Baeten	Applying automated methods for sediment classification in regional scale seabed mapping programmes - a case study from MAREANO
11:45	Craig Brown	Developing Methods for Benthic Habitat Mapping of MPAs in Atlantic Canada: St Anns Bank MPA
12:00	Nils Erik Jørgensen	OBIA classification of colour and B/W images from the seabed
12:15	Anna Downie	Mapping extent and cover of seagrass from very high resolution optical data using OBIA and Random Forest
12:30	Lunch	
	Practical Demonstrations	
13:30	Markus Diesing and Nils Erik Jørgensen	eCognition workflow demonstration
16:00	Tea and Coffee	
16:30	Tim Le Bas	RSOBIA demonstration
	Panel Discussion	
17:00	Panel discussion and questions from audience	
17:45	Summary and wrap up	
18:00	Close	

Tuesday 3rd May 2016

Conference

08:00	Registration	
08:45	Opening Ceremony	
	Keynote	
09:00	Larry Mayer	Ruminations on the Future of Ocean Mapping
	Technological Advances in Habitat Mapping	
09:30	Jonathan Beaudoin	Setting the Stage for Multi-Spectral Acoustic Backscatter Research
09:45	Duncan Tamsett	The Acoustic Colour of the Seabed and Sub-Seabed
10:00	Terje Thorsnes	Synthetic aperture sonar and AUV - important tools for studies of cold seep habitats
10:15	Mark Borrelli	Creating Benthic Habitat Maps in a U.S. National Park Using a Phase-Measuring Sidescan Sonar
10:30	Tea and Coffee	
11:00	Francisco Gutierrez	Calibrated acoustic backscatter from a phase measuring bathymetric sonar
11:15	Dimitrios Eleftherakis	Multibeam backscatter calibration on reference patch areas using single-beam calibrated data
11:30	Eli Leblanc	Evaluation of a new multibeam backscatter processing algorithm in CARIS HIPS and SIPS
11:45	Aleksandra Kruss	Multibeam echosounder backscatter variability due to sediment resuspension and environmental dynamics in shallow waters
12:00	Lukasz Janowski	Application of the Object Based Image Analysis and Template Matching method for detecting, classifying and monitoring repeatable seabed objects, case study from the Lagoon of Venice.
12:15	Geoffroy Lamarche	High swath-overlap seafloor and water column backscatter survey over the Calypso hydrothermal vents, Bay of Plenty, New Zealand
12:30	Lunch	
13:30	Jin Li	Predicting sponge species richness: a novel approach using random forest, generalised linear model and their hybrid methods with geostatistical techniques
13:45	Massimo Di Stefano	Exploring the use of accurately georeferenced stereo image mosaics to ground-truth acoustic seafloor characterization models
14:00	Oscar Pizarro	Predictive habitat mapping and iterative planning of image surveys given existing bathymetry and imagery - a machine learning perspective
14:15	Lars Martin Sandvik Aas	Underwater hyperspectral imaging assessment of drill cuttings coverage on benthic habitats using Spectral sediment analysis
14:30	Helena Strömberg	3d Visualization of Subsea Structures and Marine Habitats
	Coastal and Shallow Water Habitats	
14:45	Don Ventura	Passive and Active: Remote Survey Solutions for the Nearshore; an Integrated Approach
15:00	Ben Radford	Applications of spatial hierarchical sampling to optimism hydroacoustic based habitat mapping over large spatial extents of Kimberley, North West of Australia
15:15	Gay Amabelle Go	Mapping and Assessment of Mangroves in the Philippines using Landsat Imagery
15:30	Tobias Dolch	Complementary monitoring methods for large-area surveys of intertidal seagrass beds
15:45	Tea and Coffee	
	Poster Session	
16:15-18:00	Poster introductions, viewing and reception	

Wednesday 4th May 2016

08:00	Registration	
	Coastal and Shallow Water Habitats	
08:45	Stefano Fogarin	Benthic morphologies and habitats in a shallow highly human impacted tidal inlet
09:00	Fantina Madricardo	Benthic habitat mapping in a very shallow tidal channel
09:15	Francesco Mascioli	Geoforms and substrate characterization of a tidal inlet in the Wadden Sea (Lower Saxony, Germany)
09:30	Daria Ryabchuk	Detailed scale habitat mapping at the eastern Gulf of Finland, the Baltic Sea
09:45	Ben Misiuk	Mapping Clam Habitat in the Eastern Arctic: Species Distribution Modelling in Support of Fishery Assessment in Qikiqtarjuaq, Nunavut, Canada
10:00	Ana Castanheira	First Sabellaria spinulosa reefs habitat mapping in the Iberian Atlantic Coast
10:15	Patricia Eichler	Biodiversity patterns of benthic foraminifera associated to Geo-Habitas as first insights in delimiting Reefal Marine Parks
10:30	Tea and Coffee	
	Shelf and Deep-sea Habitats	
11:00	Alex Bastos	Mapping Rhodolith Beds Along the Eastern Brazilian Shelf
11:15	Peter Harris	Life on the edge: global variations in shelf break depth and its influence on benthos
11:30	Oliver Hogg	Landscape mapping at sub-Antarctic South Georgia provides a protocol for underpinning large-scale marine protected areas
11:45	Anu Kaskela	Seabed geodiversity and benthic assemblages at the eastern Gulf of Finland, the Baltic Sea
12:00	Jessica Tadhunter	Habitat mapping of bathyal benthic habitats in the northern Dreki area, Iceland
12:15	Brian Todd	The Skipjack Island Fault Zone: A Geohazard and Benthic Habitat-Forming Structure Separating the San Juan Islands, Washington State, USA from British Columbia, Canada
12:30	Lunch	
13:30	Veerle Huvenne	Mapping a submarine canyon in all its facets
13:45	Agno Assis	Benthic habitat for Primnoa deep-sea coral in the Fairweather Ground, Gulf of Alaska
14:00	Genoveva Gonzalez-Mirelis	Mapping the distribution of cold-water coral reefs using distribution modelling
14:15	Romina Barbosa	The effect of environmental data resolution in Habitat Suitability models: a case of study of Brazilian deep-water corals
14:30	Vaughn Barrie	Seeps and mud volcanoes âĂŞ oxygen depletion along the Northwest Pacific coast of North America and implications for habitat
14:45	H. Gary Greene	Are Seafloor Seeps, Mud Volcanoes, and Chemosynthetic Communities Significant Marine Benthic Habitats?
15:00	Heather Stewart	First direct evidence of a deep-water cold-seep ecosystem within UK waters
15:15	Andrea Fiorentino	Relationships between geological events and submarine habitats
15:30	Tea and Coffee	
	National Mapping Program Management and Data-sharing	
16:00	Drew Stephens	Ecological Marine Units Project Overview and Preliminary Results
16:15	Dayton Dove	Seabed Geomorphology: a new generation of mapping
16:30	Brendan Brooke	Seabed mapping to support management of the Australian marine environment
16:45	Andrew Colenutt	Applications of high resolution coastal data for monitoring coastal instability, hazard risk management and substrate mapping
17:00	Joey O'Connor	Recent monitoring surveys of shelf benthic habitats in offshore Marine Protected Areas (MPAs); survey designs and habitat mapping data availability
17:15	Graeme Duncan	Habitat map collation and data standardisation from a UK and European Perspective âĂŞ JNCC's work within the UK and with EMODnet
17:30	Kerstin Kröger	Using habitat maps to develop monitoring options for the deep-sea as part of the UK Marine Biodiversity Monitoring R&D Programme
17:45	Peter Walker	Making Natural EnglandâĂŹs marine evidence available to all.

Thursday 5th May 2016

	Anthropogenic and Natural Disturbance Effects on Marine Habitats	
08:45	Jens Greinert	Rapid mapping for environmental monitoring and resource assessments in the deep sea
09:00	Timm Schoening	Rapid assessment of manganese nodule abundance
09:15	Martina Pierdomenico	Physical disturbance along the Gioia Canyon (Southern Tyrrhenian Sea): sedimentary processes and human activities
09:30	Valéria Quaresma	Potential Mining waste impacts on coastal and shelf habitats: Mariana disaster - Brazil
09:45	Julian Burgos	Cold-water coral habitats on the southern Iceland shelf: mapping, prediction and anthropogenic impacts
10:00	Alexandra Davis	Regional analysis of the distribution of the invasive red lionfish (Pterois volitans) off the coast of Eleuthera, the Bahamas
10:15	Darius Daunys	Estimating benthic trawling effects using VMS dataset, macrofauna sampling, seabed acoustics and visual observations
10:30	Tea and Coffee	
11:00	Luke Hedge	Hidden heterogeneity: Novel, spatially explicit, habitat quality assessment to better inform the development of boating infrastr
11:15	David Haverson	Modelling the Impact of Tidal Energy on the Benthic Environment at Ramsey Sound, Pembrokeshire
	Role of Oceanography in Habitat Mapping	
11:30	Margaret Dolan	Improving benthic biotope maps with oceanographic data
11:45	Mary Young	Interaction between habitat and oceanographic variables affecting the connectivity and productivity of abalone populations
12:00	Lorenzo Angeletti	Habitat mapping discloses oceanographic patterns underneath
12:15	Nils Piechaud	Can global broad scale data from public repository be as accurate as field surveys data for species distribution modelling?
12:30	Lunch	
13:30	Marie-Claire Fabri	Predictive habitat modeling in Mediterranean Canyons including Hydrodynamic variables
	Development of Standards for Classification, Confidence and Assessment of Habitat Maps	
13:45	Vincent Lecours	Too Many Cooks Spoil the Broth: Assessing Which Combinations of Terrain Attributes Best Serve Habitat Mapping
14:00	Svenja Papenmeier	Habitat classification: approximation or reality?
14:15	Markus Diesing	Mapping of EUNIS seabed habitats based on ground-truth and multibeam acoustic data: What can realistically be achieved?
14:30	Peter Mitchell	Developing a tool for automated benthic habitat mapping and accuracy assessment using bootstrap aggregation
14:45	Murray Lark	Mapping seabed sediment texture classes from samples and acoustic bathymetry and backscatter: predictions and their uncertainty.
15:00	H. Christian Hass	Seafloor classification using RoxAnn: Two case studies to show the pros and cons
15:15	Jaime Davies	A cold-water coral biota classification scheme for ecosystem-based management of the deep sea
15:30	Tea and Coffee	
16:00	Khaira Ismail	Mapping of coral reefs for conservation assessment in Pulau Lang Tengah: comparison of object based image analysis and machine learning approaches
16:15	Gustav Kågesten	Automating Habitat Mapping in a complex world of corals and coastal waters
16:30	Conference End	
16:30-18:00	GeoHab Business Meeting	

Friday 5th May 2016

Fieldtrip

08:15-18:00	Coach to Stonehenge, Lulworth Cove, the New Forest and return

Contents

Workshop:
Interpretation of Marine Environments using Object Based Image Analysis (OBIA)

Mapping Coral Reef Habitats In The British Virgin Islands

Alex Callaway[1], *Simeon* ***Archer***[1], *and Koen Vanstaen*[1]

1. Centre for the Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, NR31 0HT, UK

The UK's overseas territories contain some of the most remote places on earth. Hydrographic data and the subsequent habitat maps created from that data are often largely based on 19th century observations. In 2014 the Centre for the Environment, Fisheries and Aquaculture Science (Cefas), the United Kingdom Hydrographic Office (UKHO) and the National Parks Trust of the Virgin Islands (NPT) undertook a project to accurately map the seabed surrounding the British Virgin Islands, part of the UKŠs overseas territories. The project was undertaken with the "collect once, use many times" principle with the data collected going on to serve many different stakeholders with a hydrographic, shipping, environmental, fisheries and disaster management interest.

Post-collection, Cefas was asked to produce a detailed map of the seabed habitats and map the extent of the coral reefs between the main island of Tortola and the Rhone Marine Park. Object-based image analysis (OBIA) of the multibeam echo sounder (MBES) bathymetry and backscatter data collected during the project was used to create a map of the habitats and reefs. Segmentation and classification were undertaken in Trimble's eCognition, a commercially available package designed for OBIA of remote sensing data. A training data set for the classification was created following the statistical analysis of the photographic data. Video and photographic stills were analysed recording species abundance, coral quality and substrate type. SIMPROF analysis of community composition in PRIMER V6 identified twelve statistically significant habitat classes. These classes were aligned to the habitat classes already in existence from the BVI Coastal Atlas to ensure the continued usage of legacy data. The habitat classes were used to inform the classification algorithm within eCognition and classify the remaining areas.

The resulting habitat map provided an increase in knowledge of both the presence and expanse of not only the reef habitats but of the extents of the previously unchartered seagrass beds in the Sir Francis Drake Channel. The quantification of marine resources for both conservation and sustainable exploitation assessments is particularly important for a small island economy which relies so heavily on safe access to the sea and tourism.

Influence Of Threshold Selection On Classification Results In Rule-Based Seafloor Sediment Classification Using OBIA

Evangelos ***Alevizos***[1], *Markus Diesing*[2], *Jens Greinert*[1]

1. GEOMAR Helmholtz Centre for Ocean Research, 24148 Kiel, Germany
2. Centre for Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK

Rule-based classification of multibeam acoustic data requires choices on suitable thresholds for predictors. Given a sufficient amount of ground-truth samples such choices can be informed by data exploration and statistical tests. The amount of samples that has been collected for a particular mapping task is, however, often limited by factors such as budget, time constraints and accessibility. Here we assess to what extent choices of thresholds in a rule-based classification translate into differences in the final classification and the related map outputs. We examine the effect of selecting between lower, center and upper values from the range that separates two adjacent classes for a given predictor.

We employed bathymetry, acoustic backscatter and derivatives thereof as explanatory variables collected in the former estuary of Grevelingen (Netherlands) where fine sediments (silt with admixtures of clay and sand) dominate. We apply an Object-Based Image Analysis (OBIA) approach which provides advantages over 'traditional' pixel-based approaches including several statistical properties (e.g.: mean, standard deviation, skewness, GLCMs) for each image object (group of pixels) and more unequivocal information as a result of computations from many pixels. In addition, by segmenting a raster image into objects, various effects of noise can be minimized. This is particularly useful when dealing with multibeam acoustic data which typically display artifacts to some degree. Another important characteristic of OBIA approach is that classification can be based on data exploration and developed rules applied in a consistent way. The lack of sufficient ground-truth data, however, may introduce difficulties in selecting a suitable threshold separating two classes which are close in the feature space. To overcome this problem we applied various thresholds from a given range of values of a predictor and then assessed the results both qualitatively and quantitatively.

The choice of an upper, central and lower value for each threshold leads to three different spatial representations of the splits between two classes. These three resulting maps can be summarized by displaying the majority class and the agreement between the three maps. The agreement expresses the consistency in classification for the different thresholds whereas the majority map expresses a classification based on the maximum agreement. Finally, we compare the majority map against the results of an unsupervised classification based on raw backscatter data. The choice of a threshold is a major constituent of any rule-based classification approach. By combining the results of different thresholds, we aim to better understand and visualize the ambiguity induced by limited ground-truth information.

Applying Automated Methods For Sediment Classification In Regional Scale Seabed Mapping Programmes - A Case Study From MAREANO

N.J. ***Baeten***[1], *T. Thorsnes*[1], *M. Dolan*[1], *L. Bjarnadottir*[1], *A. Jarna*[1], *V. Bellec*[1], *S. Elvenes*[1], *A. Lepland*[1], *T. van Son*[1], *R. Bøe*[1], *M. Diesing*[2], *T. Le Bas*[3], *R.M. Cooper*[4]

1. Geological Survey of Norway (NGU), Norway)
2. Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK
3. National Oceanography Centre (NOC), UK
4. British Geological Survey (BGS), UK

Sediment grain-size maps of the Norwegian continental margin, within the MAREANO programme have so far been produced using expert interpretation. The available data consist of acoustic data (multibeam bathymetry, backscatter and TOPAS) and ground-truth video data and sediment samples. The maps are created in ArcGIS.

This method is, however, relatively subjective, not repeatable and time consuming. To improve the mapping procedure within the MAREANO programme, a test project has been initiated to compare different (semi-) automated methods, to assess their benefits and challenges, and to find out which one(s) will qualify for future use. Both the quality of the end product map, and the time that was necessary to produce it will be used as criteria. Already published sediment maps and ground-truth data will be used for testing. The project is a joint effort between the national seabed mapping programmes MAREMAP (UK), INFOMAR (Ireland) and MAREANO (Norway).

Two testing areas were chosen with high-resolution bathymetry and backscatter data. The data were collected with the same multibeam system, and have as little artifacts as possible. Oceanography data were tested in addition to the available acoustic and ground-truth data. The automated methods used were; (i) object-based image analysis (OBIA; using eCognition), (ii) RSOBIA ArcGIS toolbar developed by T. Le Bas, and (iii) Using the standard functionality of ArcGIS to clean and classify the backscatter mosaic via a series of PHYTHON scripts.

We will evaluate to what extend the use of automated methods can minimize subjectivity and whether it will be less time consuming than producing maps with expert interpretation. We also discuss to which degree expert interpretation will still be necessary.

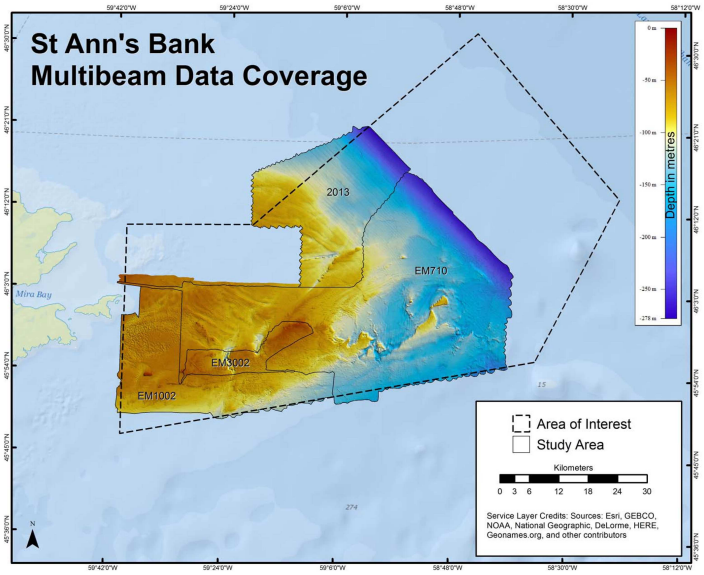
Developing Methods For Benthic Habitat Mapping Of MPAs In Atlantic Canada: St Anns Bank MPA

Craig J. ***Brown***[1], *Vicki Gazzola*[1], *Derek Fenton*[2], *Tanya Koropatnick*[2].

1. Applied Oceans Research, Nova Scotia Community College, Waterfront Campus, 80 Mawiomi Place, Dartmouth, Nova Scotia B2Y 0A5, Canada

2. Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2, Canada.

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. A range of post-processing approaches can generate customized thematic seafloor maps to meet multiple ocean management needs, thus extracting maximum value from a single survey data set.



We present results from a recent study at St Anns Bank MPA, offshore Nova Scotia (Figure 1). We demonstrate using data sets from this site how primary MBES bathymetric and backscatter data, along with a variety of supplementary data (i.e. in situ video and stills, benthic grab samples), can be processed using a variety of methods to generate a series of map products. MBES data sets were analyses using objective classification techniques traditionally developed for classification of multi-spectral satellite data. Comparisons were made between two classification/segmentation methods: 1) Object Based Image Analysis (OBIA) and; 2) a pixel-based unsupervised classification techniques. We demonstrate the challenges associated with using these objective segmentation methods when analyzing backscatter data collected using a variety of multibeam echo sounder systems from a study area due to the non-calibrated nature of the sounders, and also present a strategy to work around this challenge. 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 for marine conservation management.

OBIA Classification Of Colour And B/W Images From The Seabed

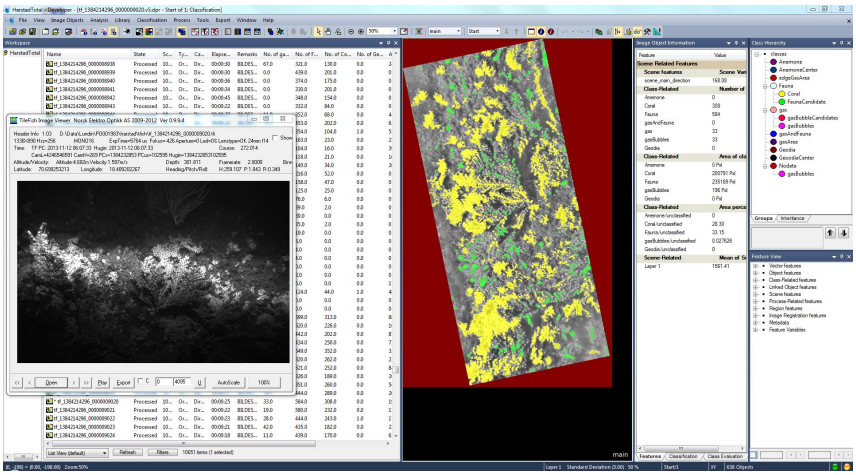
Nils Erik ***Jørgensen***[1]

1. TerraNor

Classification of the seabed is very difficult using any sensor: camera or sonar. It requires good planning to give good results. The seabed mapping project for :undin Norway AS gives a good overview of the seabed and document the amount of endangered species before and after operations. In addition, the project shows planners info about all types of fauna, gas leaks and crusts. To see the seabed as an overall image rather than a sonar DEM can help evaluate the data better. In addition to fauna, TerraNor maps gas leaks and crust.

The rotation of the image shows that that this image is geo-corrected and can be mosaicked. The AUV uses artificial light to capture the images. Artificial light makes the centre of image light and the four sides dark. TerraNor GPU based Image enhancement software solves this problem and make the images ready for machine processing. After enhancement, the image has same colour/intensity over the whole image. It is easier to see details in the dark areas. Most important, it opens for machine processing of the image. In the process we orthorectify the image so that they can be mosaicked over larger areas. Notice how we have rotated the image. We have clipped off the darkest areas of the sides of the image. The process is fully automated. TerraNor software does enhancement and orthorectification. We do mosaicking in PCI Geomatics. We correct colour JPG images captured with video or with camera. The images keep their natural colours after processing. This proves that TerraNor software can handle colour images. This image is processed from Statoil underwatercamera in Tromsø. TerraNor software will orthorectify either with DTM collected with sonar or based on a flat seabed. DTM from seabed is not easy to fit with the images. Orthorectification is optional but necessary if you want to mosaic the images.

We have processed 600 000 images for Lundin with TerraNor software so far. 10 000 images were classified in eCognition software to Crust, Gas, Coral, Anemone and Sponge. Lundin Norway approved the result. Automatic classification with a good result would not be possible without TerraNor smoothing software. We mosaicked the images with PCI Geomatica and analysed the fauna with eCognition Developer.



Corall 9020: example prosessing corall in eCogniton. Notice how the image in eCognition is enhanced.

Mapping Extent And Cover Of Seagrass From Very High Resolution Optical Data Using OBIA And Random Forest

Anna-Leena ***Downie***[1]*, Markus Diesing*[1]*, Julie Bremner*[1]*, and Tony Dolphin*[1]

1. Centre for the Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, NR31 0HT, UK

A fixed-wing remotely piloted aircraft (RPA) was flown over an intertidal seagrass meadow at Two Tree Island (Essex, UK) to acquire high resolution aerial imagery. Imagery was collected on two flights, one with a standard digital RGB camera and the second with a digital camera modified to acquire images in the near infra-red (NIR) part of the spectrum. Mosaics of the RGB and three-band NIR imagery were combined into one multiband image with 3 cm cell size. Raster layers of band ratios were created using Raster Calculator in ArcGIS. A digital terrain model (DTM), photogrammetrically derived from the imagery, was used to calculate terrain variables, including a terrain position index (TPI) with a 100 m radius as well as slope.

The multi-band image was segmented using the RGB bands in the multi-resolution segmentation algorithm in eCognition software, to produce image objects containing consistent spectral characteristics. Image objects representing water, mud, saltmarsh, 100% seagrass cover and seagrass (all seagrass /<100%) were selected visually, by expert judgement, from the image to act as training samples for classification. Summary statistics and textural attributes of input layers were calculated for objects. A Random Forest classification model was used to quantify the spectral, textural and topographic qualities of each landscape class and to generalise the classification to the whole image by predicting to unclassified objects. The model was validated using a bootstrap cross-validation procedure on 10 random subsets of 70/30% selected as training and testing data, respectively, with random selection stratified across classes.

Cross-validation scores for class sensitivity, specificity and balanced accuracy all show almost perfect prediction success. Water is distinct from all other classes by very low NIR1/red ratio values, whilst the same ratio for all vegetation is very high. Mud and 100% seagrass cover are separated by their high and low values of the red/green ratio, respectively. Out of all the landscape classes, saltmarsh and $<$ 100% seagrass cover are most similar in their spectral attributes, differing mainly in elevation and texture, where saltmarsh objects have much lower entropy in the NIR1/red ratio layer.

The link between image spectral attributes and percent coverage of seagrass was investigated using ten quadrate based coverage estimates (collected concurrently with the acquisition of the RPA imagery), together with ten 0% and ten 100% coverage objects selected from the image. Percent coverage showed a good curvilinear fit to the NIR2/green ratio. A generalised additive model (GAM) was used to predict values to the seagrass objects to create a map of percentage cover.

Keynote Speaker

Ruminations On The Future Of Ocean Mapping

Larry ***Mayer***[1]

1. School of Marine Science and Ocean Engineering, Center for Coastal and Ocean Mapping/NOAA-UNH Joint Hydrographic Center, University of New Hampshire

The past few decades have seen remarkable changes in our ability to map and visualize the seafloor and more recently, the water column, all of which have important ramifications for habitat mapping. Improvements in transducer materials and signal processing capabilities will lead to broader bandwidth systems that will provide higher temporal resolution, better signal to noise ratios (through chirp processing) and more flexibility in terms of putting multiple pings in the water column (and thus increasing data density). As processing capabilities and signal to noise ratios increase we will see more and more phase solutions made within a beam footprint eventually leasing to a blurring of the distinction between traditional multibeam sonars and phase measuring bathymetric sonars. One of the most exciting aspects of increased bandwidth is the potential for providing a multi-frequency look at the seafloor (the equivalent of acoustic "color") offering tremendous new opportunities for seafloor characterization applications.

We will also see a trend towards "software defined" sonars and with increasing bandwidth and better sonar control the opportunity for new multibeam sonar mapping geometries is opened. We may see multiple pings looking forward, aft, and perhaps even spreading radially from nadir. As a vessel surveys with these modes there will be a tremendous increase in data density and redundancy as well as the ability to look simultaneously at backscatter from the seafloor from many angles and many azimuths. Greater data density and redundancy will lend itself to more robust data processing tools with better estimates of uncertainty, the ability to handle multi-resolution grids and more automated tools for the identification and remediation of problems. Real-time estimates of total propagated uncertainty will also be a tremendous aid to survey quality assurance and better quality data sets will lead to better seafloor characterization tools.

One of the greatest sources of uncertainty we face comes from our inability to capture the details of the spatial and temporal variability of the sound speed field in the ocean. Innovative new approaches to understanding sound speed variability will also come to the fore. Better use of historical data, predictive models, and new sensors (i.e. distributed temperature sensors that use Raman scattering down a fibre to estimate the temperature profile) may help greatly in capturing the true temporal and spatial variability of sound speed.

Finally, with the addition of water column mapping capabilities, our ability to visualize in 4-D (space and time) both the seafloor and the water column opens up a world of critical applications and opportunities all of which better inform our ability to map habitat. From a mapping perspective, however, we need to better understand just what parameters need to be mapped to provide critical information to the community charged with mapping habitat. Let us know what these critical parameters are and we can better design our mapping systems to provide you the data you really need.

Technological Advances In Habitat Mapping

Setting The Stage For Multi-Spectral Acoustic Backscatter Research

J. ***Beaudoin***[1], *M. Doucet*[2]

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2. Chief of Software Research, QPS USA, Portsmouth, USA

Acoustic remote sensing of the seabed provides essential information for habitat mapping. The typical products of interest are bathymetry, slope, rugosity and acoustic backscattering strength, with multibeam echosounders (MBES) generally being the tool of choice to acquire these data sets. The combined acoustic response of the seabed and the subsurface can vary with MBES operating frequency. At worst, this can make for difficulties in merging results from different mapping systems or mapping campaigns. At best, however, having observations of the same seafloor at different acoustic wavelengths allows for increased discriminatory power in seabed classification and characterization efforts. The varying response of materials to different wavelengths of electromagnetic energy has been used to great success in the field of satellite remote sensing where the term multi-spectral is used to describe sensors that provide these type of data and also to techniques that take advantage of it.

Early research in this field shows promising results from mapping platforms that offer multiple MBES, this typically being done to allow a single platform to provide mapping capabilities over a wide range of depths (e.g. high frequency for shallow water and low frequency for deeper water). With care, the multiple MBES systems on a single platform can be operated simultaneously so as not to interfere with each other and the acquisition of multi-spectral data sets is possible on these platforms. In the past few years, MBES manufacturers have introduced systems with broadband capabilities, allowing users much more choice in terms of selecting the frequency of operation. In some systems, the frequency can be modified on a ping-by-ping basis, allowing potentially for frequency hopping ping configurations that can provide multi-spectral acoustic measurements with a single pass and a single system.

Regardless of how the multi-spectral acoustic measurements are acquired, there is a need to provide acoustic processing capabilities that respect the frequency dependence of many of the terms in the sonar equation. For example, transmission loss over the acoustic propagation path, beam apertures and beam patterns can all vary with operating frequency. Not making adequate corrections for these effects can yield misleading results which can detract from the quality of ensuing seafloor characterization efforts.

In this paper, we touch on some examples of early multi-spectral work, specifically we explore findings and various acquisition and post-processing hurdles that were discovered, followed by a brief discussion of potential applications. We also introduce how we have made improvements to FMGT, the QPS seabed backscatter processing software, to set the stage for researchers to begin exploring, developing and refining applications for multi-spectral acoustic observations of the seabed.

The Acoustic Colour Of The Seabed And Sub-Seabed

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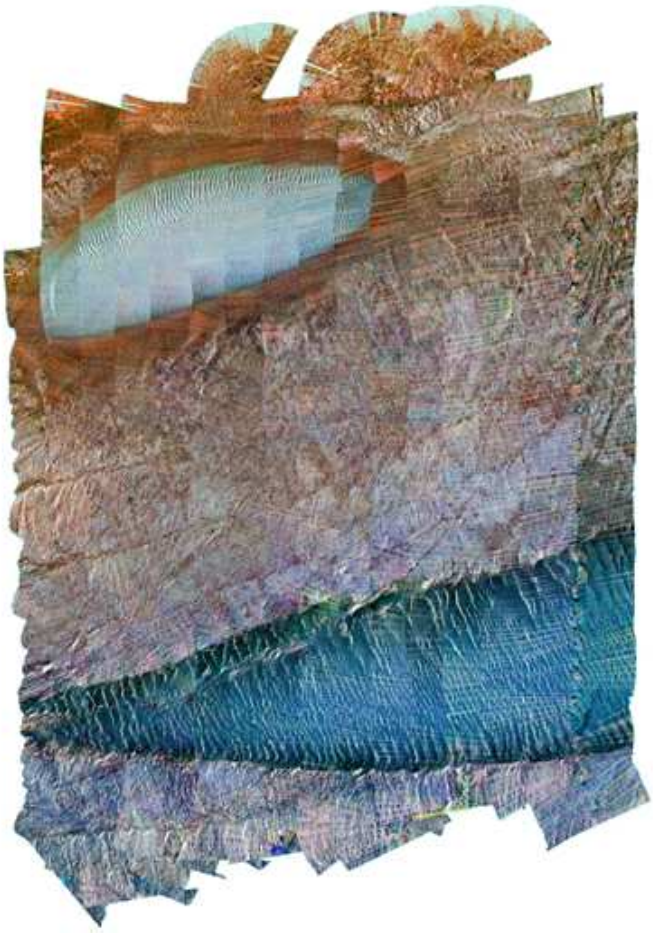
The backscatter response of the seabed to incident sonar signal is dependent on the sonar carrier wave frequency: i.e. the seabed is acoustically colourful

The seabed backscatters incident sonar signal because: 1. there are acoustic impedance contrasts across the seabed interface; and 2. the interface is rough in comparison to the wavelength of the sonar carrier wave. The response of a seabed to incident sonar signal is therefore dependent on the wavelength (frequency) of a sonar's carrier wave. A multi-frequency sidescan sonar system or alternatively, multiple single frequency sonar montages acquired for data at different carrier wave frequencies, provide a basis for generating acoustic colour images of the seabed.

Colour sonar (and radar) was patented in 1971. Why since then has colour not done for sonar what it did for TV in the 1960s? The backscatter response of the seabed is a function not only of sonar system frequency, but also of: geometrical spreading and absorption, the sonar beam and seabed backscatter functions, and sonar vehicle roll and seabed slope. Unless these effects are satisfactorily corrected for, acoustic colour produces a merely psychedelic effect which detracts from rather than facilitating interpretation. Accounting for confounding effects leads to acoustic colour becoming a meaningful property of the seabed. The additional dimensions of information inherent in colour images are then directly analogous to the additional information inherent in optical colour over images reduced to greyscale.



A montage of 15 sonar swaths in the Pentland Firth shown as a Tributive colour image. The direction of ensonification is to West. 1250m by 1500m.

Methods to map three frequency sonar data to optical primary colour frequencies for human visualisation are described and their pros and cons discussed.

A prototype colour sonar system transmits pings at three frequencies: 114, 256 and 410 kHz. Data were acquired in the Pentland Firth in June 2015. The backscatter responses of a variety of seabeds (grades of gravel and sand, rock) are associated with a wide variety of colours. A fascinating observation is of Colour Anisotropy (the dependence of seabed colour on the direction of ensonification). Data were acquired at a Marine Conservation Site in Orkney Island waters in October 2015 to explore a basis for monitoring an ecologically sensitive environment.

The sub-seabed also responds colourfully to low frequency wideband sub-seabed profiler sonar signal (1-11 kHz) seen in preliminary colour sections generated from data filtered into three band-passed components.

Synthetic Aperture Sonar And AUV - Important Tools For Studies Of Cold Seep Habitats

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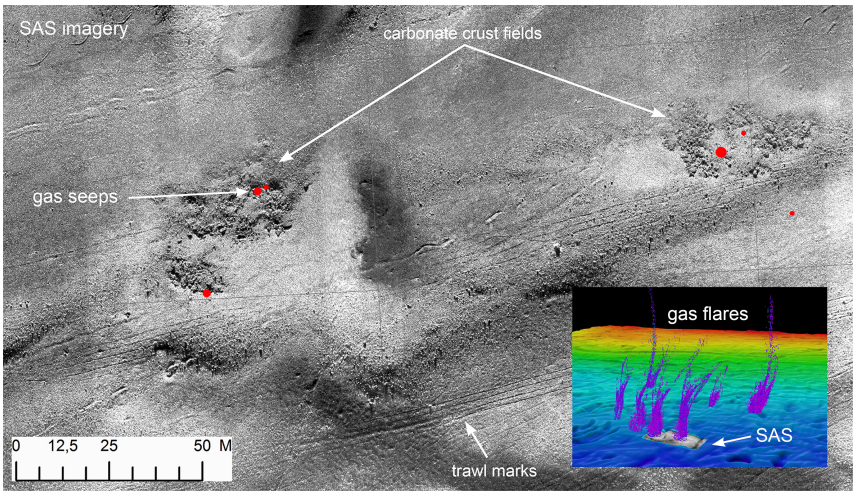
Cold seeps are commonly associated with water column and seabed features. Active seeps form acoustic flares in the water column and can be detected using data from single or multibeam beam echosounders. They may be associated with pockmarks, but the majority of pockmarks on the Norwegian continental shelf have proven to be inactive. Cold seeps are commonly associated with carbonate crust fields exposed at the seabed.

Recent studies using multibeam echosounder water column data in the Håkjerringdjupet region, underlain by the petroleum province Harstad Basin, have revealed more than 200 active gas flares related to cold seeps. We have studied the seabed around some of these, using the HUGIN HUS AUV equipped with HiSAS 1030 Synthetic Aperture Sonar (SAS) from Kongsberg. The SAS gave a 2 x 150 m wide swath. The primary product is the sonar imagery with a pixel resolution up to c. 3 x 3 cm. For selected areas, bathymetric grids with 20x20 cm grids were produced, giving unrivalled resolution at these water depths. The carbonate crust fields have normally a characteristic appearance, with a low reflectivity and a rugged morphology compared to the surrounding sediments.

The interpretation of the acoustic data was verified by visual inspection using the TFish photo system on the AUV, and at a later stage by ROV video footage and physical sampling. The integration of hullborne echosounder data with AUV-mounted acoustic and visual tools provides a very powerful approach for studies of cold seep habitats and related seabed features.



Creating Benthic Habitat Maps In A U.S. National Park Using A Phase-Measuring Sidescan Sonar

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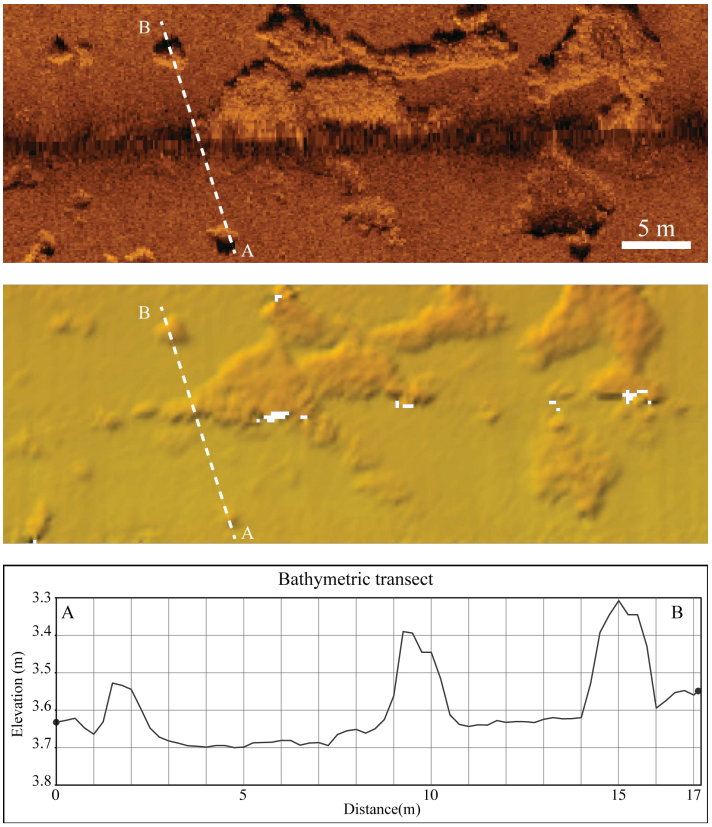
In response to Hurricane Sandy striking the east coast of the United States in October of 2012 the U.S. National Park Service (NPS) funded multi-year projects at four coastal parks to develop benthic habitat maps. These projects were designed to document current benthic habitats, and to provide a baseline data set to measure future habitat change as a result of similar storms, and/or other natural and anthropogenic impacts. The maps are to be created using a combination of vessel-based, acoustic surveys and sediment grab samples.

Cape Cod National Seashore in the state of Massachusetts is the northern most park to be mapped for the larger project. The first two field seasons (2014-2015) yielded over 1750 km of vessel-based acoustic data and were collected using a Phase-Measuring Sidescan Sonar (PMSS) within three shallow water embayments and one nearshore area, approximately 73 square kilometers were mapped. The PMSS collects dual-frequency backscatter imagery (operating frequencies 550/1600 kHz) coincidentally with swath bathymetry (op. freq. 550 kHz). This yields three distinct, yet co-located data sets (Figure 1). The sidescan resolution for the 550 and 1600 kHz frequencies is 0.01 m and 0.006 m respectively. The bathymetric resolution is approximately 3 cm vertically and horizontally. Benthic grab samples (n = 357) were also collected using a 'young-modified' Van Veen sampler at 119 stations (3 replicates per station).



Top: Acoustic bakcscatter imagery of eelgrass beds (grid size =0.25m). Middle: bathymetry for same area (grid size =0.25m). Bottom: transect drawn through bathymetry

Due to the physically driven nature of shallow water habitats, combined with the NPS's focus on physical alteration of habitats due to shoreline change and physical disturbance, biological information within a geologic framework will be used to create the final maps. This approach is also known as the "top-down" mapping approach. The top-down approach will provide the NPS with the most easily repeatable mapping procedure, as well as be extremely amenable to change-detection studies. Biophysical map units will be created as polygons across the study area and classified using Coastal and Marine Ecological Classification Standard (CMECS) terminology and structure. Samples are being summarized by species diversity and evenness metrics as well as dominant species. For each sub-area, a cluster analysis (hclust in R statistical package) will be used to define CMECS Biotic Communities.

Calibrated Acoustic Backscatter From A Phase Measuring Bathymetric Sonar

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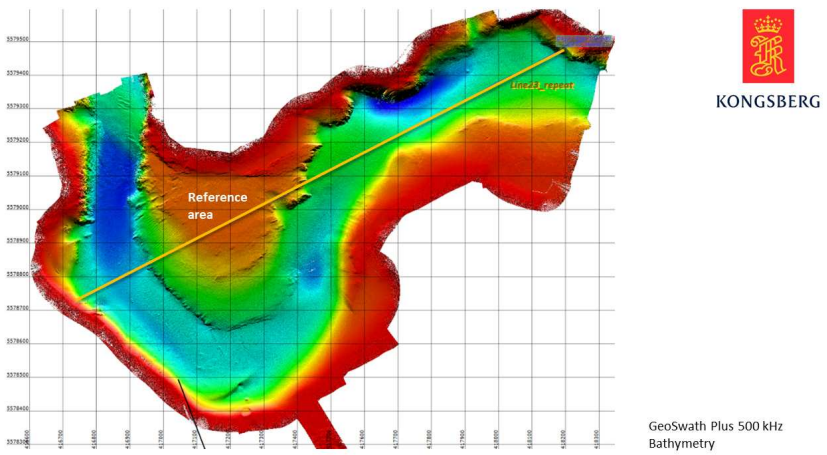
Co-registered hydrographic quality bathymetry and side scan data have been collected using a calibrated phase-measuring bathymetric sonar. This technology facilitates the production of calibrated acoustic reflectivity images of the seafloor.

This work will describe the calibration process, the various factors involved in the measurement of the reflected acoustic signal and how the measured intensity of the acoustic echo can be processed to deliver seabed backscatter intensity in absolute values. The results will be illustrated using data collected with a GeoSwath Plus system processed using GeoTexture software. This software is able to account for sonar calibration information, range and absorption in the water column, transducer directivity, vessel movement (roll), angular backscatter response and the slope of the seafloor, which enables the generation of high-quality normalised seafloor images with minimal artefacts as well as absolute backscatter intensity levels. This has a direct use in seabed monitoring application in shallow waters, and will allow changes in the composition of the seafloor to be quantified in absolute terms and included in the geomorphology of the area under study.



Multibeam Backscatter Calibration On Reference Patch Areas Using Single-Beam Calibrated Data

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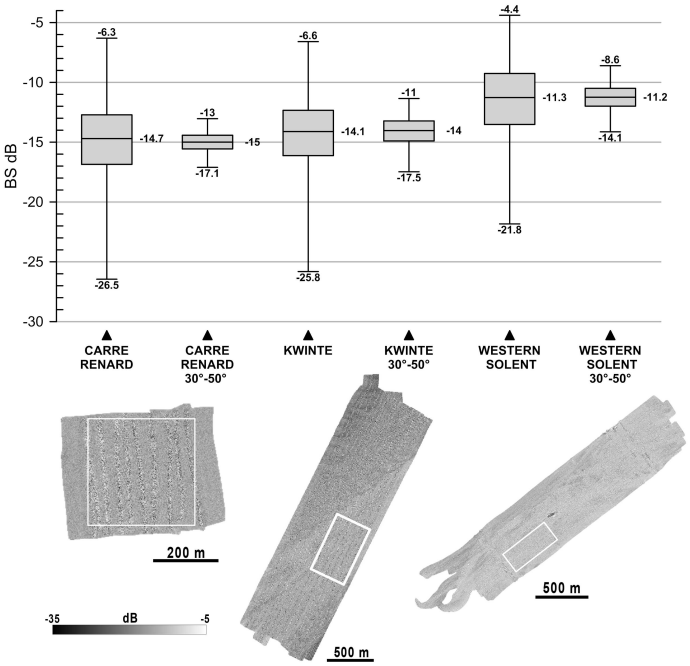
The increasing importance of seabed backscatter in seafloor-mapping raises the issue of the calibration of seafloor-survey dedicated sonars (mainly multibeam echosounders or MBES) used for seafloor backscatter intensity measurement. Several approaches of intensity calibration can be considered for MBES. A first straightforward idea is that the calibration should come directly from the constructors. The main difficulty of this method is that it is not practical to measure the response considered successively in transmission and in reception for a complete system already installed on its platform. A promising approach today could be in situ calibration on natural reference areas with known backscatter characteristics. The main advantage of calibration on such areas is that this is done over a target similar to the ones met under operation conditions, and the characteristics of the sonar upon calibration account for the specific installation environment. Moreover it can be integrated inside the bathymetry calibration routine operations. The purpose of this contribution is to promote the use of reference patch areas for swath sonar intensity calibration in shallow water. The selection of appropriate reference areas is based on strict criteria which are exhaustively discussed in our work. The criteria include the area time stability, physical characteristics, and accessibility. Our work describes the results of a pilot experiment of inter-calibration over three reference areas, using the same 300-kHz EM3002d MBES on R/V Belgica. The project involves partners from France, Belgium and UK. All partners had defined candidate sites for shallow-water reference areas close to their harbour facilities. The sonar surveys were complemented by ground-truthing operations, enhancing the knowledge and the understanding of the local geological configurations. The absolute BS angular range (AR) at Carré Renard (Brest, France) has been determined by using data collected from a tank calibrated SBES (EK60) operating at 300 kHz. The surveys were conducted with R/V Thalia and the EK60 could be steered at 5 different incidence angles: 0°, 15°, 30°, 45°and 60°. The complete AR backscatter curve was then determined by fitting a backscatter heuristical model. The calibration curve of EM3002d was calculated as the difference between the model and the MBES measurements. The complete EM3002d dataset for all areas was then corrected based on that calibration curve. Reference BS value at 300 kHz for each of the reference patch areas have been determined by integrating data for both the complete AR and the "plateau" angular sector ±(30°50°). These reference values can be used to regularly evaluate the stability of the BS level measured by a MBES working at 300 kHz, this being fundamental in the context of a seabed monitoring program. Calibrated backscatter imagery will allow the creation of larger mosaics from data acquired with different sonar systems and processed separately. The methodology and recommendations for performing a "BS patch test" and the definition of acceptance criteria for the measurements are described with respect to the measured reference BS level and with any previously acquired time series of data.



Boxplots presentation (whiskers at 1 and 99 percentile) of backscatter data recorded over homogenous sub-areas of the surveyed areas; backscatter from complete angular extent of the MBES ± [0°75°] and over a limited sector ± [30°50°]: Backscatter mosaics gridded at 1x1m for each surveyed area are shown using the same dB grey level scale. Note the different size of the areas and sub-areas.

Evaluation Of A New Multibeam Backscatter Processing Algorithm In CARIS HIPS And SIPS

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The collection of backscatter data during multibeam surveys has recently become routine for many industries that use these systems. New fields of application for multibeam backscatter are emerging, and the need for reliable and efficient tools to post-process this data is growing. Many post-processing software suites have implemented the Geocoder algorithm from the University of New Hampshire, with each vendor providing their own packaging of this toolset. While there are differences in implementation, including workflows and supported configurations, the fundamental approach to post-processing of multibeam backscatter remains constant between each implementation.

CARIS has developed a new multibeam backscatter processing algorithm to automatically produce fully compensated mosaics using industry-standard techniques and corrections tailored to each sensor's characteristics. The raw backscatter intensities are first corrected for time-varying gain (TVG), transmit power and received gain, and a robust estimation ensonified area based on beam and pulse geometry as well as local bottom slope. These corrected intensities are then normalized to reduce the influence of incidence angle and fed to the beam pattern estimator. Once the beam pattern has been removed, the user can create a mosaic from the resulting values that shows only sediment reflectivity and angular dependency. Optionally, the user can choose to apply an Angle Varying Gain correction during mosaicing to remove the angular dependency.

This paper will outline in brief the new algorithm and workflows, and provide use cases and comparisons of a variety of datasets against the CARIS implementation of Geocoder.

Multibeam Echosounder Backscatter Variability Due To Sediment Resuspension And Environmental Dynamics In Shallow Waters

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In the last two decades, the backscatter intensity of multibeam echosounder systems has been successfully used to describe the properties of the seafloor sediment distributions and benthic habitats in very shallow environments. However, it is yet not completely understood how environmental variables and local dynamics can affect the backscatter signal, including water column features.

In September 2014, we carried out a 12 hour experiment within highly dynamical environmental conditions to check how changing variables can influence surface backscatter registered over the same area. During the half tidal cycle, we performed 22 repeated multibeam surveys by means of a Kongsberg EM2040 DC system over a dune field in one of the tidal inlets connecting the Lagoon of Venice to the Adriatic Sea. At the same time, we acquired CTD and ADCP data and deployed sand traps on the seafloor to estimate salinity, temperature and suspended sediment concentration change. The currents at the seafloor varied over time in speed and direction, causing peaks of sediment concentration corresponding with the velocity maxima. Comparing the seabed and water column backscatter intensity with environmental variables, for the different surveys, we estimated their influence on the backscatter signal collected.

Application Of The Object Based Image Analysis And Template Matching Method For Detecting, Classifying And Monitoring Repeatable Seabed Objects, Case Study From The Lagoon Of Venice

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3. Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Gulledelle 100, 1200 Brussels, Belgium
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Development of Multibeam Echo-Sounder systems (MBES), which took place in the last twenty years gives a lot of opportunities to explore the seabed with very high resolution comparable to those of other land and air remote sensors. Two types of MBES data (bathymetry and backscatter) can be combined and used for mapping of underwater geomorphological structures, seafloor types and benthic habitats. Many of these features have similar characteristics such as their own range of backscatter intensity, size, shape etc. These characteristics can be mapped thanks to the Object Based Image Analysis and the Template Matching method is an image processing technique that allows one to find repeatable small parts of an image that identifies a certain object.

The Backscatter and bathymetry data have been collected during the 2013' surveys that took place in the Lagoon of Venice within the RITMARE Italian National Flagship Project. Geomorphological elements, like tidal and navigation channels were for the first time explored with very high resolution using the Kongsberg EM2040DC MBES. The data were processed using the Caris HIPS & SIPS and QPS Fledermaus softwares in order to create raster files like bathymetry and backscatter geotiffs. Georeferenced digital images in such form have been post-processed using the Geographical Object-Based Image Analysis and the Template Matching method in order to detect and classify repeatable objects. Based on the rasters and ground truth data it turned out, that certain particular objects were massive demosponges. In order to monitor seasonal sponge changes, surveys have been repeated two times at the Scanello tidal channel within the Lagoon.

Results of the research are promising. The Template Matching method with the use of backscatter, bathymetry and ground truth data gives the possibility to quickly create a template and use it to find similar objects within the considered image. Once created the template can be used many times, for other similar datasets. Finally, the method has a wide use, so there is a possibility to create templates for other objects, like other habitats, gravels, erratic boulders, etc.

High Swath-Overlap Seafloor And Water Column Backscatter Survey Over The Calypso Hydrothermal Vents, Bay Of Plenty, New Zealand

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Here we approach two apparently unrelated issues of the backscatter data collected by multibeam echosounders (MBES): (1) the angle dependence of the seafloor backscatter and (2) the potential for water-column backscatter data to provide information for habitat mapping purposes. For this we acquired high-redundancy MBES data over the Calypso hydrothermal vent field, Bay of Plenty, New Zealand, using a water-column capable EM302 system. The survey consisted of a set of 36 parallel swaths in c. 150 m of water depth and covered an area c. 5 x 2.2 km. The average, minimum and maximum line spacing of 61.3 m, 18 m and 145 m respectively, provide very high overlap of the swath, with a maximum theoretical overlap of c. 700% in the centre of the box. The area was surveyed on two occasions 7 days apart, which provides means to discuss the timing of the hydrothermal activity. We used SonarScope® software from IFREMER and Fledermaus Geocoder® software from QPS for data processing and display.

The seafloor backscatter relates to the incidence angles of the incoming echo on the seafloor, with a conspicuous strong signal response at nadir (specular) and decreasing with increasing incidence angles. The seafloor incidence angles vary in non-trivial ways so that the resulting reflectivity maps are usually difficult to process and interpret. Our approach enables us to study in detail the backscatter angular dependence by comparing the responses from different incidence angles at pixel scale. This also enables us to generate reflectivity maps according to one narrow incidence angle sector and to remove the effect of the specular reflection without loss of information. The reflectivity maps generated at fixed incidence angles and free of specular reflection are better suited for segmentation and generation of predictive substrate maps. Comparisons with backscatter response and reflectivity maps obtained from classical coverage are presented and analysed.

The Calypso vent field also provides an excellent region to test the water imaging capability of the EM302 system and to overcome the inherent imaging capability resulting from the physical shape of the swath whereby the area covered increases with depth to the maximum swath at the seafloor. Numerous hydrothermal plumes were observed over the Calypso vent field. Plumes of average strength measured approximately 100 m in height, while more prominent flares were recorded extending 180 m from the seafloor, i.e. almost reaching the surface. The plumes generally occur along fault scarps which can be several hundred meters long, making it difficult to define their extent. Comparing the temporal data sets from two surveys 7 days apart revealed that the intensity of the seeps remained consistent over this period. Following the bubble point-data to their origin revealed that the venting sites are strongly correlated, but not always spatially restricted to the surface trace of local faulting.

Predicting Sponge Species Richness: A Novel Approach Using Random Forest, Generalised Linear Model And Their Hybrid Methods With Geostatistical Techniques

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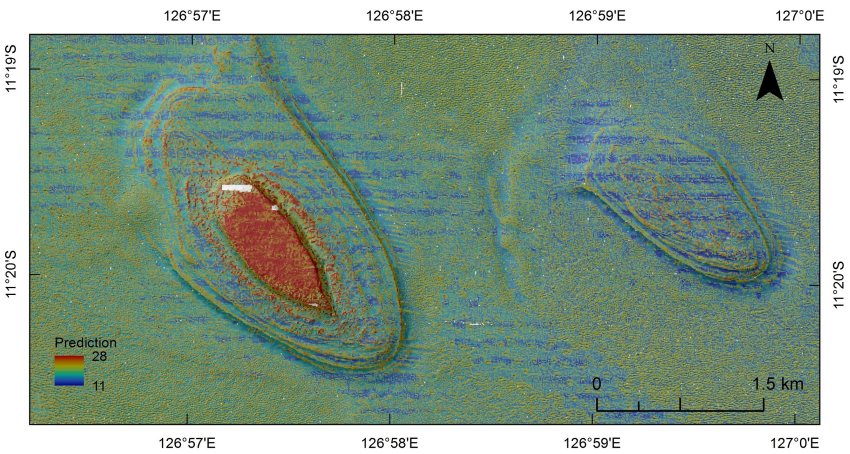
The broad continental shelf offshore northern Australia is characterised by extensive areas of carbonate banks, terraces and isolated pinnacles. These seabed features provide potential habitat for sponge communities and are recognised as Key Ecological Features of regional significance within the Oceanic Shoals Commonwealth Marine Reserve (area: 72,000 km^2). However, the spatial distribution of sponge communities is poorly documented and our understanding of their relationship with environmental variables is limited. Here we adopt a predictive modelling approach to advance this understanding of the spatial patterns and associations with a range of environmental parameters. Data to inform the predictions are taken from seven study areas aligned across the shelf, for which high resolution bathymetry, acoustic backscatter and seabed samples have been collected by Geoscience Australia and the Australian Institute of Marine Science. These samples include sponge specimens at 77 locations, from which measures of sponge species richness were derived. We modelled sponge species richness for these locations using random forest (RF) and generalised linear model (glm) and their hybrid methods with geostatistical techniques (i.e. ordinary kriging (OK) and inverse distance weighting (IDW)). The hybrid methods are RFOK, RFIDW, glmok and glmidw. We also examined the effects of model averaging and various predictor sets on the accuracy of predictive models. Four feature selection methods were applied for RF modelling: averaged variable importance (AVI); Boruta; knowledge informed AVI (KIAVI); and recursive feature selection (rfe). For glm modelling, variable selection methods included: stepAIC; dropterm; anova; and; RF. Predictive models were validated using 10-fold cross validation. Finally, the spatial distribution of sponge species richness was predicted using the most accurate model. The main findings are: 1) longitude, latitude, distance to coast, backscatter and topographic position index are the most important predictors; 2) the hybrid methods have significantly improved the predictive accuracy for both RF and glm and the hybrid methods of RF and geostatistical methods are considerably more accurate and able to effectively model count data; 3) relationships between sponge species richness and the predictors are non-linear, and; 4) high sponge species richness is usually associated with hard seabed features. The lessons from the modelling will be discussed, including the effects of important and unimportant variables, issues associated with model selection methods and so on. This study further confirms that: 1) the initial input predictors affect the model selection for RF; 2) the inclusion of highly correlated predictors could improve predictive accuracy, providing important guideline for pre-selecting predictors for RF; and 3) the effects of model averaging are method dependent or even data dependent. This study also provides important information for future monitoring design, particularly on the areas where the management and conservation of sponge gardens should be focused.



Exploring The Use Of Accurately Georeferenced Stereo Image Mosaics To Ground-Truth Acoustic Seafloor Characterization Models

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Underwater acoustic techniques like Side Scan Sonar (SSS) and Multi-Beam Echosounder Systems (MBES) are invaluable tools for seafloor mapping. A range of seafloor characterization methods have been developed to attempt to derive thematic maps from the acoustic backscatter response collected by SSS and MBES, however, given the large uncertainties associated with current seafloor characterization models, ground truthing is essential for the correct interpretation of acoustic backscatter data as well as for the further development of formal mathematical models that link acoustic backscatter observations to intrinsic properties of the seafloor. Unfortunately discrete sampling and/or high-resolution digital color imaging of large areas is costly and time-consuming. Furthermore, samples collected via drop-camera or direct sampling are difficult to georeference with high accuracy and have a very limited areal extent compared to the larger area covered by the acoustic techniques.

The work proposed here is based on a dataset wherein MBES and SSS from a ship along with SSS and stereo seafloor imagery on the same vehicle were collected simultaneously. Specifically, SSS data along with stereo images were collected by the NOAA HabCamV4 towed camera system capable of collecting overlapping stereo pair images at 7 Hz while being towed at 7 knots by a vessel collecting MBES data, providing continuous, overlapping coverage of the seafloor for all three data sets.

An Ultra Short Baseline navigation system (USBL) allowed accurate underwater positioning of the towed camera system and thus georeferenced, along-track stereo image mosaics of the seafloor for direct comparison to the MBES and SSS data. A new set of algorithms to integrate MBES, HabCamV4, and USBL datasets together with a routine to generate along-track mosaics and 3D point-clouds form the stereo images has been developed.

The stereo-mosaic was then used to validate the results of two seafloor characterization approaches: 1- an Angular Response Analysis (ARA) model applied to the MBES backscatter; and, 2- an unsupervised classification technique where geomorphological features (slope, profile curvatures) and backscatter derived from the MBES dataset were used as predictors.

The final aim is to develop a data fusion method to integrate the MBES, HabcamV4, USBL dataset (along with other remotely-sensed datasets) acquired simultaneously in order to produce a synoptic characterization of the seafloor. The outcomes from this research can be then applied to validate the results of existing and newly developed supervised and unsupervised seafloor characterization methods.

Predictive Habitat Mapping And Iterative Planning Of Image Surveys Given Existing Bathymetry And Imagery - A Machine Learning Perspective

*Oscar **Pizarro**[1], Daniel Steinberg, Simon O'Callaghan, Asher Bender, Dushyant Rao, and Stefan Williams*

1. Australian Centre for Field Robotics, The University of Sydney, NSW 2006

Machine learning research offers flexible and powerful approaches to handling observations at multiple scales and of different modalities to construct predictive models with meaningful representations of uncertainty. Beyond providing a sense of the quality of the models, these representations can guide further collection of observations to improve predictive capabilities. The traditionally-resource constrained problem of generating habitat maps from full coverage acoustic multibeam data and targeted optical surveys can be viewed through the lens of machine learning and adaptive sampling. This paper investigates the use of state-of-the-art techniques in machine learning including deep learning methods, Gaussian Processes and Dirichlet-Multinomial regressors to generate habitat maps and to suggest where further sampling would be most useful. We discuss the interpretations of the different measures of uncertainty associated with these models and their implications for the choice of observations and survey design. We also discuss novel ways of viewing the relationships between image data and bathymetry that are possible with these models. We present results based on surveys performed in tropical and temperate reefs in Australia using ship-borne multibeam sonar and precisely georeferenced imagery collected with AUVs as part of the benthic monitoring program run by Australia's Integrated Marine Observing System.

Underwater Hyperspectral Imaging Assessment Of Drill Cuttings Coverage On Benthic Habitats Using Spectral Sediment Analysis

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Larger-scale mapping of seabed areas requires improved methods in order to obtain effective and sound marine management. The state of the art for visual surveys today involves video transects, which is a proven, yet time consuming and subjective method.

Underwater hyperspectral imaging (UHI) utilizes high color sensitive information in the visible light reflected from objects on the seafloor to automatically identify seabed organisms and other objects of interest. Spectral sediment analysis is a method developed to discriminate between sediment types and coverage of sediments dispersed from a source.

Recent advantages in UHI classification includes mapping of areas affected by drill cuttings. The spectral sediment analysis tool has been developed for an automated classification of seabed of different bottom composition compared to adjacent baseline areas. We report on the use of the Spectral sediment analysis method for the assessment of drill cuttings coverage radially from the drilling hole to a baseline seabed. The results show that the spectral change in the top layer sediment is concurrent with the expected transition from homogeneous to heterogeneous composition as the dispersion extent decreases over time. The findings are supported by results from video and bottom fauna grab analysis. We propose that UHI can provide a cost-effective and objective method of mapping the extent of drill cuttings dispersion.

3d Visualization Of Subsea Structures And Marine Habitats

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The state of subsea structures has for a long time been assessed from grainy visual inspection videos and relatively coarse multibeam echosounder point clouds.

The specialized survey ROV, SROV is designed to perform surveys and environmental surveys down to 2 000 metres water depth and deliver ultra high-resolution data at a high speed and thus substantial lower cost per kilometre. Compared to the technique used until today the outcome of the SROV's first survey was much higher resolution imagery and multibeam data in less than half of the time for about 40 % of the cost.

The idea is that video is replaced with continuous still photo. The quality of these georeferenced pictures is approximately eight to ten times higher than that of standard HD video. Three machine vision cameras are synchronized with powerful strobe lights, taking continuous 3D stereo and geo-corrected photos along the survey line at as speed up to 4.5 knots, many times faster than a regular video/photo transect, to produce high-resolution 3D photo and GIS data. These pictures are part of a mapping system where stereo and 3D images can be presented in true scale and position.

As the geometry and imagery are both acquired using the same source instrument, they are seamlessly integrated into the modelling process with great precision. The exposure time for the still photography cameras is down to milliseconds to avoid motion blur and ensure crisp colour seafloor imagery. Image quality as seen from the tests performed during the trials shows substantial improvements over video imagery in clarity, colour rendition, resolution and viewing angles. It also surpasses the AUV collected still images in quality, due to full colour depth (SROV 24 bit colour versus AUV 8 bit monochrome), 10 times higher resolution (SROV 12.3 MP versus AUV 1.2 MP), and the fact that three separate cameras are simultaneously collecting data over the same area. The images from the SROV can be collected with much shorter exposure times because of less power limitations regarding available strobe power output. The images are thus less influenced by the speed of the vehicle and show less motion blur. The images from 5 m altitude have a ground resolution of 0.8 mm per pixel, which produces very sharp images. Full colour rendition allows for easier recognition and classification of detected features.

The ultra-high resolution, 5 Hz acquisition rate and 3 simultaneous viewpoints are ideal for photogrammetrical modelling of the features in post-processing. First tests have shown that centimetre level of detail point clouds and orthorectified imagery are easily achievable using such techniques on areas requiring further investigation, without the need for additional surveys.

The SROV has many possible scopes of use. Mentions are mapping of the seafloor, environmental impact assessment and habitat- and geological research. The increased photo quality is a valuable tool for environmental investigations and geohabitat classification.

Coastal And Shallow Water Habitats

Passive And Active: Remote Survey Solutions For The Nearshore; An Integrated Approach

Don ***Ventura***[1], *Matt Bergin*[2]

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2. EoMap gmbh

Emphasis on nearshore, shallow water surveys and the immediate coastal hinterland has increased over the past few years. This has been generated by concerns over various issues, including: sea level rise due to climate change and directly-attributable man-made issues such as land subsidence through extraction of valuable mineral and water resources; growth of, and reliance on, a seaborne Blue Economy delivering goods as efficiently as possible; concerns over erosion or damage to nearshore ecosystems necessitating additional focus on habitat mapping and environmental surveys in general; and an increasing percentage of the world's human population residing in close proximity to the coast which places extra emphasis on baselining and monitoring of this specific margin. At the same time, economic pressures on a great many of the world's advanced and developing nations alike bring the need for cost-effective methods of garnering geospatial data in the nearshore into sharp focus. Clearly, mapping of the land-sea interface requires the adoption of a broader approach to hydrographic surveying techniques and technologies to augment that already well surveyed with traditional methodology. This presentation will illustrate an integrated solution to this survey paradigm through the pragmatic use of satellite derived bathymetry and airborne topo- and bathymetric techniques.

Applications Of Spatial Hierarchical Sampling To Optimism Hydroacoustic Based Habitat Mapping Over Large Spatial Extents Of Kimberley, North West Of Australia

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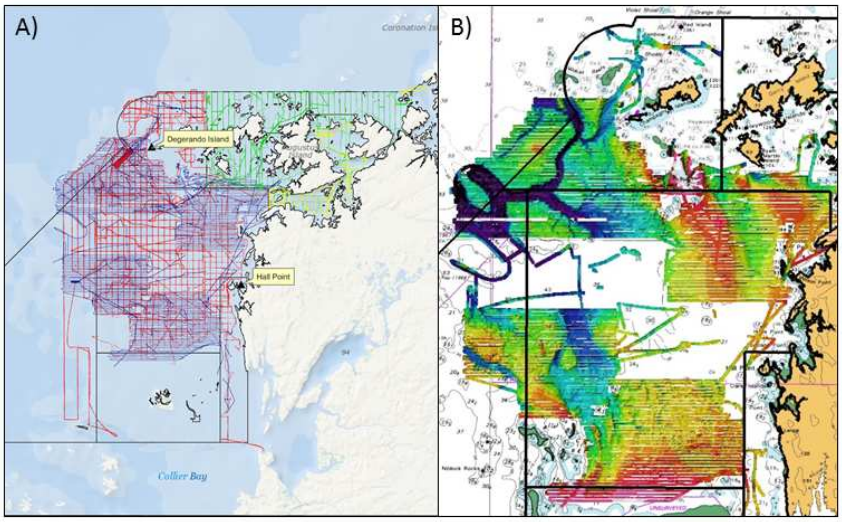
The coastal Kimberley region of North West of Australia is a vast, physically complex and remote area. It regarded as largely pristine and existing information while sparse suggests it support unique habitats and highly biodiverse benthic communities with considerable endimcity. These environmental values have prompted the state government of Western Australia to propose the Greater Kimberly Marine Park, which would cover an area of over 630,000 square kilometers and encompasses extensive fringing coral reefs, deeper shoals and over 900 islands.

However the seabed biodiversity in the region is very poorly characterised, representing a significant knowlage gap with little historic data. This is in part due to the areas size and remote location but also the difficulties working in highly turbid coastal waters, with extreme tides in many places. The Kimberley Conservation Strategy and the Science Plan identify a range of priority needs relate to establishment and management of the marine park area and this in turn highlighted the need to better characterise the spatial extent and distribution biological resources in this area.

The very poor light penetration in much of the coastal waters ares rendered broad scale habitat mapping using satellite based remote sensing method unusable. Poor light penetration lead to the adoption of shipboard hyroacoustic methods using multibeam and single beam sonar. However, large areas of coastal environments were required to be assessed for their biological importance so high resolution hydroacoustic surveys were not logistically feasible. This lead to the design of spatial hierarchical hydroacoustic survey strategies were board scaled hydroacoustic transects were used to map areas of geomorphic homogeneity and heterogeneity. This in turn led to targeted finer scale survey in areas of heterogeneity. Incorporation of both fine and broad scale survey facilitated optimal development of digital depth and geomorphic surface models. These surfaces when combined with stratified towed video surveys could be combined to produce habitat models at a range of scales and accuracy suitable for planning purposes. Hierarchical spatial hydroacoustic sampling introduces tradeoffs with between recourses require for survey verses accuracy and resolution of final habitat models. However, they can provide significant increases in the spatial coverage of hydroacoustic surveys and reduce the logistical requirements. The successful implementation of spatial hierarchical hydrodynamic survey has wide application but requires a clear understanding of spatial and attribute accuracy required for derived habitat models.



A) Spatial hierarchical sampling transects for hydroacoustic multibeam survey B) derived spatial digital depth models

Mapping And Assessment Of Mangroves In The Philippines Using Landsat Imagery

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Mangroves are not only important but crucial resource in coastal areas. They are among the most productive ecosystems providing goods and services to people and the marine environment. However, in the Philippines, being highly vulnerable to anthropogenic pressure, recent studies show a decline in cover and density. Admittedly, there is a need for protection and conservation of this resource. Monitoring through mapping of the extent and occurrence of marine habitats such as mangroves can be limited and time-consuming. But over the last decades, remote sensing has been used to map physical features and extent of mangroves. A number of studies have already been conducted, developed methods and algorithms used to extract mangroves. For this study, Support Vector Machine (SVM), a supervised classification method was used in the classification of mangroves and was further refined with the help of GIS ancillary. Landsat-8 images acquired between 2014 and 2015 were utilized. Eight (8) multi-spectral bands were used and processed using ENVI software. Radial basis function, a type of kernel function was used to extract the mangrove habitats. Results showed that classification of mangroves using SVM is an effective technique in the extraction of mangrove vegetation. The classification method was applied to other areas being able to map out mangrove areas in the Philippines. This study is a significant contribution in monitoring and data update of mangrove extent and distribution in the Philippines which can be helpful in coastal management and conservation efforts.

Complementary Monitoring Methods For Large-Area Surveys Of Intertidal Seagrass Beds

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Seagrasses are the dominant vegetation in shallow sandy coastal waters worldwide and can form dense beds. Seagrass beds are highly productive habitats and of great ecological importance as they fulfil several vital ecological functions. However, on the other hand they are also very sensitive towards a variety of parameters, particularly to human induced eutrophication. This has resulted in a worldwide decline. Due to their ecological importance, their sensitiveness and as they respond very quickly to changed environmental conditions, seagrass is regarded as an indicator for ecosystem health and is used as such in the EU Water Framework Directive. Therefore their monitoring and reliable and meaningful data about their status are important.

In the Wadden Sea seagrass beds occur only on the tidal flats which are exposed during low tide. As the tidal flat area is vast (4700 km^2) and the survey time is limited by the tides, a combination of different monitoring approaches is used to obtain a complete picture of the seagrass situation.

Aerial mapping from a plane is carried out three times during the annual seagrass growth season. Three surveyors map simultaneously the beds during low tide. It is a rapid assessment approach which has the advantage of covering large areas within just one low tide. The results are also satisfying and reliable regarding shape, size and position accuracy. The drawback is the poor detailedness. However, this approach is cost-effective and has been conducted each year in the northern Wadden Sea since 1995.

Annual ground surveys are carried out in order to obtain high-resolution and detailed information such as species composition or epiphyte cover. This survey happens on foot with precise GPS device and occurs in close coordination with the aerial mapping. However, as the survey area is vast and the terrain difficult, it can only be conducted in small representative areas.

The analysis of up-to-date aerial photographs is a method which is somewhere in between the ground surveys and the aerial mapping. It is more precise and accurate than the aerial mapping but allows also covering large areas. It is used as a large scale truthing and quality check of the aerial mapping data. However, aerial photographs are expensive and difficult to take why they are just irregularly available. One of the greatest challenges is to distinguish between seagrass and green algae which requires experience and can be done on the base of colour and texture.

Historic aerial photographs are a very valuable data source as their analysis enables to reconstruct long-term development. However, they are not often available and poor quality can limit their usage considerably.

These three methods match ideally and when they are applied in combination , they enable getting a complete picture of the seagrass situation in a vast and difficult terrain.

Benthic Morphologies And Habitats In A Shallow Highly Human Impacted Tidal Inlet

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Transitional environments like lagoons, deltas and estuaries are extremely shallow, dynamic and highly valuable in terms of biodiversity and productivity. Therefore, they require constant monitoring, but at the same time they represent a challenge both for optical (aerial- satellite) observations because of their turbidity and for swath bathymetry because of their shallowness. In this study, we present results of a high resolution multibeam echosounder survey carried out in 2013 in the Venice Lagoon, Italy. The Venice Lagoon has an average water depth of about 1 m, ranging from 2 up to 30 m in the navigation channels. It is connected to the open sea by three inlets (Lido, Malamocco and Chioggia) that since 2006 have been strongly modified by the construction of mobile barriers (MoSE Project) to protect the historical city of Venice from high water. These works could radically change the whole lagoon morphological and hydrodynamic configuration.

To quantify the impact of these major modifications and understand the ongoing processes over time we mapped with unprecedented detail the seafloor of the Chioggia Inlet thanks to a high resolution multibeam echosounder system (MBES). MBES data (bathymetry and acoustic backscatter intensity) and a total of 44 in-situ samples (bottom sediments and underwater images), were used to map the seafloor morphology and grain size distribution and to classify the substrate into benthic habitat classes. The results were compared with previous literature and with the results of a high resolution hydrodynamic model, which helped to explain the distribution of seafloor sediments.

Benthic Habitat Mapping In A Very Shallow Tidal Channel

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Tidal channels are crucial features in coastal transitional environments. Besides water, they ensure exchanges of sediments and biota with the open sea. Despite their key role, there is still a gap in knowledge on the intrinsic morphological properties of these habitats. This is because, until recently, the physical characteristics of these environments, for instance shallow water, turbidity and currents, had prevented extensive bathymetric surveys to explore them.

In order to fill this gap, starting from 2013, within the framework of the national project RITMARE, we collected very high resolution multibeam (by mean of a Kongsberg EM2040DC system) and ground truth data (grab samples, seafloor photographs and videos) within the tidal channels of the Venice Lagoon, Italy. The gathered datasets allowed a better understanding of these almost unexplored environments, allowing the mapping of tidal channel seafloor properties with unprecedented detail

Within a GIS environment, starting from the very high resolution bathymetry, we mapped the main physiographic, morphological and anthropogenic features of the tidal channel seafloor. At the same time, we classified the seafloor backscatter with the Jenks classification. Comparing the classified backscatter, grab bottom samples and seafloor images, we identified the main benthic habitats present in the study area.

As a first step, the data were organized following the benthic habitat classification scheme proposed within the European project COCONET (Towards COast to COast NETworks of marine protected areas) adapted for the Venice Lagoon environment. This classification scheme is organized in more levels in a hierarchical way, allowing a flexible and multi-scale description of each element.

In this work we present the results of a case-study of a channel located in the northern Venice Lagoon. It demonstrates the importance of organizing a high resolution acoustic remote sensing and ground truthing in a GIS framework in the study of tidal channels and, more generally, for the monitoring and management of extremely shallow tidal environments.

Geoforms And Substrate Characterization Of A Tidal Inlet In The Wadden Sea (Lower Saxony, Germany)

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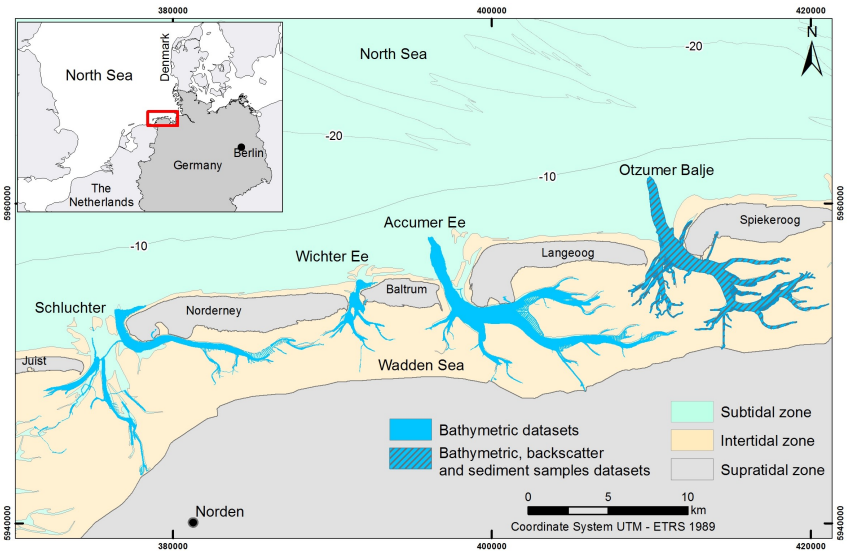
The Wadden Sea, located along the southern North Sea, is one of the world's largest intertidal systems encompassing a multitude of transitional zones between land, marine and estuarine environments. Since 2009 it belongs to the UNESCO world heritage and is protected in the framework of the Trilateral Wadden Sea Plan, which entails policies, measures, projects and actions agreed upon by The Netherlands, Germany and Denmark. The high natural heritage and the substantial presence of economic activities, as well as the European directives like FFH and MSFD, require habitats monitoring plans, which have to comprise objectivity of methods and repeatability of results. A long-term monitoring project on the subtidal habitats of the Lower Saxony Wadden Sea is carried out by the NLWKN-Coastal Research Station of Norderney, through acquisition and interpretation of different acoustic datasets. Within this context, bathymetry and acoustic backscatter are collected simultaneously by means of swath bathymetry systems, in conjunction with validation samples. These allow a robust approach to characterize substrate and bedforms, based on the assumption that there is a closed connection between morphology, geomorphological processes and seabed composition. The geomorphometric approach gives a substantial contribution to extract quantitative information on morphology and bedforms from bathymetry. The availability of a wide dataset of high-resolution DEMs, consistent in terms of survey technologies and processing methods, allows a statistical comparison of the morphology of four tidal inlets, by means of the computation and classification of slope gradient and profile curvature. Morphometric classes are used for the detailed geomorphometric analysis of Otzumer Balje inlet, by the use of the Benthic Position Index at broad- and fine-scale, and the statistical analysis of slope gradient and profile curvature with respect to their depth distribution and orientation. The geomorphometric approach allowed to map four broad-scale morphological zones, as well as fine-scaled erosive and depositional bedforms including sand waves, holes and three orders of scarps. The geological and geomorphological meaning of morphometrical parameters is investigated by means of quantitative comparison with backscatter intensity and samples. Backscatter was processed for radiometric corrections, geometrical corrections and mosaicking, according to the "Backscatter measurements by seafloor-mapping sonars - Guidelines and Recommendations" from the Backscatter Working Group. The signal recorded by the swath sonar is processed as a function of the incident angle, retrieved from the bathymetric measurements provided by the sonar itself. Further corrections are applied to filter the phenomena bound to the measurement configuration, water-column properties and the sonar itself. The relations between the acoustic facies and the seabed composition are calibrated using samples. The resulting images provide qualitative and quantitative information on the substrate composition. Within this integrated approach, it is possible to quantitatively analyse the complex morphology of subtidal areas of the Wadden Sea tidal inlets. At detailed resolution, the integration of bathymetric and backscatter data provides a bedforms and substrate characterization according to the main habitat classification schemes.



Detailed Scale Habitat Mapping At The Eastern Gulf Of Finland, The Baltic Sea

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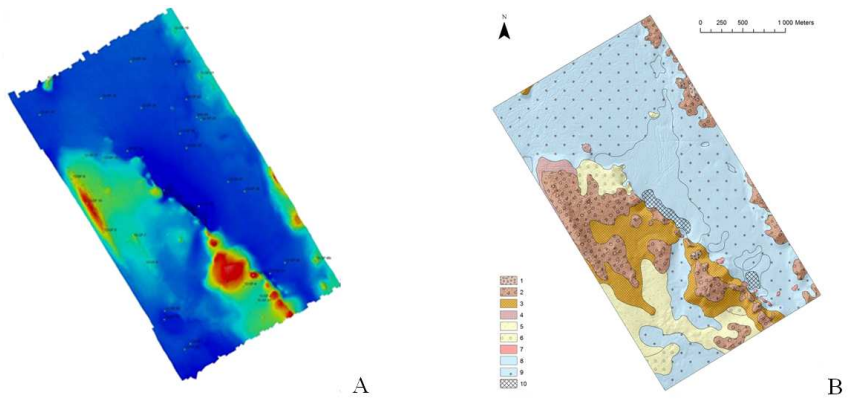
In the frame of TOPCONs project (Transboundary tool for spatial planning and conservation of the Gulf of Finland, 2012-2014) of ENPI Program, an interdisciplinary research of submarine landscapes within the three key-areas of the eastern Gulf of Finland was undertaken. Full-coverage multibeam and backscatter survey, repeated side-scan sonar profiling, submarine video observations and sediment sampling were used for geological and biological study of the sea bottom, GIS analyses and of geo- and biodiversity assessment.

Three studied key-areas very much differ by bottom relief and geology, salinity gradient and hydrodynamics. Seabed of the key-area located in the Vyborg Bay (north-western part of Russian Gulf of Finland waters) is characterized by very high geodiversity (from very shallow moraine ridges, covered by boulders to relatively deep troughs filled by silty-clayey mud) and active processes of Fe-Mn concretions development (Fig.1). Numerous dynamic forms of submarine relief (e.g. sandwaves, megaripples, erosion runnels etc.) characterize the near-shore bottom of the northern coastal zone. Submarine slope of Kurgalsky Reef represents a transect from shallow water surface of glacial ridge, covered by bounders, to relatively deep sedimentation basin with anoxic conditions. Additionally, near-shore bottom in the vicinity of nuclear power plant in Sosnovy Bor (Kopora Bay) have been studied

Contrary to results of statistical analyses undertaken for broad scale habitat mapping (Kaskela et al., this volume), results of detail scale modelling reveals dependence of benthic assemblages distribution on substrate type (soft bottoms and stony substrates) within all studied key-areas. Fouling assemblages in the vicinity of nuclear power plant Bay were dominated by freshwater and mesohaline invaders with different temperature requirements and have demonstrated spatial distribution determined by anthropogenic impacts (heating/hydrodynamics).



Vyborg Bay key area. A - multibeam image; B Ũ-sea bed map. 1 - boulders; 2 - boulders, pebble, gravel; 3 - gravel with sand; 4 - coarse grained sand; 5 - medium grained sand; 6 - fine grained sand; 7 - mixed sediments (clay with boulders); 8 - silty-clay mud; 9 - silty clay mud with Fe-Mn concretions; anoxic slity clay mud.

Mapping Clam Habitat In The Eastern Arctic: Species Distribution Modelling In Support Of Fishery Assessment In Qikiqtarjuaq, NU

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In the past two decades, clams have been harvested in the shallow (∼10 m water depth) nearshore around Qikiqtarjuaq by scuba diver. Clams are a popular and nutritious food source for the community and potentially for other Nunavut communities, creating the potential for a small commercial fishery. The community and the Government of Nunavut (GN; Fisheries and Sealing Division) are collaborating with the Memorial University Marine Habitat Mapping Group (MHMG) to assess the viability of such a fishery through a science-based approach.

We have employed a species distribution modelling methodology to predict the distribution of clam habitats around Qikiqtarjuaq. This work built upon on a study by Siferd (2005) that surveyed Mya spp. clams in the nearshore (10-40 m water depth) zone around the community to evaluate the size and age of the population, and to estimate sustainable fishing rates. The report quantified clam abundance using underwater photography and identified zones of high clam density. Siferd's (2005) database guided the current approach to mapping clam habitat distribution at a finer resolution and greater depth range. Multibeam sonar data were collected opportunistically over three summers, yielding a continuous dataset that is being cross-referenced with underwater photos to predict clam abundance over areas where it has not been directly observed. Images extracted from underwater video during the 2015 field season add to Siferd's (2005) photographic dataset for the purpose of generating a species distribution model (SDM) to a maximum depth of 200 m. A diver-based fishery would be limited to depths of <20 m, but it is important to determine optimal depth ranges for Mya spp. clam habitats, which will affect the population's resilience to fishing stress.

Forty-three four-minute vertical camera drifts were conducted in the 2015 field season for the purpose of counting clam siphons. Sampling strategy was random and stratified by depth, backscatter and slope at a depth range of 10-200 m. Data layers derived from multibeam sonar were used as predictor variables in the clam SDM. Statistical analysis demonstrated that aspect, slope, benthic position index (BPI) and backscatter were significant predictors of clam abundance. A generalized linear model using these variables, and clam counts from photos as a response, predicted high to moderate clam abundance in areas commonly harvested by divers. Though not an absolute predictor, the clam abundance map is an important tool in the fishery assessment process, giving managers an easy-to-interpret visual prediction of clam distribution.

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First Sabellaria Spinulosa Reefs Habitat Mapping In The Iberian Atlantic Coast

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Sabellaria spinulosa (Leuckart, 1849) is a marine worm (Polychaeta) that forms large reefs by building tubes (10-15cm long, up to 60cm) , with the sand available in the nearby areas, resembling the appearance of bee hives. The species distribution is limited to areas where the water movement is strong enough to create a good source of sand in suspension. This species can settle in mixed substrata (sand, gravel, pebble and cobble) or rocky substrata, only needing to ensure that the structure is sufficiently thick and persistent to support the community. These reefs are found from the lower intertidal to the subtidal fringe down to 50 meters depth, in small aggregations or, under favorable conditions, in large aggregations forming biogenic reefs.

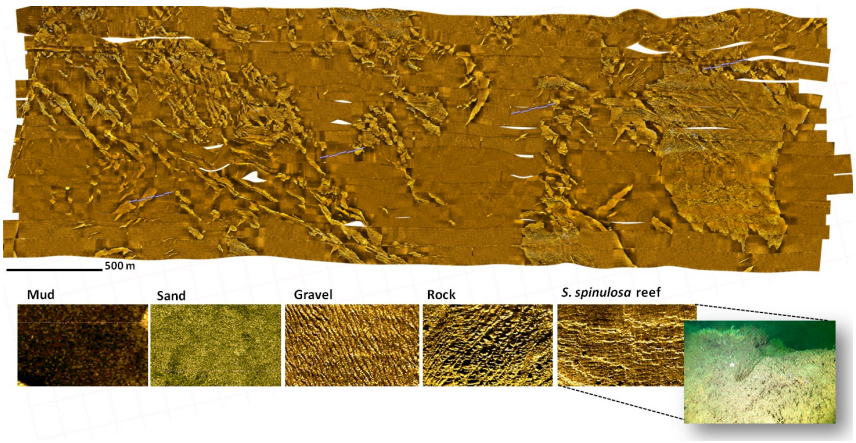
S. spinulosa is known to occur along all the European coast, from Norway to Portugal and the Mediterranean Sea.

As a biogenic reef that structures a large associated community, S. spinulosa, is a species with scientific and conservation interest. It is known that this kind of habitat increases the local biodiversity, playing a role in supporting food webs. In 2013 the OSPAR Commission, considered this habitat as ńthreatened and/or declining ż in the II and III OSPAR regions (area around the British islands), due to physical damage, mainly caused by human activities (benthic trawling). The distribution of this habitat in the area of the Iberian Peninsula is still unknown and needs to be studied.

During the oceanographic Campaign EMEPC/M@rBis2015 that occurred along the Cascais-Lisbon coast (Portugal), some areas of Sabellaria spinulosa reef were detected and sampled by scuba diving. The area containing S. spinulosa extends 3 nautical miles along the coast, from Guia to the Cascais bay, between 10-30m deep.

To understand the extension of this habitat, the substrate composition was mapped using Side Scan Sonar (Figure 1). Afterwards, different kinds of substrates identified in the map were validated by dredging. Images of these different substrates were also taken using a drop-down camera and an observer ROV (with acoustic positioning).

This study represents the first habitat mapping made for this species at its southern distribution limit in the North-East Atlantic, along the Portuguese coast.



Biodiversity Patterns Of Benthic Foraminifera Associated To Geo-Habitas As First Insights In Delimiting Reefal Marine Parks

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Coral communities worldwide are progressively more stressed by anthropogenic activities that are increasing fluxes of sediment and other pollutants to nearshore areas. Some nearshore coral-reef environments off the Brazilian coast, including Pirangi and Maracajau, seem to be under pollution or thermal stress; however, the horizontal extent, effects of pollution and assessment of environmental changes depends on the hydrodynamic conditions, sedimentary facies and ecological indicators. Our study is an attempt to investigate the health of two Brazilian reef communities by examining 7 main symbiont-bearing foraminifera in RN reefs: Amphisorus hemprichii, Amphistegina gibbosa, Archaias angulatus, Borelis schlumbergeri, Heterostegina antillarum, Laevipeneroplis proteus, and Peneroplis carinatus using numerical analysis and FORAM Index (FI). We will discuss and compare samples from Pirangi and Maracajau Coral reefs in covered reef areas, sandy sediments, and macro algae substratum, contributing to the field of taxonomy on larger foraminifera species. By associating the foraminifer composition with the geochemical data, we can conclude that grain size, to a lesser degree, coarse and sand fraction, are the controlling parameters of microfauna. It is also clear depositional energy plays an important role in transportation and deposition of sediments and foraminifera. According to the FI results, the environmental health evaluation shows the water quality of Pirangi is not suitable for coral reef growth and Maracajau has sites suitable for coral reef growth even if it has individual sites where coral could not survive after a stress event. Long-term assessments are needed in order to improve our knowledge regarding the distribution and ecological importance of Brazilian reef-dwelling foraminifers, as well as to extend the application of the FI to large-scale monitoring of this and other reef ecosystems in the Southwestern Atlantic. The present study can contribute to the management plan of the Pirangi and Maracajaú National Marine Parks by providing a first insight to the biodiversity patterns.

Mapping Rhodolith Beds Along The Eastern Brazilian Shelf

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Rhodolith beds are a very important habitat along the Brazilian shelf. Although it has been described back in the 70's by Milliman, a proper detailed mapping of the extension of these beds and their characteristics has not been well documented until the work of Amado Filho et al. (2012, Plos One) on the Abrolhos Shelf. Rhodoliths are nodules of non-geniculate coralline algae that occur in shallow waters (<150m). Considered as bio-engineers, rhodolith beds can provide a more stable habitat for a number of organisms and are well known to be associated with a great invertebrate biodiversity and associated with kelp beds. The Brazilian environmental legislation is very restrictive to the use or explotation of rhodoliths as a mineral resource and to the development of oil/gas and dredging activities on these beds. In the last decade, the eastern Brazilian shelf has been under pressure due to an increase in oil and port activities. Pipeline and oil rig installation and dredging disposal site licenses have increased considerably, and in most cases, along rhodolith areas. Here we present a case study of the acoustic, sampling and video imaging mapping of a continuous rhodolith bed along the eastern Brazilian shelf. A discussion on qualitative and quantitative acoustic interpretation from side scan and multibeam backscatter is posed, as well as the use of OBIA techniques. The importance of using a simple video recording system is also pointed out due to the high degree of heterogeneity in nodules density over the bed. We have mapped a continuous rhodolith bed that extends over 30,000 km^2. The occurrence of rhodolith beds is more common along areas deeper than 35-40m, down to 100m. In terms of acoustically differentiation, side scan sonar data seems to be a better option considering the higher resolution in relation to MB backscatter. In some cases, seabed morphology can be used as a proxy for the occurrence of rhodolith beds along the study area. The presence of erosive features as hardground is commonly associated with rhodoliths. The same is also true for paleovalley morphology. It is possible to identify the occurrence of rhodolith beds considering a qualitative analysis of a very strong backscatter signal. A relation between the density of rhodoliths per square meter and the backscatter is still a work in progress. The use of OBIA technique is very promising in this case and can be improved.

Shelf And Deep-Sea Habitats

Life On The Edge: Global Variations In Shelf Break Depth And Its Influence On Benthos

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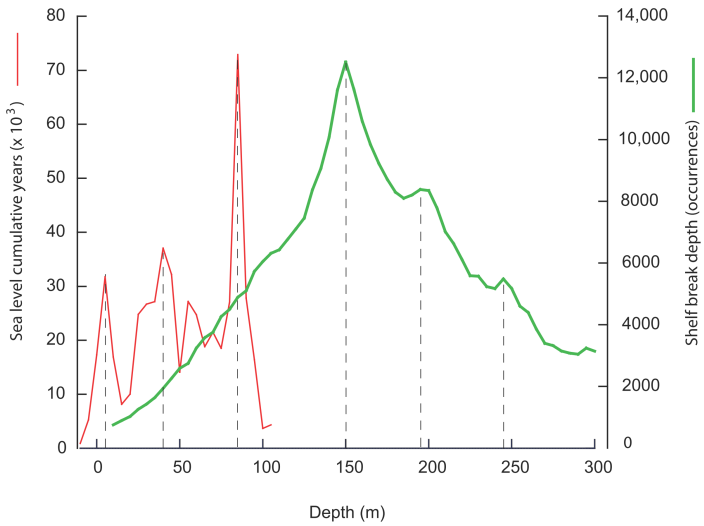
The shelf break is the defining geomorphic feature of all continental margins, marking the transition from the shelf to the slope and deep ocean habitats. It is commonly located at a depth that is at the limits of the photic zone. Ocean boundary currents, internal waves, tides, upwelling, density currents and other oceanic processes influence the life that occurs here. Biologically it is a transition zone, dividing shelf biomes from deep ocean biomes. The shelf break is populated by benthic species found in both the adjacent shelf and slope habitats; it is commonly a zone of enhanced productivity and biodiversity. Plate tectonics governs the initial formation of the shelf break because all continental margins are the product of rifting apart of continental landmasses. Post-rifting, continental margins are further modified by sedimentary (deposition and erosion) processes. The shelf break is considered to represent the boundary between wave and current processes that dominate on the shelf versus gravitational processes that dominate on the slope (Olariu and Steele, 2009). The depth at which the shelf break occurs is believed to be controlled by sediment input, wave and current energy in the receiving basin, plus other processes such as coral reef growth and glaciation.



Histogram showing cumulative amount of time that sea level has occurred at different water depths below its present position (shown in 5 m depth bins), based on 516,000 year sea level curve published by Rohling et al. (2009). The cumulative occurrences of depth of the shelf break in 5 m bins is based on 317,117 observations made at 1 km intervals along the shelf break (based on Harris et al., 2014). Vertical dashed lines indicate modal depth points for both curves.

In order to provide a quantitative assessment of shelf break depth in relation to the governing processes, we carried out a multivariate analysis of geomorphic features occurring on the global continental margin based on 11 input variables. Eight morphotypes are defined having mean shelf break depths ranging from 132 to 441 m. We find that the global mean depth of the shelf break is 220 m with modal peaks at 150, 195 and 245 m (positively skewed distribution; Fig. 1). The most frequent position of sea level during the Pleistocene (at about 85 m; Fig. 1) is 65 m above a common modal depth of the shelf break (150 m) on a global basis, consistent with existing theories relating shelf break depth to sedimentation under waves and currents and clinoform development (eg. Dietz and Menard, 1951; Olariu and Steele, 2009). Regional variations in the depth of the shelf break can be attributed to coral reef growth, glaciation, progradation and tectonism; a conceptual model is developed relating differences in shelf break morphotype with habitats and biota.

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Landscape Mapping At Sub-Antarctic South Georgia Provides A Protocol For Underpinning Large-Scale Marine Protected Areas

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Global biodiversity is in decline. Anthropogenic activities act as drivers of this decline, with the marine environment experiencing significant and increasing pressure from extractive industries such as fishing, marine deposit mining, and oil and gas extraction, activities, which are increasingly proliferating into deep sea environments. Under financial, political and social constraints however, one of the key questions that precede any conservation strategy, is how and where to prioritise limited resources and effort to maximise conservation payoff in an increasingly exploited, yet still poorly understood marine environment. Over the past decade, marine protected areas (MPAs) have increasingly been adopted as the flagship approach to marine conservation, many covering enormous areas of over one million km^2. At present however, the lack of scientific biological sampling makes understanding and prioritising which regions of the ocean to protect, especially over large spatial scales particularly problematic.

Here, we present an interdisciplinary approach to marine landscape mapping at the sub-Antarctic island of South Georgia, as an effective protocol for underpinning large-scale MPA designations. South Georgia forms part of one of the largest MPAs in the world and supports a highly biodiverse benthic fauna. We developed a new high-resolution (100m) digital elevation model (DEM) of the region and integrate this DEM with bathymetry derived parameters (e.g. rugosity, slope gradient), modelled oceanographic data (e.g. seabed temperature, salinity and currents) and satellite net primary productivity data. These interdisciplinary datasets were used to apply an objective statistical approach to hierarchically partitioning and mapping the benthic environment into distinct ecologically-relevant physical habitats. Using this benthic marine landscape map and overlaying it with a regional biological dataset we aim to assess the application of physical habitat classifications as proxies for biological structuring and as such the application of the landscape mapping protocol for informing on marine spatial planning.

Seabed Geodiversity And Benthic Assemblages At The Eastern Gulf Of Finland, The Baltic Sea

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Ecosystem based management (ESBM) requires accessible and reliable information concerning the state, species distributions and physical characteristics of coastal and marine environments. This type of marine environmental data is often spatially limited. Thus marine resource management processes must usually contend with inconsistent data concerning both biological and geological aspects of the marine environment when trying to balance conservation and human uses. Nevertheless, statistical analysis and Geographic Information Systems (GIS) have provided methods to study and map the marine environment.

In order to define habitat distribution patterns in a geologically heterogeneous seabed area in the Gulf of Finland, Baltic Sea, we have combined hydrologic and geologic information with species composition. We included datasets that describe coastal influence and geodiversity at multiple scales in the analysis. Multivariate statistical analysis (BEST, LINKTREE) were used to identify links between the datasets and to develop benthic marine landscapes for the area. Here we will present our key findings regarding the benthic environment and demonstrate that geodiversity of the seafloor should be considered in broad scale habitat mapping and marine spatial planning.

The study was made within ENPI CBC funded Finnish-Russian co-operation project, the TOPCONS (2012-2014). The aim was to develop innovative spatial tools for the regional planning of the sea areas in the Gulf of Finland, the Baltic Sea.

Habitat Mapping Of Bathyal Benthic Habitats In The Northern Dreki Area, Iceland

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Benthic habitats in the bathyal zone, defined as depths between 200 and 2000 m, account for 16% of the ocean floor, support a rich biodiversity, and provide crucial ecosystem services. Nevertheless, our understanding of the composition and distribution of bathyal benthic habitats is poor, particularly in Arctic and sub-Arctic waters. As technological developments allow human activities to expand into deeper and more remote waters, and into more rugose seabed that is likely to contain vulnerable habitats, there is an increasing need to map habitats in these areas in order to ensure sustainable resource use.

The northern Dreki area, located at the northeast border of the Icelandic Exclusive Economic Zone, is characterized by several large ridges (shallowest at 750 m depth) that run in the NE-SW direction, and deep basins (deepest at 2200 m depth). Recent interest in oil exploitation in this area has amplified the need for knowledge on benthic habitats. The Marine Research Institute of Iceland has conducted a multibeam echo sounder survey covering a 10,500 km^2 portion of the northern Dreki area, and collected biological samples at 77 stations. These data offer a unique opportunity to examine distribution patterns of bathyal benthic habitats in Arctic waters. The present study aims to identify benthic habitats within this study area, to examine how these are related to environmental variables, and to predict their distribution.

Since the study is primarily motivated by the aim of generating the most ecologically realistic habitat map possible, a supervised (bottom-up) approach is used. Oceanographic variables are incorporated in the analysis due to the large size and depth range of the study area. A suite of multivariate approaches are used to identify biological communities, defined as groups of samples with similar faunal composition, and to investigate the relationships between the communities and the environmental variables, including depth, derived terrain variables, backscatter, and oceanographic parameters. The most important environmental predictors are identified and, using Maxent, a machine learning method, these predictors are used as proxies to predict habitat distribution.

This study represents one of the first full-coverage habitat maps produced within Iceland's EEZ, and the first at these depths. The completed habitat map will provide insights into the distribution of benthic habitats in the northern Dreki area, contributing to knowledge on the factors that influence species distribution patterns.

The Skipjack Island Fault Zone: A Geohazard And Benthic Habitat-Forming Structure Separating The San Juan Islands, Washington State, USA From British Columbia, Canada

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The Skipjack Island Fault Zone has been mapped in the San Juan Islands between Vancouver Island, Canada, and the Washington State mainland, USA. A decade ago, interpretation of multibeam sonar seafloor imagery revealed that Skipjack Island, an east-west striking sedimentary bedrock outcrop, was a fault-controlled structural feature. A major fault separates Skipjack Island from a deformed sedimentary bedrock outcrop on the seafloor to the north.

Recently the Skipjack Island Fault Zone's morphology and extent has been explored both to the west and east of the island using seismic reflection profiling, sediment coring, and seabed photography that is supported, in part, by the Non-Governmental Organization (NGO) Research Now. The character of the Skipjack Island Fault Zone is well defined locally by the interpreted seismic profiles, which show active faults that displace recently deposited sediments. The central part of the fault zone, near Skipjack Island, appears as a near-vertical structure that has been subjected to left-lateral motion; the evidence is bedrock exposure on the seabed north of the island where folded strata bend eastward against the fault, the result of drag from the fault motion. This structure has produced ideal habitat for various rockfish species that are endangered or listed. Interpretation of recent geophysical data suggests an extension of the Skipjack Island Fault Zone further to the east where it either cuts through or transitions into a thrust fault and fold belt. A blind thrust fault is tentatively identified north of Lummi Island, another area where rockfish inhabit the seafloor.

The Skipjack Island Fault Zone is interpreted to be the northern boundary of the San Juan Archipelago with the Devil's Mountain Fault Zone being the southern boundary. Both of these faults represent the longest continuous fault zones of the San Juan Archipelago and are generally oriented east-west and are actively deforming the seafloor. This deformation is continuing to alter and produce benthic habitats for rockfish.

Mapping A Submarine Canyon In All Its Facets

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With recent inventories indicating numbers may exceed 9500 world-wide, submarine canyons are some of the most important features of our continental margins. They are considered the main pathways between the shelf and the deep sea, funnelling sediments in sometimes catastrophic flows, while also transporting pollutants and litter from shallow to deep waters. Their steep morphology has a strong influence on the local oceanography and current patterns, causing the formation of large internal tides, upwelling and enhanced surface primary productivity. These processes, together with the high terrain heterogeneity, often result in high biodiversity, which means that submarine canyons are generally considered biodiversity hotspots.

Still, the various processes acting in submarine canyons are poorly understood. Their extreme morphology makes them challenging and inaccessible locations for study. Thanks to recent technological developments, especially in marine robotics, we now can start to build a picture of true canyon morphology, current regimes, sediment transport processes and habitat distribution.

During the recent CODEMAP2015 expedition in Whittard Canyon, NE Atlantic, three different robotic vehicles were deployed simultaneously to image the 3-dimensional structure of this complex environment. In addition to the shipboard multibeam data, recorded at 50 m pixel size, the Autosub6000 Autonomous Underwater Vehicle (AUV) collected bathymetric data at metre-scale resolution. Ultra-high resolution bathymetry (< 0.2 m pixel size) was obtained with the Isis Remotely Operated Vehicle (ROV). At the same time, the water column structure within one of the canyon branches was continuously measured by a Seaglider. Complemented by the Isis HD video records, these nested datasets allowed, for the first time, to image all the processes in a submarine canyon at the scale they occur, in a close to simultaneous manner.

Special emphasis was also given to near-vertical and overhanging canyon walls, which play an important role in canyon formation and habitat creation, through processes that until recently could never be mapped. A new Autosub6000 multibeam set-up, specifically developed to allow side-ways mapping, was successfully tested during the CODEMAP2015 cruise. Together with ROV-based 'forward mapping', the new 3D models provide unique insights in the canyon morphology and habitat distribution.

This work is part of the ERC CODEMAP project (ERC Starting Grant no 258482).

Benthic Habitat For Primnoa Deep-Sea Coral In The Fairweather Ground, Gulf Of Alaska

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The Fairweather Ground is part of a bedrock bank on the outer continental shelf in the eastern Gulf of Alaska. It is a major commercial fishing area for yelloweye rockfish and other rockfish species. Its bedrock outcrops are also known to host deep-sea corals and sponges which, among other roles, shelter juvenile rockfish. In 2012, the U.S. National Oceanic and Atmospheric Administration (NOAA) began a study of Primnoa corals, the most abundant deep-sea corals in this region and arguably the most important as habitat-forming biological structures. This study was an element of NOAA's Alaska Coral and Sponge Initiative (AKCSI). A portion of the Fairweather Ground at the shelf edge was chosen as one of four study sites. Here we report on habitat associations of Primnoa corals in the Fairweather Ground based on mapping in 2012 and ROV dives in 2015.

Multibeam sonar mapping was conducted with a Reson SeaBat 7111 on the shelf and upper slope at 70-800m. These bathmetric and backscatter data guided ROV dives in 2015 to characterize the range of habitats in the site and to identify habitats that represented hotspots for Primnoa occurrence. Six dives were conducted in the Fairweather Ground using Odyssey Marine's ROV Zeuss II.

The Fairweather Ground is adjacent to the offshore Queen-Charlotte Fairweather Fault system, a strike-slip plate boundary between the Pacific and North American plates. One of the bedrock habitats in the study was a remnant volcanic cone with columnar basalts and pillow lavas. Other seafloor volcanics are observed in the area, related to the leaky plate boundary. An ROV dive revealed abundant Primnoa coral as well as at least seven species of rockfish. An extinct cold seep was discovered in the middle of the volcanic field, testifying to the hybrid nature of this site. Three dives surveyed a second, widespread bedrock habitat of folded, indurated siltstone with near-vertical and horizontal fracture sets. Outcrops up to 10 meters high alternated with pelagic sediment in depressions. Several species of rockfish were observed, including juveniles. Primnoa was limited to dense patches on the edges of higher outcrops, primarily on the summits. A third bedrock habitat encountered in three dives on the outermost shelf and upper slope was a similar fractured siltstone. However, this siltstone was much more friable and very difficult to sample with the ROV manipulator. It was apparently too weak to support sessile invertebrates as corals were rare on the shelf and absent on the upper slope portion of this habitat. The final habitat examined was the sedimented axis and wall of a slope canyon. The walls exposed the same soft, friable siltstone but occasional deep-sea corals were observed, including bamboo coral, black coral and Primnoa, apparently in more competent areas of the bedrock. This bedrock formation may be widespread along the outer shelf, and has important implications for limiting the distribution of deep-sea corals despite bedrock exposures.

Mapping The Distribution Of Cold-Water Coral Reefs Using Distribution Modelling

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In Norway, recent years have seen increased interest in mapping the distribution of cold-water coral habitat at high resolution due to mounting evidence of its biological and ecological importance. Various approaches can be used to achieve this goal, namely, generate spatial datasets that can support the conservation and management of this habitat at the local level. Methods vary on the basis of data available and type of output and include interpretation, object-based image analysis, and statistical methods.

A cold-water coral reef consists of live coral colonies and dead coral framework in various stages of decay and fragmentation. In addition, trapped sediments fill up the free space in the lower parts of the skeletal matrix. Coral reefs may result in small-to-medium scale landforms, and therefore can be mapped using bathymetry and limited ancillary (i.e. ground truth) data by means of either interpretation methods, or more sophisticated image analysis.

In addition to these methods, fauna-environment relationships warrant the use of statistical techniques such as Species Distribution Modelling (SDM) to map the distribution of coral habitat. In this way the probability of presence of coral at every pixel can be predicted as a function of environmental data. Furthermore, hypotheses can be generated about which factors shape the distribution of this species and the habitat it forms.

We used SDM to predict the probability of occurrence of the reef-forming species Lophelia pertusa across the Tromsø bank, Egga shelf, and sections of Nordland, in the Southwest Barents Sea (Norway). The response data was compiled from geo-referenced observations from underwater video, which was collected by the MAREANO programme. The dataset comprised 1369 samples, with a prevalence of 4%. As predictors we used topographic variables, namely depth and geomorphological, or terrain, class and ocean climate variables including current speed, temperature, and salinity. We computed terrain class from elevation, slope and curvature features and using a random forest classifier to assign terrain class across the study area based on a sample of pixels. As modelling technique we used Conditional Inference Forests (CIF). The final coral CIF had "excellent" discrimination ability (AUC=0.92).

Terrain class was a very good predictor of coral presence although this relationship was, unsurprisingly, highly dependent on whether coral colonies had developed into reef structures. Therefore, we suggest that SDM is particularly useful in situations where coral occurs as scattered colonies rather than forming reefs. In the absence of reefs other variables such as temperature, depth, and current speed proved to have more explanatory power. In this presentation we show the final map obtained for this Norwegian offshore area. Furthermore, we make the case for hybrid approaches to mapping coral habitat and the need for high-resolution bathymetry.

The Effect Of Environmental Data Resolution In Habitat Suitability Models: A Case Of Study Of Brazilian Deep-Water Corals

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Deep-water corals inhabit different latitudes, ranging from polar to tropical regions. Several species may form large reefs that add heterogeneity to the environment and provide habitat for other organisms. Therefore, it is of central importance to know their distribution in order to manage and protect these ecosystems. During the last years, habitat suitability models have been widely used to predict cold-water coral distribution at different scales. However, the resolution of predictors may influence model accuracy. In this study, we develop habitat suitability models for reef-forming deep-water corals at two scales in Campos Basin, Brazil, in order to predict their distribution and identify how differences in bathymetry resolution modify predictions.

Habitat suitability models were developed based in the Maximum Entropy approach. Models were performed with species presence data from existing datasets and new records of Solenosmilia variabilis, Lophelia pertusa, Madrepora oculata and Enallopsammia rostrata with two environmental variables resolutions. Variables selection was based on their contribution to improve model performance and their ecological importance for the corals. This study highlights the importance of variable resolution and has deep implications for the use of suitability models in the planning and management of Marine Protected Areas (MPAs).

Seeps And Mud Volcanoes - Oxygen Depletion Along The Northwest Pacific Coast Of North America And Implications For Habitat

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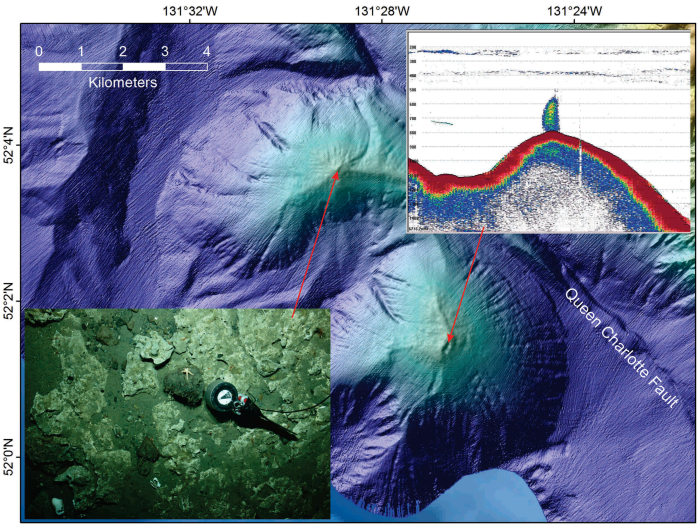
Recent surveys along the Pacific Northwest from British Columbia into Alaska have identified more than 200 bubble clouds and gas plumes rising from 10 m to >700 m above the ocean bottom. The majority of the seeps are venting along faults in bedrock at depths between 70 and 1,000 m, suggesting methane is being lost from hydrocarbon or other organically-rich deposits. On the continental shelf some actively venting seeps form authigenic carbonate chimneys (mounds), with faunal assemblages different from that of surrounding soft substrate habitat and atypical of known cold seep communities. In addition, large plumes emanate from mud volcanoes along the plate boundary of the Queen Charlotte/Fairweather Fault system (Fig. 1), from Haida Gwaii into SE Alaska. These sites, located between 1,200 and 600 m, host extensive carbonate crusts and chemosynthetic communities of mussels and clams.



Multibeam image of mud volcanoes along the southern portion of the Queen Charlotte/Fairweather Fault off Haida Gwaii, British Columbia. Inset is an 18 kHz sounder profile of the continuously rising 300 m plume from one of the cones and a seabed photo showing the carbonate crust within the second volcanic cone (length of the compass and fin is ∼40 cm).

Since the volume of deep-sourced methane from these seeps is potentially very large, we assume the identified emissions are ongoing and have existed for a long period of time. The sites form unique benthic habitats along an extensively fished upper slope and continental shelf, however, the extensive release of methane may also limit the biologic diversity of regional shelf and coastal benthic habitats. These habitats are strongly delineated by oxygen availability in the NE Pacific; therefore, one has to consider how methane emissions might impact dissolved oxygen concentrations. For example, a 15 µM reduction in oxygen is observed on the 26.5 isopycnal surface near the highest density of seeps on the southern Vancouver Island Shelf. If methane release has and is presently impacting oxygen levels, how will benthic habitat be impacted with warming seas under climate change and the increased consumption of oxygen?

Are Seafloor Seeps, Mud Volcanoes, And Chemosynthetic Communities Significant Marine Benthic Habitats?

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1. SeaDoc Society, Orcas Island, WA & Moss Landing Marine Labs, CA USA
2. Geological Survey of Canada, Sidney, B.C., Canada

During a recent scientific survey along the Queen Charlotte-Fairweather fault system, a transform plate boundary off British Columbia, Canada and Alaska, USA, seafloor fluid seeps, mud volcanoes, and chemosynthetic communities were discovered. Multibeam echosounder bathymetry, 3.5 kHz sub-bottom profile, 18 kHz sounder, piston core, grab sample, and bottom camera data indicate that significant volumes of fluid and gas is leaking into the water column along the southern half of the fault zone. While fluid seeps and mud volcanoes are ubiquitous along convergent plate margins, they are less so along passive and transform margins and these results suggest that such faulted landscapes could represent significant marine benthic habitats along the eastern Pacific Ocean.

We observed that a very large fluidized field marked by a newly discovered mud volcano, which displays a 700 m high gas plume from its 1,000 m crest located on the upper continental slope offshore Dixon Entrance (US/Canada boundary), harbors extensive chemosynthetic communities. These communities consist of Calyptogena spp. clams, Vestimentiferan spp. tubeworms, mussels, and Beggiatoa spp. bacterial mats. Carbonate slabs form hard substrate in an otherwise soft unconsolidated seafloor comprised of mud, glaciomarine sediments and boulders. The source and type of the gas is unknown, but we suspect that locally it is methane as indicated by the methanophillic organisms living near the vent sites. The presence of the chemosynthetic communities and carbonate substrate may play a major role in providing a forage habitat for fish, mammals, and other organisms. This habitat is most likely in flux and changing through time due to ephemeral fluid and gas escape. In addition, the seeps may contribute to greenhouse gases in the atmosphere and ocean acidification. Mapping these gas-rich habitats and identifying the associated benthic communities is critical to understanding the ecosystem value of these large areas.

First Direct Evidence Of A Deep-Water Cold-Seep Ecosystem Within UK Waters

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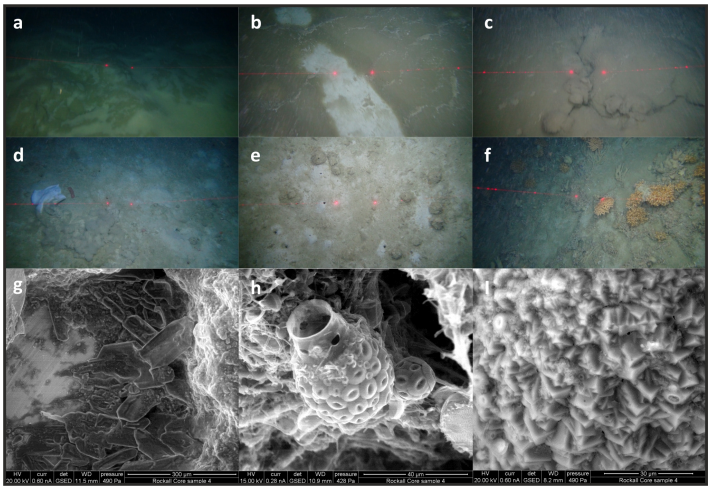
In 2012 Marine Scotland Science discovered two new species of chemosynthetic bivalve (Isorropodon mackayi and Thyasira scotiae) and a commensal polychaete (Antonbrunnia sociabilis) during a survey of Rockall Bank, 500km west of Scotland (Oliver and Drewery, 2014; Mackie et al., 2015). The discovery of these species suggested deep-sea cold-seep within UK waters. However, the precise location and size of the seep remained unknown as these new species were collected in 1200m of water during a 3 mile long trawl. This paper presents the results of an exploratory expedition in July 2015 which located and mapped the extent of the putative seep, hereafter referred to as the 'Scotia Seep'.



a) remobilised sediment; b) bacterial mats; c) active fluid expulsion and soft-sediment remobilisation at seabed; d) burrowing megafauna and anemones in bioturbated soft sediment; e) sponge aggregations on soft sediment; f) cold-water corals; g) gypsum/anhydrite crystals indicating sulphate-rich pore-waters near the sediment/water interface; h) vase-shaped coccosphere with more-typical round coccosphere adjacent on right; i) authigenic, magnesium-rich calcium carbonate precipitated on the surface of a foraminifera shell.

The Scotia Seep was located within an oceanographic furrow that forms an enclosed depression approximately 10km long and 3km wide in water depths between 1100m and 1200m. The first observational evidence revealed bacterial mats and extensive areas of remobilised sediment that form positive topographic features on the seafloor (Figure 1a-b). Evidence of active fluid expulsion at the seabed was also observed (Figure 1c) in addition to areas of suspended flocculent matter that obscured the seabed. The surrounding seabed habitats include areas of burrowing megafauna and anemones in bioturbated soft sediment, sponge aggregations on soft sediment and cold-water corals (Figure 1d-f). Macrofauna samples from the seep revealed a conspicuous lack of typical cold-seep fauna such as bivalves, polychaetes and crustaceans, with the dominant taxon being Nematoda. Amphinomid polychaetes dominated the smaller fauna recovered by the epibenthic sled, whilst burrowing anemones were abundant in the larger size group. Several chemosynthetic bivalves were also recovered and are being identified by collaborators at the National Museum of Wales.

Six megacore samples were frozen to preserve unusual stratification observed within the sediment and overlying water. Scanning Electron Microscopy revealed sulphur-rich pore-waters, precipitation of authigenic carbonate, evidence of magnesium rich-calcium carbonate and unusual shaped coccospheres (Figure 1g-i). Geochemical analysis suggested brine at the sediment/water interface, increased levels of sulphate detectable, but perhaps more interestingly a marked increase in concentration of base and heavy metals in particular copper, nickel, cobalt and arsenic within sediments immediately below the sediment/water interface. Uranium was detected as increasing from 5.36 µg l-1 at the sediment/water interface to 45.2 µg l-1 at a depth of 25cm below seabed. This may be related to precipitation of uranium at a redox front.

These analyses thus far indicate that upwelling, sulphurous and methane-rich fluids are being expelled at seabed on the western flank of Rockall Bank which supports a chemosynthetic community. This cold-seep is the first documented within the UK deep sea and the combination of unusual geochemistry and species suggests that it is quite different from the other cold-seep ecosystems in the north-east Atlantic.

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National Mapping Program Management And Data-Sharing

Relationships Between Geological Events And Submarine Habitats

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1. Geological Survey of Italy - ISPRA

The geographical distribution of habitats can be influenced by geological events. Submarine landslides and volcanic activity can disrupt the continuity of habitats or establish new ecological niches; they can also modify environmental conditions endangering peculiar species or allowing the onset of different biological communities.

In the frame of the EMODnet-Geology Project, the Geological Survey of Italy has the task to collect information regarding earthquakes, volcanoes, submarine landslides, tectonics, tsunamis and fluid emissions within Work Package 6 "Geological events and probabilities".

These data are relevant for territorial management and planning, particularly regarding coastal areas, but can also be used to infer their mutual relationship with physical habitats.

The Scopello area (Northern Sicily) is characterized by many submarine slides extending across the coastline, which indent the shelf so much as to interrupt the continuity of the Posidonia meadows.

However, seagrass meadows may locally contribute to stabilize sediments which are consequently less prone to slide downslope. This is one of the reasons why this habitat is protected.

Volcanic gas emissions enrich sediments with minerals that support the development of particular biocoenoses, as it happens in the active volcanic archipelago of Aeolian Islands (Northern Sicily).

In the Ligurian Sea a network of deep canyons, getting very close to the coast, was mapped, where mass movements take place; their presence enhances upwelling increasing primary productivity which attracts so many cetaceans that the Cetacean Sanctuary was established.

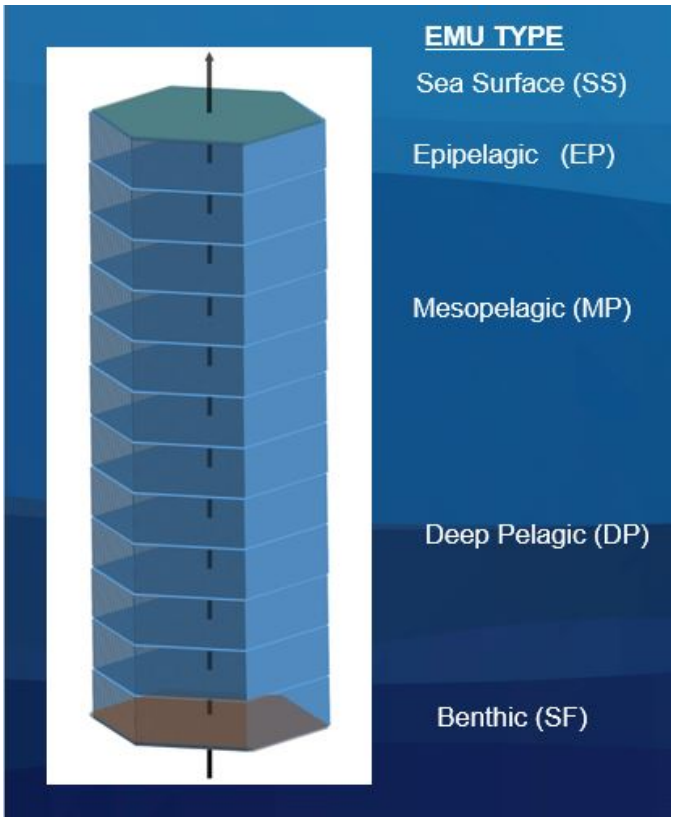
The calcareous banks of Southern Sicily, structural highs bordered by faults, allows the development of seagrass meadows and coralligenous build-ups.

The data collected would be further complemented by a morphological synthesis in order to better evidence the relationship between habitats and physiographic domains.

Ecological Marine Units Project Overview And Preliminary Results

Roger Sayre[1], *Dawn Wright*[2], *Pete Aniello*[2], *Zeenatul Basher*[1], *Sean Breyer*[2], *Mark Costello*[3] , *Doug Cribbs*[2], *Charlie Frye*[2], *Kathy Goodin*[4], *John Guinotte*[5], *Pat Halpin*[6], *Peter Harris*[7], *Mark Monaco*[8], *Lance Morgan*[5], *Drew* ***Stephens***[2], *Beata Van Esch*[2], *Randy Vaughan*[2]

1. U.S. Geological Survey
2. Esri
3. University of Auckland
4. NatureServe
5. Marine Conservation Institute
6. Duke University
7. UNEP GRID Arendal
8. National Oceanic and Atmospheric Administration



In 2014, a collaborative partnership between Esri and USGS was started to create a dynamic online map representing the world's ecological diversity at unprecedented detail and authority. This work, officially commissioned by the Group on Earth Observations (GEO), leveraged quantitative methods, geographic science, and big data produced by government agencies and the scientific community. To create this map the data were processed in Esri's ArcGIS Desktop and ArcGIS Online's cloud computing environment.

In 2015, additional resources have come together to continue this work into the oceans, known as The Ecological Marine Units. The EMU effort, led by Dr. Roger Sayre of the USGS, and Dr. Dawn Wright of Esri, is focused on the development of a standardized, robust, and practical global ecosystems classification and map for the planet's marine ecosystems. The EMU project is seen by GEO as a key outcome of the GEO Marine Biodiversity Observation Network (MBON) and is now one of the four components of the new GEO Ecosystems Initiative (GEO ECO), within its 2016 Transitional Workplan.

This paper will review methodology, data, products, and impacts of these projects on land and ocean managers worldwide, as well as provide initial findings, insights and use cases of these data. These data and map products provide new knowledge and understanding of geographic patterns and relationships by distinguishing the geography of the planets' terrestrial and marine ecosystems.

The paper will then review the need for such an undertaking, how initial data have been assembled in a 3-D mesh framework, and summarize the initial results and products, including; 1) Derived Pelagic "Seascapes" (water masses, fronts, and current "storms"), 2) Biological Attributes such as species distributions (from OBIS), Biogeographic realms (species endemicity), Seabed habitat and biotope maps (e.g., from EMODnet project) and 3) Layering in the Ocean, such as Thermoclines, Haloclines, and Pycnoclines.

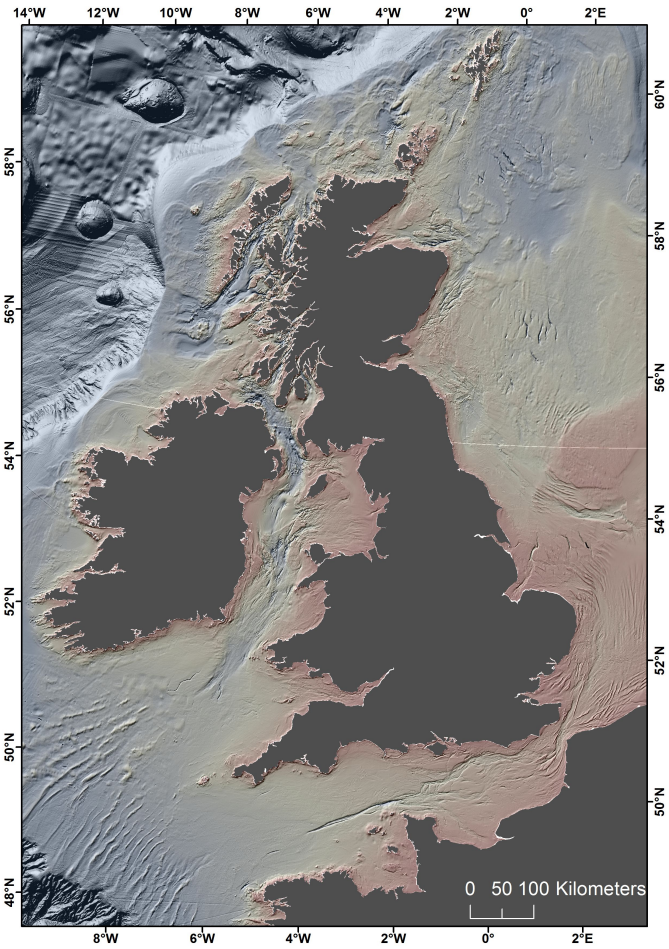
Lastly, the discussion will outline methodology for moving forward and including the contributions of the growing group of stakeholders.

Seabed Geomorphology: A New Generation Of Mapping

Dayton ***Dove***[1]

1. BGS Marine Geoscience

Within UK waters, and along the NW-European continental margin there is an extraordinary range of geomorphic features that reflect both former, and active processes. Tectonic cycles left a framework of broad-scale basins and ridges; Quaternary glaciation, through complex erosional and depositional processes left an extensive imprint on the seabed and shallow sub-seabed; And Holocene and modern hydrodynamics transformed, and continue to modify the seabed. Detailed and accurate mapping of these geological environments is important for a number of user-groups (commercial, academic, conservation, policy). For example, the designation and monitoring of marine protected areas (MPAs) requires the identification and characterisation of benthic habitats, which are underpinned and strongly influenced by the geological substrate. Characterizing the geomorphology of the seabed provides a powerful tool to understand the environmental processes which formed and actively govern the seabed environment, and to more accurately describe the present condition of the seabed. Mapping seabed geomorphology relies on a number of physical criteria (e.g. size, symmetry), as well as the association with the underlying geology and the interaction with the hydrodynamic environment. Early mapping (1970's-1980's) utilized broadly-spaced single-beam echo sounder and seismic data to depict regional-scale features, and more recent efforts have ranged from the local-scale (small swath bathymetry datasets), through to the global-scale using satellite-derived data. What is new, and increasingly the case in the UK for example, is the increasing availability of geographically extensive swath bathymetry datasets. These high-resolution data (∼0.5-20 m) not only permit geoscientists to better distinguish the origin of seabed features, they also cover sufficiently extensive areas that feature assemblages may be placed into the broader context of environmental systems. In contrast perhaps to terrestrial settings, the availability of such data in the marine realm is leading to many features being identified and described for the first time, calling for a renewed mapping effort. Further to this, geomorphic characterizations combined with groundtruthing and seismic data yield considerably improved shallow geological map outputs, including more accurate predictions of compositional/geotechnical properties. Making use of this data-rich environment, British Geological Survey (BGS) scientists are developing a new map series, 'Seabed Geomorphology', to join the existing 1:250k series (e.g. 'Seabed Sediments'). What is novel here, and useful for a survey organization, is to standardise the geomorphological classification scheme such that it is applicable to diverse environments and users (e.g. habitat mappers). The classification scheme is sufficiently detailed and interpretive to be informative, but not so detailed that we over-interpret or become mired in disputed feature designations or definitions. The maps will nominally be presented at 1:50k scale, but more focussed, as well as broad-scale characterizations will also be produced. For example, apart from swath bathymetry, recently improved regional compilations (e.g. EMODnet) may also support national and continental-scale mapping campaigns, for which there is persistent demand. It is intended that these maps (and associated spatial products and supporting documentation) will progress our fundamental scientific knowledge, while providing enabling resources for research, commercial, and educational purposes: facilitating improved applied science, and supporting better-informed management of the seabed environment.



EMODNET - Digital Bathymetry Model

Seabed Mapping To Support Management Of The Australian Marine Environment

Brendan ***Brooke***[1]*, and Scott Nichol*[1]

1. Geoscience Australia

Australia's marine estate totals 13.86 million square km, the third largest in the world. It encompasses shelf and offshore waters that surround the continent, extensive areas of the Southern Ocean and the marine extent of the Australian Antarctic Territory. A focus area for marine planning and management is the continental shelf around the mainland, which extends across 33 degrees of latitude and 40 degrees of longitude and mostly forms a broad, shallow sea (0 - 250 m). The shelf ranges in width from a few km (e.g. southern NSW) to hundreds of km (e.g. north western WA); and from flat and mostly sediment covered (northern WA), to rocky and rugose (southern Tasmania). Its waters are tropical to cool temperate, predominantly oligotrophic and range from high-energy, wave dominated in the south to tide dominated in the north.

The Australian continental shelf holds petroleum, fisheries and environmental assets of great economic value, with marine industries contributing around $44 billion to the national economy each year, which is expected to increase to $100 billion by 2025. However, the marine environment is also of great social and ecological significance, which requires development to be managed in an effective and sustainable way.

Information derived from multibeam sonar and underwater camera systems, seabed samples and satellite observations of the sea surface provide some of the few spatially extensive sets of environmental data available for the marine estate. Over the last 15 years, Geoscience Australia (GA) has been acquiring, collating and analysing these data to improve knowledge of the environmental characteristics and natural resources within the estate. A major driver of this work has been the information needed by the Australian Government to develop Marine Bioregional Plans that underpin management of the estate, and the establishment of a network of Commonwealth Marine Reserves (CMR), both key elements of Australia's Biodiversity Conservation Strategy.

GA acquired and collated a wide range of seabed data to inform the environmental characterisation of the four Marine Bioregions and the establishment of the network of 25 CMR, which cover 3.1 million square km. More recently, further insights into shelf environments derived from new seabed data and marine process models (e.g. the dispersal of larvae within submarine canyons; connectivity between regions) have been used by Government to refine management of marine reserves on the NW Shelf and inform the current review of the internal zoning of all the CMR.

This talk will outline current seabed mapping activities being undertaken by GA, which include: enhancing the discovery of, access to and value of seabed data; contributing to the Australian Government's Marine Biodiversity Hub; strategic, collaborative data acquisition projects; and the environmental component of the national offshore precompetitive data program.

Applications Of High Resolution Coastal Data For Monitoring Coastal Instability, Hazard Risk Management And Substrate Mapping

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1. Coastal and Marine Projects Team Leader, Channel Coastal Observatory
2. Geologist, Marine Geoscience Programme, British Geological Survey
3 Coastal Survey Team Leader, Channel Coastal Observatory.

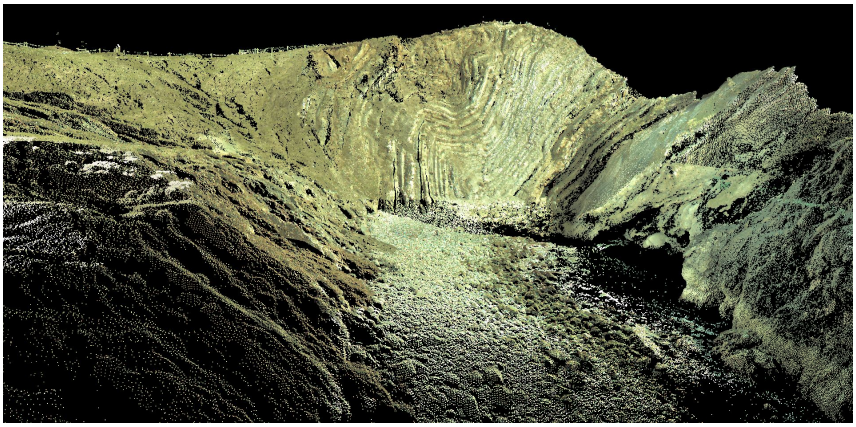
The Defra-funded National Network of Regional Coastal Monitoring Programmes of England are utilising topographic laserscan, airborne lidar and swath bathymetry technology to cost-effectively survey the coast and nearshore zone in high resolution and increasing spatial and temporal coverage to consistent specifications.

Advances in ground-based and mobile laserscanning data collection technology and processing have made these repeatable monitoring techniques increasingly viable, enabling specific issues in the coastal zone to be focussed on in unprecedented detail. For example, allowing identification and mapping of geomorphological features, coastal defence asset inspections, rapid response and incident management, and coastal erosion risk management.

The regional monitoring programmes are utilising high resolution swath bathymetry systems to achieve 100% seafloor coverage of large areas of the nearshore zone at metre-scale horizontal and centimetre-scale vertical resolution, extending from approximately Mean Low Water Springs (MLWS) to about 1km offshore, ensuring an overlap with aerial photography, Lidar, and beach topographic surveys. Interpretation of these bathymetric data and the accompanying acoustic backscatter and ground-truthing data has opened up new opportunities to understand and address a range of coastal engineering and shoreline management issues, as well as contributing towards wider scientific initiatives.

The integration of land-based topographic laserscan and nearshore swath bathymetry with other monitoring data, coupled with developments in visualisation technologies, have contributed to improved understanding of interactions between natural coastal process with coastal defence and beach management operations, and monitoring the impacts of human activities and site recovery in both terrestrial and marine environments. Temporal and spatial analyses of coastal and marine monitoring datasets are also enabling coastal geology maps to be re-interpreted and extended offshore. These provide a more complete picture of the baseline geology, physical properties, structure and geohazards in the coastal and nearshore zone, substrate discrimination and seamless onshore-offshore geological maps.

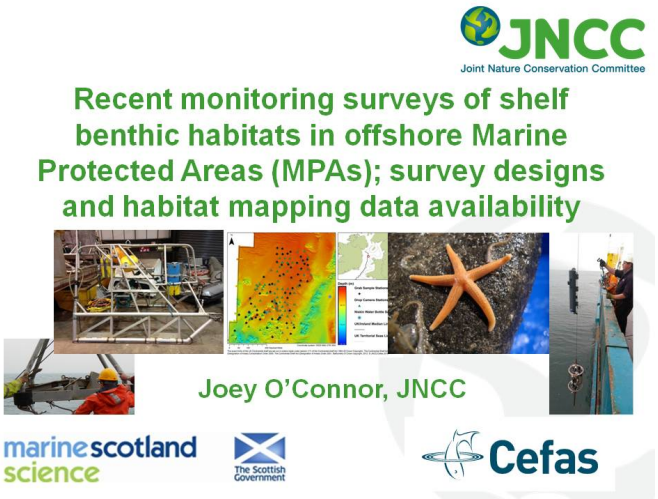
These freely available publicly-funded data and resulting GIS layers are being utilised through effective pan-governmental agreements, by government departments, public and private sector organisations and academic institutions, for a wide range of applications. Examples will be presented from eastern and southern England where coastal and marine data have contributed to the multi-disciplinary scientific evidence base to inform development of shoreline management, coastal instability and erosion risk mapping, improves our understanding of seafloor environments and informs the sustainable use and management of marine resources.



Recent Monitoring Surveys Of Shelf Benthic Habitats In Offshore Marine Protected Areas (MPAs); Survey Designs And Habitat Mapping

Joey ***O'Connor***[1]

1. Joint Nature Conservation Committee (JNCC)



JNCC is the public body that advises the UK Government and devolved administrations on UK-wide and international nature conservation.

JNCC carries out benthic surveys to gather evidence needed to support its role as a key advisor to the government on nature conservation. Evidence gathered is used in a variety of ways. These include informing development of monitoring for protected habitats and features both within and out with MPAs, as JNCC is responsible for monitoring benthic habitats within the UK offshore region (>12nm), in addition to leading on the development of an integrated UK-wide Marine Biodiversity Monitoring Programme incorporating territorial waters.

This presentation will describe benthic habitat monitoring surveys carried out by JNCC, in collaboration with Cefas and Marine Scotland Science, in different shelf habitats in UK MPAs over the past 24 months. Survey design, methods used and data collected from five surveys carried out will be outlined.

Shelf habitats surveyed include: Muds, Sands and Gravels, Bedrock Reef, Carbonate Reefs

The presentation will highlight how data collected on these surveys can be accessed to facilitate use by the habitat mapping community and others, in alignment with the 'collect once, use many times' principle.

Habitat Map Collation And Data Standardisation From A UK And European Perspective - JNCC's Work Within The UK And With EMODnet

Graeme ***Duncan***[1]

1. Joint Nature Conservation Committee, UK.

As part of its statutory responsibility for providing advice to Government on nature conservation, Joint Nature Conservation Committee (JNCC) undertakes regional and national-scale analyses relating to marine habitats. Invariably, these analyses require the collection and combination of large numbers of habitat maps, arriving from a variety of organisations and received in a variety on formats. As an organisation experienced in the management of large datasets, JNCC has been active both in mitigating these potential pitfalls within their own data holdings, and in driving data standardisation and increased data sharing at a European Level, developing data schema specifications that have proven successful over many years. Over the past three years, JNCC has been involved in the Seabed Habitats lot of the EMODnet initiative, and through EMODnet has continued to promote habitat mapping standards and data sharing to meet the requirements of Europe-wide data users.

The presentation will describe the work undertaken both currently and in the past in habitat map data standardisation and collation, and how this work has led to significant improvements in the provision of best available evidence in a variety of end-products via repeatable processes that are able to be run on a single initial data pool. It will explore how the MESH data formats have eased the need for re-processing of habitat maps ("ingest once, use multiple times" principle) and how the promotion of both these standards and the sharing of habitat maps in a European context through EMODnet Seabed Habitats has initiated and will build upon a resource that can be used to drive European policy and management of the sea. Finally it will consider the future of marine habitat data in relation to both the EMODnet initiative and the EU INSPIRE directive.

Using Habitat Maps To Develop Monitoring Options For The Deep-Sea As Part Of The UK Marine Biodiversity Monitoring R&D Programme

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The UK Government aims for a coordinated and integrated monitoring scheme for all marine biodiversity components across all UK waters. To move towards implementing such a scheme, the Joint Nature Conservation Committee (JNCC) in partnership with the UK country conservation bodies are developing monitoring options for UK benthic habitats that can provide sufficient information to advise on the management of human activities whilst also fulfilling national and international obligations for monitoring and assessment. For each habitat, the options identify monitoring requirements in terms of what to monitor (which type of monitoring), where to monitor (which areas to prioritise) and how to monitor (which parameters to monitor) as well as costings for each proposed monitoring option.

We here demonstrate how habitat maps were used to develop such monitoring options for the UK deep-sea benthic habitats. Benthic habitats were defined based on the UK deep-sea habitat classification system (1). Extent and distribution of the broad physical habitats (e.g. Atlantic upper bathyal mud) were derived from readily available national data collations (UK Annex I Reef dataset - (2)) and broad-scale mapping products (EUSeaMap seabed substrate layer - (3)). Combining information on habitat extent and distribution with information on a habitat's sensitivity and exposure to human pressures, the relative risk of each habitat being impacted by anthropogenic pressures was evaluated and priority locations for monitoring identified. Pressure footprints were estimated using a combination of qualitative and quantitative assessments. For pressures for which GIS pressure layers were available (e.g. surface abrasion caused by demersal fishing gear), the spatial extent of the pressure footprint was quantified based on the mapped habitat extent. For pressures for which pressure layers do not exist, spatial information on human activities was used as a proxy to obtain estimates of pressure footprints. To prioritise deep-sea habitats with higher monitoring requirements, a distinction was made between habitats at relatively greater and lower risk of being adversely affected by human pressures based on the current UK approach for assessing the status of benthic habitats protected under the EU Habitats Directive'.

We will describe this approach, discuss the advantages and drawbacks of it and ask the scientific community for feedback on our approach.

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Making Natural England's Marine Evidence Available To All.

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Aside from the science of collecting and analysing data for habitat mapping, increasing emphasis is now being put on how marine evidence is used, made available and disseminated to a wider audience. Adding value to data through sharing and using it many times is encouraged.

Through the 'marine evidence project', Natural England carries out the cataloguing and mapping of data collected in-house, surveys it has commissioned, or obtained from third parties. Using a series of standardised protocols, these data are analysed and interpreted in house and will then contribute to the management of Marine Protected Areas (MPAs).

There is now a commitment by the UK Government's Department for Environment, Food & Rural Affairs (DEFRA) 'Open data initiative' to ensure public accessibility to data by publishing 8000 datasets online by June 2016. Existing obligations under the EU Infrastructure for Spatial Information (INSPIRE) will enable the sharing of environmental spatial information across Europe, and facilitate easier access to these datasets by members of the public.

Driven by these obligations, and as an evidence based organisation with a commitment to making data publically available, Natural England has been working closely with organisations such as the Marine Environmental Data and Information Network (MEDIN) to ensure that data meets marine data standards. Utilising existing platforms for data sharing such as the European Marine Observation and Data Network (EMODNET) and the UK Government's 'MAGIC' web portal ensures cost effectiveness and ensures that the datasets contribute to a wider body of evidence.

The marine data that Natural England publishes is used by a wide variety of people and organisations for different reasons. Internally within the public sector the data is used by local staff for planning and casework, conservation advice, the drafting of site management plans and the designation of new MPAs. Externally, the data is publically available to view online, and attributed to give as much information as possible on each habitat polygon that is mapped. The evidence is regularly updated with new survey information as it is received, ensuring that decisions concerning the marine environment are made using the best available evidence.

Anthropogenic And Natural Disturbance Effects On Marine Habitats

Rapid Mapping For Environmental Monitoringand Resource Assessments In The Deep Sea

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The deep sea is the largest ecosystem on earth but still studied to small extent. Pressure on this ecosystem is increasing with ever deeper-aiming oil and gas exploration and possible mining activities for Mn-nodules in the Clarion-Clipperton Zone (CCZ; 4200 and 5000m water depth). Ongoing international projects (e.g. MIDAS in FP7 and Mining Impact in JPIO) invest in advancing methodologies for reliable and repeatable studies with cutting-edge technology, they aim for a better understanding of the deep sea ecosystems as such and possible impacts induced by mining activities. In addition, these projects also intend to inform the ISA about the best possible monitoring strategies and best practices for chemical and biological studies.

During three cruises with RV SONNE to different license areas in the CCZ and the DISCOL area in the Peru Basin (SO239 & 242 in 2015), ship-based (EM122, 0.5°x 1°) and AUV-based multibeam systems (RESONS 7125, 1°x 1°) were used in combination with AUV-based sidescan (EDGE-Tech, 120kHz) and camera surveys (fish-eye lens camera with dome-port) for detailed habitat studies. ROV dives and towed camera surveys with real-time annotation capabilities were employed for a fast, on-the-fly assessment of small-scale seafloor habitats. In particular the AUV proved to be an excellent tool for larger-scale acoustic mapping and highly detailed photo-mosaicking.

In several areas in the CCZ, small-scale disturbance experiments had been performed to study sediment plume settling and the impact on the benthic ecosystem. Cruise SO239 revisited some of these areas and used the AUV sidescan to map plough/tow tracks of epibenthic sled or sediment-disturbance tools that had been used some months and nearly 30 years before, respectively. All old tracks were still clearly detectable. Immediate processing on board helped provide detailed maps for subsequent TV-guided sediment sampling and ROV investigations. Photo-mosaicking prior to and after epibenthic sled deployments during the 2015 cruises showed that sediment re-deposition occurs very close to the disturbance track; slow currents of about 5cm/s transported sediment for about 30m downstream. This became clear after applying automated Mn-nodules counting algorithms for AUV image analysis. The images were made one every second while the AUV was flying at 4 to 8m altitude capturing a well illuminated area of up to 250m^2 per image. Photogrammetric 3D reconstruction of plough tracks in the DISCOL area (ploughed in 1989) show an almost unchanged morphological expression of the tracks. Large-scale photo-mosaicking (700 x 500m) provided highly accurate distribution information on sessile and motile fauna in, next to and further away from the plough tracks. Such AUV-based studies have strong advantages in comparison to smaller-scale towed video/photo surveys; they cover a large area completely and linked to bathymetric information and applying accurate post-navigation processing (LBL; DVL/INS) the area can be geo-referenced precisely. Covering the same area repeatedly allows comparing exact same seafloor areas helping to identify changes over time without ambiguity for ecosystem monitoring tasks. Real-time annotation of videos and rapid annotation of key species using the web-based annotation software BIIGLE-DIAS during the cruise allowed rapid mapping of the small scaled habitats in the deep sea.

Rapid Assessment Of Manganese Nodule Abundance

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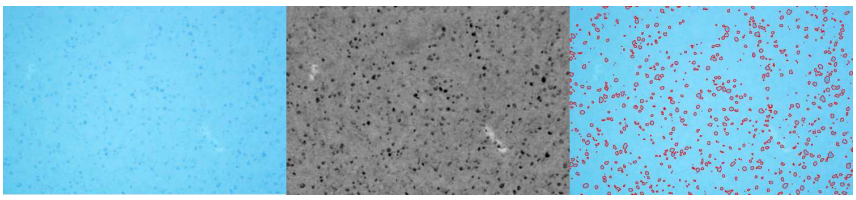
Interest in deep benthic manganese nodule exploitation has generated the need to rapidly assess not only the abundance of resources but also the state of the abyssal habitat. While high-resolution multibeams and sidescan sonars provide a large overview over areas of mining interest, visual images can link these acoustic data to ground truth observations using physical sampling gear (BoxCorer, MultiCorer).

Measuring nodule abundance is important to determine profitable mining areas as well as to link this information with environmental parameters. Geologists and geochemists require to link localized measurements with nodule coverage. Biologists are interested in large area nodule abundance overviews to assess habitat connectivity and to link species distributions with nodule coverage. Possible protectorates, where mining would be prohibited, would need to be selected by species abundance and thus also based on nodule abundance to allow for re-colonization of mined areas.

Assessing nodule abundance is can by done manually with only a few images. Large aerial overviews of nodule coverage can only be determined using (semi-)automated methods. Several algorithms have been proposed that rely on field expert knowledge (e.g. by a geologist), a computer scientists or are fully automated. While these methods can extract nodule abundance data from images with sufficient accuracy, the computation times can slow down the data extraction process, especially when modern AUVs are employed that can acquire visual image data at a rate of 1 image per second.

To allow for real-time processing of the acquired visual data, a rapid image processing algorithm has been implemented that makes use of massive parallel data processing on common desktop computer graphics cards. The algorithm was tuned for images created with the new DeepSurvey Camera system on board the GEOMAR AUV Abyss and showed to be applicable to other data sets, obtained by towed camera platforms as well.

Using the new algorithm allows to assess nodule abundance over square kilometer scales in reasonable time. It can be used on board research vessels to determine important sampling locations during expeditions and will be applied to all image sets acquired during the JPIOceans expeditions (SO239, SO242/1 and /2).



To the left, the input image for the algorithm. Shown is the central part of an image acquired by the camera on board the AUV (which flew at 8.3m altitude; the image crop has a footprint of 43.8 m^2). The middle part shows an intermediate result of the algorithm after contrast enhancement. The right part finally shows the detection result by outlining the individual nodules. By knowing the pixel-to-centimeter ratio for each image, nodule size can be measured in square centimeters, allowing to assess not only nodule coverage (here: 723 nodules, coverage of the seafloor 5.6%), but also nodule size frequencies per square meter (here: median nodule size 14.4 cm^2, maximum size 143.4 cm^2).

Physical Disturbance Along The Gioia Canyon (Southern Tyrrhenian Sea): Sedimentary Processes And Human Activities

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Shelf indenting canyons receiving sediments from fluvial input and/or along-shelf transport can be sites of organic enrichment that, along with the heterogeneity of substrates, represent favorable environmental conditions for several benthic organisms. However, these canyons can be also affected by a high degree of physical disturbance, related to the enhanced sediment transport processes, including sporadic turbidity flows. Physical disturbance can be also caused by human activities since submarine canyons often represent preferential targets for fishing and may act as main vectors transporting litter and pollutants to the deep sea. The Gioia Canyon, along the Tyrrhenian Calabrian Margin (Southern Mediterranean), is an active submarine canyon indenting the continental shelf up to very shallow depths of about 10 m. The canyon head is located in front of the Gioia Tauro Harbor, at $<$ 100 m distance from the coastline.

Research cruises in the framework of the Ritmare Project collected an extensive dataset along the Gioia Canyon, including multibeam data, video surveys, sediment samples and oceanographic measurements. Main results suggest a key role of the morpho-sedimentary processes on the composition and distribution of the benthic communities. High sedimentation rate along the continental shelf reflects in a widespread distribution of soft-bottom habitats, colonized by sea pen assemblages. Increased sedimentation rates and occasional turbidite flows along the shallower sectors may limit megafauna colonization along specific sectors of the canyon. Beyond the shelf break, lower sedimentation rates and more stable environmental conditions support communities that include Isidella elongata, Kophobelemnon stelliferum and Funiculina quadrangularis, species recognized as indicative of Vulnerable Marine Ecosystems. New ROV data were also acquired in December 2015, aimed to constrain the effect of trawling disturbance on the benthic fauna; the spatial distribution of the fishing effort was determined from Vessel Monitoring Systems data. ROV observations provided clear evidence of diffuse trawl marks over soft sedimentary bottoms. Intense trawling activity may explain the low abundances of megabenthic species observed locally, although the relationship between faunal abundance and intensity of fishing effort is not always univocal.

Moreover, an on-going assessment study on the human impact along the Gioia Canyon is actually showing remarkable quantity of litter within the thalweg area. New data will be collected during a forthcoming oceanographic cruise in February 2016 with the aim to evaluate litter abundance and composition along the canyon, and its potential impact on the benthic communities.

Potential Mining Waste Impacts On Coastal And Shelf Habitats: Mariana Disaster- Brazil

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On November 5th, 2015, a major environmental disaster caused by the rupture of an iron mining waste dam ocurred at Mariana city, Minas Gerais State (Brazil). The disaster dumped about 50 million cubic meters of waste in a valley leading to the destruction of villages, killing at least 25 people, destroing homes, affecting an entire society and local economy. In addition, the waste moved by tributaries reaching the Doce river basin, one of the most important rivers in Brazil (5th largest). All this damage caused economic, environmental and public health problemsthat are not yet fully understood. On November 21st, the high suspended particulated matter concentrated water, with the contaminated mining waste reached the mouth of the Doce river. Since then, a sediment plume is being dispersed and materila is accumullating on the seabed. Initial observations show a characteristic color appearance and suspended particulate matter (SPM) different than normally observed. The presence of SPM in the water column along a continental shelf adjacent to a river mouth is common and is part of the coastal ecosystem. However, the material that is reaching the continental shelf in question, is a mining waste, which causes concern and uncertainty, especially in terms of particle size, sediment composition (including heavy metals) and nutrient inputs. The adjacent beaches are famous for marine turtle nesting grounds and the adjacent shelf is a very importante shrimp fishing spot. This study aims to present data and analysis of samples taken on the shelf just after the waste material reached the coast and dispersed across the shelf. Vertical profiling were performed in the water column collecting water samples in three depths (surface, middle and bottom) to determine the concentration and particle size of the SPM. A total of 10 stations were collected on the 22nd and 16 stations on the 24th. Some points have been resampled, but overall the sampling strategy was to follow the displacement of waste plume. In terms of SPM concentration, on the 22nd, profile 1 (further north) exhibits higher values, circa of 9g / L close to the bottom (8m deep) and profile 2 showed values of 1 g / L, still high values. On the 24th, Profile1 showed a higher concentration near the bottom, circa of 3 g / L at 4m deep and near the coast. Profiles 2 and 4 (further South) did not show high turbidity values and profile 3 has a high concentration at the botton (8m depth). In terms of the SPM particle size, the results show that na extremely fine material with high clay concentrations sometimes over of 50% of the sample. This is completely different from previous conditions studied before the disaster. Moreover, after 4 days, bed sampling has already shown accummulation of waste material on the bed. This material is altering the sediment bottom characteristics. The large and continuous amount of material coming into the shelf might also increase sedimentation rates in the área, which will lead to a significant change in marine habitats. The impact on benthic and planctonic communities is a working in progress.

Cold-Water Coral Habitats On The Southern Iceland Shelf: Mapping, Prediction And Anthropogenic Impacts

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The continental shelf south of Iceland is intersected by several troughs (200-300 m deep). These troughs, formed by former outlet glaciers originating from the Vatnajökull ice cap, are dominated by sedimentation of fine materials. Between these troughs there are shallower bank areas characterized by coarser sediments of glacial origin. The presence of cold-water corals in the southern Iceland shelf has been known since early in the 20th century. The BIOICE project (1991-2004) provided the first coherent view on the distribution of corals within Icelandic waters. During the last decade, the Marine Research Institute of Iceland (MRI) has carried out a series of surveys with the objective to characterize cold-water corals habitats, mainly dominated by Lophelia pertusa, and map their distribution. High-resolution bathymetry and backscatter were obtained using a multibeam echosounder. Underwater video and photographs were collected along 106 transects, with focus on locations where fishermen reported the presence of L. pertusa. Cold-water coral habitats were observed at the mouth and the flanks of the troughs, and on several locations on the continental slope. The morphology of the cold-water coral habitats was diverse, from isolated colonies to very large continuous reefs.

In order to better understand the factors that influence the distribution of cold-water coral habitats, we used Maximum Entropy (MaxEnt) to model the distribution of L. pertusa on the southern Iceland shelf at a high (50m) spatial resolution, as a function of bathymetry and terrain analysis variables, as well as oceanographic parameters derived from the CODE ocean model. The model identified the southern shelf break and troughs, as well as the Reykjanes ridge, as suitable areas for L. pertusa, which agreed with the observed distribution of L. pertusa records obtained by the BIOICE project and during the MRI surveys. Predicted distributions were compared with high-resolution fishing effort maps derived from electronic logbook and vessel monitoring system data, and with observations of anthropogenic impacts obtained during the surveys. Although there was a considerable overlap between predicted L. pertusa suitable areas and fishing effort, thriving L. pertusa habitat was only observed in locations where the fishery did not operate, highlighting the susceptibility of these habitats to human impacts.

Regional Analysis Of The Distribuon Of The Invasive Red Lionfish (Pterois Volitans) Of Fthe Coast Of Eleuthera, The Bahamas

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The Indo-Pacific red lionfish (Pterois volitans) is a predatory species that was introduced to the western Atlantic through the aquarium trade. First appearing off the coast of Florida in the mid-1980s, lionfish have now spread up the east coast of the USA as far north as Rhode Island and throughout the Gulf of Mexico and greater Caribbean region. Field experiments have documented that lionfish have devastated populations of many native reef fishes. One study found that the presence of lionfish decreased the recruitment of over 50 native species by 90%. Current work on lionfish in the invaded range includes examining the effects of lionfish on native reef communities, exploring potential biotic resistance to the invasion from native species, and studying the effectiveness of lionfish removals by divers.

Lionfish are habitat generalists. Studies conducted in both their native and invaded range have shown lionfish using aggregate and patch reefs, soft sediment, sea grass, mangroves, artificial structures, and estuaries, in all cases wherever natural or artificial physical structure is present. Their habitat and depth range change from the juvenile to adult stage and they have been shown to travel substantial distances between isolated patch reefs.

This study focuses on the Southwestern coast of the island of Eleuthera in the Bahamas. Using generalized linear models (GLMs) and generalized linear mixed models (GLMMs) we will develop a species-habitat model for lionfish using SCUBA based observations. These will then be related to variables such as availability of prey as well as variables derived from high-resolution bathymetry DEMs derived from satellite images. These models can then be used to extrapolate the distribution of this highly invasive species outside of the study area. Because human removal is the only process found to be effective in curbing lionfish populations, predictive maps of high lionfish densities will help management to run an efficient removal program.

Estimating Benthic Trawling Effects Using VMS Dataset, Macrofauna Sampling, Seabed Acoustics And Visual Observations

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This study is aiming at demonstration of benthic trawling effects on the seabed of the central Baltic at small (<5 m) and larger (>1 nm) spatial scales combining Vessel Monitoring System (VMS), acoustic, ROV and benthic macrofauna data. During the first phase of the study, 5 years VMS data were collected and spatial distribution of benthic trawling intensity was estimated using 1x1 nm grid. Although long-term trawling intensity average was 13.7±0.7%, locally maximum trawling intensity reached over 200% per grid cell. These results indicated high patchiness and temporal stability of benthic trawling effects.

During the second phase of the study, correspondence between trawling intensity levels estimated from VMS data and data collected by multibeam echosounder (MMBS) during the field surveys was analysed. The results showed relatively good agreement between MMBS and VMS data ($r=0.79$, $p<0.01$, $n=14$) within approx. 20 nm long transect, however this relationship was valid in grid cells with acoustic coverage of trawling tracks less than 10% only. MMBS data also served for detailed analysis of trawling tracks based on accurate measurements of track width and depth. These measurement revealed up to 0.3 m deep and 2-4 m wide tracks produced by mobile bottom trawl doors on the surface sediment, however disturbance level of surface sediment differed significantly between seabed types.

Finally, with the help of vessel dynamic positioning system, benthic grabs and ROV were deployed for spatially precise sampling of trawling tracks in depths of 55-70 m. Seabed observations with ROV confirmed presence of dense Beggiatoa colonies within these tracks indicating increased flux of sulphides in exposed sulphide rich deeper sediment layers. Benthic macrofauna data indicated azoic sediment within such tracks and a gradient of different recovery stages of benthic community towards control sites. Although larger datasets are needed to justify observed patterns, this study shows, that satellite based VMS data may complement detection of benthic trawling spots, which indeed may have high degree of correspondence with in situ estimated seabed disturbance level including both seabed surface geomorphology and macrofauna structure.

Hidden Heterogeneity: Novel, Spatially Explicit, Habitat Quality Assessment To Better Inform The Development Of Boating Infrastructure

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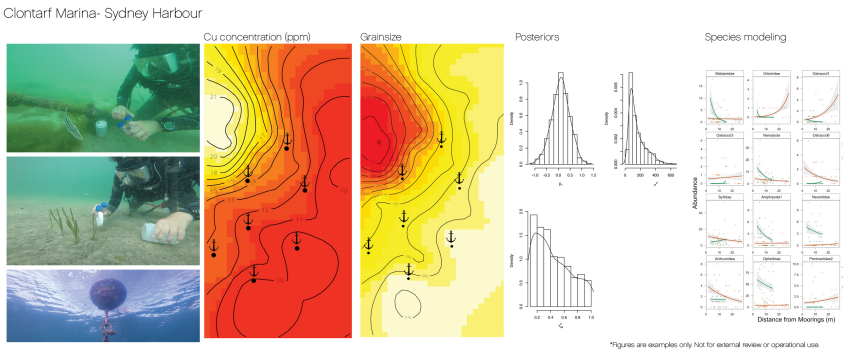
Understanding changes to the spatial distribution of natural habitats is essential for measuring the impacts of human activities. Measuring change in response to human activities has mostly taken the approach of examining the presence or absence of a given habitat (e.g. vegetation or reef present or absent), or the structure of communities in potentially impacted and control sites (e.g. BACI type designs). While this methodology is rooted in pragmatism, and in some cases policy and regulation, it fails to account for fine- and landscape- scale spatial variation in habitat quality or the ecological functions that the target habitat provides (e.g. food resources, nutrient recycling, or pollination services).

Habitat degradation in seascapes can act to create a mosaic of patches of varying habitat quality, each with varying suitability to the species it supports. Physical disturbance of benthic habitats, nutrient and heavy metal contamination and fishing efforts are spatially variable and can lead to a 'hidden' layer of heterogeneity in the seascape that goes beyond the obvious presence or absence of a habitat type. Policy makers are now calling for spatially explicit methods for quantifying these heterogenous human impacts in marine and estuarine systems.

We conducted a novel GRTS based survey design in Sydney Harbour, Australia, to quantify the spatial variability of metal contamination, sediment size, fish, invertebrates, and seagrass in and around recreational boating infrastructure. In one of the biggest studies of this type, we use multivariate species modeling, and bayesian spatial frameworks to show nuanced and complex spatial patterning around scattered boat moorings in the Harbour. This project showcases several newer technologies in the academic research space, such as diver mounted USBL and communication systems. We discuss the implications of this research for boating infrastructure design and development in a complex, urbanised, world



Modelling The Impact Of Tidal Energy On The Benthic Environment At Ramsey Sound, Pembrokeshire

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It is well understood that renewable energy can play an important role in tackling climate change and global warming. However, with the marine environment already under increasing pressure from anthropogenic sources, marine renewables need to be deployed sensitively to avoid being a hindrance.

As tidal energy is only just becoming commercially viable, development of array scale projects are restricted to a number of key geographic locations with promising resource availability, one of which is Ramsey Sound. The Sound is being used to test the prototype of the Delta Stream by Tidal Energy Ltd. After successful testing, a 10 MW tidal array will be constructed at St David's Head. To date, only single tidal turbines devices have been installed to demonstrate the application of the technology. In the absence of array scale developments, the interaction between the array and the benthic environment is still subject to speculation.

This paper presents the results of an impact assessment of the 10 MW tidal array at Ramsey Sound on the benthic environment. This has been achieved through the use of the species distribution modelling software MaxEnt. It has been shown that tidal turbines will influence local hydrodynamics which are a driver for morphodynamics. Changes to the morphodynamics will lead to a change in the sediment class distribution leading to change in the benthic habitat. For example: an increase in sediment accumulation could lead to the burial of benthic species. As such, nine non-mobile species were identified for modelling: Alcyonium digitatum, Axinella dissimilis, Bugula turbinata, Dendrodoa grossularia, Eunicella verrucosa, Flustra foliacea, Nemertesia ramosa, Pachymatisma johnstonia and Raspailia ramosa. These species represent hydroids, bryozoans, soft corals, sponges and ascidians commonly found on reefs within the Pembrokeshire Special Area of Conservation and the Skomer Marine Nature Reserve.

Environmental variables used within MaxEnt included: depth, mean and maximum bed shear stress (over a spring neap cycle), annual mean wave height, mean summer and winter suspended particulate matter, grainsize and gravel, sand and mud fraction. The hydrodynamic parameters and influence of the tidal turbines were determined through a hydrodynamic model, as detailed in (1). A prediction of the grainsize was made by back calculating the threshold of motion from the mean velocity over the spring neap cycle and determining the smallest grainsize that can be deposited. A prediction of the gravel, sand and mud fraction was made using the Random Forest algorithm (2).

The impact of the tidal turbines was determined by the change in the total area of each species with and without the presence of the tidal turbines. Results showed that whilst the presence of the tidal turbines resulted in a loss of habitat for each species, it also created areas of new suitable habitat. The percentage difference of habitat lost, for all species, ranged from 0.30% to 5.47%. The net percentage change in area ranged between -0.91% and 1.65%. Therefore, the results show, in this location, tidal turbines will not adversely affect the benthic environment.

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Role Of Oceanography In Habitat Mapping

Improving Benthic Biotope Maps With Oceanographic Data

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Biotope maps produced for Norway's MAREANO seabed mapping programme have, until recently, been produced using models employing bathymetry data and derived terrain variables, broad scale geomorphic classifications and sediment grain size maps as predictor variables. Whilst these topographic and geological variables may adequately explain the distribution of benthic communities within limited geographic areas, as we expand the extent of biotope maps it becomes more and more apparent that the oceanographic conditions near the seabed (i.e. temperature, salinity, bottom currents) may be able to increase the variance explained by our models. A first biotope model produced by MAREANO in 2014 confirmed the importance of benthic 'climate' in predicting the distribution of benthic biotopes from the shelf and shelf edge in the southwest Barents Sea. In this and subsequent MAREANO analysis and fieldwork it seems that oceanographic differences are important in explaining the distribution of benthic communities, especially where terrain and/or surficial geology may otherwise be similar.

In the early days of habitat/biotope mapping oceanographic model data were often dismissed as being too coarse, and/or providing information only on surface conditions. However, recent advances in computer power and storage have allowed for higher-resolution ocean circulation model simulations that resolve the dynamics on the mesoscale (10s metres to 1 km). MAREANO has recently gained access to modelled oceanographic datasets from ROMS (Regional Oceanographic Modelling System - www.myroms.org) at 800 m (NorKyst-800) and 4 km (Nordic-4) resolutions. Whilst neither of these datasets offers the resolution typically required to capture processes in the coastal zone, these types of intermediate resolution oceanographic datasets may be worth further consideration for offshore mapping as the mapped areas increase in size, and/or when mapping areas with limited topographic and geological variation, even when mapping at the mesoscale and finer.

We present some results from our analysis of the oceanographic datasets in the general context of benthic habitat mapping and evaluate to what extent they may help improve biotope maps produced by the MAREANO programme. We examine what effect oceanographic data resolution may have on our ability to predict biotope distribution, and also examine which oceanographic variables appear to be most relevant to explaining this distribution. We also consider the role of topographic and geological variables as predictor variables in light of these new oceanographic data.

Interaction Between Habitat And Oceanographic Variables Affecting The Connectivity And Productivity Of Abalone Populations

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A better understanding of the links between benthic habitat, oceanography and fisheries productivity is imperative to improving sustainable management of important fishery species. These links can be identified by associating drivers of fisheries productivity with a combination of factors determining dispersal, settlement, survivorship and growth in early life. However, the recruitment and persistence of stocks and the potential impacts of fishing are often species-specific and dependent on spatial context. By using recent advances in geospatial, oceanographic modelling, ecological modelling, and habitat assessment, we incorporated local variation into models of recruitment and persistence in commercially important abalone (Haliotis rubra) fisheries along the coastline of Victoria, Australia. Multibeam and Lidar bathymetry data already available along the coast were used to downscale hydrodynamic models (wave exposure and currents) hindcasted over the past 20 years to increase their nearshore resolution for fine, reef-scale analysis. Additionally, biophysical dispersal models were run on H. rubra populations to map out inter- and intra-reef connectivity. The information from these modelling studies were combined with habitat attributes derived from multibeam/lidar bathymetry data, sea surface temperature (SST) from satellite observations and yearly abalone abundance data collected using diver surveys in generalized linear mixed effects models (GLMMs) to determine those factors responsible for the abundance distribution of H. rubra. Through the GLMM, we found that depth, complexity of the reef, presence of rocky reef, SST, wave orbital velocity and connectivity helped to explain the temporal distribution of H. rubra along the Victorian coastline. These results help to understand how the combined effects of habitat, oceanography and recruitment structure H. rubra populations, which will help to facilitate performance assessments of ecosystem-based fisheries management strategies. Overall, this study helps to improve measurements of performance at the local level, which, in turn, allow better overall assessment of the sustainability of these fisheries.

Habitat Mapping Discloses Oceanographic Patterns Underneath

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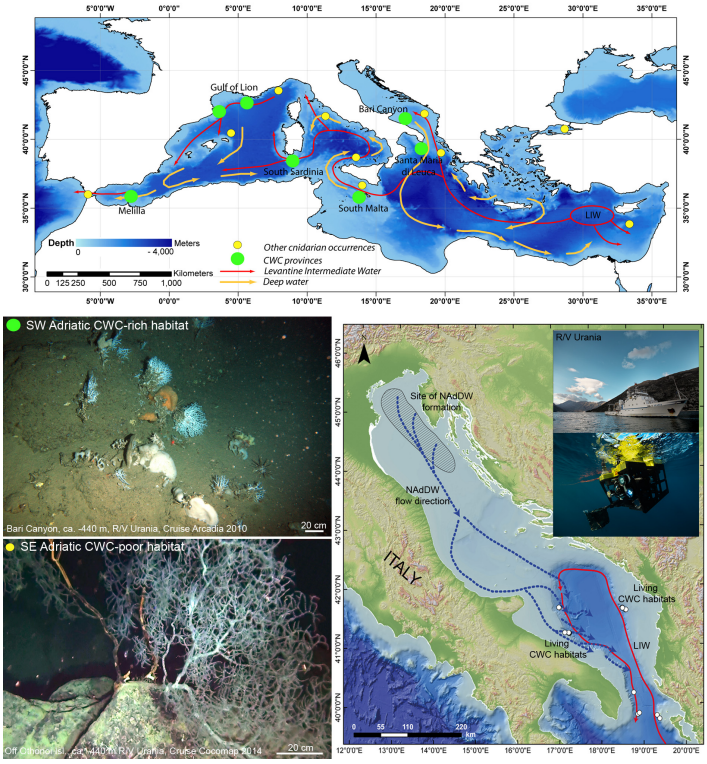

The focal mission of Habitat mapping (HB) is to assist the researcher in a better understanding of marine habitats, their areal extent, and their distributional patterns. The last years have witnessed the growing application of HB to the exploration of the deep sea biome, and a big effort has been directed to the identification of Cold Water Coral (CWC) grounds on a global scale but especially in the Atlantic Ocean and Mediterranean regions. Regarding the latter, six main CWC provinces have been identified thus far, located from the western basin eastwards to the southern Adriatic Sea, plus a number of minor spotty occurrences of live CWC, and allied cnidarian-dominated habitats. The exploratory phase of which HB has been a routine component, has not merely succeeded in its major role to discover, map and assess some relevant aspects of each site in terms of substrate and biodiversity attributes, but helped disclosing hidden patterns helpful to comprehend the onset (and eventual demise) and sustainment of such valuable marine habitats.

A case in point is offered by the skewed, asymmetrical differences observed in the distribution of CWC habitats or their surrogate equivalents (other cnidarians, sponges or lack of conspicuous sessile megabenthos) in the southern Adriatic basin. Because of the outcome of HB mapping, largely based upon the integration of multibeam mapping and visual imagery (such as Remotely Operated Vehicle ground-truthing), it came to evidence that the western side (mainly the Apulian margin) is site of important CWC growth, while the opposite side is far poorer, although potential settlement substrates are often comparable.

This observation is thus taken as an indication that oceanography is playing a key role in governing the CWC distribution, maintenance and connectivity among topographically disjoint coral sites. The broad picture is that most of the main CWC Mediterranean provinces sit in the core of the Levantine Intermediate Water in a depth range between 300 and 600 m. More in detail, the Adriatic case is also disclosing a role of cascading (North Adriatic Dense Water) events in the uneven distribution of CWC and associated megafauna in the Southern Adriatic Sea.

In summary, although indirectly, HB has proven remarkably efficient to disclose first-scale forcing oceanographic factors as likely controllers of valuable deep sea ecosystems.

Can Global Broad Scale Data From Public Repository Be As Accurate As Field Surveys Data For Species Distribution Modelling?

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The availability of global broad scale data sets from public repository such as World Ocean Atlas (WOA) or the General Bathymetric Chart of the Oceans (GEBCO) offers the possibility to study and predictively map the distribution of a species or a habitat at very broad scale when no better data exists. Considered best available information, some of these maps could be used for biodiversity management in the future but it is not clear if these models can really be a viable alternative to models built on finer scale and more specific data obtained from field surveys.

To address this question, we predictively mapped the distribution of a particular type of sponge aggregations called Ostur on the Flemish Cap (Eastern Coast of North America) using Maxent. As a Vulnerable Marine Habitat, a better knowledge of Osturs distribution is needed but a fine scale map of its whole distributional range is impossible to make. To assess the accuracy of a map built on global broad scale data we compared the results of three different approaches:

- Fine scale model: fine scale (75m) predictors from several sampling cruises and presence -absence data from within the study area
- Local broad scale model: broad scale (1km) predictors from WOA and GEBCO and presence absence data from within the study area
- Global broad scale model: broad scale predictors from WOA and GEBCO and presence absence data from the whole known range of Osturs (i.e. the North Atlantic).

All models were evaluated using AUC and threshold dependent methods on the same 10 randomly generated splits of data within the study area. Presence absence maps where produced by applying the "Maximizes (sensitivity+specificity)/2" threshold and the spatial output of models built on each split for each approach were overlaid in GIS. The similarity between each approach was quantified as the number of presence and absences predicted by all splits and all approaches.

Most models achieved good enough performances to be considered valid but the global model showed significantly lower AUCs and sensitivity while the local models achieved equivalent performances. The spatial outputs comparison shows all three approaches agree on the same small areas of predicted presences but the two local models present much more agreement on the absences distribution.

We conclude that global models do not match the accuracy of the local models when projected in a specific area, however, when comparing local models, fine scale predictors do not give significantly better performances than broad scale. Therefore, when predicting Osturs distribution on the Flemish cap, it seems broad scale data from public repository can be an alternative to finer scale predictors as long as the presence-absence data comes only form within the study area.

Predictive Habitat Modeling In Mediterranean Canyons Including Hydrodynamic Variables

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Madrepora oculata and Lophelia pertusa are the two main scleractinians engineering cold-water coral (CWC) ecosystems found in the Mediterranean Canyons. Such CWC ecosystems act as important biodiversity hotspots that also provide resources to many species, including commercial fishes, but are under threat by fishery activities (Fabri et al. 2014). Because of that CWC are identified as sensitive habitat, by the General Fisheries Commission for the Mediterranean (GFCM, 2009).

However, factors controlling the CWC repartition in the Mediterranean Sea are not ultimately understood and this fact obviously places limitations to implement at best any management and protection measure. In order to disclose the major drivers governing CWC distribution, we have focused our attention on two canyons. First, the Cassidaigne canyon located at the eastern part of the Gulf of Lion in which CWC ecosystems have settled in an upwelling environment and formed large colonies. Second, the Bari Canyon area in the southwestern Adriatic, which is site of prolific coral growth. The asymmetrical distribution of CWC and allied deep water sessile megafauna observed in this area has been hypothesized to respond to hydrographic processes, including the cascading of the North Adriatic Dense Water (Taviani et al., 2015).

The objective of our study was to combine several parameters to describe the environmental conditions in favor of CWC settlement: (1) CWC observations, extracted from geo-referenced underwater video films, (2) eco-geographic variables derived from bathymetry, (3) data on local hydrodynamics conditions (from high resolution MARS3D and COAWST hydrodynamic models). Habitat suitability models were used to identify the main eco-geographic variables explaining CWC distribution. Presence-only models (MaxEnt and ENFA) but also presence-absence model (GLMs) were compiled and compared.

Seafloor ruggedness and hydrodynamics variables were the most important predictors followed by heavy slopes. Suitable areas for CWC habitat settlement were mapped at the scale of both canyons. These theoretical distributions will help for the assessment of potential habitat extent in the deep sea and also in the scheme of the Marine Strategy Framework Directive (MSFD).

Development Of Standards For Classification, Confidence And Assessment Of Habitat Maps

Geomorphometry In Marine Habitat Mapping: Lessons Learned From The Past 10 Years Of Applications

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A dramatic increase in the availability of digital bathymetric data has occurred over the last decade, and marine habitat mapping is one of the fields that has benefited the most from access to these data. The marine habitat mapping literature is now filled with digital bathymetric models (DBM) generated from satellite data, airborne surveys, ship-based and submersible platform-based sensors. Bathymetric data quickly became an important input to habitat mapping studies due to the potential of these data to act as either direct or indirect surrogate of habitat distribution. In addition, the increasing simplicity by which terrain attributes (e.g. slope, aspect, rugosity) can be derived using Geographic Information Systems (GIS) has prompted a renewed interest in employing geomorphometric techniques to investigate seafloor habitats.

Over the last decade, a suite of marine geomorphometric techniques have been used (e.g. terrain attributes, feature extraction, automated classification) and employed to investigate a wide range of phenomena relevant to marine habitat mapping. However, geomorphometric techniques are not as varied, nor as extensively applied, in the marine as they are in terrestrial environments. This is partly due to difficulties associated with capturing and verifying terrain attributes underwater. Changes in topography are also often more subdued underwater in comparison to terrestrial landscapes.

Following the first applications of geomorphometry in habitat mapping just over ten years ago, some of the issues investigated in terrestrial geomorphometry (e.g. scale) were quickly picked up on by those working in a marine context and are documented in a few key habitat mapping papers. Nevertheless, the dynamic, four-dimensional nature of the marine environment causes its own issues, creating the additional need for a dedicated scientific effort in marine geomorphometry. For instance, technological challenges that can impact data resolution and positional accuracy in the deep-sea, or induce motion artefacts in DBMs, are problems particular to marine geomorphometry. These challenges impact the consistency of DBMs and can have a knock on effect on habitat maps that are often used to make conservation or management decisions.

Technology and equipment for surveying the seafloor are improving in quality, accuracy and cost-efficiency, which will allow an increase in data availability and quality. Availability of tools that streamline the workflow from data collection to analysis will be key in making marine geomorphometry accessible to marine habitat mappers with a wide range of background and experience. We advocate the establishment of a marine geomorphometry community that would draw on experiences from terrestrial techniques and develop issues and techniques relevant to marine bathymetric data. This community would help ensure that studies of geomorphometry become more widespread in the marine habitat mapping and related literature, whilst upholding scientific standards.

Habitat Classification: Approximation Or Reality?

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Intensive coastal and marine resource management, climate change investigations and nature conservation needs, boost the demand for adequate seafloor mapping. Habitat mapping encompasses a variety of ocean floor parameters such as sediment texture, bedforms and benthic biota allows complementing and supporting scientific studies as well as stakeholder decisions. Politics or directives are often reliant on data and experiences from science. In this course, diverging scientific and stakeholder interests increase debates about the three focal questions in habitat mapping: which map resolution to choose, which parameter to consider and which classification to apply? This conflicts arise because stakeholders have to work with simplified classifications to fulfill e.g. European guidelines (e.g. EUNIS) while scientists work with a higher degree of complexity.

In the southeastern North Sea, considerable effort went into highly resolved area-wide acoustic investigation of sediment-dynamic processes. While a huge amount of grab samples have been taken through the past 50 years (∼500,000 station in the German Bight), the systematic collection of precisely referenced backscatter data has not commenced before the turn of the millennia. Results of both approaches offer useful comparison and are matter for future discussions. Grab data support statistical model approaches, in which grain-size fraction are modeled as continuous variables with the resolution and accuracy highly depending on the method used. Sidescan sonar data provide very precise high-resolution maps. However, the backscatter data require categorization into distinct sediment classes which is a difficult, and time-consuming task since automated standard-classification routines usually fail and (sometimes subjective) expert knowledge must be implemented.

This study presents advantages and disadvantages of the different approaches (grab-sample data analysis, modelling, acoustic-data analysis) and how these complement each other in a case study undertaken in the Sylter Outer Reef, a protected (FFH) area in the German Bight. The southwest of the study area is characterized by homogeneous distributed muddy fine sands while the northeastern part is shaped by multiple Pleistocene glacial advances and retreats. As a result, the seafloor is characterized by heterogeneous glacial deposits (medium sand to gravel size with stones) partly covered with Holocene marine sediments. We discuss the different options, including automatic (unsupervised classification) and manual classification of back scatter data (following a national mapping program in Germany; cf. Propp et al.) or statistical models (based on principle component analysis). Modelling is able to provide the distribution of 'unclassified fractions', but may not reach the accuracy and resolution of hydroacoustic methods (particularly in areas with heterogeneous sediment distribution). Finally we discuss the value that can be added when merging the three methods.

Mapping Of EUNIS Seabed Habitats Based On Ground-Truth And Multibeam Acoustic Data: What Can Realistically Be Achieved?

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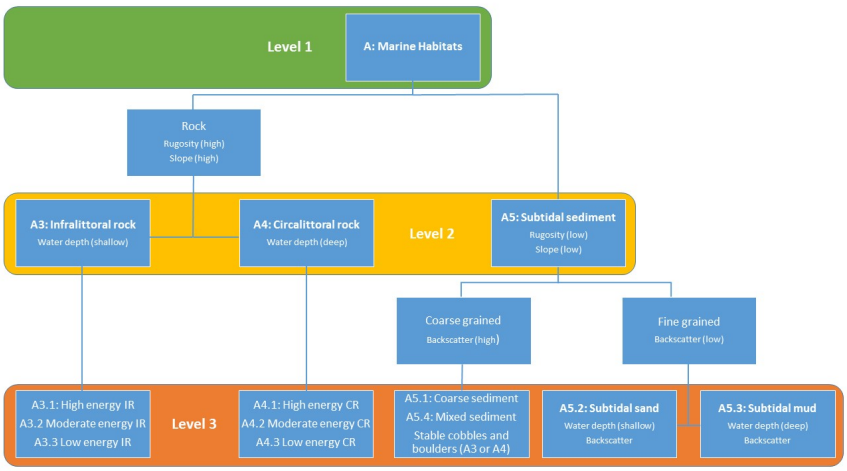
Over the past decade, multibeam echosounders, used in conjunction with ground-truth observations, have become the method of choice for benthic habitat mapping. The general approach involves some kind of spatial prediction of a response variable (e.g. habitat class) based on explanatory variables (typically bathymetry, backscatter and derivatives thereof). However, habitat classes are often vaguely defined, have gradual boundaries with other habitats or might not be discernible with the available explanatory variables. It would therefore be timely and beneficial to review which habitat classes can be realistically mapped. This contribution provides a review of 34 studies conducted as part of a programme to provide scientific evidence for the designation of Marine Conservation Zones in the United Kingdom. During the programme, so called broad-scale habitats were mapped in the subtidal zone. These habitat classes are a subset of seabed habitats included in the European Nature Information System (EUNIS) hierarchical habitat classification. Broad-scale habitats (see figure below) are separated by biological zone (infralittoral and circalittoral) and substrate type (rock and sediment) at level 2 of the classification. Further splits at level 3 are based on hydrodynamic energy (high, moderate and low) for rock habitats and particle size composition for sediment habitats (coarse sediment, sand, mud and mixed sediment). Furthermore, macrophyte-dominated sediment and biogenic reef are included as broad-scale habitats.

The review indicated that only four of the twelve subtidal broad-scale habitats can be reliably mapped with ground-truth and multibeam acoustic data. These were infralittoral rock, circalittoral rock, subtidal sand and subtidal mud. Although a successful separation was made on occasion, it is generally difficult to reliably separate energy levels of Infralittoral and circalittoral rock. Suitable explanatory variables might be modelled hydrodynamic parameters, but these do not exist at the required fine resolution similar to multibeam acoustic data. A separation of energy levels is sometimes achievable based on water depth where a depth-dependent gradient in hydrodynamic energy exists. Subtidal coarse sediment, subtidal mixed sediment and stable cobbles and boulders, which might constitute infralittoral and circalittoral rock habitats, are frequently indiscernible with the available multibeam acoustic data. These habitats are characterised by a strong backscatter return caused by the presence of gravel (>5%), but insensitive to variations in the mud/sand ratio or the size of the gravel clasts.

Apart from exposing limitations as detailed above, this review also provides a simple and straight-forward decision tree to guide the mapping of EUNIS benthic habitats (see figure below): An initial split into topographically expressed rock and sediment is made with terrain variables such as slope and rugosity. Rock habitats are subsequently subdivided into infralittoral and circalittoral rock based on a site-specific depth threshold. Subtidal sediment can be split into coarse-grained and fine-grained sediment based on backscatter. Finally, fine-grained sediment is separated into sand and mud by site-specific thresholds of water depth or backscatter.



Developing A Tool For Automated Benthic Habitat Mapping And Accuracy Assessment Using Bootstrap Aggregation

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Benthic habitat maps are an important tool for a range of disciplines including marine planning, ecosystem assessments and monitoring change through time. However, any map will be a simplification of reality, which may conceal the numerous uncertainties that are encountered during the mapping process. For example, when applying a predictive model the operator will determine the type of model used, resolution of prediction variables, and ground truth sample size, all of which may influence the final map. Therefore, it is important to perform a thorough accuracy assessment to understand the possible sources of error that may be present within a map and determine whether the map is fit for purpose. A thorough accuracy assessment should not simply involve analysis of accuracy statistics but rather should consider the frequency, magnitude, source and spatial distribution of errors. In practice this can often be complex. For example, where a suitably large and independent reference dataset cannot be collected, it has become standard practice to divide the original sample size into training and testing data for accuracy assessment. However, this can influence the fit of the model due to less training points, and potentially create misleading accuracy measures due to limited test samples.

Here we present a tool, in the form of an R-script, which we developed to automate the modelling and accuracy assessment process at a pixel or image object level. The tool allows flexibility of model selection from a number of classifier models then incorporates bootstrap aggregation (also known as bagging) to produce a more robust prediction and assessment of map accuracy. Bootstrap aggregation involves creating multiple training datasets by randomly resampling the reference data with replacement. A separate habitat map is then generated from each dataset with the remaining data used to perform an accuracy assessment. The final prediction is determined as an ensemble map, with the classification based on a majority vote from the individual maps.

In addition to the final ensemble habitat map, the tool performs a thorough accuracy assessment for each subset. Final outputs include an overall confusion matrix based on the average number of classified points per cell, and the commonly recommended class specific and overall accuracy metrics such as: overall accuracy, kappa, balanced error rate, sensitivity and specificity. Finally, two spatially explicit uncertainty maps are produced, increasing the interpretability of a map by highlighting areas of high or low confidence in predictions.

While these methods have been applied elsewhere they are rarely applied in unison to provide a detailed estimation of map accuracy. By bringing these methods together in a simple to apply methodology we improve the informative value of our habitat maps. In particular, spatially explicit uncertainty maps can be highly informative when considering marine management, yet have been largely ignored in the marine literature.

Mapping Seabed Sediment Texture Classes From Samples And Acoustic Bathymetry And Backscatter: Predictions And Their Uncertainty.

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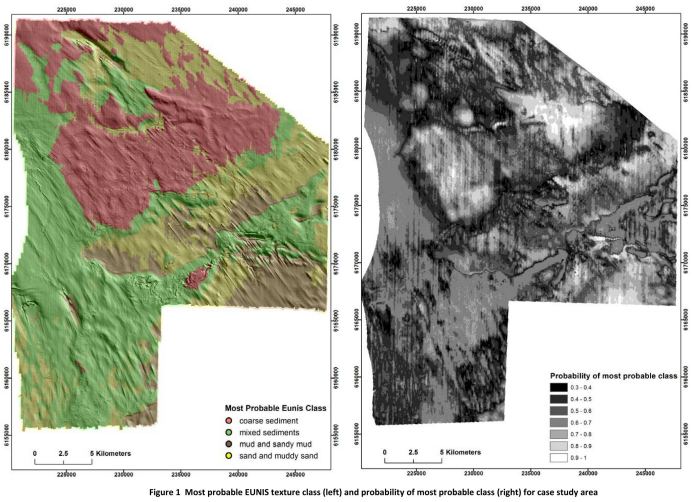
Seabed sediment texture is defined with respect to three particle-size classes: gravel, sand and mud, so any sediment can be represented on a 2-D ternary diagram. The hierarchical EUNIS habitat classification scheme incorporates substrate habitat classes as defined by four sediment texture classes on this diagram. To map EUNIS seabed sediment habitats therefore requires that we can predict the texture class at any location. In this paper we show how a spatial linear mixed model can be used to interpolate sediment classes from grab-sample data while integrating information from other sources, in this case acoustic swath bathymetry and the associated backscatter data.



Most probable EUNIS texture class (left) and probability of most probable class (right) for case study area

We transform the grab-sample data to additive log-ratios (alr) to deal with the fact that the data on particle size classes are compositional: the values are proportions, constrained to sum to 1. We fit a linear mixed model (LMM) of the alr-transformed values as a combination of fixed effects (mean values expressed as functions of the covariates, such as bathymetry and back-scatter) and spatially correlated random effects. The model can then be used to compute the prediction distribution of alr-transformed proportions at some location, given values of the covariates there and an optimal linear combination of residuals from the fixed effects in a kriging-type interpolation. We then integrate the prediction distribution over the sections of the textural ternary diagram to compute the conditional probability of finding each sediment class at some specified location.

The outputs of this analysis can be presented in different ways. The simplest output is a map of the most probable class. However, there is uncertainty in this prediction. A local indication of confidence is the probability of the most probable class, which may be close to 1 where the uncertainty is small, and close to 0.25 (as there are four classes) where the uncertainty remains substantial. Another way to indicate confidence in a local prediction is by the entropy of the prediction probabilities, which indicates whether these are dominated by one class, or are similar for all classses. Alternatively, if we are interested in a particular class, the probability of finding that class can be mapped spatially.

We will present results for such an exercise from a site off the coast of Northumberland in north-east England. We show how the significance of potential covariates can be tested statistically, and present validation results which show how including these acoustic covariates improves the quality of spatial predictions. This result encourages the inclusion of other covariates (e.g. geomorphology) that may further improve predictive accuracy. The Figure below shows the most probable class (left) and the probability of the most probable class (right) for the case study.

Finally, we shall discuss the potential of this methodology for incorporating other sources of information for mapping, such as expert interpretations of seabed geomorphology. We shall also consider how this approach allows us to make rational decisions about the design of sampling campaigns.

Seafloor Classification Using Roxann: Two Case Studies To Show The Pros And Cons

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RoxAnn is a single-beam seafloor classification system using the echo-integration method to define roughness (first echo return, E1) and hardness (second, multiple, echo return, E2) parameters. The idea is that in the E1 vs. E2 diagram different seafloor types produce distinct point accumulations that can be used for classification. In natural environments, however, the data mostly display one unstructured point cloud rather than discrete point accumulations. To overcome these difficulties a new processing routine was set up based on Matlab code. This routine provides UTM coordinates, filters, necessary statistics and interpolated 2 and 3D maps of E1, E2 and the bathymetry. It performs customized color coding of the data (10,000 color bins) and interpolation after transforming E1 and E2 to one single parameter ('E1E2'). The results include transect maps and interpolated maps colored according to E1E2. Even though the interpolated maps may be incorrect in the detail, they allow to see broad patterns that cannot easily be recognized in the transect view. In a further step, the color data form the basis for k-means fuzzy clustering.

Case Study 1 is from the German Bight (SE North Sea) close to the island of Helgoland at 15 to 35 m of water depth. It is a small area (7.2 km^2) characterized by bedrock and sandy areas. Ten grab samples were taken for ground truthing. The acoustic data reveal 'hardest' and 'roughest' conditions in areas characterized by stones and gravel in a fine-sandy matrix. Somewhat 'smoother' and 'softer' occurs the area characterized by bedrock and big stones. Here the grab sampler revealed only big stones, corals, rock-inhabiting plants and animals. It is either the case that in very rough areas the rocks are reflecting sound waves away from the transducer even though the reflection is strong ('hard') or the rock-covering biota reduce reflectivity. In the sandy area RoxAnn data clearly allow separation of unimodal fine sand ('smooth' and 'soft') and partly bimodal medium sand areas with shell detritus ('harder' and slightly 'rougher'). The fuzzy cluster analysis suggests the above-mentioned 4 classes as the best solution.

Case study 2 is from Potter Cove, a small fjord (7.5 km^2) on King George Island (Antarctic Peninsula). All acoustic measurements and grab sampling (136 stations) were carried out from a zodiac. Potter cove is characterized by basins (>50 m water depth) with muddy sediments framed by steep slopes of bedrock with stones and gravels. Here we find the opposite of what was anticipated: The soft and smooth sediment of the basins yields harder and rougher acoustic values than the rugged rocky slopes and shallow areas. However, considering this, nonetheless a meaningful classification in 7 classes including classes indicating macroalgae was possible.

It can be concluded that RoxAnn is a powerful tool for habitat mapping. However there are clearly problems when the seafloor is very rugged and/or steep. The case studies will be discussed with regard to RoxAnn performance.

A Cold-Water Coral Biota Classification Scheme For Ecosystem-Based Management Of The Deep Sea

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Despite the great ecological significance of habitats structured by cold-water corals (CWC) as refuge, nursery or mere physical support for a diversity of other living organisms, CWCs are still vulnerable to fishing activity, and as such recent initiatives have been put in place that are contributing to build a network for their protection.

Providing enhanced protection to these deep-sea organisms is one of the aims of the coherent and representative networks of Marine Protected Areas being implemented across Europe under the Habitats Directive, the Marine Strategy Framework Directive and the OSPAR Convention. In order to ensure representativeness of different ecosystems by these networks, a standardised habitat classification is needed that organises the diversity of biological assemblages and provides objective and functional criteria to map them across the European Seas. Abiotic-based levels of the EUNIS classification already provide useful standards for habitat mapping, but the classification is still lacking at the lower biotope-related levels. The current version fails to provide as much detail for deep-water habitats (>200m) as it does for shallow-water habitats.

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

This work produced a hierarchical cold-water coral (CWC) biota classification scheme to capture the diversity of CWC habitats using imagery-based habitat mapping data from across Europe. The CWC habitats were classified into three biotope, from broader functional groups (e.g. CW Scleractinian reef) to species level (e.g. Lophelia pertusa reef), thus depending on the resolution of the imagery being interpreted, this hierarchical scheme allows data to be recorded from broad cold-water coral biotope categories down to detailed taxonomy-based levels; thereby providing a flexible yet valuable information level for management. Such a scheme allows for comparability with the EUNIS system and results have been submitted for inclusion within the recent EUNIS revision consultation.

The CWC biota classification scheme identifies 80 biotopes and highlights the shortcoming of initiatives/guidance such as the EC Habitats Directive, OSPAR and FAO; with limited categories for classifying CWC habitats and limited guidance on their identification. The final classification scheme is presented, with an image catalogue of corresponding biotopes.

Mapping Of Coral Reefs For Conservation Assessment In Pulau Lang Tengah: Comparison Of OBIA And Image Learning Approaches

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Pulau Lang Tengah is part of the Redang Archipelago in Malaysia. It was recently developed to accommodate recreational activities especially for scuba diving. However, the development has taken their toll on the island and caused a significant declined in coral cover in less than 5 years. Sadly, such scenario is not foreign to most of the islands in Malaysia, therefore the need of conversation measure is urgently needed before it deteriorates further.

The aim of this study is to produce a coral zone map to facilitate conservation effort in Pulau Lang Tengah. A multi spectral Quickbird imagery with a spatial resolution of 2.5 m is used as the basis of the study. The idea is to use an approach that can produce a coral cover map with the best accuracy, repeatable for monitoring purposes and time- and cost-savvy.

The aim will be addressed through three objectives 1) produce a coral cover map using object based image analysis and machine learning approaches 2) accuracy assessment for map produced by both approaches 3) divides Pulau Lang Tengah into ecological zones and subject them to a habitat heterogeneity index. The index act as a proxy for biodiversity to provide an insight for identifying area with high prospective for conservation and reclamation area.

Automating Habitat Mapping In A Complex World Of Corals And Coastal Waters

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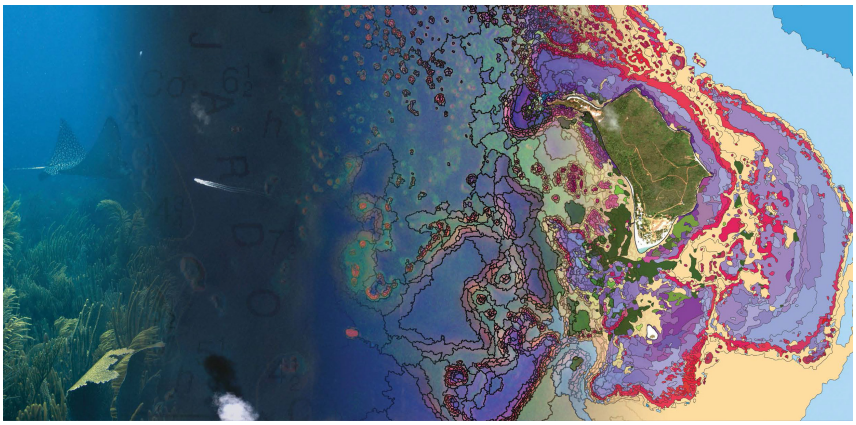
The Caribbean waters around Northeast Puerto Rico, affected by sediment loaded runoff and wave-induced resuspension, possess a substantial challenge to remote sensing based benthic habitat mapping. In addition, the quality of available hydrographic data in the region is highly variable and the cloud cover persistent. We used a combination of Worldview-2 satellite imagery, hydrographic data spanning the 20th century, aerial imagery, oceanographic data and underwater video to create a high-resolution habitat map (minimum mapping unit 100 m^2) of 744 km^2 shallow water (<35 m) coral reef habitats. A novel workflow was developed to process and integrate these multiple sources of heterogeneous remote sensing data. In a second step object based feature extraction was performed in ENVI and the resulting segments were aggregated to match the minimum mapping unit. Finally the extracted habitat features were classified using boosted regression tree models in R. An independent accuracy assessment and manual editing ensured the quality of the final map (90% accuracy for hard/soft bottom). The habitat classification scheme include geomorphological structure, percent hardbottom, topographic complexity, biological cover and live coral cover.

The robust methods developed in this project introduces new innovative tools to map large areas of complex marine habitats with high thematic and spatial resolution in support of Marine Spatial Planning, and can be used in a variety of marine environments. The methods build on previously presented work by Bryan Costa (Esri IUC 2010, Semi-automated Classification of Acoustic Imagery using ArcGIS and ENVI). The new habitat map is currently used in a spatial prioritization project supporting the development of an integrated management plan for Puerto Rico's Marine Corridor of the Northeast Reserves, which is also newly designated as a NOAA Habitat Focus Area. The project publication and the data generated is freely available online, together with a state of the art map viewer (http://coastalscience.noaa.gov/projects/detail?key=258).



High-resolution underwater video and remote sensing imagery combined with automated feature extraction and modeling (left to right) help classify complex marine habitats in Northeast Puerto Rico with reduced need for manual digitization and classification

Poster Presentations

Geostatistical And Multivariate Modelling For Large Scale Quantitative Mapping Of Seafloor Sediments Using Sparse Datasets

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Quantitative mapping of seafloor sediment properties (eg. grain size) requires the input of comprehensive Multi-Beam Echo Sounder (MBES) datasets along with adequate ground truth for establishing a functional relation between them. MBES surveys in extensive shallow shelf areas can be a rather challenging and time-consuming task, resulting in time and cost intensive data collection. It is therefore often the problem of dealing with sparse data and/or data without full coverage. This study deals with MBES data acquired within an area of approximately 30 x 55 km (Cleaverbank, North Sea, the Netherlands) with a line spacing of ∼2 km in 50 m average water depth. Additionally ground truth samples were taken with a Hamon grab in a regular grid of ∼1 x 1 km with samples at and in-between some of the MBES survey lines. These ground truth data cover a subset of the area under investigation from variable depth and sediment types ranging from silty clay to boulders. Here we combine geostatistical and multivariate modelling for predictive mapping of the median grain size across the whole area. First bathymetric data was cleaned and raw backscatter values were classified into 7 classes representing different sediment types using a Bayesian method. A multiple linear regression was performed with the ground truth (sediment grain size) data resulting in an empirical function that shows high correlation (90%) of the median grain size with depth and backscatter classes. However missing information in un-surveyed areas needs to be estimated before predictive mapping can take place. For this purpose we interpolated sparse bathymetric and backscatter class data in order to obtain layers of continuous information for the whole area. To achieve this, MBES lines were treated as Single Beam Echo-Sounder data by producing a reduced, equally-spaced grid of bathymetry and backscatter class points, for each MBES line. Interpolation of this bathymetric data set using Ordinary Kriging (OK) yielded satisfactory results with low root-mean-square errors. For the backscatter class we utilized both OK and a Bayesian Maximum Entropy (BME) algorithm which is regarded as more suitable for categorical data. As backscatter classes are ordered by increasing acoustic intensity makes the interpolation results useful as they also include values between classes. Interpolated bathymetry and backscatter classes were validated with additional data from crossing lines. Subsequently, the interpolated layers produced by geostatistical modelling became input to the empirical regression function connecting median grain size and MBES data. The predictive layer of median grain size was assessed by using independent ground truth data from not-mapped locations. By applying linear regression to the interpolated data it was found that both, OK and BME provided results that predict median grain sizes with a high correlation (up to r^2=0.85) to the observed values. The overall approach suggests that the combination of geostatistical with multivariate modelling can offer good results for large scale seafloor classification when data are limited. Additionally the prediction accuracy for each layer (bathymetry, backscatter class) can be estimated and spurious results can be identified.

Deep-Sea Habitats And Dense Shelf-Water Formation: A Fragile Climate-Dependent Relation Studied From Geomorphological Signatures

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Dense shelf-water cascading (DSWC) is an atmosphere-driven seasonal phenomenon that occurs in marine regions around the globe. DSWC starts when surface waters over the continental shelf become denser than surrounding waters (by cooling, evaporation or sea-ice formation with brine rejection) and sink, generating a near-bottom gravity flow that moves downslope along the seabed. This process contributes to deep-ocean ventilation, plays a role in the global thermohaline circulation (and hence global climate), and involves the massive transfer of energy and matter (including sedimentary particles, organic carbon and pollutants) from shallow to deep waters. Deep-sea habitats are critically dependent on this process.

DSWC is highly sensitive to temperature change in both the lower atmosphere and the sea surface. In the coming decades global warming will likely modify the frequency and intensity of DSWC, which could significantly affect the functioning of the deep-sea ecosystems. Overall, dense-water formation is expected to decline over both continental shelves and offshore, particularly in Arctic and sub-polar latitudes where sea-ice production is declining.

Here we present a new project that considers the morphological signature of DSWC events on modern continental shelves and slopes. The project aims to contribute to a better understanding of the past and future effects of climate change on the formation of DSWC, in addition to shedding new light to the on-going discussion about the potential vulnerability of deep-sea ecosystems that largely rely on the arrival of nutrients transported during DSWC events.

Marine Geobigdata Processing And Seabed Characterisation Using IQmulus European Platform

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The FP7 IQmulus project aims at the development and integration of an infrastructure and platform that will support critical decision-making processing in geospatial applications by setting the following research objectives:

- Developing a system for the fusion and integration of very large, highly heterogeneous spatial data sets such as n-dimensional grid and non-grid coverages and point clouds of different provenance, including processing and visualization;

- Building a spatial data processing middleware that abstracts from different parallel and distributed processing infrastructures;

Through land, urban and marine 'Showcases', sets of requirements were analyzed to drive the early development of the infrastructure, prototypes and basic services in the first phase of the project.

The following aspects of IQmulus functionalities are being demonstrated in the marine showcases (Figure 1):

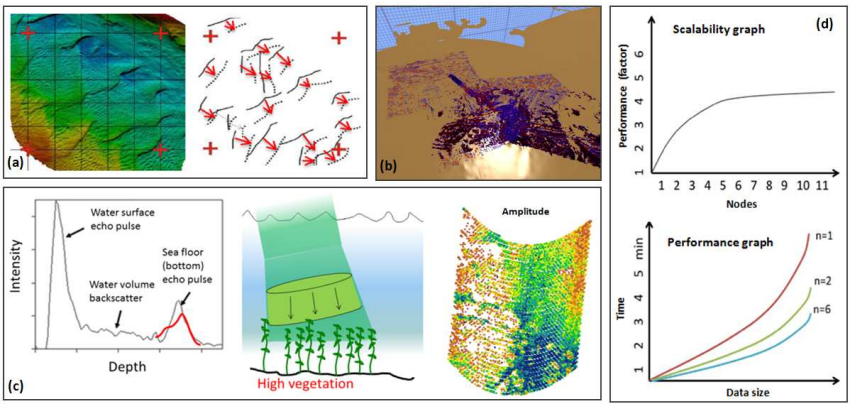
- Marine DEM generation: rapid and flexible generation of a single seamless surface from multiple disparate point cloud source data and associated visualization. The workflow includes a deconfliction step ;

- Inspection of the quality of the representation: the workflow can serve as a starting point for a more interactive deconfliction process to determine how to create an optimal bathymetric surface using all of the relevant, available data, i.e. the best surface;

- Change detection: aims to implement the possibility to generate accurate surface representations from heterogeneous measurements, which is an important prerequisite to subsequently detect features of interest and changes among multiple time steps. Thus, the workflow allows further analysis of multi-date surface model through stochastic and topological change detection;

- Lidar waveform coastal feature extraction: the objective is to extract, from the bathymetric lidar waveform, parameters such as peak height, pulse width, pulse area etc. which are useful for the classification of seabed types.

Entire workflows (i.e. a chain of logically connected services) are tested in IQmulus cloud environment and evaluated with combination of a predefined set of data sizes and computational configuration. The comparison of execution times produces information on scalability barrier in terms of parallelized service execution.



Example of IQmulus marine applications: (a) DEM generation and change detection e.g. displacement estimation , (b) deconfliction of overlapping bathymetryic survey data , (c) Lidar full wave form processing and sea bottom feature extraction , and (d) scalability test metrics.

Harmonising Sediment Mapping On The Norwegian Shelf - Challenges And Some Solutions

Valérie ***Bellec***[1], *Nicole Baeten*[1], *Heidi Olsen*[1], *Liv Plassen*[1], *Dag Ottesen*[1], *Margaret Dolan*[1], *Lilja Rún Bjarnadóttir*[1], *Reidulv Bøe*[1], *Aave Lepland*[1], *Terje Thorsnes*[1]

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The Norwegian seabed mapping programme MAREANO (www.mareano.no) studies Norwegian offshore areas. MAREANO has acquired a suite of marine data sets such as multibeam bathymetry and backscatter data, seabed samples, videos of the seafloor and high resolution shallow seismic data which provide the basis for mapping the geology, sedimentary processes and habitats on the seafloor.

More than 150 000 km^2 of the Norwegian continental shelf and slope have been mapped since 2006. Four different geological map products are compiled and published on www.mareano.no: seabed sediment (grain-size), sedimentary depositional, genesis and submarine landscape and landforms. This poster focuses on the sediment maps made by the Geological Survey of Norway at scales of 1:100 000 to 1:250 000. Some areas, especially those mapped between 2006 and 2010, were expanded with neighbouring areas being mapped in consecutive years. After 2010, the mapping of areas with higher environmental interest has been more geographically separated from previously interpreted areas.

Challenges appear when areas that were originally mapped separately need to be merged as new data become available. The combined maps should be as seamless as possible between areas mapped at different times, but this is not always straightforward. Different datasets, including multibeam data of variable quality and/or resolution often exist in different survey areas, and mapping and interpretation methods progress from year to year. Another challenge is the subjectivity of interpretation by different geologists in different areas.

In short, making consistent and repeatable sediment maps can be a challenging task. One way to avoid some of the problems is to create a good framework for the interpretation that can be followed by all the interpreters, for instance, pre-determined map scales and sediment classes. Another way to overcome some of these problems is to move towards methods that involve semi-automatic classification to guide the interpretation.

Collect Once, Use Many Times: The Multiple Applications Of IHO Order 1a Multibeam Data In Managing The Co-Location Of Marine Protected Areas And Aquaculture Activities

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Licensed aquaculture for bottom culture of blue mussels, Mytilis edulis, in Belfast Lough and Carlingford Lough, Northern Ireland, forms a significant economic activity, and covers a large proportion of the loughs' seafloor. The licensed areas fall within, and adjacent to, Natura 2000 sites, and lie beside busy commercial harbours. As part of impact assessment of aquaculture on the Natura 2000 sites, the activity patterns within the licensed areas have been determined through analysis of mussel dredgers' 'black box' data; however this is based upon a number of assumptions (such as vessel speed) that have not been fully validated. Multibeam echosounder surveys collected under collaborative hydrography programmes have provided high resolution backscatter imagery revealing a complex pattern of dredge marks over the licensed areas. The backscatter data are compared to black box data to allow accurate physical impact assessments for the areas, and provide a calibration of the effectiveness of black box data in capturing seafloor impacts, and intensity of activity.

Northern Ireland blue mussel cultivation depends upon naturally settling seed mussel beds on the open coast. These beds are assessed, opened and monitored by the NI Department of Agriculture and Rural Development; seed are fished then transported to the licensed sites for on-growing. One seed mussel bed is located adjacent to Modiolus modiolus biogenic reefs under consideration for Natura 2000 site designation. The management of the seed mussel fishery to minimise impacts on the biogenic reefs relies on critical habitat extent data derived from multibeam surveys.

Variation In Rocky Reef Habitat In California State Waters

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Since 2008 the California Seafloor and Coastal Mapping Program (CSCMP) has acquired multibeam echo sounder (MBES) data in all mainland State Waters (shoreline to 3 nautical miles). As of this writing a suite of map products derived from the data has been published for 22 of the network of 83 CSCMP map blocks along the mainland coast. These publications provide the first opportunity to contrast physical habitats in different areas; here we compare the seafloor character in a set of 6 blocks along the mainland coast of the Santa Barbara Channel (Hueneme Canyon to Refugio Beach), with that of a similarly sized subset of blocks along the more energetic coast of Northern California (Salt Point to Drakes Bay). Seafloor character, one of the products of the CSCMP, is a raster with a small number of substrate classes (soft-flat, hard-flat, and hard-rugose) designed for inclusion in multi-variant analysis of fisheries data. The small number of classes allow affordable stratified sampling of fish distribution and abundance. And the classes can be related to visual observations of substrate type made during fisheries video transects allowing the fish-substrate relationships to be extrapolated across the MBES mapped area. Seafloor character is derived using bottom-video supervised maximum likelihood classification of MBES backscatter intensity data and vector ruggedness derived from the MBES bathymetry data. Typically soft-flat areas are occupied by fine-grained sand and mud with infauna, hard-flat areas are a mix of low-relief coarse sediment and flat bedrock pavement with sparse epifauna, and hard-rugose areas are highly valued rocky reef habitat with a diverse assemblage of epifauna. In waters less than 100 m deep in the Northern California the percentage of hard-rugose habitat is 8% of the seafloor whereas in the Santa Barbara area it is 0.2%. In both areas Marine Protected Areas contain a higher percentage of hard-rugose habitat than is found in the surrounding region. The scarcity of hard-rugose habitat in the Santa Barbara area increases the value of protected habitat in the nearby Channel Islands, as well as artificial habitat created by offshore oil rigs.

Exploring The Spatial Variation Of Biodiversity In Submarine Canyons, SW Approaches, UK

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5. Joint Nature Conservation Committee, Peterborough, UK

Submarine canyons are considered to be potential biodiversity hotspots, however, to date there is very little data on canyon community composition of these features, or measures of diversity to assess their potential importance as features of conservation interest. Diversity indices such as Margalef (1958), Shannon-Wiener (1963) and Simpson (1949) index are commonly used in ecology and can measure richness, dominance and evenness.

In 2007, two adjacent submarine canyons (Dangaard and Explorer) and a flank of a third (Irish Canyon) of the SW Approaches, UK were surveyed to characterise the ecology and map the distribution of benthic assemblages. High resolution multibeam echosounder data were acquired over the survey area and 44 image/video ground-truthing were acquired. Image samples were quantitatively analysed and all taxa $>$ 1cm identified as distinct Operational Taxonomic Units (OTUs), or morphotypes. Standard multivariate analysis was undertaken (Primer v6) to define distinct faunal assemblages (biotopes).

Twelve biotopes were defined and a number of diversity indices (Simpson's reciprocal Index, rarefaction curves etc.) were used to measure the alpha (α) diversity of biotopes. When comparing diversity, caution needs to be taken regarding which indices are used, simply averaging species richness across samples can be misleading as no standardisation for sampling effort is made. Using a single diversity measure only provides one aspect of the diversity of that assemblage, with individual indices capturing a different aspect of diversity. Therefore undertaking a multivarate diversity test (using multiple indices) captures other aspects of diversity that genuinely exist, strengthening the comparative tests between biotopes.

Structurally-complex biotopes displayed the highest Simpson Index (with Lophelia pertusa reef having the highest) and soft sediments displayed the lowest, rarefraction curves also showed L.pertusa reefs to have the highest species richness while a seapen (Kophobelemnon stelliferum) community had the lowest.

Here, we explore spatial variations in diversity (uni- and multivariate) within and between the canyons of the SW Approaches system and its applicability as a habitat mapping tool.

Using Novel Mapping Tools To Predict The Small Scale Spatial Distribution Of Cold-Water Coral In The Mingulay Reef Complex

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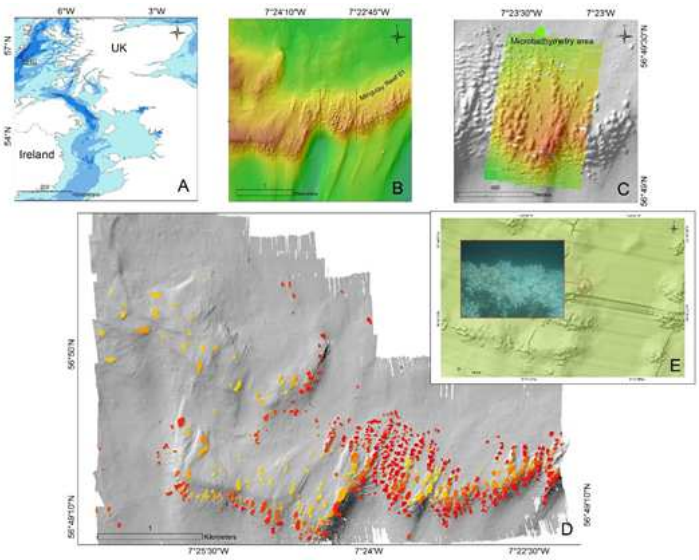

The Mingulay Reef Complex (MRC) located off the West Coast of Scotland, has the ecosystem engineer Lophelia pertusa as its dominant framework forming coral. Predictive models and maps of cold-water coral habitats are useful to understand the factors that control the distribution of these organisms. In this study we predict coral presence at one of five mounds at the MRC, by using the new ArcGIS-based "BGS Seabed Mapping Toolbox", which was developed for this study, together with random forest modelling. By using this toolbox almost 600 carbonate mounds were semi-automatically delineated from bathymetry data of the Mingulay Reef 1, obtained as part of the MINCH project in 2003 with 2 m resolution, and their characteristics were quantified and captured. Coral presence data were derived from HD video and from a microbathymetric grid with a resolution of 35x35cm. This microbathymetry covers the centre of the study area and its high resolution allowed the observation of individual coral colonies. Random forest classification identified 1) Maximum Water Depth, 2) Maximum Rugosity, 3) Bathymetric Positioning Index (BPI), 4) Orientation and 5) Maximum Current Speed as the environmental variables that contributed most to the prediction of live coral presence. A detailed map with the presence of corals on minimounds will be specifically valuable for future sampling and monitoring climate change surveys. This is the first study using an ROV-based microbathymetric grid and the newly developed "BGS Seabed Mapping Toolbox" to explore the environmental variables that control coral growth on minimounds.

Predictive Models Of Vulnerable Marine Ecosystem Indicator Biomass Distribution - Including The Effects Of Fishing Activity

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Information on the distribution of vulnerable marine ecosystems (VMEs) in the deep sea, and the effect fishing activities are having on them, are required to implement informed spatial management plans. With the difficulty in obtaining comprehensive survey data, habitat suitability models (HSM) are often used to define areas where VME are likely to occur. Models can, however, be confounded by current and historical fishing activities. Normally HSM do not account for the effects of human disturbance. Hence, input data can indicate absences or low biomass in areas that would otherwise be suitable physical habitat, adding noise to the models.

Here we take a novel approach to the problem, by including fishing effort into the habitat suitability modelling process. Data from Vessel Monitoring System (VMS) records has been used to determine the level of bottom fishing effort around the Flemish Cap and the tail of the Grand Banks of Newfoundland (NAFO Regulatory Area). The VMS data has been used, in conjunction with high resolution bathymetric data and other available environmental layers, to construct random forest regression models for the biomass of sponges (Porifera), large gorgonian corals (Octocorallia) and sea pens (Pennatulacea). Predictions were made both for current fishing level and a 'no fishing'-scenario. The latter predictions represent the expected distribution of biomass in prevailing environmental conditions, with fishing intensity set to zero. Hence areas that are currently heavily fished, but have the appropriate environmental conditions, will show higher biomass than is currently observed.

All of the models predicted biomasses with a RMSE within approximately 10% of the range observed for the taxa. Models for sea pens and sponges each achieved R^2 values of 0.38. The model for large gorgonians, however, only had an R^2 value of 0.04, indicating very low correlation between predicted and observed values and hence a poor model. The gorgonian biomass prediction was largely driven by terrain features and depth. Fishing intensity was not found important. Sea pen biomass was best approximated by minimum bottom temperatures above 3.5 ℃, sediment with a high clay content and low bottom fishing intensity. Sponge biomass was found to be most sensitive to the fishing pressure. Fishing intensity was the most important factor in the sponge model, with high biomass found only at very low fishing intensity. Otherwise, high sponge biomass was predicted in coarser sediments with low silt and clay content, high bottom current speeds and low temperature variability.

Potential biomass predicted for sea pens and sponges under the 'no fishing' scenario was overlaid with the known heavily fished area and current bottom fishing closures. In the modelled area almost half of the potential sponge biomass (48%) is currently protected by fisheries closures, whilst 21% falls within the currently fished area and the remaining 31% is located in areas open to fishing, but not currently utilised by the fishery. For sea pens, on the other hand, only 26% of potential biomass falls within fisheries closures, whilst 39% and 35% fall within fished areas and currently unfished areas open to fishing, respectively.

Black Bream Nest Identification - A Habitat Mapping Case Study

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As part of the Fugro Group, Fugro EMU delivers a comprehensive solution to all of our clients, integrating Marine Environmental Consultancy, Marine Environmental Ecology, Nearshore Geophysical, Hydrographic and MetOcean survey and Laboratory analysis coupled with Fugro's other earth science services. Fugro EMU have delivered habitat maps and characterisations to the industry for nearly 20 years, influencing wind farm placement, aggregate monitoring and oil and gas assessments, all whilst utilising the knowledge from their experienced staff.

Fugro EMU present a case study of habitat mapping within the industry, using a range of sensors and noting the struggles trials and successes throughout.

As part of the Marine Management Organisation's Licence Conditions for Area 435/396, Tarmac Marine Ltd and Hanson Marine Aggregates Ltd are required to complete additional monitoring surveys over a region north of their Aggregate Licence Areas. Some of these areas are now located within the Kingmere Marine Conservation Zone (MCZ).

The monitoring areas are over shallow seabed (typically 10 m below Chart Datum, Newhaven), often rocky and littered with static fishing gear and trawlers. This presents its own challenges for survey, but to add to this the survey data will be analysed for Black Bream nests: typically only 1 m in diameter.

During this case study we utilise the latest technology with the aim to reduce the health and safety risks during the survey and increase the detection of bream nests during processing and analysis.

The results of the study have fed into the aggregate monitoring reports, as required by the licences; plus have been included in the research and monitoring of the Kingmere MCZ, managed by the Sussex Inshore Fisheries and Conservation Authority. The information used has the potential to aid in the monitoring of Bream nest habitats, as well as other protected habitats, feeding into the monitoring and management of other MCZ's across the country.

Examples of the data collected during the survey will be displayed showing the ability to detect the Black Bream nests in sidescan sonar, multibeam bathymetry and backscatter datasets.

Using A Lightweight Drone To Map Shallow Coastal Habitat In The Amvrakikos Gulf, Greece

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Coastal environments are typically challenging to monitor. Optical Remote Sensing has become an invaluable tool allowing for the study of coastal processes. However, data collected with sensors on board satellite and airborne platforms are often lacking in spatial and temporal resolution to suitably describe heterogeneous and dynamic ecosystems. Lightweight and low-cost drones have the potential to be used as scientifically viable tools for collecting accurate Remotely-Sensed data in such areas, yet there have only been a few studies that exploit them in these settings. Here we demonstrate the advantages of aerial drone technology to collect optical data of a shallow neritic habitat within the Amvrakikos Gulf, Greece.

The Amvrakikos Gulf is a semi-enclosed body of water of high ecological importance due to the presence of seagrass (Posidonia oceanica) meadows, Loggerhead Turtle (Caretta caretta) and Common Bottlenose Dolphin (Tursiops truncatus) populations, as well as several wetland bird species. Increased anthropogenic pressure on the natural environment has led to reduced water quality with potential impacts on submerged aquatic vegetation. For these reasons, this area lends itself as an ideal study system for fine spatial scale proximal coastal Remote Sensing, with interesting questions to explore.

In the summer of 2015, multiple aerial surveys using a customized lightweight drone and consumer grade camera were conducted in the area. Here I will present the methods used to collect the data, the post-processing procedures (including orthorectification and spectral correction) and the classification analyses employed. This novel workflow has created high spatial resolution habitat maps of benthic submerged aquatic vegetation, suitable for environmental monitoring purposes. The techniques described demonstrate the benefits of low-cost drone systems for proximal sensing and could likely be applied in a variety of coastal ecosystems.

A Comparison Of Image Annotation Data Generated By Multiple Experts For Benthic Ecology

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Multiple experts often annotate images within a single dataset to reduce the time burden of annotation, particularly with the large photographic surveys now available to in ecological studies. Annotations provided by experts are known vary as a result of differences in expert opinion on organism identification, and human factors such as fatigue and cognition. These variations are rarely recorded or quantified, nor are their impacts on derived ecological metrics. We compared the annotations of three experts of 71 megafaunal morphotypes in ∼28,000 images, including 650 common images. Estimated specimen detection success rate was 77%, and identification success rate some 95%, giving an annotation success rate of 73%. Specimen detection success varied substantially by morphotype (12-100%). Variation in the detection of common taxa resulted in significant differences in apparent faunal density and community composition. We determined that bias between experts exceeded within-expert variation in apparent community composition (as faunal similarity) above ∼600 images. We recommend that photographic studies document the use of multiple expert annotators, and quantify potential expert bias. Randomisation of the sampling unit (photograph or video clip) is clearly critical to the effective removal of human annotation bias in multiple annotator studies (and indeed single annotator works).

Cold-Water Coral Ecosystems In Cassidaigne Canyon: An Assessment Of Their Potential Distribution

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The Cassidaigne canyon is one of the two canyons (together with Lacaze-Duthiers) of the French Mediterranean coast in which cold-water coral ecosystems have settled and formed large colonies, providing a structural habitat for other species. Unfortunately, the communities settled in the Cassidaigne canyon are physically impacted by red mud.

New information on the distribution of the species Madrepora oculata and the associated species diversity in Cassidaigne canyon was provided by video films and photos acquired in 2013 (ESSNAUT). An area investigated at 515 m deep harbored a high density of small colonies of M. oculata. High resolution (10 m and 2 m) bathymetric data were collected in the Cassidaigne canyon in 2010 (ESSROV) and 2014 (Bathycor01). Seafloor characteristics were derived from the 10 m resolution bathymetric data. Data on local hydrodynamic conditions in the first 10 meters above the seafloor were produced by configuring the MARS3D hydrodynamic model in the Cassidaigne canyon at a horizontal resolution of 80 m (CASCANS). These environmental datasets combined with the geographic coordinates of the known occurrences of dense M. oculata colonies in the canyon (presence-only data) allowed establishing a model using the MAXENT software package to predict the habitat distribution in terms of probability of occurrence.

It is probable that the living conditions of M. oculata can be found in areas of the Cassidaigne canyon where the substratum shows irregularities, slopes and topographic heights. According to the data resulting from the hydrodynamic model for autumn 2013, M. oculata habitats are located where a gentle mean current circulates with several acceleration events.

Seafloor ruggedness and water temperature were the most important predictors followed by current velocity, heavy slopes and elevated topographic structures. Suitable areas for M. oculata habitat settlement were mapped at the scale of the canyon.

Predictive Habitat Modeling Of Cold Water Coral Distribution In The Bari Canyon (Adriatic Sea) With Hydrodynamic Variables

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The Bari Canyon is located along the South Western Adriatic Margin and represents the main sediment conduit active since the last glacial interval (Trincardi et al., 2007). It is the main path for the North Adriatic Dense Water cascading and represents the main biodiversity hotspot for cold-water coral (CWC) habitats in the Adriatic Sea (Taviani et al., 2015). CWC ecosystems are especially vulnerable (Freiwald, 2004) and suffer from many physical damages, particularly anthropogenic impacts (Fabri et al. 2014). However factors controlling their repartition are still not entirely understood.

In our study, CWC occurrences, extracted from georeferenced underwater video films, were statistically related, using habitat suitability models, to several parameters of their living environmental conditions, such as eco-geographic variables derived from high resolution bathymetry and hydrodynamic data at sea bottom (based on ROMS for ocean currents, coupled with SWAN within the COAWST modelling system in order to account for wave-current interactions). These statistical predictive habitat models were used to identify the main eco-geographical variables explaining CWC distribution in the Bari canyon. These results were exploited to produce habitat suitability maps.

Automated Mapping Of Seabed Features

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Pockmarks are seabed depressions that can occur in vast numbers in many marine and lacustrine environments. In some areas of the North Sea, more than 30 percent of the seabed is shaped by this type of fluid flow feature and it is in the North Sea that some of the worldŠs largest and deepest pockmarks (e.g. Scanner and Challenger) can be found.

Manual mapping of these features can be extremely time-consuming and subjective. In order to efficiently map pockmarks a semi-automated mapping method was developed, which recognise, spatially delineate and morphologically describe pockmarks at the seabed (Gafeira et al., 2012). This method requires multibeam data or any other bathymetric dataset (Geldof et al., 2014) that can be used to produce digital depth models of the seafloor with sufficient resolution to characterise individual pockmarks of a few tens of metres diameter. This method also captures into a geodatabase an extensive list of morphological attributes for each pockmark and, when available, properties extracted from supplementary datasets. These geodatabases enable the quick selection of pockmarks with specific size or depth or at certain distance from an object on the seabed.

Since it was first developed, we have mapped and characterised more than 4500 pockmarks, around UK continental self, especially within high-resolution survey areas located in the central North Sea Basin. The characterisation of such vast number of pockmarks with multiple attributes allows a unprecedented statistical analysis of the features. Combining this statistical analysis with the geological and oceanographic knowledge of individual areas, we could identify for example: 1) where certain morphological trends reflect the hydrodynamic regime and 2) situations where the density and spatial distribution of pockmarks are mainly attributable to differences in shallow gas availability and deeper geology as opposed to variation in the nature of seabed sediments.

Following on, similar automated methods were and are being developed for other seabed features. For instance, a tailored ArcGIS toolbox was created to assist the predictive mapping of deep-sea organisms and habitats within the Mingulay Reef, combining automatic identification and characterisation of coral mounds from multibeam data with both ROV microbathymetry and high definition videos.

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Spatial Transferability Of Species Distribution Models In The Deep Sea

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Determining the distributions of species and/or communities in the deep sea is vital for their conservation and the management of resources. Expensive survey costs and the sheer expanse and isolation of this ecosystem has resulted in many areas for which there is little or no distribution data available. Species Distribution Models (SDMs) have so far been useful in maximising limited data for specific regions allowing the production of predictive habitat maps, in which species-environment relationships are quantified and patterns of distribution can be predicted.

Less studied is the ability of these models to be effectively transferred into new areas outside of the calibration region. To date, transferred models based on environmental variables within both terrestrial and freshwater systems have performed quite poorly. Although explored very little across marine ecosystems, spatial transferability has been marginally successful, albeit results should be treated cautiously due to the limited understanding of this technique. To date, the influence of dominant landscape features and high landscape variability across different spatial scales are factors considered to hold control over the success of model transfer. Within the deep sea this technique has not yet been exercised, however it is possible that model transferability is achievable due to the large scale homogeneity of this habitat.

This study will aim to determine if SDMs focusing on fifteen deep sea biotopes including Lophelia pertusa reef frameworks and Xenophyophore fields can be successfully transferred from northern Rockall Bank to southern Rockall Bank within the Northeast Atlantic and whether this provides useful results to inform marine policy.

Multi-Species Modelling Of Key Reef-Building Organisms Allows Unique Insight Into Ecological Gradients Present In Sydney Harbour

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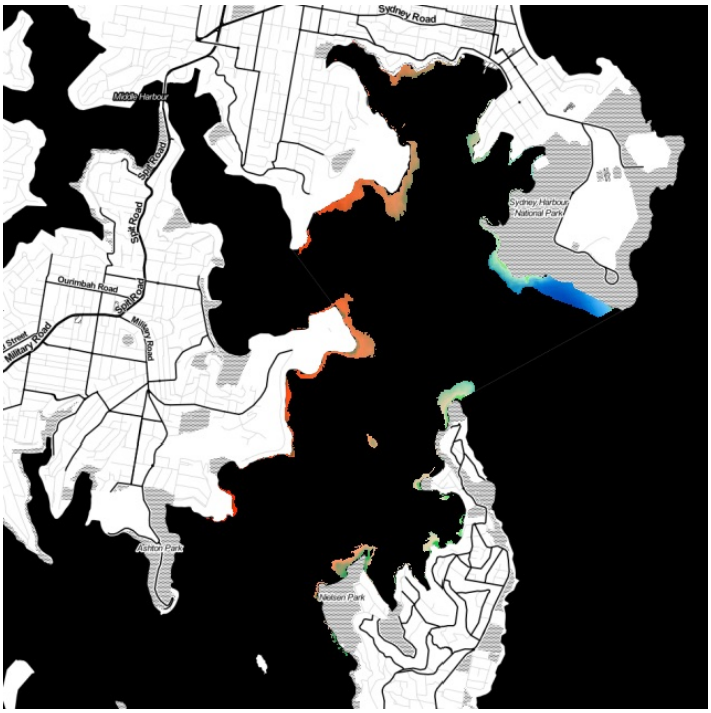

Species distribution modelling has been utilised to great success in terrestrial systems, often to interrogate the influence of climatic or environmental disturbance on a species range. In marine systems, ecologists are confined by a paucity of biological data, and a highly dynamic, hetereogeneous system. Habitat maps have often failed to represent this inherent variability due to small sets of low-detail point-data abstracted across broad spatial areas. Species distribution models predict distribution across space based on point data, but respond to a suite of environmental factors. This study used data from images collected with the Catlin Seaview Survey and classified with SCRIPPS CoralNET machine learning software to build fine-scale species distribution models for key marine habitats in Sydney Harbour, Australia. Although Sydney Harbour is relatively iconic, and central to Australia's largest city, this is the first time comprehensive information about marine habitat distribution and condition has been collected. The outcomes from this project are an example of improvements in our ability to assess and monitor the distribution and condition of marine habitats at a fine scale, given recent technological developments.

The Benthic Impact Of Fishing Around Pipelines

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Fishing and oil and gas are two of the most spatially extensive offshore activities in the North Sea and yet interactions between them are poorly documented in the scientific literature. Commercial fisheries deliberately target pipelines as fishing grounds due to the local reef effect created by the pipeline and associated material surrounding it. We are interested in the impact of trawling on the benthos surrounding pipelines in fishing hotspots in the North Sea. A number of these hotspots were surveyed in 2015 on the MRV Scotia using side scan sonar and a multibeam echosounder. Transects ran across the length of the pipeline covering an area beyond the zone of elevated fishing either side of the pipeline. The seabed was ground truthed using a drop frame video and camera unit towed behind the vessel.

We aim to use an impact gradient approach in order to quantify the macrobenthos distribution progressively closer to the pipeline. We will also identify differences in small scale seabed morphology arising from elevated fishing activities. Evidence of trawl marks running perpendicular to the pipelines are immediately visible from the side scan and similar marks can be seen in the photographs. Understanding how commercial fishing interacts with oil and gas infrastructure will influence decisions on the potential consequences of decommissioning pipelines on the marine environment.

Mapping The Shallow Water Environment Of The Great Barrier Reef

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The Great Barrier Reef is a globally unique resource and is recognised internationally through treaties such as the World Heritage Convention. However, current estimates are that less than 5% of the GBR is regularly measured, and no maps exist that detail the geomorphic and coral community zonations for the GBR as a whole. Such data sets are critical to the succesful conservation and management of this ecosystem.

These maps have to date not been produced due to the remoteness, extent and complexity of the mostly submerged reefs that cover the 350,000 sq km expanse of the GBR. Recent breakthroughs in technology (e.g. low flying drones, underwater vehicles, image recognition/machine learning, access to robust earth observation-derived data sets and habitat mapping approaches) are ushering in novel opportunities to measure, map and model the ecosystems of the GBR at unprecedented scales and frequencies. The University of Queensland is leading the development of such a multi-disciplinary approach, where the earth observation-sourced data sets of bathymetry and seafloor reflectance underpin an indispensable component of the methodology; serving as stand-alone inputs as well as being used to create derivative information layers such as slope and wave exposure models, as well as spectral and textural classifications. These derivative information layers are used as additional inputs to the overall methodology, which in turn is driven by object-based image analysis algorithms.

This multi-disciplinary approach has been tested with a pilot study over the Capricorn Group reefs. For this work, using proprietary physics-based aquatic remote sensing algorithms, EOMAP created the fundamental bathymetry and seafloor reflectance input layers using image data from the earth-orbiting Landsat 8 sensor. However, with the recent launch and coming online of the European Sentinel 2 satellite, a brand new image data source is available which offers higher spatial resolution (10m instead of 30m pixels), an open and free data policy, and a nominal re-visit frequency of just 3-5 days. As part of the ongoing methodology development for identifying the most viable method for mapping the entire GBR, image data from this new sensor were investigated for the retrieval of the required data layers of shallow water bathymetry and seafloor reflectance spectra. Here, we present the methodology and results from using these new data. These results include the validation of the bathymetry output, a comparison with the equivalent Landsat 8-derived products, as well as selected examples of the end-result habitat mapping outputs. In addition, we discuss the implications for deploying these methodologies across the entire Great Barrier Reef.

Centimetric Resolution 3-D Shapes Of Fish Schools: A New Method To Use The Water Column Backscatter From Hydrographic MultiBeam Echo Sounders

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The Multi-Beam Echo Sounder (MBES) is an instrument that allows getting information about bathymetric, morphological and compositional characteristics of the seabed surface. Although it is still one of the most important tools in hydrographic research, MBES can now also discriminate the acoustic imaging of the water mass by recording sampled reflectivity measurements along each beam. In this research, two MBES, namely the Kongsberg Simrad EM3002D (300 kHz) and the Reson Seabed8125-H (455 kHz), which are generally employed to study seafloor characteristics, have been used for high resolution identification and graphical representation of fish schools along the water column. In detail, a methodology to identify and analyse fish schools through the Water Column Backscatter (WCB) is presented. This methodology made it possible to obtain a wide variety of fish schools shape in 3-D (in our case, anchovies and sardines), which allowed a first study on the ecological behaviour of the schools according to their shape. Beyond the mere visualization of shapes, we also attempted to gain numerical values of the school volumes, thus gathering more detailed information about anchovies and sardines school shapes. According to the current literature, this study also showed that there are three main factors influencing the shape of a school:

- The depth of the bottom;
- The time of the day when data are acquired;
- The density of individuals in the investigated area.

The data presented in this research were collected during two oceanographic surveys within the project MEDIAS (MEDiterranean International Acoustic Surveys), Ancheva 2010 and Ancheva 2011.

Object Based Image Analysis Of Bioclastic Mounds For Ecosystem-Based Ocean Management

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Mounds composed of bioclastic sediments occur widespread on the mid-Norwegian shelf. Bioclastic sediments is a common term for carbonate-rich sediments, where the carbonate originates from different types of dead organisms. BCS include a range of grain sizes and origins, from silt to gravel clasts, coral rubble and dead coral blocks, and normally have a minerogenic component. The bioclastic mounds may be wholly or partly covered by living corals and other organisms, and is then recognised as a live coral reef.

Bioclastic mounds are structures with sediments of biogenic origin (e.g. cold-water corals) and are currently mapped as part of MAREANO's sediment genesis map (www.mareano.no) The mounds can be solitary or form complexes. They are visible in multibeam bathymetry data and sometimes have a distinctive backscatter signature. Solitary mounds on the Mid-Norwegian shelf are often elongated in a NE-SW direction, but can also be semi-circular. The mounds are usually up to 100 meters long, and 10-15 metres high. Bioclastic mounds are often located in places controlled by the seabed geomorphology, like iceberg ploughmarks. We have investigated the Aktivneset area, located close to the shelf edge and Storegga Slide at the northern end of the Norwegian Trench. The majority of the solitary mounds in this area are positioned on the raised berms of the iceberg ploughmarks.

The potential for mapping bioclastic mounds using Object-Based Image Analysis (OBIA) is currently being evaluated using eCognition® software. eCognition Developer® offers suite of algorithms tailored to various aspects of image analysis and has previously shown promising results for the analysis and classification of bathymetric data. OBIA-based classification works on objects produced by image segmentation where more elements than simply bathymetry data alone can be used in the classification. An object is a group of pixels, and various object characteristics can be calculated to describe it, such as standard deviation, mean value, ratio. Terrain indices including BPI (bathymetric position index) can also be used within OBIA to aid classification. BPI calculates use focal statistics to calculate a measure of curvature of the surface, defining the elevation a particular location with reference to the surrounding landscape. BPI is particularly useful in identifying geomorphic features like mounds, crests and depressions, and since BPI is readily calculated at different spatial scales can be easily tailored to match the scale of the feature of interest. Classification of bioclastic mounds is being investigated using segmentation algorithms such as multi-resolution segmentation, which will help reduce the heterogeneity of objects in testing areas by merging the pixels until a certain threshold is reached.

We discuss some initial results and fine-tuning of OBIA techniques for the classification of bioclastic mounds. OBIA offers many potential improvements for interpretation of bioclastic mounds and coral reefs compared with manual interpretation and digitisation. OBIA based classification of bioclastic mounds should allow interpretation to become faster and less subjective, which would lead to more efficient and consistent production of sediment genesis maps.

Maerl: A Rare Seabed Habitat Documentary

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"Maerl- A Rare Seabed Habitat" is an hour long scientific documentary about coralline red algae habitats found in the clear, shallow waters of the west of Ireland and worldwide. As benthic habitats of great conservation significance, marine scientists have researched maerl in Ireland for over a century. This scientific documentary explores a diverse range of multidisciplinary research areas related to maerl, including marine botany, zoology, habitat mapping, conservation management to geology, hydrographic surveying and geophysics. With nine interviews with knowledgeable experts on maerl and the seabed, it explores the threat of anthropogenic activity on maerl, including extraction and dredging, salmon farming near maerl, trawling beds and numerous suggestions of marine spatial planning solutions by leading experts some of whom have studied maerl for 20 - 40 years. Marine science documentaries can inspire, educate and transform the science and serve to be an informative tools in science communication (Staaterman, 2014). We hope this documentary will be one step towards educating the next generation of scientists, policy makers, for stakeholder management and the threats faced by exploitation of this vulnerable benthic habitat.

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Compiling Data On Seabed Substrates And Sedimentation Rates From Europe - EMODnet Geology

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The European Union's (EU) Marine Strategy Framework Directive targets to achieve Good Environmental Status (GES) of the EU's marine waters by 2020. However, it has been acknowledged that the poor access to data on the marine environment is a handicap to government decision-making, a barrier to scientific understanding and a break on the economy. The effective management of the broad marine areas requires spatial datasets covering all European marine areas. As a consequence the European Commission adopted the European Marine Observation and Data Network (EMODnet) in 2009 to combine dispersed marine data into publicly available datasets covering broad areas.

The EMODnet data infrastructure is being developed through a stepwise approach in three major phases. Currently EMODnet is in the 2nd phase of development. EMODnet Geology was initiated in EMODnet Phase I (2009-2013) through the ur-EMODnet-Geology project. During the current Phase II (2013-2016), EMODnet Geology will extend the work carried out during the preparatory Phase 1 to cover all European sea-basins (e.g. the Baltic Sea, the Barents Sea, the North Sea, the Iberian Coast, and the Mediterranean Sea within EU waters). The partners, mainly from the marine departments of the geological surveys of Europe (through the Association of European Geological Surveys - EuroGeoSurveys) have aimed to produce medium resolution data products from the sea areas.

The EMODnet Geology project includes collecting and harmonising the first seabed substrate map for the European Seas, as well as data showing sedimentation rates at the seabed. The data is essential not only for geologists but also for others interested in marine sediments like marine managers and habitat mappers. A 1:250,000 GIS layer on seabed substrates has been delivered in the EMODnet Geology data portal, in addition to an updated 1:1 million map layer from the previous phase. A confidence assessment has been applied to identify the information that underpins the geological interpretations.

Benthic Habitat Mapping For The Nearshore Ecological Monitoring Of Dokdo (Dok Island) In The East Sea (Sea Of Japan)

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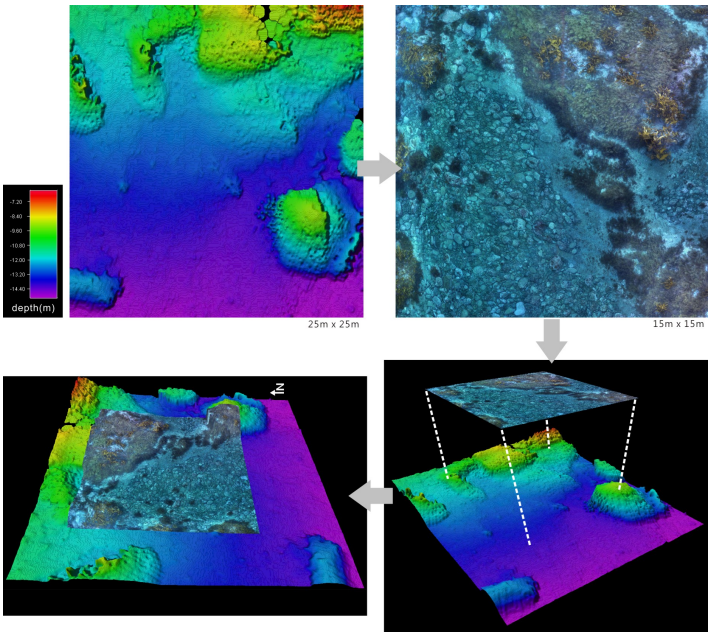

The Dokdo (do means an island) volcano comprises two main islets (Seo-do and Dong-do) and the associated submerged volcanic edifice in the Ulleung Basin, the East Sea. We have been obtained the detailed bathymetry data using multibeam echosounder for the benthic habitat mapping of the southern coastal area of Seo-do. The side scan sonar survey for producing seafloor backscattering images was carried out. High-resolution underwater photograph images and surface sediment samples were acquired by scuba diving surveys. The precise topographical maps of the survey area show that the range of water depth is about from 1 to 28 m and the underwater reefs are irregularly scattered and extended from inland of Seo-do in the shallow water area. In the underwater reefs area, the flank slopes are very steep and irregular, overlain by many large or small submerged rocks, indicating partial erosion due to waves, strong currents and weathering. And below ~15 m, the bathymetry gradually transitions to a relatively even undulation with a smooth slope. The seafloor backscattered image maps show that many large or small submerged rocks occur in the shallow water and other seabed area is covered with small gravels. Based on the analysis of the sediment samples, gravels were dominated in shallow water whereas sand particles increased in deep water. High-resolution underwater composite photograph image maps are draped on the bathymetry for integrated analysis. Moreover, underwater camera image surveys show that the community structure of the marine benthic fauna and flora. Especially, we could monitor the macrobenthic invertebrate, sea urchin population, and macroalgae, Ecklonia cava population, most dominant algae around the nearshore of Dokdo. Benthic habitat mapping using the bathymetry data, the integrated maps, and the sediment data is effective method for long-term monitoring of the nearshore ecosystem of Dokdo.

Setting Up The Assessment Of Marine Habitat Types In Finland

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Climate change, a growing population and increased activities in marine and coastal areas are threatening the marine environment worldwide, also in the Baltic Sea. To ensure the sustainable use of marine resources and nature conservation, effective tools are needed. Marine Spatial Planning (MSP), with the ecosystem approach, is a powerful tool for analyzing, coordinating and allocating the distribution of human activities in marine areas. That enables us to achieve sustainable development by balancing economic, environmental and social objectives. However, successful MSP requires a lot of multidisciplinary information on marine environment. One type of the environmental data needed is the state of marine habitats and possible threats to them.

The 1st assessment of threatened habitat types in Finland was conducted between 2005 and 2007 (Raunio et al. 2008). Habitat types, also the Baltic Sea marine habitats, were classified according to their risk of human-induced decline and deterioration in Finland. However, at that time not too much data on marine habitats existed in Finland. At present we are setting up the 2nd assessments of marine habitats types in Finland, including also threatened habitat types. The new, large datasets on marine species and habitats collected e.g. in the VELMU Programme (The Finnish Inventory Programme for the Underwater Marine Environment) and projects like FINMARINET and TOPCONS, are available for the assessment. The 2nd assessment of marine habitat types in Finland will be based on IUCN Red List of Ecosystems Categories and Criteria (Rodriguez et al. 2015). Marine habitat types (based on the Helcom Underwater Biotopes (HUB) classification) that will be assessed include e.g. Zostera marina, red algae, Fucus and FeMn concretion bottoms.

The assessment of marine habitat types will be carried out 2016-2017 in a group of national experts from the universitys, research institutes and authorities. The assessment will be coordinated by SYKE.

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Making The New Zealand Kapiti Marine Reserve An Integrative Part Of Its Natural And Societal Environment Through Habitat Mapping

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Kapiti Island, along the west coast of southern North Island of Aotearoa New Zealand is one of the country's iconic natural places. The ca. 6 km-wide passage between the mainland and Kapiti Island is characterised by a c. 70 m-deep channel that experiences strong currents, and that has been, until the turn of the twentieth century, a well-known passage for whales. The seafloor surrounding Kapiti Island is of significant cultural and environmental value to Aotearoa New Zealand. The Kapiti Marine Reserve was established in May 1992 and is divided into eastern and western sections. The eastern section is 1825 ha and extends across to the mainland. The western seaward component is 342 ha and encompasses a dynamic and rugose sea floor that creates suitable habitat for a diverse and abundant group of fish and iconic invertebrates such as paua (Haliotis iris) and rock lobsters (Jasus edwardsii). The reserve provides popular recreational dive locations. The geology surrounding Kapiti Island is dynamic with several active faults running along both sides of the island. Bathymetric and seabed habitat maps are prerequisites for informed and effective management of the environment. Information about the seafloor morphology around Kapiti dates from the late 1990s and has a low level of detail.

We used a Kongsberg EM2040 Multibeam Echosounder (MBES) to produce highly detailed maps of the reserve and surrounding area. The white gap, between land and the MBES-mapped area was covered by satellite derived bathymetry, so that complete coverage was obtained. While bathymetry data reveal the shape and depth of the seafloor, the strength of the return signal (backscatter or imagery) provides valuable information on the bottom types and habitats. The definition of the data will enable to image objects less than 50 cm wide in 20 m of water. Visual assessments via remote video and diver surveys were conducted in November of 2015 to validate the multibeam data acquisition. 216 camera drops, 4 sled tows, 46 dives and 30 sediment samples were conducted on targeted habitats to provide comprehensive ground-truthing. Collectively the physical and visual assessments covered 13 different habitat types and enabled the mapping of this important area including spatially describing critical habitat areas such as the nationally protected Rhodolith beds (coralline red algae "balls"). Overall, the data collected enabled a greater ability to effectively manage the area and promote awareness of the richness, diversity and complexity of the seafloor of the Kapiti Island region and the biota it supports.

Too Many Cooks Spoil The Broth: Assessing Which Combinations Of Terrain Attributes Best Serve Habitat Mapping

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Terrain attributes (e.g. slope, aspect, rugosity) derived from digital bathymetric models are commonly used in benthic habitat mapping. The increasing availability of GIS tools that easily generate those attributes can encourage selecting an arbitrary, potentially sub-optimal, combination of attributes. Such selection may induce covariation in the analysis, produce non-comparable results, and may not capture the key properties of the terrain relevant to a particular application. This study aimed at identifying a selection of terrain attributes that best captures terrain properties, to assess how this selection varies with surface complexity, and to demonstrate its applicability to habitat mapping.

Terrain attributes were derived from nine artificial surfaces of different complexity using 230 tools from 11 software packages. Covariation and independence of terrain attributes were explored using three iterative statistical methods: principal component analysis, variable inflation factor, and mutual information. In general, terrain attributes were highly multicollinear and often ambiguously defined within software documentation.

Distinct groups of correlated terrain attributes were identified, and the importance of particular terrain attributes and algorithms in describing a surface varied with surface complexity. We found that a combination of the same six groups of terrain attributes always optimized the amount of captured topographic structure. Based on these groups, we recommend a combination of six terrain attributes that optimizes the information extracted from the terrain while reducing covariation and ambiguity and increasing generalizability: (1) relative difference to mean value (i.e. a measure of relative position), (2) local standard deviation (i.e. a measure of rugosity), (3-4) easterness and northerness (i.e. measures of orientation), (5) local mean, and (6) slope. A toolbox called TASSE (Terrain Attributes Selection for Spatial Ecology) was developed to easily compute these attributes in ArcGIS.

The proposed combination of terrain attributes was compared to six other comparable selections in a real habitat mapping exercise, using bottom-up and top-down approaches to map habitats on German Bank, an area of the Eastern Canadian continental shelf. The seven selections of terrain attributes were used to build habitat maps using only the terrain attributes, hence considering only topography to discriminate habitats, and in combination with other environmental variables (e.g. backscatter). 30 maps of potential habitats based on biophysical characteristics of German Bank were built using unsupervised classifications, and 30 species distribution models of sea scallops (Placopecten magellanicus) were computed using the maximum entropy method (i.e. MaxEnt). The performances of the 60 maps were quantified and compared.

Habitat maps and distribution models created using the proposed selection yielded better results than the maps and models made with other selections. For the unsupervised classifications, maps built with the proposed selection generally produced higher accuracies, in addition to better discriminate specific habitat types. For the MaxEnt models, the proposed selection had generally a higher predictive capacity and produced more robust and generalizable models. Maps and models that combined terrain attributes with other environmental variables performed better than those generated with only terrain attributes, suggesting that the distribution of the studied habitats and commercial species are not only explained by terrain geomorphology.

Piddington Mound: Preliminary Results From Cold-Water Coral Reef-Scale Habitat Mapping

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Despite the recent increase in number of publications on Cold-Water Corals (Roberts et al., 2009), there is still need to better constrain the environmental parameters affecting the topographic features developed by these autogenic, mound-generating biota. This is true, not only for local-scale factors (10cm-1km) (Dolan et al., 2008), but also to account for the spatial heterogeneity observed over individual mounds.

While previous work on the Moira Mounds deals with the mid-slope, prodominantly inactive mounds (Foubert et al., 2011; Wheeler et al., 2011), this research examines variation observed in the western, lesser-studied, Moira-type mounds, Belgica Mound Province, North East Atlantic. In particular, these mounds show a broad gradation in mound size, stage of growth and general 'vitality'. The aim of this work is to link patterns and variations to the processes affecting habitat development and resulting topographic features.

A reef-scale, groundtruthed, video mosaic is used to examine the distribution of sedimentary facies and other attributes across the mound. Currently, this research is focussed on utilising this video mosaic, CTD's, box cores, gravity cores and ROV-borne multibeam (microbathymetry) to develop the first reef-scale habitat zonation model. In light of reef-scale heterogeneity, local-regional scale variation is also under examination, in particular, the distribution of hydrodynamics as recorded by sedimentological parameters and bedforms. This presentation demonstrates a range of work to date.

Seabed Habitat Mapping Of The Continental Slope Of Uruguay (SW Atlantic Ocean) And Coral Mounds Fishing Interaction

*Guzmán **López**[1], Julio Chocca[2], Camila De Mello[1], and Yamandú Marín[2]*

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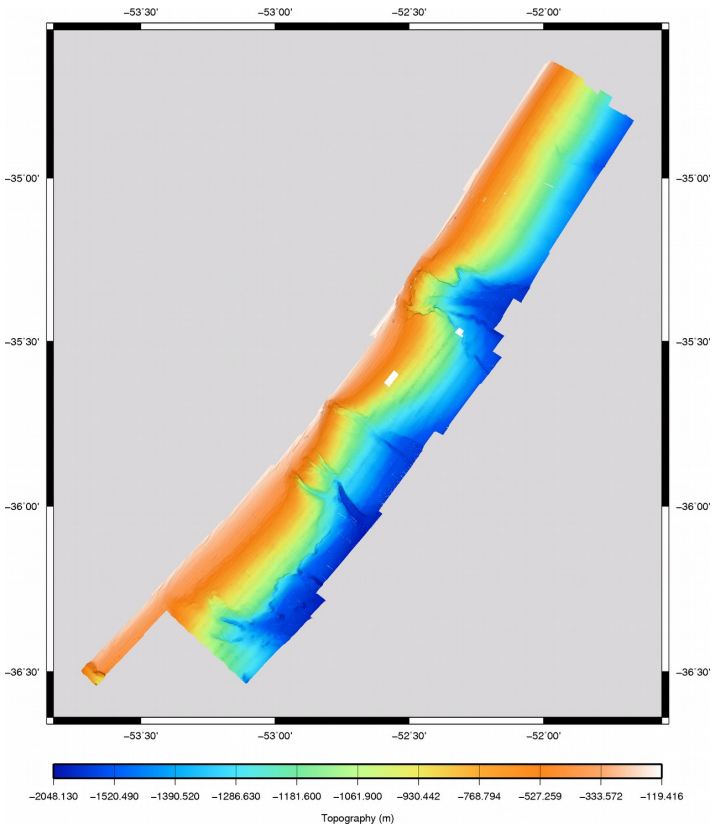
We analyzed the acoustic data obtained with a multibeam echosounder during an oceanographic survey aboard the "R/V Miguel Oliver" in january-february of 2010. The aim was to map the sea floor of the continental slope of the Uruguayan Exclusive Economic Zone (EEZ). The acoustic data was processed with MB-System software and then incorporated into a Geographic Information System (QGIS). We obtained 3 m for 3 m grid files to describe small submarine structures (mounds and pockmarks), and also a topographic map of the entire area to describe large submarine structures (submarine canyons and landslides, Figure 1). When we analyzed the topography of the entire area we identified 4 submarine canyons and the beginning of a fifth in the south end. We also observed 63 small submarine structures in the seafloor, where 22 were mounds and 41 were pockmarks (PM). The mounds were classified according to their grouping and the presence of erosive traces (scarps), like Solitary Mound with Scarp (SMwS), Solitary Mound without Scarp (SMwoS) and Grouped Mounds (GM). High spatial correlation was observed between the wreck fish Polyprion americanus longline fishing activities and mounds presence. This information may be useful to define priority areas to protect by its geomorphological features, its present biota and/or ecological role enabling responsible fisheries management.



Disturbance In The Deep: A Model For Ecological Succession In The Deep Sea

Leigh ***Marsh***[1], *Steve Carey*[2], *Steve Sparks*[3], *Peter Talling*[4]

1. University of Southampton
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3. Bristol University
4. NOCS

This will be the first study to use a chronological sequence of volcanic eruptions to: 1) establish how deep-sea organisms and communities respond to infrequent large-scale disturbance events and, 2) provide the first example of successional dynamics of deep-sea fauna associated with hard-substratum.

The spatial and temporal distribution of pyroclastic flows and historic submarine landslides around the volcanic island of Montserrat have been documented by repeated high-resolution bathymetric surveys, coring of the new deposits and most recently, in-situ Remotely Operated Vehicle (ROV) investigations. Crucially, these studies provide age constraints on the submarine landslide deposits. Coupling this knowledge with Remotely Operated Vehicle (ROV) imagery available from the dated volcanic events will provide an insight into rates of recovery of marine ecosystems as deep as 1,000 m following large-scale geological disturbances over longer time frames (decadal to millennial) than previously documented.

MeshAtlantic - Mapping Atlantic Area Seabed Habitats For Better Marine Management

Fergal ***McGrath***[1]

1. Marine Institute, Ireland and MESH Atlantic Project Partners

MeshAtlantic is an EU funded project (INTERREG IVB, 2010-2013) which has provided a harmonised seabed habitat map of the coastal and shelf areas of the Northeast Atlantic. The primary aim of the project was to aid the development of sustainable marine management plans at both regional and European levels. It involved the collation of habitat mapping information across several countries, including Ireland, France, Spain and Portugal as well as acquisition of new data in MPAs in each country.

MeshAtlantic has acted as a focal point for collation and standardization of these datasets at an international level. It has also resulted in improved interaction between the European agencies responsible for seabed mapping and stakeholders. The collation of these data has also resulted in close collaboration with other EU funded projects (e.g. EMODNET).

The key outputs of the project are three different sets of maps harmonized and classified using EUNIS across the project area. These are:

1. Pre-existing habitat maps that have been enhanced and harmonized
2. Detailed national and transnational habitat maps covering a limited set of Natura 2000 sites
3. A broad-scale modelled habitat map extending from Ireland to Portugal (including the Azores)

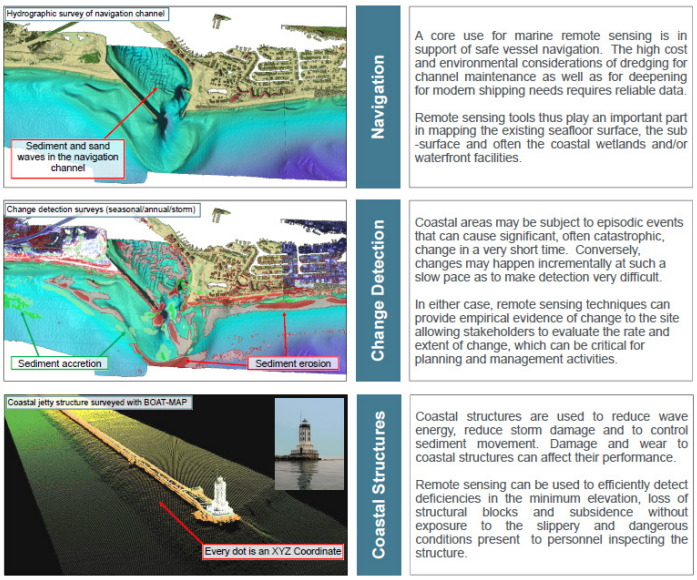
The outputs of the project in Ireland include acquisition of new data in Kenmare Bay, a EUNIS habitat map for Kenmare Bay, direct support of monitoring work in the WFD, a collated habitat map for a significant part of Irelands seabed, and collation of existing habitat maps and source data. MeshAtlantic was supported by INFOMAR, Irelands national seabed mapping programme. Involvement in MeshAtlantic has facilitated leveraging of extra resources in order to discharge a programme of data collation which otherwise could not have been carried out.

This paper will focus on how MeshAtlantic promoted harmonised production and use of marine habitat maps covering the Atlantic Area, and look at the approaches adopted to delivering habitat maps for marine spatial planning in a transnational context.

The Remote Coast: Baseline Mapping In Preparation For Arctic Coastal Disasters

Todd ***Mitchell***[1]

1. Fugro



Our coasts are a critical intersection of ecological, social, and economic interests. They are the breeding ground for aquatic plants and animals, the playground for residents and tourists, and the launching ground for shipping, fishing, and resource development projects. In arctic regions, these areas are generally poorly characterized (often due to their sheer size, sparse population and inaccessibility), yet are perhaps the most fragile environment. The arctic coast is particularly vulnerable to the impacts of human activity - particularly accidental chemical spills. Reducing the risk of and/or responding to emergency situations requires a thorough understanding of both the coastal environment, adjacent submerged lands and often the jurisdictional boundaries of stakeholders. As such, this effort begins with a mapping program that identifies the land/seabed boundaries and usage, and provides adequate charting for over-water emergency response activities. However, existing mapping and charting data is often limited to navigational corridors, resource development sites and fishing areas - or is so dated as to be insufficient for the task. This leaves most of the arctic coast inadequately mapped to be able to track changes wrought by a coastal disaster and/or to safely respond to it. Due to the enormous extent of arctic coastlines relative to the population, the economic situation for most government agencies does not readily support extensive and expensive survey campaigns. Similarly, the difficulty in securing the long-term funding necessary for monitoring changing conditions is also often a challenge. Therefore, it is a great advantage to identify methodologies that are economically advantageous, can capture data at a regional level and that can be performed in a time-efficient manner. Whereas small, local site investigations are typically best performed from vessel-mounted sensors, aerial and satellite remote sensing technologies can often offer an option to meet all three goals, although these techniques rely upon suitably clear water to do so. This poster will provide information on how aerial and satellite remote sensing techniques can be integrated into conventional coastal mapping programs to meet these goals.

Comparison Of Supervised And Unsupervised Benthic Habitat Classification: Case Study From The Belgian Shelf

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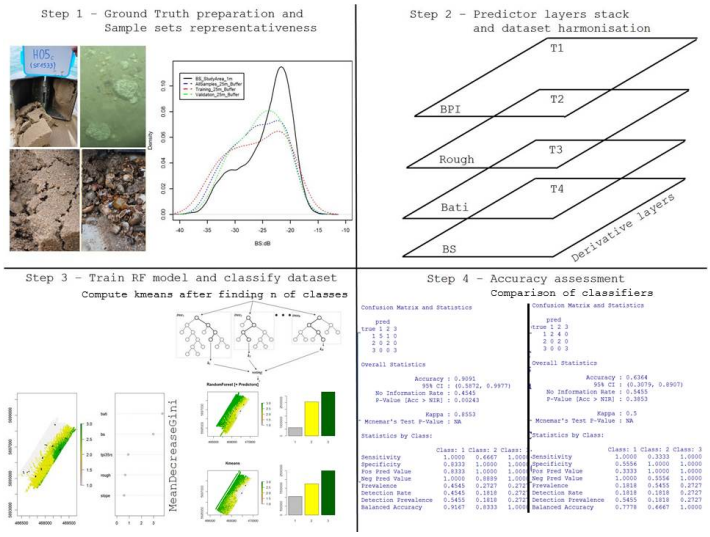
Multibeam echosounders (MBES) provide state-of-the-art data to explicitly map and discover the marine environment. Acoustic data originating from co-registration of high density echoes' geometries, angles and intensities represent a valuable proxy to discriminate and quantify the underlying geomorphology and surficial seabed composition with unprecedented detail.



As a result, benthic habitat mapping (i.e. mapping for "discovery" and mapping for monitoring) has become a fundamental prerequisite of marine spatial planning and ecosystem-based management. Ideally, decisions are made on a series of thematic maps that summarize portions of the seabed, following repeatable routines of automated classification and accuracy assessments.

With increasing availability of datasets (including time-series data) the interest in automatization of otherwise labour-intensive and often subjective classification processes is steadily growing, as also its publication in peer-reviewed papers. Increasingly, comparison of segmentation and classification methods are dealt with, often using optimized routines, though ultimately, high level mapping and monitoring as currently achieved with optical remote sensing data for the terrestrial realm, is targeted.

In this study, we apply supervised and unsupervised image classification of multibeam depth and backscatter data within a sandbank area of the Belgian part of the North Sea. We validate the results against a set of ground-truth data collected complementary to the acoustic survey at the study site. We apply Random Forest (RF) and K-means classifiers following a statistical investigation of the datasets and compare their accuracy metrics (overall, producer, user and kappa metrics) in respect to a common ground-truth test data-set.

Bathymetry And Recent Sedimentation From Cienaga Grande De Santa Marta (Magdalena, Colombia)

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The single beam bathymetry from Cienaga Grande de Santa Marta (CGSM) and shallow shelf to depths of 10 m front of towns Cienaga and Pueblo Viejo (Magdalena), was acquired with interest in develop hydrodynamic models (Carvajalino-Fernández, 2015) and to describe the main submerged geoforms and their relationship with the littoral dynamics. The digital depth model was interpolated with ArcGIS 10.2, and compared with past bathymetric sources (CIOH-Invemar-Corpamag, 2001; Posada et al. (2009), showing similarities on the distribution of the bottom surface. We identify the shallow zones at northeast and southwest of the water body, with depths less than 1.4 m, and 1 m of mean value. In contrast, deeper zones are located at northwest and southeast where the water table of the estuary reaches 2.2 m. At south, we identify monticules related with shell's banks of 1 m elevation from bottom. At the continental shelf was located a delta front modified by the littoral drift, showing the formation of submerged bars with similarities to a spit. This form reflects the incidence on the water exchange through the Boca de la Barra, acting as hydraulic barrier for sediment transportation from east to west. In addition to these, we take 28 corers to describe the sedimentological characteristics of the estuary bottom, identifying layers of mud, sand, peat and those with biogenic fragments (shells).

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3D Model of CGSM seen from NW, showing main hydric sources and representative morphological features.

Combining Vessel Monitoring System (VMS) And Benthic Habitat Data To Investigate Pressure-State Relationships In Offshore MPAs

Tammy ***Noble-James***[1]

1. Joint Nature Conservation Committee

Benthic habitats and communities within UK waters are considered to be at high risk of damage from abrasion pressures associated with demersal mobile gears. The relationship between abrasion pressure and habitat condition - the pressure-state relationship - is well understood for some habitats (e.g. cold water coral reefs), whilst further research is required for others. Investigation of pressure-state relationships requires an understanding of the pressure distribution within the habitats of interest. In contrast to many other anthropogenic pressures, such information is accessible for abrasion pressure in the offshore region due to Vessel Monitoring Systems (VMS) onboard commercial fishing vessels, which relay positional 'ping' data at two hour intervals. Scientists from the Joint Nature Conservation Committee (JNCC) and the Centre for Environment, Fisheries and Aquaculture Science (Cefas) have used VMS data to produce abrasion pressure maps at an ecologically meaningful scale.

JNCC is responsible for monitoring benthic habitats within UK offshore MPAs, and is conducting R&D studies to investigate relationships between designated habitat condition and abrasion pressure (where these are not already established). VMS mapping products provide a significant resource for sampling design, being used in combination with habitat maps to identify pressure gradients within MPAs.

This poster will explore various aspects of abrasion pressure-state studies, including:

- The advantages and limitations of using VMS data for sampling design;
- The combined use of VMS ping data, abrasion pressure maps and habitat maps to assess study feasibility and design sampling strategies, with examples from UK MPAs;
- The potential use of VMS products for indirect monitoring where pressure-state relationships are sufficiently understood.

EUSeaMap: A Broad-Scale EUNIS Seabed Habitat Maps For European Seas

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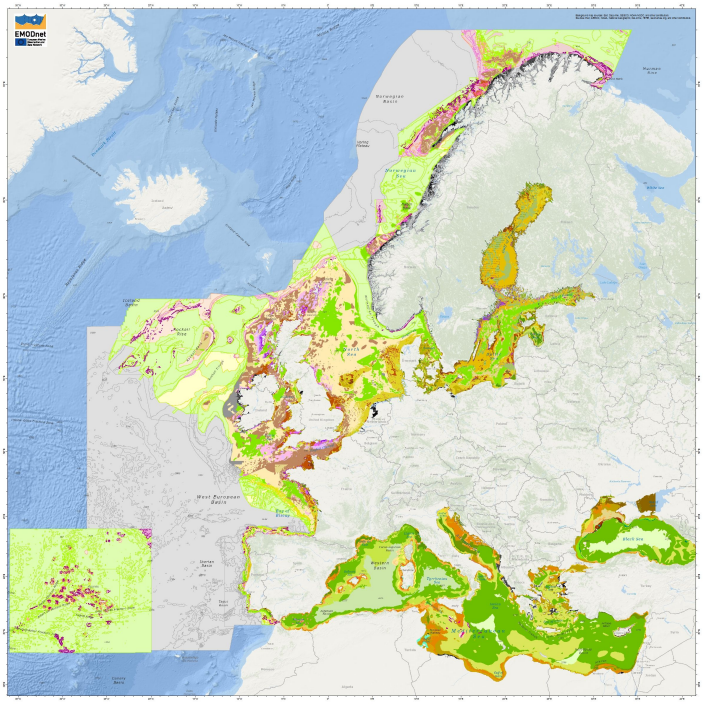

Within the Seabed Habitats lot of the EMODnet (European Marine Observation and Data Network) initiative a full coverage broad-scale habitat map has been produced for the European waters. This map, named EUSeaMap, aims to describe the environmental conditions occurring at the seabed that are known to influence the distribution of plant and animal communities. Where possible, the marine section of the European Nature Information System (EUNIS) habitat classification scheme is used to describe the environmental conditions. The exception to this is the Black Sea where EUNIS is not applicable; as a result, the project agreed on a new pan-BlackSea classification of physical habitat types.

Taking into account the way seabed habitats are described within the EUNIS classification, the broad-scale habitat map is, in its basic form, a combination of two key categorical spatial layers: seabed substrate types (e.g. rock, sand, mud) and biological zones (e.g. infralittoral, circalittoral). Depending on the biogeography, other categorical layers can also come into play, for example hydrodynamic energy levels (high, moderate or low) in the Atlantic or the oxygen regime (oxic, suboxic, and anoxic) in the Black Sea.

The seabed substrate layer is provided by EMODnet Geology. The production of the other categorical layers is carried out within the framework of EMODnet Seabed Habitats by intersecting oceanographic layers that are statistically compiled from fundamental physical parameters in the various basins, including 1) bathymetry (provided by EMODnet Bathymetry), 2) light energy at the seabed, 3) current- and wave-induced kinetic energy, 4) seabed temperature, 5) density and 6) salinity.

The poster is a compilation of the draft maps that were delivered in September 2015. If in waters such as the North EastAtlantic, the Baltic, North and western Mediterranean Sea the maps were updates of those produced by previous initiatives (namely the ur-EMODnet and MeshAtlantic projects), this second EMODnet phase is providing for the first time a comprehensive perception of habitats spatial distribution in other areas such as the Adriatic, Eastern Mediterranean, Black and Norwegian Seas. The final version of the maps will be delivered in September 2016 and will be freely available at: http://www.emodnet-seabedhabitats.eu/

Guideline For Standardized Seafloor Mapping In The German Exclusive Economic Zone (EEZ)

Claudia ***Propp***[1]*, Alexander Bartholomä, Christian Hass, Peter Holler, Svenja Papenmeier, Peter Richter, Klaus Schwarzer, Franz Tauber, Manfred Zeiler*

1. Bundesamt für Seeschifffahrt und Hydrographie (BSH), Bernhard-Nocht-Str. 78, 20359 Hamburg

Offshore activities and protection of the marine environment require a better knowledge of seabed conditions. Detailed information of seabed sediment types is a prerequisite for the identification, monitoring and protection of marine benthic biotopes according to the implementation of EU directives.

The Federal Maritime and Hydrographic Agency (BSH) of Germany has started a new sediment mapping program in cooperation with the Federal Agency for Nature Conservation (BfN) based on side scan sonar and ground truthing using grab sampler and underwater video. To establish a standardized mapping procedure, BSH and its project partners AWI, CAU, IOW and SaM have developed a specific technical guideline that includes requirements for the collection, processing and interpretation of backscatter data. Focus was put on the latter, whereby standardized strategies for the classification and discrimination were defined for different seafloor sediment types.

Different levels of classification have been introduced for the sediment types, primarily based on the FOLK scheme (Folk, 1954). For the German North Sea, sand is classified according to the national classification scheme (Figge, 1981) to meet the requirements for biotope modelling on the sandy shelf of the German North Sea sector. All these data are combined in one sediment map, together with additional information about the genesis of sediment types as well as the type of transition between them. In addition, the technical guideline comprises a national catalogue of characteristic backscatter images of sediment types which occur in German territorial waters.

The guideline has been discussed with experts from state agencies for nature conservation and environmental protection or commented by consultancies in civil and environmental engineering. At present, it is tailored to support German governmental marine mapping tasks in the EEZ but will soon be extended for mapping specifications applied in coastal zones. An alignment with similar efforts of the EU countries is planned in a further step in order to promote the effort of producing standardized maps that can easily be connected across the borders of the European coastal countries.

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Hanging Gardens: Vertical Walls From Images To Fine-Scale 3D Reconstructions

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Vertical and overhanging walls in complex deep-sea environments can harbour high biodiversity and host Vulnerable Marine Ecosystems, to which they provide natural protection from human activities such as trawling. Traditional ship-board multibeam systems cannot adequately replicate the complete 3D structure of vertical habitats, and towed video systems are challenging to operate in these rugged environments. In this study, we combine front-mounted ROV multibeam sonar data and ROV video imagery to examine vertical walls from the Rockall Bank Slide Complex and the Whittard Canyon, Northeast Atlantic. High resolution point clouds of bathymetry are extracted from sonar data, but, to obtain even higher resolutions, photogrammetry techniques (structure from motion) are applied to create 3D representations of video transects along the walls. With these reconstructions, it is possible to interact in 3D with extensive sections of video footage which cannot otherwise be visualized in their entire context. The videos, once georeferenced and scaled, can be used to ground-truth the broader scale geological setting of the wall (as obtained from ROV multibeam); they also allow very accurate positioning and measurement of individual organisms. Moreover, derived terrain variables can now be extracted on scales similar to those experienced by megabenthic individuals (<20cm for sonar and <1cm for photogrammetry) and employed to explain fine-scale habitat selection. The most commonly observed species in this study include Acesta clams, cerianthids, the cup coral Desmophyllum, the soft coral Primnoa and cold-water corals such as Lophelia pertusa, Madrepora oculata and Solenosmilia variabilis. A key finding is that vertical walls with different lithologies harbour different species assemblages, and fine scale structures such as ledges and overhangs were preferentially selected by certain species. The heterogeneity generated by individual coral colonies was also resolvable and used to examine associated fauna. These new technologies are allowing us, for the first time, to map the physical 3D structure of previously inaccessible walls, and are demonstrating the complexity and conservation importance of these habitats.

This work is part of the ERC CODEMAP project (Starting Grant no 258482). Data were collected during the CODEMAP2015 cruise, and during the SORBEH expedition which was supported by the Irish Marine Institute and funded under the Marine Research Sub-Programme of the Irish Government.

Fine-Scale Mapping And The Edge Effect: Distribution Of Non-Vent Endemic Fauna From Antarctic Hydrothermal Vents

Leigh Marsh[1], *Virginia* ***Russell***[1], *Veerle Huvenne*[2], *Jon Copley*[1], *Paul Tyler*[1]

1. University of Southampton
2. NOCS

Co-registering high-definition ROV videography and fine-scale (0.15m) resolution ROV multibeam, the distribution of non-vent endemic fauna around the active E2 hydrothermal vent field on the East Scotia Ridge have been mapped. These communities have been spatially correlated with bathymetric derivatives (e.g. slope) and environmental variables (e.g. temperature) with the specific aim to see whether or not there is evidence of the 'edge-effect' - a change in population or community structure that occurs at the boundary of two habitats: In this example, vent endemic and non-vent endemic assemblages.

Geomorphological Control On Extent And Vulnerability Of Deep-Sea Habitats In The North-Eastern Ionian Margin (Eastern Mediterran

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On the North-Eastern Ionian margin, multiple Pleistocene mass-movements have created unique morphological forms and small-scale changes in substrate distributions, yielding long-term, suitable environmental conditions (hard substrates and increased bottom currents) for the settling of specific Vulnerable Marine Ecosystems (VMEs). In 2000, the discovery of a Cold-Water Coral (CWC) province dominated by frame-building scleractinians, located a few miles off of Santa Maria di Leuca (SML), led indeed to significant ecology and biodiversity research within the margin, which identified a variety of different macro-habitats (sensu Greene et al., 1999), including the L. pertusa and M. oculata coral frameworks, hard-ground crusts and boulders colonized by the antipatharian species L. glaberrima, and a heterogeneous distribution of Pennatulaceans. CWC predominantly grow on the exposed summits and flanks of failure-related sediment blocks (up to 300 m wide and 25 m high), facing the main incoming bottom current from the north-east and forming coral topped mounds.

Through production of a detailed geomorphological map and an examination of published data on the multi-scale extent and distribution of all mapped deep-sea habitats in the area, relationships between the complex seafloor topography generated by geomorphic processes and VMEs documented occurrences were here investigated.

Coral growth in particular at elevated positions, where nutrient inputs were supplied by rich NE bottom currents, and they emphasized seafloor roughness originally generated by mass-movements, especially along the top of regional blocks that dissect the margin through a series of NNW-SSE oriented normal faults, probably still active. Such configurations have been interpreted to be a result of a recent margin evolution that underwent regional uplift during the Late-Middle Pleistocene. Uplift reduced the accommodation space and created a physiographic context where large areas became swept due to local bottom-currents, especially on the tops of large-scale, up-thrown, faulted regional blocks due to their elevated position.

We also mapped and classified anthropogenic threats that were identifiable within a wide set of video data collected at some locations, and results on relationship between the mapped distribution of benthic habitats and anthropogenic threats are here presented to document the relevant role that seafloor geomorphology have in influencing deep-sea habitat vulnerability to detected anthropogenic impacts.

Megafauna Distribution Patterns Along Different Geomorphological Units In The APEI-4 Of The Clarion Clipperton Fracture Zone

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1. National Oceanography Centre, University of Southampton Waterfront Campus, European Way, Southampton, UK
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The potentially imminent start of the exploitation of polymetallic nodule fields in the Clarion-Clipperton Fracture zone (CCFZ) in the Pacific Ocean has highlighted the lack of basic ecological knowledge about these deep-sea abyssal systems. Novel underwater technology enables this extraction, but it conditions its economic feasibility to a minimum seabed disturbance of 3000 m^2 per day. Besides the direct effect of mechanic compression and substrate removal, Mn-nodule mining would also affect habitats located in the margins, or even several hundreds of meters away from the exploitation zones due to the re-deposition of sediment plumes. Mn-nodule fields have shown to host highly diverse faunas, with samples often composed by a large number of species new to science. The low metabolic rates observed in the fauna living in this oligotrophic benthos has enhanced the general scientific conception that recovery rates after disturbance in this region could be extremely low. Hence, the detection of different habitats and determination of the environmental ranges that delimit these within the CCFZ is crucial for the generation of ecologically comprehensive management policies and legislation. Here we show differences in community composition between 3 different topographical units found within a randomly selected 40 x 40 km square of seafloor located within the area of particular environmental interest (APEI) number 4 of the CCFZ. Significant differences in species richness (S), diversity (H') and evenness (J') were found between three habitats: a flat zone, a ridge zone, and a valley area located between 4050 and 4200 m depth. These stratums were defined a priori, as a result of a terrain classification based on pre-set limits of bathymetric derivatives, such as slope, bathymetric position index and roughness. Relative Mn-nodule cover in each of these areas also showed to have an effect on the community composition and diversity. These results underline substrate composition and seafloor morphology as key environmental factors for the diversification of niches within Mn-nodule fields. However, given the low megafauna densities observed and the large extension of the CCFZ, top-down mapping effectiveness shall be limited until the potential effect of the observational scale and other environmental drivers is better understood. Hence, further exploration is required to map and describe a further number of habitats, and to compare different areas of the CCFZ. A precise spatial determination of the limits and ecological similarity of each of these habitats shall be indispensable to ensure the efficiency of future protection measures.

The Integration Of Seabed Mapping Information In The UK, Europe And Recent Trans-Atlantic Collaboration.

*Alan **Stevenson**[1], and the MAREMAP, EMODnet-Geology and Atlantic Seabed Mapping International Working Group members*

1. British Geological Survey

Much of Europe's seafloor is still unmapped using high-resolution technologies and continues to be a major undertaking that involves many national organisations. Collaboration at national level has improved during the last 10-15 years through multidisciplinary programmes such as INFOMAR in Ireland, MAREANO in Norway, and the UK's MAREMAP Programme. MAREMAP is built mainly upon agreements between the UK's public sector organisations, who are working together to improve the ways in which planning for marine surveys is co-ordinated to avoid duplication of effort, and to store, share and make use of the information that is available. The sea-floor data that is now being shared is being used to deliver a new generation of geological maps that support more detailed habitat maps.

In addition to working closely to align marine mapping programmes at national level, 36 geological survey organisations from 30 countries participate in the European Marine Observation and Data Network (EMODnet), a programme funded by the European Commission to assemble marine data, products and metadata to make these fragmented resources more easily available to public and private users relying on quality-assured, standardised and harmonised marine data for all of Europe's seas. In addition to geology, EMODnet includes information for seabed habitats, bathymetry, chemistry, biology, physics, coastal mapping and human activities. EMODnet is currently in its second development phase with the target to be fully deployed by 2020.

The 'Galway Statement' signed in May 2013 by the European Union, the United States and Canada, agreed to join forces on Atlantic Ocean research. The agreement focuses on aligning the ocean observation efforts of the three partners to better understand the Atlantic Ocean and to promote the sustainable management of its resources. In 2015, the committee tasked with implementing the Galway agreement established an Atlantic Seabed Mapping International Working Group, which will provide recommendations for an integrated approach to seafloor mapping, including geology and seabed habitats. This initiative further demonstrates the importance placed on seabed mapping at a governmental level and the commitment to establishing systems that will ensure the integration of national and international seabed mapping activities.

Progress on MAREMAP, EMODnet and the Atlantic Seabed Mapping International Working Group will be presented.

Quantitative Analysis Of Mini-Mounds From The Explorer And Dangeard Canyons Area: An Automated Approach

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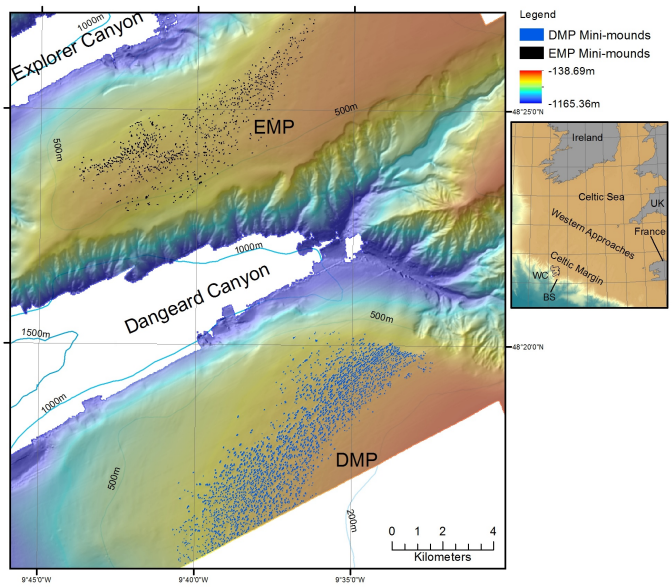
1. British Geological Survey

The Dangeard and Explorer canyons are located on the Celtic Margin, offshore UK, and are tributaries to the Celtic deep-sea fan via the Whittard Canyon. The heads of the Dangeard and Explorer canyons were surveyed during the MESH canyons cruise in 2007. Two previously unknown provinces of cold-water coral mini-mounds were discovered on the interfluves of these canyons (Stewart et al., 2014) and observed to comprise coral rubble and associated fauna including ophiuroids and the squat lobster Munida sarsi (Davies et al., 2014). In this paper we show results from the application of an automated mapping method to morphologically characterise these mini-mounds.



Shaded relief image of the high-resolution multibeam bathymetry data acquired over the Explorer mini-mound province (EMP) and Dangeard mini-mound province (DMP) with polygons created using the automated technique delineating individual mini-mounds overlain. See inset map for location. Generalised bathymetric contours on main map and shaded relief on inset map are derived from GEBCO (www.gebco.net). BS = Brenot Spur, WC = Whittard Canyon.

The method employed was initially developed to map and characterise fluid-escape pockmarks at seabed (Gafeira et al., 2012), and was subsequently tailored to delineate positive topographic features such as mounds and compiled into an ArcGIS Tool Box (BGS Coral Mound Tools). This toolbox comprise two scripts that allow the systematic application of a sequence of tools available in ArcGIS and can be used to recognise, spatially delineate and characterise morphometrically seabed mounds using a Bathymetric Positioning Index (BPI) raster derived from the multibeam echosounder data. This time-efficient approach provides an unbiased and accurate mapping methodology, and through morphometric analysis, enables quantitative analyses of potentially vast numbers of seabed features.

Multibeam bathymetry data were gridded at 5m cell size to generate a fine-scale BPI raster using the Benthic Terrain Modeler extension for ArcGIS (Wright et al., 2005). The first script generates an output polygon shapefile delineating the mini-mounds. The second script captures the morphological characteristics of each mound and populates the attribute table of the delineated polygons. Two other point shapefiles are also generated: 1) showing the centroid, and 2) marking the shallowest point, of each delineated mound.

The outputs from the automated process reveal more than 2000 mini-mounds present in the Dangeard mini-mound province and more than 800 in the Explorer mini-mound province, representing a significant increase on previous estimates of mini-mounds in the area (Stewart et al., 2014). Morphometric data show that the mini-mounds of the Dangeard province are larger (3-4m high and up to 3.5km^2 in area) than those observed in the Explorer province (2.5-3.5m high and up to 2km^2 in area). While further work will be required to explain this phenomenon, it may reflect trawling damage within the Explorer province. The morphometric data also reveal that the mounds are elongated along slope, likely due to the influence of contour currents.

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An Hybrid And Integrated Approach To Map Seafloor And Clam Presence Using Multibeam Data

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The improved quality and volume of Multibeam Echosounder (MBES) data is increasingly ensuring the suitability for seabed classification and driving the desire for repeatable seafloor characterization approaches, analogous to the automated classification of satellite imagery for terrestrial mapping.

In this context, the research group investigates how to tailor a proprietary hybrid classification framework, successfully developed for terrestrial Land Cover/Land Use mapping, to benthic habitat characterization.

Dataset includes full-coverage Kongsberg EM3002D multibeam data and derived textural / statistical features, encompassing a 11 km^2 shallow coastal area in the Adriatic Sea.

Concurrent clam fisheries surveys (striped venus shell Chamelea gallina) give the chance to carry out sample-specific quantitative correlations and investigate how baby clams can affect MBES backscatter and consequently be used to detail the seafloor characterization.

Dealing with backscatter segmentation and hybrid classification, the overall acoustic seabed classification is improved first integrating MBES data along with their derivatives and later employing a fuzzy object classifier, implemented on the basis of a Winner Take All (WTA) approach, to manage the pixel-based results and detail the seafloor map legend in terms of probable presence of clams.

Cluster analysis and supervised classifications yield pixel-based results while a supervised rule-based approach sorts segmented regions into seafloor thematic classes in terms of winner sediment and clam presence.

The final habitat data is GIS-ready, hence suitable to be directly used for marine spatial/temporal planning and resource management.

Spatial information on human disturbance pressures (Automatic Identification System - AIS) are integrated in the rule-based WTA approach to elucidate distribution patterns of benthic fauna and aid the research evaluation in terms of stability assessment, helping the user to recognize stable regions (classified with high accuracy) from those whose classification result should be verified before being used.

Experimental results show promise for increasing the amount of automation with which thematically accurate habitat maps can be generated from acoustic imagery and represent a good first step of an important research field. In fact, widely distributed along European coasts, C. gallina has long been a very significant resource on the western Adriatic coast making its stock management a valuable key issue.

Mapping For Management And Conservation Of Subtidal Habitats

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Habitat maps are essential for management and conservation of marine habitats. The EU Habitats Directive requires Member States to maintain or restore a list of natural habitats (and species), that in the marine environment are generally quite broad, for example, Reefs, Sandbanks and Estuaries. Other biodiversity commitments require the protection of threatened and declining habitats such as seagrass beds and fragile sponge and anthozoan communities. Natural Resources Wales (NRW) has a programme of creating, collating and updating maps of habitats currently listed in the Habitats Directive, the OSPAR Convention and the NERC Act.

The methods for creating maps vary according to habitat type. This poster describes map creation for a selection of different subtidal habitats found in Wales. Maps of subtidal seagrass beds have been created using a variety of data sources including direct observations (e.g. dive surveys, snorkelling and drop down video), aerial photography and acoustic methods. Fragile sponge and anthozoan communities are mapped mainly using point data from diver observations, as there are not many other survey methods suitable for detecting this habitat. Our current Reef maps have been created from a range of data sources, including various remote sensing datasets (multibeam, sidescan sonar, AGDS, aerial imagery), direct observations (e.g. video and dive surveys) and / or predicted and interpolated GIS datasets. NRW recently became a member of the Pan-Government data sharing agreement for multibeam data. We intend to analyse this data using a variety of techniques including "Object Based Image Analysis" (OBIA), to identify and delineate habitats particularly bedrock, sediments and stony reef areas, and update our maps accordingly. Confidence in both the determination of habitat type and habitat boundary delineation are integral to our maps and are based on the type, quality and accuracy of the data used.

The maps are used for a variety of purposes. They fulfil reporting requirements of the EU Habitats Directive on habitat extent and distribution. They also enable NRW in conjunction with others in the UK and Europe to report on the coherence of our Marine Protected Area (MPA) network as part of our duty and commitments in the Marine and Coastal Access Act, and to the OSPAR Commission respectively. In addition to this, habitat maps are vital in advising developers and managers on the location of habitats, particularly those that are sensitive and protected, aiding the development of marine plans, contributing to wider habitat maps at the UK level, research and education.

Seafloor Mapping Of Frobisher Bay, Baffin Island, Canadian Arctic Archipelago

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Frobisher Bay, a macrotidal inlet of the Labrador Sea in southeastern Baffin Island, is 230 km long and varies in width from 40 km at its southeastern extremity to 20 km at its northwest end. It lies within the territory of Nunavut, which has the land area equivalent to Western Europe, but with a population of only ∼30,000. Competing industrial uses of ocean space in Frobisher Bay, coupled with concern for habitat protection, has led to the Canada-Nunavut Geoscience Office and the Geological Survey of Canada, in partnership with Memorial University Marine Habitat Mapping Group, ArcticNet and the Government of Nunavut, to undertake a regional seafloor geoscience mapping program to provide the scientific knowledge of geohazards and seabed geology to underpin and manage future development. Because of constraints of climate, vessel availability, and logistics, the mapping coverage is sparse in some areas, but nevertheless provides insights into geological processes.

The inner bay is characterized by narrow, NW-SE trending bedrock ridges with slopes up to 30°, mantled by glaciomarine sediment, with postglacial mud confined to linear basins. Superimposed glacial megaflutes demonstrate ice flow down the bay during the last glacial cycle; arrays of De Geer moraines point to incremental retreat of the grounded margin towards the NW. In shallow coastal areas the seafloor is imprinted by iceberg furrows and pits, mostly relic, with a modern population down to depths of 80 m. The truly distinguishing aspect of the inner bay is the large number of translational submarine slides developed on ridge flanks, typically with steep headwalls, erosional chutes, long runouts, and low-relief depositional lobes with compressional ridges. In contrast, the outer bay has low relief, and the gently-dipping Ordovician bedrock is mantled with glaciomarine sediments, imprinted by iceberg furrows in places.

The presence of numerous translational slides in this Arctic embayment is distinctive and anomalous. Most of the submarine slides preserved on the seabed in the inner part of the bay appear to occur within post-glacial sediments. In Atlantic Canada, mass transport is generally confined to the continental slopes and fjords, with the most intensive activity in the Late Glacial. In Frobisher Bay, seismic activity and macrotidal location might contribute to the abundant seabed instability in the region.

Methods For Creating The EUSeaMap, A European Broad-Scale Map Of Seabed Habitats

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Central to the Seabed Habitats lot of the EMODnet (European Marine Observation and Data Network) initiative is the production for all the European basins of a broad-scale cartography of seabed habitats, named EUSeaMap. A broad-scale seabed habitat map typically describes the environmental conditions that occur at the seabed that are known to influence the distribution of plant and animal communities.

The approach that is used draws extensively on that developed in the framework of past European projects (MESH, ur-EMODnet Seabed Habitats), which proposes overlaying mapped physical variables using a geographic information system (GIS) to produce an integrated map of the physical characteristics of the seafloor. Where possible, the marine section of the European Nature Information System (EUNIS) habitat classification scheme is used to describe those physical characteristics. The exception to this is the Black Sea, where EUNIS is not applicable; as a result, the project agreed on a new pan-Black-Sea classification of physical habitat types.

The poster illustrates the method using the example of the Black Sea. Full-coverage oceanography spatial layers are compiled for fundamental physical parameters in the basin including bathymetry, seabed light energy, seabed temperature, and densities. Based on statistical analyses of relevant biological occurrences, significant thresholds are fine-tuned for each of these abiotic layers. Those cut-off values are later used in multi-criteria raster algebra for the classification of the layers of physical parameters into two ecologically-relevant categorical spatial layers, i) the biological zones (infralittoral, coastal circalittoral, deep circalittoral, bathyal, abyssal) and ii) the oxygen regimes (oxic, suboxic, anoxic). The overlay of those categorical layers with a layer of seabed substrate types (provided by the Geology lot of EMODnet) is eventually performed, the result of which is the broad-scale seabed habitat map for the Black Sea basin.

The poster presents the overall workflow as well as each specific step that it comprises i.e. i) generating oceanography data layers, ii) selecting optimal thresholds, iii) classifying the oceanography layers into the categorical layers and, eventually, iv) creating the habitat map.

An Illustrated Glossary For Underwater Video Analysis Of European Cold-Water Coral Habitats

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In the last decades a large amount of video documentation, by means of remotely operated vehicles (ROV), submersibles and sledges, has been collected in deep seafloors to "groundtruth" remote interpretations and to get insights into the composition and distribution of the still little known deep-water fauna. In particular, special emphasis has been recently given to video analysis of cold-water coral (CWC) habitats.

One of the main goals of the EU project CoralFISH was to assess interactions between deep-water coral and fish communities from different European regions. In order to carry out this study and to avoid further proliferation of hardly comparable scientific results, the CoralFISH participants have developed a standardised methodology and compiled an illustrated glossary for underwater video analysis.

The glossary presented herein aims at assisting scientists in the objective description of CWC habitats. It includes almost 300 terms, listed in alphabetical order and divided into two sections: an introductive one, comprising basic definitions related to modern and fossil CWC ecosystems, and a more specific section restricted to seafloor features detectable during video survey. The definitions of the second section, generally supported by representative underwater images, refer to geological and biological seafloor components as well as to items of anthropogenic origin. The glossary entries allow both basic and detailed habitat characterizations, depending on the quality of video data and of the focus of the specific study. This is facilitated by the fact that, besides the alphabetical order, most terms are hierarchically ranked according to their importance and/or specificity. All term explanations have been compiled taking into account both glossaries already existing in the literature and unpublished documents. The creation of new terms has been kept at minimum and, where possible, definitions conform to those of the "European Environment Agency Glossary" and "The Coastal and Marine Ecological Classification Standard".

The Role Of Food Input In Shaping Biodiversity Patterns In Benthic Seamount Habitats Across The Equatorial Atlantic

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Seamounts are prominent, globally distributed seafloor features, which are often considered as "hotspots" hosting diverse benthic communities and abundant fish stocks. Concerns about the effects of human impacts, such as bottom trawling and potential seabed mining, have necessitated the development of appropriate management scenarios. However, those need to be underpinned by a thorough understanding of biodiversity spatial distribution, and the environmental drivers which shape the structure of seamount communities.

Here, we investigate differences in benthic community structures in relation to changes in food input in three different seamount sites in the Equatorial Atlantic. The study is based on a comprehensive nested dataset collected during the 'TROPICS' cruise on board the RRS James Cook, and is linked to the ERC Starting Grant projects CACH and CODEMAP (grant nos 278705 and 258482). Shipboard multibeam and backscatter data is combined with ROV-video records, high-resolution bathymetry, in addition to extensive water column characterisation by CTD and Particulate Organic Carbon (POC) filtrations for quantifying food input. Food input is highly variable between the different seamounts, with POC values ranging from 5 - 95 µg/L and high POC concentrations are consistently found at the base of each seamount. Preliminary results suggest that thriving coral communities occur in depths of relatively high POC values, which in terms enhances local biodiversity. Pencil urchin distribution has also been mapped and appears to be driven by POC pulses, which are likely to act as a reproductive cue, causing spatial clustering. Future analysis will focus on quantifying and integrating food input into spatial habitat models.

The Natural England Marine Evidence Project.

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Natural England needs to provide marine evidence and data products for a number of projects, such as the designation of marine protected areas (MPAs), fisheries management, conservation advice, and European Union Habitats Directive reporting obligations. This information was historically stored by individual staff on a local basis, resulting in a fragmented evidence base that was difficult to access, audit or collate. Inefficiencies in the use of our marine evidence included duplication of effort, contradictory information, multiple versions and misplaced datasets as staff left or moved on.

The requirement for a single, centrally managed marine evidence base in order to minimise these inefficiencies led to the marine evidence project being set up in 2013. This was further driven by the need to improve access to marine evidence both between public bodies, and for the general public.

The marine evidence project is made up of a number of different strands, which fit together to form the components of an evidence cycle. These range from identifying the need for evidence, carrying out surveys, data analysis and mapping through to robust QA, publishing and archiving of the final product.

Data collection, collation and cataloguing form a major part of the project, and involve the use of a centralised metadatabase for all survey projects. Standardised protocols and procedures for staff to follow ensure consistency, and a confidence in the quality of the data. This stage is carried out using existing procedures and protocols, such as through the Marine Environmental Data and Information Network (MEDIN) and European Marine Observation and Data Network (EMODnet).

The collated datasets are then processed into a single marine evidence layer in the form of a standardised marine habitat map in GIS format, with a regular update cycle and QA audit process for staff to raise any issues or queries in their local areas. This mapping layer and the associated products it provides (such as the extent of marine features) forms the basis of Natural England's advice and evidence to support a number of projects both internally and externally. This information is currently being incorporated into a 'Designated sites system', an internal system for staff to use when managing both marine and terrestrial protected areas.

In order to comply with existing obligations under the EU INSPIRE directive, and the UK Government 'Open data initiative' to ensure public accessibility to data, the marine evidence base is published externally through existing web-based data portals for anyone to view. In addition, it is shared with partner organisations in order to facilitate the effective management of the marine environment.

Geology, Ecology & Society: Exploring The Bounds Of Habitat Mapping.

C.K. ***Wilson***[1]

1. OceanDTM

The need for spatial management of the marine environment has been recognised for as long as humans have had to resolve competing interests there, but recent concerns over the increasing severity of pressures on the marine ecosystem have resulted in the implementation of ambitious legislation such as the European Union's Marine Strategy Framework Directive (MSFD). In order to effectively assess current status and identify trends, eleven qualitative descriptors have been developed and are used to parametrise Good Environmental Status (GES). All eleven descriptors and their associated criteria are assessed spatially at the regional or sub-regional level; but there is a specific requirement to monitor some indicators at the resolution of species' habitat. Mapping the exact distribution of a species would require a knowledge of the location of each and every member of that species. This is obviously not practical and so environmental proxies are used to infer the distribution of the species based on correlative relationships between species presence and environmental conditions. Again, there is not enough information regarding all relevant environmental conditions for each species and so modeled information, related to a subset of environmental parameters, is used to create "predominant" habitat classes which are considered to be generally applicable to multiple species.

In the process described above there is a complex interaction between societal goals (such as the maintenance of biodiversity and economic prosperity), practical limits to the evidence base which informs scientific research, and the need for better fundamental theoretical understanding of very basic concepts such as biodiversity. In order to meet these challenges it is necessary to identify where the current limits to our capabilities are being reached and what the limiting factors are. Having investigated the current boundaries to progress, we go on to demonstrate the possibility of a more fruitful incorporation of geological knowledge of spatial and temporal environmental variability into the assessment of ecosystem state and resilience. This not only improves our ability to make better informed decisions but also helps address some of the fundamental questions regarding the development, maintenance and future of the ecosystem.

Habitat Mapping Of VMEs Along The Inner Shelf Regions Of The South-Western Tyrrhenian Margin (Southern Mediterranean): A Geo-Statistical Predictive Approach

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The main aim of this work is to statistically predict the distribution of Vulnerable Marine Ecosystems (VMEs) along the continental shelf regions of the northern Sicilian margin (southern Mediterranean).

The considered habitats, already mapped in the area on a qualitative base, are the Posidonia oceanica and Cymodocea nodosa seagrasses and the Coralligenous biocenosis. Posidonia oceanica and Coralligenous are considered as VMEs owing to their value as environmental indicators and biodiversity hotspots in coastal marine areas. For this reason, several actions were aimed in recent years to their complete characterization and mapping.

The study area is located in the continental shelf of the northern Sicily margin, between the Cape San Vito (Gulf of Castellammare) and Cape Zafferano (Gulf of Palermo).

Different physical characteristics of the seafloor were extracted from a database acquired in recent years in the frame of official national cartography (CARG) and hazard assessment (MAGIC) Italian Projects, including geological and geophysical data (seabed sampling, ROV footage, multibeam bathymetry, backscatter maps, high resolution seismic reflection records).

The ultimate goal is to apply a statistical methodology allowing to predict the distribution of marine habitats from a "'resence only" sampling dataset. This target was pursued by using a multidisciplinary approach, including abiotic (i.e. depth, morphological and hydrodynamic features, type of seabed) and biotic components (benthic communities) that define and characterize the mapped habitats.

Predictive maps are based on the Maximum Entropy model (MaxEnt), a statistical method based on punctual occurrence of specimen (presence-only). The punctual occurrence of the three habitats was already known, whilst we considered the bathymetry, seabed steepness, aspect, fluid escape, erosional areas and sediment type as physical features for the model.

The analysis was also aimed to test the performance of models obtained by choosing the training samples with different criteria. Therefore, different outputs (42 in total) have been produced by selecting samples on the basis of the area (regional analysis), the type of coasts (morphological) or randomly (random). Moreover, the models were built up both with only training samples either with training and test samples to obtain more constrained distribution patterns.

Almost all the created predictive models produced good performances, with statistical parameters (gain, AUC standard deviation) very positive on average. The models derived from the regional analysis resulted to be more performing than the others, with the random-derived being the worst. The response curves pointed out that bathymetry and sediment types are the most important physical features influencing the distribution of the mapped VMEs, whereas aspect and slope are not-independent variables. These outputs also provided important information and constraints on the favorable environmental conditions for the three habitats.

Results from this preliminary statistical modeling appears potentially useful in the evaluation of important environmental parameters, allowing to draw the broad distribution of marine habitats in areas where only presence data are available, and can represent a contribution in the design and monitoring of marine protected areas.

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