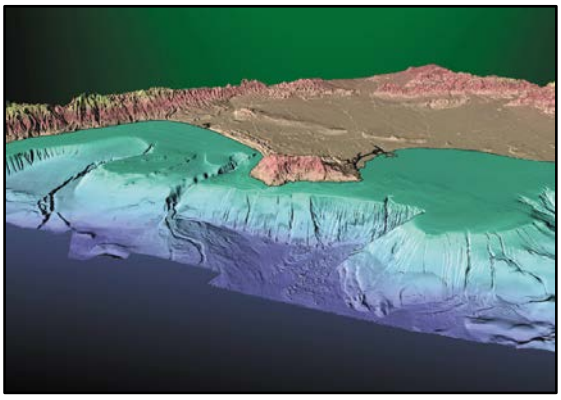
GEOhab 2018

Santa Barbara, USA

Marine Geological and Biological Habitat Mapping

Abstracts



Editors:

Donna M. Schroeder[1], Catherine A. Dunkel[1], Guy R. Cochrane[2]

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2. Dept of the Interior, U.S. Geological Survey

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Introduction

We welcome you to the seventeenth annual GeoHab Conference, held this year at the Fess Parker Resort in Santa Barbara, California, USA. We hope your stay on our coast, where the Santa Ynez Mountains meet the Pacific Ocean, will inspire you both professionally and personally.

Through our annual conference we examine the achievements and challenges of current efforts to illuminate the structure of the ocean floor, understand how this structure affects the marine life which resides there, and to guide management efforts in both protecting and using our natural resources wisely. GeoHab has always been a venue for international collaboration and sharing scientific research across disciplines. In today's climate, such collaboration has never been more important as human society faces a number of global challenges that require to working together to find solutions.

We thank our industry partners for their continued interest in, and financial support of, annual GeoHab conferences around the world. Without this support, GeoHab would not be able to encourage and sponsor students through the Ron McDowell Student Award. We thank Craig Brown and Brian Todd, Co-Chairs of the Student Selection Committee, and the committee members, for their dedication to their task. Student support has always been a mainstay of GeoHab, and in 2018, ten international graduate students will be funded to travel to Santa Barbara to give oral presentations on their research during the conference. The success that past students have enjoyed in their early academic and industry careers in seafloor mapping may be GeoHab's greatest legacy.

The heart of any GeoHab Conference is the oral and poster presentations of exciting new research. We sincerely thank the global cadre of scientists who submitted abstracts this year. This rich and diverse material was carefully reviewed by the members of the International Scientific Committee.

With warm regards,

The Local Organizing Committee

Guy Cochrane, U.S. Geological Survey
Donna Schroeder, Bureau of Ocean Energy Management
Chris Caldow, Channel Islands National Marine Sanctuary

NOTE:

Shortly after the conclusion of the conference the 2018 GeoHab abstracts volume will be published as a Bureau of Ocean Energy Management report. The document will be available at https://www.boem.gov/Pacific-Completed-Studies/. Prior to publication, please report any errors or omissions in the abstracts volume to Donna Schroeder at donna.schroeder@boem.gov.

2018 GeoHab Committee Membership Roster

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Claudia Propp, BSH, Hamburg, Germany
Brian Todd, Geological Survey of Canada, Canada

GeoHab Conferences 2002–2018

Year	Location	Host(s)	Affiliation(s)
2018	Santa Barbara, California, USA	Guy Cochrane Donna Schroeder	U.S. Geological Survey Bureau of Ocean Energy Managment
2017	Dartmouth, Nova Scotia, Canada	Craig J. Brown Brian J. Todd	Nova Scotia Community College Geological Survey of Canada
2016	Winchester, United Kingdom	Tim Le Bas Markus Diesing Heather Stewart Kerry Howell	National Oceanographic Centre Centre for Environment, Fisheries & Aquaculture Science British Geological Survey University of Plymouth
2015	Salvador, Bahia, Brazil	Alex Bastos Helenice Vital José Maria Landim Dominguez Tereza Araújo	Federal University of Espirito Santo Federal University of Rio Grande do Norte Federal University of Bahia Federal University of Pernambuco
2014	Lorne, Victoria, Australia	Daniel Ierodiaconou Scott Nichol	Deakin University Geoscience Australia
2013	Rome, Italy	Andrea Fiorentino Silvana D'Angelo	Geological Survey of Italy (ISPRA)
2012	Orcas Island, Washington State, USA	H. Gary Greene J. Vaughn Barrie	SeaDoc Society/Tombolo Geological Survey of Canada
2011	Helsinki, Finland	Aarno Kotilainen Anu Kaskela	Geological Survey of Finland (GTK)
2010	Wellington, New Zealand	Geoffroy Lamarche	National Institute of Water and Atmospheric Research (NIWA)
2009	Trondheim, Norway	Terje Thorsnes Kim Picard Margaret Dolan Pål Buhl-Mortensen Kari Nygaard Ingrid Bysveen	Geological Survey of Norway (NGU) Institute of Marine Research Institute for Water Research Directorate for Nature Management
2008	Sitka, Alaska, USA	Cleo Brylinski Tory O'Connell Jennifer Reynolds	Alaska Department of Fish and Game University of Alaska
2007	Nouméa, New Caledonia	Yves Lafoy	Direction de l'industrie, des mines et de l'énergie de Nouvelle-Calédonie
2006	Edinburgh, Scotland	Alan Stevenson Heather Stewart	British Geological Survey
2005	Sidney, British Columbia, Canada	J. Vaughn Barrie Kim Conway	Geological Survey of Canada
2004	Galway, Ireland	Anthony J. Grehan Colin Brown	National University of Ireland, Galway
2003	Hobart, Tasmania	Peter T. Harris Alan Butler	Geoscience Australia CSIRO Marine Laboratories
2002	Moss Landing, California, USA	H. Gary Greene Joe Bizzarro Isabelle Herbert	Moss Landing Marine Laboratories

Infralittoral/Circalittoral Biozone Boundary Definition in a Riverine Input Influenced Area

S. Agnesi, A. Annunziatellis, R. Inghilesi, G. Mo

ISPRA - Italian National Institute for Environmental Protection and Research, Italy

Marine habitat cartography is a key tool for the environmental assessment, monitoring and management of the seabed. Several EU environmental policy instruments require spatial information in order to reach the policy objectives; amongst these, is the Marine Strategy Framework Directive, which requires the assessment, evaluation and the definition of specific environmental targets for seabed broad habitats (BHs). A homogeneous broad-scale seabed habitat map of European seas can therefore help to address these requirements. The pan European broad scale habitat map, produced in the framework of the EMODnet EUSeaMap project (Populus *et al.* 2017) is the result of a modeling process based on the primary input of several abiotic variable layers. Seabed substrate information intersected with modelled benthic (depth) zone boundaries are the principal drivers behind the modeling of the BHs.

Benthic zones are defined as areas in which the principal abiotic variables, that are known to influence benthic assemblage distribution, range within specific threshold limits. In EUSeaMap, the boundary between the infralittoral and circalittoral zones of most European basins has been modelled by calculating an estimated amount of light reaching the sea bottom. The northwestern Adriatic Sea is strongly influenced by the Po river inputs and for this reason, the above mentioned light based approach for defining the benthic zone boundary is not applicable because of the combination of fine sediment apposition and the conspicuous fresh water load. The present work proposes an alternative approach for the identification of the infralittoral/ circalittoral boundary in the Adriatic Sea.

The rationale on which the alternative proposed rule is built is that, at the scale of the modelled map, sand and muddy sand substrata can be considered as proxies for the infralittoral zone whereas sandy mud and mud substrata typically occur in the circalittoral zone. Therefore, a GAM analysis was run to investigate the influence of specific environmental variables on the sediment distribution. The sediment datasets, described in the higher resolution EMODnet Geology delivery maps (1:50,000), joined with additional in-house sediment data, were used to define the response variable.

The abiotic variables considered as predictors are: wave energy at sea bottom (kinetic wave energy), depth and geographic position (latitude and longitude). The first two variables are directly related to the typology of sediment size deposition; whereas the geographic position can be assumed as a proxy for distance to the mouth of the Po River delta. The grid used to extract the training and the test data sets, both for predictors and response variable, is that of the wave energy (approximately 1.2 Km). Different models were tested in order to individuate the best one in terms of deviance explanation and number of variable used. The predictive accuracy was then applied and evaluated on the test dataset using: i. the threshold-independent Receiver-Operating Characteristic (ROC) plot; ii. the estimation of the area under the Receiver Operating Characteristic curve (AUC). The optimum probability threshold for the model was identified and the relative threshold, yielding the best data test correctly classified, was selected. The model was then used to assign a predict value and relative standard errors to each cell of the study area. All the statistical analysis were run using R software and the probability maps of the infralittoral and circalittoral zones were created using ArcGIS (ESRI inc.).

Repeat Mapping in the Lower Monterey Submarine Canyon Sheds Light on Morphological Change During Discrete Sediment Density Flow Events

K. Anderson[1], M. Schwehr[1], E. Lundsten[1], D.W. Caress[1], C.K. Paull[1], K.L. Maier[2,1], R. Gwiazda[1], J. Gales[3], P. Talling[4], J. Xu[5], D. Parsons[6], H. Thomas[1]

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2. United States Geological Survey, USA
3. Plymouth University, UK
4. Durham University, UK
5. Southern University of Science and Technology, China
6. University of Hull, UK

The Coordinated Canyon Experiment (CCE), a multi-institutional collaboration effort, was designed to monitor the passage of sediment density flows along the axis of Monterey Canyon, offshore California, between ~200 and 1850 m water depth. An array of moorings and sensors were deployed for three 6-month periods from October 2015 to April 2017. Aligned with the CCE deployments, repeat high-resolution multibeam bathymetric surveys of the Monterey Canyon floor were conducted with a mapping AUV (Autonomous Underwater Vehicle). The AUV carried a Reson 7125 multibeam echosounder (vertical precision of 0.15 m and horizontal resolution of 1.0 m). An inertial navigation system combined with a Doppler velocity logger allowed the AUV to fly pre-programmed grids at 3 knots, while maintaining an altitude of 50 m above the seafloor, to obtain a nominal line spacing of 130 m.

The floor and lower flanks of the canyon between 200 to 540 m and 1350 to 1880 m water depths were mapped six times during the CCE. These repeat maps are subtracted to create bathymetry difference grids to show morphological change. Coupling the sensor observations with the bathymetric surveys, the CCE successfully documented sediment density flow events as well as the associated changes in seafloor morphology. Between repeat surveys, three sediment density flow events reached the lower canyon, extending to at least 1850 m water depth. On January 15, 2016, a particularly large density flow traveled more than 50 km down Monterey Canyon.

Unlike in the upper canyon where this event caused wholesale reorganization of geomorphological features, changes to the lower canyon morphology involved a more moderate re-sculpting of the features. The effect of a sediment density flow of known magnitude and duration on the seafloor morphology has never been documented in a deep-sea setting before.

Along with 1-m AUV mapping, a patch of the lower canyon, surrounding an instrumented seafloor node, was subject to repeat mapping using an ultra high-resolution system mounted on an ROV. This system fielded a Reson 7125 multibeam sonar, a 3D at Depth subsea lidar, two Prosilica stereo color cameras, a Kearfott SeaDevil INS, and a Doppler velocity log sensor. At a nominal survey altitude of 2.5 m above the seabed, the system provides collocated 5-cm resolution multibeam bathymetry, 1-cm resolution LiDAR bathymetry, and 2-mm resolution photomosaics, and can cover a 100-m survey area. This novel system is able to document changes in seafloor morphology on the scale of local benthic communities, including polycheate worms and chemosynthetic clams. During the CCE, the system captured the dynamic nature of flute-like scours as the flow events erode and deposit material along the canyon floor, as well as the evolution of scours between events.

A New EMODnet Seabed Habitat Product: Ground-Truth Data Collection

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2. Joint Nature Conservation Committee (JNCC), UK

The first consistent broad-scale seabed habitat maps for European waters were developed under the preparatory action for EMODnet (EC contract no. MARE/2008/07). The second EMODnet Seabed Habitats (ESBH) project (EC contract no. MARE/2012/10) has extended these prototype maps so that they now cover all European basins, building on the method with enhanced validation. This broad-scale product has been complemented with a collation of habitat maps from surveys that are freely disseminated online through the ESBH portal (http://www. emodnet-seabed habitats.eu). In the current phase of EMODnet (phase III, 2017-2019) the project will also deliver the collation and the dissemination of habitat point data from surveys through the portal.

The aim is to provide a standardized, centralized and free access point for habitat ground-truth data at a European scale. In this way, all the spatial information about the habitat occurrence (both polygon and point data) will be accessible using the same portal. As there is no single point of access to point records of seabed habitats, biotopes, communities and/or biocoenoses (hereafter all referred to as "habitats"), this work will fill a critical gap in the availability of such information.

The present work aims to focus the attention of the scientific community about this new habitat archive by describing its rationale and schema. This project is collecting habitat data in the broadest sense. In fact, habitat data can encompass all the levels of detail covered by hierarchical systems such as EUNIS (https://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification) as well as those recognized or identified under the Habitats Directive (http://ec.europa.eu/environment/nature/legislation/habitatsdirective) or international conventions as being of special scientific or biodiversity interest. Furthermore, benthic broad habitats described in the Marine Strategy Framework Directive (http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive) can feed the database. Finally, whilst the main objective is to collect data according to pan-European classification systems, in order to capture all the available data, ground-truth data classified according to national, regional and/or specifically designed classification systems are also accepted.

A key objective of this project is to make use of existing data schemas and infrastructure to make the data available, namely the Ocean Biogeographic Information System (OBIS). This has been possible thanks to the creation of the new OBIS-ENV standard, which means for the first time additional measurements, including habitat type, may be combined with sampling events and species occurrences to provide much richer associated information. Two parallel approaches were needed, depending on whether or not sampling events were already present in OBIS. For those that were, project partners have been working with data providers to resubmit datasets with the habitat information included, according to standard guidance produced by the project. For those that were not, an intermediate database was designed to ensure that project partners formatted the information in a standard way before uploading it to OBIS's European node, EurOBIS.

The ESBH portal will use machine-to-machine connections to harvest all the European habitat point data from OBIS and allow users to view, query and download the data they need, as well as providing links with any associated species occurrence data available via the EMODnet Biology portal. Some data gathered by the project has some sharing restrictions, which means it cannot be uploaded to OBIS but it may still be viewed online at certain resolutions. ESBH is maintaining this data in a separate database that follows the same format but limits access. This will ensure maximum possible access to all habitat point data in Europe.

The international scientific community has the opportunity to greatly contribute to this European initiative by sharing its ground-truth point data within the framework of the most wide-ranging and long-term pan-European seabed habitat web portal, EMODnet Seabed Habitats.

A Geomorphological Seabed Classification for the Northeast Brazilian Continental Margin*

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2. Applied Research, Nova Scotia Community College, Dartmouth, Nova Scotia, Canada

Geomorphological characterization of the seabed offers a valuable first step for delineating regions of the ocean floor that are likely to support particular fauna, thereby providing value for future targeted studies on benthic communities and habitats. The aim of this study is to perform, for the first time, a geomorphological classification for the Brazilian continental margin (encompassing the exclusive economic zone – EEZ) using Benthic Terrain Modeller (BTM), with 1x1 km resolution bathymetric data (from GEBCO). The classification of the seabed is based on the bathymetry, broad and fine scale BPI (Benthic Positioning Index), seafloor slope, and a decision table containing definitions and thresholds appropriate to the data input. Finally, 14 seabed classes are recognizing at the seafloor highlighting the geomorphic diversity of the area. Results from the BTM analysis revealed that almost seventy-five percent of the area were classified as plains deeper than 1,000 m, and several seamounts were mapped within this region (approximately 6% of the study area). The continental shelf is narrow in the central part of the study area, becoming wider to the north and south. Along the shelf edge was observed a complex morphology of flat ridges, troughs, pinnacles, steep slopes, narrow ridges and also seamounts. The BTM analysis also revealed a complex morphology associated with the Pernambuco plateau indicating where scarps and depressions control the connection between shelf and abyssal plain. This study significantly improved geomorphic information offshore NE Brazil, contributing to the development of national marine datasets for use in marine planning and management. These region geomorphological maps will reflect biogeography and ecosystem process and provide much needed information to support future regional marine planning in Brazilian waters.

* This study is a contribution of the inct AmbTropic, CNPq/FAPESB grants: 565054/2010-4 and 465634/2014-1.

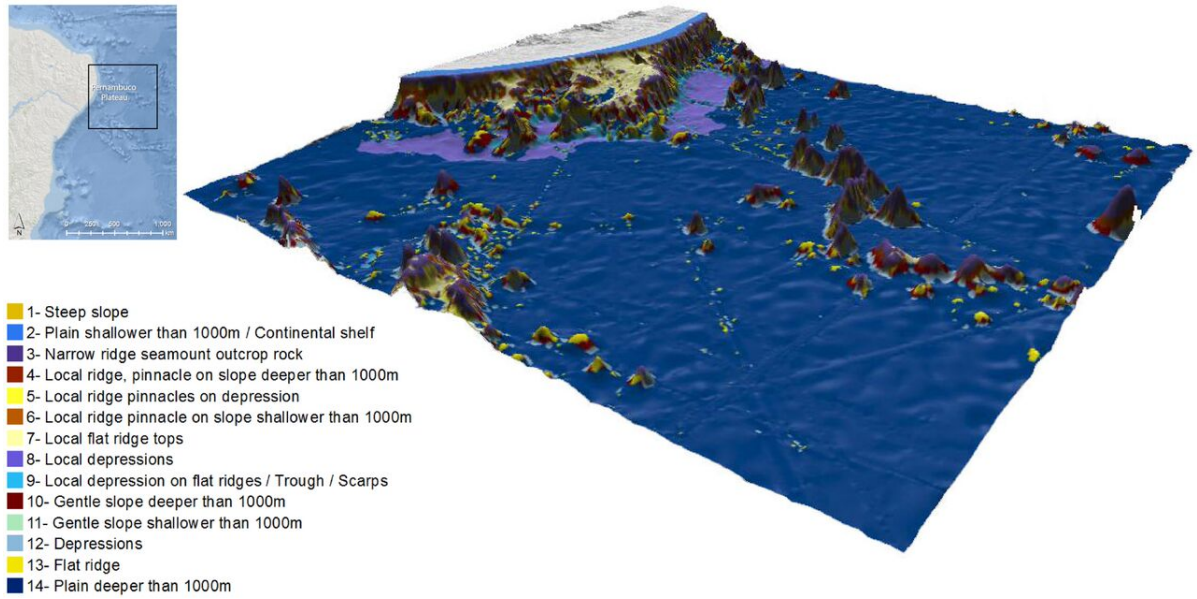

Figure 1: BTM output from the study area in NE Brazil.

Predictive Rockfish Habitat Modeling in the Salish Sea

J.G. Aschoff[1], H.G. Greene[2]

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The inland waters of Washington, known as the Salish Sea, are home to many species of rockfish (*Sebastes* spp.). Populations of some species are healthy but others, such as yelloweye (*S. ruberrimus*) are declining and have been listed under the Endangered Species Act (ESA). We describe a rockfish predictive habitat-modeling project aimed at enhancing efforts to identify potential benthic habitats for endangered rockfish species. This project took a multi-pronged approach, which used computer-based methods for statistical analysis of terrain, combined with visual analysis and interpretation of geomorphic features.

The study focused on the south and central Salish Sea, ranging from the San Juan Archipelago in the north to the southern portions of Puget Sound. We used results from fish surveys taken over several decades, along with multibeam echosounder (MBES) bathymetric surveys gathered from multiple sources that were used to train and validate the predictive model. The MBES surveys were obtained by working jointly with Geologic Survey Canada that were combined with published NOAA surveys. Rockfish location data were obtained from various remote operating vehicles (ROV) and drop camera surveys provided by the Washington Department of Fish and Wildlife, along with line catch data from NOAA hook-and-line bottom fishing surveys.

Statistical analysis of terrain was one method used to identify potential rockfish habitat. Based on bathymetry using a standard horizontal resolution of 10 m and using tools in ArcGIS 10.3 and the Benthic Terrain Model, parameters for terrain complexity and slope were extracted for each observed rockfish location, and for a set of representative points within the search domain (transect areas) and within the total possible habitat range. Using that data set and custom R scripts, a simulation was developed to examine the effects of varying thresholds for complexity and slope on the metrics for fish capture (fraction of total observed rockfish), habitat or search cost (area), and fish density (observed fish locations per search area). We examined the tradeoffs in defining these thresholds. As thresholds become more stringent, smaller search or habitat areas are needed, but with reduced fish capture. Using this statistical modeling, habitat maps settled on the identification of “high density areas” that exhibit the highest terrain complexity and fish density but with moderate fish capture (e.g. 50% of searched rockfish locations), and the identification of “high capture” areas (usually surrounding the “high density” areas) that had somewhat lower terrain complexity and fish density but with high fish capture (e.g., 90% of observed rockfish locations). One theory suggested by this analysis is that the high-density areas represent primary habitat for rockfish surrounded by roaming areas with lower fish densities.

A prior study had developed comprehensive benthic habitat definitions in the vicinity of the San Juan Archipelago. That prior study benefited from a combination of high quality bathymetry and backscatter data, along with the time and resource for full interpretations. Potential habitats identified from the statistical modeling described above corresponded closely with locations and habitats that had been interpreted as “sedimentary bedrock” and “fractured bedrock”, and overlapped significantly with the “high capture” areas identified by terrain modeling.

Seeps along the Pacific Northwest of North America – Ecologically, Biologically and Geologically Significant Habitats

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2. Moss Landing Marine Laboratories and SeaDoc Society Tombolo Lab, Orcas Island, Washington, USA
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Seafloor methane cold seeps are common from offshore Washington State, British Columbia and into the Gulf of Alaska along the upper slope and continental shelf, with plumes > 800 m above the seafloor in the water column. Many hundreds of seeps off western Vancouver Island, British Columbia, within the Cascadia sub-ducting margin, occur along faults and folds that in most cases can be sourced to hydrocarbon deposits of Tofino Basin. North of Vancouver Island seeps and mud volcanos occur adjacent to the Queen Charlotte-Fairweather transform fault zone and within the Queen Charlotte hydrocarbon basin in 1200 to 100 m of water. Carbonate crusts and authigenic chimneys, bacterial mats, and chemosynthetic mussel and clam communities are common features of the majority of the seeps. In addition, the seep habitats result in faunal assemblages different from that of surrounding soft substrate and sometimes atypical of known seep communities. The significant numbers of seep habitats that occur along the Pacific offshore of Canada has resulted in Fisheries and Oceans Canada establishing them as Ecologically and Biologically Significant Areas (EBSA) within the Ocean Action Plan for conservation and management.

The volume of deep-sourced methane (thermogenic) from these seeps is potentially very large, as the extensively faulted and carbonate rich geological environments indicate long-term venting processes. The complex vent sites form unique benthic habitats along an extensively fished upper slope and continental shelf, however, the massive release of methane may limit the biodiversity of regional shelf and coastal benthic habitats. Deeper water habitats are strongly delineated by oxygen availability in the NE Pacific and such methane emissions may reduce dissolved oxygen concentrations. Such a reduction in oxygen is observed near the highest density of seeps on the southern Vancouver Island shelf. Consequently, it is imperative that we better understand the role these seeps play in the ecology, ocean chemistry, and tectonic structure (earthquake and tsunamis risk) of this dynamic region.

Mapping Bedforms with Different Bathymetry Grid Resolutions – Link between Mapping Scale and Time-Scale of Geological Processes

V.K. Bellec, R. Bøe, L.R. Bjarnadóttir, M. Dolan

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MAREANO is a Norwegian mapping programme which started in 2006. The program currently focuses on the Barents Sea, and seven 500-1,000 km^2 areas (boxes) are mapped between Nordkapp (mainland Norway) and Sørkapp (Svalbard). Box 5 is located on the shallow Spitsbergenbanken northeast of Bear Island, in water depths of 25-55 m. This box, which displays sandwaves and sandbanks, has been mapped in high resolution by EM2040 Dual Head multibeam echosounder, with sufficient data density to permit gridding at 20 cm (figure 1).

Several fine-scale bedforms have been identified in 20 cm resolution grids. These bedforms are mostly 10-20 cm high and with a few meters wavelength (Figure 1). According to Ashley (1990) bedform classification these are megaripples. Sand megaripples formed by bottom currents/tidal currents are most common. Their crest orientations change over short distances and are easily reversed when the directions of the currents change. Megaripples formed by waves occur in topographic lows and in areas with a higher percentage of gravel in the sediments. Interference megaripples are likely formed by the convergence of wave and current (tidal) megaripples. These megaripples are indicators of ongoing sediment transport by waves and bottom currents – processes that are important to understand, not only for geological mapping but also for the mapping of benthic habitats.

Long sandbanks (up to 15 km long) and sandwaves occur on Spitsbergenbanken; these prominent features are well resolved in the 5 m bathymetry grid and are also visible in coarser grids due to their extent. They are formed over longer time spans but may also be relict features indicating past hydrographic conditions. They influence modern bottom currents by being obstacles, e.g. by creating local gyres which may be important for the distribution of bottom fauna on a longer time-scale than megaripples do.

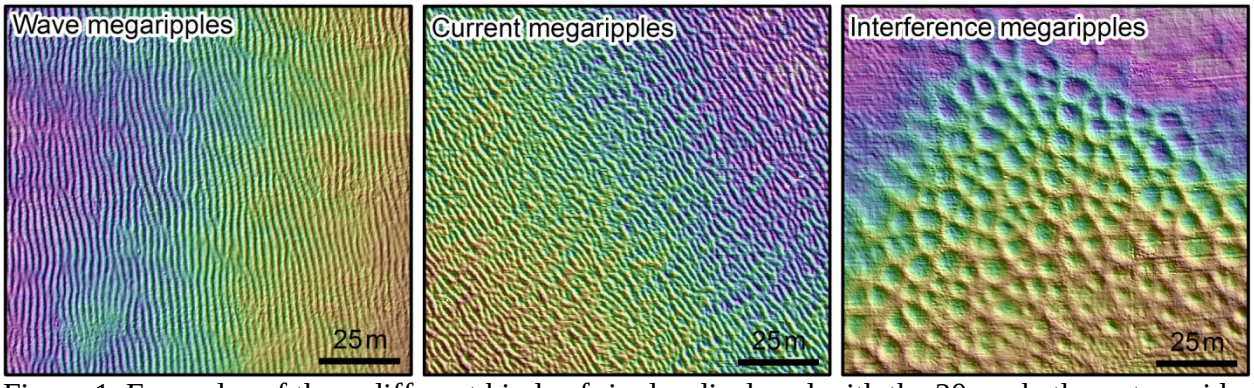

Figure 1. Examples of three different kinds of ripples displayed with the 20 cm bathymetry grid.

Reference: Ashley, G.M., 1990. Sand waves: a model of origin and internal structure. Sediment. Geol. 26, 281-328.

Seabed Sediments Grain Size, Genesis, and Sedimentary Environments – MAREANO Methodology

V.K. Bellec, R. Bøe, L. Rise, A. Lepland, L.R. Bjarnadóttir, T. Thorsnes

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The Norwegian seabed mapping programme MAREANO (www.mareano.no) was launched in 2005 to improve the knowledge of the Norwegian seafloor. The programme performs detailed mapping of bathymetry and topography, seabed sediments, contaminants, biodiversity and biotopes. The Geological Survey of Norway, the Institute of Marine Research and the Norwegian Mapping Authority are responsible for cruises and field sampling, mapping and scientific studies. The knowledge gained from MAREANO provides input to ecosystem-based management, organised through integrated management plans covering the Norwegian offshore areas.

Geological seabed maps made by NGU (Figure 1) are essential for compilation of biotope maps and nature type maps used by the management and the industry for planning purposes. The methodology, from initial planning and data collection to published map, of the grain-size, genesis and sedimentary environment maps will be detailed. These maps are based on bathymetry (mostly multibeam, but also coarser grids from single beam data), multibeam backscatter, TOPAS parametric sonar, and ground-truthing (videos, grabs, boxcores and multicores).

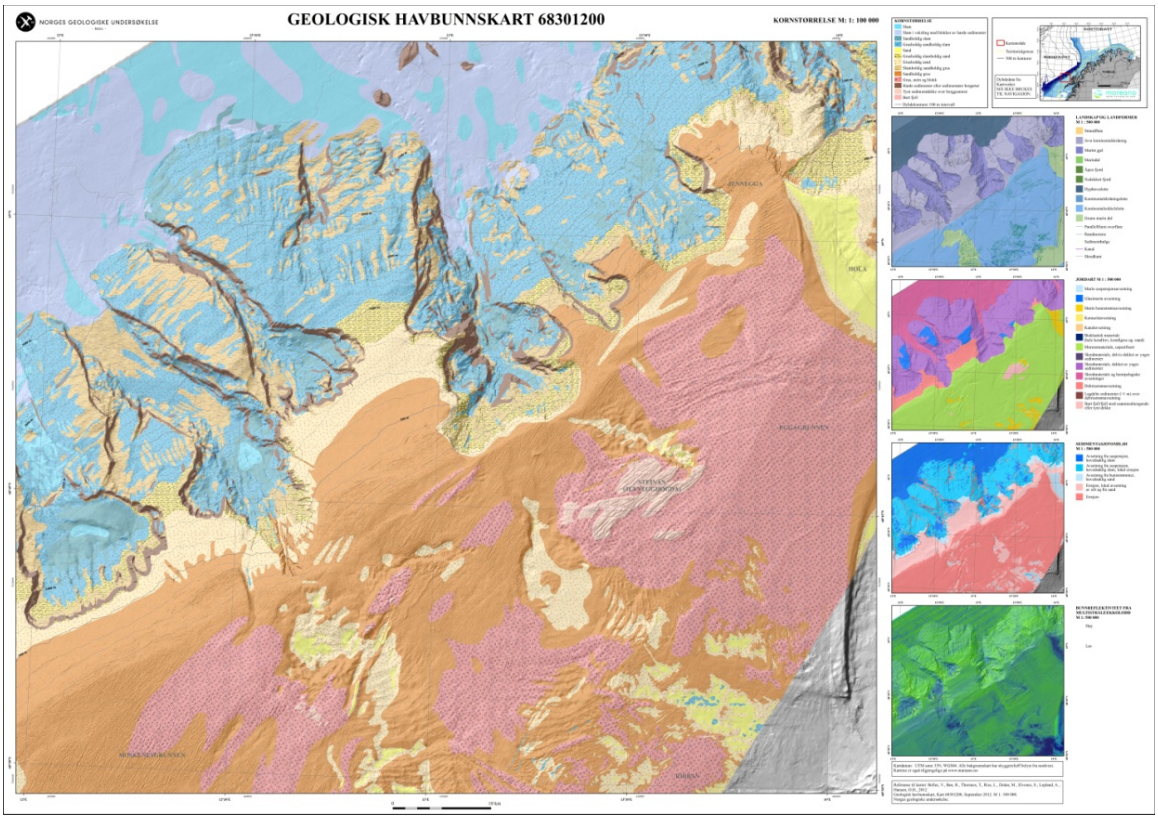

Figure 1. Example of MAREANO maps produced by NGU.

Harmful Algal Blooms (HABs) in İzmir Bay, Aegean Sea

N. Bizsel, K.C. Bizsel

Dokuz Eylul University, Institute of Marine Science and Technology, İnciraltı-İzmir

Based on current knowledge, HABs in the Mediterranean Sea usually occur in near shore coastal areas and in some specific "hot spots": the Alboran Sea, the Ligurian-Provençal Basin, the Adriatic Sea, and the Northern Aegean Sea are the record rich areas (Moncheva *et al*., 2001; Ignatiades and Gotsis-Skretas, 2010). Some hotspots in Aegean Sea are Thermaikos and Kavalas Bays in the North Aegean Sea, Pagassitikos, Malliakos, Evoikos and Saronikos in the Western Aegean Sea, Messiniakos Bay in the Southern Aegean Sea, Amvrakikos in the Ionian Sea and the Kalloni Bay of Mytilini Island, Izmir Bay and Gulluk Bay in Eastern Aegean Sea.

The typical observational cases are the regional or local monitoring programmes. For instance, The monitoring programme of İzmir Bay, started in early 1980s, and it has been continued since mid 1990s with varying temporal scale mainly which were bimonthly, seasonal and annual. Nevertheless, a discrete research project in which monthly sampling was carried out has provided 38 new records for the list (Bizsel and Bizsel, 2004; Bizsel and Nezan, 2007). Considering the short doubling time of microalgae in addition to the activities creating favorable environmental pressures such as species translocations by intensive maritime traffic (e.g., ballast waters) and by discharges and wastes promoting nutrient enrichment, appearance of new species record for Izmir Bay should not be perceived as an unexpected consequence.

The first recorded toxic phytoplankton species in Izmir Bay was *Alexandrium minutum* Halim (exceeding 8.106 cells/l) in April-May 1983, and it was found in the harbor region of the inner section of the bay, during a red tide event (Koray and Büyükışık 1988). Today, there are about 40 HABs species recorded from spring season in Izmir Bay during the period of 33 years between 1983 and 2015.

The most causative organism of dense red-tide in Izmir Bay is particularly *Noctiluca scintillans* and this species had very strong correlation with ammonium (Bizsel *et al.,* 2002). The discolourations have also been occurred by *Prorocentrum micans* in 2001, *Scrippsiella trochoidea, Alexandrium minutum* and *Eutreptiella gymnastica, Dinophysis rotundata, Nitzschia longisima,* and *Prorocentrum dentatum* in 1999 and *Scrippsiella spinifera* in 2006, *Gonyaulax sp., Cylindrotheca closterium,* and Oscillatoria sp from Cyanophyceaea group in 2010. Their frequency of occurrence and the cell abundance in blooms have been gradually increasing.

Factors that actually trigger growth of the species likely include the combined influences of hydrographic patterns, particularly those of temperatures, as well as solar irradiance and day length.

Creation of a U.S. West Coast Substratum Map and its Use in Estimating Deep-Water Coral Habitat Suitability

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Substratum data, and specifically induration type, are a critical habitat input for the spatial modeling of groundfishes and structure-forming marine invertebrates such as deep-water corals. To facilitate this type of modeling effort, as well as to inform broader scientific and fisheries management needs, a West Coast substratum map was produced in 2005 and updated in 2011 as part of NMFS' five-year review of essential fish habitat (EFH). Induration was defined as hard, soft, or mixed substratum at cell sizes of 25 m x 25 m ranging from the Canadian to Mexican borders and offshore to the EEZ. The West Coast substratum map recently was updated as part of a larger effort to produce higher-resolution deep-water coral and sponge habitat suitability maps. This effort added new data acquisitions and addressed key concerns of the 2011substratum map, including a lack of data quality information and an inconsistent data type and resolution between California and the Northwest. The primary goals of this study were to 1) produce a new substratum map that is more consistent and accurate at depicting seafloor induration; and 2) determine the relative importance of induration (with and without data quality information incorporated) in predicting deep-water coral distributions. Accounting for differential quality of induration data required the creation of an appropriate scheme with three fundamental categories: data type, interpretation type, and groundtruthing. Scores ranged from 0 to 3 in each category, and were combined and scaled to produce 18 different data quality scores ranging from 1 to10. Data quality was then incorporated into the West Coast substratum map for each 25 m cell and used as an environmental input for modeling deep-water coral distribution. Specifically, a comprehensive database of presence information was used to create maximum entropy (MaxEnt) models that relate deep-water corals to environmental information (e.g., seafloor topography, seafloor induration, oceanography) to estimate the likelihood of suitable habitat throughout the study region. Comparisons of MaxEnt models with and without data quality information will be presented to evaluate the impact of adding this information to the West Coast substratum map for selected deep-water coral taxa.

The Norwegian Seabed Mapping Programme MAREANO – Moving into New Waters

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Geological Survey of Norway (NGU)

Norway has large areas of marine waters (> 2 million km^2) which are divided into three management regions and regulated by region-specific ocean management plans that are updated about every 15 years. The activities of the Norwegian seabed mapping programme MAREANO are aligned with ongoing management plan work, and survey areas are chosen within the regions where management plans are undergoing updates. Since 2005, MAREANO has mapped over 200,000 km^2 in the Norwegian and Barents Seas, feeding new information into the management plans and helping to close knowledge gaps identified in earlier plans.

Currently, MAREANO is looking north to the Barents Sea, where the management plan is due to be updated in 2020. Here, MAREANO performs baseline mapping of ecosystems in areas that have only recently come under Norwegian jurisdiction, and areas experiencing increased stresses due to ongoing climate change and fisheries moving farther north. In 2018, MAREANO will move into new waters, surveying in the high Arctic on the continental shelf and slope west and north of Svalbard. The remote location and cold climate presents new challenges for MAREANO, demanding vessels suitable for operating in regions with drifting sea ice and calving tidewater glaciers, and an increased risk of technical challenges.

MAREANO is also moving into new waters method-wise. After many years of "standard" mapping using the same field methods, many of these are now being revised. An important driver for these changes has been the ICES advice to MAREANO which was published in 2016. The main changes include 1) shortening the video transect length from 700 to 200 m but doubling the sampling density of these video transects; 2) using a 0.1 Van Veen grab instead of a 0.25 Van Veen grab for biological seabed sampling; and 3) acquiring dedicated grab samples for geological analyses at every video transect. Other important ongoing methods projects include further evolving MAREANOs sampling design and increasing use of (semi)automated mapping methods. MAREANO is also working on improving several aspects of data acquisition, management and distribution. These efforts include securing and utilizing more existing data from the oil industry; simultaneous acquisition of sediment profiler data during multibeam surveys; ensuring that map products and data are designed to fit user needs and are readily available.

Habitat Mapping the Fjords of Chilean Patagonia using Autonomous Underwater Vehicles

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Chilean Patagonia has one of the most extensive coastlines in the world spanning *c.* 84,000 km. This complex environment consists of many islands, bays, channels, and fjords. The landscape is sparsely populated by humans due to the inhospitable conditions and lack of landscape connectivity.

Due to this, while limited research has identified unique, diverse and species rich marine ecosystems, data is limited by challenging site conditions and survey capabilities. Therefore the region is still largely unmapped and the extent of species and habitat composition is still largely unknown.

Anthropogenic activity has increased rapidly in the fjordic regions of Chilean Patagonia; intensive salmonid aquaculture and infrastructure developments and a rise in human habitation being the main causes. It is unknown what pressure this is putting on these pristine ecosystems. Habitat maps that identify species and habitats of conservation importance are crucial tools for implementing effective marine spatial planning (of developments such as aquaculture) and designating Marine Protected Areas. Autonomous Underwater Vehicles (AUVs) offer a novel approach to mapping seabed habitats in such remote areas; they are relatively lightweight and capable of being deployed to depths and seabed conditions unsuitable for boats, divers and tethered equipment.

Habitat maps were created for sites within Comau fjord in the Los Lagos region of Chilean Patagonia. The maps utilise bathymetry, side scan sonar and high-resolution images collected using a Teledyne Gavia AUV. Data processing was conducted in Caris HIPS and SIPS. Habitat classifications were adapted from the EUNIS and Marine Habitat Classification for Britain and Ireland classification systems version 15.3 and classified to Level 3. The output maps were produced in ArcGIS software. These maps act as an important baseline for informing policy and planners, and will assist in wider scale predictive habitat mapping of the fjordic region.

California Undersea Imagery Archive

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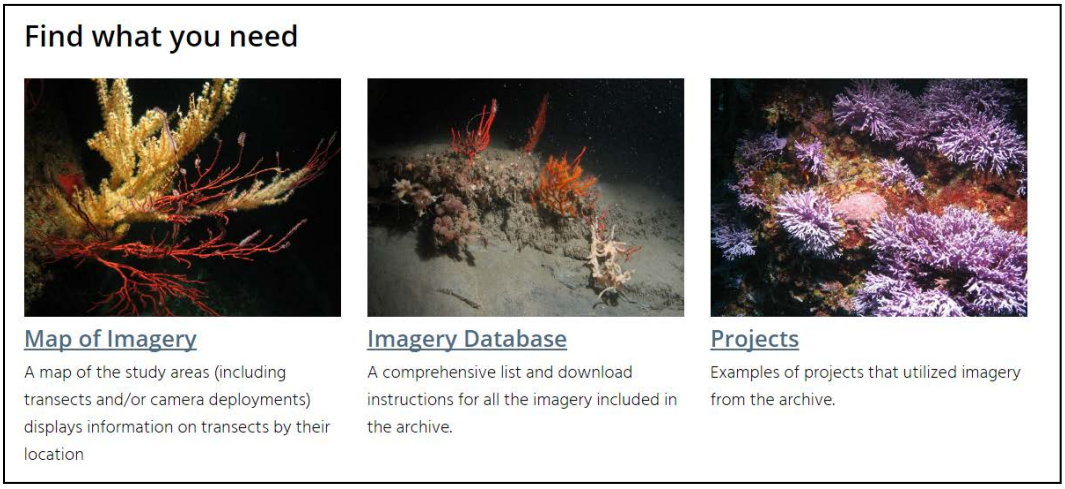
The deep (> 20 m water depth) ecosystems of California's continental shelf have been surveyed using visual tools (such as remotely operated vehicles) to address a variety of pressing management issues, including the baseline characterization and monitoring of state marine protected areas and various fishery-related studies. This imagery, collected state-wide, constitutes a vital resource for addressing management questions in the future. Data (biological and habitat) can be mined from the imagery to answer questions that were not posed as part of the original studies that collected the imagery, and the imagery can serve as an important visual baseline against which future change (from climate change and/or other factors) can be evaluated. While a number of existing portals have focused on the upload and maintenance of data extracted from undersea imagery, there has yet to be a coordinated effort to organize and store the imagery collected across a variety of projects. A single-point of contact for access to all existing state-wide imagery will serve as a vital resource as the state moves forward with new initiatives, including the long-term monitoring of MPAs and any new climate change-related research.

The primary objective of this effort is to establish a physical archive of undersea video imagery collected state-wide using various visual tools (including ROVs). The overall goal is to accumulate all existing imagery stored on tape (including mini DV, Hi-8, etc.) that was either collected by, or supported financially by, the state, and house those tapes in the accessible, temperature-controlled facility located at the Institute for Applied Marine Ecology (IfAME) at California State University Monterey Bay (CSUMB @ Ryan Ranch complex). A part-time technician monitors the archive, as well as makes any requested tape copies, and has initiated the digitization of all tapes for future use in an on-line web portal. (Funding from the California Ocean Protection Council supports this archive.)



Characterizing Benthic Habitats Using Multibeam Sonars and Towed Underwater Video on the West Florida Shelf

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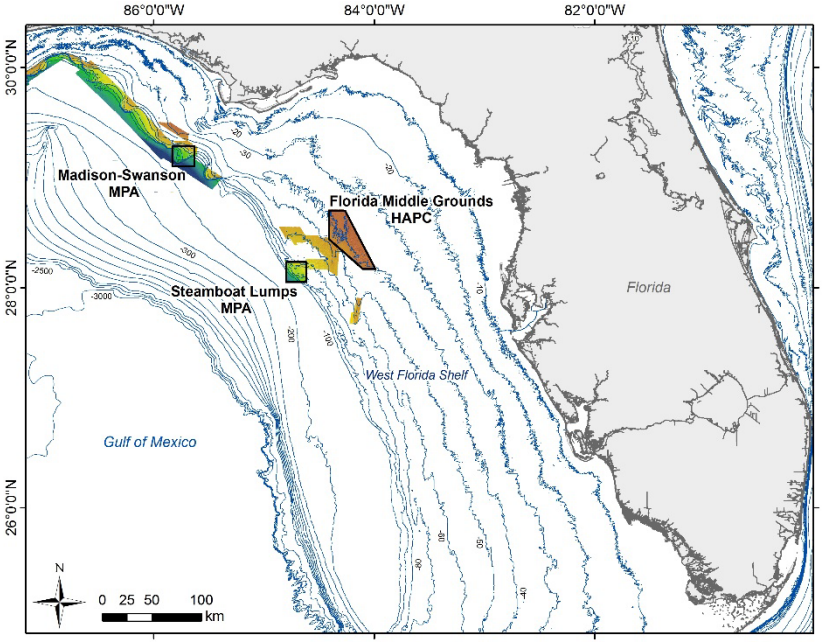

The Madison-Swanson and Steamboat Lumps Marine Protected Areas and The Florida Middle Grounds Habitat Area of Particular Concern are located on the West Florida Shelf (WFS) in 25 to 180 m of water. These and surrounding areas have been mapped using multibeam sonar systems beginning in 2002. The bathymetry and backscatter data from these multibeam sonar systems in combination with towed-underwater video imagery are used to characterize benthic habitats in these areas.

Bathymetric analyses were completed using GIS to derive slope, curvature, and rugosity from bathymetry data. Pattern-recognition analyses were also performed to define geoforms from bathymetry data. Object-based image analysis was used to segregate areas of differing backscatter and to investigate interspatial relationships between backscatter and bathymetry-derived seafloor characteristics. A scale-based characterization scheme adapted from NOAA's Coastal and Marine Ecological Classification Standard (CMECS) was developed and used to characterize habitat in towed-underwater video imagery. This scheme utilizes aspects of the geoform, substrate, and biological components of CMECS observed in towed-underwater video on the WFS. Habitat characteristics from video were then georeferenced and compared to multibeam sonar bathymetry and backscatter, as well as their derivative maps.

The results of these analyses demonstrate that the seafloor in these areas of the WFS encompass a large range of hard bottom types including pinnacles, ledges, high-relief hard bottom, moderate-relief hard bottom, and low-relief hard bottom. Attached biota observed in video imagery also indicate that some low-relief hard bottom is covered with a thin layer of sand. Soft bottom areas include fine sand to gravel-sized shell hash, in flat, rippled, and hummocky bedforms. Results of these analyses are used to determine relationships between benthic habitat characteristics as well as relationships between benthic and pelagic fauna with those benthic habitat characteristics. This allows for more automated, focused, and efficient benthic habitat characterization and maps following future survey efforts.

Seabed Sediment Mobilisation in the Deep Ocean – An Example from Broken Ridge, Southeastern Indian Ocean

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The spatial resolution (> 5 km^2) of maps covering most of the deep ocean seabed is usually too coarse to enable the identification of seabed features that record the mobilisation of fine-grained sediment that accumulates over vast areas. To examine seabed morphology that records the mobilisation of this sediment, we utilise multibeam echosounder (MBES, 12 and 30 kHz) data for Broken Ridge and environs in the remote Southeast Indian Ocean. The data cover an area 75 to > 200 km wide and > 2,500 km long (279,000 km^2). Water depths range between 634 and 6,300 m, and the sedimentary section typically comprises up to hundreds of metres of calcareous ooze above the carbonate compensation depth (CCD). The MBES data were acquired to assist in the search for Malaysia Airlines Flight 370 (MH370) and have a spatial resolution of 40 to 100 m.

Seabed morphology indicates that sediment has eroded from the southern side of bedrock outcrops on the crest of Broken Ridge (≥ 634 m water depth), forming moats on the southern side of the outcrops and preferentially accumulating on the northern sides. These features indicate that northward flowing bottom currents appear to accelerate as they flow over the crest of the ridge. The northern flank of Broken Ridge and margin of the adjoining plateau (1,200 – 3,000 m water depth) are dissected by numerous cross-cutting retrogressive slumps. Sediment flows northwards from the ridge and plateau into the adjoining semi-circular basin. Flow structures extend from the margins of the basin northward for ≥ 150 km, into an adjoining deeper basin.

In the ocean basin (2,200 – 5,000 m water depth) to the south of Broken Ridge are areas with pockmarks and seabed scours (200 – 800 m diameter, 1 – 10 m deep). These features record localised erosion of sediment by fluid and gas escape from calcareous ooze and clay, as well as by bottom currents. Farther south in the many fracture zones, including the Geelvinck Fracture Zone, seabed features record the flow of sediment down the steep flanks of fault valleys (≤ 900 m deep and ≤ 8 km wide), which are partially infilled by sediment.

These records of sediment erosion and accumulation indicate modes of seabed failure and pathways of benthic sediment transport in a deep ocean setting, as well as provide useful insights into the direction of bottom current flow. The variable hydrodynamics of this seabed environment point to a potential diversity of habitats over areas with similar fine-grained sediment. They also highlight the discontinuous accumulation of sediment over large areas of relatively flat seabed. The MBES data also show that morphologically distinct seabed features, composed of similar sediment types, may not be discernible in MBES backscatter data.

Multispectral Seafloor Classification: Applying a Multidimensional Hypercube Approach to Unsupervised Seafloor Segmentation

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The establishment of multibeam echosounders (MBES) as a mainstream tool in ocean mapping has facilitated integrative approaches towards nautical charting, benthic habitat mapping, and seafloor geotechnical surveys. The development of a multispectral multibeam system by R2Sonic offers tremendous potential for improved seafloor segmentation and classification for these applications. In this R2Sonic system, the operating frequency can be modified on a ping-by-ping basis, which can provide multispectral acoustic measurements with a single pass of the survey platform. Here, for the first time, we present the results from a novel seafloor segmentation approach of the multispectral MBES data using multidimensional hypercubes. The MBES sounding data (bathymetry and backscatter) from several test data sets collected using the R2Sonic 2026 system were converted into a unique spatial data type (VCCodes) and integrated into a Variable Size Cell (VSC) database architecture. This database architecture allows each sounding point to store information on multiple variables (e.g. latitude, longitude, bathymetry, raw and corrected backscatter, derived seafloor morphology measurements, ping ID, beam ID etc.). Seafloor geomorphometric information are calculated within the architecture from the bathymetry (e.g. seafloor slope, curvature, aspect etc.), and can be calculated using variable spatial resolutions. Spatial patterns of different combinations of these seafloor variables can then be determined through clustering multidimensional hypercubes. Each hypercube is represented by its diagonal and is unique. The hypercubes cluster based on the similarity of the diagonal bit patterns. In this way, spatial patterns on the seafloor can be mapped and compared with ground validation data sets. Results from three test areas demonstrate that the approach can be used to accurately identify patterns in seafloor characteristics, offering a versatile, repeatable and easy to use approach for seafloor segmentation. The developed methodology offers tremendous potential to improve the way we store, manipulate and classify geo-spatial data sets.

Relationships between Eastern Oyster Density and Seabed Metrics Derived from Multibeam Sonar

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Large-scale oyster recovery began in the Maryland waters of Chesapeake Bay with the closure of approximately 24% of the public harvest bottom in 2010. By 2015, large-scale oyster restoration projects were initiated in three tributaries of the Choptank River; and by 2018 over 700 acres of restoration reefs had been created.

We discuss a study designed to develop a base-line understanding of the relationship between habitat complexity and oyster populations before restoration and the observed relationships post restoration across a range of oyster habitats. Using multibeam sonar, habitat metrics were collected from oyster census sites, in Harris Creek, Little Choptank River and Tred Avon River oyster sanctuaries, Maryland, USA. Mean seabed slope (degrees) was calculated from bathymetry grids at each sample site. The standard deviation of slope at each site was used as a roughness index, and mean acoustic reflectivity (-db), extracted from acoustic backscatter, provided an index of seabed hardness.

In the pre-restoration study, oyster densities were greater in the Little Choptank than at Harris Creek, but habitat metrics did not vary by location. Oyster density varied significantly with seabed roughness, hardness, and by location, but slope was not a strong factor. Model comparison using Akaike Information Criteria indicated that seabed hardness generally contributed to better models at Harris Creek, but at the Little Choptank seabed roughness was a more descriptive variable. Live oyster density generally increased with seabed roughness and hardness. Total shell volume collected with live oyster samples was positively related to seabed hardness but was not related to slope or roughness. The post restoration surveys are unfolding.

Geohabitats and Seabed Characteristics at Natural Gas Seepage Sites of the Barents Sea

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Since 2007 Lundin Norway has, in collaboration with academic and governmental partners as well as commercial vendors, developed an extensive seabed investigation program focusing on: seabed morphology and its relation to mapped subsurface geology, habitats for different life-forms, geohazards that might be relevant to future drilling, but also features that can be directly related to petroleum exploration and underlying hydrocarbon reservoirs. The main study area in this context has been the Barents Sea, especially around current Lundin-operated exploration licenses, where seismically defined shallow gas anomalies as well as indications of gas seepage have been identified. We have collected several thousand km^2 of multibeam echosounder data, high resolution interferometric synthetic aperture sonar data (HISAS), millions of black and white and color photographs of the seafloor, hundreds of drop cores and dozens of biological, methane-derived carbonate crust and physical gas samples.

The seafloor data collected during a number of surveys spanning the period 2008 to 2016 have yielded important observations about the nature of the seabed such as pockmarks, iceberg plough marks, glacial prod marks, carbonate crusts, bacterial mats and ongoing/past gas seepage. These observations have provided the basis for interpretation of seabed features and their relation to subsurface geology, which can be directly related to petroleum exploration and mapping of deeper hydrocarbon reservoirs.

Detailed examination and sampling of active gas leakage sites (identified by sonar and high-resolution seabed mapping) using remotely operated vehicles has revealed a strong leakage of thermogenic gas occurring today. Stable isotope obtained from carbonate crusts indicate their formation via anaerobic methane oxidation. As such, carbonate crusts can be used to identify and distinguish sites of thermogenic vs. biogenic gas leakage. Carbonate crusts have additionally been dated using the Uranium-Thorium method, yielding clustering of ages between 8 and 15 thousand years, but also some younger ages, indicating multiple episodes of gas leakage in the (geologically) recent past.

Sites of active gas leakage are characterized by abundant macro- and micro-fauna, as well as extensive occurrence of microbial mats. Such sites are hot-spots of biological activity, as also evidenced by abundant fishing related trawl marks on the seafloor. We have constructed a seafloor lander equipped with a variety of sensors to monitor gas seepage rates, temperature, pressure, water composition and biologic activity for the period of one year in order to cover as many temporal scales as possible. Our aim is thus to better understand the periodicity and rates of natural gas leakage as well as the effects on seafloor ecosystems.

The approach we have established integrates seafloor data and the results of systematic chemical, physical and biological sampling with geological records obtained through more traditional geophysical surveys. The combined datasets significantly enhance our understanding of the dynamic processes occurring and controlling present and past petroleum seepage in an arctic environment.

Mapping Vulnerable Marine Ecosystems in Arctic and Sub-Arctic Waters

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Distribution of vulnerable marine ecosystems (VME´s) in arctic and sub-arctic waters is poorly known. The NovasArc (2016-2018) project, funded by the Nordic Councel of Ministers, represents a continuation of a decade-long research collaboration between Iceland and Norway, joined recently by the Faroe Islands. One of the objective of the NovasArc project is to map the distribution of VME habitats and indicator species in the area between Greenland Sea and the Norwegian Sea, and between 62°N and the Svalbard archipelago. Species distribution models using a maximum entropy approach (MaxEnt) were used to predict the distribution of VME´s and their indicator species within this area. An extensive database with records of VME indicator species was compiled from habitat mapping surveys, bycatch data from bottom fish surveys, and records published in reports and peer reviewed publications. Predictors included terrain analysis parameters, bottom temperature and salinity estimates obtained from the NISE (Norwegian Iceland Seas Experiment) project, among others. This project is significantly increasing the knowledge on distribution VME´s in arctic and sub-arctic waters, allowing for the evaluation of potential interactions with fisheries and other anthropogenic activities and providing an important input for managers.

Exploration for Offshore Placer Deposits: Integrating Shallow Seismics with High Resolution Seabed Mapping Techniques - NW Mayo, Ireland

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Ireland has not yet fully explored the potential for economically viable offshore mineral deposits. Heavy mineral rich sands have been identified in Ireland bearing lucrative Ti-rich minerals e.g. ilmenite, rutile and titanite but could also possess other economically important minerals i.e. rare earth elements (REEs) and platinum gold elements (PGEs), amongst others. Their distribution and accumulation are controlled by source, hydrodynamics and a tendency to sort by individual mineral densities therefore understanding sediment transport pathways is imperative in identifying priority targets and assessing economic viability.

In NW Mayo, heavy mineral sand deposits have been found on beaches and offshore Ireland and are forming offshore placers. A multidisciplinary approach is being employed to quantify, characterize and map potential offshore deposits, through a combination of geophysical (high-resolution shallow seismics, multibeam echosounder bathymetry and backscatter) and geochemical techniques (Raman, EDS, LA-ICP-MS and trace element analyses). Sediment grain size and composition distribution mapping within bays are utilized as vectors for concentration of sands but will also aid by identifying spatial and temporal sediment sources.

Preliminary results show the presence of economic Fe-Ti oxides onshore with a significant volume offshore. High-resolution single channel reflection seismic data reveal concentrations of sand ranging between 10 m to 20 m in thickness from Clew Bay, Keem Bay and offshore of Dooega (South Achill) with other locations pending interpretation. Ongoing fieldwork and analyses strongly indicate an onshore – offshore heavy mineral exchange.

Probabilistic Substrate Mapping in Rivers and Seas with Conditional Random Fields of Acoustic Backscatter

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We present a fully connected conditional random field (CRF) algorithm for discriminative substrate characterization using backscatter measurements from multibeam echosounders. The CRF considers both the relative backscatter magnitudes of different substrates as well as the proximity between substrate classes, and can be optimized using parameters. The approach is applicable for single-frequency (monospectral) and multi-frequency (multispectral) backscatter data. The algorithm can be used in conjunction either with sparse observations of the bed (grab samples, photo/video samples) or, where bed observations or physical samples are unavailable, with geoacoustical model outputs such as roughness or acoustic impedance.

We demonstrate the CRF algorithm by presenting estimated substrate maps from both seabed and riverbed environments, using data from three different multibeam systems. First, seafloor sediment maps are generated using multispectral (100, 200, and 400 kHz) and monospectral backscatter data collected with a R2Sonic 2026 multibeam system during surveys of Bedford Basin, Nova Scotia, and Patricia Bay, British Columbia. These data are provided by R2Sonic for the 2017 Multispectral Backscatter Competition. Second, riverbed sediment maps are generated using 400 kHz backscatter collected with a Reson 7125 and Norbit iWBMS multibeam system during surveys of the Colorado River in Grand Canyon. Additionally, we examine the performance of the CRF approach to data inputs from multiple surveys of the same area with different systems operating at different frequencies.

We show that the CRF algorithm is computationally efficient, flexible, and accurate, outperforming a generative probabilistic approach based on a Gaussian Mixture model for both monospectral and multispectral backscatter inputs. We also show how the CRF model may be used in conjunction with multispectral backscatter data and outputs from a mathematical geoacoustical model, in order to predict the physical properties of the seafloor at a finer spatial resolution than is possible using the geoacoustical model alone. The algorithms presented here are coded in a python toolbox for Probabilistic acoustic Sediment Mapping, called PriSM, which can be used for both monospectral and multispectral backscatter. The toolbox is freely available at https://www.danielbuscombe.com/prism/. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Bedford Basin R2Sonic 2026 Backscatter – ML Classification Based on Modes of 3D Histograms of CV Scores

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3. Acoustic Imaging P/L
4. Fugro Surveys P/L, Balcatta Western Australia

An approach is presented for classifying the seafloor that exploits the multi-frequency backscatter response from the R2Sonic 2026 in combination with the multi-angular response curves, based on classical statistical procedures for discrimination and Gaussian-based maximum likelihood classification.

A canonical variate analysis (CVA) of the backscatter – incidence angle curves for the three backscatter frequencies, based on contiguous segments along the tracks, is used to provide a display of the main patterns in the backscatter data in the first few CVs. Uniform segments of the multibeam tracks are identified based on their similarity to local modes in 2D density plots and 3D histograms of the CV2 – CV1 scores.

Clusters evident in CV2 – CV1 plots of these uniform regions are then interpreted in conjunction with corresponding backscatter – incidence angle plots to identify representative reference classes that define the main seabed classes of interest.

A Gaussian-based maximum likelihood classification, incorporating information from neighbouring pixels, completes the analysis.

Overlooked Deep Water 'Reefs': Mapping Mediterranean *Dendrophyllia* Habitats

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Stony coral bioconstructions (reefs s.l.) characterize the temperate Mediterranean Sea from shallow to bathyal depths. Most research has been focused thus far on the zooxanthellate *Cladocora caespitosa* known to form small reefs between 2-40 m, and the 'white corals' *Madrepora oculata* and *Lophelia pertusa* (CWC: cold-water corals) documented to build conspicuous bioconstructions between 200-800 m. Much less information is available on intermediate stony coral reefs as those formed by the 'yellow corals' *Dendrophyllia* spp.

In this respect, the branching scleractinian *Dendrophyllia cornigera* is a considerable component of Mediterranean mesophitic habitats but extending its presence down to bathyal depths. More in detail, *D. cornigera* may form on hard substrates either relatively large bioconstructions at intermediate water depths (ca. 80-200 m) or contribute to CWC habitats as scattered colonies between 200-600 m. Furthermore, post-mortem skeletal accumulations could generate graveyard bottoms, especially on seamounts and banks, eventually exploitable by marine life.

Beginning from 2016, systematic research is conducted in Italian waters to monitor valuable marine habitats in the frame of the E.U. Marine Strategy Framework Directive (2008/56/EC). Multibeam and Remotely Operated Vehicle (ROV) surveys between 80-600 m disclose the role of *D. cornigera* as important habitat-makers in the southern Adriatic, northern Ionian and eastern Tyrrhenian seas, and in the Strait of Sicily. Habitat mapping of sites containing *D. cornigera* clearly points out that this coral is consistently an extra in the 'white coral' grounds (such as the Santa Maria di Leuca and Southern Adriatic CWC provinces) or the protagonist in their absence at shallower depths (such as the Amendolara Bank in the Ionian Sea).

In this context, we have examined *D. cornigera* abundances in each investigated site, the shape of the bioconstructions, and the seafloor morphometric variables influencing its distribution to identify preferential habitats. *D. cornigera* apparently prefers to settle gentle slope situations, forming larger colonies (> 1 m). Furthermore, the analysis of type of trophic habits of macro- and megabenthos associated with *D. cornigera* reveals a prevalence of encrusted filters (e.g., encrusting sponges) at those shallower-water sites where *D. cornigera* produce large bioconstructions, whilst at CWC-dominated situations, with smaller and scattered *D. cornigera* colonies, there is a relative abundance of erected filter-feeding organisms.

The Continental Shelf of Southern South Africa as a Refuge for Early Modern Humans through Glacial Conditions

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With the onset of the rhythmic Quaternary glacial-interglacial climate cycles, South African shorelines have shifted between a maximum lowstand depth of 130 m below and a maximum highstand elevation of 13 m above present-day sea level approximately every 100 kyr since 900 ka. During most of this time (~90 %) sea level has been significantly lower than it is at present, exposing a now submerged terrestrial ecosystem of what is now the continental shelf and drastically altering the landscape. The ~500 km long South African South Coast coastal plain was at least doubled and through much of the Pleistocene there was a large rather flat landmass exposed that is now submerged as the Agulhas Bank. From a heritage perspective, the South Coast has one of the richest Middle Stone Age archaeological records in the world, with sea cliff caves and open-air sites on the exposed landscape holding rich archives of early humans. In the vicinity of the town Mossel Bay, multibeam echosounder, side-scan sonar, boomer seismic and pinger seismic data have been collected with full seafloor coverage. Geological samples and observations were obtained by mapping the shoreline and offshore area, the latter using scuba diving and sediment coring techniques. The combination of surficial information with sub-bottom profiling data allowed a depositional history of this shelf to be constructed. The rich heritage of the seafloor, linked to the evolution of Homo sapiens, further highlights the need to understand the resources of the submerged environment. In the case of the South Coast, a depositional record for at least the last 250 ka showed that accommodation space for coastal deposits is controlled by antecedent drainage pathways and the gradient of the adjacent inner continental shelf. The geological deposits on the emergent shelf indicate a greatly expanded glacial coastal plain that potentially received more rain feeding low-gradient meandering rivers and wetland lakes. These extensive wetland environments provided a rich source of diverse food types which along with abundant marine resources on the shoreline made the Southern Coastal Plain an ideal habitat for our ancestors. Piecing together fragments of information from these submerged landscapes aims to inform the evolution of this environment through time. In addition to the aspects of a submerged landscape, South Africa is an excellent locale to study past fluctuations in global sea level. The relevance of these studies to Quaternary palaeoenvironments is demonstrated here through numerous case studies.

Case Study from the South African Nearshore Mapping Programme: Continental Shelf Deposits and Processes in Table Bay, Cape Town

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The Council for Geoscience has initiated the South African Nearshore Mapping Programme (SANMAP). The broad scientific aims of SANMAP are to acquire new marine geophysical datasets from regions of strategic interest and importance; to develop a high-resolution geophysical/geomorphic/palaeoenvironmental database for key sections of South Africa's continental shelf embracing technological development and innovation; and to design a methodology for marine geoscientific data management. With these data, the CGS is generating models of offshore geological and palaeoenvironmental settings under various climatic/sea level scenarios and create habitat maps for the living marine resource to be applied in sustainable marine planning through collaboration with partners, as two examples. The maps are being produced as a series of 1:50,000 geological maps, both covering the shelf or presented as seamless onshore-offshore geological maps where they extend across the shoreline. Methods applied in new marine geophysical surveys incorporate the application of multibeam bathymetry, side-scan sonar, boomer seismic profiling, pinger seismic profiling and marine magnetics. We present the seafloor of Table Bay as a case study of the outputs of this continental shelf mapping programme.

An Analysis of the Fish Assemblages Around 23 Oil and Gas Platforms off California with Comparisons to Natural Reefs

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Fish assemblage surveys were conducted annually from 1995 to 2013 around oil and gas platforms and natural rocky reefs off the coast of southern California using manned submersibles, or ROVs in a few cases. Every site was not sampled each year, but overall the data set included the fish assemblages (taxa specific density and size structure) associated with 23 platforms and 70 natural reef sites that was categorized into 50 m depth zones (from 0 to 350 m depth) and habitat types.

Both depth and habitat type had significant effects on fish community structure. A clear depth gradient in the fish assemblages across all habitat types is evident in ordination analyses. The influence of habitat is primarily due to clear separation between fish assemblages in platform midwater habitats (fish observed within 2 m of platform crossbeams at various depths throughout the water column) from those in all other seafloor habitat types (i.e., natural reefs, platform bases and platform associated shell mounds).

Platform midwater habitat fish assemblages tended to be more similar to those on different platforms in the same depth zones, than those from different depth zones on the same platform. For platform seafloor habitats (i.e., platform bases and associated shell mounds), depth appears to be the most important factor in structuring their associated fish communities, followed by geographic proximity, with habitat type (base or shell mound) only becoming important at the smallest spatial scales.

The distribution of young-of-the-year fishes suggests platform habitats serve a nursery function. Further, patterns in fish size-structure, species richness and species-specific densities demonstrate how fishes distribute themselves across a depth gradient on platform structures, while they tend to co-occur in natural rocky reef habitats with more limited vertical relief.

The Influence of Ocean Currents on Macrofauna Distribution in a Coarse Grain Habitat

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Subtidal coarse grain (> 63 mm) substrates provide a habitat for a variety of macrofauna species. The density of macrofauna can differ significantly on a scale of decimeters to meters. The mechanism of colonization is interesting because it helps to map macrofauna in other coarse grain habitats.

Videos of the “Helgoländer Steingrund” (HSG) research area in the German Bight have revealed areas of irregular macrofauna density, but the extent of the influence of water currents on the distribution is still unknown.

In order to answer that question an acoustic Doppler current profiler (ADCP) that measures water speed and direction was deployed. The data were collected along four tracks, and current speeds and directions were then correlated with the densities of different macrofauna species.

The results show that there are two main macrofauna species colonizing the sea floor of the HSG: the bryozoan species *Alcyonidium diaphanum* and *Flustra foliacea.* A strong correlation between the water currents and the presence of *F. foliacea* was identified, with *F. foliacea* preferring non-uniform current directions that change significantly over time. In more constant current areas, the substratum is mainly barren. The presence of *A. diaphanum* is much less influenced by the currents and depends to a greater degree on the distribution of grain sizes. *A. diaphanum* primarily colonizes transition zones between sandy and boulder areas.

In conclusion, grain sizes and currents are important drivers of the irregular macrofauna density. The extent of the influence is specie specific.

Faunal Characterization and Predicted Distribution of Cold-Water Coral Assemblages on the Cabliers Coral Mound (Western Mediterranean)

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Cold-water coral (CWC) reefs are key geomorphic features for benthic organisms, as they increase the spatial heterogeneity and complexity of the habitat, enhance the local hydrodynamics, provide substrate for benthic organisms and shelter from predators. Therefore, understanding their environmental and ecological dynamics has important implications in biodiversity conservation. This is particularly true for the Mediterranean Sea, where living CWC reefs are uncommon.

In this study, we present a quantitative analysis of the CWC assemblages from the Cabliers CWC Mound, in the Alboran Sea (southwestern Mediterranean), and the preliminary results from statistical models predicting their distribution. The Cabliers Mound extents NE- SW for 20 km, raises up to 100 m from the surrounding seafloor and is partly topped by living CWC reefs. The encountered megabenthic species were quantified through the analysis of ROV videos and correlated with the geomorphic characteristics of the reefs, extracted from 1m resolution AUV MB bathymetry. Both video footage and AUV bathymetry were acquired in 2015 during the SHAKE cruise by means of the ROV Max-Rover (HCMR) and the AUV IdefX (IFREMER). The ROV transects covered a total distance of 5164 m, in which 7855 organisms were identified. *Phanopathes rigida* was the most conspicuous species with 1541 living patches followed by Acanthogorgia hirsuta (1490) and *Madrepora oculata* (1217). Canonical correspondence analyses (CCA) on the faunal and environmental data allowed the identification of three main megabenthic communities, one of them dominated by the framework-building corals *Madrepora oculata* and *Lophelia pertusa*. The distribution of both the corals and the associated megabenthic species is correlated with the morphology of the mound, with antipatharians mostly occurring at its flanks and framework-building corals growing on top of reef-mini mound- features located at the mound's top.

The model predictions (BRT, RF, GLM and GAM) indicate that the areas of the mound characterised by increased roughness, shallower depths and very gentle slopes, coinciding with the top of the reefs, have a higher suitability for the growth of *M. oculata* and *L. pertusa.*

Overall, obtained results provide crucial information on the state of conservation of the Cabliers CWC assemblages and can represent a baseline for future monitoring and conservation strategies of these unique CWC reefs in the Mediterranean Sea.

The Utility of Multispectral Backscatter for Characterizing Benthic Habitats§

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Marine managers routinely use benthic habitat maps to make decisions about the seascape. Acoustic backscatter is often critical for developing these benthic habitat maps in turbid areas or at deeper (> 30 meters) depths. Recent technological advances in multibeam echosounders have made it possible to collect multispectral backscatter (i.e., intensity at multiple acoustic frequencies). This type of data could help researchers more accurately map benthic habitats, and by extension, help managers more confidently make decisions. However, new research is needed to better understand the utility of this new technology for characterizing benthic habitats, including surficial substrates and biological communities. To help fill this information gap, we mapped three surficial substrate types (i.e., rock, cobble and mud) and four biological cover types (i.e., clams, limpets, urchins, bare) using multispectral data in Bedford Basin, Canada*. The relative importance of different acoustic frequencies was calculated to identify which frequency was most influential in the habitat mapping process. Response curves were generated describing the acoustic thresholds that were most important for distinguishing among benthic habitat types. The 100, 200 and 400 kHz frequencies were equally important for mapping bare substrate (colonized by < 10% biological cover), but the 100 kHz frequency was the most important multispectral predictor for the remaining habitat types. Key thresholds for distinguishing between habitats changed based on frequency (i.e., -16 dB at 100 kHz, -20 dB at 200 kHz and -23 dB at 400 kHz), but were very similar (± 2 dBs) across habitat types. These findings suggest that multispectral data may enhance our ability to detect certain bottom types in temperate environments, depending on the specific research needs and management goals. Researchers and marine managers can use this information to make more informed decisions *a priori* about the backscatter frequency (or frequencies) best suited to their benthic habitat mapping needs, research objectives and management actions.

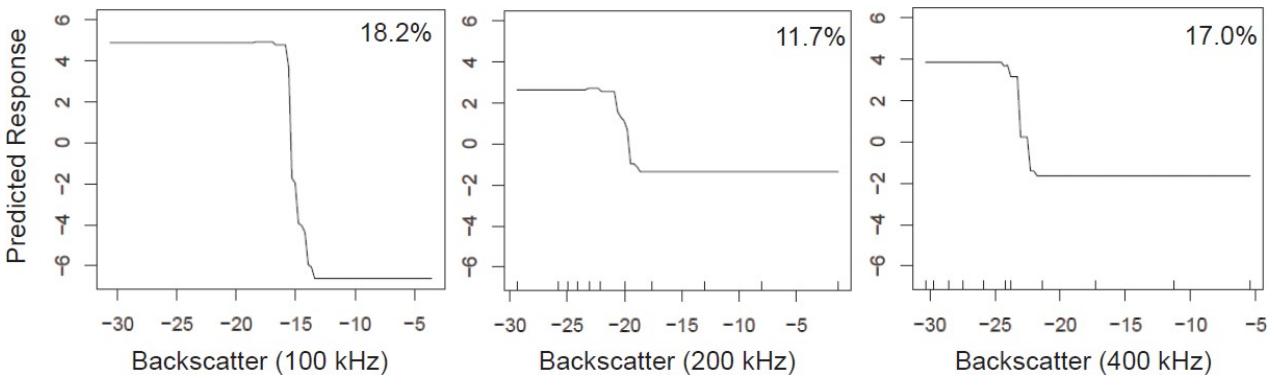

Figure 1. The multispectral backscatter response curves for the bare substrate habitat model. The numbers (top right) denote the relative importance of each frequency for model development.

* Multispectral dataset provided by R2Sonic for Multispectral Challenge.

§ Manuscript is currently in review with PLoS One.

Integrating Remote Sensing and Diver Observations to Predict the Distribution of Invasive Lionfish on Bahamian Coral Reefs

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Ecosystem based management (EBM) is a holistic approach that uses species specific data to guide management but also incorporates environmental factors such as habitat and human-caused effects. Instead of focusing on the species of interest in isolation, EBM focuses on the system as a whole in order to create a comprehensive plan that ensures sustainability of the entire system. Though EBM is more common in terrestrial systems, this it is becoming more popular in management of marine ecosystems.

The coral-reef ecosystem in the Bahamas has experienced severe stress in the last few decades. In addition to habitat degradation due to coral bleaching, overfishing, and disease, a predatory fish species invaded the region in the early 2000s. The Indo-Pacific red lionfish (*Pterois volitans*) has added insult to an already injured system by reducing densities of a variety of reef fishes, which in some cases leads to local extinction of species. If we wish to preserve diversity of coral-reef fishes, it is now more important than ever to have a comprehensive view of species of importance and distributions in order to manage and conserve the coral-reef ecosystem effectively.

Here I present distribution and abundance maps of the southern edge of Eleuthera Island, the Bahamas for invasive red lionfish. Previous datasets for this area are relatively depauperate and mostly limited to long line catch and release of sharks, and time series data of large grouper for one or two isolated locations. By incorporating species counts and microhabitat observations from SCUBA surveys over multiple years with satellite derived bathymetry data, we can create a more comprehensive picture of the macrofauna of the area that will aid the Bahamian government with removal effort and to manage and conserve species of interest.

The coarse habitat predictors explained 34% of the variance and was accurate 73% of the time predicting presence and absence. When microhabitat data collected by a diver was added the variance explained increase to 67%. Adding in biotic data, counts of a potential competitor (Nassau grouper) increased the variance explained to 56%. Though the additional data sets increased the variance explained by the models, it is unclear whether the additional time needed to collect the data is worth the effort. The original model was accurate 73% of the time predicting presence of lionfish, which is likely to be sufficient from a management perspective to help aid in removal efforts.

Incorporating Spatial Analyses into Conservation and Monitoring of Deep-Sea Megafauna in Marine Protected Areas (MPAs)

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Deep-sea ecosystems are being impacted by anthropogenic stressors, such as trawling and oil-gas exploration. Protection of these ecosystems is delayed by limited understanding of spatial distribution, suitable habitat, species associations, and recruitment. Imagery was analyzed from the Laurentian Channel AOI and 3 canyons (Corsair, Georges, Fiddlers Cove) on the western Scotian Slope in the Northwest Atlantic Ocean. We used two sampling designs, exploratory linear transects and a systematic-cluster transect array, and will compare the information that can be extracted from each method. Megaepifaunal biodiversity, abundance, and species-species associations were identified at each site. For example, at Fiddlers Cove, different types of Gorgonian corals (e.g. *Acanella*, *Desmophyllum*, and stoloniferous coral), soft corals, and sponges occurred mainly on outcrops; sea pens and anemones, along with large colonies of *Paragorgia arborea* were present in Corsair Canyon; and several Gorgonian corals, anemones, lobsters, and Holothuroidea were present in Georges Canyon. We will use spatial analyses to measure spatial structure at local and regional scales, identify species-environment associations, and predict suitable habitat for deep-sea megaepifauna. Overall, the study will provide a broader understanding of deep-sea megaepifaunal ecosystems, and develop recommendations for a deep-sea MPA monitoring framework to achieve effective conservation that promotes biodiversity.

Reclaiming the Knowledge of Fisheries Habitat Distribution Within a Customary Management Framework

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A comprehensive understanding of the spatial distribution of key fisheries habitats once underpinned the sustainable management of culturally important fish stocks in southern New Zealand. Much of this knowledge - which sustained māori communities and was transferred through whakataukī (stories) and oral tradition - has now been lost. In order to regain kaitiakitanga (stewardship) and sustainable management this information must be reclaimed.

Customary Protection Areas (CPAs) in New Zealand provide the legislative framework to alter fishing regulations at ecologically and culturally relevant scales i.e. small scale, local management to achieve local objectives. These areas encompass diverse, productive, shallow (< 30 m), near-shore ecosystems. In order for managers to make informed decisions, high resolution data regarding the distribution of key habitats that support fisheries of importance is needed. This project utilises a R2 Sonic 2026 multibeam echosounder to produce bathymetric and habitat maps within CPAs around New Zealand's South Island. It couples this information with drop camera and SCUBA surveys that quantify habitat structure, and local scale fisheries assessments to generate a better understanding of the spatial distribution and status of valuable habitat. This approach enables more effective management including the refinement of reserve boundaries, direction of restoration efforts, identification of kōhanga (nursery) habitat and implementation of bylaws such as modifying catch limits and instating rāhui (closures).

By marrying the latest technologies in marine mapping and habitat assessment with mātauranga māori (customary knowledge) under a flexible legislative framework we hope to provide an alternative approach to fisheries management that is led from an ecologically relevant, customary management foundation.

Marine Geomorphometric Toolbox (MGT): A Set of Tools for Bathymetry Segmentation

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Multibeam Echosounder (MBES) datasets along with their derivative products, such as seafloor morphology and sediment type, are commonly used to explain the spatial distribution of benthic assemblages (i.e., as surrogates), making these datasets one of the most valuable sources of information to characterize seafloor habitat. However, owing to the wide range of possible analysis scales and seascape ecological units of interest, a unique and generic framework for terrain analysis that will work in any situation is difficult, if not impossible, to achieve. Therefore, a modular, extensible set of tools for the generation of MBES derivative products is crucial for the production of habitat surrogates suited for the development of benthic/demersal species distribution models and thus the better documentation of benthic habitat.

In this paper we introduce the Marine Geomorphometric Toolbox (MGT), a collection of Digital Terrain Analysis algorithms for the segmentation and characterization of MBES datasets. MGT comprises a series of tools for: Terrain Parameter Extraction (TPE), Terrain Feature Extraction (TFE), and GIS Rule-Based Modeling (GRM).

The TPE tools consist of routines to extract surface derivatives including slope, aspect, curvatures, bathymetric position index, roughness, and fractal dimension. The TFE tools can perform bathymetry segmentation via methods based on either differential geometry, or pattern recognition principles and can be used to identify major geomorphological features (e.g., flat areas, peaks, ridges, shoulders, valleys, etc. The GRM set of tools offers a user interface for the development of case-specific geospatial processing routines.

The MGT is written in the Python programming language and is available as an extension to two of the most popular Open Source GIS environments (QGIS and GRASS GIS) as well as a standalone web service.

Semi-Automated Mapping of Cold-Water Coral Carbonate Mounds with Image Segmentation and Random Forest

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Cold-water coral reefs are rich, yet fragile ecosystems found in colder oceanic waters. Knowledge of their spatial distribution on continental shelves, slopes, seamounts and ridge systems is vital for marine spatial planning and conservation. Cold-water corals frequently form conspicuous carbonate mounds of varying sizes, which are identifiable from multibeam echosounder bathymetry and derived geomorphometric attributes. However, the often large number of mounds makes manual interpretation and mapping a tedious process. We present a methodology (Figure 1) that combines image segmentation and random forest spatial prediction with the aim to derive maps of carbonate mound presence and an associated measure of confidence. We demonstrate our method based on multibeam echosounder data (5 m grid, water depths 135 – 270 m below sea-level) from Iverryggen on the mid-Norwegian shelf. Image objects were created by segmenting an 8-bit image of the bathymetric position index (3 by 3 pixel kernel). To make the process more efficient, candidate mounds were identified based on positive relief and pre-existing information. Image objects classified as candidate mounds were exported as a shapefile associated with a wide range of image-object features. One thousand image objects were randomly selected, visually classified and used as sample objects to fit the model and test the predictions. Important and uncorrelated features were selected with the Boruta algorithm and a correlation analysis. A random forest model was fitted and the performance tested. We identified the image-object mean planar curvature as the most important feature. The presence and absence of carbonate mounds was mapped with high accuracy (overall accuracy = 84.4%, sensitivity = 0.827 and specificity = 0.866). Spatially-explicit confidence in the predictions was derived from the predicted probability of the random forest model and whether the predictions were within or outside the modelled range of values. In the future, we will apply the showcased method to other areas of the Norwegian continental shelf and slope where multibeam echosounder data have been collected with the aim to provide crucial information for marine spatial planning.

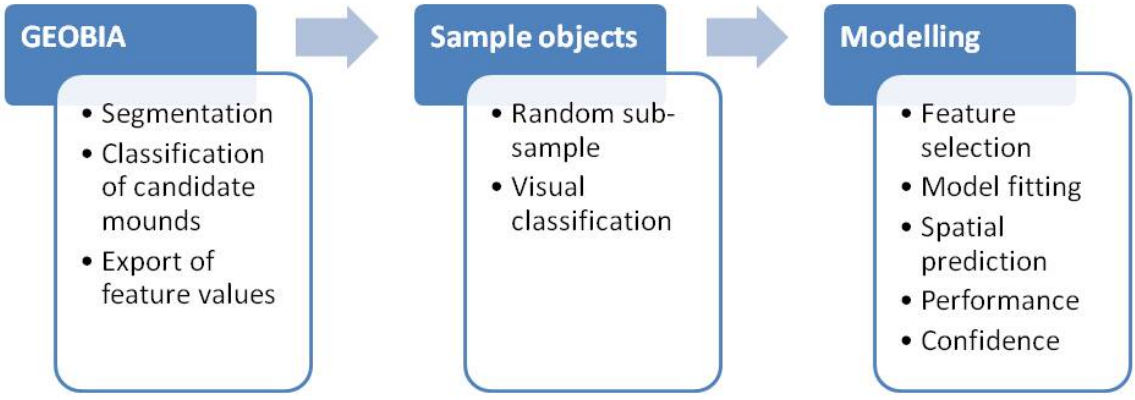

Figure 1. Overview of the general workflow developed to map cold-water coral carbonate mounds and the confidence in the predictions.

Connecting Physical and Ecological Tidal Marsh Processes through a Combination of Remote Sensing Platforms

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Tidal marsh ecosystems are fragile, dynamic, and ecologically-rich transitional zones between fresh and salty water bodies. Due to their location, this zone is berated from all sides by storm events, land use change, anthropogenic alterations of sediment transport, and sea level rise to name a few. Quantifying marsh response to the aforementioned forcings on the physical and ecological dynamics is a herculean task due site sizes, conditions, and remoteness. Rapid technological advances have made some aspects of this issue easier to tackle using remote sensing autonomous platforms such as unmanned aerial systems (UAS), autonomous surface vehicles (ASV), and portable laser scanners to map larger, more detailed marshes areas than previously performed with traditional survey techniques such as quadrat counts, point instrument deployments, and plane-borne LiDAR.

Canary Creek Marsh in Lewes, Delaware was surveyed using a combination of remote sensing platforms and traditional ground truthing techniques including UASs, ASVs, and a backpack-borne LiDAR to collect RGB and NIR images, sidescan sonar (SSS), bathymetry, and laser point clouds. Quadcopter (DJI Phantom 3) and fixed-wing (senseFly eBee) drone images created orthomosaics and digital elevation models following processing in Agisoft Photoscan and Pix4D, both structure-from-motion (SfM) software. SSS and bathymetry were collected using a Seafloor Echoboat and Lowrance 3DStructure Scan with Hemisphere GPS and processed with SonarWiz software. Terrestrial LiDAR was collected using a Velodyne 16L laser and SBG Ellipse D IMU. Ground truthing data included RTK GPS transects for error comparisons of the drone and laser digital elevation models. Vegetation species, percent cover, and percent composition were determined using a 0.25 square meter quadrat and handheld GPS.

Analysis of the collected data consisted of vegetation species classification using manual and automated methods in ESRI ArcGIS. Percent agreement between classifications and ground truthing fell between 75 and 83 percent with the largest errors occurring in mixed species areas. NIR orthomosaics revealed high stands of water and clearly delineated water channels previously invisible to the naked eye or RGB images. ASV surveys will reveal shallow water bathymetry within the creeks and drainage ditches in water as shallow as eight inches deep. These types of shallow water areas had never been fully surveyed due to water depth and deep layers of organic material preventing wading for RTK GPS surveying. Terrestrial LiDAR aims to delineate vegetation canopy height versus bare earth elevation but coverage due to human maneuverability with the system may be a drawback.

Preliminary results indicate seasonal changes in vegetation location show minor movement of species mostly within the well mixed zones of the inner marsh. Changes in water channel widths and locations will be analyzed the year but the collection period is too short to determine if these are long term trends or merely seasonal or event-based responses. Marsh vegetation zonation is well documented in the literature and clearly observed in this study. This points to tidal flooding extent as well as salinity and provides validation data for hydrological and sedimentation modeling of marshes, particularly when including the collected bathymetry. This combination of remote sensing platforms reveals the dense layers of data within tidal marshes for better understanding the interactions between vegetation, water movement, sediment transport, and marsh response to short-term storm events and long-term climate pressures. The collection and analysis methods demonstrated in this study are transferrable to other marsh environments whether swamps, bogs, fens, or freshwater marshes so that the most appropriate monitoring and management practices are employed.

A Pilot Project for Mapping Marine Nature Types Within the NiN Framework, Coastal Norway

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"Nature types in Norway" (NiN) is the Norwegian national standard for classifying and describing environmental and ecological variation. The first version was published in 2009 and was significantly revised in 2015. NiN spans terrestrial, freshwater and marine environments and provides a common scientific standard for mapping, data and knowledge acquisition. Mapping of nature types at the ecological system (local habitat) level has already been adopted for terrestrial mapping, supported by guidelines which have been developed for practical mapping based on NiN theory which is well tested.

In marine and freshwater environments, where the ecology is generally less well understood, work on testing NiN theory and development of practical mapping guidelines is just beginning. In 2017, a pilot project for mapping marine nature in within the NiN framework was initiated on the west coast of Norway (Møre and Romsdal). This project builds upon previous work in the same area, where Marine Base Maps (bathymetry, geology and associated maps) have already been produced, and where some existing biological information are available.

The current project aims both to map nature types according to NiN, and also to test out the theory that lies behind NiN and provide feedback for further development. The project will also provide input to the development of national guidelines for practical mapping according to NiN. This will help the system become more widely adopted by scientists and management, in accordance with parliamentary requirements. Here we provide an overview of the project objectives and main results to date as well as highlighting potential international relevance of NiN concepts.

Towards Multibeam Data Acquisition Specifications which Promote Good Backscatter Data: Experiences from the MAREANO Programme, Norway

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2. The Norwegian Mapping Authority Hydrographic Service

The MAREANO seabed mapping programme (www.mareano.no) is one of the world's largest mapping programmes, which has to date acquired multibeam data across more than 200,000 km^2 of Norwegian continental shelf and slope areas. Whilst the focus of multibeam mapping has traditionally been on acquisition of good bathymetric data the backscatter data have been a vital source of data for geological mapping by the Geological Survey of Norway (NGU) ever since the start of the MAREANO in 2006, even though the quality of these data have been variable.

Whilst some of the MAREANO multibeam data are acquired by the Norwegian Hydrographic Service (NHS) on their own vessels, the bulk of the work is done via commercial tender, following specifications set out by NHS in partnership with NGU. Over the past few years, spurred on by the work of the GeoHab Backscatter Working Group (BSWG), MAREANO has made several changes to the multibeam specifications to try to redress the balance between bathymetric and backscatter data quality such that the quality of each is equally important.

We examine the impact of these specification changes on the quality of backscatter data acquired, as well as on elements of the multibeam processing workflow including quality control. We also present recent examples of data acquired in Arctic waters where the environmental conditions are particularly challenging, and report on how these experiences have challenged existing acquisition and processing software as well as made NHS and NGU reflect on the specifications. We discuss potential further revisions to specifications that may help promote the acquisition of good backscatter data without unduly compromising bathymetry data. We hope that the MAREANO specifications can provide a basis for the development of a suite of standard multibeam acquisition specifications for different purposes that will help continue the work of the BSWG, and also contribute to global mapping initiatives under Seabed 2030.

From Shallow Reefs to the Abyss: Seafloor Substrate Maps to Support Fisheries and Coral Science around Hawai‘i and the Pacific Remote Islands Marine National Monument (PRIMNM)

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We have developed seafloor substrate classification approaches for Hawai‘i and PRIMNM to be applied in shallow and mesophotic reef environments, as well as at greater depths on seamount slopes, oceanic plateaus, and the surrounding abyssal floor. As validation data of sufficient geographic accuracy are sparse or absent, we have adapted unsupervised classification methods using satellite imagery and multibeam echosounder (MBES) bathymetry and backscatter data to characterize the spatial distribution of hard substrates. Pacific island marine habitats are facing a variety of environmental and anthropogenic pressures, and marine scientists are working to understand ecosystem responses. In many areas, however, simple baseline information (e.g., accurate substrate mapping) that it is needed to understand and adequately manage these ecosystems is currently not available.

In ‘deep’ areas below satellite penetration (~30-5,500 m), we use MBES bathymetry and backscatter acquired from multiple vessels (e.g., 30 kHz system for bathyal depths). Within the PRIMNM, classifications are based on collated data at varying resolutions and scales, whereas within the main Hawaiian Islands, classifications are based on previously synthesized data products gridded at 5-m resolution. In both areas, the classification method employs clustering on a number of key bathymetric derivatives together with normalized backscatter data. In shallow areas (~0-30 m), we utilize depth-invariant seabed indices from 2-m resolution WorldView2 multispectral satellite imagery, again using clustering to identify groups and segregate areas of shared attributes. We initially intended to use terrain metrics from satellite-derived bathymetry, but while broadly accurate, these data were found to include too much random/textural noise to discriminate between distinct geomorphic features.

Seafloor substrate maps of the type we describe form the basis for stratified surveys used to generate fishery-independent estimates of bottomfish abundance. However, binary classifications such as hard/soft are typically based on subjective thresholds for continuous underlying variables. What is “hard” for one species may be “soft” for another. We describe a logistic regression method for objectively setting an appropriate hard/soft threshold for the Hawaiian Deep7 stock assessment survey, comparing results from new mapping with previous results, which used backscatter data alone to predict hard substrates.

In another application around Hawai‘i, the Atlantis Ecosystem Model depends on spatial biomass distribution maps of key species. Direct-observation survey data however are rarely complete, so we often rely on spatially-continuous predictive (proxy) maps. These maps are being derived statistically through overlapping biomass data on our continuous substrate classifications, together with further terrain derivatives and environmental metrics.

Predicting the Distribution of Threatened Stony Coral in Shallow and Mesophotic Caribbean Coral Reef Ecosystems

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Mesophotic coral ecosystems (MCEs) (30 - 150 m) in the Caribbean contain a unique assemblage composed predominantly of orbicellid and agariciid stony corals at high cover relative to most shallow coral reefs. Despite the importance of these high coral cover ecosystems, there is a large gap in the knowledge of where high coral abundance MCE habitats are present in the Caribbean. Part of this knowledge gap stems from a lack of understanding of what factors control the distribution of MCE orbicellids compared to their shallow reef counterpart, which are driven by seafloor topography and lack of wave exposure. By determining the environmental factors that drive MCE distribution, species distribution modeling (SDM) can be used to predict orbicellid distribution at mesophotic depths in the Caribbean, thus, locating potential high cover mesophotic reefs with important ecological attributes.

Using the US Virgin Islands (USVI) with its well-characterized south shelf mesophotic reefs, SDMs were used to explore environmental constraints on the spatial patterns of orbicellids. Presences and absences of orbicellids were compiled from prior surveys including 1) the University of the Virgin Islands (UVI) mesophotic spatially stratified random drop camera and diver surveys characterizing the north and south shores of St. Thomas, 2) UVI's Territorial Coral Reef Monitoring Program (TCRMP), 3) NOAA's National Coral Reef Monitoring Program (NCRMP), and 4) NOAA National Centers for Coastal Ocean Science's (NCCOS) ongoing project on mapping the habitats of the USVI insular shelf. Environmental variables included NOAA NCCOS high resolution bathymetry, associated derivatives derived in ArcGIS, NASA sea surface temperature data, wave data from the Caribbean Coastal Ocean Observing System (CariCOOS), and benthic currents from the Regional Ocean Modeling System (ROMS).

Maximum entropy models (presence only) and generalized linear models (presence/absence) were created for orbicellids expanding from depths of < 1 m to 150 m along St. Thomas and St. John, USVI. Models will be evaluated based on cross validation, area under the receiver operator curve (AUC), and the Akaike's Information Criterion (AIC). Finally, the resulting predictive map and models will be assessed to see if it is sensible ecologically based on expert opinion.

Cross Shelf Changes in Reef Morphology and its Implications for Connectivity and Conservation

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The Abrolhos Bank is an enlargement of the Eastern Brazilian Shelf. It comprises the most important reef complex in the Western Atlantic, forming a complex mosaic of seabed habitats. Considered as an open shelf, this carbonate platform is very distinct in terms of reef morphology when compared with the classic barrier reefs. Reef distribution has been described in terms of two distinct areas, the inner and outer arcs. The mushroom-shape pinnacle, locally known as chapeirões, is an endemic form and dominates the shallow water reef morphology.

Here, we present results from different detailed acoustic surveys carried out along a shelf gradient, from 10 to 40m deep. Simultaneous multibeam and sidescan data were collected in a 40 km^2. New results show that reef morphology can be classified in 4 distinct types: high-relief Banks/Plataforms, Pinnacles/Chapeirões, low-relief banks/hardground, Small Pinnacles.

Isolated platforms usually occur along the shallow inner arc, where tall Chapeirões are well developed. Seaward, pinnacles become to show deeper tops (from 2-3m to 10-20m) and an important change in reef morphology. The deeper pinnacles have a distinct morphology and do not resemble the Chapeirões. The deepest reefs mapped in this study are very distinct from the anyone else ever mapped in Abrolhos. Low-relief banks/hardground are extensive reefs, with no more than 2m in height, showing an elongated form. Preliminary results in the benthic community shows that the endemic and so called coral reef framework builders in the Abrolhos area are not present in the 30-40m deep low-relief banks.

This new finding brings a new concept in terms of potential benthic and fishing connectivity within the area, considering that seaward from these reefs the dominant habitat is rhodolith beds.

Marine Geomorphology of Cubbera Snapper Spawning Aggregation Sites in the SW Atlantic

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Spawning aggregations of cubbera snapper *Lutjanus cyanopterus* are spectacular events of transient nature that occur at specific places and are associated to particular topographic features. From 2011 to 2017 we conducted surveys along the Northeast Brazilian Coast from 7ºS to 16ºS latitude. The continental shelf in this region varies from 18 to 5 miles wide, is typically carbonatic, featuring drowned reefs associated to sea level changes. Occurrence and timing of spawning aggregations was first inferred from monitoring of fisheries landings, using both CPUE (catch-per-unit-effort) and reproductive stage analysis. Fishery surveys, biological sampling, technical dives and towed cameras prospections were used to validated the occurrence of events and describe locations. In situ verifications of spawning aggregations were positive in six locations, all being known fishing grounds. We used single-beam bathymetry and towed cameras for mapping and classification of benthic habitats as well as behavior of both fishing fleet and fish aggregations in one site. Spawning aggregations of cubbera snapper typically occurred at outer portions of shelf valleys (paleochannels), at depths from 56 to 70 meters, distant less than 2 miles from the opening on the steep shelf break. Fish swam encircling an area of 2,1 ha around the channels were bottom habitats include sponge-coral and high relief reef formations. These findings are in contrast with previous studies in the Caribbean, where aggregations were described to occur at reef promontories. As local oceanographic features, including tidal cycles, differ between regions, it is likely that interactions may result in distinct patterns, explaining both selection and persistence of sites. Furthermore, neighbor shelf valleys were also mapped and camera-surveyed in the area with no record of aggregations, indicating that particular and more cryptic local features may also play an important role. These areas are critical for conservation of fish and fisheries and their protection from possible impacts, including unregulated fisheries, should be a priority. The Brazilian NE shelf break region has been declared an Environmentally and Biologically Significant Area (EBSA) according to the Convention of Biological Diversity (CDB), but specific protection and management actions area still lacking for the area.

A Cost-Effective Method for Mapping Seabed Habitats using Calibrated Backscatter: A Case Study for the Multi-Year EVHOE Bottom-Trawl Survey using Simrad ME70 Multibeam Echosounder

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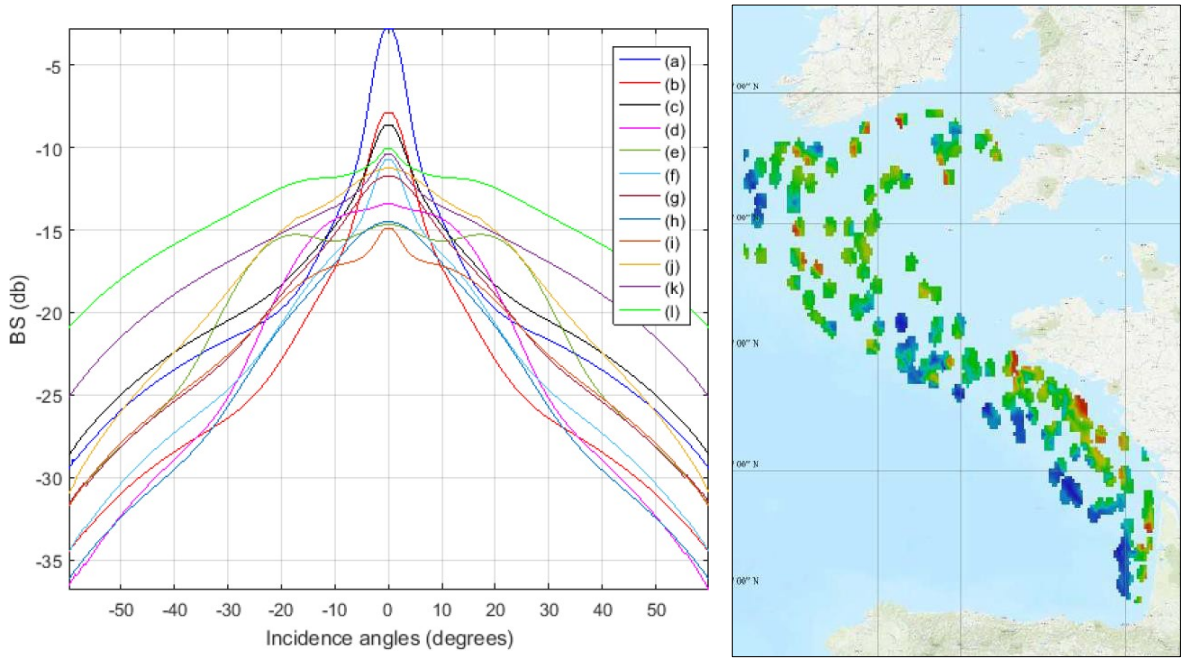
An automated signal-based method was developed in order to analyse semi-automatically the seafloor backscatter data logged by the Simrad ME70 calibrated multibeam echosounder. The dataset was acquired using a standardized protocol in order to map the area covered by the trawl during 8 years (2008-2016) of the annual EVHOE bottom-trawl survey in the Bay of Biscay, France and Celtic Sea, Ireland. The processing consists first in the clustering of each trawling area into a small number (2 or 3) of homogeneous sediment types, based on the backscatter average level at one or several incidence angles. Second, it uses their local average angular response to extract discriminant descriptors, obtained by fitting the field data to the Generic Seafloor Acoustic Backscatter parametric model (Lamarche et al., Cont.Shelf Res., 2010). Third, these descriptors are used for seafloor type classification. The method was applied for seafloor- type classification into 12 classes, to a dataset of 158 spots surveyed for demersal and benthic fauna study and monitoring. Qualitative analyses and classified clusters using extracted parameters show a good discriminatory potential, indicating the robustness of this approach. The study resulted in a large-scale mapping of the seafloor areas surveyed by the EVHOE cruises.



Left: Mean calibrated backscatter angular response for twelve sediment types in the Bay of Biscay and Celtic Sea ordered a priori from (a–l) from fine sediments to the coarsest ones. Right: Resulting segmented mapping of the seafloor acoustic response.

Seabed Segmentation of Sidescan and Multibeam Sonar Data in SonarWiz

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For several years, Chesapeake Technology's SonarWiz has provided a software module to develop seabed characterization polygons using sidescan sonar imagery. In SonarWiz 7, this tool is further enhanced to support most swath mapping sonars including interferometric sidescan systems and multibeam echo sounders. In addition, the tool can incorporate up to 6 user-specified grids into the analysis. These grids were originally envisioned to supply non-acoustic properties of the seabed such as topographic slope or topographic position index (TPI), but they also make it possible to process multi-frequency multibeam data in a way that avoids the problems of data gaps between pings as the sonar cycles frequency.

The seabed characterization tools in SonarWiz offer several advantages over using similar tools developed for conventional image processing or geographic information systems (GIS):

(1) It is possible to pre-process the acoustic data using SonarWiz's signal processing algorithms which support sidescan, interferometric, and multibeam systems equally well.

(2) The characterization is performed on waterfall images of the acoustic imagery rather than working on a map-view mosaic of the data. In this way, it is easy to isolate the nadir and far-range artefacts in the pings and remove them from the data before the characterization process begins. Only after the characterization process is completed are the classified pixels georeferenced and mosaicked into a map.

(3) The segmentation can be performed in the same software tool used to collect and post-process the raw sonar data, removing the need to make a round trip through a 3rd-party GIS or an image processing application during each iteration of the map creation process.

Three example characterization maps will be shown, including a segment map of conventional sidescan backscatter data, a segment map developed from interferometric sidescan data incorporating both backscatter and topographic information; and finally, a segment map developed from multi-frequency multibeam data where the system was cycling between 3 different frequencies.

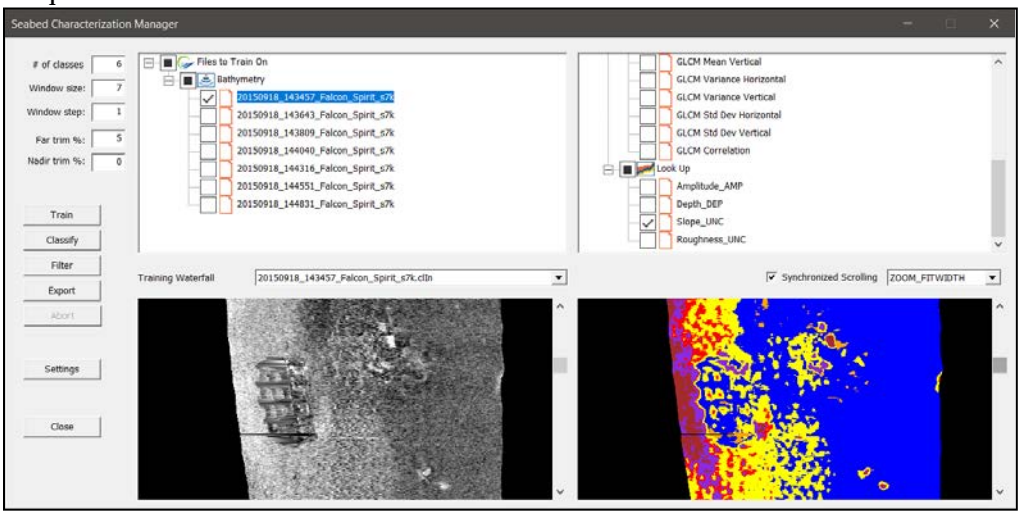

Figure 1. SonarWiz seabed characterization user interface.

Sedimentary and Morphological Features of a Very Shallow River Delta: Integration of High Resolution Multibeam Bathymetry and Satellite Images of Po di Pila Delta (Italy)

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Transitional environments like deltas, lagoons and estuaries are complex systems, dynamic and highly valuable in terms of biodiversity and productivity. High dynamism of the seafloor requires their constant monitoring, but at the same time they represent a challenge both for optical observations related to their turbidity and for high resolution multibeam bathymetry because of their rapid evolution morphology. For these reasons, a hybrid solution mixing terrestrial and shallow water remote sensing is a good methodology for studying these systems.

In this preliminary study, we present the first results from a high resolution multibeam echosounder (MBES) survey carried out in 2016 in the Po estuary, the most important Italian river. To cover even the shallow water and emerged areas, we connected these data with satellite images collected by *Sentinel-2a* (ESA) in the same periods. Furthermore, surficial sediment samples and drop-frame images were collected to validate the acoustic data and define the territory in terms of grain size distribution and biologic coverage.

In the MBES dataset, all the morphological features (dune fields, erosive scarps, collapse depressions, etc.) were identified and the main bedforms were analyzed using morphometry techniques. Different automatic algorithms were tested to classify the acoustic backscatter intensity and checked against the sedimentological analysis in order to obtain the seafloor sediment and habitat characterization. Thanks to satellite images, it was also possible to observe the evolution of the mouth bar and the development of the typical emerged deltaic morphologies (spits, bars, etc.).

This research shows, with unprecedented detail, the Po delta features and the rapid influence induced by tides, onshore current, waves and river sediment supplies in a transitional ecosystem.

Underwater Hyperspectral Imaging in the Adriatic Sea: A New Technology for Benthic Habitat Mapping and Monitoring

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Benthic habitat mapping and modelling are methodologies largely applied for Marine Spatial Planning (MSP), governance of marine resources, recognition of habitats and their conservation. Monitoring habitats is a necessary step to check any change and impact on their status and this aspect is considered of paramount importance within European programs, such as the EU Marine Strategy Framework Directive (MSFD: 2008/56/EC). Hence, it is necessary to provide a tool that enable researchers and institutions at monitoring Good Environmental Status (GES) of benthic habitats objectively and with the lowest possible impact on seafloor.

A promising technology is provided by the use of cameras able to acquire hyperspectral images of the seafloor, which could be complementary to the RGB images routinely collected. This system records upwelling radiance or reflectance in the entire visible band (390-700 nm) up to 1 nm resolution (Pettersen et al. 2014; Johnsen et al. 2016). A radiometric calibration and a geocorrection are applied in pre-processing to produce not-distorted and georeferenced hyperspectral images of the seafloor. At this point, the images can be classified (supervised or unsupervised methods are available) with a quantile-based spectral analysis in an Object-Oriented framework. A critical prerequisite is the construction of a library of spectral signatures of the different objects (i.e. species or communities) that need to be identified and isolated. Ultimately, using machine learning and specific software, it possible objectively and efficiently analyse data gathered in a simple-to rad GIS format map.

In the framework of the RITMARE flagship project, we tested the Underwater Hyperspectral Imaging (UHI) developed by Ecotone on February 2017, during cruise SPECTRA17 of R/V Minerva Uno. Two test sites of the southern Adriatic Sea (Italy) were selected for this purpose: 1) the cold-water coral habitat of Bari Canyon (Freiwald et al. 2009; Taviani et al. 2011, 2016; Angeletti et al. 2014; D'Onghia et al. 2015a, b); 2) the coralligenous habitat offshore Brindisi (Bracchi et al. 2015, 2017). The UHI camera was mounted vertically beneath the ROV Super Mohawk II 34 Observation Class together with two lamps and a 2D high resolution camera. Navigation data from the ROV was utilized for geo-referencing the hyperspectral dataset.

In this work we present the results of the analysis and classification of the UHI images in the test sites and we discuss the potentialities and limitations of this technology for monitoring the extent of vulnerable habitats both in shallow and deep sea environments.

An Advanced Method to Make Your Habitat Mapping Researches Findable, Accessible, Interoperable, and Re-Usable - A Case Study from EVER-EST

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One of the main challenges in marine science is to facilitate knowledge building by assisting humans and machines in their discovery of, access to, integration and analysis of task-appropriate scientific data and their associated algorithms and workflows. In general term, our researches should be “FAIR”, that is findable, accessible, interoperable and re-usable. These principles precede implementation choices and do not necessarily suggest any specific technology standard, or workflow. Good research data management is not a goal in itself, but rather the key conduit leading to knowledge discovery and innovation, and to subsequent data and knowledge integration and reuse.

The EVER-EST project (http://ever-est.eu/) developed a Virtual Research Environment (VRE) tailored to the needs of and validated by the Earth Science domain. To achieve this, the EVER-EST VRE provides earth scientists with the means to seamlessly manage both the data involved in their computationally intensive disciplines and the scientific methods applied in their observations and modelling, which lead to the specific results that need to be attributable, validated and shared within the community. The EVER-EST VRE offers a framework based on advanced services which are delivered both at the infrastructure and domain-specific level, with the objective of supporting each described phase of the Earth Science Research and Information Lifecycle using Research Objects (http://www.rohub.org/). Research Objects allow to organize and describe resources, materials and methods of an investigation; to preserve and share research materials with other scientists at discrete milestones of the investigation. Uniquely identified by an URI, pref. as a DOI, Research Object enable full reproducibility and reuse of scientific methods ensuring proper citation.

In particular, ISMAR-CNR provides useful and applicable contributions to the identification and definition of variables indicated by the European Commission in the Marine Strategy Framework Directive (MSFD) to achieve the Good Environment Status (GES). ISMAR-CNR is willing to deliver practical methods, procedures and protocols to support coherent and widely accepted interpretation of the Descriptors 1 (Biodiversity), and 6 (Seafloor integrity).

Here we present how EVER-EST can support the habitat mapping Virtual Research Community, going towards the new role of scientists of 2030, through two case studies: the Cold Water Corals Habitat Suitability Model of the Bari Canyon (South Adriatic Sea) and the new geomorhometric methodologies applied to the lagoon of Venice (Italy).

Geohabitats Mapping of the Continental Shelf of Tamandaré (PE), Brazil

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The Tamandaré-PE continental shelf has mixed carbonic and siliciclastic sedimentation, is shallow with a narrow -50-60 m break, and has a wide distribution of reef bodies parallel to its coast. Coral reefs develop controlled by sea level and contribute significantly to the evolution of mixed sedimentation of the platform. Thus, the mapping of reef environments was carried out in the proximal regions of the Tamandaré platform. Are used an interferometric sweep system (EdgeTech 4600), digital processing of LandSat 8 image, surficial sediment samples and underwater videos to identify sedimentary cover zones, bioconstructed structures and the geomorphology of the area. The acoustic images obtained were processed and interpreted using the software SonarWiz6 and ArcGIS 10.3, respectively. The bathymetric data were processed and interpreted using the software Hypack 2014 and Oasis montaj 8.4, respectively; the LandSat 8 image was processed using the software ArcGIS 10.3 and ENVI 5.3; and the samples were treated in laboratory and characterized with the aid of SAG software.

Seven distinct background patterns, named from P1 to P7, are observed; being P1, P2 and P3 associated to different forms of reef occurrences. P1 presents a rugged homogeneous texture pattern with high amplitude of the return signal, this pattern is associated with proximal reef bodies that present north-south orientation; P2 is characterized by displaying a moderate return signal with a rough texture interlayer with a flat texture and a preferred orientation NE-SW, being related to reef bodies more distal to the coastline; P3 shows moderate return signal and smooth homogeneous texture, preferential orientation NE-SW being associated with reef bodies possibly covered by calcareous algae or with bioconstructors other than the P1 and P2 patterns, which causes this return signal response; P4 presents smooth and flat textural pattern with high backscatter, being a gravelly bottom, identified from the analysis of the sample collected; P5 is a homogeneous, flat pattern and presents low backscatter, interpreted as sandy bottom; P6 is a soft and moderate textural pattern return signal, interpreted as gravel-sand bottom; and P7 presents a pattern with low return signal, homogeneous and flat texture, and an interdigitated spatial distribution, being interpreted as a mudy background.

Also are observed the presence of paleochannels in the area, in which their edges are associated with reef bodies. The LandSant 8 image shows the continuity of the reef bodies along the continental shelf of Tamandaré where does not exists sonographic and bathymetric data.

Southern California Seafloor Mapping Initiative

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Place-based fisheries and coastal zone managers depend on fine scale bathymetry and habitat maps for an array of critical decisions including: navigational safety, disaster response, endangered species and fisheries management, conservation, research, energy development, and marine planning. Yet as of 2014, nearly 90% of U.S. waters in the southern California Bight remain unmapped at an appropriate resolution. This data need spurred the creation of the Southern California Seafloor Mapping Initiative (SCSMI) in 2014. A kick-off workshop brought together over 20 agency, non-profit and academic partners to outline priority areas for new data acquisition. To-date, this partnership effort has leveraged an investment of over $4.5 million and a commitment of over 120 days-at-sea since 2014. The partnership has launched over eight missions across five vessels to map over 2,500 km^2 of seafloor and conducted over 30 ROV dives. Data collected has been used to inform resource management, identify hazards to navigation and highlight potential essential fish habitat. In addition, there has been a number of technology milestones from the SCSMI, including the testing and use of an ME70 and REMUS 600 AUV to map bathymetric features. Looking to the future, SCSMI will feed into the launch of a large US West Coast wide mapping and exploration campaign: EXpanding Pacific Research and Exploration of Submerged Systems (EXPRESS).

A Multispectral Bayesian Method for Improved Discrimination Performance of Seabed Sediment Classification Using Multi-Frequency Multibeam Backscatter Data

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Seabed backscatter data collected from multibeam echosounders (MBES) can provide valuable information about various sediments types and habitats. The interest of employing different acoustic frequencies with the aim of increasing the discrimination performance between different sediment types becomes increasingly popular. Although several experimental studies have already shown and proven the strong dependency of acoustic backscatter strength on frequency. The field of satellite remote sensing has indicated the enormous potential of using multispectral data for several decades. However, just recently the R2Sonic 2026 MBES was introduced which allows to emit a series of signals over frequencies from 100 kHz to 400 kHz on a ping-by-ping basis. This study presents the working steps taken to process multispectral backscatter data. Followed by introducing an extension of the Bayesian method for seabed classification to multispectral backscatter including the application to a dataset acquired in the Bedford Basin, Canada in 2016. It is shown that this data can be properly processed to be used for acoustic seabed classification. The Bayesian method is successfully extended to multispectral backscatter data producing a so-called multispectral acoustic classification map while accounting for the probability of misclassification at a single frequency. The results of the Bayesian method indicate that sensing this study area with a frequency of 200 kHz and 400 kHz yields to the highest number of acoustic classes. There is, indeed, an increase in discrimination performance by using different frequencies. The combination of the most separated frequencies (100 kHz and 400 kHz) achieves the highest discrimination performance in this study area. These results indicate the potential for solving existing ambiguities in the relationship between single- frequency backscatter and certain sediment types. A correlation of the acoustic classes can only be found with soft, mixed and had substrata. The benefit of using several frequencies cannot clearly quantitatively assessed on the basis of the existing video footage. Still, a qualitative comparison indicates a correlation of more than three seabed types to the acoustic classes and, in addition, an improved discrimination between different sediment types by combining 100 kHz, 200 kHz and 400 kHz to a multispectral acoustic classification map.

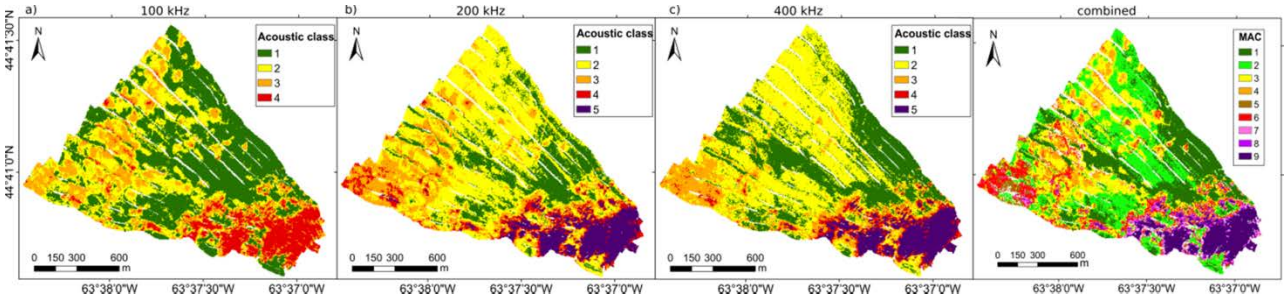

Figure 1. Acoustic classification maps obtained from the Bayesian method for seabed classification applied to MBES backscatter of a) 100 kHz, b) 200 kHz and c) 400 kHz. d) Multispectral classification map generated from all frequencies.
**Data set is provided by R2Sonic.*

Application of GIS Analyses to Quantify Bedform Stability in the German Bight, North Sea

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Bedforms can be used as an indicator of patterns of sediment dynamics in an offshore environment. Several studies analyzing bedform stability in the German Bight have been conducted, but detailed quantification of bedform change is lacking.

In this study, time-series analysis of data from multi-beam echosounder, side scan sonar, and sediment echosounder was conducted to quantify bedform change in the German Bight. The study presents a novel concept on maximizing the use of acoustic data from different equipment to provide more detailed evaluation of bedform stability. Data from offshore hydro-acoustic surveys conducted in 2016 and 2017 were analyzed in ArcGIS using techniques applied in shoreline change analysis, and correlated with grab samples for ground-truthing. A new approach on improving the rectification of backscatter images from side scan sonar was also proposed. The method was tested in a small area in Sylt Outer Reef, Germany.

Results include the range and rate of change of bedform movement, deposited/eroded sediment volume, and the possible causes of change. Challenges encountered in analyzing multiple datasets with different resolutions were also presented.

Mapping Cold-Water Coral Mounds in the Straits of Florida

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6. Ocean Exploration Trust

The cold-water coral ecosystem is a complex system that is greatly impacted by various factors. With recent discovery of cold-water coral mounds the Straits of Florida can be considered a large cold-water coral province. Using data collected from previous expeditions in the Straits of Florida, including multibeam bathymetry, backscatter, sub-bottom profiles, CTD, video footage, and samples (grab samples and gravity cores) the regional habitat can be explored and mapped. The habitat map is based on morphological classification of the sub-environments of the slope off western Great Bahama Bank. The classification uses bathymetry, attributes such as slope, curvature, and bathymetric positioning index (BPI). A classification dictionary then is used to assign each area to a predefined class: crest, ridge, depression, flat, or slope. The acoustic backscatter maps are overlain on the classifications (where high amplitudes are interpreted as coarse material, e.g. coral skeletons) and assigned attributes according to four stages of habitat classes identified from an ROV video footage transect: (1) dense coral thickets (25-100% of alive and dead covering seafloor), (2) isolated coral thickets (< 25% coverage), (3) coral rubble (debris on sediment bottom), (4) soft-mud to sand-sized sediment (devoid of coral). Using a series of supervised classification algorithms, the entire extent of the backscatter image is classified and then draped over a bathymetry map, creating a 3-D coral habitat classification map. Creating models for potential sites where more modern cold-water coral habitats exist could provide a glimpse of what the Pleistocene to ancient ecosystems may have been.

Repeat-Mapping Bathymetric Change and Substrates in a Large River: Application to Sediment Budgeting and Physical Habitat Mapping in the Colorado River in Grand Canyon

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The Colorado River in Glen, Marble and Grand Canyons has long been a focus of management interest and scientific research owing to the juxtaposition of one of the largest dams in North America and two National Park Service units, Grand Canyon National Park and Glen Canyon National Recreation Area. Management interests include native and nonnative aquatic species, riparian vegetation, cultural resources that are within the river corridor, and sediment that is vital for building and maintaining sand beaches used by river recreationists. To support scientific research and river management in these and other areas, we have been creating integrated maps of the river bed and shorelines by applying a variety of terrestrial and bathymetric survey methods. Here, we present high-resolution digital elevation models (DEMs) and maps of substrate composition derived from acoustic backscatter that span approximately 260 km of the ~490 km segment of the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. The surveys were collected over a nine-year period (2009-2017), where each survey expedition mapped different 50 to 95 km segments.

The DEMs were constructed by combining data collected using three methods: 1) multibeam echosounder surveys; 2) singlebeam echosounder surveys; and 3) ground-based total station surveys. Data from all three survey methods are spatially positioned by occupying benchmarks within a geodetic control network that provides local accuracies of 3 cm, both horizontally and vertically. Positions of sonar systems are telemetered at 20 Hz to vessels using robotic range-azimuth systems situated over benchmarks. Edited survey data points are used to construct Triangulated Irregular Network (TIN) terrain models of the reach, and then the TIN models are converted to 1-m resolution DEMs for analysis. DEM uncertainty is estimated by both fuzzy inference system (FIS) modeling and computing the absolute difference between features that are assumed not to have changed between surveys (so-called fiducial surfaces, such as the tops of rocks). The FIS approach models spatially-distributed uncertainty, incorporating information about surface roughness and slope. The fiducial surface approach results in a scalar uncertainty applied to the entire DEM, and is computed for each of the three survey methods. Maps of river bed substrate composition were developed for areas of the bed mapped by multibeam sonar based on acoustic backscatter, using a method in which the backscatter is spectrally filtered into morphological and compositional components and the compositional backscatter is classified by substrate category in a probabilistic framework. The maps are used are used for streamflow and sediment modeling, habitat characterization, and repeat maps are used for computing mass-balance sand budgets.

Seafloor Geology and Its Application to Potential Benthic Habitats of Selected Areas Within the Channel Islands National Park, California Borderland

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A compilation of offshore and island geologic, marine acoustic, and seafloor sampling data for the Channel Islands National Park Service was used to construct geologic and potential marine benthic habitat maps of selected areas around various Channel Islands. Our results represent the most detailed offshore mapping in the region to date and provide insights into the geology and potential benthic habitats that can be used to manage marine biological and other resources.

The geology of the offshore areas is essentially an extension of the Tertiary geologic formations that have been mapped on the islands, but locally covered by deposits of Quaternary marine sediments. Structure in the north-central part of Santa Rosa Island and in the northeastern part of Santa Barbara Island appear to represent the most active regional tectonic processes, while the areas in the southern parts of Santa Barbara Island appear more passive with few well-defined faults. Anacapa Island and the surrounding seafloor is composed of Tertiary volcanic rocks.

The potential marine benthic habitat maps illustrate that diverse and favorable habitats exist. For example, the extensive areas of rugose, differentially eroded bedrock outcrops on the mid-shelf seafloor of the islands provide good habitats for demersal rockfish (*Sebastes* spp.) and that rock outcrops in the nearshore areas provide hold-fasts for kelp, which can provide habitat for larval and young-of-the-year rockfish. Although true habitat is not well known in the areas studied, the potential habitat maps provide an effective management tool that can be used to protect and conserve the most promising probable habitats.

National Seabed Mapping Programmes Collaborate to Advance Marine Geomorphological Mapping in Adjoining European Seas

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2. MAREMAP, British Geological Survey (BGS), Edinburgh, United Kingdom
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Marine geomorphological mapping is an effective means of characterising and understanding the seabed and its features with direct relevance to; benthic habitat mapping, offshore infrastructure placement, conservation & policy, marine spatial planning, fisheries management and pure research. Advancements in acoustic survey techniques and data processing methods resulting in the availability of high-resolution marine datasets e.g. multibeam echosounder bathymetry and shallow seismic mean that geological interpretations can be greatly improved by combining with geomorphological maps. Since December 2015, representatives from the national seabed mapping programmes of Norway (MAREANO), Ireland (INFOMAR) and the United Kingdom (MAREMAP) have collaborated and established the MIM geomorphology working group with the common aim of advancing best practice for geological mapping in their adjoining sea areas in north-west Europe. In the past year the collaboration has expanded to include Geoscience Australia who share many of MIMs geomorphological mapping objectives including developing a broadly applicable geomorphic scheme.

A two-part classification system for Seabed Geomorphology ('Morphology' and Geomorphology') has been established as a result of an initiative led by the British Geological Survey (BGS) with contributions from the MIM group. To support the scheme, existing BGS GIS tools (SIGMA) have been adapted to apply this two-part classification system and here we present on the tools effectiveness in mapping geomorphological features, along with progress in harmonising the classification and feature nomenclature.

Recognising that manual mapping of seabed features can be time-consuming and subjective, semi-automated approaches for mapping seabed features and improving mapping efficiency are being developed using Arc-GIS based tools. These methods recognise, spatially delineate and morphologically describe seabed features such as pockmarks and cold-water coral mounds. Such tools utilise multibeam echosounder data or any other bathymetric dataset (e.g. 3D seismic) that can produce a depth digital model. The tools have the capability to capture an extensive list of morphological attributes. The MIM geomorphology working group's strategy to develop methods for more efficient marine geomorphological mapping is presented with data examples and case studies showing the latest results.

Seafloor Geomorphology as Benthic Habitat: GeoHab Atlas of seafloor geomorphic features and benthic habitats – Update on the New Edition

P.T. Harris, E.K. Baker

GRID-Arendal, Arendal, Norway

It has been decided that GeoHab will undertake the production of a second edition of the *GeoHab Atlas of seafloor geomorphic features and benthic habitats*, published by Elsevier in 2011. The second edition will include an update of the 6 introductory chapters, an update of some the original case studies, add new case studies and update the final synthesis chapter. Calls for contributions to the second edition during 2017-18 have resulted in about 40 expressions of interest from members of the GeoHab community, mainly for new case studies.

This presentation will provide an overview of the case studies that have been submitted for consideration for publication in the second edition. The new content of the introductory chapters will include new material as follows:

- Role of habitat mapping in design of marine protected areas
- Habitat mapping and marine policy
- Ecosystem services of benthic habitats
- Updated seafloor geomorphology maps
- Reference to GeoHab CSR special volume on renewable energy
- Reference to GeoHab backscatter working group report

Each case study will be required to complete a questionnaire that will provide information to be included in a final synthesis chapter, similar to the first edition. This will include more detailed information on the naturalness of the case study site, specifying a baseline year, trend and confidence estimates.

Multifarious Benthic Habitats Characterize Deep-Ocean Mineral Deposits

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The main three deep-ocean mineral deposits contracted for exploration and mining include ferromanganese (FeMn) crusts, manganese (Mn) nodules, and seafloor massive sulfides (SMS). Each of these have unique characteristics, compositions, bathymetric and geologic settings, and ecosystems.

FeMn crusts form by precipitation and accretion of metals from ambient cold seawater at depths of 400-7,000 m, and occur on seamounts, ridges, and plateaus where rocks are exposed; they do not grow where the seafloor is sediment covered, although sediment-covered areas do occur between outcrops of Fe-Mn crust covered rocks. On large flat-topped seamounts called guyots crusts are likely to be mined in water depths from about 1,500-2,500 m. Various kinds of sessile organism attach to the Fe-Mn crusts surfaces, especially sponges, crinoids and deep-water corals, such as gorgonian corals. The crusts of economic interest grow at a few mm per million years and form under the low oxygen zone, which typically occurs from 600-2,000 m water depth. Removal of the Fe-Mn crust will leave a rock substrate that could likely be recolonized by sessile biota. FeMn crusts will be mined primarily for Mn, Co, REY, Ni, Te, Tl, V, Bi, Mo, and Pt.

Mn nodules grow by accretion of metal oxides around a nucleus, and only form on sediment. Those of economic interest form on abyssal plains at water depths of 3,500-6,000 m. Nodules on the sediment can vary from less than a kg per square meter up to about 50 kg per square meter. Two ecosystems characterize this environment, sediment infauna and sessile biota attached to the nodules, the only hard substrate available in this environment. So, mining nodules will make recolonization of the sessile organisms impossible in the mined area unless a substrate, such as basalt fragments, are placed there after mining operations cease. Otherwise, areas must be left unmined within the defined mine area and be connected via unmined corridors to other such areas in and around the mine site to maintain a healthy ecosystem. Mn nodules would be mined primarily for Cu, Ni, Mn, and depending on location, Co, Ti, Mo, Li, and REY.

SMS form at hydrothermal vent sites where acidic, metal-rich hot fluids encounter cold seawater and metal sulfides precipitate from solution. These active hydrothermal systems are found at seafloor spreading centers, arcs and back-arcs, and intraplate hotspots, and form chimneys and mounds of sulfide rubble. Active SMS host communities of biota that vary from dense fields of tube worms to swarms of shrimp and large masses of snails and mussels, among others. These communities are chemosynthetic, dependent on reduced chemicals such as sulfur in the hot fluids for primary production. SMS deposits hosted at spreading centers are removed from the heat source over time, become inactive, and start to be buried by sediment; these SMS generate the most interest for mining and the majority are likely undiscovered to date. The biological communities at inactive systems are much less abundant than those at active systems, and consist typically of bacterial mats, anemones, hydroids, sponges, barnacles, and coral. SMS will primarily be mined for Cu, Zn, Au, and Ag, and depending on location Cd, Ga, Sb, and As.

Based on International Seabed Authority regulations, the following maximum sizes are set for exploration and extraction:

Manganese Nodules:
Exploration 150,000 km^2
Extraction 75,000 km^2
Likely size of 20-year mine site ~20,000 km^2

Ferromanganese Crusts
Exploration 3,000 km^2
Extraction 1,000 km^2
Likely size of 20-year mine site 400 km^2

Seafloor Massive Sulfides
Exploration 10,000 km^2
Extraction 2,500 km^2
Likely size of 20-year mine site 7-10 sites less than 1 km^2 each

ECOMAP - Baltic Sea Environmental Assessments by Innovative Opto-Acoustic Remote Sensing, Mapping, and Monitoring

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2. GEOMAR - Helmholtz Centre for Ocean Research, Kiel, Germany
3. NORBIT Director Sonar Systems
4. Institute of Baltic Sea Research (IOW), Rostock, Germany

In this demonstration we want to present the ongoing work in the EU funded BONUS project ECOMAP (http://www.bonus-ecomap.eu), highlight first results, and report about future directions. One fundamental goal of ECOMAP is to establish optimized remote sensing and classification procedures for dedicated habitats on the seafloor of the Baltic Sea (Northern Europe).In the project we use multibeam mapping systems and their water column imaging capabilities, LiDAR overflights with full waveforms and aerial photography, deploy in situ laser, aerial photography with unmanned aerial vehicles, and apply customized subbottom imaging. Those sensors are all considered valuable for the analyses of the seabed in regard to benthic life assessments. E.g. a combination of the sensors allows for “imaging” the subbottom (with acoustics) and to sense the water column above the seabed, e.g. for macrobenthic flora analyses (with opto-acoustics).

First results are presented here showing how various sensors respond to a *Zostera marina* seagrass meadow that was repeatedly surveyed by multi-frequency MBES, LiDAR, and unmanned aerial vehicle photography. Without a doubt, the diver-validated seagrass meadows were clearly detected by each sensor. Uncertainties on depth-sensitive efficiency, robustness on detection, biomass estimate and monitoring potentials are part of the ongoing research and will likely be quantified during the runtime of the project.

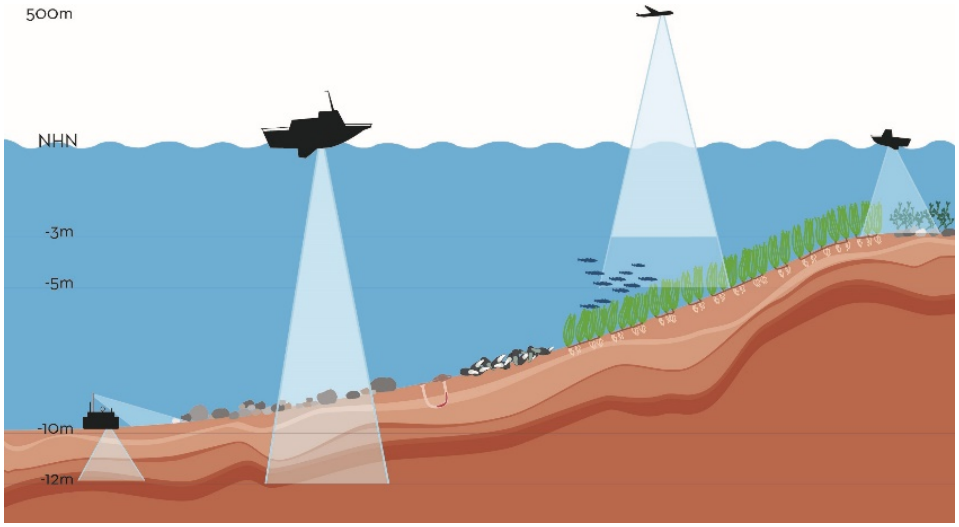

Figure: Selected habitats and remote sensors in ECOMAP (www.bonus-ecomap.eu)

Shoreline Fault and Seafloor Mapping from MBES and High-Resolution 3D Seismic-Reflection Data, Offshore Diablo Canyon, Central California

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2. Moss Landing Marine Laboratories, Moss Landing, CA
3. Pacific Gas and Electric Company, San Francisco, CA

The global dialog on the safety and reliability of nuclear power plants changed following the 2011 M 9 Tohoku, Japan earthquake and tsunami. Critical facilities located near active fault zones in coastal environments, like Pacific Gas and Electric's (PG&E) Diablo Canyon Power Plant (DCPP) in Central California, have been the focus of increased attention to earthquake and tsunami hazards. Extensive geological and geophysical investigations were undertaken to assess earthquake hazards in the region around DCPP using the most up-to-date technologies and methodologies that required stringent environmental assessment that led to marine benthic habitat mapping. Detailed mapping and characterization of the seismic potential of the Shoreline fault zone offshore DCPP was performed using high-resolution data collected for PG&E's Central Coastal California Seismic Imaging Project. The new data consist of acoustic data (multibeam bathymetry and ultra-high-resolution multichannel 2D and 3D seismic), which were complemented by seafloor samples, gravity, aeromagnetic, and legacy 2D seismic data as well as ocean-bottom seismic monitoring.

For much of its length along the coast, the Shoreline fault zone is located in the shallow water Transition Zone and expressed in exposed bedrock. This zone is often less than 25 meters deep, with intervening kelp beds, wash rocks and pinnacles. Combined with steep coastal bluffs on an exposed coastline, the Transition Zone around DCPP presented a challenging environment for data collection. PG&E sponsored a detailed MBES survey offshore DCPP to document bathymetry, seafloor habitats, and the surface geomorphic expression of the Shoreline fault. The survey was conducted by the CSU Monterey Bay (CSUMB) Sea Floor Mapping Lab. For areas within very shallow sub-tidal and intertidal zones CSUMB used an armored airboat-jet ski-rigid inflatable boat (RIB) hybrid equipped with a fully integrated suite of hydrographic and topographic mapping instrumentation (Sea Technology, 2012).

Fugro collected and interpreted 2D and 3D ultra-high-resolution seismic reflection data for PG&E to map the Shoreline fault in the subsurface. The use of new MBES bathymetry, 2D seismic-reflection profiles, and 3D seismic volumes allowed us to map and characterize the Shoreline fault zone for seismic hazard analysis and refine habitat maps. The shallow nearshore zone was accurately imaged by the new MBES data, revealing a seafloor primarily composed of differentially eroded bedrock outcrops. Deeper water areas have a cover of mobile sand sheets of variable thicknesses that required high-resolution seismic-reflection profiling to image the buried irregular bedrock surface and deeper strata. To map the subsurface geologic conditions we produced a 3D seismic volume cube that can be viewed in various orientations to show both user-selected cross-sections and horizontal surfaces (time slices) within an area of interest. This allowed for detailed structural mapping of folds, faults, and the top bedrock surface. The high-resolution bathymetry and seismic-reflection data were also used to map seafloor outcrops, rock formations, habitats, and identify Late Quaternary geomorphic features offset by the Shoreline fault zone. Data and results of this project used for geologic characterization and habitat mapping are available to the public.

Mapping Benthic Habitat and Fish Populations on the West Florida Shelf: C-SCAMP Progress and Promise

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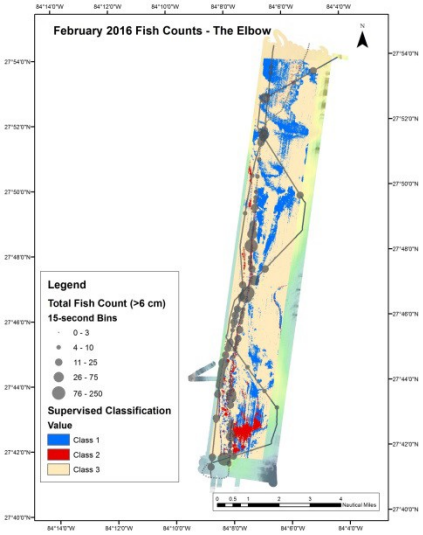
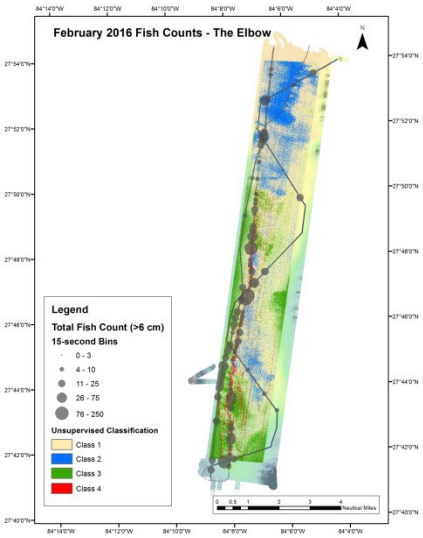
It has been demonstrated though hydrographic modeling that oil from the *Deepwater Horizon* blowout likely reached the West Florida Shelf (WFS) not long after the time of the incident in the spring of 2010. Fortunately, the majority of the benthic habitat on the WFS was less impacted than the ecosystems in closer proximity to the wellhead. However, the extensive impact of this event within the Gulf of Mexico underscored the need for more baseline data to better understand the potential impacts of any future oil spills. Robust assessment is difficult when the baseline condition of the resource is largely unknown. A gap analysis of coastal and marine data sets conducted in 2012 identified "benthic habitat" and "living marine resources" as the top two categories for which increased research in the eastern Gulf should be prioritized. Yet, only a small fraction of the seafloor on the WFS has been characterized at the spatial resolution achievable by contemporary instrumentation.





The Continental Shelf Characterization, Assessment and Mapping Project (C-SCAMP) continues to survey areas on the WFS that are likely to contain essential habitat for reef fish and sea turtles. Multiple complementary technologies are employed in this effort, including multibeam and split-beam echosounders as well as a towed camera system. As of the end of this project's second full field season (2017), ultra-high resolution bathymetry and co-registered acoustic backscatter data has been collected for approximately 1,500 km^2 of seafloor, complemented by more than 250 hours of recorded video transects across these areas.

This poster will provide an update on C-SCAMP's progress since the authors' introductory talk presented at the GeoHab 2017 meeting. Several promising aspects of the overall project will be presented, including: development of software tools for auto-identification of marine flora/fauna and basic seafloor characteristics, quantitative methods for classifying benthic habitats and analyzing their relationships to recorded fish abundance, assessment of the distribution of sea turtle observations, and initial geomorphological interpretations of prominent mapped seafloor features.

Combining Multibeam Bathymetry and Backscatter with Towed Video Data: An Application for Fisheries Management

A. Ilich[1], J. Brizzolara[1], S. Grasty[1], J. Gray[1], M. Hommeyer[1], C. Lembke[1], S. Locker[2], A. Silverman[1], T. Switzer[3], A. Vivlamore[1], S. Murawski[1]

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2. U.S. Geological Survey, USA
3. Florida Fish and Wildlife Conservation Commission, USA

Using a towed underwater video camera sled, various demersal reef fish species were enumerated and benthic habitats were classified along transects in a popular offshore fishing area on the West Florida Shelf known as "The Elbow." Additionally, high resolution multibeam bathymetry and co-registered backscatter were collected for the entire study area. Using these data, quantitative relationships between multibeam bathymetry and backscatter, benthic habitat, and fish abundance were established through multivariate analysis.

Traditionally, benthic habitat maps have been created manually; however, recently there has been more focus on developing quantitative methods that can create habitat maps in a more objective, automated, and reproducible way. For this study, complete coverage thematic maps representing various characteristics of benthic habitat were derived using quantitative semi-automated procedures. Both supervised and unsupervised methodologies were explored. The advantages and disadvantages of each approach will be discussed and the performance and accuracy of the differing methodologies will be assessed. Additionally, habitat specific densities of select fish species were determined from the video transects and were extrapolated out to the entire study area using the derived benthic habitat map to provide an estimate of the total abundance of those species in the entire study area. This type of information can be useful to fisheries managers in order to assess fish abundance, determine sampling and survey design, and for identifying essential fish habitat. This research is meant to demonstrate how modern technologies, specifically multibeam echosounders and a towed video platform, can provide information relevant to fisheries managers.

Amphibious Coastal and Nearshore Habitat Mapping Following a Massive Earthquake in Kaikōura, New Zealand

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A 7.8-magnitude earthquake struck Kaikōura, New Zealand in November 2016, causing widespread landslides and significant horizontal movement and uplift along the coast. Following the quake, Land Information New Zealand (LINZ), initiated a hydrographic surveying project in the nearshore waters surrounding Kaikōura peninsula to re-map 35,000 hectares of seafloor. iXblue was contracted to conduct hydrographic charting, following LINZ's standards, of the area. This included marine priority areas designated for production of additional science bi-products. From November 2017 through February 2018, these areas were sonified using high-resolution multibeam technology. In addition, detailed acoustic backscatter analysis, laser scanning, seabed sediment sampling, and drone-based photogrammetry were used to map the coast in specific sites.

This suite of technologies identified undocumented faults which influence the structure and sediment type of the seafloor. The complex fault regime controls the alluvial river systems sculpting the land and the offshore canyon morphology. Our data suggests the faults also play an important role in the seafloor habitats and resulting biological communities. The recent uplift, up to six metres in some areas, has formed new reef structure while other pre-existing reef platforms have become subaerial, causing massive die-offs in important nearshore habitat. Quantifying these shifts is vital for local fisheries and coastal management.

High Resolution Habitat Mapping Using Continuous Variables to Comply with Multiple Classification Schemes and Scales in a Complex Environment – A Study from the Swedish National Marine Mapping Program

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3. Helmholtz Institute for Functional Marine Biodiversity at the University Oldenburg, Oldenburg, Germany (HIFMB)

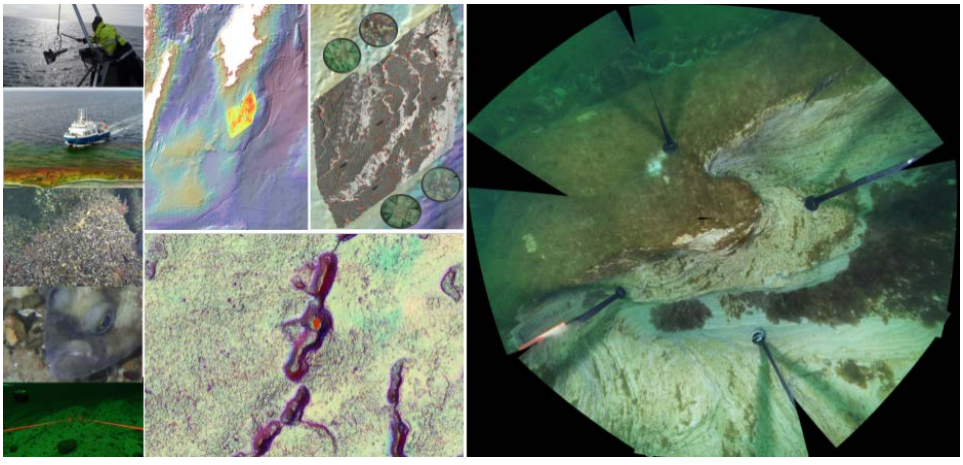
The Geological Survey of Sweden (SGU) surveyed a 1400 km^2 offshore bank in the Baltic Sea during 2016 and 2017, with the aim to efficiently produce full coverage benthic habitat maps. In addition, we collected hydrographic data for charting, as well as fish and infauna data.

This study is part of a new national marine mapping program led by the Swedish Agency for Marine and Water Management with the primary purpose to map benthic species, habitats and biotopes in Swedish waters. This information is in high demand for ongoing marine spatial planning (national and regional), marine reserves and fisheries management. The study will help evaluate the costs and benefits of high resolution habitat mapping versus lower-cost, coarser models of benthic habitats and species distributions, which are also included in the program.

Aside of the challenges and tradeoffs associated with collecting and processing multi-purpose data (e.g. multibeam, splitbeam, sediment profiles, ctd, mvp, gillnet, sediment grabs and underwater observations) in an integrated expedition, a major challenge has been to create maps for multiple classification schemes and scales (e.g. Helcom HUB, EUNIS, Nature 2000, SGU geological maps) in a transparent, replicable and efficient manner.

The main approach is to use continuous substrate and epibenthos data (percent coverage from photo mosaics, supplemented by lower quality historical data), as well as grain size distribution data for finer sediment fractions, to develop continuous models using both raster and object based (ENVI Fx) variables. The predictors, including multiscale metrics 0.5 m – 2km, are developed from 0.5 m high-resolution backscatter and bathymetry data, interpreted sediment profiles and oceanographic data, then aggregated to the modelling resolution of 5 m pixels.

From the raster “blueprints” containing high resolution features and percent coverage maps, we derive the required products of lower spatial and thematic resolution schemes. In this way, we aim to obtain useful information of habitat complexity that potentially could be lost in current classification schemes while producing maps that adhere to national and European standards.



Assessing the Impacts of Manganese Nodule Mining on the Marine Environment - Implications for Environmental Risk Assessment

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Mineral extraction from the seabed has experienced a recent surge of interest both from the mining industry and marine scientists. While the improved methods of geological investigation enable mapping new seafloor mineral reserves, the ecological impacts of seabed mining in both coastal seas and the deep sea are still poorly known. We use a problem structuring framework to evaluate the environmental impacts of polymetallic nodule extraction and discuss data requirements for environmental risk assessment. Traditionally environmental impact assessments build on an understanding of how ecosystems respond to human induced disturbances. However, little previous experience with mining projects has been documented to date. Baseline data on species and habitat characteristic associated with seafloor mineral deposits is severely lacking, compromising the representability of impact statements. This requires a more structured approach for estimating the adverse effects to marine ecosystems compared to traditional EIA to ensure transparency of the assessment.

We have identified causal relationships between pressures caused by nodule extraction and the associated changes in marine habitats from experimental evidence. We discuss the role of latent parameters and identification of ecosystem services for impact assessments. A key issue in management of seabed exploitation is estimating how ecosystem structure and ecological functions convert into benefits to society. Adequately estimating the potential state changes to the environment by habitat characterization is thus essential for translating the impacts of seabed exploitation into losses to ecosystem services. In the next phases of the project, the ecological role of metal concretions and associated ecosystem services as a part of a risk assessment and their characterization will be addressed. Further, we discuss habitat mapping requirements for a comprehensive risk assessment and implications for marine spatial planning.

MORE-MAPS: A Suite of Methods and Open Source Software to Facilitate Mapping of Submerged Habitats Via Multispectral Satellite Imagery

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Thematic maps of shallow submerged habitats are vitally, and increasingly, important to ecological studies and resource management efforts worldwide. Classification of high resolution multispectral satellite imagery can be an efficient and cost effective means of generating these maps. However, there is a disconnect between optical remote sensing methods (e.g., Water Column Correction (WCC), depth estimation, etc.) and those who need to use habitat maps. Ecologists and resource managers who want habitat maps must partner with remote sensing specialists in order to understand the range of methods available, chose methods appropriate to their study area, collect and process complex ground truth data, write code to implement those methods, and assess the accuracy of the resulting map. This makes map users (e.g., ecologists and resource managers) dependent on a separate class of map producers (i.e., optical remote sensing specialists). This dependency creates a bottleneck and increases the expense of map production, leading to a large unmet need for habitat maps. Furthermore, the paucity of open source code for method implementation hampers the progress of map producers, requiring them code existing methods from scratch in order to build on them or compare results with newer methods.

Marine Optical Remote sEnsing Map and Assessment Production System (MORE-MAPS) is a suite of methods and open source software created to address this situation. MORE-MAPS provides map users with the tools they need to become map producers. MORE-MAPS includes Benthic Photo Survey: a software tool for efficiently processing benthic photos into ground truth shapefiles, and OpticalRS: a Python library featuring depth estimation, WCC, and accuracy assessment methods. When used in conjunction with existing open source GIS and image classification software, MORE-MAPS provides an entirely free and open source pathway for map users to start with input comprising multispectral satellite imagery and relatively inexpensive field data and produce a thematic habitat map accompanied by an accuracy assessment error matrix. Additionally, OpticalRS provides implementations of novel approaches to depth estimation and WCC as well as more commonly used methods developed by Lyzenga, Sagawa, and others.

A detailed overview of MORE-MAPS will be presented along with 2 case studies. MORE-MAPS was used to map temperate rocky-reef habitats in and around 2 marine reserves in northeastern New Zealand. In both cases, marked differences in kelp cover were apparent between reefs within the reserve and those outside. These case studies will demonstrate the broad applicability of MORE-MAPS as tool for cost-effective habitat mapping, and will specifically highlight its potential for the monitoring of marine reserves. Current limitations and future research opportunities will also be discussed.

Seagrass Mapping on a Budget using a Kayak, Lowrance HDS Sidescan Sonar System, ReefMaster and Google Earth Software

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Seagrasses are declining across the globe due to a variety of primarily anthropogenic influences, e.g. pollution, global warming, sea level rise, land reclamation, dredging, sedimentation, eutrophication. The seagrass beds in Trinidad and Tobago are no exception and currently succumbing to some of these threats. Along the shore of the northwestern peninsula of the island of Trinidad where a once thriving seagrass meadow existed, intense coastal development is underway. A large seawall, boardwalk, restaurant and numerous recreational facilities including a miniature golf course, go cart track and water park are under construction. Sedimentation from these building activities appears to be the main culprit in the disappearance of the adjacent seagrass beds over the past four years. Unfortunately, we do not have detailed pre-construction seafloor maps of the area, but we have developed an inexpensive methodology to map and monitor the seagrass that remains. We used a low-cost Lowrance HDS sidescan sonar (SSS) system attached to a kayak to map the effected bays. The acquired data from the Lowrance HDS system includes georeferenced SSS imagery, depths, hardness, water column features, tracks and waypoints. These data were then imported into ReefMaster software for processing. SSS mosaics, bathymetry and hardness/roughness maps were produced (Fig. 1) and exported as kmz files for use in Google Earth. Google Earth was then used to manually create polygons around the various seascape classes that include seagrass patches. A cost breakdown for this work is shown in the table below.

Equipment	Cost USD
Kayak	$879
Paddle	$50
Life Jacket	$35
Lowrance HDS-9 Gen 3 with StructureScan 3D	$1999
Transducer mount	$150
ReefMaster v1	$150
Google Earth	free!
Labor	free!
TOTAL	**$3,263**

The expenditures are much reduced compared to using a typical SSS towfish system which would cost upwards of $30,000 USD and also require expertise to collect and process the data. The Lowrance system is easy enough for an undergraduate student to quickly utilize and the Reefmaster software is straightforward to use. The results were of high enough quality to satisfy the objectives of this study – map the benthic features including seagrass – and show promise for use in other nearshore mapping applications, as well as continued monitoring of our study area and change analyses as sedimentation rates vary.

Fig. 1. From left to right: roughness map (E1), bathymetry map (0-11 m) and SSS mosaic for Williams Bay, Trinidad.

Habitat Mapping of the Great Salma Strait (Kandalaksha Bay of the White Sea)

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Habitat mapping using side-scan sonar, multibeam, benthic and sediment analysis was conducted in the Great Salma Strait (Kandalaksha Bay of the White Sea) in summer 2016. The survey area is located near the White Sea Biological Station of the MSU. Previous studies in this area were conducted in 1953-1960 and in 2003-2006. Results of these studies are consistent with each other. In 2009 – 2012 the habitat mapping survey conducted westward in Rugozeraksya Bay near the Vysokiy island revealed an area with *Arctica islandica* community. The underwater landscapes and spatial distribution in *Arctica islandica* density were described using side-scan sonar profiling.

Despite the availability of modern techniques for both geophysical and benthic researches, the approaches of habitat mapping through integration of remote and direct methods are still insufficiently developed in Russia. Indeed, there are large geophysical data sets accompanied with data of benthic researches for the same areas (particularly for Arctic); but these data are not integrated. The main goal of this study is to develop the methodology for integration of geophysical (side-scan sonar, multibeam) data and quantitative benthic data obtained by sampling.

During this project the following procedures have been performed*:* side-scan sonar survey, multibeam survey and benthic survey using grab sampling, characterization of bottom communities and integration of geophysical and biological data using k-means clustering. Benthic and sediment sampling have been conducted at 36 points located in 5 polygons using Day grab and Haps bottom corer. The following data were collected: backscatter map, bathymetry map, sediment and quantitative benthic data (benthic organisms were identified to species level, counted and weighted). Four communities have been allocated using MDS by Bray Curtis similarity based on combination of abundance and biomass data. CCA confirms theses groups and explain their separation by the sediment character.

Combined analysis of the backscatter attributes and bathymetry data by k-means clustering (using benthic communities as clusters centers) allowed us to create detailed map reflecting distribution of the two main soft bottom communities and rocky grounds. Two of four clusters match the main silt bottom community (*Galathowenia oculata – Chaetozone setosa*) located at depths below 27 m, one cluster corresponds to the sand bottom community (above 27 m, *Macoma calcarea – Scoloplos acutus*) and one cluster corresponds to rocky grounds. Mean error of the correspondence between stations and geophysical data for main communities was about 30%. N*o correspondence has been found* between small groups of stations (*Portlandia arctica* and *Macoma calcarea – Chaetozone setosa*) and geophysical data. Using the remote sensing approaches we created more detailed, in comparison with previous studies, map of benthic communities' distribution in the Great Salma Strait, providing better delineation of the rocky ground area. The communities located at this study and their depths are the same as described earlier in 1963 and 2012 although the roles of the dominant species have partly changed. Data on biomass of the communities are in a good agreement with previously obtained results.

This work is part of the project, funded by Arctic Research Center (Rosneft Corporate Research and Engineering Division).

100% of the World Ocean Floor Mapped by 2030 – Contribution of the South and West Pacific Regional Data Assembly and Coordination Centre to the Nippon Foundation-GEBCO Seabed 2030 Project

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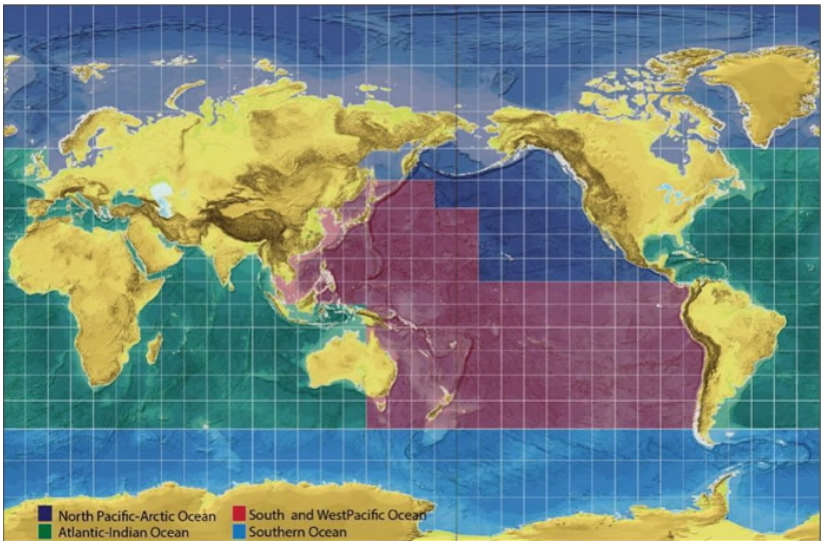
Despite many of years of mapping effort, only a small fraction of the world ocean's seafloor has been sampled for depth, greatly limiting our ability to explore and understand critical ocean and seafloor processes. Recognizing this situation, GEBCO and the Nippon Foundation have joined forces to establish the Nippon Foundation GEBCO Seabed 2030 Project, an international effort with the objective of facilitating the complete mapping of the world ocean by 2030. The Seabed 2030 Project is established in four regional data assembly and coordination centers (RDACCs).

The South and West Pacific RDACC based in Wellington New Zealand has responsibility over a region covering 123,000,000 km^2 from South America to Australia, between latitude 50°S to 10°N and the western part of the Northern Pacific Ocean to 50°N. The region includes the world's deepest trenches, internal seas, politically contested areas, EEZ from Small Islands Developing States (SIDS) and from s ome of the largest countries on Earth, and covers some of the most remote regions of the planet where bathymetric data originate from existing ship tracks that are spaced up to 100 km apart.

The South and West Pacific Centre is responsible for assembling a regional database of cleaned bathymetric data and the production of a regional bathymetric grid for merging with grids from the other centres into global product. It will identify existing data that are not currently in publicly available databases and seek to make these data available. It will develop protocols for data collection and common software and other tools to assemble and attribute appropriate metadata as it assimilates regional grids using standardized techniques. The Centre will also be responsible for identifying data gaps and opportunities for new data collection, including the facilitation of new mapping endeavors through coordination of ongoing activities among stakeholders in the region. The Centre will establish a Regional Mapping Committee, a group of regional experts who will work with the Centre in identifying data sources and facilitating the collection of bathymetric data in the region. The Centre will encourage and help the development of new and innovative technologies that can increase the efficiency of seafloor mapping, including crowd sourcing, and thus make the ambitious goals of Seabed 2030 more likely to be achieved.



The Brazilian Equatorial Margin Geomorphometry and Benthoscape

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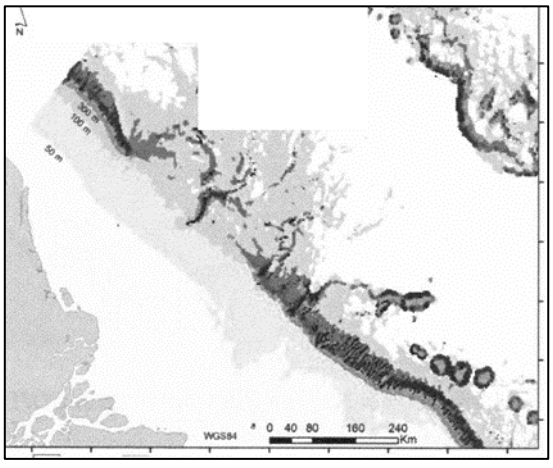
The purpose of this work is to geomorphologically describe part of the Equatorial Brazilian margin focusing on the transition between the continental shelf and slope and compare with published benthic data. A classification based on morphometric parameters such as slope and Bathymetric Positioning Index was carried out using the Benthic Terrain Modeler (BTM), an ArcGIS tool. The 2,500 meters resolution bathymetry grid was obtained from LEPLAC, a Brazilian Navy survey plan for the Brazilian continental margin, that compile bathymetry data from single beam , multibeam, remote sensing and seismic (GEODAS, GEBCO, Petrobras, ANP, STRM30_Plus V7.0). Moreover, a higher resolution multibeam data were acquired using Reson 7160 MBES for 3 distinct areas during the Amazon Reef Cruise (July, 2017 -Alucia vessel) and it was also used to discuss the morphological differences and the benthoscape.

Twelve seabed classes were defined in terms of major regions : (a) shelf (inner: 0 to 50 m depth; mid: 50 to 100 m depth; outer: I 00 to 300 m depth); (b) shelf break; (c) plateaus; (d) slope (plain: 0 to 0.56°; gentle: 0.56 to 1.58°; moderate: 1.58 to 2.83°; steep: > 2.83°); (e) depressions; (f) crests; and (g) seamounts. The Amazon Cone is the most notorious feature varying, in terms of slope from the shelf break to almost 4,000 m depth, from moderate to steep. Also, within this area depressions (canyons) are depicted and recognized for their steep slope. The shelf break depth varies along the studied area. Taking the Amazon Cone as the reference, the shelf break reaches 300 m depth to the NW, whereas on its SE side it reaches only 100 m depth. The presence of a plateau reflects a distinct shelf-slope transition pattern. This steep-like feature is pronounced in both west and east sectors. Finally, depressions and crests are also part of the geomorphic classification that represents canyons.

Comparing the seabed classes and available benthic data (mainly in Moura et al., 2016) shows that mesophotic reef occurrence along the Amazon shelf is related to the shelf break feature and the presence of an outer shelf and plateau. Submerged "erosive" reefs were observed in the NW pa11, while a sponge and rhodolith-rich shelf with a gully slope were observed in the SE part of the area (mid-shelf, shelf break, steep slope, and depression). The shelf break adjacent to the Amazon cone is a gentle slope showing no reefal structures, but only large-scale bedforms.



Stratified Random Sampling and Using a Mini-ROV for Shallow Water Habitat Mapping

T. Le Bas, D. Price

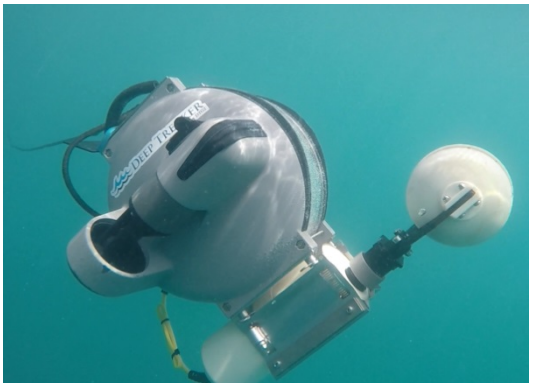
National Oceanography Centre (NOC), UK

Multibeam bathymetry and backscatter data are a usual starting point for habitat mapping. With quality data the bathymetry and backscatter can be combined and interpreted using Object Based Image Analysis (OBIA). OBIA methodology segments the data in to geographic areas of similar characteristics, in the same way as the human eye might be able to do if looking at all the data. These geographic polygons have a cluster classification number but this in turn requires ground truth data to convert classification numbers into real world habitats. As the polygons have widely differing sizes we assume that larger areas need more groundtruth points in terms of samples or photos to confirm the validity of the OBIA segmentation. Stratified random sampling selects random sampling sites within each polygon.

We will show data from Tanna, Vanuatu. The island of Tanna is the home of the active volcano Mt Yasur. It is often described as one of the world's most accessible volcanoes being just 350m above sealevel and easily reached by a short drive. The volcano is known for its spectacular and persistent strombolian activity.

A hydrographic survey was carried out in 2017 using a pole-mounted EM2040 on a local boat, to update the previous 1860 charting. OBIA segmentation was completed using slope and roughness derivatives together with the backscatter imagery. The resulting OBIA polygons were then sampled. We used a DeepTrekker mini-ROV to video, photograph and take sediment samples of each point using the random stratified sample points. Maximum depth capability of the system was about 70m. In one week we completed over 275 dives and comprehensively sampled the area. Video interpretation was done by two independent workers and a habitat map created. Degree of interpretation correlation and data confidence will be discussed.

Tourism to the island is limited due to the lack of landing points on the coast and infrastructure. Creating infrastructure for tourism will impact on the marine environment and thus gaining an understanding of the navigation limitations and marine habitats can assist the decisions of placing jetties and wharfs for cruise ships and their passengers. The bathymetry and habitat maps are currently being considered and a decision is expected soon.



DeepTrekker ROV with cup sampler

Massive/encrusting hard corals - *Pachyseris* sp.

A Hierarchical Approach to Quantifying Fine-Scale Habitat Availability

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Many areas of coastal Florida are home to Eastern oysters (*Crassostrea virginica*). Those oysters form reefs and play a critical ecological role by providing habitat and refuge for many other species (e.g. crabs, juvenile fishes). Oyster reefs also play an important socio-economic role in the state of Florida, particularly on the Gulf of Mexico coast. Due to a combination of anthropogenic and natural stressors, efforts to restore and closely monitor those reefs have become necessary.

The goal of this study is to establish a protocol for long-term monitoring of oyster reefs on the Gulf Coast of Florida. Here we present preliminary results of an ongoing feasibility study for which a hierarchical approach to reef mapping was proposed. At the broadest level, existing aerial photos (5 m resolution) from near Cedar Key, Florida, were used to locate reefs and measure their extent using traditional, pixel-based remote sensing classification techniques. Existing airborne Lidar data (1 m resolution) were used to estimate the volume of the reefs above the water line. At the finest level, pictures of an oyster cluster on a reef were taken to estimate the amount of available habitat per unit of area. Figure 1 shows a 3D reconstruction of the oyster cluster produced from 149 images using structure-from-motion photogrammetry. The point cloud and mesh, built in Agisoft Photoscan Pro, were imported in CloudCompare to perform 3D geomorphometric analyses.

Results for the measurements of the extent and volume of reefs from aerial photographs and airborne were not conclusive. The resolution of both types of data was not fine enough to measure those reef components with the level of accuracy required for monitoring. At the oyster cluster scale, however, the mean error calculated for the 3D model was 0.65 millimeter, and 3D measures of curvature, roughness, volume, surface area, and openness were successfully computed for a number of interstitial spaces (i.e. empty space between oysters that are used by other species).

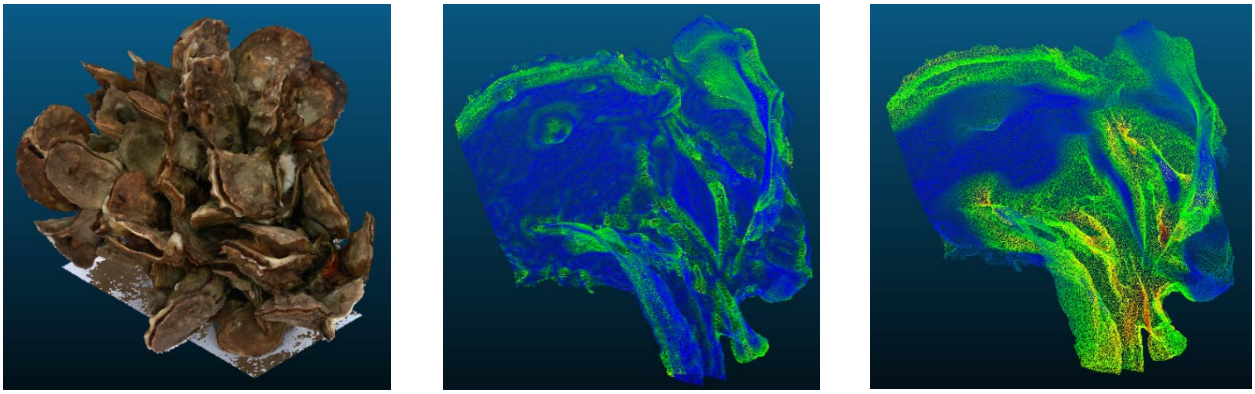

Figure 1: 3D texturized mesh of a 10 x 20 cm oyster cluster (left), and 3D measure of roughness (center) and curvature (right) of an interstitial space of about 5 cm wide. Colder colors indicate low values and warmer colors indicate high values.

Given the inadequacy of aerial photographs and airborne Lidar for accurate monitoring, a drone survey is planned in the near future to collect higher-resolution images and elevation data, with the known tradeoff of covering a smaller extent. The use of object-based image analysis techniques will also be tested on those images to detect and count oyster clusters on reefs. An evaluation of the use of interstitial spaces by macroinvertebrates is also planned to establish, using species distribution modeling, whether there is a relationship between the morphological characteristics of those spaces (e.g. openness, roughness) and their use as refuge against predators. The proposed approach maps only the intertidal portion of the reefs; the second phase of this project is planned to test a variety of acoustic methods to map the subtidal portion of the reefs.

Evaluating Oceanographic Drivers of Deep-Sea Corals at Multiple Thematic Scales

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It is now well recognized that habitat maps must be placed in context with the appropriate spatial, temporal, and thematic scales. While our understanding of the roles of spatial and temporal scales in habitat mapping and modeling has improved in recent years, little is known about the role of thematic scale. Thematic scale refers to the level of organization at which objects of study are described. In habitat mapping, the thematic scale may be associated with the level of details at which geomorphological features or habitat classes are defined or characterized. Thematic scale is also related to the way ground-truthing data like species occurrences are described. For example, benthic species observations from video data are not always identified at the same taxonomic level due to data collection issues; an inconsistent scene illumination or the motion of the platform may prevent the accurate identification of a sample. To remove uncertainty, the sample may then be identified following a broader classification scheme. Geodatabases storing such data are consequently highly heterogeneous, which may complicate further analyses (e.g. habitat mapping) and prevent proper comparisons among studies.

The goal of the research presented here is to explore the effects of changing thematic scale on habitat modeling. High-resolution, near-bottom video and oceanographic data were collected using the Canadian ROV ROPOS in deep-sea coral habitats located off Eastern Canada (The Gully, the Flemish Cap, and the Orphan Knoll). Deep-sea coral observations were characterized to the highest possible taxonomic resolution, which varied depending on observations. Of the 2,365 observed occurrences, only about 17% could be identified to the species level, while 64% were identified at the genus level, 74% at the family level, and 98% at the order level. About 2% (39 observations) of the corals could not be identified.

Boosted regression tree models were built using presence/absence data at five different levels of organization: the species, genus, family, order and the functional group levels. Models were generated with combinations of (1) oceanographic and geographic (i.e. longitude, latitude, depth) variables, (2) oceanographic variables and depth, and (3) only oceanographic variables. The importance of predictor variables in explaining the response variable (e.g. the presence of a specific species, the presence of corals from the same family) was assessed for each model, and the ability of the different models to fit the data was compared.

Results indicate that, when used, geographic variables may obscure other potential drivers of species distribution. Generally, models built using a finer taxonomic resolution (e.g. species level) included more explanatory variables than models produced at a broader thematic scale (e.g. functional group level). This may relate to the spatial scale at which habitats are described, and whether species are generalists or specialists. In addition to geographic variables, salinity, pH, and oxygen and nitrogen saturation were often found to explain coral distribution.

The selection of thematic scale, or in this instance taxonomic resolution, should be carefully approached. Our results suggest that using a finer scale provides a more detailed and comprehensive representation of coral habitats. However, there is a tradeoff between thematic scale and number of samples; species distribution models built at a finer thematic scale may have less available samples than models built at a broader thematic scale. In the end, it is the questions asked that define which scale is most appropriate, and producing models at multiple thematic scales may help determine which one is best to use in a particular context.

Comparison of Megainfaunal Assemblages Observed on Hueneme Shelf in 1974 and in 2012 Geophysical/Acoustic Habitat Maps

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In 1974, I compared species composition, density, biomass, and other factors for megafaunal and macrofaunal assemblages on four transects at five depth levels between 14 m and 55 m on the Hueneme Shelf in southern California. That study revealed fundamental differences between the two assemblages in this study area and demonstrated how little we know about a diverse range of variables that can be used to describe infaunal assemblages. I concluded that four different megafaunal assemblages were the most important components of the infaunal assemblages, each dominating in different habitats at different depth zones.

These observations differ dramatically from habitat patterns reported in the 2012 USGS habitat mapping report for Hueneme Shelf. They show that ecologists and the animals living in the sediments view the meaning of the term ‘habitat’, i.e., ‘the natural environment of an animal or plant’, very differently from the primarily geological way that physical scientists appear to portray habitat in their mapping efforts for unconsolidated sediments on Hueneme Shelf. Ecologists see the concept of habitat as holistic and diverse. In addition to the geological attribute shown in the 2012 USGS habitat map, the “critters” and ecologists who study them see: 1) hydrodynamic regimes, 2) biological attributes, 3) sediment chemistry, 4) water temperature, and 5) water chemistry, as important habitat attributes that govern biological distribution patterns. Thus, on Hueneme Shelf, where geophysical/acoustic mapping finds primarily only a single fine sand ‘habitat’, infaunal animals and ecologists see at least four depth-related habitats.

In addition, ground-truth photographs and video suggest that the biota in the area is impoverished compared to the richness of the biota observed in 1974. This indicates that either: 1) the ground-truth surveys do not accurately represent the nature of the biological assemblages in the area; or 2) the area has undergone catastrophic losses since 1974.

High Resolution Facies Zonation and Survey Design at a Deep-Water Coral Mound; the Case of Piddington Mound, Porcupine Seabight, NE Atlantic

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Framework-forming cold-water corals (CWC's) such as *Lophelia pertusa* and *Madrepora oculata* generate positive topographic features on the seabed called CWC mounds. These mounds contain high-resolution records of paleoenvironmental change. In the North East Atlantic, CWC mounds have been studied in detail but many of these studies are limited by a paucity of data (cores, remotely-sensed and video imagery). Here, we present the first attempt to video mosaic an entire CWC mound and the first attempt at standardising a cost-effective video-survey design specific to CWC mounds.

An entire CWC mound surface has been imaged by downward-facing ROV HD video in 2011 and 2015. The mound has also been surveyed by high-resolution, ROV-mounted multibeam echosounder. The HD video is automatically mosaicked and georeferenced. The mosaic is divided into 18,980 0.25 m2 cells with a manual classification applied to each within a geographic information system (GIS). Geospatial analysis shows that coral distribution is not random but clustered significantly across the mound surface. These clusters of coral make up a ring-like facies pattern. A model for the processes that lead to this facies pattern is suggested based on contemporary environmental controls.

Further, the minimum number of random downward-facing images from the mound are determined to accurately characterise mound surface sediment facies proportions. This minimum sample size is used to test the effectiveness of various common survey designs for ROV-video-based habitat investigations. Single-pass video lines are not representative of the mound surface whilst gridded survey designs yield best results, similar to 100% mound coverage. The minimum sample size and manual classification are applied to the 2015 video data to show a 19% mound surface facies change over 4 years at 0.25 m2 resolution. The proportion of live coral facies show little change while coral rubble facies show most change. This highlights an inconsistency between temporally-separated data sets and implies that in 20 years, the mound surface may almost entirely change. These results can be directly applied to imaging and sampling heterogenous seabeds.

Repeat Mapping in Upper Monterey Canyon Captures the Effect of Sediment Transport Events of Known Magnitude and Duration on the Seafloor Morphology

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As part of a multi-institution submarine canyon study, the Coordinated Canyon Experiment (CCE), high-resolution multibeam bathymetric surveys of the floor of Monterey Canyon, offshore California, were conducted to capture the changes in seafloor morphology directly related to the passage of sediment density flows documented during the study. The goals of this study were to monitor the passage of sediment density flows as they move through the axis of a submarine canyon in order to understand the velocity structure of these flows and to document the associated changes in seafloor morphology and the resultant deposits. The CCE consisted of an array of moorings and sensors deployed on the canyon floor during the 18-month period between October 2015 and April 2017. In addition, a mapping AUV (Autonomous Underwater Vehicle) repeatedly surveyed sites along the canyon during the study. Differencing the repeat grids quantified the morphological changes directly related to specifically documented, individual flow events. The AUV carried a Reson 7125 multibeam echosounder (vertical precision of 0.15 m and horizontal resolution of 1.0 m). An inertial navigation system combined with a Doppler velocity logger allowed the AUV to fly pre-programmed grids at 3 knots while maintaining an altitude of 50 m above the seafloor and obtain a nominal line spacing of 130 m. The axial channel between 200 and 540 m water depth was surveyed six times. Fifteen sediment density flow events were captured by the array of CCE instruments within this AUV survey area. Repeat mapping surveys conducted November 4, 2015 & January 28, 2016 were used to create a difference map showing the change in seafloor bathymetry. These changes, restricted to a ~200 m wide band on the canyon floor, are characterized by a +/- 3 m change in bathymetry and are primarily attributed to the sediment transport captured on January 15, 2016. While crescent-shaped bed-forms were seen on the canyon floor before and after this event, the kilometer-scale displacements of large instruments (> 500 kg) suggests that the changes in the sea-floor are not simply due to short distance migrations of individual crescent-shaped bed-forms. This study highlights the changes in seafloor morphology in response to sediment transport events of known extent, magnitude, and duration.

Multibeam Backscatter Calibration by Comparison with a Reference Single- Beam Echosounder

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The calibration of multibeam echosounders (MBES) for absolute-level backscatter measurements can be conducted efficiently and accurately by comparing the measured levels with those from a calibrated reference single-beam echosounder (SBES) at the same frequency over a same patch of natural area, possibly opportunistic but fulfilling conditions of regularity and homogeneity. The reference SBES is calibrated by the classical sphere-target method from fisheries acoustics. This method was applied to a Kongsberg EM 2040-D installed on Ifremer's RV Thalia. A shallow area (20 m) has been defined and qualified in the Bay of Brest (France), and subsequently chosen as a reference area for high-frequency multibeam systems (above 200 kHz). The absolute reflectivity over the area was measured using fishery calibrated SBES (Simrad EK60 at 200 and 333 kHz) deployed on the ship's side and tilted at incidence angles varying between 0° to 60°. These reference levels were first fitted to a heuristical model of angular backscatter, then compared to the average angular backscatter values from the MBES at close frequencies. The difference gives the angular bias applicable to the multibeam system for recorded level calibration; the operation has to be repeated for every working mode of the MBES. The calibration results were finally validated by checking the single- and multibeam data obtained on other areas with sediment types different from the reference area. This field method of cross-calibration is far more practical than the time-consuming and difficult metrology operations in controlled environment, while providing accuracy compatible with most applications of seafloor backscatter for mapping or monitoring. The method will still be improved by the availability of the new-generation wide- band SBES; moreover it is now being extended to lower-frequency systems.

Repeated Multibeam Surveys to Assess Sea-Floor Changes Induced by Recently Build Hard Structures in a Very Shallow Coastal Environment

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Coastal hard defence structures are ubiquitous all over the world and their presence will likely increase to protect the shoreline from global mean sea level rise. The processes induced by the construction of coastal hard structures are well studied in the scientific literature mainly based on laboratory experiments and/or numerical models. Less scientific studies have focused on the sea-floor changes induced by coastal hard defence structures based on field surveys, particularly in very shallow environments.

However, the recent development in multibeam echosounder technology now provides such high resolution for shallow water sea-floor mapping that it is possible to assess quantitatively the changes induced by recent human modifications on the sea-floor in coastal areas with high accuracy. For this assessment, it is crucial to define repeatable workflows to be applied to different multibeam datasets collected over time and use appropriate standards.

In this study, through the combined use of repeated multibeam and ground truth data, together with semi-automatic geomorphometric analysis, we document the rapid change related to new hard coastal structures built to protect the historical city of Venice (Italy) at the Venice Lagoon tidal inlets. Specifically, we quantitatively describe the morpho-sedimentary changes of the tidal inlet sea-floor and the scouring process currently on-going at the tips of newly built breakwaters. Through the comparison of the multibeam data collected in 2011, 2013 and 2016, we estimated the volume of eroded sediment since the breakwater construction and relative error and the rapidity of the scouring process.

The geomorphometric analysis workflows based on ArcGIS and MATLAB were designed to be as repeatable and re-usable as possible and can be applied to multibeam data collected all over the world to monitor the sea-floor physical changes induced by the construction of hard structures.

Methodological Approach to Characterized Coral Reef Ecosystem with Hydroacoustic in the Surrounding Area of the Cayo Serrana Island, Seaflower Biosphere Reserve, Colombia

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Acoustic methods allow access to the seafloor characteristics in a rapid and extensive manner, which is not possible using other underwater methods or technologies. Currently, acoustic investigations are widely used to determine the topography and identify the type of sediments of the seabed, but there has not been a significant development in the detection and classification of the structures present above the seabed which have a great ecosystemic importance, such as the coral reefs and marine grasslands. The remote acoustic mapping of these benthic ecosystems could provide value information for research and for the proper management of the oceanic natural resources. In the present study, a new methodological approach is proposed to characterize the seabed at Cayo Serrana Island (CSI, at 14° 23'- 14° 29' N and 80° 06 '- 80° 14' W) in the Colombian Caribbean, combining acoustic information (Echosonde Split beam) and underwater imagery. Forty-nine (49) acoustic tracks were made using a Biosonics DT-X scientific echosounder (with 38 KHz Split Beam transducer and FURUNO differential GPS), during the III Seaflower Scientific Expedition (Colombian Ocean Commission - Colciencias), between August 12 -15, 2016. The acoustic tracks files (.dt4) were extracted and processed using a toolbox implemented in Matlab. The georeferenced acoustic files (longitude, latitude and range, which refers to the depth) were converted to distance (meters) from the initial point. After removing atypical profiles (with mean Target Strength TS < -40), the acoustic tracks were re-generated to a regular distance of 1 m and interpolated in order to fill gaps. Further, the acoustic reflectance profiles on each track were aligned according to their maximum refraction. Using cluster analysis with a Spearman correlation distance of more than 80%, twelve (12) different Types of Acoustic Profiles (TAP) were obtained. The resulting TAP were grouped according to the sediment types and ecological structures present on the seabed. When comparing these TAP with the photographic record and previous ecological maps, various ecological structures above the seabed can be identified: 1. Coral reefs (massive corals, branched corals, octocorals), 2. Coral debris (rocks and dead coral) and 3. Macroalgae grasslands (calcareous algae and seagrass meadows). On the base of these results it is further discussed the potential of this approach to generates a low cost automated method for mapping the seabed ecosystems (coral reef and grasslands) that can enable feasible assessment in other especial and/or protected marine areas.

Bathymetric and Reflectivity-Derived Data Fusion for Preliminary Seafloor Segmentation and Strategic Bottom Sampling

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Modern multibeam sonars and processing software typically produce geo-located bathymetry and backscatter mosaic products, thus offering the opportunity to treat both data sets together to support seafloor characterization. However, there are few studies that have offered general methods for using machine-focused (automated) approaches for seafloor segmentation that combine and use the information found in co-located bathymetric digital elevation models (DEMs) and acoustic reflectivity mosaics.

We explore a methodology to combine both bathymetry and backscatter data to automatically segment the seafloor. The proposed method attempts to mimic the approach taken by a skilled analyst assuming that, when called upon to manually segment a seafloor area, the analyst initially evaluates the context surrounding the area and attempts to take full advantage of both bathymetric and reflectivity products rather than focusing on small-scale geomorphometric variability (e.g., local rugosity). The result is a bathymetry- and reflectivity-based estimator for seafloor segmentation that mimics the positive aspects of the segmentation process as performed by a skilled analyst (e.g., the use of context and multiple inputs) but avoids the inherent deficiencies (subjectivity, processing time, lack of reproducibility).

The algorithm starts by adopting principles of topographic openness, pattern recognition, and texture classification to identify geomorphic elements of the seafloor or “area kernels”, and then derives the final seafloor segmentation by merging or splitting the kernels based on the principles of similarity and multi-modality.

The output is a collection of preliminary, homogeneous, non-overlapping seafloor segments of consistent morphology and acoustic backscatter texture. Each labeled segment is enriched by a list of derived, physically-meaningful attributes that can be used for subsequent task-specific analysis. In this work, the resulting segments have been evaluated as possible inputs to identify a strategic seafloor sampling (ground-truthing) plan aimed at advancing characterization results while optimizing operational field efforts.

Benthic Habitat Mapping and Monitoring in the Mississippi Sound: Multidisciplinary Integration of High-Resolution Acoustic Data and Object-Based Analysis Techniques

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Over the past two decades, the health and productivity of oyster reefs in the Mississippi Sound has declined approximately 90% due to the combined effects of Hurricane Katrina, the Deepwater Horizon oil spill, and massive freshwater overflow events from the Mississippi River. In support of the Mississippi Sound Oyster Restoration and Management Project, funded by the National Fish and Wildlife Foundation's Gulf Environmental Benefit Fund, our team has been leading a multi-year benthic habitat mapping and monitoring effort. Since 2016, our team has acquired and compiled approximately 60 km^2 of high-resolution bathymetry and acoustic backscatter imagery and over 9,500 km of subbottom profile imagery throughout the Mississippi Sound. These data have been acquired through high-precision hydrographic surveys in water depths as shallow as 1.5 m. Multidimensional data integration, object-based image analysis techniques, and extensive geologic interpretation have facilitated the production of detailed habitat maps.

The first component of the project included baseline habitat mapping of a 2 km^2 research area near Ocean Springs, Mississippi. The baseline habitat map products were used to select optimal sites for the experimental deployment of various types of reef-building substrates. These experimental sites will be monitored annually over the next several years to quantify the growth of the nascent oyster reefs on each type of substrate. The second component of the project included large-scale baseline habitat mapping of 58 km^2 of active oyster reef complexes in the western Mississippi Sound. In this area, the habitat map products have revealed that the current spatial distribution of oyster reef resources varies significantly from the managed boundaries. These habitat maps will serve as the foundation for future oyster restoration and aquaculture projects in the Mississippi Sound and will be used to inform and update management strategies to ensure the sustainability of Mississippi's oyster reef resources. In addition, this project is a valuable case study for other comprehensive habitat mapping initiatives in shallow marine environments.

Forecasting Fish Community Biomass and Production on Offshore Pacific Oil Platforms under Three Decommissioning Scenarios

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Pacific offshore oil and gas platforms function as artificial reefs, providing habitat used by invertebrates and fish. The management of underwater infrastructure therefore impacts the fish communities that are associated with these structures. To inform the platform decommissioning process in southern California, we estimated fish biomass and somatic production on 24 Pacific platforms under three possible decommissioning scenarios: leave in place, partial removal at 26 m, and complete removal of the platform and shell mound. We used fish density data from SCUBA and manned submersible surveys from 1995-2013 conducted along the jacket, rig base and shell mound of each platform. Because fish densities on the platform jacket are not homogeneous, the surveys conducted along horizontal jacket beams were scaled up to estimate total platform biomass and production using three alternative models, providing a range of estimates that vary in their assumptions about fish habitat usage. To estimate biomass and production under the complete removal scenario, we assume an eventual reversion to soft bottom habitat, and use fish density data from nearby bottom trawl surveys conducted by the Southern California Coastal Research Project and the NOAA West Coast Groundfish Bottom Trawl survey. We present the expected loss in fish biomass and somatic production under the partial removal and complete removal decommissioning scenarios to inform offshore platform decommissioning options in the Southern California Bight. Further research should be conducted to contextualize these local effects on a larger scale by assessing the contribution of platforms to larval production, regional production of fish species, and connectivity between natural reefs.

Long and Short-Term Impacts of Marine Sand Mining on Shallow Sandy Habitats (German Bight)

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With regard to current and projected sea-level rise, sandy shorelines are under increasingly strong pressure. In order to compensate the loss of material at threatened coastlines, soft coastal protection measures such as beach nourishment are considered to be environmentally-friendly and sustainable way, all over the world. This results in a higher demand of nourishing material, which is frequently extracted from the near-shore seafloor. In order to predict long- and short-term impacts of such mining on the seafloor habitats, as well as the potential for natural regeneration, we investigated the largest extraction area in the German Bight the (*Westerland Dredging Area, WDA*). Here, sand mining began in 1984. We conducted several measurement campaigns between the years 2008 and 2016 using a set of high-resolution hydroacoustic techniques including multibeam echo-sounder and sidescan sonar. For ground-truthing, sediment samples and underwater videos were taken. The measurements show that up to approximately 20 m deep pits with a diameter of particularly more than 1 km were dredged into the seafloor. The depressions caused by this sand mining are still detectable more than 30 years later. The formerly steep slopes at the fresh dredging pits flattened out due to slope failures and spilt sand after only a few months. Grain-size analyses revealed that mainly fine sand entered the pits in this early phase. However, after approximately one-year, muddy sediments, most likely of terrigenous origin, dominate the deposition. Since the sedimentation rates of this muddy material seem to be relatively slow, a complete refill of the post-dredging pits is likely to take many decades. A natural regeneration towards the former seafloor conditions is only visible at the edges of the very oldest dredging pits. Underwater video recordings and samples show that new habitats for e.g. brittle stars were established on the muddy seafloor. These organisms are not normally found in such sand-dominated coastal areas in high abundances. The same applies to stone deposits lying on the sandy seafloor at the edges of the dredging zones. These were separated from the sand during the extraction process. Stones on the seafloor provide protection for many species and might form important hotspots for biodiversity in this area.

Accounting for the Effects of Spatially-Autocorrelated Sampling in Marine Species Distribution Models

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It is generally accepted that benthic habitat maps are essential tools for the management of coastal marine resources. The quality of these tools is commonly assessed using metrics of map performance (e.g. correct classification, correlation, variance or deviance explained) that rely on testing map predictions against "ground-truth" observations. Because of the prohibitive cost of seabed sampling, data are often collected in transects to maximize the use of ship time. Because collecting independent evaluation datasets is seldom feasible, data are commonly partitioned into "training" data for model building and "test" data for evaluation. One issue that arises with this methodology is that proximal samples within a transect are spatially autocorrelated – they are similar simply because they are close together. The use of randomly selected test data from a spatially-autocorrelated dataset can artificially inflate performance metrics because test data that are proximal to training data are easier to successfully predict than those that are distal; in other words, the data are not independent.

Using multibeam echosounder data and derivative terrain variables, we modelled the abundance of *Mya* spp. clams in Qikiqtarjuaq, Nunavut, Canada, from underwater images (n = 1990) collected in transects, to support the management of a local small-scale clam fishery in an area ~135 km^2. Initial 10-fold cross-validated (CV) model predictions seemed highly accurate, yet we suspected these were artificially inflated due to the spatial autocorrelation of sample points. We developed a methodology for estimating the inflation of model performance, and penalized the full model to obtain an unbiased estimate of performance.

Semivariograms suggested that samples > 37 m apart were spatially-independent, yet the average distance between samples within a transect was ~3 m. We bootstrapped the dataset many times with a minimum distance of 40 m between sample points to acquire spatially-independent subsamples, which we used to model the abundance of clams with identical parameters as the full model. The same number of points were then redrawn many times with no minimum distance between sample points, which were used to create spatially-autocorrelated models of clam abundance. The difference in performance between spatially-independent and -autocorrelated bootstrap models suggested that Pearson's and Spearman's correlations were inflated by 0.09 and 0.05, respectively, and percent deviance explained by 9.1%. We used these estimates to correct the apparent performance of the full *Mya* spp. model, yielding Pearson's and Spearman's correlations of 0.69 and 0.75, respectively, and 54.1% deviance explained. This methodology provided a non-spatially-biased estimate of model performance, and permitted the use of all samples for model training.

By explicitly accounting for the effects of spatial autocorrelation on our abundance model, we increased the integrity and transparency of our map products. We consider the evaluation of spatial structure to be an extremely important part of habitat modelling, especially in the marine realm where transect data are commonly used. In this study, the spatial structure of transect sampling inflated apparent model performance by up to 9.1%.

Deepwater Hydrocarbon Seep Hunting – An Integration of Hydrographic and Geologic Approaches

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Natural hydrocarbon seepage modifies physical and biological characteristics of the seafloor that can be detected by low-frequency multibeam echosounders up to 4,000 m water depth. Seep-related features such as authigenic carbonate deposits, chemosynthetic communities and shell debris, gassy muds, and brine pools have characteristic acoustic reflective responses that can be imaged with multibeam backscatter. Bathymetry can highlight seep-related morphology that includes localized highs associated with mud volcanoes and mounds, localized lows associated with pockmarks, and seafloor faults that serve as petroleum fluid migration pathways. Midwater backscatter can detect free gas release at the seafloor that expels clusters of oil and gas bubbles hundreds of meters into the water column. Integrating these multibeam datasets coupled with the wide swath of the MBES allows for efficient mapping and localization of seafloor hydrocarbon seeps.

As frontier exploration moves into deeper waters in search of oil and gas deposits, resolving fine-scale seep features becomes challenging and studies that examine the acoustic responses of seep features using deep-water multibeam systems are needed in order to identify and characterize deep seeps. Small nuances in both hardware and software settings can dramatically impact the detectability and interpretation of seep features in deep-water. Fugro's regional seep hunting surveys cover over 1,000,000 km^2 annually in deep unexplored frontier basins searching for hydrocarbon seeps for the oil and gas industry. We will discuss how these commercial deep-water seep hunting surveys differ from traditional hydrographic surveys from an operational and scientific standpoint. Detection and analysis of deep-water seeps is an integration of using a low-frequency MBES optimized for seep detection that includes specific acquisition and processing parameters along with analytical and 3D interactive visualization techniques.

Short-Term Variability of High-Frequency Seafloor Multibeam Echosounder Backscatter: Results from Field Experiments on the Belgian Continental Shelf

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To map substrate type and distribution, multibeam echosounder (MBES) backscatter is increasingly used. Challenging remains the use of the technology in a monitoring context, e.g., to assess good environmental status of marine waters within Europe's Marine Strategy Framework Directive. A prerequisite is to control system stability and calibration (relative or absolute) of the sensors, but also acquisition and processing routines (and standardization). Evaluations are needed on the precision, sensitivities and repeatability of the acoustic observations and factors other than those exclusively related to the seabed need investigation since they may influence the mean backscatter level from one survey to another.

Three experiments were conducted in the Belgian Part of the North Sea and targeted the investigation of the effect of external sources of variance on the acoustic signature of predominantly gravelly, sandy and muddy areas. Repeated measurements of high-frequency (300 kHz) MBES backscatter data over single tidal cycles (13h) were combined with different ground-truth approaches, including seabed and water-column sampling. Additionally, a benthic lander was deployed, equipped with a suite of oceanographic sensors (e.g., turbidity chains and current velocimeters). Results point at a high stability of the sandy gravel area (< 0.5 dB @ BS_{45}), whilst the shallow sandy and muddy areas showed very high variability over a tidal cycle presenting ranges in mean variability of > 2 dB and 4 dB @ BS_{45}. While transmission losses due to seawater and suspended sediment gave negligible effects on the observed variability, roughness polarization, as well as actual seafloor interface changes appeared as explanatory factors of the observed oscillation.

Results evidence the sensitivity of high-frequency backscatter to a range of environmental factors that users and surveyors must account for when designing surveys aimed at detecting changes in seabed habitats.

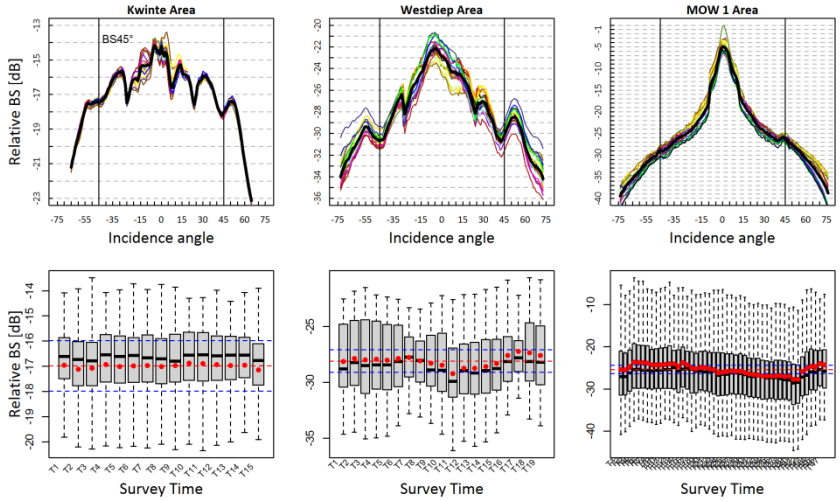

Figure 1: Angular response (AR) short-term time-series for the three experiments. Overall 15, 19 and 47 MBES passes were performed for the 1st, 2nd and 3rd experiment respectively. Vertical black lines indicate the Backscatter Strength at 45° and the solid black AR represents the average curve of the time-series. Below, same data presented as boxplots against survey time with mean values plotted along with a ± 1dB confidence interval (reflecting system sensitivity and half the mean dB distance required to discriminate between different sediment types). For experiment 2 and 3 strong tidal dependencies are visible.

Geomorphic Mapping of Perth Submarine Canyon, Southwest Australia: Insights into Canyon Evolutionary Processes and Relevance for Management

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Perth Canyon is incised into the continental slope and shelf of southwest Australia. The canyon covers ~1,500 km^2 and extends from water depths of ~170 m at the shelf break to ~4700 m at the foot of the slope, and follows a path that appears structurally controlled. Within its upper reaches, the canyon interacts with regional oceanographic currents (the Leeuwin Current and Undercurrent) that drive summertime up-welling of nutrients. In turn, this promotes plankton production and aggregations of pelagic fish, including blue whales and migrating humpback whales. In recognition of this biodiversity the canyon is part of a Marine Protected Area, incorporating a Marine National Park and Habitat Protection Zone. Previously, detailed information of the spatial patterns of the seabed features that influence the potential benthic biodiversity of Perth Canyon were lacking. Here we present a new geomorphic map of the Perth submarine canyon using 20 m resolution bathymetry and acoustic backscatter data acquired in 2015 by the Schmidt Ocean Institute, plus sub-bottom datasets and sediment samples collected by Geoscience Australia in 2005. Mapping is based on a new classification scheme that incorporates large-scale Surfaces (Plain, Slope and Escarpment) defined from seabed slope data that are manually divided into sub-Features. Geomorphic features are based on established classification schemes and definitions, including the International Hydrographic Organization and the US Coastal Marine and Ecological Classification Standard.

Mapping results show that 45% of the canyon is characterised by Escarpments (gradient > 10 degrees), 37% by Slope (2-10 degrees) and 18% by low gradient Plane (< 2 degrees). Geomorphic features that make up Escarpment surfaces include ridges, gullies and blocks that collectively define mass movement features that extend most of the length of the canyon and span water depths of over 2,000 m. These escarpments provide exposed rock surfaces for sessile organisms to colonise (including hard and soft corals as observed by ROV). Lower gradient Slope surfaces also display geomorphic evidence for mass wasting, including aprons and irregular depressions. Sub-bottom data for a profile that crosses a canyon feeder channel show a 1.5 km wide tilted slump block as further evidence for instability. Along the lower reaches of the canyon floor (Plane surface) fields of bedforms up to 5 m high are evidence for bedload transfer from the canyon walls to the floor. Overall, the distribution of mass movement features and bedforms is a key factor influencing the long-term stability of the seabed and potential diversity of benthic habitats within the canyon. This new information on seabed form is now being used by managers of the Perth Canyon Marine Park to support management plans, prioritise monitoring and undertake assessments of proposed activities within the park.

A Method for Applying Crowd-Sourced Single Beam Bathymetry and Substrate Classification to Large-Scale Benthic Habitat Mapping

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Increased pressure on marine ecosystems and prioritization of marine spatial planning have created an urgent need for a better understanding of marine habitats. Development of surrogates for the distribution of marine species, like depth, geomorphology, or substrate type, rely on high resolution bathymetry generally collected through multibeam echo sounding; data which is only available for a small fraction of the global ocean. We will demonstrate a method for mapping the seabed based on existing single beam bathymetry and substrate data compiled from industry (crowd-sourced Olex bathymetry from fishing vessels) and government (Fisheries and Oceans Canada RoxAnn seabed classification and Geological Survey of Canada sidescan, imagery and grab samples) at > 100x finer resolution than previously available and at very little cost.

Empirical Bayesian Kriging was used to generate a continuous bathymetric surface from incomplete and, at times, sparse Olex coverage for an area of 690 725 km^2 of the Newfoundland and Labrador shelf. The result is a 75m bathymetric grid, a much finer spatial resolution than previously available for the majority of the study area (30 Arc seconds, via the General Bathymetric Chart of the Oceans). Correlation between the interpolated Olex surface and RoxAnn bathymetry (n=383 967 test points) is > 95%, showing strong agreement between independent datasets. Continuous marine substrate distribution was predicted via Boosted Regression Trees, based on the relationship between Olex-based geomorphology, RoxAnn substrate classes, and in-situ samples. Results of these models show realistic relationships (ex. occurrence of mud positively associated with depth and topographic depressions) and 10-fold cross validated models yield robust predictions (ex. cross-validated correlation of 0.7 and receiver operator score of 0.9 for predictions of mud).

Olex and RoxAnn datasets are available throughout Canadian territorial waters, and represent decades of survey effort that have been largely unused in ecological research to date. Olex data is also collected in the exclusive economic zone of many nations, and previous work by the MAREANO program has also demonstrated the utility of Olex bathymetry for mapping marine biotopes. Bathymetry, terrain attributes, and substrate models generated from this work provide useful information on marine habitats for management, conservation, and ecological research. This presentation will outline the generation of continuous bathymetry and substrate maps for the Newfoundland and Labrador shelf and the application of these data layers to improve estimates of demersal fish distribution for conservation and fisheries management.

Investigating the Potentials of an Automatic Seafloor Classification from Multibeam Backscatter Data in Fledermaus Geocoder Toolbox (FMGT)

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Multibeam echo sounder backscatter intensity measurements have been used to infer seafloor properties and segment the seafloor into different acoustical regions. Acoustic backscatter strength is dependent on various properties of the seafloor, which has direct link to the incidence angle of beams in contact with it. In addition, the backscatter intensity and its statistical properties measured with multibeam systems depend on the insonification area and footprint size of the received beams (Parnum, I.M and Gavrilov, A.N, 2012).

The main objectives of this study were to investigate the possibility of an automatic seafloor classification from various backscatter data sets acquired from different survey locations with different multibeam systems. Subsequently, results obtained from the software were extracted and numerically analyzed with the aid of Matlab programming. This was necessitated as there were certain limitations in Fledermaus Geocoder that hindered a more efficient numerical analysis of its results.

Analysis of the results suggests that the models implemented in FMGT enhanced the correlation between backscatter return strengths from different seafloor types and its associated grain sizes, irrespective of the multibeam type or the location the data was acquired. Results were further improved and verified with available ground truth information, while numerical extraction and analysis was achieved with a Matlab program.

Acoustic Investigation of Gas Domes in Lumparn Bay, Åland Island

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Acoustic surveying of Lumparn Bay, at Åland Island in the Baltic Sea shows an abundance of signs for gas occurrences in the sediments based on data from acoustic investigations. The most notable gas related features are the gas domes occurring throughout Lumparn bay. To date approximately 2,000 domes have been observed in the 100 km^2 Lumparn bay. The gas domes are shallow features with an average diameter of 30 m and a height of < 1 m. The domes are easily seen in the acoustic profiles, and occasionally associated with underlying acoustic chimneys.

Although other literature has suggested that gas domes are the first stage in formation of pockmarks, this does not seem to be the case in the case of Lumparn since there are no recent pockmarks observed. Considering the great number of domes observed, you would expect there to be at least a few pockmarks, which there are not. This suggests that the domes may be independent features, created independently of pockmarks. The domes are likely formed by biogenic methane gas produced in the sediments under reducing conditions. The domes are also restricted to a certain depth, with the majority of the pockmarks found on a depth of around 17 m, with a significant reduction in domes in the deeper areas of Lumparn. The few domes observed in deeper waters tend to be both fewer in number and smaller in size. This suggests the physical environment such as depth is a significant factor in the occurrence of domes.

Using Cold-Water Corals from the Porcupine Bank Canyon, NE Atlantic, as a Palaeoarchive

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Cold water corals (CWCs) are sessile suspension feeders and occur globally in deep sea settings. They trap current-suspended particles (food, nutrients and sediment) from their environment which becomes deposited in and around the coral framework resulting in the growth of topographic features called CWC mounds. As such, these coral mound features now contain a record of paleoenvironmental change through time. Here, we present a project within the Mapping, Monitoring and Modelling Mapping, Modelling and Monitoring Key Processes and Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonkey_Pro; www.marinegeology.ucc.ie) research programme which focuses on the temporal development and paleoenvironmental history of CWC habitats (reefs, gardens, mounds and coral-derived tallus slopes). This project started in January, 2018.

A number of ROV-mounted vibrocore samples have been retrieved from the Porcupine Bank Canyon (PBC), NE Atlantic. These cores will be scanned using computed-tomography following, and further developing, a novel methodology. The cores will be logged and subsampled for high-resolution laser granulometry, composition (CaCO3% and Organic%) and dating. This unique multidisciplinary approach will allow to determine the controls of mound cessation and development. For the first time, we aim to shed light on what controls the formation of different CWC habitats (gardens vs. mounds). Furthermore, analyses of these cores will be an essential component in understanding the key PBC processes and controls on habitat development in submarine canyons.

A number of other ROV-vibrocore samples will be acquired, including those from coral tallus deposits in late July 2018 (CE18011). Sediment traps and further sub-bottom profiler data will also be gathered during this time.

Biological and Geomorphological Description of a Prominent Escarpment along Ireland's Shelf Edge in the Northeast Atlantic

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A requirement exists to quantify the abundance and distribution of Annex 1 Reef habitat (1170) in Irish waters to fulfil Ireland's legal mandate and to generate baseline data from which appropriate monitoring systems can be established. A deep-water survey took place in 2017 using the Marine Institute's *Holland 1* ROV equipped with HD recording capabilities to observe seabed features and biological associations in previously unexplored canyons along the northwest Irish continental shelf.

The survey area extends approximately 560 km from south of the Hebrides Terrace Seamount to the northern part of the Porcupine Bank. Survey transects were pre-selected using criteria that included depth range, areas of highly sloping terrain, geographical spatial discreteness, historical fishing activity, historical scientific studies and the presence or absence of certain target geomorphological features which included, canyons and canyon walls, gullies, escarpments, ridges, carbonate mounds and cobble fields.

The video footage documented previously undescribed habitats associated with a number of morphological features (e.g. within canyons, mounds, ridges) including an escarpment extending for ~160 km. This escarpment, originally identified in multibeam echosounder data acquired as part of the Irish National Seabed Survey, extends in water depths from 473 to 835 m and its biological communities have not been described.

Preliminary video analysis from the escarpment reveals an along-slope moat with soft sediment and dropstones transitioning to carbonate ridges and overhangs that form a series of sub-parallel escarpments up to 100 m high in some places. Due to the depth range and orientation (contour parallel) it is likely the moat feature is current generated. This combination of topography and water movement along the survey area is ideal for filter-feeding, cold-water coral species which are frequently present as small discrete colonies but also occur as larger reef-forming colonies, particularly on ridges and overhangs. Their presence promotes higher marine biodiversity along the shelf edge and the escarpment is characterised by a diverse fauna including anemones, ophiuroids, crinoids, brisingids, asteroids, crabs, galatheids and hermit crabs.

The presence of slope failures leading to sediment deposits and localised steep scarps suggests the escarpment feature is of erosional origin similar to the 250 km Blake escarpment in the Bahama-Blake Basin. The video data acquired during the survey will help to map the extent of sensitive ecosystems in Irish waters and their associated morphology. It will broaden our understanding of the ecological requirements of these environments and lead to the sustainable management of Ireland's marine biodiversity.

Telescoping Resolutions for Abyssal Seafloor Mapping

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Over the last 15 years, the Monterey Bay Aquarium Research Institute (MBARI) has focused on developing systems to collect bathymetric maps of small sections of the seafloor at increasing levels of resolution. Because the resolution of mapping systems is inherently controlled by the range between the sensor and the seafloor, the primary approach to enhance the resolution of seafloor maps has been to carry the sensors on Autonomous Underwater Vehicles (AUV) and operate them 50 m off the seafloor. At this range surveys can produce grids with 1-m resolution using commercially available 200 and 400 kHz multibeam sonars, regardless of water depth. These surveys frequently reveal the existence of features and environments in deep water (e.g., > 1 km) which are unseen in the best available surface ship multibeam survey data.

Repeated 1-m resolution AUV surveys have successfully documented the on-going landscape evolution occurring in some of the most geologically active areas on the seafloor (e.g., seafloor volcanos and submarine canyon channels) with mapping frequencies of one year or less. However, the amount of change that can be anticipated to occur within most abyssal areas, over even decade long intervals, is too small to be captured using repeated 1-m resolution surveys.

A higher resolution seafloor visualization system, involving a suite of complementary survey technologies, is being developed at MBARI with the goal of being able to quantify small changes in the seafloor associated with biological and geological process. This system incorporates co-registered, multibeam sonars, stereo cameras, and LiDAR sensors on a remotely operated vehicle (ROV). When surveys are conducted ~2-4 m above the seafloor, lateral resolutions of 5-cm are achieved with the multibeam sonar, 1-cm with LiDAR, and 2-mm with the stereo cameras. At these resolutions, changes associated with the movements of animals within chemosynthetic biological communities and the development of cm-scale bedforms associated with ambient tidal currents are being measured. An added advantage of the co-registered multibeam and LiDAR mapping systems is that many animals are characteristically, acoustically transparent, but optically opaque. Thus, a biomass estimate can be obtained from the difference between two simultaneously surveys collected by the two sensor. The increased resolution and coupling of acoustic and optical mapping sensors offers the new approaches to assessing and quantifying changes within seafloor habitats.

Interdisciplinary Approaches for the Study of Cold-Water Coral Ecology and the Production of Habitat Maps to Assist Spatial Management Within Submarine Canyons

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Cold-water corals (CWC) situated in submarine canyons represent features of high conservation value that are under increasing anthropogenic pressure. Accurate CWC distribution maps are required to implement effective spatial management and monitor change. However, due to the challenges of surveying such remote locations, little is known about these systems. Habitat/species suitability modelling is one possible approach that can address these gaps by extrapolating existing habitat/species knowledge, based on environmental relationships, to predict suitable locations where similar habitat/species could occur. Fundamental to this principle is that the scales at which data are collected relate to the scales at which phenomena determining CWC distributions are suspected to operate. However, few interdisciplinary data sets collected at consistent spatial scales exist for canyons, and those that are available are often constrained by technological capabilities, rather than reflecting scales at which phenomena determining CWC distributions are suspected to operate.

This study utilizes multi-scale data sets acquired using remote technologies and subsequent modeling to produce distribution maps and elucidate aspects of CWC ecology. Data were acquired from the Whittard Canyon, collected during the JC125 expedition funded by the ERC CODEMAP project (Starting Grant no 258482) and the NERC MAREMAP programme. Video analysis was conducted to identify, enumerate and georeference epibenthic megafauna which was then used to create presence/absence data sets for scleractinian cold-water corals. Environmental variables were derived from bathymetry, the FOAM AMM7 ocean model and a canyon specific oceanographic model. Regression, classification tree, additive and ensemble modeling techniques were used to explore the relationship between CWC distribution and environmental variables to elucidate factors that may influence CWC distributions and produce suitability maps for the canyon.

The objectives of the study were 1) to ascertain which environmental variables and at what scale explain the greatest variation in CWC distribution and 2) how the inclusion of hydrographic variables affects model performance. Such studies are important to feed into future predictive modeling of CWC responses to management and environmental change.

Planning for Floating Wind Energy in California – A Case Study

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BOEM is responsible for leasing federal waters for Renewable Energy Development. In California, we are in the early stages of selecting offshore areas suitable for Floating Wind Energy Development. I will discuss the present state of floating wind technology, and present a case study demonstrating GIS in marine spatial planning as it relates to offshore wind energy in California.

BOEM is presently working with the state of California to locate suitable areas for wind energy development. Key datasets for our analysis at this stage include shipping traffic (AIS), wind speed, fishing, bathymetry, political boundaries and distance to electrical grid connection. As the leasing process progresses, we will do finer scale analyses involving birds, marine mammals, sediments, benthic habitats and other factors.

My talk will be very visual based showing how several of these datasets are developed, and how they affect the area we can consider for offshore wind development.

National and International Collaboration to Maximise and Standardise Australian Seabed Mapping Efforts

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Safe navigation, resource assessment and environmental management are the main drivers of high-resolution seabed mapping in Australia and its Antarctic Territory. Survey data is acquired by fewer players than end users who rely upon the either the raw data or the derived products. Until recently, there has been limited coordination of mapping efforts in Australia. This has resulted in a duplication of effort, limited use of data and lack of uptake by the community and a deficiency in processing methods for data consistency (both in acquisition methods and data processing). To improve this situation the Australian Government, through Geoscience Australia and key collaborators (such as Institute of Marine and Antarctic Science, Commonwealth Scientific and Industrial Research Organisation, the Australian Hydrographic Office), are undertaking the following activities:

- *Facilitating a national seabed mapping working group.* The National Seabed Working Group includes Australian and New Zealand representatives from federal and state governments, universities and industry. Driven by the principle of "collect once, use many times", the group is developing a priority plan for data acquisition in Australia, a national multibeam echosounder guideline and other common seabed mapping tools, and an on-line register where seabed mappers can advise of their pending activities within regions around the nation.
- *Developing field manuals to standardise marine monitoring.* Marine Parks (MP) cover over 30% of the Australian economic exclusive zone (EEZ) but less than 27% of the seafloor within the MPs is mapped at a high enough resolution to be able to derive habitat types. Habitat maps and significant topographical features are critical to supporting effective monitoring of these areas. To help address this, the National Environmental Science Program (NESP) Marine Biodiversity Hub (www.nespmarine.edu.au) - is developing standardized data acquisition and product development guideline (www.nespmarine.edu.au/field-manuals).
- *Developing a common geomorphic mapping approach for data interpretation.* Geomorphic maps are essential to understand seabed processes which in turn influence the distribution of marine biodiversity. Geoscience Australia is collaborating with the Geological Surveys of Ireland, Norway and Britain to develop semi-automated mapping tools and methods to standardise geomorphology products derived from high resolution bathymetric data.

This presentation highlights the progress and output products of these initiatives and demonstrates how collaboration is crucial to achieving efficient mapping effort around one of the world's largest marine jurisdictions of 9 million square kilometres.

A Review of Benthic Habitat Mapping on the South African Continental Shelf and Margin

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Seafloor mapping is a widely used tool and practice for a number of reasons; however there is a lack in terms of linking these maps to benthic habitats in a South African context. There has been notable focus on invertebrate fauna and flora, water chemistry, with little to no inclusion of sediment analysis or the effect of different substrata on benthic communities.

This paper provides a comprehensive review of the work which has been carried out to determine benthic habitats in South African waters. We focus on the continental shelf and the adjacent margin, to a maximum depth of 1,000 m. We compare methods to those employed in other areas globally and provide a mechanism for suggested future investigations.

The South African coastline is divided into nine marine bioregions that influence the distribution of faunal and floral species and benthic habitat diversity. The highest peaks in species richness and restricted endemics are found along the borders between bioregions. Species diversity is also affected by; climatic variations, depth differences, water chemistry and nutrient content within the water column, and changes in geomorphology and sub-bottom geology.

A benthic habitat study is currently being conducted by the authors along the west and southern coasts of South Africa, in the Table Bay and Cape Saint Francis areas. This study aims to fill the gap in our knowledge of inshore systems using new geophysical techniques and tools to predict benthic distributions of biota based on the seafloor geology.

Marine habitats are still significantly underrepresented in the protected areas network, with further research needing to be conducted in the fields of marine geology, ecology and biogeography. Biogeographic classifications are essential for developing ecologically representative systems of protected areas, as required by international agreements.

Cross-Shelf Transport and Delivery of Larval Flatfish to Nursery Habitat in the Gulf of Alaska

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Arrowtooth flounder (ATF: *Atheresthes stomias*), an ecologically important predator, spawns along the continental slope in water depths of ~400-500 meters, and after a pelagic larval duration of several months, late-stage larvae settle to juvenile nursery habitats in shallower water on the continental shelf. Successful transition between the pelagic larval stage and settled juvenile stage is influenced by two major processes: 1) dispersal and along-shelf transport of larvae, and 2) cross-shelf transport from offshore habitats to high quality inshore nursery habitats. Here we combine two basin-scale modeling approaches to determine the mechanisms that link these processes to influence survival to recruitment during this critical early life history transition. We apply an individual-based biophysical model (IBM) for ATF, using the Regional Ocean Modeling System for the Gulf of Alaska. We pair the IBM with an ATF nursery habitat model based on seafloor substrate, bathymetry, and occurrence of settlement stage juveniles.

Our results suggest that inter-annual oceanographic variability influences larval along-shelf transport with implications for local retention, long distance dispersal, regional connectivity, and realized nursery habitat. Submarine canyons along the continental slope are important conduits of shelf-ward transport for larvae. Eddies influence local retention, the geographic location of cross-shelf transport, and the degree that larvae are successfully transported from offshore pelagic habitats to inshore nursery habitats. These findings suggest that in the heterogeneous marine environment of the Gulf of Alaska, dispersal, transport, and offshore to inshore habitat connectivity are mediated by the interaction between persistent bathymetric features and transient oceanographic processes that ultimately affect survival and recruitment for these early life stages. This work informs ecosystem-based fisheries management.

Restoring a Nearshore Rocky Reef Ecosystem in the Challenge of an Urban Setting

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The subtidal rocky reefs that surround the Palos Verdes Peninsula in Los Angeles County, California USA are subject to multiple anthropogenic impacts, including many (at least partially) human-induced landslides over the past half century, which have resulted in chronic sedimentation (e.g., reef burial and scour) and associated turbidity effects along a major stretch of this coastline. The amount of rocky reef habitat has significantly decreased, as such determining the optimum technique for restoring this lost habitat is the focus of this study.

Over the past decade we have mapped and intensively surveyed the nearshore physical and biological characteristics both inside this impacted area and in surrounding reference areas that contain extensive rocky reef habitat with established kelp forests. Notable among all survey locations is a relatively high relief (~5 m) area of reef within the sediment impacted area, that consistently has the highest fish biomass density among anywhere on the peninsula. The high structural relief prevents sediment accumulation, scour, and subsequent reef burial, and this reef ultimately served as the example for the design of sets of quarry rock reef "blocks" that together form the proposed restoration reef.

Our primary objective is to use the 63,500 metric tons of quarry rock the budget would allow to create the most productive habitat by restoring the natural reef environment, while balancing scientific study design considerations (i.e., replicated reef components at multiple spatial scales) with maximizing the potential for an effective restoration effort across the range of important species and overall kelp forest biodiversity. To meet this objective, we considered multiple criteria that incorporated engineering specifications and biological performance, and were informed by the scientific literature and results of natural and artificial reef surveys in this region.

Ultimately the design incorporated heterogeneity at multiple spatial scales, while attempting to maximize high relief components, surface area to volume ratio, perimeter, ecotones, and small-scale current flow features and nutrient flux, while being consistent with the size of natural reefs along the Palos Verdes Peninsula. Further, placement and spacing of individual reef blocks, i.e., 32 m by 48 m heterogeneous quarry rock reefs, included space for sand channels between blocks to permit sediment transport and create sand/rock ecotone habitats, while remaining close enough to each other and existing natural reefs to maintain biological connectivity. Reef blocks were also located at the depth (15-20 m) where the most productive reef habitat in the region was observed.

Characterizing Drivers of Fish Biomass on Nearshore Rocky Reef in the Southern California Bight

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Using data sets that span the Southern California Bight (SCB), we analyzed nearshore rocky reef fish biomass using generalized linear modelling within the information-theoretic approach. Fish abundance and length were visually sampled, via SCUBA, within a random stratified sampling design using line transects across depth strata in < 20 m depth. This data was converted to biomass using published length-weight relationships.

Our spatially resolved explanatory variables included sea surface Chlorophyll a, maximum wave height, kelp biomass, urchin density, habitat relief and substrate indices, social factors, such as minimum distance to port and fishery harvest intensity index, among others. We also ran similar models to relate the biomass of the six most abundant species to the correlates.

The confidence model set (< 2 ΔAICc) for total fish biomass included the variables distance to the shelf break, sea surface chlorophyll a, sea surface temperature, and slope. The explanatory variables had different relationships with fish biomass, for example, distance to the shelf break was positively correlated with high fish biomass, but chlorophyll A was negatively correlated with high fish biomass.

Different suites of the environmental variables were correlated with biomass of the most abundant fish species. Not all rocky reefs in the SCB equally support high densities of fish biomass, and our results suggest that an optimal combination of environmental and habitat conditions may support increased reef fish biomass, and could also inform the design of manmade reefs and interpretation of spatial management action effectiveness, including marine protected areas.

Multiscale and Hierarchical Classification for Benthic Habitat Mapping

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Coastal zones are often under threat due to their proximity to anthropogenic disturbances such as catchment inputs and resource use. As a result, benthic habitat maps are increasingly recognized as a key component for marine spatial planning. Developing quantitative and objective approaches to integrate multibeam sonar (MBES) data with ground observations for predictive modelling is essential for ensuring repeatability and providing confidence measures for benthic habitat mapping products. The scale of predictors within the model influence the final distribution of habitats, therefore matching the scale of predictors to the scale of environmental factors is key to improving model accuracy. The aim of this study is to evaluate multiple spatial scales and variable importance for predicting benthic habitats.

The study site encompasses 700 square kilometers surrounding Cape Otway in southeast Australia with full MBES data coverage and depths ranging from 10-80 metres. Additionally, over 180 linear kilometers of towed video data collected in this area were classified using Combined Biotope Classification Scheme (CBiCS), a hierarchical classification approach applied in Victorian temperate coastal waters. Using a machine learning approach, Random Forests, we combined MBES bathymetry, backscatter, towed video and wave exposure to model the distribution of biotope complexes at three different hierarchical levels. Confusion matrix results indicated the more classes within the hierarchy the lower the overall model accuracy and broad scale predictors were generally favored across all three hierarchies. This study demonstrates the benefits of testing multiple hierarchies and predictor scales to obtain the most relevant results for the location of study.

Characterizing Distributions of Deep-Sea Corals on the Pacific Outer Continental Shelf through Spatial Predictive Modeling

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The Pacific Outer Continental Shelf (OCS) encompasses an area of 250 million acres offshore California, Oregon, and Washington for which the Bureau of Ocean Energy Management (BOEM) oversees the responsible development of energy and mineral resources. Information on the distribution of sensitive biota, such as deep-sea corals, is critical for making environmentally sound decisions about identifying priority areas for renewable energy planning and development, and for developing mitigation strategies to avoid or minimize impacts on marine environments and organisms. Deep-sea corals are of particular concern because of their slow growth rates and vulnerability to disturbance. However, much less is known about the distribution of deep-sea corals compared to their shallow-water counterparts due to the difficulty and expense of surveying the deep sea. Predictive modeling can help fill these information gaps by identifying potential locations of suitable habitat for deep-sea corals, including in areas that have never been explored.

We are developing models that build off of previous efforts to predict areas of suitable habitat for a number of deep-sea coral genera and species in the Pacific OCS. We have compiled survey data describing locations of deep-sea corals, including data from the NOAA National Database for Deep-Sea Corals and Sponges and data from recent visual surveys. For each taxon we are developing statistical models using maximum entropy (MaxEnt) methods to relate the locations of deep-sea corals to information describing the environmental conditions at these locations, including measures of seafloor topography, surficial sediment character, and oceanography. We implement a stepwise model selection procedure that choose models that balance predictive performance with complexity. We then use the selected models to predict and map the relative likelihood of suitable habitat occurring within each model grid cell. Map products also include measures of model performance and spatially explicit depictions of prediction uncertainty to help inform environmental assessment and management decision making.

The Use of Unmanned Aerial Vehicles (UAV) and Emerging Advanced Imaging Techniques to Map Coral Reef Habitats in Three Dimensions

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Fringing coral reefs surround many of the 82 islands that form the developing nation of Vanuatu, providing ecosystem services to local communities. Recent plans to develop tourism infrastructure may directly threaten the marine environment to the East of Tanna Island. Few maps of the area and brief records of the fauna exist, thus we aimed to create the first high resolution maps of the shallow water environment, in accordance with the Commonwealth Maritime Economies programme.

Shallow water coral reef mapping often encompasses manned aircraft for aerial imagery and LIDAR, or satellite imagery. Recent advances in consumer grade Unmanned Aerial Vehicles (UAV) have progressed coral reef mapping and conservation science due to their accessibility, affordability and high-resolution imagery. In this study, a DJI Phantom 4 was used to create high resolution maps of a coral reef fringing Tanna island under windy conditions, testing the boundaries of this mapping technique and presenting scientific fieldwork difficulties.

Surveys were carried out at various altitudes (80 m, 40 m, 25 m and 12 m), to gain multi-scale maps of the reef using overlapping images aligned in Agisoft Photoscan software, to create photo mosaics and 3D reconstructions using Structure from Motion techniques. 170,000 m^2 of the reef was mapped from 80m altitude to provide a 3.26 cm/pixel image, and smaller sections to 5.59 mm/pixel, supplemented by snorkel surveys to provide sub millimeter mosaics. Digital Elevation Models (DEM) of the reef surface were rendered in multiple resolutions, from 2.5 to 13 cm/pixel. However, 3D reconstructions from low altitude missions produced noisy DEMs due to environmental factors. We demonstrate the prerequisite conditions and processing techniques conducive to this methodology.

Data from the mosaics and DEMs were fed into Remote Sensing Object Based Image Analysis (RSOBIA) software to provide multiscale baseline habitat and species distribution maps. The use of high resolution mosaics in tandem with past satellite imagery may progress our understanding of coral reef systems in the long term, as morphological changes in sea grass beds and coral structures were apparent in our case study. We explore the use of 2D and 3D maps in the context of conservation measures in a rapidly changing environment, whereby high resolution aerial mapping expeditions can monitor coral reefs.

One's Trash is Another's Treasure: Utilizing Water Column Returns from Multibeam Acoustic Bathymetric Data to Assess Biomass Distribution and Habitat Utilization

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Full water column data from multibeam sonars can lend a wealth of information regarding biological and physical processes above the sea floor, ranging from biomass distribution to the presence of hydrate seeps emerging from the benthic substrate. Unfortunately, collecting full water column data is extremely storage-intensive and often cost-prohibitive for most applications. However, bathymetric data collection often results in erroneous returns from fish assemblages in the water column, especially when these fish are clustered over benthic features. Typically, these soundings are either manually or automatically rejected as noise and never utilized for other purposes.

Here, we investigate a methodology to exploit this "noise" and provide a low-overhead alternative to collecting full water column data to assess biomass distribution and habitat utilization. We used several high-resolution bathymetric and acoustic backscatter imagery data sets collected over various geographic areas for the specific purposes of habitat mapping. Utilizing field observations and general knowledge of fish distributions in these areas, we isolated the rejected soundings most likely to be caused by fish and generated ASCII point files from them; these point files were then incorporated with bathymetric digital terrain models (DTMs) as well as backscatter imagery mosaics.

These multi-dimensional data sets can then be used to create a range of products for general visualization as well as three-dimensional geospatial analysis to investigate the relationship between fish distribution and habitat features such as bathymetric relief and substrate type. Possible future exploration includes determining the best sonar settings to intentionally obtain water column returns from bathymetric data by collecting test data sets over known fish "hot spots."

Integrating Benthic Habitat Mapping, Landscape Connectivity and Marine Protected Area Design

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The composition and configuration of seafloor landscapes (benthoscapes) is important for structuring habitats and supporting movement processes for many organisms. While many species rely on large habitat patches and benthoscape structural connectivity for foraging and migration, this is rarely considered in Marine Protected Area (MPA) design. Rather, representativity is targeted without considering the spatial arrangement of habitats. However, advances in seafloor mapping have allowed for the production of fine scale seafloor maps that are essentially analogous to terrestrial land cover maps. These maps provide the foundation for assessing spatial arrangement (using landscape connectivity and fragmentation metrics) that was formerly restricted to terrestrial systems. By integrating benthic habitat mapping, landscape connectivity analysis and a reserve selection algorithm, we have developed a novel method that considers the spatial arrangement of habitat patches in MPA design.

We applied our approach to the Eastport MPA and surrounding region in Newfoundland, Canada. This small, no-take MPA was established in 2005, based on a voluntary fishing closure initiated by the local community in 1997. The primary goal of the MPA is to protect the American Lobster population. However, a recent benthic habitat mapping study done within the boundaries of the MPA determined that the MPA contributes little to the conservation of regional biodiversity and habitats representative of the broader region.

To explore potential adaptive management scenarios in the form of new or expanded protected areas that would address this lack of habitat representativity, we first mapped the benthoscape adjacent to the MPA using multisource multibeam echosounder (MBES) data, seafloor videos and a pixel based classification method. To address challenges associated with analyzing backscatter data collected from multiple uncalibrated MBES systems, each MBES coverage was mapped independently and subsequently merged. Six substrates were identified within the extent of the MBES coverages – four of which were not found within the boundaries of the nearby Eastport MPA.

We then quantified the composition and configuration of the benthoscape using patch size, shape and connectivity metrics. Using Marxan, a reserve design algorithm, we set representativity targets and compared outputs that included and excluded the prioritization of benthoscape connectivity. In doing so, we illustrate how benthic habitat mapping and landscape ecology can be coupled to better understand the impact of benthoscape connectivity on ecological processes how this can inform MPA design and adaptive management.

Deep-Sea Coral Abundance and Diversity on the West Florida Escarpment

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Stony coral and Black coral are foundational ecological groups common on the West Florida Escarpment in the Gulf of Mexico. The distribution of these corals, and most other deep-sea coral, depends primarily on depth, presence of hard substrate, and vertical relief of the seafloor, but less is known about how deep-sea coral assemblages vary with different geomorphologic features. The primary goal of this study is to compare abundance and diversity of deep-sea coral assemblages as they relate to specific geomorphologic features. This study focuses on three Habitat Areas of Particular Concern (HAPC) recommended for regulation by the Gulf of Mexico Fishery Management Council with depths between ~200 and 1,000 m. High-resolution multibeam sonar data from a survey by NOAA Ship *Nancy Foster* (2008) are used in concert with historical coral presence data from NOAA's Deep-Sea Coral Research and Technology Program (DSCRTP). Additionally, coral presence-absence data from ROV images collected by NOAA Ship *Nancy Foster* in August 2017 and NOAA Ship *Okeanos Explorer* in November 2017 and April 2018 are used to enumerate and identify assemblages on flats, mounds, and ridges. Understanding the relationship between specific geomorphologic features and deep-sea coral communities will better inform managers regarding which geographic areas are critical to the protection of these animals. The results of this study will also provide insight into whether the West Florida Escarpment has fragmented deep-sea coral habitat or is continuous, high-quality habitat along the entire feature.

Marine Sampling Field Manuals for Benthic Monitoring

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Australia has one of the world's largest marine estates and has recently established the Australian Marine Parks (AMPs), the largest national network of marine protected areas in the world. The Australian marine estate is used by a variety of industries including fishing, oil & gas, and shipping, in addition to traditional, cultural, scientific and recreational uses. Monitoring the impacts of these uses on the marine environment is a massive shared responsibility that can only be achieved by making the best use of all the information that is collected. Without some common and agreed standards, data may not be comparable with other areas or sectors, thus reducing its value to regional and national management, while the individual project or survey may lose the opportunity to interpret results in a regional or national context.

Through the National Environmental Science Program Marine Biodiversity Hub, the Australian Government coordinated the development of a suite of field manuals to guide the acquisition of marine benthic data so that data are directly comparable in time and through space (www.nespmarine.edu.au/field-manuals). This poster describes the content and development process of these manuals, including the following sampling platforms selected based on frequency of use: Multibeam sonar, autonomous underwater vehicles, baited remote underwater video, towed cameras, grabs and box corers, and sleds and trawls.

The main challenge in the development of these manuals was to find a balance between being overly prescriptive (such that people follow their own protocol, ignoring the manuals) and overly flexible (such that data is not consistent and comparable). A collaborative approach was paramount, and ultimately, over 65 individuals from 30 organisations contributed to the field manuals. By engaging researchers, managers, and technicians from multiple agencies with a variety of experience, sea time, and subject matter expertise, we strove to ensure the field manuals represented the broader marine science community of Australia. This not only improved the content but also increased the potential for adoption across multiple agencies and monitoring programs. Future work is based on the understanding that sampling protocols should be periodically updated, lest they become superseded or obsolete. Version 2 of the field manual package is due for completion in late 2018, including potential new manuals and a long-term plan for their management and integration into a national Australian monitoring program.

Seabed Habitat Mapping for Marine Spatial Planning Purposes: A Case Study of the Eastern Brazilian Shelf

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In the past decades, the increase in multiple uses of the seabed along the eastern Brazilian continental shelf led government authorities to question the available information supporting the Environmental Agencies on the evaluation or analysis of potential impacts or conflict management for several activities. Based on that, the Espirito Santo State Environment Institute and the Science and Technology State Secretary set a joint program to map the seabed habitats over a 20,000 km^2 shelf area. The research was conducted by the Dept of Oceanography of the Universidade Federal do Espirito Santo, and started in December 2014. The collected database encompasses acoustic imaging (side scan sonar, multibeam and sub-bottom profiler), seabed sampling and high resolution imaging (drop cameras). A total of 5,000 km of acoustic images was collected, alongside with 360 bed samples and images. Samples analysis include benthic community, geochemistry (metal and elemental analysis), grain size and mineralogical components. A digital bathymetric model was used as a base for a benthic terrain model analysis, and a semi-automatic classification using pixel values were applied.

The results show a complex mosaic of reefs, rhodolith beds and a significant influence of river discharge. Shelf morphology is an important indicator of benthic habitats, in combination with major riverine sediment input areas. Rhodolith beds dominate the outer shelf, encompassing a continuous area of more than 7,000 km2. Distinct reef types were observed, ranging from very shallow water (5m deep) to outer shelf reefs related to paleovalley margins. The benthic fauna from carbonate and terrigenous sedimentary regimes was distinct.

The influence of a major river discharge along the 450 km coastline controls the occurrence of mud depocenters, forming important shrimp fishing grounds (trawling areas). The biogenic bed (hardground, rhodoliths and reefs are also important hotspots of biodiversity and fishing.

The actual conflict in the shelf is the increasing oil and gas activities, combined with seafloor mining and port developments. All of this in an area that hosts the greatest biodiversity of coralline algae in the Western Atlantic and the recently mapped “Forgotten Reefs”.

The mapping results are supporting the decision makers in order to plan the seabed use and the potential development for new MPAs.

Mapping the Seascape of Fear at Abrolhos Marine National Park, Brazil

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The occurrence of halos of herbivory around sheltered reef substrate has been well documented since the 60's. These features are interpreted as resulting from a collective grazing behavior of herbivorous species in the presence of predators, a cost-benefit analysis of the trade-off of food and safety, that models the seascape and is called the land scape of fear (LOFs). One evidence of this process in tropical seascapes formed by the association between coral reefs and seagrass beds is the absence of vegetation around some patchy reefs. Herbivorous species that remain close to the shelters in the presence of predators form these bare zones. The halos resulting from this process contrast with the vegetated environment surrounding the reefs and thus can be visible from space. LOFs may be affected by biological, evolutionary and geographic variables. To date, there have been no reports of herbivory halos occurring in the West South Atlantic.

We investigated the formation of halos in the seascape located in Abrolhos National Park (Brazil) using a WorldView-2 (WV2) image, underwater images and underwater visual surveys. We corrected the atmosphere in the WV2 image using the Atcor-2 and the water column using Depth Invariant Index (DII). We also performed seagrass density estimates by multiple regression between DII results and coverage percentages measured by scuba underwater images using Multi-Layer Perceptron (MLP).

The results showed that the density of seagrass was close to zero in the halo increasing in the opposite direction to the reef. Both the WV2 image and the scuba images detected a transition zone in which there is a higher diversity, which may indicate that different levels of disturbance are distributed in a decreasing gradient away from the reef. The observed abundance of predators such as juvenile *Mycteroperca bonaci* and schools of juvenile herbivorous fish (mainly surgeonfishes *Acanthurs* sp), in addition to the variation in seagrass densities, were consistent in all the halos investigated, corroborating the hypothesis of the existence of a landscape of fear working in Abrolhos.

Standardized and Cost-effective Benthic Habitat Mapping Tools for Marine and Hydrokinetic Site Environmental Assessments

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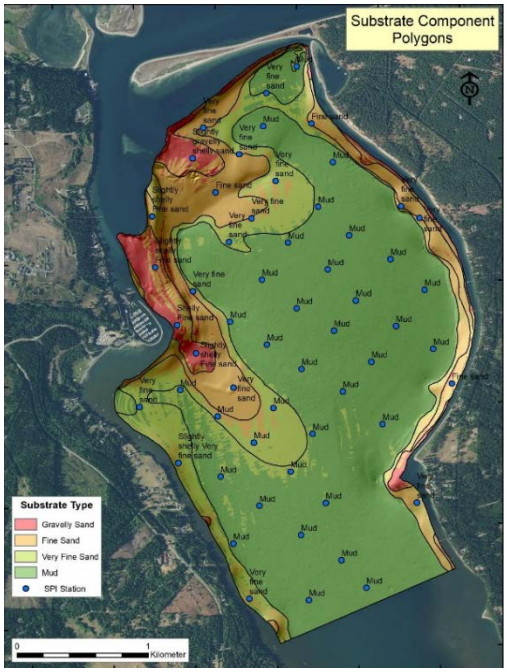
Baseline benthic habitat characterization and subsequent monitoring at marine and hydrokinetic (MHK) sites have used a variety of tools and techniques applied in different combinations. The lack of standardization has led to expensive efforts that often prove confusing and contentious among regulators and stakeholders evaluating these sites. Benthic habitat maps have traditionally been developed from a suite of geophysical data sets including multibeam echosounder (MBES) bathymetry and backscatter, sidescan sonar, submersible or remotely operated vehicle observations and video, sediment sample data, and specific surveys of benthic communities (e.g., box cores, video surveys, trawls).

With funding from the Department of Energy's Office of Energy Efficiency and Renewable Energy, Integral is developing a standardized soft-bottom benthic habitat mapping toolset for MHK sites. The approach uses rapidly obtained sediment profile image (SPI) and plan view (PV) imagery to ground truth MBES bathymetry and backscatter benthic habitat maps.

The primary technological innovation associated with this approach is the development of a computer vision (CV) system for automating the measurement of key physical and biological features in the SPI and PV images. The CV system uses a unique combination of machine- and deep-learning techniques (e.g., convolutional neural networks) for grain size classification, interface delineation (e.g., the sediment-water interface), and object detection (e.g., identification of organisms and biogenic structures). Data from the imagery are obtained using our CV system and are used to inform the interpretation of the acoustic maps, and the collection of images rather than bottom samples allows for a higher density of ground truth data points.



The CV system streamlines and standardizes the generation of data from SPI and PV imagery and makes this mapping approach both cost-effective and repeatable. The CV system development and results of a 2017 case study of this technology in combination with acoustic surveys for mapping soft-bottom benthic habitat in Sequim Bay, Washington, will be presented.

Acknowledgements

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Water Power Program Award Number DE-EE0007826. The authors would also like to thank the staff at the Pacific Northwest National Laboratory (PNNL) for their assistance conducting the field surveys.

Estimating the Global Distribution of Cold-Water Coral Communities on Rocky Walls

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Similar to their shallow water counter parts, walls in the deep sea provide a different set of environmental conditions than the surrounding terrain. The rough topography provides exposed hard substrate and creates complex interactions with currents, which may explain why diverse filter-feeding communities are being discovered on steep walls. These environments are of particular interest as they can provide natural protection against anthropogenic activities such as trawling, and larval dispersal from these refuges may also help recolonize damaged habitats. However, despite their likely significance, the factors driving vertical wall community structure as well as habitat frequency or distribution along the continental slope remain unknown. In this study, we employed publicly available global bathymetric datasets and Harris et al (2014)'s catalogue of large-scale terrain features to estimate the likely importance of these habitats for cold-water corals (only 5 reef-forming species were considered). Two approaches for the assessment of habitat suitability were used: (1) a strict assessment that only included known occurrences based on OBIS records, and (2) a lenient assessment that was based on the predicted distributions presented in Davies and Guinotte (2011). We found over 6,000 features likely to harbour rocky walls with cold-water corals, whose estimated surface area is equivalent to 15% of the estimated surface area of shallow coral reefs. Although our analysis shows such habitats likely to occur worldwide, the small number of geomorphic features with OBIS presence records illustrates how little we know of the global spatial distribution of cold-water coral species, with many areas of the world remaining greatly under-sampled.

This work is part of the ERC CODEMAP project (Starting Grant no 258482) and data were collected during the CODEMAP2015 cruise and the SORBEH expedition (Marine Institute, Ireland).

Monitoring the Direct Impact of Sand Extraction on the Bathy-Morphology and the Seabed Sediment in the Belgian Part of the North Sea: Lessons of Ten Years of Measurements

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Sand is an important resource on the Belgian Part of the North Sea (BPNS). Since 2012, around 3 million m³ of marine sand is extracted each year for construction purposes and coastal protection. The extraction is only allowed offshore in specifically defined areas on sandbanks and only with trailing suction hopper dredgers. As a precautionary principle, the extraction is limited to 5m under a reference bathymetric surface.

Inevitably, the extraction of large volumes of sediment disturbs the seabed. The changes in surficial sediments and the deposition of suspended fine sediments plumes, generated during dredging operations and through changes of wave and tidal currents, have a direct and indirect impact on the seabed habitats. The monitoring of the impact of the extraction on the marine environment is a legal obligation enshrined in Belgian and European legislation.

The evaluation of the impact of extraction on the marine environment requires multiple scientific and technical expertise, generating a broad knowledge field. In Belgium, for more than 15 years, several teams have been working on this theme and have enabled the development of a well-controlled monitoring program based on highly valuable and informative time series.

Our contribution focuses on lessons learned from time series acquired to assess the direct impact of extraction on the seabed in the most intense areas of extraction. This direct impact assessment is based on multiple types of data: statistics derived from the extraction registers, data from the Electronic Monitoring Systems (EMS = “black-boxes”) on board the dredging vessels, and bathymetric and backscatter time series derived from regular multibeam echosounder (MBES) surveys, primarily carried out with the RV Belgica Kongsberg EM3002D. The most extracted areas are surveyed several times each year. In addition to this local approach, regular but less frequent surveys along straight lines, parallel and perpendicular to the sandbanks and the gullies, provide valuable information on the global evolution of the bathymetry allowing a comparison between extracted and non-extracted areas. Using the backscatter level as a proxy of the seabed interface in a monitoring program implies a full control and stabilization of the acquisition parameters of the MBES on board the research vessel. As well, a stable backscatter processing method, which does not introduce any varying adaptive compensation, makes it possible to rigorously compare over time the evolution of the average backscatter levels estimated in a constant angular sector. Throughout the monitoring program, regular MBES measurements on a stable reference area allow the control of the hydrographic quality of the bathymetric data and the repeatability of the backscatter data.

This multi-scale approach combining various types of data provides a 4D (space and time) overview of the evolution of the extraction and leads to robust and pragmatic conclusions about the impact of the sand extraction on the bathymetry, the morphology and the seabed habitats.

Improving the Accuracy of Benthic Habitat Maps in the Gulf of Mexico: Integration of BOEM Gulf of Mexico High-Resolution Bathymetry and Geophysical Data with a CMECS-Classified Geomorphic Features Basemap

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Application of the Coastal and Marine Ecological Classification Standard (CMECS) Geoform Component (GC) vocabulary to deepwater bathymetry data in order to enhance their utility and application toward Gulf of Mexico deepwater habitat mapping will be presented. This work supports development of comprehensive habitat characterizations that are fundamental to assessment and monitoring of marine ecosystems, and the management of energy and natural resources sector impacts on those ecosystems. This project comprises three datasets: 1) the US Bureau of Ocean Energy Management (BOEM) Gulf of Mexico Deepwater Bathymetry Grid from 3-D Seismic (https://www.boem.gov/Gulf-of-Mexico-Deepwater-Bathymetry/), 2) the BOEM Seismic Water Bottom Anomalies GIS dataset (https://www.boem.gov/Seismic-Water-Bottom-Anomalies-Map-Gallery/), and 3) a Global Seafloor Geomorphic Features Map (GSFM) derived from 30-arc second NASA JPL-NGA Shuttle Radar Topography Mission data (Harris, P. T., Macmillan-Lawler, M., Rupp, J., Baker, E. K., 2014. Geomorphology of the Oceans, Marine Geology, 352, 4-24). Geomorphic features identified in the BOEM Gulf of Mexico Deepwater Bathymetry Grid are first digitized using mapping and image analysis software (ArcGIS and ENVI). The resulting GIS polygons and the BOEM Seismic Water Bottom Anomalies GIS data are then merged with the lower-resolution but more extensive GSFM geoform basemap that also covers the shelf, slope and abyssal settings. The CMECS GC units and hierarchical structure provide a framework for integrating these geomorphic features derived from different types of source data, resulting in a full-coverage, more accurate and informative map of varying spatial resolution and descriptive detail. This enhanced basemap will be used to encourage other data collectors and mappers to contribute additional existing and newly-collected geomorphic data to the ongoing enhancement of the CMECS Gulf of Mexico Geoform Basemap. Future work to assist potential contributors will include development of an atlas-type publication that incorporates detailed definitions of the CMECS units and habitat reference images, and a web-based map and data discovery application.

Using ROV Video Imagery to Map Benthic Habitat and Fish and Invertebrate Populations on a Defined Rocky Reef Feature off Central California

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The use of predictive habitat maps derived from species distributions models (SDMs) have been increasingly used in recent years to inform marine spatial planning. Model-based approaches that incorporate bathymetry, benthic habitat, environmental data, and species records better inform researchers and resource managers during the implementation of fisheries management actions, including closure areas. SDMs also assist in ecosystem-based management approaches, which ensure the sustainability of the entire system, not just targeted species.

In this study, three high-resolution fish and invertebrate surveys of a single 0.5 km by 0.2 km rocky reef feature were conducted between 2011 and 2016 within the Rockfish Conservation Area (RCA) offshore of Morro Bay, California.

A species distribution model (SDM) was constructed for fish and invertebrate species within this area, ranging in depths from 67 to 100 m. Correlations were quantified among observed species, and between species and habitat factors like substrate and bathymetry.

The convergence of the SDM was also compared against varying amounts of input data to determine the amount of data needed to produce consistent modeling results, and to draw conclusions about in situ visual observations and sampling design.

New Data about Geomorphology and Late Pleistocene-Holocene Sedimentary Processes of the Eastern Gulf of Finland Based on High-Resolution Multibeam and Sub-Bottom Profiling Data*

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In 2017 during the cruise of RV "Academic Nikolaj Strakhov" a detailed study of the eastern Gulf of Finland (the Baltic Sea) seafloor was to identify and map submerged glacial and postglacial geomorphologic features and collect data pertinent to the understanding of sedimentation in postglacial basins. Two key areas within the Gulf were investigate using a multibeam echosounder SeaBat 8111 and an EdgeTech 3300-HM acoustic sub-bottom profiling system. High-resolution multibeam bathymetric data (3-m resolution) were used to calculate Aspect, Slope, Terrain Ruggedness and Bathymetric Position Index using ArcGIS Spatial Analyst and the Benthic Terrain Modeler toolbox.

The dominant seafloor geomorphology in the eastern Gulf of Finland are the 1,000 m long, 100 to 170 m wide and 15 to 20 m high SSE–NNW (160° - 170°) oriented elongated linear oval-shaped ridges interpreted as streamlined moraine ridges and classified as drumlins. These features formed beneath an ice sheet as it moved over the land, parallel to the ice direction and composed of basal till or lodgement till. The 10 to 20 m high, 70 to 1,000 m wide, approximate 4,300 m long crescent ridge-oriented NE–SW to SE–NW (65°-100°) mapped in Vyborg Bay is interpreted as an end-moraine, parallel to the terminal ice margin. Among the most interesting submerged glacial relief features found in our study are series of rhythmic parallel ridges 1 to 1.5 m high elongated at a slightly different direction within our two study areas. These ridges are overlaid both drumlin and end-moraines. The small parallel ridges can be identified as De Geer moraines, which are typically described as relatively low till ridges, rhythmic parallel linear to curved positive relief features in plan view. These data and resultant thematic maps are used for reconstruction of the deglaciation in the eastern Gulf of Finland, occurred between 13.8 and 13.3 ka BP (Pandivere-Neva stage) and 12.25 ka BP (Salpausselkä I stage).

Our interpretation of high-resolution seismic-reflection profiles and 3D models of the till surfaces, Late Pleistocene sediments, and the mapping of the modern seafloor relief indicates significant fall in water level in the Early Holocene and that most likely several water-level fluctuations occurred, documented by erosion surfaces (acoustic unconformable horizons) in silty-clay mud. We conclude that the distribution and thickness of Holocene silty-clay mud mapped within our study areas indicated a drastic change in sedimentation since the beginning of the Ancylus Lake stage (about 10.7 ka BP). Since the Ancylus, accumulation occurred within local sedimentary basins, while conditions of large bottom areas of the Gulf of Finland remained starved of sediment or suffered from erosion. Modern silty-clay accumulation in the eastern Gulf of Finland occurs in local sedimentary basins located at depths from 5 to 6 m in Neva Bay to 80 m south of Gogland Island and separated by vast sediment starved and/or erosional areas.

Multibeam data processing was supported by the state assignment 0149-2018-0012. Data analyses and interpretation was carried out under project 17-77-20041 of Russian Science Foundation.

* Published on-line March 18, 2018. Geosciences 2018, 8, 102; doi:10.3390/geosciences8030102

Recent Applications of Deep Water MBES Studies and Large Programs for Industry, Government and Academia Involving Bathymetry, Backscatter and Water Column Data – An Industry Perspective

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2. Fugro

In the past decade the seafloor mapping industry has been actively collecting multibeam echosounder imagery (MBES) worldwide. Often these data are proprietary, however much data is surprisingly publically available and could be useful to the GeoHab community. For example, since 2014, Fugro has been conducting greater than 1,000,000 km^2/year of deep water MBES imagery throughout the world's oceans. These projects have been as diverse as the search for Malaysia airline flight MH370 in the southern Indian Ocean, the completion of the world's largest seabed seeps study in the entirety of the Gulf of Mexico, participation in the XPrize effort and recently donating data routinely to the SeaBed 2030 effort. These efforts have included eight different vessels with both 12 khz and 30 khz MBES hull mounted sensors, sub bottom profiling systems, seabed sampling gear, and occasionally complimentary high resolution deep-tow or AUV platforms, including camera systems. Much of the data is currently in the public domain, and Fugro is working with both Industry and Government clients to move additional data into the public domain as well, and will be engaging the Circum-Pacific Council in assistance with this effort, especially in regard to GeoHab interests.

Data examples, survey area polygons and other related information will be presented. Lessons Learned and some findings will also be discussed. Future trends, programs and technologies will also be presented in relation to marine benthic habitat mapping.

The Application of Multibeam Water Column Acoustic Detection on Submarine Cold Spring Plume

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The detection of the methane plume formed by the leakage activity of the seabed cold springs and the study of its basic characteristics and distribution have important resource and environmental benefits. There is an evident difference in acoustic impedance between seawater and natural gas. When a sound wave encounters a bubble in seawater, strong scattering occurs. Through the shipborne high-frequency sonar scanning, a flame-like acoustic reflection image can be formed. At present, acoustic detection of submarine cold spring plume is mainly dominated by shipborne single-beam and split-beam sonar systems. However, the acoustic image of multi-beam sonar system is high-resolution and wide-coverage, which can be used for rapid large-area identification of submarine cold spring plume.

Recently, multi-beam bathymetry and water body acoustic detection aimed at leakage activities of the seabed cold spring have been carried out in some areas of China. The noise and reverberation analysis of the multi-beam water column data and the correction and compensation of the raw data were carried out. As a result, a large number of seafloor bubble plumes were detected. Compared with the topography data obtained by the multibeam system, it is found that the plume in this area is closely related to the leaking activity of cold springs that originate from special landscapes such as mud volcanoes and marshes.

The highest plume detected was about 578 meters high above the seafloor, and its shape was curvilinear smoke-like. Proved by other detection means and compared with similar researches at home and abroad, it is confirmed that the giant plume is the typical result of leakage of cold spring caused by mud volcano, which is also the largest seabed cold spring plume found in China sea. The study shows that the multi-beam acoustic detection technology, supplemented by conventional geochemical characteristics deck test and other means, can play an important role in the seafloor fluid anomaly detection and gas hydrate environmental effect monitoring.

Requesting and Comparing Intermediate Results from Several Backscatter Data Processing Software: A First Step Towards Future Consistency of Multibeam Backscatter Estimation

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Backscatter mosaics of the seafloor are now routinely produced from multibeam sonar data, and used in a wide range of marine applications. However, significant differences (up to 5 dB) have been observed between the levels of mosaics produced by different software processing a same dataset. This is a major detriment to a number of possible uses of backscatter mosaics, including quantitative analysis, monitoring seafloor change over time, and combining mosaics. The Backscatter Working Group (BSWG) identified this issue and recommended that "to check the consistency of the processing results provided by various software suites, initiatives promoting comparative tests on common data sets should be encouraged […]". However, backscatter data processing is a complex (and often proprietary) sequence of processing steps, so that simply comparing end-results between software does not provide much information as to the root cause of the differences between results.

In order to pinpoint the source(s) of inconsistency between software, it is necessary to understand at which stage(s) of the data processing chain do the differences become substantial. Schimel et al. (2018) recently provided a comprehensive framework for this processing chain, including a self-consistent terminology for intermediate processing steps and corrective terms. We propose to invite willing software developers to discuss this framework and collectively adopt a list of intermediate processing steps that they can all generate. We will then provide a small dataset consisting of various seafloor types surveyed with the same multibeam sonar system, using constant acquisition settings and sea conditions, and have the software developers generate these intermediate processing results, to be eventually compared. If the experiment proves fruitful, we may extend it to more datasets, software and intermediate results. Eventually, software developers may consider making the results from intermediate stages a standard output as well as adhering to a consistent terminology, as advocated by Schimel et al. (2018). To date, the developers of four software (Sonarscope, QPS FMGT, SwathEd, MB Process) have expressed their interest in collaborating on this project.

Schimel, A. C. G., Beaudoin, J., Parnum, I. M., Le Bas, T., Schmidt, V., Keith, G., & Ierodiaconou, D. (2018). Multibeam sonar backscatter data processing. *Marine Geophysical Research*.

Acoustic Sensing of Marine Gas Seepage – Opportunities and Pitfalls in Acoustic Analyses of Minor to Major Flux Sites

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Sonar is extremely sensitive to detecting free gas bubbles buried in the seabed or seeping into the water column. Inversion of acoustic backscattering strength from so-called gas bubble plumes or flares into gas volume and flux remains an extremely challenging, if not impossible, task in many cases. The backscattered sonar strength from gas bubbles is very high but also strongly modulated by resonance phenomena, bubble size distribution, depth, and beam-bubble geometry. Nevertheless, acoustic imaging is the ultimate tool for remotely characterizing gas release from the seabed.

With fine-tuned sonar settings even single gas bubbles (minor fluxes) can be detected in the water column and traced along their rise path. We suggest that such minor fluxes can be generally be quantified within a reasonable degree of uncertainty. However, the stronger a gas seep flux is the more complicated its fluid flow seepage character becomes. Major seep flux and bubble plumes are characterized by complex phenomena such as vertical upwelling of surrounding water induced by the uprising gas bubbles (up to 3 m/s), internal jets, marginal eddies with high turbulence and gas dissolution kinetics, bubble breakup and the formation of microbubbles (< 1 mm), as well as intrusion layers. Such phenomena are very poorly constrained but likely have a high impact on the measured backscattering, and dissolution and dilution kinetics of free and dissolved gases.

Here we present new acoustic data records showcasing various seep-related phenomena. The data show very high quality multibeam water column images of minor single bubble seepage as well as prominent methane and carbon dioxide point source records around the globe. We hypothesize that accurate 3D analyses of gas plume shape and trajectory analyses support the estimate of gas fluxes and fate of the gases.

Impact of Seafloor Sub-mm Topography on Broad-Band Acoustic Scatter

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A common habitat classification concept relies on interpreting backscatter data, which is ground-truthed by sediment point samples. An uncertainty within this method is the lack of understanding small scale acoustic scatter processes at the seafloor surface especially at high frequencies. A more detailed acoustic habitat classification requires either time consuming retrieval of additional seafloor surface samples or a better understanding of seafloor acoustic scatter mechanics. Technical improvements in recent years initiate new possibilities to measure key parameters – like seafloor micro topography – which are required to improve acoustic scatter models significantly. This study directly links high resolution optic and acoustic experiments in shallow water environments by recording sub-mm 3D seafloor images and broad band acoustic scatter simultaneously. The test area is located offshore of the island of Sylt in the German Bight of the south-eastern North Sea. This site was selected based on available hydroacoustic survey data and biological diversity background information, especially of tube worm habitat locations. First published data results are based on the optical bathymetric data and point out differences in the spatial roughness power spectra between hydrodynamic and biological seafloor types. Here, we will present results of the acoustic scatter data and show correlations between micro topography and broad band (80-310 kHz) scatter measurements, using incidence angle settings between 0 and 55 degrees. The discussion is focused on the benefit of lander experiments to improve the general understanding of small scale backscatter processes and at later stage ship-based habitat classification.

Exploring the Potential of Multi-Frequency Multibeam Backscatter Regarding the Classification of Marine Sedimentary Environments

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The recent development of multi-frequency multibeam echo sounders (MBES) opens up new perspectives for acoustic remote sensing. Exploring the potential of a multi-frequency MBES backscatter data in order to improve the classification of the seafloor composition and benthic habitats is part of the multidisciplinary EU-funded project BONUS ECOMAP, which involves international researchers from the fields of geoscience, biology, and remote sensing as well as partners from industry and public authorities.

For recording of multi-frequency backscatter data two test sites were chosen: 1) a zone of fine and coarse sands with different abundances of the tubeworm *L. conchilega* , located offshore the island of Sylt in the North Sea, and 2) an area in the south-western Baltic Sea, heterogeneously composed of glacial lag deposits, mobile fine sands, and mud deposits. Three-frequency (180, 400, and 650 kHz) backscatter data were collected with the same NORBIT iWBMSe, whereby every transect was sailed three times, recording one of the frequencies each. Grab samples and mm-scale optically derived bathymetry are available to ground truth the acoustic data. After a basic multibeam processing with MB-System, the backscatter mosaics were converted into negative BGR images, which allow an optical visualization of the seafloor response to varying frequencies.

All frequencies show similarly low sensitivity to sediments composed of silt and clay-sized particles. The low frequency (180 kHz) exhibits largest overall sensitivity with a strong response to coarse sand. Differences between the medium (400 kHz) and high (650 kHz) frequencies are less, and both show a pronounced sensitivity to sediments of the fine sand interval. First results show great potential to improve the classification of marine sedimentary facies.

Exploring High Density Aggregations of Gorgonian Octocorals and Groundfish in the Mesophotic Depth Zone of the Channel Islands National Marine Sanctuary in Southern California

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Mapping and exploration of Channel Islands National Marine Sanctuary (CINMS) since 2005 has revealed numerous small scale (100 – 1,000 m) rocky ridge features in the sublittoral mesophotic zone (30-150 meters) along the continental shelf surrounding the Channel Islands. These features are of interest to biologists, geologists, and federal managers, as well as recreational and commercial fishing interests. This presentation will share observations and insights of the distribution and abundance of deep-water corals and groundfish associated with the rocky features and their surrounding environment.

Remotely operated vehicle (ROV) video transects targeted deep-water habitats around Santa Rosa Island and San Miguel Pass in 2015 and 2016. Many octocoral aggregations had densities greater than 100 colonies/100 m^2, exceeding the OSPAR Convention's definition for 'coral garden'. The high density 'coral gardens' were associated with rocky features. While, the average octocoral density was lower, at 28.9 corals/100 m^2, across all substrate types in the study area. Groundfish commonly associated with rocky features included multiple species of rockfish (*Sebastes* spp. - vermillion, bocaccio, copper), Lingcod (*Ophiodon elongatus*) and California Sheephead (*Semicossyphus pulcher*). The extent of the 'coral gardens' in CINMS may be large, given large areas of high reflectance (presumably hard bottom) apparent in backscatter data. Soft bottom (i.e., low-reflectance) areas surround the rocky features. Sandy areas had fewer gorgonian octocorals, more sea whips, and more sea pens and flatfish.

'Coral gardens' were present on rocky features outside of essential fish habitat areas, which restricts all bottom-contact gear, but within Rockfish Conservation Areas, which restrict bottom trawls. The coral occurrence data will be made publicly available through NOAA's National Database of Deep-Sea Corals and Sponges to be further integrated into regional habitat suitability models in the future, as a spatial analysis tool for marine stakeholders.

Mapping Coastal Coral Reef Habitats Using Landsat 8 Imagery and GWR

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Bathymetric maps are one of the first steps for most hydrological and ecological studies of the seascape, as depth is a determining factor in the vertical distribution of organisms and patterns of wave exposure and coastal circulation. The coral reef complex of Tamandaré (Brazil), located at Costa dos Corais MPA, embrace a mosaic of interconnected habitats (coral reefs, sand bottom, algal and seagrass beds) of complex geomorphology. These coastal habitats are under chronic impacts such as sedimentation, reef erosion and human use that may lead to habitat loss or transformation. In spite of their importance for local use and conservation, there is a lack of bathymetric and habitat maps of the shallow area. This study aims to use satellite imagery to facilitate the derivation of bathymetric (1-15 m depth) and habitat maps of Tamandaré coral reefs.. We performed bathymetry using a single-beam echo sounder and interpolate depth data using Geographically Weighted Regression (GWR) and a PCA of visible bands of a Landsat 8 image, in order to minimize variability caused by bottom heterogeneity. The imagery pre-processing included atmospheric correction with Atcor-2, masking of land areas and de-glint. We achieve a $R^2 > 0.9$ using this technique to our bathymetric map. We use this result asinput in Benthic Terrain Modeler (BTM) add-in software, in order to create a geomorphological broad scale habitat map. We are able to recognize main habitats as “fore reef”, “back reef”, “lagoon”, “channel”, “reef crest”, “depression” and “pinnacles”. We concluded that affordable methods such single-beam data combined with satellite imagery through GWR can produce viable inputs for habitat mapping in shallow waters and thus contribute to the multiple-use zonation foreseen in MPA management plans.

Applying a Standardized Classification Scheme (CMECS) to Multibeam Sonar and ROV Video Data on Gosnold Seamount

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The Coastal and Marine Ecological Classification Standard (CMECS) is a federally-endorsed marine ecological classification scheme used in the United States. CMECS provides a useful framework for integrating available datasets about a marine region in order to characterize environmental attributes and habitat features. Developing pragmatic methods to apply the standard in a repeatable way (with limited field data) for initial characterization of deep sea habitats remains a challenge.

This study focused on application of CMECS to Gosnold Seamount within the New England Seamount Chain by analyzing multibeam sonar bathymetry and backscatter data and high-definition remotely-operated vehicle (ROV) video data collected by NOAA's Office of Ocean Exploration and Research. A preliminary spatial segmentation was obtained by first automatically segmenting the seafloor into geomorphic landform types (i.e. CMECS "geoform" units) based on multibeam bathymetry; then, to inform potential CMECS "substrate" classification, the method used co-located multibeam backscatter to detect similarity among segments. ROV video imagery was analyzed through a separate annotation process and used as ground-truth information to describe the general substrate character of seafloor segments over which the ROV had traversed. ROV video imagery was also analyzed to describe biological composition, diversity, and abundance (i.e. the CMECS "biotic" component).

This work provides a case study to assess methodology for practical application of CMECS for initial characterization of a deep sea seamount feature by combining observations from a ROV and multibeam sonar-derived bathymetry and backscatter.

Shallow Seafloor Gas Emissions near Heard and McDonald Islands on the Kerguelen Plateau, Southern Indian Ocean

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Heard and McDonald Islands are two active hotspot volcanic edifices on the Kerguelen Plateau, in the southern Indian Ocean. We explore the potential manifestation of this hotspot magmatism on the seafloor, using hydroacoustic, geophysical, and geochemical data acquired in 2016 during RV *Investigator* voyage IN2016_V01. We document the first evidence of submarine gas emissions around the under-explored islands, mapping 13 seeps over three sites in water depths < 150 m. Seepage was observed as acoustic 'flares', with a split-beam echosounder. Deep tow camera imagery (with on-board CTD), sub-bottom profiler data, and grab samples were analyzed to understand the source[s].

One site lies northeast of Heard Island, one northeast of the McDonald Islands, and one south of the McDonald Islands. Flares at the Heard site were associated with visible rising bubbles and potential microbial mats. The greatest Heard flares overlie sub-seafloor acoustic blank zones where sediment thickness exceeds 30 m. No bubbles were observed coincident with either McDonald site, though visibility was poor on all camera deployments. Sub-bottom profile data revealed thin sediment coverage (< 5 m) at one McDonald site, and no sub-bottom penetration at the other. No temperature anomalies were observed near any flares, and the entire water column was well-mixed. Geochemical analyses of sediments collected around both islands show a coupled sulfate-carbon interaction characteristic of sediments rich in organic matter.

Heard Island data suggest a methanogenic flare origin (flares, bubbles, microbial mats, sub-bottom acoustic blank zones, sulfate-carbon coupling), a cold methane seep, where methanogenic bacteria in sediment produce methane that is emitted from the seafloor as bubbles. A thermogenic source [deeply buried organic matter warmed by nearby active volcanism] may also be present.

McDonald Island data (flares, no bubbles, no microbial mats, no sub-bottom acoustic blanks, but with very thin surficial sediment with sulfate-carbon coupling) suggest another gas source. While more diffuse cold methane seepage is likely present, mirroring the thin or absent sediment, the physical cause of the acoustic flares is suggested as CO_2 bubbles associated with diffuse hydrothermal seepage. A weak excess ^3He signal in seawater around the McDonald Islands (Lupton et al., personal communication) suggests hydrothermal activity in the region associated with hotspot magmatism may play a role in generating gases at the seafloor.

Sea floor methane is typically not considered to be released to the atmosphere, but the shallow water depths and well-mixed water column of Heard Island may provide a direct pathway for methane from seafloor to atmosphere.

Quantifying Benthic Worm Reef Ecosystem Services through Biological Sampling and High-Resolution Remote Sensing Platforms

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Oyster, mussel, and coral reefs are poster species for providing ecosystem services to their surrounding environment by filtering nutrients, protecting shorelines, and increasing habitat biodiversity. Another benthic reef building species found throughout the world provides similar services as these other, more well known, species but is not currently given credit for its services. *Sabellaria vulgaris* is a Polychaete worm species which forms pillow-shaped mounds, platform reef structures, and encrusting reefs in low-energy, shallow beach environments. Increasingly, these beaches are being nourished within the United States as a soft shoreline protection option and *S. vulgaris* reefs are buried and killed without consideration or remediation. Quantifying the sediment trapping, wave attenuation, and biodiversity produced by worm reefs is time and labor intensive as these structures are wide-spread spatially and highly three-dimensional in distribution. It is necessary to establishing their value amongst reef forming species like oysters and corals so their ecosystem services are not lost to their environments. Rather than relying on laboratory tank studies to determine ecosystem services, this study used unmanned aerial vehicles (UAVs, drones) and traditional biological sampling methods to quantify ecosystem services of these worm reefs in the field.

Data was collected seasonally at Big Stone Beach and Broadkill Beach, Delaware, USA for two years. Field observations were made using a DJI Phantom 3 Advanced and senseFly RTK eBee to collect aerial imagery of the reef when exposed during spring low tides. A DJI Mavic Prop collected aerial video to perform calculations of nearshore bathymetry and wave runup using cBathy algorithms. Orthomosaics and digital elevation models (DEMs) were created using Agisoft Photoscan and Pix4D Structure from Motion (SfM) software. Reef surface area and location were taken from orthomosaics using ArcGIS classification techniques while beach and nearshore slope were determined from the DEMs. Reef samples were collected and processed in the lab by crushing samples then counting and identifying species under a microscope. Quadrat (0.25 m^2) photos taken at each site provided worm hole density and size. *S. vulgaris* populations were calculated for each season by combining drone reef surface areas, quadrat hole densities, and sample counts. Species compositions were determined using normalized indices calculated with PRIMER software. Sediment volume and shoreline changes were taken from drone orthomosaics and DEMs while nearshore slope, wave attenuation, and bathymetry were documented through drone video analysis.

Preliminary results show worm reefs in platform and pillow mound formats at Big Stone Beach are capable of trapping sediment in a manner similar to detached breakwater structures. These reef types also reduced wave energy were present and protected the back marsh from erosion due to high wave runup during the stormy winter season. An Encrusting worm reef at Broadkill Beach improved the functionality of the groin it settled on by trapping alongshore sediment and reducing wave attenuation through the rock rubble groin. *S. vulgaris* at both sites provided improved benthic habitat for invertebrates such as crabs, snails, mussels, oysters, and anemones while providing islands of food for migratory birds. Methods used here are transferrable to study sites around the world and demonstrate the necessity of combining remote sensing platforms with traditional biological sampling techniques to better quantify and represent benthic habitat ecosystems services, thereby ensuring appropriate monitoring and management approaches are employed.

Gas Flare Database from the Norwegian EEZ – A MAREANO Product

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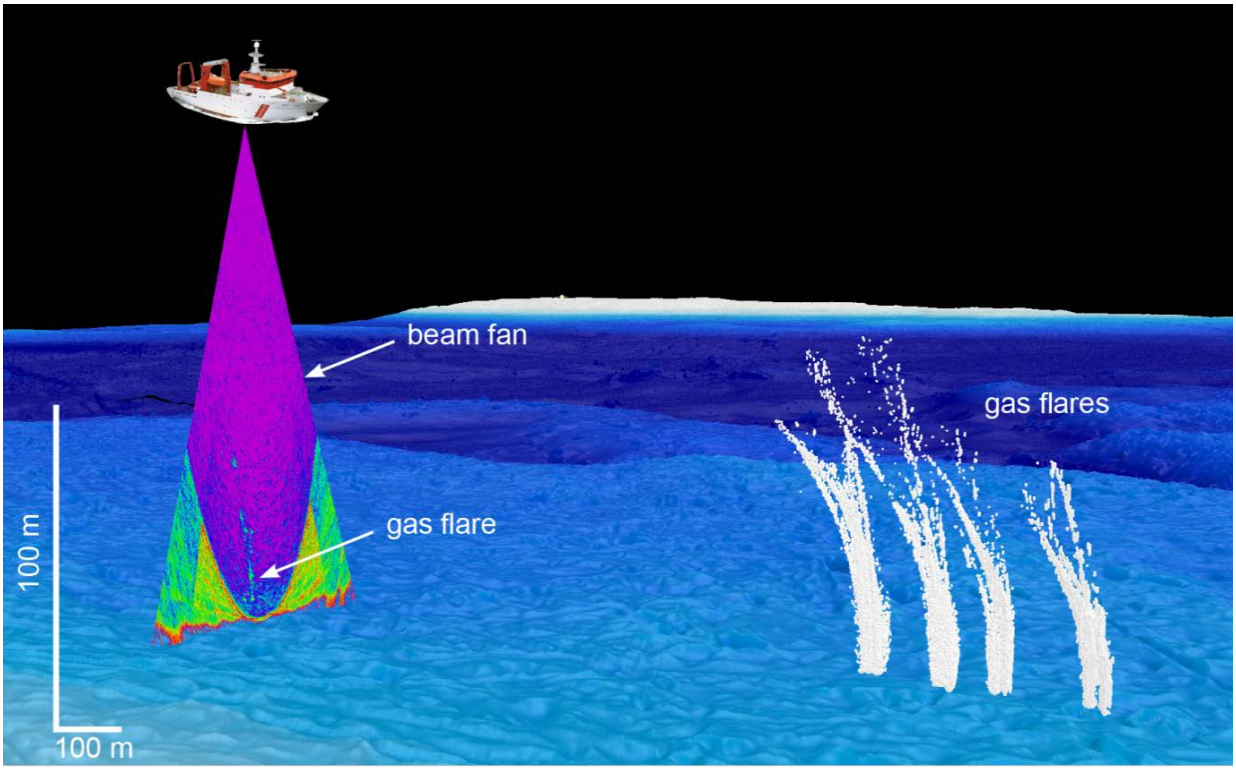
Gas flares in the water column and seabed features related to fluid flow are found over the entire Norwegian exclusive economic zone (EEZ). The gas emitted from these cold seeps is mostly methane, which has in many places, led to the formation of methane-derived authigenic carbonate crusts. The carbonate crusts in turn provide evidence for extensive and persistent gas seepage in the past. Chemosynthetic communities are commonly associated with cold seeps, and may form special habitats together with the carbonate crusts.

Methane seepage has been proposed to make a significant contribution to the global carbon budget, and may be associated with gas hydrates giving rise to potential geohazards. Gas flares can be identified and spatially mapped using multibeam echosounder systems having the ability to record reflections from both the water column and the seabed.

Water column data have been recorded in the MAREANO programme by the Norwegian Mapping Authority Hydrographic Service since 2010, over an area of 141,000 km^2, with a data volume exceeding 100 Tb. Analysis of water column data from c. 25,000 km^2 using the Fledermaus Midwater software have revealed more than 500 sites with gas flares, including many sites with multiple flares. Observations of extensive gas flares in the Norwegian EEZ are now going to be made available to the scientific community and other users through a dedicated MAREANO data and web access system. The information will include the location of gas flares, survey name and line ID, a visual assessment of gas seepage intensity, and height (not all flares).



Towards Habitat Mapping Multibeam Data Collection Protocols –- A Case Study from Coastal Otago, New Zealand

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The University of Otago is developing a Near-Geophysical Imaging Facility (NGIF) to advance the research disciplines of hydrographic surveying, marine science, geology, geography and zoology. A key component of the NGIF is our recently purchased R2 Sonic 2026 multibeam echosounder. The versatility of this equipment supports our wide-ranging activities in shallow coastal areas, deep lakes, offshore canyons and fiords.

The array of multibeam setup and operation options presents challenges to our scientific users and will greatly influence their data processing and analyses. The most common issues arise from inexperience, insufficient time given to setup and calibration, other spatial data collection considerations and conflicting demands from multiple end users. Despite these, all users want repeatable and robust scientific data to use in their research projects.

In New Zealand we have recently been collecting multibeam data in the shallow (< 30 m) East Otago Taiāpure (customary protection area) for the purposes of generating an initial habitat map. High-resolution seafloor bathymetry and backscatter has never been gathered here before. This project has given us the chance to begin the development of a marine data collection protocol for scientists using our system. We aim to equip our operators with scientifically-informed best practice methodologies in bathymetric and backscatter data gathering *and* the ancillary spatial measurements they will need to compliment the final product (sidescan sonar, aerial drone use, dive locations, drop cameras, oceanographic and seabed sampling etc.).

This presentation considers: a) the setup requirements and knowledge base of our users; b) the work we are planning to develop data collection protocols - including initial trials into frequency and operational settings, sound velocity regularity, tides and vertical datum integration and the multispectral abilities of our system in coastal Otago; and c) integration with other data collected.

Transnational Belgian-Dutch Geological Knowledge Base on Marine Aggregates: From 3D Voxel Modelling to 4D Cross-Border Environmental Assessments

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Mineral and geological resources are non-renewable on time scales relevant for decision makers. Once exhausted by humans, they are not replenished rapidly enough by nature, meaning that truly sustainable resource exploitation is not possible. Comprehensive knowledge on the distribution, composition and dynamics of geological resources and on the environmental impact of extraction is therefore critical. Anticipating on this, a geological knowledge base has been developed as a platform for resource management (Belspo Brain-be TILES, 2014-2018).

Backbone of the knowledge base is a 3D voxel model (volume pixels) of the surface and subsurface of the Belgian and southern Netherlands part of the North Sea. Standardized and harmonized databases have been created and a methodological workflow for the 3D modelling of offshore aggregates published. Data were added to the highest detail as to maximize their classification to any application (e.g., aggregate industry). Metadata were carefully added to estimate data-related uncertainty.

The 3D geological models were further coupled to 4D numerical environmental impact models as to quantify environmental impact under various scenarios of exploitation. Furthermore, the voxels were filled with decadal sediment transport calculations allowing assessing seabed recovery estimations after extraction, an important asset in many environment-related European Directives.

Data, models, and their uncertainties, are embedded in an end-user driven decision support system (DSS) that uniquely allows querying the full 3D resource volume, and integrating it with any third-party data. Visualization is an inherent part of the DSS, but to maximize impact towards a broader user community, a virtual reality application has been built too.

From a management perspective, the DSS allows long-term resource predictions, balancing aggregate quality and quantity against various applications, whilst minimizing environmental impact. Finally, a vision will be presented on how incorporating the geological knowledge base into a future national seabed mapping programme.

High-Resolution Habitat Mapping off Capri Island, Southern Italy

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This paper deals with the characterization and mapping of benthic habitats off Capri island in the Bay of Naples, southern Italy. For this aim, we used high-resolution swath bathymetry and Side Scan Sonar imagery data integrated with grab sampling and ROV inspections. Seafloor investigations covered an area of ca 15 km^2 including both the nearshore and the offshore zones up to a depth of – 140 m. The collected geophysical and sedimentological data allowed us to map benthic habitat at 1:5,000 scale on the base of both substrate and morphology. Information on benthic community resulting from grab samples analysis have been taken into account as well.

Heterogeneous textural and morphological features characterize the study area. In particular, a shallow rocky (carbonate) substrate along with very scarce sediment supply favour starved conditions/amalgamation with high in situ sediment production by biological activity. Bioconstructions of different size occur as both isolated and grouped/aligned mounds surrounded by coarse organogenic deposits.

The collected bathymetric data resulted in a 5x5 m DEM which permitted us to recognise meter-scale seafloor features. Based on these data, a map depicting geoform distribution in the study area was produced. Five different types of geoforms have been identified: bank, terrace, ledge, plain and slope. At the same time, a backscattering mosaic at 1m resolution from Side Scan Sonar data was used to map seafloor acoustic facies. Eleven acoustic facies have been recognized and classified on the base of ground-truth data derived from grab sampling: two of them are associated with landslide deposits, one corresponds to rocky substrate, five acoustic facies are identified by sediment grain-size and composition, two relate to bioconstruction and one is due to seafloor vegetation. Substrate features aided by benthic community data were combined with geoforms by GIS overlay analysis to obtain a map of the benthic habitats of the study area. Such a quantitative approach provided useful tools for conservation and management of marine resources with particular reference to seafloor areas that are exposed to intense human activity.

Seabed Character and Associated Habitats of a Tropical Shelf: Equatorial Rio Grande do Norte Shelf, NE Brazil

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The Brazilian tropical shelf is not well known. An improved understanding of how biological habitats vary in relation to substrate types and seabed features is the main result of the Science and Technology National Institute in Tropical Marine Environments (INCT AmbTropic), through its Working Group 2.1 Geodiversity and Biodiversity of substrates in the continental shelf. In this work we investigate the spatial heterogeneity of shelf substrates in Equatorial Rio Grande do Norte State shelf, northeast of Brazil, the controls of this heterogeneity, and the communities of organisms associated with them. The integrated data set used in this study consist of acoustic data (single and multibeam bathymetry, backscatter, interpherometer, chirp), remote sensing, ground-truth video data and sediment samples. The maps are created in ArcGIS.

Distinct geomorphic features observed in this shelf include very large dune fields (longitudinal, oblique and transverse), submerged sandstone outcrop, coral patch reefs, isolated shallow-marine sand bodies, and incised-valleys. The inner-middle-, and outer-shelf are broadly distinguished according to the water depth, geomorphology and sediment characteristics as follows: inner shelf down to 15 m water depth, presents very large oblique dunes composed mainly of quartz sands (slightly coarser on the troughs than on the crest), as well as very large longitudinal dunes characterized by coarse bioclastic sands (crests) and gravelly bioclastics sands (troughs), composed mainly of coralline red algal and Halimeda fragments and rhodoliths. The middle shelf, between 15 and 25 m depth, is characterized by very large transversal dune field, composed of fine- to medium-grained siliciclastic sand on the crests, whilst the troughs are composed of coarse bioclastic gravel, stabilized by living coralline algal maërl and Halimeda meadows. The transition from mid- to outer-shelf, around 25 m isobath, is defined by alignments of submerged outcrops, composed of carbonate cemented sandstones and grainstones, often covered by seaweeds, rhodoliths and sponges. Incised valleys are muddy dominated.

The Ostracod assemblages show far higher diversity and abundance in the incised valleys (mud) than in the dune fields areas (bioclastic and siliciclastic sands). This difference may be related to higher organic matter input from the river. Foraminifera species community also revealed a depth and sediment type influence. The results also indicate that the grain size may determine the structure and composition of benthic macroinfauna and epifaunal communities in this tropical shelf of RN, where the mud, with finer particles, show a less diverse and dense macroinfauna assemblage. In this area, amphipods are dominant possibly because they find ideal conditions foraging. Environments with sandy bottoms tend to harbor denser and more diverse faunas, possibly because of greater availability of microhabitats. The epifaunal species that contributed the most for the group formation were: the echinodermata *Leodia sexiesperforata* in siliciobioclastic sand; the snail *Strombus pugilis* in the mud; and the clam *Pinctada imbricata* and the crab *Menippe nodifrons* in bioclastic sand. The high abundance of *L. sexiesperforata* (beach dollar, with flattened and oval format) in the silicibioclastic sediment may be related with its behavior of burying in sediments of intermediate grain size. Moreover, the occurrence of the snail *Strombus pugilis* (herbivore) in the finer sediments may be related to the occurrence of macroalgae and marine plants at this habitat type. In contrast, the bioclastics sands, with larger grain sizes has the characteristic of a low deposition of organic matter and particulate material, favoring adhesion to the substrate of sessile and filter feeding organisms such as the *P imbricata* bivalve. Thus, the seabed features and different types of sediment seem to be good indication of the infaunal and epifaunal communities that inhabit this shelf.

Building a Case for How to Use a Multi-Year NOAA-Funded Deep-sea Mapping Initiative to Greater Utility

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Supporting the United States' Extended Continental Shelf Project and broader cooperative mapping campaigns, NOAA has mapped roughly 900,000 square nautical miles of deep-sea area. Across 10 different regions, the data collected include multibeam echosounder bathymetry, water column, and backscatter; high resolution sub-bottom profiler data; salinity/temperature measurements; geologic samples; and more. These rich data sets and associated new discoveries not only help the United States determine the bounds of its extended continental shelf, but provide a basis for additional exploration and research. This poster provides an overview of these mapping efforts to generate discussion among stakeholders about future baseline bathymetry mapping needs as well as use cases for open access, integrated, and quality controlled deep-sea data that will support future science and societal needs.

Mapping, Modelling and Monitoring Key Processes and Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonKey_Pro)

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Submarine canyons are dynamic environments that support diverse biological communities including fisheries. Recent work on the Irish Porcupine Bank Canyon (PBC), a natural laboratory isolated from major terrigenous input, has revealed extensive speciose, high biomass cold-water coral (CWC) structural habitats. This project uses Irish state-of-the-art and new innovative marine exploration and analysis technologies to explore and monitor the PBC-CWC habitats and relate to ocean-climate environmental dynamics. Spatially, the project combines multiscale mapping (hull-mounted, ROV-mounted multibeam bathymetry and structure from motion-derived bathymetry) and novel 3D photogrammetric techniques with 8 deep water mini-lander systems (sediment traps and current profilers) for characterisation of habitats and their temporal dynamics. Monitoring of canyon hydrodynamic and sedimentary processes, core and coral-morphotype analysis will reveal the process thresholds defining coral sub-habitats' limits, in space and time, and allow predictive CWC, and habitat sensitivity models to assist marine spatial planning. By assessing the magnitude of existing anthropogenic impacts within the constraints of the sensitivity model, recommendations can be extrapolated from the data for sustainable, responsible intervention in these habitats for fisheries and hydrocarbon exploration. Likewise, process thresholds will reveal the potential impact-response from climate change facilitating knowledge-based recommendations for effective management. Temporally, novel dual energy CT-scanning is applied to ROV-guided vibrocores to understand palaeo- and recent CWC habitat development and link to modern processes. This project adds to Irish seabed mapping capacity, develops a critical mass to generate large consortia, building further capacity and relationships with industrial (hydrocarbon)/international partners.

Creation of a Synthesized Reef Habitat Map for the Southern California Bight, California, USA

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Little is known about the extent of manmade versus natural reef habitat in the Southern California Bight (SCB) and their relative biological contribution to the system. While relatively complete data existed for the distribution of different hard substrates within the SCB, they are from disparate sources and have remained unsynthesized. Here we take an initial step towards understanding the effects of these manmade habitats by creating a complete map of the available natural and manmade hard bottom habitats in this region.

Natural hard substrate has been mapped with multibeam and side-scan sonar, but these methods are unable to effectively map many shallow (< 30 m depth) coastal areas, where much of the critical reef habitat exists, due to interference with kelp. Recent multi-spectral aerial imagery collected as part of the CA MPA Baseline Program (2011-2013) now permits shallow habitat classification to fill in these gaps. For some manmade reef habitats, such as breakwater habitats, there are other spatially-georeferenced datasets that also have not yet been integrated into a comprehensive, spatially-referenced data layer.

We mapped the geographic extent of both natural and manmade benthic reef habitats by combining several different spatial datasets. These sources included habitat classification derived from multibeam bathymetry surveys and multi-spectral aerial imagery, where only those habitat types that correspond to or function as reef were selected. Additionally, the areal extent of some manmade reef structures (e.g., shipwrecks, breakwaters, petroleum platforms, and other rocky manmade reefs) were mapped with historical resources and visually using GoogleEarth™ satellite imagery.

The layers were merged in ArcMap v. 10.3 to create a single map, retaining reference to the source data in the attribute table of the resulting shapefile. A significant outcome of this project will be to create a unified data layer and make it available to resource managers, researchers and stakeholders. This will also permit us to quantitatively assess the proportional biological contribution of manmade habitats to natural reefs in the SCB.

Environmental Drivers of Spatial and Temporal Productivity of Abalone Populations

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With the combined pressures of fisheries extraction and shifting oceanographic conditions due to climate change, management of fisheries is becoming more difficult. An understanding of how fisheries species respond to these pressures can help improve guidelines for sustainable management. In this study, we focused on an important fisheries species off the coast of Victoria, Australia, blacklip abalone (*Haliotis rubra*), and used spatial modelling techniques to associate changes in biomass with seafloor habitat and temporal variations in oceanographic conditions, recruitment patterns, and fishing pressure. Biomass for *H. rubra* was calculated from yearly, fishery-independent abalone surveys across 180 sites in Victoria from 1992 to 2015. The seafloor habitat information was derived from a combination of coastal LiDAR and multibeam bathymetry across the depth range of *H. rubra*. From this bathymetry data, we derived a number of variables associated with the depth, slope, and complexity of the seafloor terrain. Hydrodynamic models (wave exposure and currents) were downscaled to 500 m and hindcasted over the past 20 years at 5 min increments across the entire study area. These hydrodynamic models were converted into seasonal and annual means for use in the spatial models and used to develop biophysical dispersal models of *H. rubra* populations to map out networks of reef population connectivity. We also used satellite observations to characterize annual and seasonal sea surface temperatures (SST) over the time period of the study. Finally, spatially explicit maps of fishing pressure were developed using the landings data from the *H. rubra* fishery zones, which we normalized based on the amount of suitable reef within each zone. Each of the environmental and fishery extraction variables were used in a generalized linear mixed effect model (GLMM) and associated with the yearly *H. rubra* biomass information to determine which variables were responsible for the temporal and spatial distribution of this species. Through these models, we found that depth, complexity of the reef, presence of rocky reef, SST, fishing pressure, wave orbital velocity and connectivity helped to explain the temporal and spatial distribution of *H. rubra* along the Victorian coast. Additionally, genomic research aimed to characterize patterns of population connectivity through genetic structure was used to assess the relationship between structural and functional connectivity. These results help to understand how the combined effects of habitat, oceanography, recruitment and genetics structure *H. rubra* populations, which will help to facilitate performance assessments of ecosystem-based fisheries management strategies.

Predicting Optimal Sites for Habitat Restoration Using Multi-Species Distribution Modeling

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Habitat restoration is an important tool for managing degraded ecosystems, yet the success of restoration projects depends in part on adequately identifying ideal sites for restoration. Species distribution modeling using a machine learning approach provides novel tools for mapping areas of interest for restoration projects.

Here we present a method for identifying ideal locations for manmade reefs using multi-species distribution models. We created species distribution models for 40 species of commercial, recreational, ecological, or conservation importance within the Southern California Bight based on observations from long-term reef surveys combined with fine-scale (200 m) geospatial environmental data layers, including bathymetry, aspect, slope, distance to shore, and mean annual sea surface temperature. We then combined the individual species models to create a multi-species habitat suitability map to identify specific locations within the bight with highly suitable habitat for the maximum number of species.

To validate this method, we compared predicted habitat suitability to species richness observed on current manmade reefs within the region. We mapped manmade reefs across the region, quantified area, and calculated species richness per area on each manmade reef that was surveyed. The average multi-species habitat suitability score for each reef was compared to area-corrected species richness to determine the success of this metric in predicting success of manmade reefs for hosting multiple species.

Our results provide insight for marine restoration projects in Southern California specifically, but this method can also be more widely applied to other types of habitat restoration including both marine and terrestrial.

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