

Geoscience Characterization of the Seabed for Environmental Assessment of Marine Renewable Energy Development

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Many governments are faced with changing to a blend of conventional and alternative energy sources to meet future energy demands, with an increasing focus on clean and renewable energy. Of this a significant contribution will likely be generated in the marine environment. Seabed site characterization is a critical part of the engineering design process as well as to for the understanding of environmental impacts. Added to this is the transfer of energy across the seafloor to coastal facilities. Consequently, the development of standards and best practices for site and submarine transmission corridor characterization and environmental impact assessment are important requirements for moving marine renewables forward.

In May 2011 the first workshop Mapping the Seafloor for Ocean Renewable Energy Development was hosted at the Geological Survey of Finland as part of the GEOHAB annual conference and sponsored by the Circum Pacific Council. This second workshop will build on the first by bringing together representatives from government, industry and academia to engage in a discussion on how geoscience data can be used for site characterization and environmental assessment to underpin ocean renewable energy and to develop a GEOHAB publication communicating our collaborative research.

Workshop objectives:

- Discussion of best practices for site characterization and environmental impact assessment of marine renewable energy sites and cable corridors, utilizing knowledge already gained from the European industry
- Discussion of what are the best strategies to emplace the science into the policy development and decision-making by government and industry
- What role should GEOHAB play in marine clean and renewable energy science
- Discussion of CPC/GEOHAB special journal publication

Workshop Abstracts

Seabed Characterization for the Development of Tide and Wave Renewable Energy on the Pacific Margin of Canada

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An inventory of marine renewable energy resources in Canada's Pacific region, based on numerical modeling of the potential of wind, tide and wave sources, have been published that identifies areas with maximum potential. However, the inventory does not identify socio-economic feasibility of power development, nor does it provide for the seabed geologic conditions that will control the safe development of seabed installations and cable corridors. In many areas the seabed will be unsuitable for siting facilities due to slopes, faults, shallow gas, erosion and critical habitat. The Geological Survey of Canada (Natural Resources Canada) is undertaking an assessment of environmental barriers to deployment of marine renewable energy systems on a national scale. By adding seabed characteristics, geohazards and habitat layers to the Canada's marine renewable energy resources inventory in a GIS database, a more knowledgeable assessment of energy estimates, both for project proponents and regulators is provided. In addition, a Best Practices guideline is being developed for all proponents and regulators of marine renewable energy in Canada.

Two examples from this inventory for tidal and wave marine renewable energy development are highlighted. Near the southern boundary with the United States restricted deep water channels are very promising sites for tidal generation. Here large sand waves, up to 28 m in height, and active faults present a significant challenge to site development. One region offshore western Vancouver Island has been identified as having the highest potential for wave energy for the entire coastal region. Here the proposed Ucluelet Wave Energy Project will require foundation conditions for anchoring on a mobile gravel seabed. These two examples show how geoscience has and will provide critical information to project proponents and regulators for the safe development of marine renewable energy.

Development of Temporal Monitoring Techniques for Benthic Habitat Impacts of Tidal Energy

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Deployment of Tidal in Stream Energy Conversion (TISEC) devices, including turbines and cables, may impact benthic habitats through the alteration of environmental conditions (i.e. changes in physical processes, scour etc.) with subsequent impacts on benthic productivity and diversity. *In situ* sampling methods including sediment sampling, quadrats and scuba divers have been traditionally used to monitor marine habitats with respect to human impacts. However, these methods lack data density and spatial coverage to accurately define habitat heterogeneity and variability across meso- ($10\text{ m}^2 - 1\text{ km}^2$) and broad-scales ($>1\text{ km}^2$). This highlights the need to develop methods across broader spatial scales in order to monitor both physical and biological characteristics of the seafloor environment. This is particularly relevant for monitoring TISEC devices where potential impacts may occur over a range of spatial and temporal scales. The objective of this study is to develop standardized acoustic monitoring procedures for assessing the impact of TISEC devices on marine benthic habitats in terms of structure and associated benthic assemblages resulting from bed-form movement and scour formation.

Acoustic mapping devices, including multibeam echosounders (MBES) and side-scan sonars (SSS), can ensonify broad scale areas with 100% spatial coverage at sub-meter resolutions in shallow coastal waters. Recent developments in acoustic classification methodologies (i.e. image-based and signal-based backscatter classification methods) may offer a cost-effective approach for detecting change in seafloor conditions when applied to data from repeat acoustic surveys over the same area. When coupled with the collection and analysis of conventional seafloor sampling techniques (i.e. benthic grab samples and underwater video), this combination of survey methods may offer a suitable approach for monitoring change associated with the deployment of TISEC devices in the marine environment.

In the spring of 2012 repeat inter-tidal acoustic and seafloor sampling surveys will be conducted over 3 case study areas to assess physical/biological changes in seafloor features over short time-frames. The same areas will be surveyed again in the spring of 2013 to assess any inter-annual changes in seafloor conditions at these sites. Backscatter mosaics will be generated from the MBES and SSS data, and the backscatter data will also be processed using image-based (*QTC Swathview*), and signal-based (*Fledermaus FM Geocoder*) classification software tools. The classified data sets will be compared to provide an objective assessment of any change in backscatter characteristics between the temporal data sets that may be indicative of changes in physical and biological characteristics of the 3 study areas. Ultimately, this study will assess the utility of repeat acoustic surveys for monitoring changes in seafloor characteristics in the connection with the deployment of TISEC devices in the Bay of Fundy.

Dogger Bank – A Geo-Hab Challenge!

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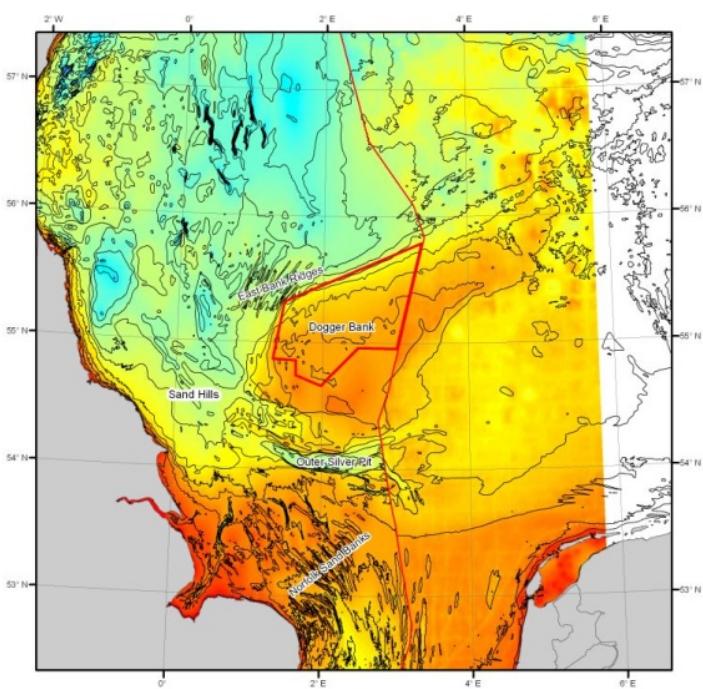
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In June 2008 The Crown Estate announced the opening of nine development zones within UK waters for offshore wind farm leasing. The Dogger Bank Zone is the largest of the Round 3 wind farm zones, extending over ~8660 km². It is located between 125 and 290 kms northeast of Yorkshire on the Dogger Bank, a topographic high in the middle of the North Sea. Water depths across the zone range from 18 to 63 m, with a historically mapped sediment cover comprising re-worked glacial sands and gravels.

Forewind, a consortium of four energy companies, is committed to securing the necessary Zone Appraisal and Planning (ZAP) consents for construction and development of the Dogger Bank Zone. To achieve this end, Forewind has developed an intensive program of geophysical, geological, geotechnical, meteorological, biological and archaeological surveying which will encompass the entire zone (8,660km²), undertaken in four Tranches. The sheer size of this zone is considerably greater than that of previous windfarm developments or standard oil and gas site investigations, leading to the generation of extremely large data volumes to manage, interpret and move between partners. The resolution of the datasets will enable the project partners to refine and amend previous sea bed sediments and geomorphology interpretations from a 2008 survey, upon which habitat designations have been made. This raises the question about resolution in geohab mapping for legislative purposes, and how this meshes with the development of marine renewable energy sites in the future.



This paper outlines the methodologies Forewind is utilising to prepare for the zone's development, including activities undertaken to develop a 3D model of the geology, stratigraphy and geotechnical conditions to assist in optimal selection of wind turbine foundations. It will also address the challenges associated with developing geological models and habitat maps over such an extensive area within the time constraints dictated by the licensing processes. Preliminary results from Tranche A are presented and discussed, along with lessons learnt in the first few years of this ongoing project.

Figure 1: Gridded regional bathymetry showing the relative location Dogger Bank. The Dogger Bank Zone is outlined in red, with the UK median line marking the extent of UK waters. Data: DIGBath for UK waters, EBCO for non-UK.

Assessing living marine resources and habitat in Oregon's Territorial Sea for guiding renewable energy development and marine spatial planning

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For the past four years, the state of Oregon has been preparing for the development of wave energy and other renewable energy projects in its Territorial Sea (0-3 nm from shore). Early on, the need became clear for a comprehensive characterization of the ecological and physical resources within State waters to support marine spatial planning (MSP), so we began an exhaustive compilation of relevant extant ecological and physical datasets that met the following criteria: 1) filled an important or representative ecological or physical niche within the spectrum of all possible species and habitats; 2) were coast-wide in extent; 3) had a continuous response surface; and 4) had a range of response values. Ecological datasets that met these criteria spanned the gamut of cetaceans (2 datasets), pinnipeds (2), seabirds (4), fish and invertebrates (5), and algae (1). However, because ecological datasets that met all of these criteria were relatively rare, numerous physical datasets were included as proxies for biological/ecological processes and species distributions to help fill the gaps. Physical datasets included oceanographic variables such as upwelling, dissolved oxygen, and chlorophyll-a concentration, as well as seafloor habitat datasets such as substrate type, depth, and shoreline type. In sum, these datasets comprise the Nearshore Ecological Data Atlas (NEDA), a “living” atlas that will be updated continually as time and financial resources allow (available on the Oregon MarineMap website at <http://oregon.marinemap.org/>). The second phase of this project involved synthesizing the NEDA datasets to develop a map of ecological sensitivity. The purpose of this phase was to guide alternative energy project developers to areas with the least potential for significant environmental impacts. This was a two-step exercise, with the first step being a simple process of overlaying datasets for resources warranting complete protection (e.g., rocky reefs). The second step was to prioritize the remaining areas by identifying ecological “hotspots,” or areas of overlap which are important for many species to feed, breed, rest, and migrate. To accomplish this, we used Marxan, a software program designed to aid conservation planning that uses a stochastic optimization algorithm. Using Marxan, we identified areas of maximum ecological “value” with the minimum amount of total surface area and perimeter. The results of the NEDA and Marxan processes are currently under peer review by scientists, the general public, and stakeholder groups (for more details, see the Oregon Ocean Information website at <http://www.oregonocean.info/>).

Habitat Evaluation For Renewable Tidal Energy – San Juan Archipelago

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The process of selecting a seafloor location to site a tidal powered generator for electricity is primarily based on physical oceanographic forces and geology. However, potential ecosystem and benthic habitat disturbances from development of tidal energy sites are also critical to any decision making process and often the major concern of regulatory and permitting agencies. Therefore, the evaluation of habitat types needs to be undertaken if any site is to be permitted.

Generally unique and robust ecosystems occur at locations preferable for tidal energy development. In these dynamic environments coarse-grained substrate or bedrock outcrops are present that host sessile and encrusting fauna and flora. Fishes and other organisms (e.g., invertebrate epifauna) forage on these fauna and flora and their activities need to be considered when assessing a tidal energy site. Concentrated tidal flow throughout the San Juan Archipelago makes the region promising for the development of such renewable energy resource and habitat evaluation is needed to determine which sites can be developed without major impacts to the ecosystem. Lessons learned from a pilot project in Admiralty Inlet of Northern Puget Sound region provide a template for future assessments. A major contribution of the project is the methodology used to inventory the habitat types using an ROV and multibeam echosounder bathymetry and backscatter data. Results and discussion of this work will be presented.

Gravel ripples in the Minas Passage, Bay of Fundy, as indicator of flow energy

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Similar to submarine barchan dunes gravel ripples are indicative of high energy seabed environments such as contourite channels and shallow shelf environments exposed to swells. We have studied granulometric composition of gravel ripples in the Minas Passage (Bay of Fundy), a narrow body that connects the main part of the Bay of Fundy with Minas Basin. The observed gravel bedforms compose the eastern banner bank off Cape Split, while the companion western banner bank is composed of coarse sand. The gravel bedforms are located at water depths of 100 m and are likely created by tidal currents. Barren seabed here is composed of rounded pebbles, cobbles and boulders with no visible epifauna or encrustation. The median wavelength of the observed gravel ripples was 25 meters, with a range of 14 to 51 m and crest heights of less than 2 m. Mean grain size and particle angularity significantly varied between different types of seabed morphology – ripple crests, troughs and open flat gravelly areas surrounding ripple field. The fraction of cobbles and boulders was considerably higher in the troughs between gravel ripples as well as on the open flat seabed outside of gravel ripple field. The majority of the measured gravel particles were between 10 and 70 mm in length with average grain size of 59.2 mm and an average length to width ratio of 1.48:1. More angular gravel particles were outside of the ripple field. Using a Shields parameter of 0.028 we conservatively estimate that tidal current required to initiate mobility of gravel particles on ripple crests is 1.7 m/s. The roundness of gravel indicates a significant degree of mechanical erosion and the lack of growth suggests recent and sustained mobility of the seabed. The Bay of Fundy tidal range of over 17 metres causes surface currents of up to 8 kilometres per hour (2.2 m/s) to sweep through Minas Passage. Our findings suggest that near-bottom currents at 100 m depth are potentially as strong as the surface currents. This flow is capable of entraining gravel particles and transporting them along the seabed. These estimates of strong near-bed tidal currents and potentially high bedload transport in Minas Passage have direct implications to safety of in-stream tidal energy installations in this area.



Figure 1. Banner bank composed of gravel bedforms in Minas Passage.

Developing benthic habitat maps to assist wind farm siting in Rhode Island waters

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Recent interest in development of offshore wind facilities in Rhode Island waters has initiated a need to map the distribution patterns and processes of benthic habitats and identify biological-environmental relationships. A thorough understanding of benthic habitats is essential for siting and minimizing impacts of development, and to serve as a baseline for impact assessment studies. Two challenges to habitat characterization are developing appropriate methodology and effectively conveying information relevant to a range of users (scientists, managers, public). The methodologies applied here can be extended to other locations, contribute to establishing a standard mapping protocol, and facilitate more effective communications among users.

To address the first challenge, top-down and bottom-up mapping methodologies were compared for their ability to characterize benthic habitats. The traditional top-down approach identifies biological assemblages based on geologic habitat map units, as it assumes geologic environments contain distinct assemblages. Alternatively, the bottom-up approach aims to generate ecologically meaningful map units by establishing habitats based on biological similarity. Statistics are then used to determine relationships with abiotic parameters. The bottom-up approach, however, is more resource-intensive. Both methods generated habitats with significantly distinct biological assemblages and revealed abiotic-biotic relationships. Overall, though, the bottom-up approach was more effective, as it produced more clearly defined biological assemblages and classified habitats over a finer spatial scale.

The creation of an index of benthic habitat value to identify habitat “hot-spots” addresses the second challenge. Benthic habitats were defined and classified according to five metrics: abundance, diversity, value as a food source, presence of habitat-forming fauna, and habitat stability. Preliminary results revealed a positive correlation between tube-building macrofauna and species richness, suggesting tube mat structures lead to increased diversity. In general, however, preliminary results show that while “hot spots” were identified, the index did not indicate specific abiotic or biotic attributes that lend to high habitat value. Therefore, management efforts should consider all habitat types.

Comparison of Heterogeneous Coarse-Grained and Homogeneous Sediments: Do They Represent Distinctively Different Paradigms?

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While evaluating effects of high-pressure washing on bivalve assemblages living in coarse-grained sediments oiled by the *Exxon Valdez* oil spill in Prince William Sound (PWS), we observed that relationships between particle size and sedimentary properties (*e.g.*, quantities of silt/clay or organics) and biological properties (*e.g.*, abundance, species richness, or bivalve biomass) differed dramatically between heterogeneous coarse-grained sediments (often referred to as gravel) and finer homogeneous sediments (*e.g.*, sand, silt, or mud). Quantities of silt/clay, sediment organics, and bivalve biodiversity living in heterogeneous coarse-grained sediments were substantially higher than would be expected based on relationships observed in homogeneous sediments.

In homogeneous sediments, values for those sedimentological and biological properties begin to approach zero when median particle size approaches 0.25 to 0.5 mm. In coarse-grained heterogeneous sediments with mean particle size ranging from 2 to >35 mm, we observed values far exceeding those predicted by regression equations for these properties in homogeneous sediments. Based on a review of published literature, it appears distinctive heterogeneous sediments have not been previously recognized geologically or biologically. In this paper, I demonstrate differences in physical, chemical, and biological relationships characterizing these contrasting sediment types.

Differences are quite quantitative. Sediment weight size classes for the two sediment types occupy very different portions of diagrams in cumulative frequency curves. Moreover, concentrations of silt/clay, sand, organics, and biomass and numbers of taxa and individuals are significantly higher in heterogeneous coarse sediments than would be expected based on comparisons in homogeneous sediments.

Additionally, we observed evidence suggesting that heterogeneous coarse-grained sediments in PWS were structurally organized before washing but that washing disrupted that organization. Comparisons of various geological and biological variables among unwashed and washed sites suggest this organization is a vital factor in development of rich, long-lived infaunal assemblages observed in these sediments. For example, as levels of hydrodynamic energy increased, mean particle size increased among Washed sites whereas that property was stable among unwashed sites. Moreover, numbers of taxa, total bivalves, and small or juvenile clams declined with increasing exposure among Washed sites but were stable among unwashed sites across the exposure gradient. In contrast, the number of adult hard-shell clams increased with increasing exposure among Unwashed sites but that benefit was not realized among Washed sites.

Based on these comparisons, we hypothesized that reduced organization was a major factor responsible for lagging recovery observed in long-lived clam assemblages in PWS through 2002. These findings have important implications for managing resources living in or over heterogeneous coarse-grained sediments. This sediment type, widely distributed in intertidal and subtidal habitats from high latitudes to the tropics, supports a rich, stable infauna of considerable ecological value. Thus, proposals to disturb heterogeneous coarse habitats should be approached with extreme caution.

Morphology and mobility of large-scale bedforms near Cape Split, upper Bay of Fundy

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Various types of large-scale bedforms develop under the influence of strong Bay of Fundy tides. Geomorphological characterization and mobility assessment of these bedforms are required for the design and siting of tidal power seabed installations. Multibeam bathymetry data are combined with geophysical surveys, seabed sampling, and tidal model predictions to investigate the geomorphology, mobility, and formation processes of large-scale bedforms near Cape Split in the upper Bay of Fundy. The main seabed features in the study area include the Cape Split banner bank, the Scots Bay barchan dune field, and a megarippled gravel bank trapped in the Minas Passage. The banner bank, oriented southwest to northeast, is about 5.5 km long, 2.2 km wide and stands about 23 m above the surrounding seafloor. Sand waves with various sizes are superimposed on the banner bank. The height of these sand waves ranges from 1-2 m to >15 m. The mean wavelength reaches 165 m near the top of the banner bank and become bifurcated and smaller (mean wavelength 12 m) towards the edges of the banner bank. Megaripples are superimposed on the flanks of sand saves. The sand waves are asymmetric to the southwest on the northern flank of the bank, and to the northeast on the southern flank. This asymmetry is indicative of the direction of sand wave migration and hence net sediment transport pattern on the banner bank. The sand body of the banner bank was composed of coarse to very coarse sand (mean grain size 0.75 – 1.02 mm), while the surrounding seafloor is covered by bouldery gravel with discontinuous veneers of sand. The barchan dune field lies south of the banner bank in the outer Scots Bay. These dunes are generally oriented northwest to southeast with their horns pointing to the northeast. The barchan dunes are spaced from 40 m up to 250 m, 1 to 4 m high and generally asymmetric to northeast. The geometry of these bedforms thus indicates net sediment transport to the northeast. The sediment of the barchan dunes is medium sand with a mean grain size of 0.49 mm. The gravel bank is located in Minas Passage in depths of 85–120 m. The bank, oriented roughly east-west, is ~20 m thick, 850 m across and 3.5 km long. While the southern half of the bank is featureless, the north face is covered by gravel megaripples with 30-80 m wavelengths and 1.5 to 5 m heights. The mean diameter of gravel is about 4 cm over the megaripples and increases to 7.9 cm, with significantly higher content of cobbles and boulders, on the smooth southern face of the bank. The well roundedness of the pebbles and cobbles with no biologic attachments indicates that they are mobile under the strong tidal current in the scour trough.

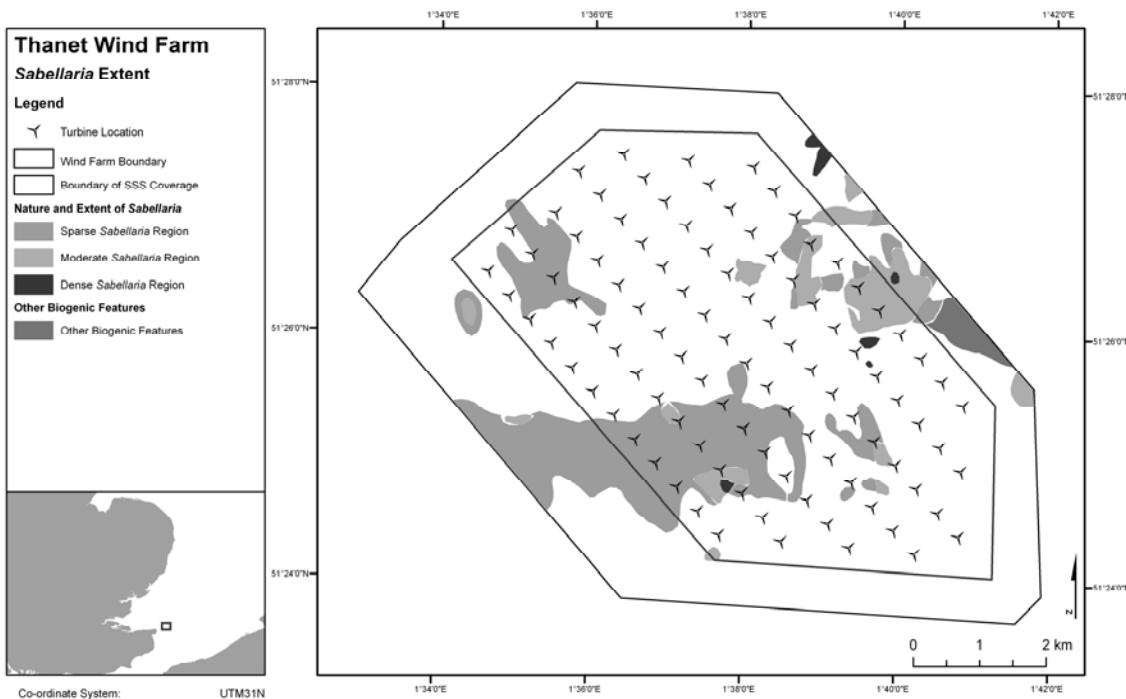
High Resolution, Time-Series Acoustic Surveys to Support Environmentally Responsible Windfarm Developments

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Britain is the world leader in offshore wind energy production with as much capacity already installed in UK waters as has been installed throughout the rest of the world. There are currently 15 operational windfarms in our seas, with a further 7 under construction and 6 with planning consent. This level of offshore development is a reflection of the British government's commitment to reduce the environmental impacts of energy production. However, offshore windfarm developments present their own threats to the environment. Turbine installations and cable laying associated with offshore windfarm constructions involve a physical disturbance to the seabed and therefore, accurate mapping of sensitive habitats plays a critical role in the planning of these developments.

The largest offshore wind farm in operation in the UK (and worldwide) is the Thanet development off the coast of Kent which produces 300 MW of energy per year. High resolution acoustic surveys at the Thanet site revealed extensive *Sabellaria spinulosa* reefs which are protected under Annex I of the EU Habitats Directive. Detailed mapping of the extent and quality of this habitat allowed the construction to go ahead with individual turbines being positioned in such a way that damage to the most important parts of the reef was avoided. Now that the windfarm has been constructed it is hoped that the turbines will provide some degree of protection for the reefs by excluding large commercial beam trawlers which target this sensitive habitat because of the known association with flatfish. The reef extent and condition is being monitored on an ongoing basis through repeated high resolution acoustic surveys. This has revealed some natural variability in the extent of this habitat and will in-time help us better understand the interaction between offshore windfarm developments and sensitive reef habitats.



Benthic habitat maps and models inform assessment and monitoring of wind energy development in offshore Rhode Island

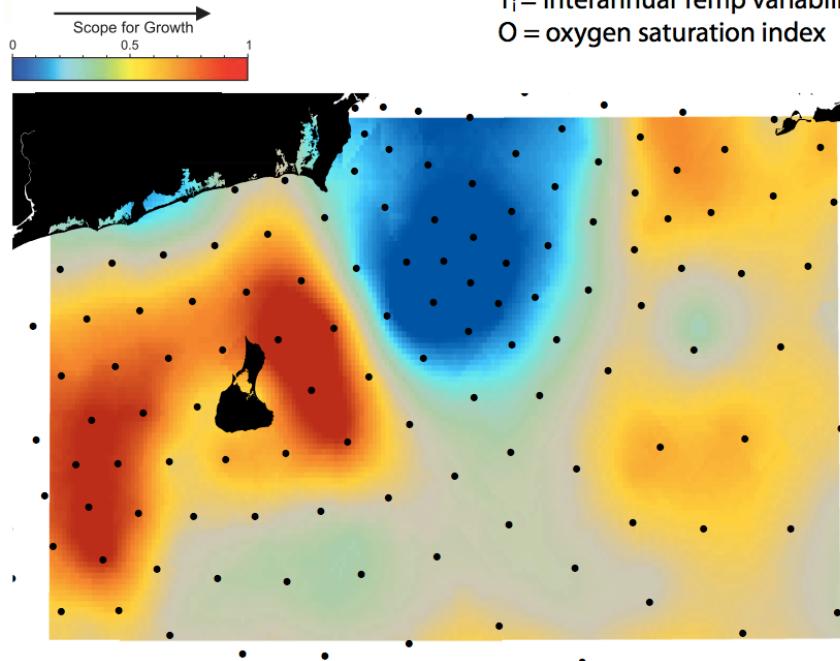
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The process for developing wind energy sites offshore of Rhode Island is moving forward rapidly. Initial benthic habitat maps were constructed at areas targeted for development by a formal marine spatial planning process and at relatively high resolutions (1 meter pixels). In order to understand how these benthic habitats fit into the larger Rhode Island Sound study area (~1500 sq. mi), and to better characterize physical-biological relationships in general, we modeled the scope for growth (i.e., energy available for growth and reproduction; Figure 1) and the natural seafloor stability using a suite of geophysical and biological variables. Associating species occurrences (e.g., benthic invertebrates, fish, marine mammals, birds) to the habitat template model at multiple scales is a research priority and progress in this area will be discussed. We will also discuss how the habitat template model will contribute to and inform ecological valuation of the Rhode Island Sound ecosystem and environmental monitoring efforts related to wind energy developments. Furthermore, we seek to understand how the high-resolution benthic biological and geological habitat maps relate to the broader-scale habit template model, and if these relationships (or lack thereof) may be used to inform further ecological study and marine spatial planning efforts.

SCOPE FOR GROWTH

$$S_g = (F_a + T_a - T_m - T_i + O)/5$$



F_a = food availability index

T_a = mean bottom Temp index

T_m = annual Temp variability index

T_i = interannual Temp variability index

O = oxygen saturation index

Figure 1. The scope for growth index mapped for the Rhode Island Sound ecosystem.

Sediment bedforms in the Bay of Fundy: a geohazard for tidal power development?

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Located on the Atlantic coast of Canada, the Bay of Fundy is a large macrotidal embayment with the World's highest recorded tides and thus the focus of international interest in tidal power development. High-resolution multibeam sonar imagery of seafloor terrain and backscatter strength, combined with geophysical and sampling data, reveal for the first time the morphology, architecture, and spatial relationships of a spectrum of sediment bedforms. Flow-transverse bedforms include elongate trains of dunes oriented parallel to the principal current directions, trains of barchan dunes, and dunes occurring as both large fields or in trains that lie transverse to the bay. Larger dunes show evidence of being "trapped" as a result of being incised into underlying glaciomarine sediment (Fig. 1). Flow-parallel bedforms are principally multiple straight ridges formerly described as horse mussel reefs but now recognized as bio-bedforms. Banner banks flank prominent headlands. Bedform assemblages have formed in the lee of major shoals.

This suite of bedforms developed during the Holocene as tidal energy increased due to the Bay of Fundy approaching resonance. In concert with broad-scale winnowing (resulting in surface lags throughout the bay), large tidal scours developed in places. In northeastern Bay of Fundy within Minas Passage at the tidal current maxima, one tidal power device has been deployed for testing and retrieved. Three more devices are scheduled for deployment in 2012 to 2013. Although these prototype devices will be situated on a (rare) exposed bedrock platform, future commercial-scale device arrays will undoubtedly be deployed farther afield in the bay where they will have to contend with sediment bedforms. The bedforms and their mobility may pose a geohazard for such marine renewable energy development.

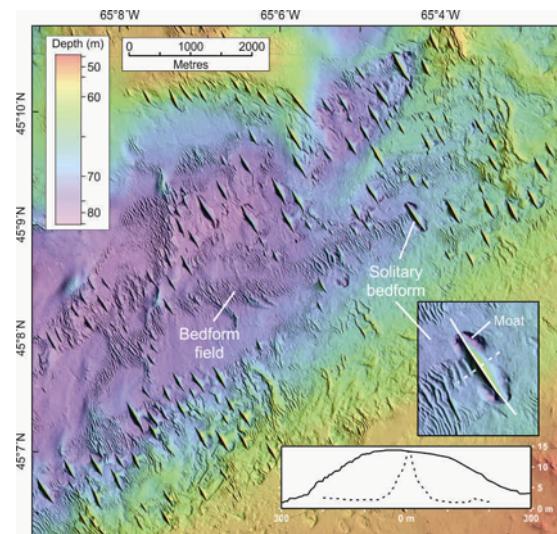


Figure 1. A field of flow-transverse bedforms showing the development of moats associated with large bedforms.

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Habitat Characterization and Mapping in Coastal and
Inland Seas

Abstracts

Oral Presentations

Habitat complexity and bottom fauna composition at different scales on the continental shelf and slope of northern Norway

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The MAREANO (Marine AREA database for Norwegian coast and sea areas) mapping programme includes acquisition of multibeam bathymetry and backscatter data together with a comprehensive, integrated biological and geological sampling programme. Equipment used includes underwater video, box corer, grab, epibenthic sled and beam trawl. Habitat maps are produced by combining information on landscapes, landscape elements, sediment types and biological communities. Video observations provide information about the megafauna diversity of large (>1 cm) epifauna and bottom types, whilst bottom samples describe the composition of epifauna, hyperfauna (crustaceans living in the upper part of the sediment and/or swimming just above the substratum) and infauna, and sediment composition. In this study, two biological data sets are used to study fauna response to environmental heterogeneity at two different spatial scales: (1) broad scale, megahabitat (1–10 km), based on information about megafauna taxa observed during video surveys in the Nordland/Troms area, (2) fine scale, mesohabitat (10 s m⁻¹ km), based on information about species composition documented with video records and bottom sampling gear from the bank “Tromsøflaket”. In general, the highest diversity is found on bottoms with mixed substrates indicating that substratum heterogeneity is very important for the biodiversity at both scales. The number of taxa shows a maximum at depths between 200 and 700 m followed by a gradual decrease down to 2,200 m. At the broad scale, multibeam data provides a variety of terrain variables that indicate environmental variation (e.g. exposure to currents, interpreted substrates). This analysis identifies six fauna groups associated to specific landscape elements. Diversity of megafauna shows a strong correlation with number of bottom types occurring along video transects. It is highest at the shelf break and decreased with depth on the slope in parallel with a decrease in habitat heterogeneity and temperature. At a fine scale, six biotopes are identified based on megafauna composition with habitat characteristics ranging from homogenous muddy bottom, biotope 1, to the most heterogeneous bottom with >20% rocks and several bottom types present in biotope 6. The macro faunasampled is used for description of the whole benthic community related to these six biotopes. The variation in percentage cover of substrate types and in particular the cover of hard substrates demonstrate to be a good proxy for the benthic community composition (mega- and macrofauna) and its diversity.

Sand Wave Dynamics in the San Juan Channel

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Sand waves within the San Juan Islands channels are an important habitat for the Pacific Sand Lance (PSL, *Ammodytes hexapterus*). Significant numbers of these important forage fish have been captured in bottom sediment samplers, and have been observed in bottom surveys using underwater video in the sand wave fields. We are investigating sand-wave sediment dynamics in these sub-tidal channels as part of a multi-disciplinary project to examine benthic habitats and life-history parameters for the PSL in Northwest Straits.

Our field work to date has included detailed bottom mapping, underwater bottom video and photographic transects, and grab sampling of bottom sediment and PSL. Prior extensive bathymetric and acoustic backscatter mapping of the entire region using Multi-Beam Echosounder Sonar (MBES) has revealed remarkable large sand waves up to 5 m high contained within discrete elongate sand patches that are scattered throughout the region in water depths of 20 to 100 m.

Analyses of bottom grab samples within the large sand wave field in San Juan Channel (water depths of 60 to 80 m) show that surficial sediment is composed of a mixture of terrigenous and organic materials. Coarser sediment (mostly gravelly shell hash with median size of about 2 mm) is generally situated in the sand wave troughs, while better-sorted and finer sediment with median sizes of 0.25 to 0.5 mm is found covering the upper flanks and crests. Bottom surveys using a novel sediment camera (USGS “eyeball” camera) collected images of the sediment surface at many locations in the sand wave field. These images provided median grain size data that corroborated the results from the bottom grab samples, and extended the grain size measurements throughout the study area.

Grain size data were plotted on bed phase diagrams along with water depths and estimated tidal current speeds. These diagrams indicate that the San Juan Channel sand waves are stable under present-day flow and depth conditions. This stability will be discussed in terms of potential changes to tidal heights and speeds due to sea level rise. Estimates of bed load transport for present-day tidal and sediment parameters suggest that sand waves in this region are undergoing active migration. New measurements of tidal current velocities are needed to improve the estimates of sand wave migration and stability for the multiple bedform scales.

High resolution seabed classification of human impacted areas: does it work?

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Coastal domains are between the most vulnerable areas to human usage and the most difficult ones to be studied in detail; in fact, the natural complexity of the ecosystem is increased by the anthropogenic activities which modify morphology, biology, hydrodynamics and sediment composition of the seabed. As a consequence, high resolution mapping of human impacted ecosystems is becoming a key tool for environmental and socio-economic policy and management.

An extensive research is currently ongoing in the Jade area (Wadden Sea, Germany) close to the Jade-Weser Port, a new container terminal under construction where a land-reclamation action has been completed, coupled with dredging and dumping operations.

Within this frame, a survey has been carried out to assess the reliability of seabed classification systems in such a heterogeneous environment.

Acoustic data have been collected over an area of 0.7 km² in the Jade Channel, using different devices (multibeam, side-scan sonar and single-beam systems). 6 stations have been sampled (4 replications each) for sediment analysis. Acoustic data have been processed and classified by means of QTC™ software suite. Sediment samples have been analysed for grain size description, the results being processed with PAST software for statistical comparison.

Actual sample positions resulted to be shifted respect to the planned location (due to the strong tidal-induced currents acting in the area). Consequently, replications did not perfectly overlay, although in most of the cases the distance between them was small enough to use them for ground-truthing the same acoustic area. However, results of grain size analysis demonstrate that there are significant differences in sediment composition between replications. No clear relationship occurs between replication closeness and statistical similarity.

Acoustic classification from single beam appears to be mainly controlled by the sediment micro-roughness, resulting in a highly heterogeneous seabed texture with no clear dominant pattern (which reflects the patchy distribution of the sediments).

On the contrary, swath system based classifications reveal to be less dependent on the sediment roughness, with a dominance of topographic features imprint (i.e. dredging marks and bedforms fields) on the final classification, likely due to the grid-based approach which decreases the footprint resolution and averages between local differences.

In such a highly variable system, acoustic devices allow classifying the area in high resolution but resulting classes can only partly be addressed to a proper sedimentological meaning by means of ground-truthing.

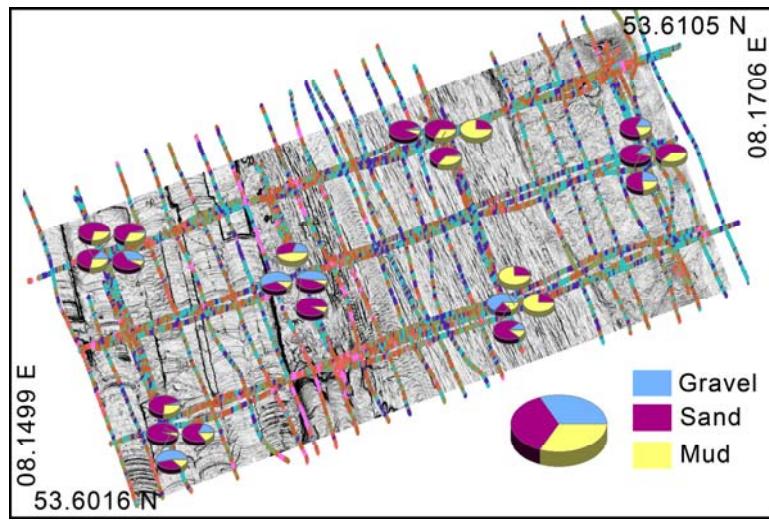


Figure 1. QTCTM Impact classification and sediment distribution pie-charts on a shaded relief map.

Habitat Mapping and Vulnerable Marine Ecosystems: can we bring the two together?

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The management of deep-sea fisheries is increasingly involving an assessment of marine habitats as well as fish stocks. Resolutions at the level of the United Nations General Assembly, and also under the Convention for Biological Diversity, call for reducing human impacts and the conservation of deep-sea ecosystems. This is tending to focus on benthic habitat, and the identification of areas where there are invertebrate communities that are considered vulnerable to fishing, especially bottom trawling. In some coastal areas there are extensive maps of seafloor characteristics, and distribution of biological communities, that can guide appropriate spatial management. But for many countries and regions this is beyond available resources, and in areas of the High Seas there are extremely limited biological data on which to base any robust analysis.

Management of human activities, whether it is fisheries, waste disposal, oil and gas, or deep sea minerals exploitation, is increasingly reliant upon the production of marine habitat maps, that identify seafloor bathymetry, topography, and substrate type. These geological characteristics can be used as proxies for biological communities in regions where there are few biological samples. Predictive habitat suitability modelling is one technique that has been increasingly used in recent years to estimate the likely distribution of benthic fauna (and vulnerable marine ecosystems) based on environmental factors. Biogeographical and topographical classifications and seascape analyses have also proven useful. However, these are generally broad and cover large areas, or are based on presence/absence data, that don't give managers sufficient resolution or detail to identify vulnerable marine ecosystems at a realistic scale. Detailed geological and biological mapping shows that the spatial variability of species composition and abundance in small areas can be high. Hence, there is an ongoing need for biological and geological communities to work together to produce suitable information to improve environmental management.

In this presentation I will briefly examine some of the habitat mapping approaches that have, or can be, applied by environmental managers, evaluate how useful these are for identifying vulnerable marine ecosystems, and make some suggestions for future habitat mapping needs.

Characterisation of sub-aqueous dunes in the western English Channel

Roger Coggan¹ and Markus Diesing¹

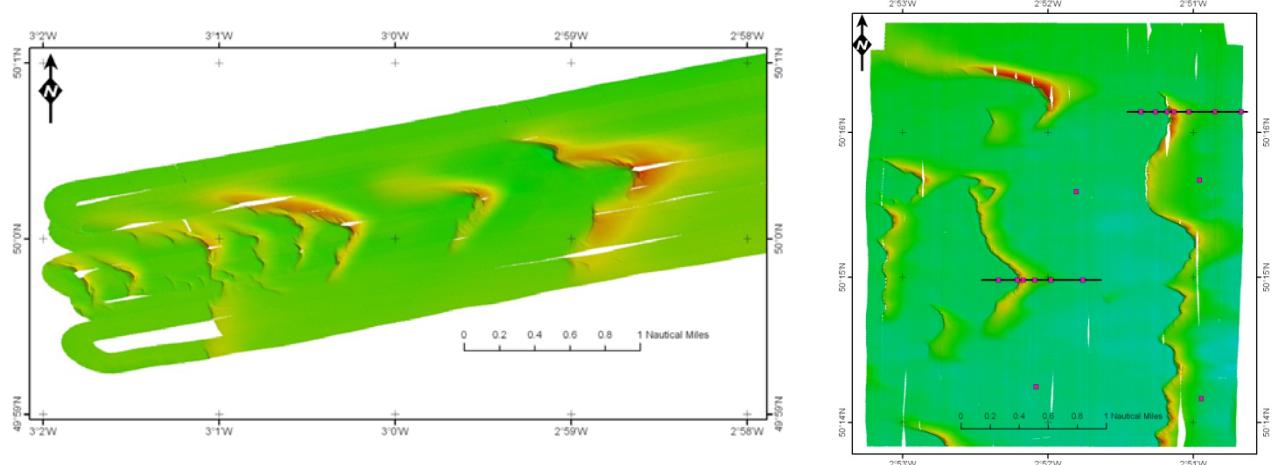
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The English Channel is a gently sloping shallow coastal sea between France and England that has been subject to a series of marine regressions and transgressions resulting from sea level changes associated with glacial-interglacial cycles. Phases of seabed erosion and sediment deposition have structured the modern physical habitat, leaving a range of geomorphic features and a diversity of habitats. The eastern and central Channel areas are commercially important for marine aggregates and have been much studied in recent years, but the western Channel is less well known, although it supports important fisheries.

A recently compiled digital terrain model shows the western Channel to be dominated by a system of sub-aqueous dunes, starting abruptly at around 50°15'N, 2°45'W and extending westwards for more than 220 km, well beyond the landmasses of Cornwall and Brittany. We report on a more detailed characterisation survey of some of the larger dunes at the eastern edge (start) of the system which we surveyed in 2009 using acoustic, video and grab sampling techniques.

The dunes were up to 12 m high and 6 km long with wavelengths in the order of 1 to 2 km. They were barchanoid (crescent shaped) in form, having an asymmetrical cross-section with a gentle stoss slope facing east and a steeper, concave, lee slope facing west. Wave crests were generally aligned in a north-south orientation, perpendicular to the main tidal flow, but the northern horns of the barchans were typically longer than the southern horns and skewed westwards. The shape, length and location of the dunes matched almost precisely with features on the digital terrain model derived from earlier data.

Camera-sledge tows over the dunes revealed a gradation in sediment type, the coarse sandy gravel of the stoss slope changing to fine mobile sand at the dune crest, with coarse sand on the lee slopes changing abruptly at its base to consolidated cobble pavement with shell hash. This rapid local variation in sediment type is unusual and presents a range of niches for marine fauna to colonise. Epifauna were nearly absent, except on the cobble pavement where some large, sessile long-lived taxa were seen, suggesting these areas remained clear of sand for decades. A grab sample transect over the dunes revealed a variable infaunal community. This characterisation study will inform the management of this region, which is currently assessing the suitability of areas as Marine Conservation Zones.



Multibeam images of sub-aqueous dunes in the western English Channel

Habitat maps derived from multibeam acoustic data using Random Forest and Object-Based Image Analysis

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The United Kingdom's (UK) Marine and Coastal Access Act 2009 provides the legal basis to designate and protect Marine Conservation Zones (MCZs). These are a type of marine protected area, which will exist alongside European Marine Sites (Special Areas of Conservation and Special Protected Areas); Sites of Special Scientific Interest, Ramsar Sites and other national designations to form an ecologically coherent network of marine protected areas. Whilst recommendations for a suite of MCZs have recently been made, it became apparent that further work needs to be undertaken to strengthen the evidence base for some of the recommended MCZs. The primary aim of this study was to improve the understanding of seabed substrates and habitats in selected areas of the UK's offshore waters where recommended MCZs overlap with existing multibeam acoustic data.

We used multibeam echosounder data (bathymetry, backscatter strength and derivatives of both) from the UK's Civil Hydrography Programme and available seabed sampling data from the British Geological Survey to map seabed substrates in an area in the North Sea off the north-east English coast measuring 6395 km². Habitat maps according to the EUNIS classification at level 3 for rock and level 4 for sedimentary substrates were derived by combining modelled layers of biological zones (circalittoral and deep circalittoral) and kinetic energy at the seabed with mapped substrate types.

We applied semi-automated approaches to map seabed substrate type and composition. The Random Forest machine learning algorithm belongs to the family of decision tree learning and was employed to predict sediment composition (content of mud, sand and gravel). It proved to be effective in handling large amounts of input data layers derived from multibeam acoustic data.

Additionally, Object-Based Image Analysis was employed to map exposed bedrock. For input image layers, we used multibeam backscatter and the bathymetric position index (BPI) calculated from the multibeam bathymetry data. Experimentally determined threshold conditions for backscatter strength and BPI were employed to delineate exposed bedrock.

Overall, the predictions produced plausible results in agreement with general knowledge of the site. Statistical indices of accuracy did, however, indicate lower levels of agreement. The most likely reason for this are positioning inaccuracies of the legacy sampling data, which were collected prior to the introduction of GPS positioning and are subject to an unknown but potentially significant positional error.

A web application and open dataset to facilitate the collaborative development of workflows for seafloor habitat classification

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Habitat maps of benthic and pelagic communities that combine many layers of environmental data including biology, geology, chemistry, and hydrography are becoming common. However, in order to produce habitat maps a user must access data from many different data portals resulting in data of varying formats, sizes, and can be costly. A major goal of this project is to provide marine scientists and spatial planning and resource managers with a common portal in which to access open datasets and source code in order to produce habitat maps. The portal facilitates the collaboration for the development of workflows and statistical algorithms required to produce the maps. The portal is a place for users to contribute code, datasets, and discussion surrounding production of the maps. The dataset is inclusive of the following materials: digital terrain models, raw seafloor imagery, manual and automated species identification, environmental parameters (T, S, time, depth), bathymetry, and indices of benthic geomorphology (slope, rugosity, curvature, etc.). All data sources are available in common GIS file format. The datasets and associated software products are available under an open source license to allow users the freedom to use, redistribute and modify both data and software. A second goal is to provide a common dataset that can be used to test and develop several approaches to generate current and potential habitat distribution maps. In the form of a wiki, the procedure is documented detailing workflows which produce preliminary habitat maps using the common datasets. Modifications to the workflow may be added in order to describe several approaches using the same datasets for comparison of results. The wiki application provides a tool to start an open discussion between marine scientists to increase the performance and accuracy of results from a specific approach with the intent of convergence into a common software framework for seafloor and pelagic habitat classification. Most importantly, the wiki documents the need for and provides a common ontology (standard tables to describe taxonomy, substrate, etc.) onto which submitted datasets are mapped. The data for the described project is the result of collaboration between, Academia, Government and Fishing Industry (WHOI, RPI, NOAA, USGS, Arnie's Fisheries).

Astafjord – A showcase for coastal seabed mapping in Norway: developing habitat maps for coastal management.

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The Norwegian coastal zone is very important for exploitation of marine and mineral resources, aquaculture, transport, leisure and many other activities. All these activities are of key economic interest for the local coastal communities and many also make a substantial contribution to the national economy. Despite this, Norway has no dedicated coastal mapping programme. Only some areas are fully mapped using modern methods. Without basic knowledge of the seabed and the environmental conditions management of the coastal zone is not optimal, and coordination of the activities of the many user groups is difficult. One of the areas is Troms County, northern Norway. Under the Astafjord Project twelve local municipalities have joined forces to coordinate management of their marine areas. This is the first area to be mapped under an integrated project for geology, biology and environmental status.

Through this project The Geological Survey of Norway (NGU), developed a series of Marine Base Maps providing information on bathymetry, sediment grain size, backscatter, anchoring conditions, diggability and sedimentation basins (www.ngu.no). The maps are complemented with additional biological and environmental analysis and as a result, the project has become a showcase for integrated coastal seabed mapping in Norway. The Marine Base Maps are now the basis for a cross-municipality coastal management plan. In 2012 this map series is being extended to include benthic habitat maps, such that this important information, integrating biology and the physical environment, can also be used for management and made available to other end users.

We present the data and methods used to develop these habitat maps and introduce the Norwegian Nature Type Classification System (NiN) (www.artsdatabanken.no), which will be applied for the first time in the coastal zone under this project. Focusing on methods, we present approaches to top-down and bottom-up habitat classification and modelling in accordance with NiN. This work draws on experience in offshore mapping under the MAREANO programme (www.mareano.no) where habitat maps have been produced using multivariate analysis and modelling and NiN has been applied on a top-down basis using physical data.

With an extensive coastal and offshore area Norway need methods for habitat mapping that can be readily extended as new areas are surveyed. It is essential that all information and maps developed are effectively delivered to managers and end users of the coastal and offshore areas. Dedicated efforts to ensure this information transfer will be discussed in the context of ongoing projects.

Using acoustic and lidar acquisitions for mapping soft and hard bottom communities in the bay of Morlaix (North Brittany french coast)

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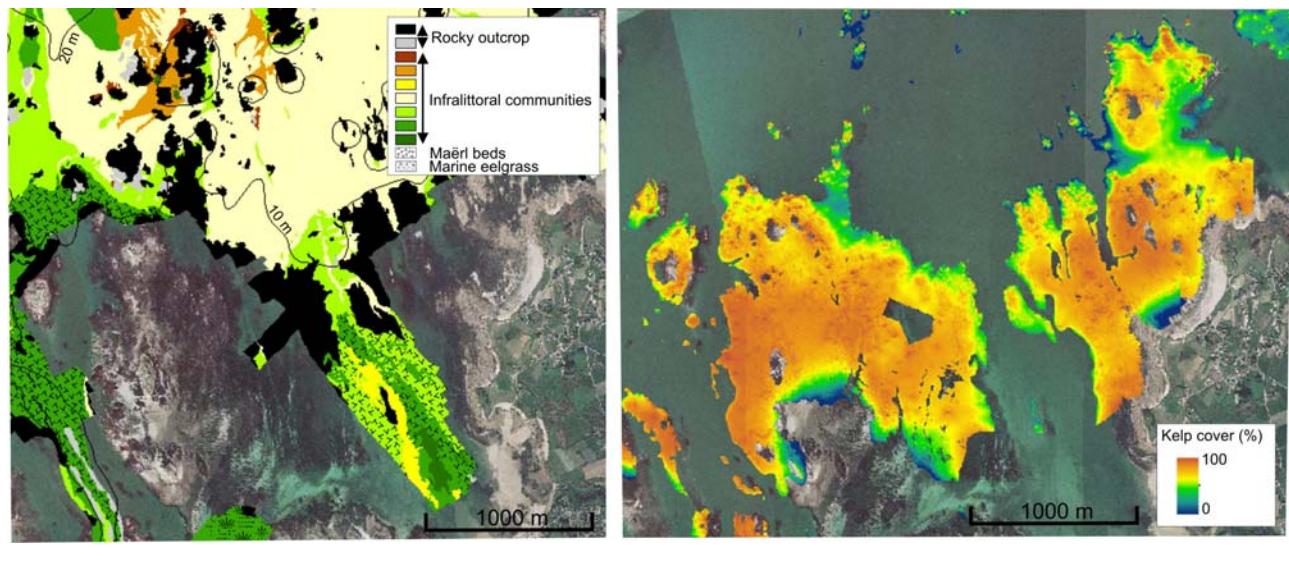
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The bay of Morlaix is one of the sites monitored by the regional REBENT network. The aim of which is to define a reference state and to provide regular monitoring of the marine coastal fauna and flora from the intertidal area to water depths of about 60 meters (www.rebent.org). This sector has been a good example to develop a specific survey strategy combining submarine and aerial tools and predictive modelisation. Geomorphological and sedimentological aspects, infralittoral communities of macrofauna and kelp forests distribution were the focus of this study.

Between 2008 and 2010, 940 km of acoustic profiles were collected in the deeper part of the bay, using towed sidescan sonar combined to a multibeam echosounder and in shallow waters, an interferometric sidescan sonar coupled with a roxann AGDS. Seabed substrate was interpreted from the backscatter imagery and roxann results. Acoustic data were calibrated from direct observations using shipek (sediment) and hamon grabs (macrofauna), video sequences and diver acquisitions, to produce a geomorphological and sedimentological pattern and ultimately habitat maps (fig. 1a). The seabed in this bay is very heterogeneous in terms of sediment and macrofauna distribution and subject to a strong hydrodynamic gradient. Rocky bottoms are scattered throughout the bay and are playing a major role in explaining the distribution of some benthic communities.

To better understand, protect and manage habitats such as kelp forest, species distribution modelling approach was applied. The principle of kelp forest prediction is based on the use of in situ biological data derived from video and subtidal surveys along with high resolution environmental data (abiotic variables) to predict the distribution, relative cover (fig. 1b) and biomass of kelp forests. The rock layer was extracted by combining acoustic data with two others sources: lidar surveys and photo-interpretation of aerial imagery. Acoustic signature of vegetation has been used and validated by biological data. Empirical relationships between predictor and response variables were integrated into a geographic information system to produce high accuracy maps (5 metre horizontal resolution) for *Laminaria digitata* and *Laminaria hyperborea*, the main kelp species present on the site.



a

b

Figure 1: Example of habitat map (a) and kelp cover prediction (b) in a part of the Morlaix bay

Relationship between seabed characterization and phanerogam meadows inferred from the Geological Map of Italy

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Surveying aimed at the Geological cartography of submerged areas of the Italian territory has allowed to identify and map several types of organogenic deposits (such as phanerogam meadows, coralligenous build-ups, organogenic sediments). The distribution of phanerogam meadows in the Tyrrhenian Sea has been tentatively associated to geomorphic features and sediment dynamics derived from the data available on the maps. Phanerogam meadows distribution is influenced by several parameters among which shelf morphology, slope, hydrodynamics, sediment supply. According to shelf morphology, they form continuous belts running more or less parallel to the coastline in front of wide coastal plains. Alternatively, they form patches in morphologically complex areas, such as volcanic islands or submerged coasts. They also form extended covers on banks. The extension of phanerogam meadows decreases where slope increases, because light penetration drops faster. Extended phanerogam meadows are interrupted where sediment supply increases, especially because of river input. On the other hand, where sediment supply is lower, for instance in case of rocky outcrops, they almost reach the coastline. Meadows are widespread in areas protected from the prevailing wave fetch. The relationship between phanerogams and anthropic settlements cannot be inferred clearly from the maps; in some cases phanerogams do not grow next to anthropic features, whereas in other cases they surround such structures. In these areas *Cymodocea nodosa* seems to be more common than *Posidonia oceanica*. In order to verify the degree of reliability of the interpretation obtained from the Geological Map of Italy, the distribution observed therein has been compared with data collected by detailed studies focused on the identification of phanerogam meadows.

Combining video and scanning-sonar imagery to quantify the impact of trawling off British Columbia

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Impacts of bottom trawling on deep-sea ecosystems vary depending on habitat types and species present. Environmental factors such as depth, dissolved oxygen concentration, substratum type, and bottom roughness also affect the diversity and composition of benthic communities. We studied two transects (30km and 12km long) on the upper continental slope off Vancouver Island, BC, Canada that included areas of seafloor with visible trawl marks. The main target for bottom trawling fisheries in this area is the longspine thornyhead (*Sebastolobus altivelis*). Field data were collected using the ROV ROPOS equipped with a 3CCD video camera and high-resolution scanning sonar. Megafaunal composition/abundance and bottom characteristic information were extracted from video imagery and assembled using a custom-designed *MS Access* database. The same database was used to compile information on trawl-door marks detected in recorded sonar imagery. The sonar surveyed a 50m radius around the submersible during transects, providing a broader view of evidence of trawling in the area and a fairly accurate number of trawl marks when compared to fishing effort data. We will report on relationships between environmental variables and faunal abundance, diversity and species distribution. Following the video and sonar analysis, diversity patterns and general species distribution for both transects were determined. Relationships of community structure to depth and trawling intensity were investigated and differences in total abundance, species composition and distribution, and species diversity were detected between the high and low trawling intensity areas. Our study area is located in an oxygen minimum zone with very low bottom water dissolved oxygen concentrations in its core (600m-1000m). This area also corresponds to the highest trawling intensity. While it may seem counterintuitive to have higher fishing intensity in a lower quality habitat for most organisms, *S. altivelis* is the main target of bottom trawling fisheries and this depth range corresponds to its habitat. Future survey will determine *in situ* horizontal oxygen levels and help understand the role in shaping megafauna assemblages and its interaction with trawling.



Fig. 1 Trawl-door mark in sediment along ROV transect off Vancouver Island, Canada.



Fig. 2 Boulder covered with sea anemones, sessile holothurians, and ophiuroids (450m).

Bayesian Siting Model for Marine Spatial Planning

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With so many spatial planning and decision support tools available today, all of which claim to solve a multitude of problems, why introduce another tool? Virtually all spatial planning and analysis tools today are built around the power of Geographic Information System (GIS) software applications. These systems exist, are in wide use, and adapting them for planning tasks seems an attractive and straightforward path. Despite their ease of use and spatial intelligence, GIS systems alone fall short for decision support: They (1) do not explicitly account for or propagate uncertainties in the underlying data or models, (2) do not handle temporal and multidimensional data well or at all, and finally (3) they do not really help the user make a decision or find common ground.

Bayesian analysis methods, however, provides a way to incorporate uncertainties (model or measurement), time or trends, disparate and patchy data, or even missing data into a robust analysis system. This type of system not only provides an outcome but also reports the certainty of the outcome as well as the sensitivity of the outcome to any particular piece of data.

The Bayesian decision support system allows the user to discover which data are important, which can be ignored, and which are needed to make an optimal decision. The system treats all data probabilistically, combining probabilities in conceptually the same way a GIS combines layers, but Bayes Theorem replaces the ad-hoc map algebra methods used in typical GIS analysis. The Bayesian system can also be used in the final stage of decision-making, allowing users to engage in “what if” scenarios by permitting them to input their subjective values into the decision process. Lastly, since the problems addressed here are spatial and the analysis has been applied to spatial datasets, the output can be visualized in a GIS system so that the users can view the outcomes, the underlying data, and the analysis results in an intuitive way. By having all cards on the table, with a robust science based foundation, consensus building is simplified.

Supporting benthic habitat mapping by means of marine (geo)databases

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Marine scientists must deal with a variety of data sources and data structures (e.g., tables of species abundances, raster images of sea surface temperature, gridded bathymetry, etc.). Furthermore, mapping and modelling require that data from conventional sensor and sample analysis systems be integrated with interpretive information from e.g. video data analysis procedures. In a database, data from multiple sources can be integrated into a coherent system for access and manipulation as well as primary and ancillary information (i.e., metadata) seamlessly integrated. Further, geodatabases (databases with the ability to handle geographic objects) facilitate the analysis and interpretation of spatial data. In such setups, development of scientific hypotheses, forecasting, and decision support are greatly enhanced. Geodatabases are particularly suited for tasks like visualization and mapping. Each particular setting, however, requires custom-made solutions. In this presentation I will describe different ways to handle some of the challenges of dealing with multiple sources of marine data to the end of improving modelling, classification and mapping of the benthic landscape. Examples are taken from two data-rich marine areas, very different in their scope but with similar needs: Norway's entire continental shelf, being mapped under the auspices of the MAREANO Program, and the two adjacent Marine National Parks *Kosterhavet* and *Ytre Hvaler*, straddling the border between Norway and Sweden and managed jointly by the regional administrations.

Marbunn is a database designed to store metadata on MAREANO cruises as well as data and metadata from all samples collected during those cruises. The database is complete with specialised software for editing the data in post-processing and a web interface to view and download the data. Marbunn is planned to eventually contain all data from the MAREANO program (including data from partner institutions) and to be incorporated into a more comprehensive geodatabase (Sea2Data). The Koster-Hvaler Geodatabase was created for assembling, managing, storing, and querying marine data to support research and management of the entire protected area, and it is based on ESRI's ArcMarine data model. This geodatabase is oriented towards the integration of survey geospatial biological data and it provides an ideal setting for visualizing, modelling and ground-truthing maps of underwater habitats. Additionally, the geodatabase is anticipated to serve as a platform for enhanced cooperation between two national parks, which are neighbours in geographical space but a long way apart both politically and economically. The achievements and pitfalls of both approaches are discussed, and some recommendations are put forward.

Characterization of Benthic Habitats in the Salish Sea – An Inland Sea Supporting a Unique Ecosystem

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Orcas, “killer whales”, (*Orcinus orca*) are the top marine predator in the Salish Sea and a great draw for tourists from around the world. The local pod of Salish Sea Orcas is dependent upon salmon (*Oncorhynchus* spp.) for food and the salmon depend on forage fish to survive. Disruption, whether it is natural or anthropogenic, to this intricate balance of the trophic food web can produce a cascade of a far ranging nature, extending from economic impacts to sustainable food supply. Understanding of habitat types that support the ecosystem is a first step in the management of a marine resource critical to the livelihood of humans and a healthy environment. For the past 16 years a major marine benthic habitat characterization and mapping program has been underway between Canada and the US, primarily supported by private funds and organizations of Orcas Island. Detailed maps have been constructed and unique seafloor habitats identified, many of which are dynamic and found to harbor critical forage fish such as Pacific sand lance (PSL, *Ammodytes hexapterus*) that are preyed upon by rockfish (*Sebastodes* spp.) and lingcod (*Ophiodon elongatus*). Extensive investigations of PSL have recently been completed with the support of the Northwest Straits Commission and the SeaDoc Society. From these investigations predictive models and metrics have been produced that will be useful in the management of forage fish, rockfish and salmon. The interrelationship of geology, habitat types, currents, and biology learned in the past 16 years should be helpful in managing the Salish Sea’s important habitats and forecasting potential impact to its living resources.

Substrate Classification Derived From Marine Geological Information

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Traditionally, the Geological Survey of Sweden (SGU) has produced marine geological maps according to a classification scheme based on genesis, grain size and organic content. The classification scheme is mainly divided into the two subgroups; glacial deposits and post glacial deposits. The glacial deposits comprise Glacial Clay, Till and Glaciofluvial sediments such as Gravel, Sand, and Silt. The post glacial deposits mainly comprise redeposited sediments such as Clay, Silt, Sand and Gravel as well as residual material such as Boulders and Pebbles, along with organic content (e.g. gyttja). The marine geological maps show the original deposited material and reflect past and present hydrodynamic processes such as bottom currents, wave exposure, sediment-erosion, -transportation and -deposition as well as bathymetry. However, in order to fully understand the seabed characteristics from this classification scheme, some knowledge of Quaternary geology and sediment dynamic processes is needed.

Due to an increased interest from the environmental management community as well as from industrial stakeholders, there is a need for a more straight forward and easily understood classification of the seabed. Therefore, SGU has reclassified the original Quaternary marine geology maps into superficial substrate maps based on the EUNIS classification scheme for habitats.

The substrate maps show nine different classes of substrates, which are based on the EUNIS-classification scheme. The classes are defined through Factor analyses of 2 900 visual seabed observations, evenly distributed within Swedish sea areas, described according to the EUNIS-terminology. The nine substrate classes were mapped to a corresponding Quaternary deposit class, resulting in a direct translation of the original marine geological map into a superficial substrate map in compliance with the EUNIS-terminology.

In addition, mobility maps were developed showing the coarsest grain size, according to the EUNIS grain size scale, which erode (become mobile) within different areas of the seabed due to the effect from wind-induced waves

In conclusion, the method of using direct translations from geological nomenclature and SGU marine geological maps to EUNIS-classification and superficial substrate maps were found to give satisfactory results. Substrate maps will continuously be produced by SGU in forthcoming surveys and investigations.

Nearshore Habitat Mapping in Foxe Basin, Canadian Arctic

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A major shipping port in Foxe Basin is proposed as part of the development of an iron-mine on Baffin Island. The port is being designed to accommodate year-round shipments of iron ore as well as the delivery of construction materials and fuels. There is a concern that port facilities could directly and indirectly impact nearshore habitat. Potential indirect impacts include propeller wash, wind-blown ore dust, changes in ice regime, and fuel spills. Seabed characteristics at this location were completely unknown.

Multibeam and single-beam echo-sounding, side-scan sonar, and towed video surveys were conducted from locally-chartered vessels and provided the basic data for habitat characterization. Areas from the upper intertidal zone to 45 m depth were surveyed. 14 km² of seabed were surveyed. Habitat units were delineated by expert classification of side-scan acoustic units, and biotic attributes, based on classification of videography, were attached to define biophysical habitat units. Based on the substrates and dominant floral communities, four distinctive habitat associations were defined:

- (1) Fucus/Gravel-sandy Gravel (< 3 m depth; 21,000 classified images);
- (2) Foliose red algae-Bladed kelps/muddy sandy Boulder-Cobble (~3-15 m depth; 23,000 classified images);
- (3) Foliose red algae-Bladed kelps-Filamentous red algae/muddy sandy Gravel (15-25 m depth; 7,000 classified images);
- (4) Foliose red algae-Coralline red algae-Filamentous red algae/muddy sandy Gravel (> 25 m depth; 13,000 classified images).

Depth stratification was very evident in these communities. The distinct character of the associations permitted the confident extrapolation of the mapping from areas where both side-scan sonar and video imagery existed into areas where only bathymetric data and side-scan sonar mapping were available. Ice-related features were abundant in water depths less than 9 m and consisted of: (1) ice wallows, shallow circular depressions several metres in diameter, rimmed with coarse materials; and, (2) linear ridges and troughs, parallel to sub-parallel to the shoreline and extending many tens of metres. The biota was dominated by floral communities and, because of the clear water, attached algae extended to the 45 m depths; kelp cover in 15 m to 35 m depth range often exceeded 75%. Invertebrates and fish were scarce in general, with anemones, urchins, brittle stars and other sea stars being the most commonly observed.

Submerged coral reefs: “life boats” for shallow reef systems in a warming global ocean?

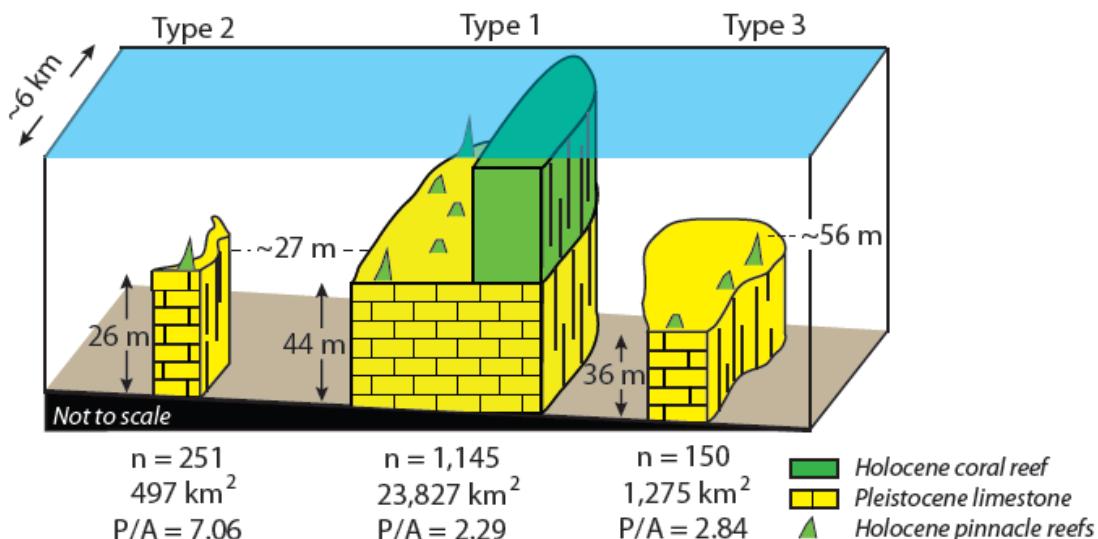
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Anthropogenic global ocean warming is predicted to cause bleaching of many near-sea-surface (NSS) coral reefs and could turn deep-water, mesophotic coral ecosystems (MCEs) into coral reef “life boats” for many coral species. The question arises: how common are MCEs in comparison to NSS reefs? We used a dataset from the Great Barrier Reef (GBR) to show that only about 37% of available seabed on submerged banks is capped by NSS coral reefs ($16,110 \text{ km}^2$); the other 63% of bank area ($25,599 \text{ km}^2$) is submerged at a mean depth of around 27 m and represents potential MCE habitat that is spatially distributed along the GBR continental shelf in direct proportion to NSS coral reefs. Out of $25,599 \text{ km}^2$ of submerged bank area, predictive habitat modelling indicates that about 55% ($14,000 \text{ km}^2$) is potentially occupied by coral communities.



This conceptual diagram illustrates the three classes of bank identified in our study. Type 1 banks are the most common ($n = 1,145$), occur on the mid- to outer-shelf, have the largest mean area (21 km^2), support a NSS coral reef of some size, have a mean depth of 27 m, a mean height of 44 m and a perimeter/area (P/A) ratio of 2.29. Type 2 banks do not have NSS coral reefs, occur mainly the mid-shelf, are the smallest (mean area of 2 km^2), have a mean depth of 27 m, a mean height of 26 m and a P/A ratio of 7.06. Type 3 banks do not have NSS coral reefs, occur mainly on the outer-shelf, are of intermediate size (mean area of 8.5 km^2), have a mean depth of 56 m, a mean height of 36 m and a P/A ratio of 2.84. Holocene pinnacle reefs occur on all three types of bank but their vertical growth is restricted and they have not reached the sea surface.

Seabed mapping to support long-term CO₂ storage in offshore Australia

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Seabed mapping studies by Geoscience Australia are helping reduce uncertainty associated with the long-term storage of CO₂ in Australia's deep offshore sedimentary basins. In the 2011-12 Federal Budget the Australian Government allocated \$55.65 M to Geoscience Australia over four years to undertake a 'pre-competitive' data acquisition campaign, including new regional geological studies to assess the suitability of deep offshore sedimentary basins for the long term storage of CO₂. The purpose of the data acquisition program and regional geological assessments is to encourage Australia's largest CO₂ emitters to bid for tenements released in 2009 over four offshore basins deemed prospective for CO₂ storage.

In Australia, the Federal Government assumes liability for the CO₂ stored in the offshore basins for a period of 15 years after the project has been completed. Assessing the potential liability requires information on: 1) the total amount of CO₂ that can be stored; 2) the probable subsurface migration pathways; and, 3) the risk of escape to the seabed and/or into other subsurface reservoirs (e.g., petroleum plays) and any environmental, economic and social consequences. For each offshore basin, Geoscience Australia is undertaking integrated seismic reflection and seabed mapping surveys to characterise the reservoir storage capacity and integrity of the capping seal(s) to help reduce the uncertainties associated with storing CO₂. There are two principal aims of the seabed mapping studies. The first is to collect data from the shallow (<100 m) subsurface sediments to determine if there is any evidence for deep-seated CO₂ leakage to the seabed, including observing and measuring background fluxes. This aim will be achieved by collecting and analysing high-resolution multibeam bathymetry, sub-bottom profiles and shallow (<4 m) cores to look for recently active near-surface faulting and seabed and water column features such as pockmarks and acoustic flares, respectively. The second aim is to characterise the benthic environments for their ecological function and significance. This will be achieved using multibeam bathymetry and backscatter data, seabed video footage and photographs and direct sampling of seabed sediments and biota.

Long term storage of CO₂ in deep offshore sedimentary basins is a priority for Australia if it is to meet its internationally agreed emissions targets and transition itself to a lower carbon emission economy. Investment in pre-competitive data acquisition and research is one part of a larger policy that the Australian Government has in place to help achieve these goals.

Maximising multibeam sonar data to map and predict seabed physical properties

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Multibeam sonar data incorporates a wide range of metrics of physical seabed properties that can be utilised to generate substrate maps for marine habitat mapping. In particular, statistical descriptors of seabed form and texture can be derived to maximise the information provided by multibeam data. This study investigates the full potential of multibeam data for mapping seabed properties for an area of geomorphically complex seabed on the continental shelf offshore from Point Cloates, Western Australia. In 2008, as part of a collaborative survey within the Commonwealth Environmental Research Facilities (CERF) Marine Biodiversity Hub, Geoscience Australia acquired high resolution multibeam data and sediment samples across a 280 km² area of the shelf, using a Kongsberg EM 3002 (300 kHz) system. Using this data, a two stage analysis was developed to: (i) separate ‘hard’ seabed (e.g., reefs, ridges and mounds) from ‘soft’ sediments, and; (ii) predict textural properties for seabed sediments, including %Gravel, %Sand, %Mud, mean grain size and sorting. For a mapping tool, we chose the Random Forest Decision Tree technique. This entailed using ten combinations of input datasets as explanatory variables, including morphometric variables derived from bathymetry, and angular response curves and related statistics derived from backscatter mosaics. The training dataset was derived by combining sediment data from grab samples with locations of hard substrate inferred from bathymetry data.

The predictive mapping of ‘hard’ and ‘soft’ seabed types resulted in predictions with very strong confidence levels, especially when bathymetry information was combined with backscatter data (i.e., cross-validated Area Under Curve = 0.99). The five sediment properties were predicted with moderate to good cross-validation accuracies (Figure 1). The highest accuracies were achieved for %Mud and Sorting, (R^2 s equal 0.73 and 0.68, respectively). The prediction maps of individual grain size properties and ‘hard’ and ‘soft’ seabed were merged and classified into a seabed coverage map (Figure 2). Rocky substrates in shallow water of the inner shelf were well-predicted and are tightly correlated with sites of observed hard substrate. In deeper waters of the mid to outer shelf, seabed sediments are predicted as zones of ‘Sand’ and ‘gravelly Sand’ to ‘sandy Gravel’, then to the combination of ‘gravelly muddy Sand’ and ‘muddy sandy Gravel’. These patterns are also consistent with observed distributions of sediment facies. The success of this study demonstrated the full potential of multibeam data in mapping complex seabed environments.

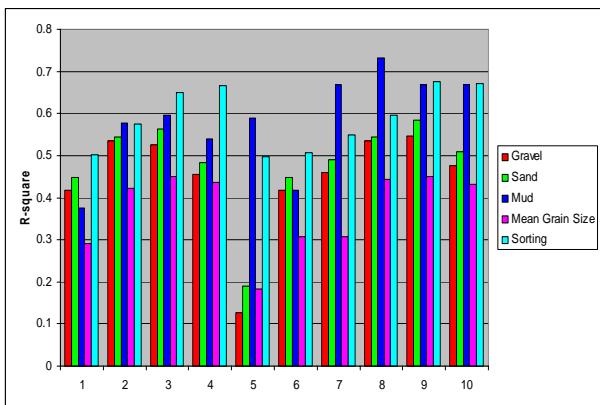


Figure 1: Prediction accuracies for sediment textural properties. The ten classes represent the ten combinations of input datasets.

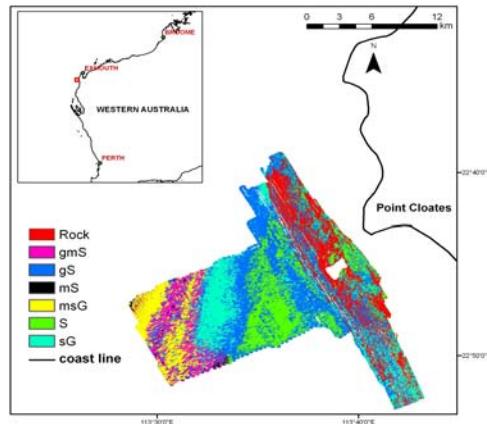


Figure 2: Predicted seabed cover map: gmS (gravelly muddy Sand), gS (gravelly Sand), mS (muddy Sand), msG (muddy sandy Gravel), S (Sand) and sG (sandy Gravel).

A Statistical Approach for Habitat Classification in Submarine Canyons

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Advances in technology have enabled numerous developments in deep-sea habitat mapping. As a result, a broad spectrum of data is increasingly being incorporated into seabed classification and many classification techniques have been proposed. Ideally, automated seabed classification for the deep sea is aiming for a statistically robust, objective and repeatable method, applicable at a variety of scales.

This paper presents a study from the upper Cascais and Lisbon-Setubal Canyons offshore Portugal, and will address 3 of the main objectives in automated seabed classification: 1) objective parameter selection, 2) data clustering and 3) determination of the optimal number of classes. Prior to parameter selection, it is important to ensure all spatial data integrations are carried out correctly. To achieve this, TOBI sidescan data of high image quality but with poor locational accuracy were reprocessed using synthetic imagery produced from multibeam bathymetry. Subsequently, abiotic terrain variables (bathymetry & derivates, sidescan imagery, sediment properties) were subjected to a statistical approach using the Akaike Information Criterion (AICc) and Principal Component Analysis (PCA) to select optimum parameters for habitat classification. Unsupervised fuzzy clustering was used for data clustering. Lastly, the optimal number of clusters was defined using Xie-Beni (XB) and Partition Coefficient and Exponential Separation (PCAES) index.

The proposed method gave promising results in these submarine canyons with high terrain variability. TOBI reprocessing successfully improved the sidescan sonar imagery registration onto the multibeam bathymetry. The habitat maps are groundtruthed and evaluated using cross validation. The percentage of correctly classified pixel yields a worthy result. Lastly, method comparisons are made between AICc and PCA for parameters selection and XB and PCAES for optimal number of clusters. A critical evaluation using SLOP analysis on the overall method is carried out to identify its strength, limitations, opportunities and threats.

Where's the reef? An inexpensive approach for mapping nearshore hardbottom reefs

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Benthic marine habitats are difficult to map even in coastal and nearshore waters where depth is not a complicating factor. Wind, waves, and terrestrial runoff are common conditions in inshore areas and make mapping the substrate with optical remote sensors extremely difficult. However, acoustic remote sensors are negligibly affected by turbidity and produce satisfactory benthic imagery during rough seas. Both acoustic and optical remote sensing can be extremely expensive to collect. My research attempts to uncover ways to map benthic habitats, particularly hardbottom reefs, in the nearshore region of the northeastern Gulf of Mexico by employing relatively inexpensive methods. Windy weather, choppy waves, and turbid waters are typical in this area but calm seas occur intermittently throughout the year and clear waters are common in the late winter and early spring. I collected aerial photographs during that time of year when weather conditions were ideal. The imagery of the substrate is not of high resolution due to the water clarity (i.e. some particles still exist in the water column unlike the oligotrophic waters typically found around tropical coral reefs) but it is possible to distinguish between colonized and uncolonized substrate which generally correlates with hardbottom and unconsolidated sediments. Sessile macro-invertebrates (the primary colonizers) require hard substrate to recruit to, attach, and then grow. These macro-invertebrates give the hard substrate a dark color that highly contrasts with the adjacent light-colored sand. This contrast allows potential hardbottom habitat in relatively shallow waters, <15 m, to be quickly identified from the aerial photographs and over a broad area for a reasonably low cost. I then mapped the identified hardbottom in more detail using a commercially-available sonar system, the Humminbird 997c. This system produces sidescan imagery, GPS locations, and depth data for under \$2000. Sea state can affect the quality of the sidescan maps, but the rocky features of the hardbottom were generally distinguishable even through the noise. I targeted days with calm conditions to collect the sidescan imagery and achieve the best results. Dive surveys at each site provided accuracy assessments of the two remote sensing techniques and revealed fine scale details about the habitat for more detailed characterization. Hardbottom reefs harbor high biological diversity and are essential habitat for many economically important fish species in the region. Therefore, it was critical to find the hardbottom in this region, map it, and characterize it before it is further impacted by human activities.

Models and maps: predicting the distribution of corals and other benthic macro-invertebrates in deep water

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The seafloor within California state jurisdiction (3 nmi (5.6 km)) recently was mapped using high-resolution sonar to quantify seafloor character, depth, and rugosity at a fine scale (2 m and 5 m grid size). Subsequently, presence-absence data of benthic macro-invertebrates and associated habitat (i.e., sediment type and depth) were collected during ground-truthing cruises using a towed camera sled in selected areas along the coast. Using this information, we developed generalized linear models (GLMs) to predict the probability of occurrence of five commonly observed taxa (cup corals, hydroids, short and tall sea pens, and brittle stars in the sediment) within the Santa Barbara Channel (SBC) off southern California. We employed a utility-based approach to validate the models and to identify optimal cutoff thresholds for the GLM predictions, given a relative cost of false negatives and false positives. We present values under a range of cost ratios to evaluate their influence on optimal cutoff values. Out-of-sample predictive accuracy, assuming equal costs of false negatives and false positives, ranged from 75% to 89%. Estimated area under the characteristic curve (AUC) in our models ranged from 0.76 for brittle stars in sediment to 0.91 for cup corals. An AUC value above 0.7 is an acceptable level of performance, between 0.8 and 0.9 is excellent, and above 0.9 is outstanding. We developed predictive maps of probability of occurrence using our validated models and a seafloor character map provided by USGS. Cup corals and hydroids had high predicted probabilities of occurrence in areas of hard substrata, while short and tall sea pens were predicted to occur in parts of the SBC that had unconsolidated and mixed sediment. Our model predicted that brittle stars would occur throughout the entire channel on various bottom types. The combination of high-resolution, comprehensive seafloor maps and predictive models of invertebrate distributions will aid managers in identifying habitats of particular concern and areas with vulnerable deep-sea corals. Our models will be useful for marine spatial planning and ecosystem-based management as well as for assessing the effectiveness of essential fish habitat closures and other marine protected areas.

User-supervised segmentation and classification of shallow water backscatter data, Wellington Harbour, New Zealand

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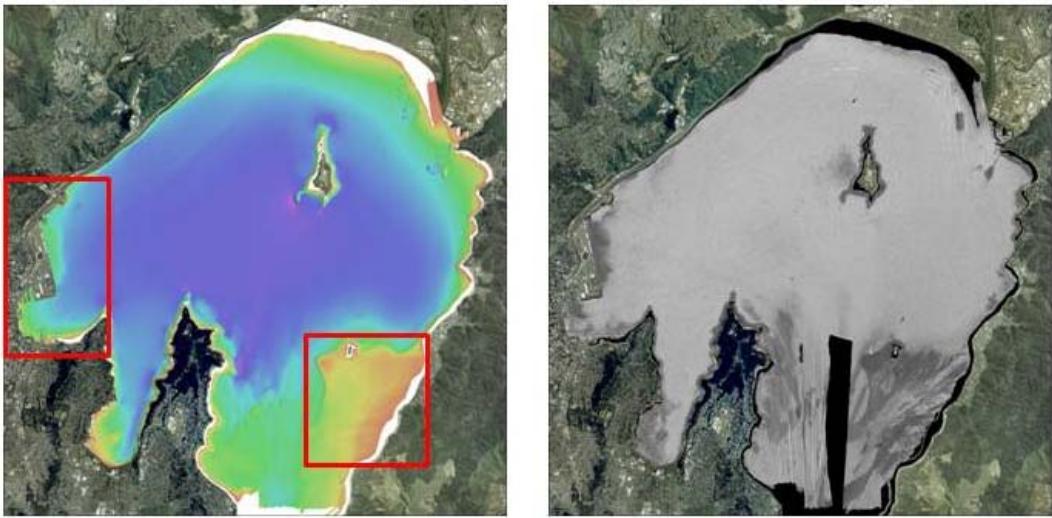
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We present a backscatter map of Wellington Harbour generated from EM3000D multibeam echosounder data. The survey covers the breadth and width of the harbour, covering 80 km², ranging in depth from -1.3 m (above chart datum) to +32.1 m. Full processing of the backscatter data were undertaken using IFREMER's SonarScope® software, and included signal corrections, attenuation of specular reflection and speckle noise filtering aiming at attenuating the effects of recording equipment and water column. The result is a comprehensive backscatter map of the Wellington Harbour. The backscatter imagery was first used for qualitative detailed morphological interpretation and provides a level of detail greater than with conventional multibeam bathymetry.

Second, we segmented the backscatter data, using SonarScope® user-supervised approach, whereby areas of homogeneous backscatter are selected manually as training regions. Sonarscope® uses cooccurrence matrices to segment the backscatter data thus generating classes based on signal mean value and backscatter texture. The segmentation was run over two independent regions: the harbour entrance, where current-generated landforms (e.g. sediment waves) and rocky outcrops dominate the seafloor; and the inner harbour with reclamation areas along the Wellington city wharves. Six classes were tested using a cooccurrence matrix of the backscatter, and five distinct classes were selected for the segmentation. The diversity and complexity of subtle seafloor landforms are well depicted in the harbour entrance by the segmentation, revealing differences in backscatter not readily visible to the human eye. In the inner harbour the transition from reclamation land to natural seafloor is characterised by a simple progression from one class to the other, reflecting a progressive transition from reclaimed to natural seafloor.

Finally, we used c.260 geological samples collected and analysed between the 1950 and 1990 to associate a geological significance to the classes, using grain size, percentage of mud, sand gravel, and carbonate content.



Wellington Harbour bathymetry and backscatter (image is $\sim 12 \times 12$ km).
Frames indicate the areas where the segmentation was run.

Combination of morphometric and textural techniques for mapping coastal benthic habitats

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For many years, seafloor maps of coastal waters have been based on high resolution multibeam bathymetric data. Visual interpretation of these data, integrated with ROV photos, videos and samples, has been the preferred tool to outline provinces of benthic habitats and biotopes. Over the years, the quality of multibeam bathymetric data has improved sufficiently to enable numerical techniques to be applied and to allow objective, accurate and statistically valid interpretations to be made. Many of these numerical techniques, however, have been based on a single method and, so far, a standard automated seabed classification technique that works well for all habitat types in all kinds of environments has never been defined.

In this study we present a new multi-method approach for benthic habitat mapping of shallow coastal areas. The data sets available include high-resolution multibeam bathymetry and backscatter from a 28 km² area of seafloor offshore the Maltese Islands, Mediterranean Sea. The acoustic data are ground-truthed with ROV imagery and seafloor photographs and samples from dive surveys. Our approach is based on a set of geomorphometric and textural analysis techniques to map specific seafloor morphologies and composition classes. Morphometric attributes, the Bathymetric Position Index and geomorphometric mapping segment the seafloor into five morphological classes – flat and sloping zones, crests, depressions and breaks of slope. Subdivision into the predominant classes of seabed composition – medium sand, maerl associated with sand and gravel, seagrass settled on sand and gravel, and seagrass settled on bedrock – is carried out through supervised classifications of morphometric attributes and backscatter textures (TexAn). The morphological and seabed composition classes are subsequently combined to chart 12 predominant habitats.

We have developed a simple GIS-based method for an accurate characterisation of coastal habitats while using all the information available in the multibeam echosounder data. The method is not a fully automated one and it does require some expert input. As the Government of Malta embarks on mapping of its coastal waters in fulfilment of the EU Marine Strategy Directive, we expect our approach to provide an efficient and cost-effect tool to map and manage the Maltese coastal waters.

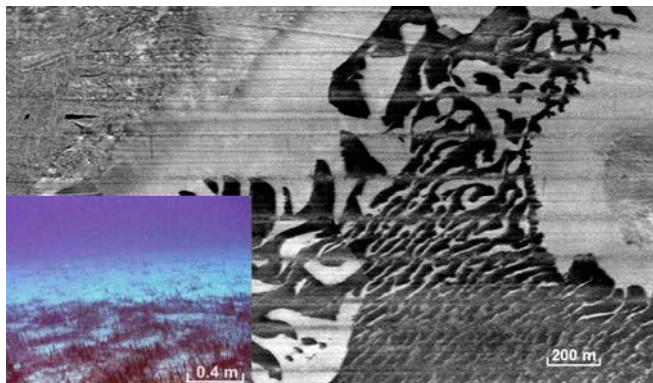


Figure 1 – Backscatter imagery showing curved and elongated patches of medium sand draping a smooth flat surface of maerl, sand and gravel. ROV Imagery (inset) showing patches of photophilic algae.

Geological mapping for inferring the potential location of sandeel habitats in the North Sea, Denmark.

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The seabed sediment distribution has been mapped in the Danish part of the North Sea. The Quaternary stratigraphy and the palaeo-landscape have been described to understand the geological development and the distribution of the seabed sediments and the benthic habitats.

A specific focus has been to examine the geological and physical characteristics of sandeel (*Ammodytes marinus*) benthic habitat in an attempt to predict the presence of this species outside its normal fishing area. Sandeels are important prey species for many marine predators (such as seabirds and fish). Stock assessments are continuously evaluated to ensure the minimum level needed to keep up a sustainable fishery.

From previous studies it was found that the sandeel fish is absent when the silt/clay content is >10 % and densities decline when this ratio is between 2 and 10%. Further, sandeels prefer seabed structures associated with an abundant supply of sand with a maximum current flow of 1 m/s and water depths between 30 and 70 m. Information on the actual sandeel fishing grounds was available for the study.

The sediment distribution of the Danish North Sea region reflects the geological processes acting during the last glaciations and the post-glacial sea level fluctuations. Four seabed types have been recognized: Glacial deposits from two glaciations forming hard substrates with boulders and gravel; Glacio-fluvial sandur deposits; Holocene sand ridge and sandwave deposits; Holocene, marine, silty sand deposits.

It is evident that the largest sandeel fishing grounds are closely linked to very large ridges of well-sorted sand in the north-eastern part of the North Sea. These ridges are connected to the nearby Weichselian glacial landscape and were originally formed as tidal sand banks during the early Holocene. Sandeel fishing grounds are also found in a similar environment in the southern part of the Danish North Sea with sand ridges related to Saalian glaciation. Examples of the no sandeel fishing grounds are the poorly sorted meltwater deposit areas.

It is concluded that knowledge of the geological settings and sedimentary environments can be used for designating benthic fish habitats and as such potential sandeel fishing grounds. Future sandeel habitat studies are planned in the Dogger Bank area including geologists and biologists.

Advances in multibeam processing and spatial analysis for the characterisation and prediction of temperate seabeds to support the management of Australia's marine biodiversity

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The effective management of marine biodiversity is often hampered by a lack of basic information on the spatial distribution of biota. Predictive modelling using physical surrogates, that often have better coverage over broader spatial scales, can make efficient use of sparse biological data and help address this knowledge gap. A promising source of physical surrogates for benthic biodiversity is multibeam acoustic data. The techniques outlined in this research describe how to dismantle multibeam acoustic data into spatial layers that can be useful for biological modelling.

We define a multi-staged approach where substratum and seabed biotope are characterised and then predicted at fine spatial scales across large areas by combining spatial analysis of multibeam acoustic backscatter with angular response classification. We demonstrate a methodology for the extraction of these derivatives to predict seafloor substratum. Predicted substratum, in combination with other multibeam-derived spatial layers, then forms the input for statistical models that explicitly relate seafloor characteristics with the distribution of biota associated with benthic substrata. In the first stage of this research, the angular response profiles are combined with image segmentation of backscatter (BS) imagery to characterize benthic substrata. The shape of the BS angular profile provides information on the seafloor characteristics (interface roughness, impedance and volume scattering) which helps us to describe the classes and relate them to seafloor variations. BS angular response can be used to show acoustic class separation and validate the segmentation and textural analysis results. Seabed classes are validated from substrata scored in images collected by an autonomous underwater vehicle (AUV). Results show that there are good class relationships between the qualitative AUV visually identified classes and quantifiable environmental characteristics that can be measured by multibeam acoustics.

In the second stage of this research, biological data of key taxa, again collated from scored AUV imagery, are modelled against substratum and seafloor characteristics derived from the multibeam data using boosted regression trees. The resulting models had reasonable to excellent predictive performance (as measured by AUC) and can then be used to predict the spatial distribution of biological groups across the entire domain of interest (with estimates of uncertainty). Additional outputs from the models allow us to identify multibeam variables which can successfully act as surrogates for biodiversity and define the physical environment of biological groups in temperate waters.

This methodology will advance research that assesses the utility of high resolution acoustic data for quantifying and predicting patterns of marine benthic biodiversity. Through the NERP Marine Biodiversity Hub this research will be extended to assist the development of sampling designs and methodologies for monitoring ecosystem health within Australia's Commonwealth Marine Reserve network (<http://www.nerpmarine.edu.au/>).

Geological and geophysical dataset integration when investigating the effects of anthropogenic activity, pollution signals and modern sedimentation on freshwater lake habitats

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Windermere is the largest freshwater lake in the English Lake District, measuring approximately 17km in length with a maximum width of 1.5km in the north. It occupies a radial north-south pre-Glacial river valley and is divided into two distinct basins with a maximum depth of 62m in the North Basin and 44m in the South Basin. One of the most important species within the lake is the nationally rare fish Arctic Charr (*Salvelinus alpinus*). Windermere represents the southern most extent of this fish globally, however it has recently shown a marked decline in population in the lake, with population differences observable between both of Windermere's sub-basins. High resolution multibeam bathymetry data has revealed a lacustrine environment controlled by glacial geomorphology and landforms shaped by modern day sedimentary processes. Multibeam backscatter data, remote acoustic observations and grab samples are used to identify six distinct bottom environments which categorise the lake bed. These are defined by modern limnological and sedimentary processes relating to the Holocene period, driven by fluvial and hillslope processes and anthropogenic activity. XRF analysis on 16 grab samples has identified elevated concentrations of lead and zinc in recent lacustrine sediments. High lead concentrations represent possible chemical signatures from mining activity and past mineral-workings within the catchment. Geological mapping has revealed fluvial processes and hillslope gullying act as transportation pathways for mineralogical signals from these anthropogenic activities. It is likely that elevated concentrations of zinc and other trace elements in recent sediments are linked to processed waste and sewage inputs. ROV recordings have further identified a facies of filamentous growths which possibly represents a sewage fungus in the lake (Figure 1). Preliminary interpretations suggest that a combination of the above factors could be responsible for changes in the range and distribution of the spawning grounds of the Arctic Charr, and the increase in observed stress in the fish population.



Figure 1: Facies of filamentous growths, identified in ROV recordings

Spatial patterns of benthic megahabitats in the Abrolhos Bank

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A regional scale benthic habitat map of the Abrolhos Bank is presented based on sidescan sonar surveys and ground-truthing with remotely operated vehicles (ROV) and mixed-gas diving operations (TRIMIX). The benthic habitat mosaic is more complex than previously supposed. The shelf encompasses three main megahabitats and a complex bathymetry. It includes 8,844 km² of reefs (earlier estimates from remote sensing were around 500 km²) and the world's largest continuous rhodolith bed, with 20,904 km², which corresponds to 43% of the Bank surface. Unconsolidated sediments, including bioclastic/terrigenous sand/gravel and mud, cover about 19,151 km². In terms of morphology, the reefal megahabitat is structurally complex and more patchily configured, even when examined at the regional scale. Besides the well-known pinnacles and banks with high coral cover, typical of the emergent and quasi-emergent reefs previously known from the region, we found a much larger realm of mesophotic reefs across the mid and outer shelf, in depths from 25-90 m. These structures include non-emergent pinnacles, coalesced reef structures, paleovalleys and channels, as well as sinkhole-like depressions locally known as "buracas". The mesophotic reefs interact predominantly with unconsolidated sediments and secondarily with rhodolith beds. The rhodolith bed megahabitat is widely distributed, ranging from the mid shelf to the shelf break across most of the latitudinal range of the study region and associated to gentle bathymetric gradient. Unconsolidated sediments occur continuously in a broad latitudinal gradient as a sandy and muddy bottom strata along the shore. The three megahabitats of the Abrolhos Bank continental shelf seem to be conditioned by the interaction between the coastal input of sediments, depth, and antecedent geology. We expect that the habitat mapping of the Abrolhos will stimulate a broader participatory spatial planning process engaging conflicting sectors, centered on, but not limited to Marine Protected Areas.

Multiple applications of seabed mapping for offshore northern Australia

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Seabed mapping studies are supporting the regulation and management of a range of competing industries in northern Australia. These industries include fishing and an expanding offshore energy sector, with new developments to include seabed pipelines and subsurface storage of CO₂. Set in tropical waters, the northern Australian shelf is also recognised in marine management plans for its high-value marine biodiversity associated with a complex geomorphology. To reduce uncertainty and risk in the future development and management of this region, the Australian Government is supporting seabed mapping research under a series of programs aimed at delivering integrated information relevant to infrastructure development (Offshore Energy Security Program, 2007-2010), offshore storage of CO₂ in deep sedimentary basins (National CO₂ Infrastructure Program, 2011-2015) and marine biodiversity conservation (National Environmental Research Program, 2011-2014). In 2009 and 2010, Geoscience Australia undertook collaborative seabed mapping surveys with the Australian Institute of Marine Science (AIMS) to deliver to these programs, with an initial focus on the eastern Joseph Bonaparte Gulf (Timor Sea). Objectives were to characterise the physical and biological properties of the seabed across the shelf, assess potential geohazards and identify unique or sensitive benthic habitats. The AIMS research vessel *Solander* was used to acquire high resolution multibeam sonar bathymetry and backscatter across four study sites covering ~1900 km², sub-bottom profiles, sediment grabs and vibracores, oceanographic data from moored instruments, towed video observations of the seabed, and biological samples from epibenthic sleds. Geomorphic features mapped range from expansive soft-sediment plains, to isolated carbonate banks that rise tens of metres, and incised valleys up to 200 m deep. Each feature is characterised by a particular biota, ranging from coral and sponge gardens on banks to diverse infaunal communities across plains. Geohazards include localised slumping in valleys and escape of subsurface fluid/gas on plains and valley floors where pockmarks are widespread. To facilitate uptake of this information by stakeholders, results are integrated as generalised graphical models representing key spatial patterns of shelf ecosystems.

In 2012, further data acquisition is scheduled, including: (i) a targeted seabed mapping and sampling survey within an area permitted for offshore CO₂ storage, and; (ii) cross-shelf mapping and sampling of banks, pinnacles, terraces and valleys in western Joseph Bonaparte Gulf within the proposed Oceanic Shoals Marine Reserve. Together, these new data will provide for a more complete regional interpretation of seabed habitats and the factors influencing their form and distribution for this multiple-use area.

Title: Intertidal Forage Fish Spawning Habitats in Puget Sound

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Several ecologically-important marine forage fish species, Pacific herring (*Clupea*), surf smelt (*Hypomesus*), and Pacific sand lance (*Ammodytes*) use broad areas of the intertidal zone of the Puget Sound Basin, Washington State, for spawning habitat.

Governmental agencies and NGOs have expended considerable amounts of time, effort and funding mapping the locations of these critical spawning habitats over the last 40 years, largely due to concerns about negative impacts of human shoreline development on these habitat types. All such mapped habitats, as evidenced by eggs observed *in-situ*, are presently afforded “no-net-loss” regulatory protections from local, state and federal governmental agencies.

Herring utilize nearshore-intertidal beds of marine vegetation for spawn deposition. Surf smelt and sand lance use upper intertidal mixed sand-gravel beaches for their spawn deposition. Surf smelt and sand lance spawning habitats are closely tied to intertidal fine-grained sediment behaviors. All species use their spawning sites on a predictable annual basis. Taken together, the pooled spawning seasons of these three species encompass the entire calendar year in Puget Sound.

The presentation will briefly summarize the distribution of spawning habitats, details of spawning substrate for each species, their spawning ecologies, habitat stressors, habitat restoration efforts, and survey methodologies, based on the author’s 40+ years of field experience with these species in the Puget Sound basin.

It is hoped that the audience will be introduced to the possibilities of applying the Puget Sound forage fish habitat management experience and protocols to other sectors of the NE Pacific Coast and the world, for increased awareness and conservation of the often-neglected forage fish species group.

Seafloor Characterization for Trawlability Using the Simrad ME70 Multibeam Echosounder in the Gulf of Alaska

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Rockfish (*Sebastodes spp.*) stocks that associate with rugged seafloor types are difficult to assess with bottom-trawl sampling gear. Alternative methods including acoustic remote sensing and video imagery may improve rockfish assessment in untrawlable locations. Acoustic remote sensing can also be applied to quantify regions of trawlable or untrawlable seafloor and thus identify locations where alternative assessment methods may be required. We are using the Simrad ME70 multibeam echosounder (ME70), Alaska Fisheries Science Center (AFSC) trawl survey data, and video imagery to assess seafloor trawlability for locations in the Gulf of Alaska (GOA).

We surveyed areas of the GOA (20-500 m depth) using the ME70 aboard the NOAA Ship *Oscar Dyson* during summer 2011, from the Islands of Four Mountains, in the Aleutian Islands (169°59'0"W 52°43'11"N) to eastern Kodiak Island (151°5'25"W 57°20'46"N). Multibeam acoustic data was collected continuously along the ship trackline (1-20 nmi trackline spacing) and at fine-scale survey locations with 100% bottom coverage ($n = 21$). Video data was collected at fine-scale survey sites using a drop camera to groundtruth the acoustic seafloor characterization and to identify associated fish and invertebrate species ($n = 47$ camera dives). At locations where historical bottom trawl hauls and 2011 camera drops were conducted, the acoustic-derived seafloor parameters that were most discriminatory in characterizing trawlable and untrawlable seafloor types were identified using a stochastic modeling approach. The extension of this approach to fish habitat characteristics will also be discussed.

Benthic Monitoring assisted by Robots in Australia – lessons so far

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Australia's Integrated Marine Observing System (IMOS) has a strategic focus on the impact of major boundary currents on continental shelf environments, ecosystems and biodiversity. To support an improved understanding of natural, climate change, and human-induced variability in shelf environments, the IMOS Autonomous Underwater Vehicle (AUV) facility has been charged with generating physical and biological observations of benthic variables that cannot be cost-effectively obtained by other means. Starting in 2010, the IMOS AUV facility began collecting precisely navigated benthic imagery using AUVs at selected reference sites on Australia's shelf. This observing program capitalizes on the unique capabilities of AUVs that have allowed repeated visits to the reference sites, providing a critical observational link between oceanographic and benthic processes. In 2011 benthic reference sites were revisited in Western Australia, Tasmania, and SE Queensland, in collaboration with groups from the University of Tasmania, the University of Western Australia, the University of NSW, CSIRO, AIMS, the Tasmanian Aquaculture and Fisheries Institute.

This presentation covers the relevant capabilities of the AUV facility, the design of the IMOS benthic sampling program, and preliminary results from the 2010 and 2011 surveys around Australia. We also report on some of the challenges and potential benefits to be realized from a benthic observation system that collects several TB of geo-referenced stereo imagery a year. This includes semi-automated image analysis and classification, visualization and data mining, and change detection and characterisation. New projects to coordinate and enable collaborative analysis for marine scientists across the country are described. We also discuss the design of an enhanced monitoring system that lowers shiptime requirements while increasing reliability.

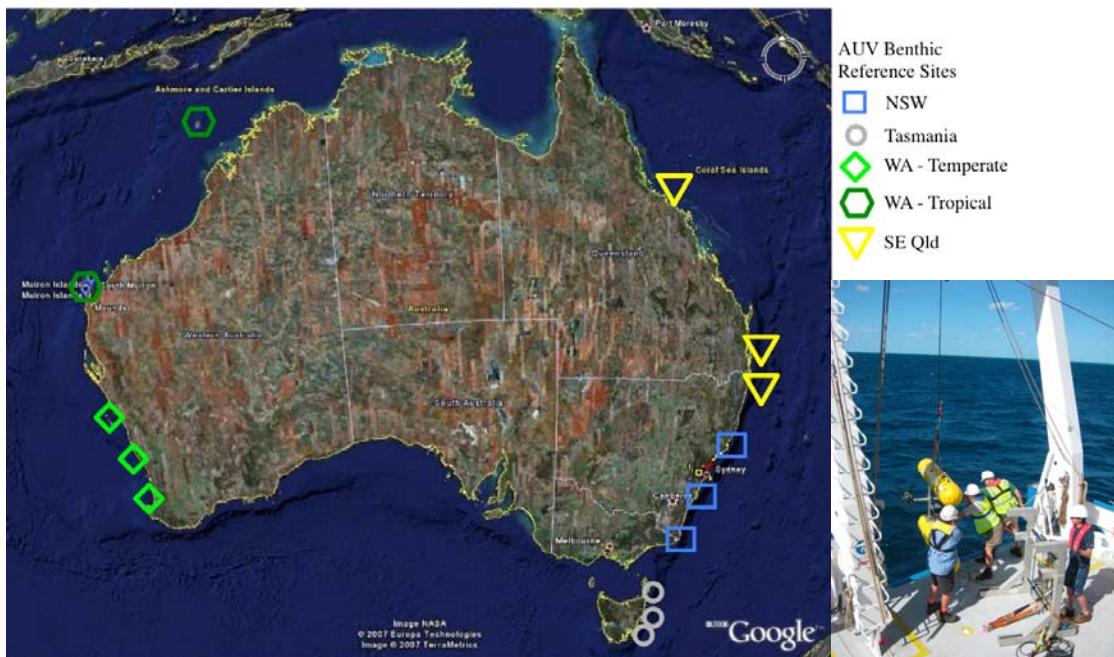


Figure 1. AUV Benthic reference sites visited in 2010 and 2011. Inset: AUV recovery in Scott Reef, 2011.

Case of Lissi Island Marine Damping (Nakhodka bay, Japan Sea)

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Underwater marine excavations and dredging in ports areas presumes damping and sediment accumulations someplace else. Transportation of contaminated sediment inland is expensive and does not achieve ecological safety at all. But this technology of disposal for drilling material from wells during gas and oil exploration in Russian seas is the unavoidable precondition where it concerns licensing. It is almost never accepted when it concerns port areas and underwater channels silt cleaning. The only solution used is in appointing the damping sites in the seabed.

Meant to be harmless or neutral, actual damping does not appear as such. Deep water burial is normally avoided because of long distances of troublesome transportation, and it is very expensive. Accurate following and monitoring the prescribed route and damping routine cannot be granted. And it does not solve marine environment pollution problems either. Operative solution of environmental problems is doubtful mostly due to fuzzy legislative acts regulating the status of damping sites in the shallow sea and their possible licensing. One of most dangerous consequences of damping in shallow water environment is the secondary levying of pollutants from shifted deposits even after ostensible settling down suspended matter. Therefore, damping polygons present the sources of long lasting severe secondary pollution.

Data on ecological state of actual damping sites are rather scant. The first underwater landscape investigation of the polygon at Lissi Island near Russian far-eastern port Nakhodka gives some optimistic implications for the possible working out the strategies of marine damping polygons management. Maps of distribution of heavy metals and petrol fractions in the sediment, in the bottom layer of water and in surface water in the direct projections over sampling locations allow identifying numerous centers of concentration which is a telltale of sources and timing of the damping. Mass disposal of dangerous concentrations of all toxic elements in southern limit of polygon is revealed. The investigations were supplemented with underwater landscape mapping.

The general strategies and logistic technologies of permanent isolation of polluted sediment from circulation are discussed.

Key words: damping, pollutants, ecology, underwater landscape mapping.

A regional high resolution habitat suitability model for *Lophelia pertusa* reefs in Irish waters

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Habitat suitability models (HSMs) provide useful estimates of deep sea coral distributions. Global analyses for framework-building deep sea corals predict a high probability of coral occurrence along the slopes of continental margins, offshore banks and seamounts in the North-East Atlantic. These predictions are useful indicators of global trends in distribution, but cannot provide the detail suitable for local-scale assessments. In order to support marine management, knowledge on the distribution and extent of coral habitat is needed on much finer scales.

As part of the EU FP7 project CoralFISH we used a maximum entropy algorithm to predict the distribution of *Lophelia pertusa* reefs in Irish waters at a spatial resolution of 0.002° (~200 m grid size). *L. pertusa* occurrence points were assembled from public databases, cruise reports and publications as well as from video footage obtained during two CoralFISH cruises. A set of environmental predictor variables was produced by re-sampling gridded data from the World Ocean Atlas, the Global Ocean Data Analysis Project and the Irish Marine Institute's regional hydrodynamic model to match the Irish National Seabed Survey bathymetry grid of 0.002° spatial resolution. Terrain derived predictors such as slope, bathymetric position index (BPI) and rugosity were computed based on multiple analysis windows.

Out of the large range of variables tested, standard deviation of the slope (small scale), mean temperature, mean current speed, dissolved oxygen concentration and BPI (small scale) were the most important parameters to determine habitat suitability. The resulting model successfully explained the observed distribution of *L. pertusa* reefs and predicted suitable habitat on mound features and in canyon areas along a narrow band following the slopes of the Irish continental margin, the Rockall Bank and the Porcupine Bank. More validation data is needed to confirm the existence of reefs in newly defined areas and to further assess model accuracy.

The integration of high resolution environmental and terrain derived parameters ensured identification of suitable habitat on small morphological features (such as carbonate mounds) while highlighting areas of unsuitable terrain in areas otherwise indicated as suitable by the prevailing oceanography. The generated high resolution habitat suitability maps can be used for future survey planning and to support management decision making particularly in areas where empirical data is sparse or absent.

Patchwork and edges: Using seascape metrics to examine habitat heterogeneity and seafloor biodiversity near a coral conservation area

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The seafloor is characterised by a patchwork of habitats, forming a mosaic, which recent acoustic mapping methods can quickly describe in finer detail over large extents. In terrestrial systems much thought has been given to quantifying the composition, spatial configuration and complexity of habitat heterogeneity in order to examine its links to biodiversity. However, this landscape ecology approach has rarely been employed in deeper benthic ecosystems. We present here on a hierarchical survey which was carried out as part of the CODEMAP project on Rockall Bank, a ~200 m deep plateau off the northwest coast of the UK. Inside and outside the boundary of a fisheries closure zone, video surveys of the megabenthos were carried out using a remotely operated vehicle (ROV). Larger areas surrounding these transects were also mapped at high resolution (50 cm) using a side-scan sonar mounted on the autonomous underwater vehicle Autosub6000. Ship-based bathymetry linked all the sites at a coarser resolution (10 m). The ROV imagery was examined and three distinct faunal assemblages were found; soft-bottom (e.g. sand), hard-bottom (e.g. cobbles, boulders and exposed bedrock) and coral associated (e.g. live and dead corals as well as rubble). Based on the side-scan sonar imagery, it was possible to distinguish between soft and hard substratum, thus yielding larger extent habitat maps. Seascape metrics (e.g. patch and edge density, division and cohesion indices as well as fractal dimensions) were compiled to describe the complex spatial arrangement of the areas surveyed which are characterized by iceberg ploughmark formations. Combining this information with biodiversity indices obtained from the smaller-scale imagery makes it possible to test the hypothesis that habitats exhibiting increased heterogeneity show higher species richness. Live coral stands were found to harbour higher diversity of species, but both trawled corals and remaining live coral stands were observed on the outside edge of the protected zone, highlighting the need to better describe benthic habitats in order to design effective conservation measures. The creation of larger extent habitat maps may help define areas of high biodiversity and conservation need without having to rely on time consuming collection of biological data.

Pacific sand lance (*Ammodytes hexapterus*) hot-spots in the Strait of Georgia, British Columbia, Canada

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Pacific sand lance (*Ammodytes hexapterus*), an important prey species for many vertebrate predators in the northeast Pacific, lacks a swim bladder and relies on coarse sand substrates to bury in overnight and during the winter. Surprisingly little information is available describing the spatial distribution and extent of burying habitat along the British Columbia coast. Thus, we developed a habitat suitability model for the Strait of Georgia that considered information on shallow depths (< 80m), high bottom current speeds (25-63 cm sec⁻¹) and coarse sand (0.25-2.0 mm grain diameter). Overall, the model identified < 6% of the study domain as suitable burying habitat with the southern Strait containing the largest burying areas. We also used by-catch data from mid water trawl and purse seine sets to map the location of pelagic schools of foraging sand lance. The persistent location of large sand lance by-catches over many years identified key foraging areas adjacent to several burying habitats. The median distance of 88 sand lance schools to coarse sand patches was 2 km; 75% of the schools were found within 4.9 km of coarse sand. Overall, the mapping of suitable burying and foraging areas in the Strait of Georgia will assist managers in guarding against anthropogenic activities that might impact the relatively uncommon and patchy habitats of a key coastal food-web species.

The Oregon State Waters Mapping Project

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The Oregon State Waters Mapping Project represents the realization of an ongoing effort to map and characterize benthic environments within Oregon State Waters using high resolution seabed imaging supported by both statistical and interpretive geological mapping techniques. Early mapping work (pre 2005) by the Oregon Department of Fish and Wildlife (ODFW) targeted nearshore rocky outcrops and provided the first high-resolution and 3-D views but only accounted for about 5% coverage within State Waters. Multibeam bathymetry and backscatter data collected recently by Oregon State University (OSU) and by NOAA National Ocean Service (NOAA NOS) under the guidelines of the State Waters Mapping Project bring this coverage total close to 60% complete.

The at-sea data collection phases of this project were undertaken during the summer months of 2009, 2010, and 2011. OSU and NOAA contractors used R/V Pacific Storm to collect multibeam bathymetry and backscatter coverage (Reson 8101) uniformly along the northern coast and at targeted locations south of Newport, OR. Multibeam bathymetry data processing and publication was handled by the data collectors (OSU or NOAA NOS) yielding 2 meter pixel resolution bathymetry for most areas. All backscatter processing was done at OSU where the (beam time series) backscatter data allowed for processed imagery at 1 meter pixel resolution or better.

Following acoustic data collection, typically within 2 weeks post-survey, reference sediment samples were collected using a Shipek sampler ($n=860$) deployed from a commercial crab fishing vessel. OSU and ODFW also collected over 40 hours of ROV, towsled and drop camera video. The sample and video ground-truth information were used for modeling soft sedimentary seabed habitats and for geological interpretation of hard rocky reef habitats in a hybrid classification method. Sediment grain size analysis was performed using a laser diffraction particle size analyzer and results were binned to sedimentary classes. A supervised maximum likelihood classification of acoustic imagery was performed using the classified sample dataset to map the distribution of soft sedimentary habitats. Hard substrate habitats (Boulders and larger) were mapped by human interpretation of bathymetry and backscatter textures using video ground-truth data to guide interpretation. The results of this project are high resolution maps of bathymetry, backscatter, habitat, and grain-size datasets for Oregon State Waters produced as a set of sixteen 1:24,000 scale maps. Corresponding GIS datasets are available online at <http://pacoos.coas.oregonstate.edu>.

Natural and anthropogenic driving forces of marine landscapes development in the eastern Gulf of Finland (the Baltic Sea)

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The eastern Gulf of Finland (the Baltic Sea) is highly and increasingly exposed to anthropogenic impacts especially within the easternmost lagoon-like Neva Bay. Recent creating within the Neva Bay of large new territories, fairway dredging with exceeding consequences, submarine dumping completely changed sedimentation conditions and benthic landscapes here. However it is still being the area that is important for recruitment of natural resources and nature protection. Aquatic and coastal landscapes, their habitats and living communities are under strong influence of the Neva river discharge, its catchments area and climatic conditions, erosion and accumulation processes, geochemical barriers, expressed natural gradients and impacts (salinity, temperature, mosaic benthic relief, currents, inflows, coastline etc.). Thus the events and phenomena realized as environmental problems herein are naturally originated and men-mediated. Results of marine geological investigations as well as analysis of remote sensing data, and archive nautical charts permit to conclude that during last three centuries sedimentation processes in the eastern Gulf of Finland and especially its easternmost part – the Neva Bay have changed. The special conditions of mud accumulation in the western part of the Neva Bay have developed. Investigation of 2007-2008 has shown that most part of the bottom is completely transformed by technogenic processes. Active hydro-engineering works caused formation of clayey layer up to 5 mm thick on the sandy bottom surface of the Neva Bay bottom in the water depth less than wave base. Environmental changes caused the drastic decreasing of benthos biomass. The main goal of on-going research is to study the ability of sedimentation system and benthic communities' adaptation to increasing technogenic load.

Benthic Habitats in the Puget Sound: A Rockfish Perspective

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Rockfish comprise at least 28 of the over 200 species of fish that live within the Salish Sea. Due to their unique life-history, past over-exploitation and currently degraded habitats, populations of many rockfish species in the Salish Sea have declined and some have been listed as Species of Concern by the State of Washington, under the US Federal Endangered Species Act (ESA), and the Canadian Species at Risk Act. On April 28, 2010, NMFS listed the Puget Sound/Georgia Basin Distinct Population Segments of yelloweye rockfish (*Sebastodes ruberrimus*) and canary rockfish (*Seb. pinniger*) as threatened, and listed the Puget Sound/Georgia Basin DPS of bocaccio (*Seb. paucispinis*) as endangered under the ESA.

Despite numerous private, state and Federal research institutions located in the region, most of what we know about rockfish life-history and habitat associations comes from studies conducted outside of the Puget Sound. This provides management challenges as we assess current rockfish populations in the region, and attempt to identify important habitats. Further challenging our understanding of rockfish in Puget Sound Proper (not including the San Juan Archipelago) is the relative lack of rocky benthic habitats and comparatively coarse-scale habitat characterizations that have been conducted. Though the Puget Sound proper has comparatively few rocky habitats, rockfish were a large component of historical bottom fish commercial catches and continue to persist at depressed levels there. The habitat associations of rockfish within Puget Sound proper may represent habitat usage that is unique within the range of particular rockfish species. Section 4 of the ESA requires the designation of critical habitat for threatened and endangered species. Given the current status of knowledge, Geographic Information System tools are being employed and numerous factors are being considered for the critical habitat of the 3 listed rockfish species. They include seafloor rugosity, benthic terrain, habitat types, depth, freshwater sources, kelp, and shoreline geomorphic classifications. More sophisticated habitat mapping and benthic habitat characterizations of Puget Sound habitat would aid our understanding of these habitat associations and further enable recovery planning for depressed rockfish populations.

The geological diversity of the near-shore bottom of the Curonian Spit, as an abiotic component of the submarine landscape of south-eastern the Baltic Sea

Alexander Sergeev

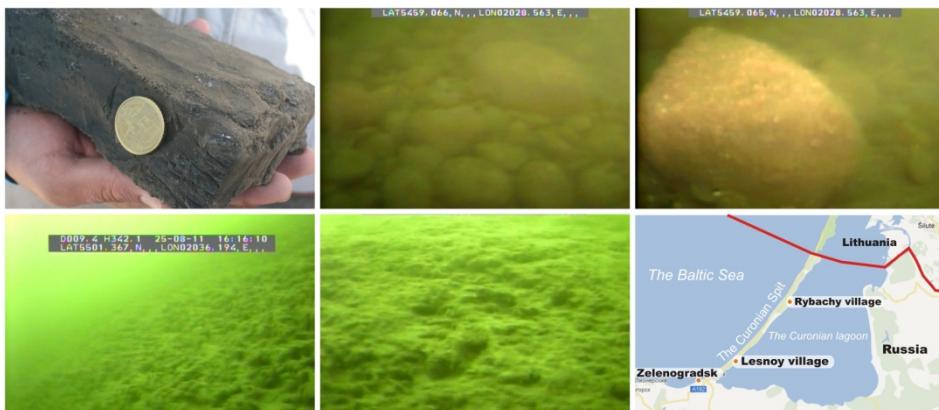
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The Curonian Spit is a large sandy accumulative body of 100 km length. The southern part of the spit (48 km) belongs to Russian Federation. The spit is located along the southeast coast of the Baltic Sea and separates the large Curonian Lagoon from the Baltic Proper. Nowadays the southern part of the spit is a subject to intense wave erosion, while its northern part is an area of sediments accumulation. Differences in dynamic processes, demonstrated by the shores, reflected in the submarine coastal slope. The different types of sediments were formed on the sea bottom surface during complicated processes of Holocene coastal development and the gradual inland movement of the Curonian Spit.

The southern (attached) part of the spit (from Zelenogradsk town to Lesnoy village) is a continuation of the Sambia Peninsula coast composed of glacial till. Shore's retreat under the influence of the erosion caused the deposition of boulder bench. This bottom cover is an excellent substrate for the high diversity of benthic life forms.

The central part of the spit (from Lesnoy village to Rybachi village) was originally developed as a sand bay-bar between the islands formed by glacial deposits. There are different bottom processes. In the shallows the wave accumulation develops; in the middle part of the underwater coastal slope is active migration of sediments, forming the "dynamic sand" zones with distinct ripple marks; the offshore bottom surface is under the impact of bottom erosion. The outcrops of dense deposits with high organic content to the bottom surface, so-called "lagoon marls" (dated as 5510-6260 cal.BP), represent one of remarkable geological features of this part of the near-shore bottom. Scuba diving studies of these relict marls showed an active underwater life in caverns of deposits.

In the coastal zone of the northern part of the spit (from Rybachi village to the border with Lithuania) the processes of accumulation are dominated, forming a sandy cover of the bottom and stop the intense dynamics processes of the coastal zone. Wide geodiversity of sediments and their unique features (like "lagoon marls") to the south-eastern Baltic, concentrated in a small area, is an excellent training ground for the comprehensive studies of the submarine landscapes. The Curonian Spit has the status of UNESCO World Heritage Site and the National Park. The uniqueness of the underwater world of the Curonian Spit is a good reason to expand the boundaries of the National Park to the underwater coastal slope.



"Lagoon marls". Outcrops of dense deposits with high organic content. Boulder bench on the near-shore bottom.

A High-Density Image Analysis of Sea Scallop Habitat in the Mid-Atlantic Bight

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The sea scallop (*Placopecten magellanicus*) fishery in the US EEZ of the northwest Atlantic Ocean has been, and still is, one of the most valuable fisheries in the United States Historically, the inshore sea scallop fishing grounds in the New York Bight, i.e. Montauk Point, New York to Cape May, New Jersey have provided a substantial amount of scallops. These areas can be highly productive but are at times rapidly depleted due to heavy fishing pressure. In our project we used a digital, rapid-fire camera integrated with a Gavia autonomous underwater vehicle (AUV) to collect a continuous record of photographs for mosaicing and subsequent scallop enumeration and size distribution. During our 2011 pilot study survey we collected over 255,000 images of the seabed. The entire image catalog was manually analyzed in the laboratory for estimates of abundance and size distribution. The AUV collected altitude and attitude data allowing us to georectify each image into scaled images for size measurements and enumeration. Thirteen mission sites reoccupied previous NMFS (National Marine Fisheries Service) monitoring stations. A typical AUV mission ran along ~14 km of seabed trackline covering approximately 22,400 m² of continuous seabed in color camera images and approximately 280,000 m² in sonar coverage of the seabed. A typical survey day involved four AUV missions of three hours each resulting in ~90,000 m² of continuous seabed color camera imagery. Based on the altitude of the AUV and the geometry of the camera each image is ~ 2.0 m across with a resolution of 2 mm/pixel. The scallop sizes can were manual measured using a heads-up digitizing computer software-measuring tool.

AUV camera image counts and sizes were compared to NMFS dredge survey measurements and coeval commercial dredge tows conducted during the AUV missions. A comparison of the imagery-based results to dredge tows confirms dredge efficiency values as have been previously reported. The camera surveys provided a non-extractive remote sensing approach for obtaining distributions over length-scales from meters to 10s of kilometers. Summary plots of AUV vehicle tracks and water column parameters (e.g. salinity and temperature) can be accessed publically at the URL links below.



Benthic Image of Scallop (*Placopecten magellanicus*) Beds from AUV survey- Mid-Atlantic Bight

http://cshel.geology.udel.edu/kml_files/Scallop/CruiseData/
<http://cshel.geology.udel.edu/GoogleEarth/>

**Storm-driven sediment transport on a shallow bank
segregates the seabed into mappable substrates**

Page C. Valentine

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Stellwagen Bank is a shallow (25-70 m) north-south oriented bank off eastern Massachusetts. The seabed of the bank is sand and gravel of glacial origin. Published reports based on sediment transport modeling have shown that tidal currents alone are too weak to erode the bank surface; and that only currents generated by major storms from the northeast quadrant can resuspend sediment and, aided by tidal and wind-driven currents, cause periodic erosion of the bank. A multibeam sonar survey of the central part of the Stellwagen Bank region (360 km^2) revealed seabed features whose morphology suggests sediment movement from the bank's gently-sloping east flank (8 km wide) westward onto its more steeply-sloping west flank (3 km wide) and into the deeper waters of Stellwagen Basin. Bathymetric imagery was groundtruthed using 881 grain size analyses of surficial sediment (0-2 cm). Plots of individual grain sizes (phi) along east-west transects across the bank indicate three major substrate types are present. Mud (11 to 5 phi) is almost absent on the bank crest and the east and west flanks, but becomes dominant at the foot of the west flank (>70 m) and in the basin to the west. Fine-grained sand (4 and 3 phi) is sparse everywhere except on the lower west flank (50-70 m). Coarse-grained sand (2, 1, and 0 phi) is dominant on the east flank, the bank crest, and the upper west flank. A major transition in seabed morphology occurs at 40 to 50 m on the west flank where a large sheet of coarse-grained sand that extends westward from the bank crest laps onto the deposit of fine-grained sand. Transport by storm-induced currents causes segregation of grain sizes such that: a) mud and fine-grained sand are moved westward across the bank and deposited on separate parts of the lower west flank; b) elements of coarse-grained sand (2 and 1 phi) are moved westward to form a sand sheet on the upper west flank; c) source areas on the east flank are principally coarse-grained sand. Small depositional features on the bank crest represent interrupted westward transport of 3 and 2 phi sand. Substrate distribution will be adjusted by the effects of future storms. However, the formation on the bank of geographically coherent substrate types by storm-driven sediment transport is predictable, and resulting substrates (habitats) characterized by grain size and episodic erosion or deposition likely will support recognizable communities of invertebrates and fish.

Sea floor mapping as a tool for marine spatial planning in Europe

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The European seas are today under a much harder pressure than ever before as we are running out of land for food and energy and are increasingly looking to the sea. Different activities such as maritime traffic, off shore energy, aquaculture, and deep-sea mining compete in an area which is only partly thoroughly mapped. In such a situation it is obvious that there is a danger of destroying vulnerable habitats. Better information could help us protect sensitive habitats and rare species for future generations. Many countries have taken the step into systematic multidisciplinary sea floor mapping of their territorial waters as well as EEZ:s. The European Commission is also very well aware of the situation. In order to best meet the needs of the marine industry, the European community and the vulnerable marine nature the European Commission is aiming at complete mapping of the European seabed by 2020, including data on water depth, sediments, minerals, chemical pollution and marine species. Thus sea floor mapping activity in Europe will increase manifold during coming years.

Sediment dynamics as a proxy for soft substrata habitat distributions, Belgian part of the North Sea

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Fine-scale seabed mapping (<5m resolution) (e.g. geology, surficial sediments, morphology and benthos) was conducted at several locations along the Belgian part of the North Sea. Together with modelling results on hydrographic conditions (e.g. residual currents; sedimentation due to tidal forcing; suspended particulate matter or SPM), and current measurements, variability in sediment processes can be discussed and linked to variation in habitat distributions. Highest biodiversity is often found where finer sediments are naturally trapped (e.g. near sediment transport convergence zones). Sometimes, this process is enhanced by changes in morphology, due to e.g. long-term disposal of dredged material or marine aggregate extraction. Evidence will be presented on disposal activities that have induced permanent modifications of hydrographic conditions. Around these areas, where mostly transient fluxes of SPM prevail, high abundances of opportunistic and invasive species occur. In the framework of Europe's Marine Strategy Framework Directive discussion is on-going whether or not this causes adverse effects on the ecosystem. The adversity of effects links to issues on biodiversity, food webs and seafloor integrity.

Understanding natural sediment dynamics is also crucial to predict the spatial scale of the effects of human activities on the habitats. In the case of disposal activities, fine-grained material may be dispersed over several kilometers, though the interplay of currents, in combination with availability of SPM, will determine the importance of smothering on the benthos. The severity of the impact on the benthos will then further be determined whether or not a habitat change occurs (e.g. difference in sediment nature between disposed material and substrate type). Around the disposal grounds, habitat creation or modification takes place. The extent depends on amount, frequency and duration of disposal activities, in combination with residual currents. In any case, increased system knowledge (incl. morphological setting, substrate characteristics, sediment processes, sediment dynamics, habitat sensitivities and recovery potential) is needed to estimate final impacts.

Results are valorized in the framework of the projects QUEST4D (Belgian Science Policy, <http://www.vliz.be/projects/quest4D/>), and Geo-Seas (EU FP7-I3; <http://www.geoseas.eu>).

From benthic landscape to habitat: examples from the Campania offshore, Eastern Tyrrhenian sea

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The Marine Landscape concept aims to describe the marine environment with respect to its main geophysical features. It focuses also on the formation and consequences of spatial heterogeneity and dynamics in natural and human dominated environments and how spatial pattern controls ecological processes. Moreover, landscape and habitat are hierarchical related, meaning that all landscapes can be considered as a heterogeneous mosaic of habitat which are repeated at intervals over space.

Marine landscapes off Campania region are dominated by geologically young structures and sedimentary processes. This mid-latitude sea area is composed of three main basins namely Volturno Bay, Naples Bay and Salerno Bay and by a number of minor basins. It develops along the eastern margin of the Tyrrhenian sea across the boundary between the Apennine chain and the Tyrrhenian extensional area where Quaternary tectonics deeply controlled the physiographic setting. Sedimentary processes related to dynamics of Volturno and Sele rivers contributed to shape the seascape off the Volturno and Sele plains respectively. In the Naples Bay the occurrence of some of the most active volcanoes, the Phleorean Fields and Somma-Vesuvius, significantly influenced marine and coastal habitats and landscapes.

The present study employed high-resolution bathymetry and backscatter images, coupled with underwater grab sampling, collected from aboard CNR Research Vessels equipped with Multibeam echosounder (MBES) and Side-scan sonar systems. Other available data included previously compiled seafloor geological maps at CNR_IAMC in the frame of projects for MPA management, and some biological information. These data allowed to identify morphology, bedform features and substrate of the seafloor as a first step towards a classification and mapping of marine landscapes and habitats off the Campania Region.

Spatial distribution of the selected elements and chemical compounds in the deposits of the Szczecin Lagoon (Poland, Germany), Southern Baltic Sea

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The Szczecin Lagoon, NW Poland and NE Germany, lays within the range of the influence of freshwater and marine water bodies. It is a part of the Odra river mouth system that is strongly affected by the Baltic Sea. As a part of the big intracontinental and shallow Baltic Sea, connected with the North Sea only by a system of narrow and shallow straits, it is of a brackish character. It is considered to be a unique area in terms of geological processes, depositional conditions and quality of habitats.

In 2007-2010 the Institute of Marine and Coastal Science led a project aiming, among others, to recognize the content of the selected elements and compounds in the surfacial deposits of the Szczecin Lagoon. Heavy metals and other polluting substances, such as persistent organic pollutants (POP's) were emphasised. In addition, the standard sedimentological analyses were applied in order to obtain the information on the recent depositional conditions.

Basing on the 255 samples, a model of spatial distribution of 106 chemical components was drawn. It revealed the strong correlation between the contamination and grain size of the deposits as well as organic matter content. The maps of spatial distribution of the all components were created and included into the Atlas of geochemistry of the Szczecin Lagoon. There is no clear geographical pattern of the spatial distribution and it does not reflect the influence of the local immediate sources of pollution. What is worth underlining, also the geochemical composition of the deposits surrounding the artificial deepened navigation fairway is not significantly different from the other areas of the Szczecin Lagoon. That suggest the low influence of the marine transportation to the sediments' pollution.

The surfacial sediments of Szczecin Lagoon are strongly polluted with mercury, TBT and aliphatic hydrocarbons (C₁₂–C₃₅). The As, Zn, Cd, PCB, PAH's and pesticides' contamination is not significant but visible.

Data to Support a Review of Essential Fish Habitat for Pacific Groundfish

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In this presentation, we provide a summary of data used to support Phase I of a 5-year Review of Essential Fish Habitat (EFH) for 91 species of groundfishes off the West Coast of the US. We highlight some of the key products developed for this review and are now available to the public. Initial EFH designations were based on best available data developed from 2002 to 2005; NOAAs National Marine Fisheries Service (NMFS) approved these designations in May 2006. Beginning in 2010, the Pacific Fisheries Management Council (PFMC), Northwest and Southwest Fisheries Science Centers, and the NMFS Regions initiated the first mandatory 5-year review for EFH provisions of the groundfish Fishery Management Plan. In Phase I of this process, we evaluated the extent of new information available for the review and for potential modifications of current EFH designations. Sources of information included published scientific literature and unpublished scientific reports; solicitation of data from interested parties; and the review of previously unavailable or inaccessible data sets. Coast-wide maps were updated for (1) bathymetry and interpreted groundfish habitat types; (2) the distribution and extent of groundfish fishing effort (as potential impact to EFH); (3) the distribution and relative abundance of biogenic habitat (i.e., sponges and corals); and (4) spatial management boundaries (as potential mitigation of impacts). In addition, new information has been identified on habitat associations for the 91 groundfish species, including modeling efforts relevant to the determination and designation of EFH. This new information has been presented to the PFMC, its advisory bodies, and the public, and the Council will solicit proposals to modify EFH and Habitat Areas of Particular Concern. This 5-year review represents a major update of the groundfish habitat assessment for the California Current and will have research and management applications well beyond satisfying the regulatory guidelines associated with EFH.

GEOHAB 2012
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Habitat Characterization and Mapping in Coastal and
Inland Seas

Abstracts

Poster Presentations

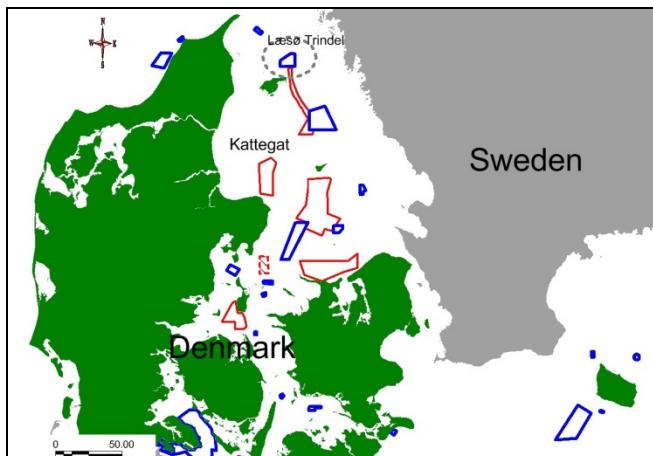
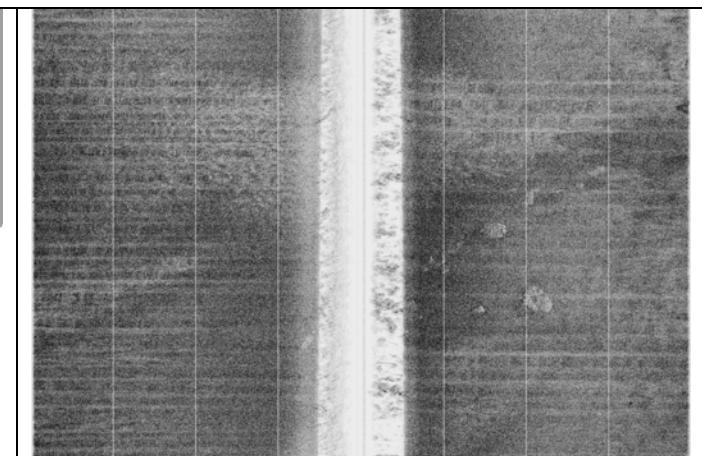
Mapping Natura 2000 habitats in Læsø Trindel, Kattegat / Denmark

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A survey campaign was conducted in 2011 to map 18 Natura 2000 areas as well 7 pre-designated raw material extraction regions in Kattegat as well as in southern Baltic, Fig1. The project was funded by the Danish Nature Agency and conducted by The Geological Survey of Denmark and Greenland (GEUS) for the geological and geophysical part and Orbicon A/S for the biological screening and ground truth sampling.

The Natura 2000 areas were mapped with survey lines as close as possible to ensure full coverage of the surveyed seabed. Sidescan sonar, shallow and deep sub-bottom profilers as well as single beam echosounder were used in the survey. Læsø Trindel, shown in Fig. 1 is an example of the Natura 2000 areas. This area was surveyed in 2005 where only the main boulder reef regions were mapped. In the recent survey the whole Læsø Trindel was surveyed and the substrate map was interpreted from the collected datasets. Results indicated that the boulder reef occupies around 38% percent of the total Læsø Trindel area. They also enable the identification of a number of “Bubbling reefs” in the region. These “Bubbling reefs” are unique feature in the area and was formed by seeping methane gas that led to carbonate cementation of sand in the oxidation zone, they were exposed by subsequent erosion of the surrounding sand. Figure 2 shows a sidescan image of a “Bubbling reef” site.

	
Figure 1. The Surveyed Natura2000 areas (red) and the raw material regions (blue) in Kattegat and southern Baltic.	Figure 2. Sidescan image of a “Bubbling reef” in Læsø Trindel Natura 2000 area.

MAREANO - revealing the secrets of Norway's seafloor

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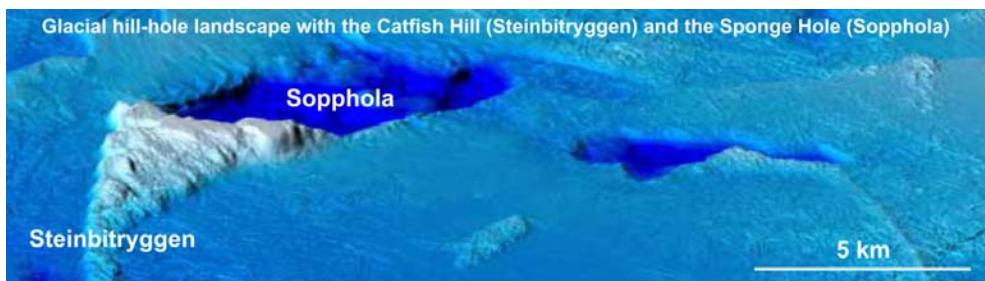
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Since 2005, the MAREANO programme (www.mareano.no) has been mapping the seafloor off northern Norway. To date, ca. 90 000 km² spanning broad environmental gradients with water depths extending to 3000 m, ocean currents exceeding 1 m per second and sea water temperatures falling to -1 °C have been mapped. A rich faunal diversity within dramatic landscapes of deep canyons, steep continental slopes and wide shelf plains has been found.

MAREANO is an integrated, multidisciplinary seabed mapping programme designed to fill knowledge gaps in the offshore area. The programme is a collaboration between the Institute of Marine Research, the Geological Survey of Norway and the Norwegian Hydrographic Service. In 2012, MAREANO will continue its work in the Norwegian Sea and in the new areas in the central Barents Sea. The ultimate goal is to map the seafloor in all Norwegian offshore areas.

A great variety of bottom substrates has been observed, including crystalline bedrock, glacial moraines, debris flow deposits, mega slide deposits and Holocene sand and mud. In the outer coastal zone, a submerged crystalline bedrock strandflat is overgrown by kelp forests. On the shallow banks offshore and along the shelf edge the seabed is dominated by coarse grained glacial deposits and sand. Macroalgae have been observed down to depths of around 75 m where calcareous encrusting red algae represents the deepest MAREANO discoveries of photosynthetic organisms. The glacial trenches crossing the shelf are characterized by finer sediments with variable sand content. Where the bottom currents are relatively slow, sea pens and other burrowing megafauna are common. Cold water coral reefs grow where there are stronger ocean currents, both on the shelf and in deep slide scars on the slope, where they live on elevated slide blocks. The continental slope is dissected by canyons and slides and displays varied substrates with rich fauna, often being dominated by dense colonies of deepwater soft corals, basket stars and sponges. Towards the base of the slope, as we reach the greatest depths and lowest temperatures, there is a reduction in the species richness.

The results from MAREANO so far show that Norway has a rich and diverse offshore seafloor. Both the geomorphology and sediment distribution patterns reflect the complex geological history, and modern-day hydrodynamic processes. The structure of the seafloor and processes operating there are intrinsically linked to the biology and this is reflected in the distribution of habitats and biodiversity.



Benthic Habitat Mapping in the Southern Salish Sea

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The United States Geological Survey (USGS), in collaboration with the National Oceanic and Atmospheric Administration (NOAA), Washington Department of Natural Resources (WDNR), and the University of Washington Friday Harbor Labs, is mapping the surficial benthic habitat of 900 square kilometers of sea floor recently surveyed with multibeam sonar by NOAA in southern Puget Sound. Funds from Environmental Protection Agency have been used by the USGS and WDNR to conduct multi-disciplinary video surveys of sea floor substrate, fauna, and flora. The sea floor imagery will be used to supervise interpretation of the multibeam sonar data to provide baseline ecological information for marine-resource managers. Maps and GIS data sets of bathymetry, surficial substrate, benthic habitat, and sea floor biotopes will be published online as USGS Scientific Investigation Maps. These maps will be developed using the Coastal and Marine Ecological Classification System to provide baseline geo-spatial information for ecological management specified in the Western States Governors Agreement for Ocean Health.

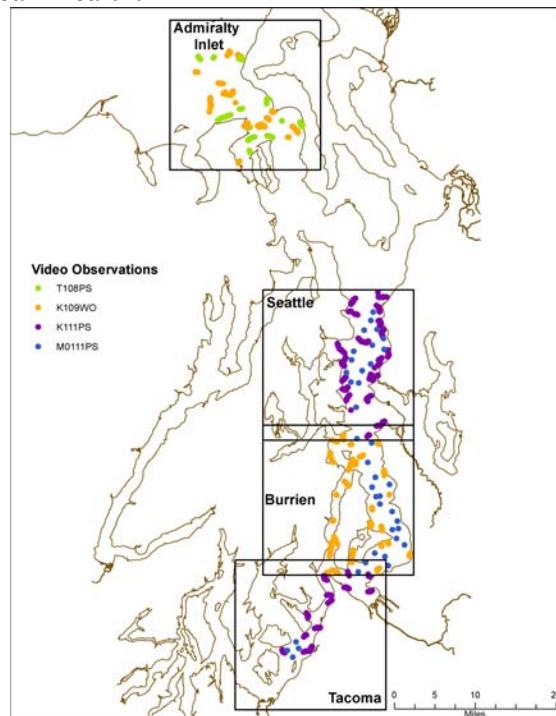


Figure 1. Video Transects completed to date.

We're Rich! Millions of Sand Dollars Discovered Off Oregon Coast

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Until five years ago, only ~5% of Oregon's Territorial Sea (0-3 nm from shore) had been mapped using high-resolution sonar (i.e. multibeam sonar and associated backscatter, sidescan sonar). As of 2012, nearly 60% of the Territorial Sea has been mapped, in large part due to the State Waters Mapping Project led by Oregon State University. With these new mapping data have come new discoveries, including that of large beds of sand dollars (*Dendraster excentricus*) in the shallow waters offshore of Oregon's north and central coasts. While the existence of sand dollars off the Oregon coast is well known both anecdotally and from opportunistic small-scale scientific observations, the spatial distribution and abundance of these organisms was largely unknown. The recent seafloor mapping was the first systematic survey of nearshore habitats with the spatial scope and resolution capable of delineating sand dollar beds on a large scale. Fortunately, these beds exhibit a distinct signature in the backscatter imagery because of the higher reflectance relative to adjacent sandy substrate, and they are characterized by a dense band parallel to the depth contours. A mapping project for the area offshore of Cape Foulweather (central Oregon coast) by USGS during summer 2008 was the first time that these unique backscatter signatures were reported in Oregon, and subsequent groundtruthing via sediment grab sampler and a Remotely Operated Vehicle informed and confirmed the interpretation. The sand dollar bed off of Cape Foulweather had dimensions of ~6 km alongshore by ~600 m cross-shore, and occurred in 15-20 m water depth. This depth distribution was similar to a bed described offshore of Humboldt Bay in northern California (another open coast site), but significantly deeper than beds found in wave-protected southern California. Sand dollar beds like the one off of Cape Foulweather now appear to be a common feature offshore of the northern Oregon coast, as determined by preliminary interpretation of seafloor maps produced by the Oregon State Waters Mapping Project. These beds likely serve important ecological functions in Oregon's nearshore ocean (e.g., as biogenic habitat for other organisms), and this combined with the significant areal extent and biomass of this species highlights the need for additional research into their ecology and susceptibility to human-induced impacts (e.g., dredge disposal, wave energy development).

Gathering additional evidence for Marine Conservation Zones in the UK

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In 2009, the Marine and Coastal Access Act came into force, and allowed the creation of a new type of Marine Protected Area (MPA) called a Marine Conservation Zone (MCZ). MCZs will protect a range of nationally important marine wildlife, habitats, geology and geomorphology and can be designated anywhere in English and Welsh inshore and UK offshore waters. The Marine Conservation Zone Project is being led by the Joint Nature Conservation Committee and Natural England to identify and recommend MCZs to Government. The MCZ Project, set up in 2009, consisted of four regional MCZ projects covering the south-west (Finding Sanctuary), Irish Sea (Irish Sea Conservation Zones), North Sea (Net Gain) and south-east (Balanced Seas). These regional MCZ projects worked with sea users and interest groups to identify MCZs within their regions and submitted their recommendations to JNCC, Natural England and the Science Advisory Panel (SAP) in September 2011.

The SAP's advice indicated that there were a number of gaps and limitations in the scientific evidence base supporting the MCZ recommendations. As a result, a massive survey effort was undertaken to gather additional evidence prior to Ministerial review of the MCZ site recommendations and SNCB (Statutory Nature Conservation Bodies) advice due to be submitted in July 2012.

Cefas have taken a lead in coordinating this significant, short-term, survey programme, using a combination of existing government survey platforms (including Cefas and Environment Agency (EA) vessels) and external contractor vessels. Over forty surveys have been commissioned over a 3 month period. Cefas have worked with JNCC, Natural England and the EA to review existing data and identify priority areas for survey.

A range of data types have been gathered including acoustic (multibeam bathymetry, backscatter and sidescan sonar), seabed imagery and benthic samples, and the next stage of data processing/interpretation will soon be underway. This valuable new evidence will be reviewed and inform advice submitted to Ministers by the JNCC and Natural England. Ministers will give careful consideration to all the advice received before undertaking formal public consultation on MCZs by the end of 2012. This consultation will include all sites recommended by the regional MCZ projects with clarity on which sites the Minister is minded to designate and the reasons why. It is envisaged that the first MCZ designations will take place in 2013.

Statistical mapping of seabed sediment texture classes

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The traditional approach to interpreting the distribution of sea bed sediments on the United Kingdom Continental Shelf involved integrating various geophysical and geological data types e.g. multibeam bathymetry and physical samples, using expert geological judgement to delineate distinct sediment assemblages, typically in accordance with the Folk classification. This methodology produces accurate mapping at varying scales and can be continually groundtruthed and updated by new sample data.

However, there is an increasing requirement from scientific and policy sectors to produce broad scale maps, with the capacity to use different classification systems and derive a statistically meaningful measure of confidence in the maps produced. These maps are of value to a range of users including the habitat mappers, the geoscience community, marine spatial planners and policy makers.

Using particle size data from the British Geological Survey, a geostatistical approach has been developed to address these requirements. In order to produce the predicted sediment class, the percentage composition of the three particle size classes was modelled geostatistically to produce a linear model of coregionalization. A fine grid was applied over the study area to predict the sediment composition at each node. This approach generates a computed probability of each class occurring, at each node of the grid. Based on previous work contributing to the UKSeaMap¹ project (a modified Folk scale was used. This involved simplification of the Folk classification to 4 broader categories, consistent with EUNIS Level 3. Using these values, derived data such as the class of maximum probability was mapped. This approach also generates an intrinsic measure of uncertainty and avoids subjective issues associated with other approaches to confidence assessment.

This geostatistical approach was tested on the British Geological Survey sample database for the United Kingdom Continental Shelf. The map shows a broad level of consistency with the UKSeaMap sediment map produced through more traditional methods.

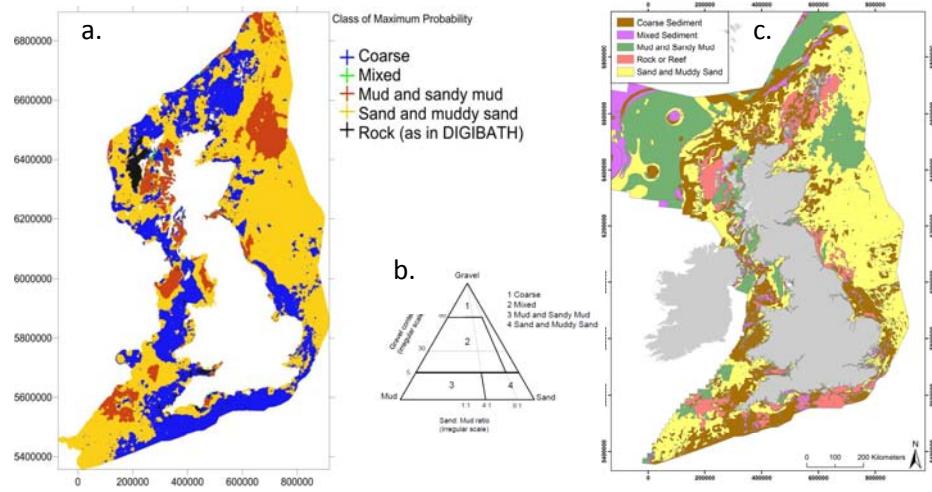


Figure 1. a. Geostatistical mapping of the class of maximum probability for the simplified Folk classification (b). c. UKSeaMap conventional mapping for the same classification (with the exception of rock or reef category).

The aim for future work in this area is to integrate the geostatistical approach with conventional map line work and geophysical data in order to maximise the value of this semi-automated approach to mapping the distribution of seabed sediments.

1. <http://jncc.defra.gov.uk/page-2117>

Geological inventories of FINMARNET project in Rauma archipelago

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Inventories and planning for the marine Natura 2000 network in Finland (FINMARNET) is a Life+ - funded project that carries out inventories of the marine habitat types of the EU Habitats Directive along the Finnish coastline including the Finnish territorial waters and the Finnish exclusive economic zone (EEZ). The major Finnish marine Natura 2000 sites and their adjacent areas potentially valuable for the extension of the Natura 2000 network will be assessed. The main objective is to produce cartographic images to underpin decision making regarding the key marine habitat types related to the Habitats Directive. The project is coordinated by the Finnish Environment Institute (SYKE), with four associated beneficiaries: Geological Survey of Finland (GTK), Metsähallitus Natural Heritage Services, Åbo Akademi University and the University of Turku. The FINMARNET project is implemented in close relationship to the Finnish Inventory Programme for the Underwater Marine Environment (VELMU).

GTK has carried out marine geological inventories in 5 research areas. In 2011 inventories were made in Rauma archipelago Natura 2000 site and its neighbourhood. The research area covered about 200 km² ranging from the inner archipelago to the open sea. All together some 421 kilometres of acoustic survey lines were run including continuous sub bottom profiling, reflection seismic, side scan sonar and multibeam echo sounding. In addition 23 bottom samples were taken. All acoustic survey profiles were interpreted. Surface geological maps were drawn based on the acoustic data supported by bottom sediment samples. Outputs of the geological studies consist of substrate, seafloor feature and landscape maps.

When compiling the maps, special emphasis was given to the topmost centimetres of the sediment layers. Traditional surface geological maps, which usually describe the uppermost one meter of the sediment layers, are not always the ideal starting point for biological studies and marine habitat mapping. Thus, the sediment classification and the interpretation process were slightly altered to better fit the requirements of habitat mapping.

Marine Riparian Inventory for San Juan County, Washington

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The Puget Sound region of Northwest Washington State has a resource rich history and scenic beauty which has attracted ongoing human growth and development for the past century. The islands that compose San Juan County, located at the north end of Puget Sound are uniquely positioned at the confluence of the inland estuaries of Straits of Georgia, Straits of Juan De Fuca, and Admiralty Inlet. The shores of these islands are part of the greater marine ecosystem that provides significant food web support and habitat for multiple federally listed species, including Chinook salmon. Washington state governance has adopted a “no net loss” policy regarding ecological functions and values from human development. Effective implementation and monitoring of this policy in San Juan County requires closure of data gaps defining existing habitat conditions along its shorelines.

While much data exists on valued ecosystem components, wide data on riparian condition (marine or freshwater) is lacking in San Juan County. This study tests a methodology for quantifying vegetation types and characteristics along the marine shoreline and fresh water creeks. Using a combination of remote sensing data (LIDAR, Aerial Orthophotometry) and GIS tools, the sample study defines procedures for coarse identification of vegetation type and density, also overhanging vegetation categories. Results will be applied to a science based prioritization of salmon habitat restoration and protection priorities for San Juan County, Washington.

Screening restoration and conservation priorities for potential implications of sea level rise in San Juan County, Washington.

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Sea level rise and climate change present additional constraints and opportunities to nearshore restoration and conservation. This restoration and conservation screening tool was developed as part of the final phase of a comprehensive prioritization of salmon recovery actions for San Juan County. The restoration and protection prioritization was developed to highlight process degradation at the shoreform unit and integrated priority nearshore habitats for forage fish and juvenile Chinook. This climate change and sea level rise tool was intended to offer a reality check on the sustainability of different salmon recovery actions, as well as highlight nearshore habitats that may be at risk due to the combined effect of shoreline modifications, process degradation as well as both natural and anthropogenic (upland) constraints to SLR/CC adaptation. The GIS-based screening tool integrates shoreform resilience, the presence of stressors and, opportunities for added habitat benefit and risks associated with infrastructure. The tool relies on habitat data, level of intact sediment supply (within drift cells and pocket beaches), toe elevation of shoreline armoring and other infringing shore modifications and surface geology. In addition, a MHHW + 2 ft shoreline was created in GIS to identify at risk infrastructure and highlight restoration opportunities – such as road relocation to and tide gate removal. Methods and results are highlighted in this poster presentation.

Transferability of fine-scale habitat suitability models for temperate marine demersal fishes

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Numerous models for predicting species distribution have been developed. Such approaches are useful for informing marine conservation policy (e.g. reserve network selection). The efficiency of these models is usually tested on the area for which they were developed. However, practitioners may have distribution models based on data from one area that they want to apply in other areas. Hence, an important question is: how accurate are models of species distribution when applied beyond the areas where they were developed? We tested the transferability of maximum entropy (MAXENT) for five temperate marine demersal fishes, between two study localities in south-eastern Australia. The MAXENT models were based on spatially-explicit multibeam-sonar derived seafloor variables and geo-located towed-video occurrence datasets. Comparisons of evaluations (via area under the curve of the receiver operating characteristic plot; AUC, and transferability index) and spatial predictions within and between regions were conducted in order to test if species meet the criteria of full transferability. By full transferability, we mean that: (1) the internal evaluation (i.e. internal AUC) of models fitted in region A and B must be similar; (2) a model fitted in region A must at least retain a comparable external evaluation (external AUC) when projected into region B, and vice-versa; and (3) internal and external spatial predictions have to match within both regions. Only three of the 10 models achieved the transferability requirements (i.e. when internal evaluation AUC > 0.7 and external evaluation AUC < 0.7). In addition, the transferability index and similarity between spatial predictions suggested considerable differences for most models. The pronounced asymmetry in transferability between the two study regions may be due to differences in the ranges of environmental predictors, impact of fishing, or varied dependence on biotic interactions that are not properly incorporated into these models. Overall, the limited geographical transferability calls for caution when projecting these models for predicting the distribution of species beyond the areas where they were developed, and further highlights the importance of ground-truthing.

Marine Base Maps - providing essential seabed information for coastal management - examples from the Astafjord project, North Norway

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Information on the seabed for management of coastal communities, activities and resources must be delivered in a format that is easy for end users to digest. As part of the Astafjord project in Northern Norway the Geological Survey of Norway (NGU) has developed a series of Marine Base Maps (MBMs). The map series include geological maps plus derived thematic maps which are directly targeted to the needs of coastal managers. Data contributing to the maps includes swath bathymetry and backscatter, together with ground truth data from video and grab sampling. Benthic fauna and content of pollutants in the sediments have also been mapped by project partners. The MBM series provides information on sediment grain size, anchoring conditions, trenching conditions (diggability), sedimentation basins, slope, slide hazard, average current velocity, and in 2012 the map series will be extended to include habitat maps.

The Astafjord project benefits from the fact that twelve coastal municipalities have joined forces to make better plans for the management of their marine areas. The project is defined and run by the local management in cooperation with end users including fish farmers and the fishing community. Special dedicated efforts have been made to ensure effective transfer of project results, maps and scientific knowledge to coastal managers and other end users. All data have been incorporated in a GIS system for office use by local managers and NGU has visited the municipalities to ensure these systems are being used effectively. The MBMs are made into electronic charts for use on working vessels, and they are published on www.mareano.no and www.ngu.no.

Through the MBM initiative the municipalities in the Astafjord area have gained tools for knowledge based management of their marine areas. The maps will provide a scientific basis for management tasks related to fish farming, fisheries, biological diversity (e.g. protecting spawning areas), environmental monitoring, and planning of infrastructure to optimize use of the marine areas. With the addition of habitat maps to the map series the management knowledge base will be extended further, and will be better equipped to promote sustainable management whilst protecting vulnerable species and habitats. The MBM initiative under the Astafjord project has been well received by local managers and seems to offer a good basis for effective knowledge delivery and one that could be extended to other coastal areas.

Ripple dynamics and scour morphology at an inner shelf artificial reef site

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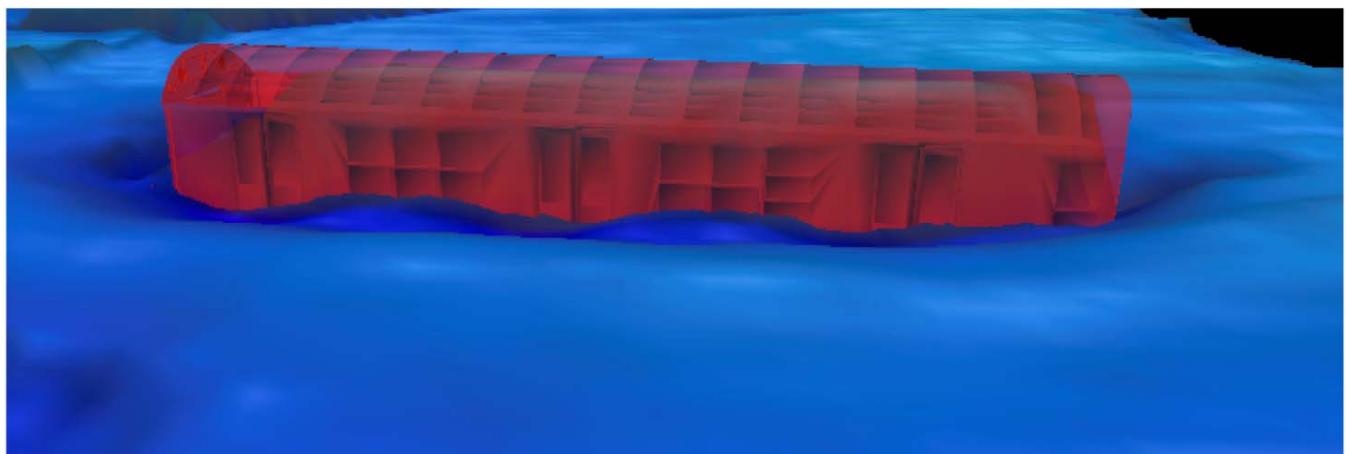
The influence of reef structures on seafloor surface sediments has implications for marine spatial planning and coastal development, including use of the coastal zone for offshore wind energy. We present observations of interannual changes in bedform morphology (ripple wavelength, orientation, and defect density) and seafloor scour at the Redbird artificial reef site, located on the continental shelf offshore of Delaware. The Redbird reef is composed of NYC subway cars, barges, tugboats, and other sunken objects. Because the objects were added periodically between 1996 and 2009, the survey area acts as a natural laboratory to study the evolution of the surrounding seafloor at a structural reef habitat through time. In August 2010 we used a 500 kHz phase-measuring bathymetric sonar to collect bathymetric and backscatter data at the Redbird site. Additionally, we conducted 500 kHz side-scan surveys of the site annually between 2008-2011. The seafloor classification program QTC SWATHVIEW was used to determine the spatial coverage of three acoustic bottom types, which were then characterized with ROV, video, and grab samples. Certain large-scale boundaries between fine and coarse sediment exhibit interannual persistence indicative of sorted bedform processes. However, clear interannual variability in many sediment and biological patterns emerged revealing the influence of the reef structures on the seafloor. Comet-shaped patches of sandy gravel surround single objects and grow to form large-scale homogenous patches around groups of objects. Alignment of sediment patches suggests influence from intense stochastic storm events. The coarse sediment supports ripples with wavelengths of ~1-2 m, which are fairly spatially consistent in orientation and wavelength, except near reef objects, a characteristic we seek to exploit for object targeting purposes. Evidence of scour includes the erosion of fine sediments and the formation of motes 12-30 m in diameter and 0.5-1 m deep around the reef objects. Altogether the 0.25 m/pixel backscatter mosaics, 0.5 m bathymetric grids, and 1 m classified maps provide detailed information about the evolution of surface texture and morphology and associated biology of the seafloor in the vicinity of reef structures.

Summary plots of AUV vehicle tracks and water column parameters (e.g. salinity and temperature) and acoustic backscatter, bathymetry, and classified seafloor kmls can be accessed publically at the URL links below

http://cshel.geology.udel.edu/kml_files/DEBay/

<http://cshel.geology.udel.edu/GoogleEarth/>

New York City Subway (Redbird) Artificial Reef



Multibeam bathymetric maps of cold-water coral hot spots in the Drake Passage

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Several sites of abundant cold-water coral growth in the Drake Passage, between the Antarctic Peninsula and the tip of South America, were identified, mapped, photographed, and sampled during two research cruises onboard the icebreaker *Nathaniel B. Palmer* in 2008 and 2011. Small numbers of cold-water corals had previously been collected from the Drake Passage, but our two recent cruises constitute the first dedicated effort to study the corals and their habitats. Bathymetric data were collected using a Kongsberg EM120 multibeam sonar system. Photographic data, used to characterize the seafloor habitats, were collected using the Woods Hole Oceanographic Institution's deep-towed camera system, TowCam, in areas of flat or gently sloping seafloor. A simple drop camera system was employed in steep or rugged areas. Corals were identified using these photographs and specimens collected by dredge.

Of the seven sites chosen for detailed mapping, two were on the northern side of the Drake Passage on the outer continental shelf and slope off South America, three were in the middle of the Drake Passage on two seamounts and a fracture zone, and two were on the southern side of the Drake Passage on the Antarctic Shelf and Slope. At each site we mapped an area of 1000 square kilometers or more, from shallow (several hundred meters) to deep (over 4000 meters) water to obtain information from a range of contiguous depth habitats. Sample collections included rocks, live animals, and fossil (dead) coral. Radiocarbon dating of the fossil corals will allow us to study the biogeography of the corals through time as well as space.

The continental margin sites were predominantly sediment covered, but also displayed hard substrates of outcropping sedimentary rocks and, in some places, ice-berg dropstones. Large areas of rocky substrate (including pillow basalts) with patches of coarse sediment were seen at the three sites in the middle of Drake Passage. Sars Seamount, now about 480 meters deep, is flat-topped, presumably a result of past sub-aerial erosion, whereas Interim Seamount, on the extinct Phoenix Spreading Center, is deeper (900 m) and ridged.

A wide variety of corals, including scleractinians, octocorals, and stylasterids, were found at all sites, along with diverse assemblages of associated fauna. Stylasterids dominated at the seamount and fracture zone sites in the middle of the Drake Passage. Scleractinians (mainly solitary species) and octocorals were more abundant at the outer continental shelf and continental slope sites.

PROTOCAST: Prototyping a computer-aided sonar screening tool

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Analysing side scan sonar data can be a labour intensive task, with a large proportion of interpretation time spent screening data that shows a seabed scarce in features of interest. The systematic mapping procedure in this workflow however, lends itself well to automation using modern image-analysis software techniques. Human expertise is founded on reason, previous experience, and knowledge of typical object appearance and context. Conversely, automated systems must have their “common sense” programmed in, but intrinsically excel in rapid and consistent measurements and calculations. A synergy between the two was explored through a pilot project funded by the Department of Food and Rural Affairs (Defra) through the Marine Aggregate Levy Sustainability Fund (Project RK7108) in 2009. The pilot project identified potential for a more rapid classification of acoustic data combining human expertise with automated image-analysis.

The next stage in this research saw the development of a prototype system, PROTOCAST, which can independently screen side scan data to produce maps illustrating the locations of features of interest, preliminary habitat classifications and value-added statistical data. This was achieved by training an artificial neural network to recognise a set of typical seabed features, including trawl scars and biogenic reefs.

The neural network successfully located linear features including cables and trawl scars on a background of sand with 90% confidence. The network initially failed at delineating biogenic reefs formed by the polychaete worm *Sabellaria spinulosa* from background sand, but an increase in the number of training images showed some success, though with much lower confidence (20%) than linear features. It is thought that further increase of the training set size would improve this confidence.

Although the prototype is not yet in its final form, it does demonstrate the possibility of being able to develop a semi-automated screening system that can reduce the time needed to analyse acoustic data. It is envisaged that batch processing of survey data could be carried out using a neural network based system which would enable preliminary results of a survey to be produced in near real time. Verification and classification of detected features of interest by a human expert could then be conducted using the automatically produced data as a guide.

Standardisation and Harmonisation of Geological and Geophysical data for improved Seabed Habitat Mapping

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

A report will be presented including: (1) the importance of sediment/terrain characterisation within habitat mapping initiatives (soft vs hard bottom types / flat vs high relief areas); (2) a demonstration of main methodological approaches and classification; (3) an investigation on how different resolution of data affects the sediment/terrain characterisation; and (4) recommendations on parameters, resolution, formats, confidence, and data query tools to be used for habitat mapping. Results are framed within the context of major European Directives (e.g. Europe's Marine Strategy Framework Directive). Cross-fertilisation exists between Geo-Seas (<http://www.geoseas.eu>) and EMODNET-Geology (EU DG MARE, <http://www.emodnet-geology.eu/>).