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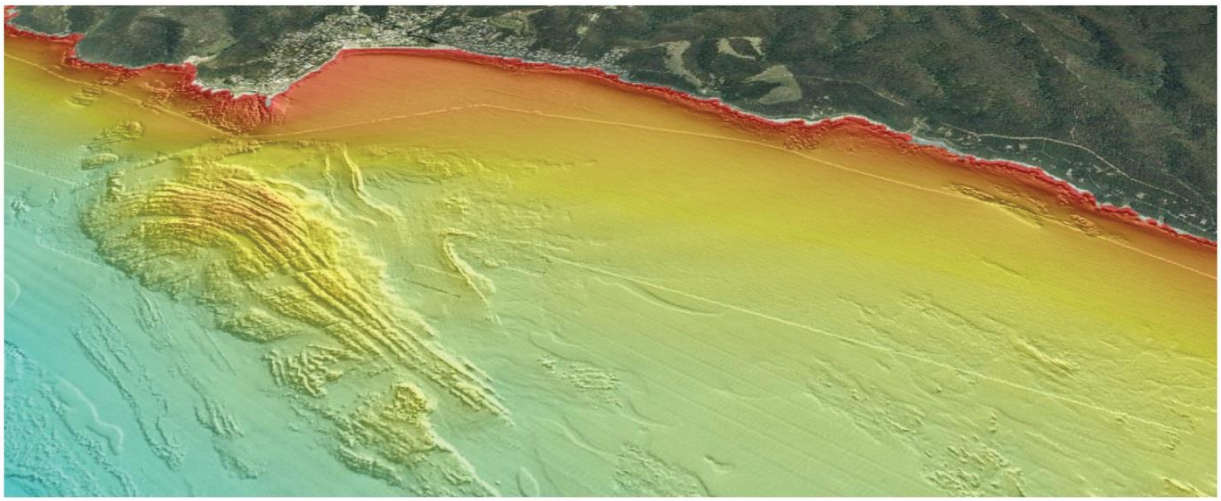

ABSTRACT VOLUME

GEOHAB
Marine Geological and Biological Habitat Mapping

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Calculating the Tidal Prism Using Combined Robotic and Remote Sensed Methods

Simon Allen[1], Simon Collings[2], Hannalie Botha[3] and Boo Davie[4]

[1]CSIRO Wealth from Oceans, Hobart, Tasmania, simon.allen@csiro.au

[2]CSIRO Wealth from Oceans, Floreat, Western Australia

[3]CSIRO Wealth from Oceans, Canberra, ACT

[4]CSIRO Wealth from Oceans, Sandy Bay, Tasmania

Bays and estuaries dominate Australia's inhabited coastline. The majority of these are shallow and their carrying capacity is determined to a large degree by their tidal prism.

Current methods for accurately determining the tidal prism require significant capital equipment from LIDAR equipped light aircraft to jet skis with RTK GPS. The associated expense of the data collection leads to a temporal under sampling which in turn makes the understanding of the evolution of our coastal ecosystem increasingly difficult.

Bathymetry from satellite imagery has been proposed (and practised) since the 1980s but continually fights for acceptance as a legitimate methodology. New satellites and new access methods make the calculation of bathymetry from satellite data relatively easy, and the challenge has now moved on to the affordable collection of ground truth data and the application of tides to make the best use of these instantaneous and holistic snapshots of our coastal waters.

The authors presents their recent experiences in developing a new bathymetric surface using a mix of satellite data and robotic and human gathered ground truth data for the Pittwater area in South Eastern Tasmania as a base layer for an estuarine hydrodynamic model.

Environmental sensitivity index to oil spills for submerged habitats: an application to the marine area of the state of Pernambuco, northeast Brazil

Tereza Araújo[1], Daniele Mallmann[1] and Katia C. Nunes[2]

[1]Laboratório de Oceanografia Geológica/DOCEAN/UFPE, Recife/PE/Brasil, tcma@ufpe.br

[2]Petróleo Brasileiro S.A – PETROBRAS, Brasil

Mapping of Environmental Sensitivity to oil spills (ESI Maps) are important tools for contingency plan and response actions in incidents of oil pollution because they allow us to identify and locate environments with priority protection as well as identify potential losses. In Brazil the cards are normalized by the Ministry of the Environment (MMA), and the methodology has been adapted from the standards set by the National Oceanic and Atmospheric Administration (NOAA). The methodology classify the coastline according to indices of environmental oil spill sensitivity, and coastal segments are grouped in indexes ranging 1-10. The increase in these indices is given in accordance with the decrease of the degree of exposure to wave energy and increased penetration into the substrate, the retention period on the coast, and the biological productivity of the local. However, until now, there is not an index for submerged habitats in the national legislation. In order to fill this gap, the development of an environmental sensitivity index (ESI) for submersed habitats found in the inner continental shelf was necessary during the development of the Project SAO maps (Maps of Environmental Sensitivity to Oil Spill to the Coast of Pernambuco). The accurate representation of submerged habitats in these type of cards is essential, especially regarding the banks of coral and calcareous algae, because they have several ecological functions, such as a nursery, breeding, feeding and protection of different aquatic organisms. Thus, the criterion according to which the different habitats were ranked according to priority degrees of protection was based on that used for the coast (ranging from 1-10), through the analogy of these with the coastal environments, as described below: (i) inventory of submerged habitats present in the inner continental shelf, (ii) defining the criteria for the allocation of ESIs to these environment, (iii) analysis of similar submerged environments habitats concerned, is considered the index for coastal environments, and (iv) reorganization of environmental sensitivity index at an appropriate scale to the number of degrees of priority, thus established: algal banks/ seagrass meadows (ESI 4); coral reefs (ESI 3), piers (ESI 2), sandstone reefs (ESI 1). ESI 4 represents the highest sensibility. 300 km² of submerged habitats were mapped, where the diversity of the ecosystems, which is typical of tropical coastal environments, requires versatility in any response actions to oil spills. It is important to mention that such events tend to be more common due to the increase shipping activities imposed by the development of the oil industry and logistic activities in Pernambuco coast.

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Geohabitat mapping in the inner continental shelf of Recife, Pernambuco, Brazil*

Tereza Araújo[1], Antonio V. Ferreira Jr.[1] and Mirella B.S.F. Costa[1]

[1]Laboratório de Oceanografia Geológica/DOCEAN/UFPE, Recife/PE/Brasil, tcma@ufpe.br

The continental shelf of Pernambuco, northeast Brazil, presents reduced wide (35km), with the shelf break located at 55-60m depth. In front of Recife city, the continental shelf is intensively used for various purposes, eg, fishing, telecommunication cables, recreations shipwreck diving, dredging disposal and conservation. A morphological characteristic of this coast is the presence of lines of beachrocks parallel to the coast, which serve as substrate for the development of corals and coralline algae. The objective of this study was to analyse the actual morphology and sedimentology features of the inner continental shelf of Recife-PE, aiming to assess the geodiversity of the area. The methodology involved sonographic and bathymetric survey, sediment sampling and video images. Results have indicated the geodiversity of the area, in terms of gemorphology and seabed domains or habitats. The morphology of the area was characterized by positive (submerged reefs) and negative (paleocanal) reliefs, intercalated by plain surfaces. Four reef lines were identified, all being approximately parallel to each other and to the coastline, plus some isolated reefs, which demonstrates the irregularity of the inner continental shelf. The most prominent feature is a submerged reef bank in depth of 8m, with 17 km long and 1 km wide, parallel to the coastline, which have a quasi-horizontal top that vary from 0.5 – 4 m in depth, at low tide. Video images taken in it revealed that the same is covered by algae. In addition to details of the submerged reef bank geometry, it was possible to observe the presence of the other two deeper reef lines, another smaller near the beach (in depth of 2m), and other isolated reefs distributed along the area. In relation to seabed domains, the average grain size showed a variation of very fine to very coarse sand and poorly selected to well selected grains, in the region before the submerged reef bank. After this, grains ranged from coarse to very coarse sand, and are moderately selected. The quartz grains varied from rounded to well rounded, predominantly sub-round grain with high sphericity and bright. The bioclastic grains are formed by fragments of calcareous algae, halimeda, sponges, coralínea algae, gastropods, foraminifera and bivalvia. The distribution of the seabed domains showed different characteristics in relation to the average grain size, due to the presence of the submerged reef bank. This feature seems to have an important role in the distribution of sediment and, therefore, in the distribution of marine habitats.

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Living in a landslide

Nicole J. Baeten[1], Margaret F.J. Dolan[1], Liv Plassen[1], Pål Buhl-Mortensen[2], Lilja R. Bjarnadóttir[1], Leif Rise[1] and Valérie K. Bellec[1]

[1]Geological Survey of Norway (NGU), P.O. box 6315 Sluppen, NO-7491 Trondheim, Norway, Nicole.Baeten@ngu.no

[2]Institute for Marine Research, P. O. Box 1870 Nordnes, 5817 Bergen, Norway

Some of the largest submarine slides in the world occur on the formerly glaciated Norwegian - Barents Sea - Svalbard margin, including the Storegga and Bjørnøyrenna Slides (e.g. Haflidason et al., 2004; Laberg and Vorren, 1993). Submarine mass movements have a very dynamic morphology and sedimentology, dependent on numerous different factors. The Storegga Slide is a particularly rugged area, extending over 95,000 km^2 (Haflidason et al., 2005). It is characterized by a ridge and trough morphology formed by the spreading of slabs of sediments over different glide planes. The ridges and blocks consist of compacted sediments. The troughs often act as sediment traps, where finer sediments can accumulate. These differences in morphology and bottom type are important for the animals that have colonised the slide areas, many of which have been revealed through underwater video surveys conducted as part of Norway's offshore seabed mapping programme, MAREANO (www.mareano.no).

During surveys in 2013, a rich variety of habitats were found within the Storegga Slide – these include cold-water coral reefs, coral forests, basket stars and cauliflower coral meadows, brittlestar communities, and seapen and burrowing megafauna communities. Whilst some animals prefer the softer sediments in the troughs, others thrive best on the more compacted and exposed ridges and slide scars. We will present some examples of the habitats found to date within selected slide areas on the Norwegian margin, and discuss their relationship to the underlying submarine landslides and their processes.

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Predictive substrate mapping in the active volcanic environment of the Kermadec arc

Sophie Barton[1,2], Richard Wysoczanski[2], Geoffroy Lamarche[2] and Arne Pallentin[2]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand, Sophie.Barton@vuw.ac.nz

[2] National Institute of Water and Atmospheric Research (NIWA), Private Bag 14-901, Wellington, New Zealand.

The Kermadec arc is a region of high geological and biological interest as it is home to a magmatically and hydrothermally active volcanic front. In addition to the geological importance of the Kermadec arc, the region is host to rich biological communities, supported by the ranges in water depth and habitat provided by the seamounts, and the presence of chemosynthetic communities associated with hydrothermal venting. Geological mapping of the substrate can aid characterisation of the volcanic and tectonic histories of the seamounts, providing insight into subduction processes. It can also help predict the distribution of biological assemblages on seamounts, as an aid to understanding unique communities (see Boschen et. al abstract). However, mapping of the seabed substrate is time consuming and expensive as it relies on direct observations from ROV and towed cameras combined with sampling of the substrate. Predictive substrate mapping is a viable alternative method of mapping seabed substrate that is less expensive and time consuming than direct observations.

Predictive substrate mapping utilises multibeam echosounder (MBES) bathymetry and backscatter data to construct segmented maps based on their acoustic properties. This enables large areas of seafloor to be mapped by acoustic properties that correspond directly to substrate morphology and composition, with a coverage that would otherwise be unobtainable by direct methods. In order to achieve such maps, however, it is first necessary to have a sound understanding of the backscatter response to the various substrates that occur in volcanic arc environments, along with the bathymetric controls on substrate distributions. These relationships can be established with the use of ground-truth data, which can also be used to test the applicability of models developed for one seamount to other seamounts within the region.

In this study we use backscatter and bathymetric data to construct predictive maps of three Kermadec arc seamounts (Brothers, Rumble II West and Rumble II East). Data used was collected using a hull-mounted Kongsberg Maritime EM 300 MBES on the KARMA voyage of the R.V. *Tangaroa* in 2010. The backscatter component has been processed using the Sonar Scope software. Bathymetric proxies investigated include slope, flow accumulation, water depth, bathymetric position index, and rugosity. Video footage of the seafloor obtained using a deep towed image system acts as a ground-truth for data, and allows us to assess the ability of MBES data to provide substrate information in this highly complex environment. A range of substrate classification models will be presented based on the data and their accuracy evaluated and the application of the data will also be discussed. The production of high quality maps of substrate distributions within the region is of use not only from a scientific perspective for volcanic, tectonic, and biological habitat research, but has important applications for assessing natural hazards such as eruptions and edifice collapses and the potential tsunami. They are also a powerful tool to industry as in aid in mineral exploration, especially given the potential economic value of seafloor massive sulphides hosted by these seamounts, and in evaluating the impact of offshore mining on communities. In this way they can also aid governmental policy decisions regarding the sustainable environmental management of the region.

Change of benthic marine communities cover during a small time scale at Old Providence Island, Colombian Caribbean

Angélica Batista-Morales[1], Harold Mauricio Bejarano[2] and Katherine Bernal-Sotelo[3]

[1]Universidad de Los Andes, Carrera Primera # 18A-12, Bogotá Colombia, ambatistam@gmail.com

[2]Universidad Karlsruhe Institute of Technology, Karlsruhe, Germany

[3]Universidad de Costa Rica, 11501-2060 San Pedro Montes de Oca, San José, Costa Rica

Changes in benthic marine communities in many areas of Colombian Caribbean have been detected during monitoring field survey over the past two decades. A reduction of coral cover and increase of algae like other life forms were reported by these studies. Understand the extension of this problems are relevant especially for effectiveness and functionality of marine protected areas. McBean Lagoon National Park in Old Providence Island is one of the most important marine national parks in Colombia and it is located in the northeast jurisdictional edge of Colombia in the Caribbean Sea. It is protecting a large variety of marine and coastal strategic ecosystem in its 995 ha, for these reason the park was included along with San Andres archipelago in the first Biosphere reserve of Colombia in 2000 year by UNESCO and since then are known as Seaflower reserve (CORALINA-INVEMAR 2012). In order to understand the temporal dynamic of benthos in this National Park, two multispectral satellite images of high spatial resolution, from 2006 and 2012 were processed following the protocol established by Lozano-Rivera (2007) and according to ground control points taken in both years. The main changes detected, were the increase of seagrass and algae cover, as of the macroalgae meadow with low cover of lived coral. Probably, the results are a consequence of water quality decrease and impact of hurricanes, such as Hurricane Beta in 2005. This research represents an initial approach for generating an early warning monitoring model to inform environmental shifts and produce proxy indicators of ecosystem health which could be used to address management efforts of conservation stakeholders and policymakers.

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ROV transect reveals the mesopelagic Osprey Reef, Coral Sea, Australia

Robin J. Beaman[1], Carsten Lüter[2], Joachim Reitner[3] and Gert Wörheide[4]

[1]School of Earth and Environmental Sciences, James Cook University, Cairns, Queensland, Australia, robin.beaman@jcu.edu.au

[2]Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin, Germany

[3]Faculty of Geosciences and Geography, University of Göttingen, Göttingen, Germany

[4]Department für Geo- und Umweltwissenschaften & GeoBio-Center, Ludwig-Maximilians-Universität München, München, Germany

When Australia's Coral Sea Reserve was proclaimed in Nov 2012, Osprey Reef was highlighted as the jewel in the crown of the new system of ocean reserves. This oceanic seamount lies at the northern end of the Queensland Plateau and is regularly used for dive adventure tourism due to the beautiful coral and prolific sharks found there. For many years, these vessels have also carried scientists to this remote site and we installed software to automatically capture singlebeam echosounder data. The crowd-sourced bathymetry data were used to create a 10 m-resolution 3D gridded surface of north-west Osprey Reef to a depth of 932 m. A steep cliff lies between 30 to 130 m, then a narrow shoulder with less gradient occurs to about 250 to 300 m. Below the shoulder, the seabed becomes steeper again forming a rough zone to depths of about 320 to 420 m. A broad apron then extends out around the base of Osprey Reef which is incised with canyons.

In Dec 2009, the Deep Down Under expedition, a German-Australian collaboration, brought a 1000 m-rated Cherokee ROV with a manipulator arm to collect relict fauna in the mesopelagic zone. The 3D map helped guide the ROV dive below North Horn at Osprey Reef to a depth of 787 m. Over five hours of georeferenced video imagery were analysed at 1 min intervals using a programmable keyboard with up to 144 keys available for a classification scheme, using the headings: Primary substrate (>50%), Secondary substrate (>25%), Features, Relief, Bedforms, Biological cover, *Lebensspuren* (life traces) and Biota. The resulting presence/absence matrix was converted to a point shapefile for viewing in ArcGIS, thus providing a dense record of the physical and biological character of the ROV traverse in relation to the 3D bathymetry grid.

We discovered a strong relationship between taxon assemblages and the physical substrate and relief, and observe a major change in benthos assemblages around 500 m depth. On the deeper apron within the axis of a prominent canyon, we found mostly barren, loose boulders and gravel, with large (>2 m long) echiuran worms scavenging within this disturbed area. Up on the canyon wall away from the canyon axis, carbonate sand blankets the seafloor, providing a soft sediment environment for *Lebensspuren* tracks and pits, and the occasional echinoid and large spider crab. A dramatic contrast occurs wherever a rock wall protrudes through the sand. These walls have a high coverage of precious, golden and bamboo corals, together with epibenthic crustaceans and crinoids. Nautilus shells also appear in the video, drawn to the ROV's lights.

Above the apron in depths less than 500 m, the rough geomorphic zone has only minor sessile benthos, even on the obviously stable rock walls. Motile fauna are the occasional echiuran worm and ophiuroids found in areas of disturbed seabed. Around 250 m, the transect over the narrow shoulder reveals an increase in benthic coverage with a lower mesophotic assemblage of stylasterid hydrocorals and black corals. The first coral fish and sharks appear here. Higher up, larger soft coral colonies, stylasterids and seawhips appear, mostly along the protruding edges of rocks. Around 150 m, the seabed becomes very steep where large overhanging caves and tunnels appear likely related to previous lowstand sea-levels. Above 125 m, an upper mesophotic assemblage of dense soft corals, seawhips and gorgonian fans complete the transect.

The ROV video analysis is a valuable record of a deep Coral Sea reef which has seldom had such exploration at these depths. For the wider Coral Sea Reserve, the implications for managers are that the patterns observed here are broadly applicable to the other seamounts on the Queensland Plateau as their geomorphology and oceanography are similar. Together with the new records of taxa, such as the precious corals, Osprey Reef may justifiably be called the (deep) jewel in the crown of Australia's ocean reserves.

Recent Improvements to Seafloor Imagery Acquisition and Processing Procedures for R2Sonic Multibeam Echosounders

J. Beaudoin[1], T. Reis[2] and M. Doucet[3]

[1]University of New Hampshire, jbeaudoin@ccom.unh.edu

[2]Substructure Inc., Portsmouth, NH, USA

[3]QPS Inc., Portsmouth, NH, USA

Bathymetric performance is typically the primary focus when bringing a new multibeam echosounder to market. Whereas software vendors and seabed mappers quickly adjust to new hardware products, support for a system's seabed imaging capabilities often lags behind. Introduced to the market in 2008, the R2Sonic 2024 multibeam echosounder is no exception. The 2024 quickly established itself as a hydrographic-grade mapping system, however, limited understanding and support in post-processing software, along with a general lack of configuration and acquisition "best practices" knowledge in the mapping community, has limited its widespread use for projects where seabed imagery products are required.

In this paper, we examine the technical challenges involved with establishing an acquisition and processing workflow for R2Sonic 2024 multibeam echosounders for a large-scale mapping project of Lake George, NY. For this project, two vessels operated for nearly two months in late 2013 with one of the vessels being outfitted with a dual head configuration.

Challenges included:

- Implementation of a real-time method for monitoring signal saturation
- Determining the ideal dual-head frequency separation to avoid interference
- Establishment of a backscatter reference surface to support inter-vessel calibration
- Establishment of acquisition guidelines and best-practices
- Automation and streamlining of CTD data delivery for refraction and attenuation corrections
- Adding support for dual-head post-processing
- Streamlining data import procedures
- Improvement of imagery quality in post-processing

A close partnership between surveyors, academic consultants and hardware/software vendors allowed not only for the successful completion of the project but has also demonstrated an acquisition and processing workflow where none existed before.

Challenges in sediment interpretation without multibeam backscatter data – experiences from the MAREANO programme, Norway

Valérie K. Bellec[1], Reidulv Bøe[1], Leif Rise[1], Lilja Rún Bjarnadóttir[1], Margaret Dolan[1], Terje Thorsnes[1] and Sigrid Elvenes[1]

[1]Geological Survey of Norway, Trondheim, Valerie.Bellec@ngu.no

The Norwegian seabed mapping programme MAREANO (www.mareano.no) has mapped more than 100 000 km^2 of the Norwegian offshore area. MAREANO has acquired multibeam bathymetry and backscatter, seabed samples, videos and high resolution shallow seismic data which provide the basis for mapping geology, sedimentary processes and habitats on the seafloor. More than 1000 video lines have been recorded between 40 m and 3000 m water depth, documenting structures and bottom types hosting a variety of fauna. Interpretation of surficial seabed sediments is a core activity in MAREANO, and the resulting sediment maps form a crucial input for habitat modelling.

MAREANO mapping started in the Barents Sea in 2006. During the first 5 years of the programme, full coverage multibeam data were acquired, including backscatter data which provide a solid basis for interpretation of seabed sediments and production of maps at 1:100 000 scales. In 2011, MAREANO initiated mapping also in the Norwegian Sea. To complement new multibeam surveys in priority areas, increasing use has been made of other existing bathymetry information, or legacy multibeam data. These data are typically from older industry surveys which lack backscatter information. As a result, for substantial parts of the mapping offshore Mid-Norway, sediment mapping has had to be conducted without access to backscatter information, but with a similar level of ground truthing to areas where backscatter is available. We describe our experience from this mapping and indicate how some challenges have been overcome while others have resulted in a modified mapping procedure.

Detailed bathymetry data (10 m resolution grids or better) provide important information for interpretation of the seabed sediments. Features like pockmarks, sandwaves and slide deposits are the result of particular sedimentary processes and are therefore indicative of sediment type. For example, pockmarks occur in soft sediments whereas sandwaves typically indicate a dominance of sand. Ridges, such as moraines and iceberg plough mark levees, are usually poorly sorted clayrich sediments with coarse fragments (till). The ridges commonly have a thin winnowed top layer of sand, gravel and stones.

In MAREANO, seabed maps from 3500 km^2 have been made from single beam echosounder data (Olex; 50 m resolution) without backscatter. These coarser bathymetry grids provide a good overview of broad-scale geomorphology, covered by MAREANO's marine landscape maps. It is however challenging to make seabed sediment maps from bathymetry and limited ground truthing alone, and maps can only be produced at a scale of 1:250 000 or greater. The interpretation process requires greater use of bathymetric contours as a guide. Also, use of additional opportunistic multibeam and TOPAS parametric echosounder data acquired during transit between MAREANO sampling stations has been invaluable, even though acquisition conditions were not optimal. Despite these challenges, MAREANO sediment maps have provided valuable information for the revision of the Norwegian Sea Management Plan and have been successfully used further to model benthic habitats (biotopes) in the area. Some results from these related products will be presented together with the sediment maps.

Mapping of bioclastic sediments at cold-water coral reef areas

Valérie K. Bellec[1], Terje Thorsnes[1], Reidulv Bøe[1] and Lilja Rún Bjarnadóttir[1]

[1]Geological Survey of Norway, Trondheim, Valerie.Bellec@ngu.no

Norway's MAREANO programme has recently shown that acoustic mapping is a powerful tool for mapping biogenic mounds and associated bioclastic sediments, even when ground truthing is limited. Biogenic mounds built by corals, sponges and other organisms with carbonate shells are a few meters up to 1 km long, and can be recognized in 5 m bathymetry grids when they are wider than about 20 m. Larger reefs can be recognized in coarser bathymetry grids.

Bioclastic sediments have been mapped between the outlet of the Norwegian Trench at c. 62º N in the south, and as far north as Fugløybanken at 70º32' N. A total area of about 95 000 km^2 has been mapped, and bioclastic sediments cover around 1000 km^2. Within this area, biogenic mounds, likely to host coral reefs, constitute 100-200 km^2.

Interpretation of bioclastic sediments from multibeam (bathymetry and backscatter) data relies on the fact that biogenic mounds can be distinguished from the surrounding seafloor based on morphology and acoustic signature. The size of the mounds, however, affects the confidence of the bioclastic sediment maps. Where mounds occur in otherwise flat or low relief areas, interpretation confidence is high. By contrast, on bedrock, or in areas where landslides have created a rugged topography, interpretation confidence is lower, particularly in deep water or where bathymetric data resolution is lower than c. 15 m. Interpretations without ground truthing were checked by video, which revealed a high match between interpreted mounds and mounds observed to host cold water coral reefs.

Interpretation of biogenic mounds and associated bioclastic sediments by use of acoustic methods has proven possible, although it is challenging in some areas. In addition, existing ship-borne multibeam data cannot be used to distinguish between living or dead corals, or coral rubble. Thus, all of these fall in one class named bioclastic sediments. Despite the limitations acknowledged above, bioclastic sediment maps showing the extent of cold-water coral reefs and coral rubble has proven to be important for ocean management. The maps complement verified observations of coral reefs.

Use of Observation Class ROVs to Perform Shallow Water Marine Monitoring

Andrew N. Bickers[1]

[1]BMT Oceanica, Perth, Western Australia, andy.bickers@bmtoceanica.com.au

Western Australia is home to one of the ten largest gas provinces in the world. The scale of the development of oil and gas projects on the North West Shelf carries the inevitable prospect of environmental impact. The complex coastline and numerous islands of the region increase the amount of shallow benthic primary producing habitats potentially influenced by 'offshore' oil and gas development.

All developments are subject to marine compliance monitoring, the plans for which must be carried out subject to the satisfaction of the Environmental Protection Authority (EPA). The tasks required are undertaken by a range of institutions, agencies and organisations including numerous environmental science consultancies.

A great deal of the monitoring undertaken in shallow water in the region is carried out by divers performing video and still imagery acquisition, sediment sampling and deployment and retrieval of longer term monitoring equipment. Regulation compliant diving operations have a high cost and many of the regions carry a potentially high risk to divers due to predatory marine animals, strong currents and tides and poor visibility. Generally due to these reasons and other Health and Safety implications Oil and Gas companies are investigating ways of performing the required monitoring and mapping operations without the use of divers. This involves the use of Remote Operated Vehicles (ROVs) or Autonomous Underwater Vehicles (AUV) as appropriate for the task and environment.

Although ROVs are routinely used for large budget oil and gas subsea operations, environmental projects typically have smaller budgets and are carried out on smaller vessels. This limits the size of both the ROV and the survey and positioning equipment that can be used and presents some logistical problems not encountered on larger (and deeper water) projects.

During 2012 and 2013 Western Australian marine environmental consultancy, BMT Oceanica, have undertaken extensive trials using observation class ROVs to develop efficient techniques to remotely perform the work of divers for marine compliance monitoring. These trials have focussed on techniques for high quality video and stills imagery acquisition, accurate and assessable subsea positioning, facility of navigation and physical sampling. Specific attention was made to the issue of being able to navigate the ROV back to specific biological targets using acoustic and visual navigation. Developments have also been made in camera systems suitable for small vehicles that can acquire high quality imagery suitable for quantitative analysis.

All developments have been made to be used on smaller vessels and not to impede the performance of the ROV. Integral to these developments are partnerships with offshore survey organisations and professionals allowing the use and integration of survey grade positioning software, techniques and equipment including miniature inertial navigation systems.

In this presentation we will show and discuss the results of these trials and how they have helped us to confidently offer and provide an alternative for many of the tasks currently undertaken by divers on the North West Shelf.

MAREANO - past, present and future

Lilja R. Bjarnadóttir[1], Terje Thorsnes[1], Hanne Hodnesdal[2], Børge Holte[3], Margaret Dolan[1], Valérie Bellec[1], Sigrid Elvenes[1], Henning Jensen[1], Leif Rise[1], Liv Plassen[1], Nicole Baeten[1], Reidulv Bøe[1] and Aave Lepland[1]

[1]Geological Survey of Norway (NGU), Postboks 6315 Sluppen, 7491 Trondheim, Norway, lilja.bjarnadottir@ngu.no

[2]The Norwegian Hydrographic Service, Kartverket sjødivisjonen, postboks 60, 4001 Stavanger, Norway,

[3]Institute of Marine Research, Nordnesgaten 50, Nordnes, 5817 Bergen, Norway

MAREANO (Marine AREA database for NOrwegian waters) is a government funded programme that has been mapping the seabed in Norwegian waters since 2005. Core datasets include multibeam data (mostly including backscatter and water-column data), video transects and physical samples of the seabed. Integrated knowledge of the morphology, geology, habitats and the environmental status of the seabed is gained from the combined datasets, and all results are presented in a systematic manner on www.mareano.no. The results from MAREANO provide a foundation of knowledge which serves as a baseline for management and decision-makers, and is actively used by scientists, industry and the public.

In the first phase of MAREANO (2005-2010) mapping activities were concentrated in the SW Barents Sea and the areas outside Lofoten. During this phase the programme grew rapidly, both in terms of budget (2005: 23.6 mill. NOK; 2010: 50 mill. NOK), and areal coverage (2005: c. 2000 km^2 bathymetric data; 2010: 7069 km^2 bathymetric data and 16000 km^2 sampled). The programme growth culminated in 2011 with an increase of the budget (to 96.4 mill. NOK) and the area (to 23 640 km^2 bathymetric data and 21 700 km^2 sampled). At this time MAREANO moved into the Norwegian Sea and also started mapping in the previously disputed areas along the border towards Russia in the Barents Sea, marking the start of MAREANOs second phase (2011-).

As MAREANO entered this second phase as a mature, and ever more extensive, national programme, the need for a timely review of methods and organizational structures became apparent. The programme was subject to an external evaluation in 2012 and many of the recommendations arising from this process have already been implemented. Following on from this, internal re-evaluations will be carried out on an annual basis to ensure that a transparent and streamlined workflow is maintained that optimises the cost-effectiveness of the programme. MAREANO is currently preparing a comprehensive report which will document and evaluate current methods focusing on the relationship between data density, map scales and confidence, and review sampling/mapping standards based on management needs.

Whilst the methods adopted by MAREANO to date have largely proved effective, several recent advances in technology within the various fields of seabed mapping offer great potential for improvements, and it is clear that MAREANO should strive to keep pace with these opportunities. During 2014 MAREANO will start testing out some of this new technology. A total of 2.5 mill. NOK will be used to evaluate new and emerging methods. This includes acquisition of seabed data with improved resolution and autonomy in data collection, using AUVs equipped with synthetic aperture sonar and ROVs with underwater hyperspectral sensors. MAREANO scientists will also explore new, more automated methods for data interpretation, classification and modelling which will help to streamline the workflow.

Kermadec Arc seamount communities and the benthic environment: implications for SMS mining

Rachel E. Boschen[1,2], Ashley A. Rowden[2], Sophie J. Barton[2,3], Arne Pallentin[2], Malcolm R. Clark[2] and Jonathan P. A. Gardner[1]

[1]School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand, rachel.boschen@vuw.ac.nz

[2]National Institute of Water and Atmospheric Research, Private Bag 14901, Kilbirnie, Wellington, 6241, New Zealand

[3]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand

Deep-sea seamounts are increasingly becoming of interest for their mineral resources, such as cobalt crusts and seafloor massive sulphide (SMS) deposits. SMS deposits form by hydrothermal circulation and occur across a range of tectonic environments globally. Typically, SMS deposits are rich in iron, copper, zinc, silver and gold. Active deposits host unique chemosynthetic communities dependent on the reduced chemicals emitted through hydrothermal venting. Inactive deposits typically support slow-growing, sessile taxa that benefit from biological material advected from the active areas. Both of these communities are potentially vulnerable to mining disturbance. Mining for SMS deposits will probably remove all benthic organisms in the immediate area, whilst communities of the surrounding habitat may also be impacted by suspended and deposited sediment resulting from the mining activities. In order to design mitigation measures (e.g. areas closed to mining) it is important to determine the distribution of benthic organisms in the vicinity of the proposed mining, and using information about their habitat preferences, predict where else in the wider region such organisms may also exist.

SMS deposits of commercial interest exist within the New Zealand EEZ, but little is known about the specific influence of habitat they provide on the structure and function of associated communities. This research investigates benthic faunal communities, and the habitat characteristics that influence their distribution, over three seamounts in the Kermadec Arc; Brothers, Rumble II West and Rumble II East. These seamounts span a range of environments; Brothers has large hydrothermally active areas where SMS deposits are forming, Rumble II West is predominantly inactive with inactive SMS deposits, and Rumble II East is inactive with no SMS deposits. We hypothesise that the habitat provided by SMS deposits will support unique benthic communities not found at other locations across seamounts in the Kermadec Arc.

Video transect data were collected during a survey on R.V. *Tangaroa* in 2010, using the NIWA deep-towed camera system. Transects were distributed to cover the range of broad environments present at each seamount. For processing, each video transect was divided into 200m sections to enable greater spatial resolution of faunal distribution. All fauna were identified to the lowest taxonomic level possible, taking into consideration limitations from the camera set up. Depth and position of each faunal record were noted. The substrata were also described and identified from the video using a hierarchical classification system. Additional habitat data, such as seafloor backscatter, topography and roughness were extracted from multibeam data. Faunal distribution information from the video samples was analysed in PRIMER using multivariate routines, and identified communities mapped using ArcMap10. PRIMER routines were also used to determine the relationships between habitat characteristics and community structure.

The distribution patterns of benthic communities on the three studied seamounts will be described, and the variables that account for these patterns identified. Future research plans will also be presented that include habitat suitability modelling to predict the likely composition of benthic communities at SMS deposits on a regional-scale. This research project, which identifies the relationships between faunal distribution and the environment, will help to inform the development of management options for mining at SMS deposits in the Kermadec region.

Seabed Environmental Baselines: Multiple Applications for Marine Zone Management

Brendan Brooke[1] and Scott L. Nichol[1]

[1]Geoscience Australia, GPO Box 378, Canberra, ACT, 2601, Australia, brendan.brooke@ga.gov.au

Baseline data on the seabed environment represents fundamental information for effective characterisation, management and monitoring of the marine environment. A range of commonly collected seabed parameters are useful for identifying baseline environmental conditions, including seabed physical characteristics (bathymetry/morphology, sediment, hardness), habitat types (high-relief reef, sand flats) and biological communities (sponge gardens, seagrass meadows). Baseline conditions are usually not static and useful datasets encompass spatial and temporal variations in environmental characteristics. Variations can be due to natural fluctuations (water temperature, turbidity, currents) that occur seasonally or over several years (e.g. ENSO; IOD). Longer-term trends are also important to identify, such as shifts in benthic species range due to changes in climate. In this presentation, we outline the multiple applications for seabed environmental baselines in the Australian context and give examples where information on habitats and ecosystem processes is being used to support monitoring of marine reserves at the national scale.

Environmental planning and management
Baseline data on the spatial distribution of seabed physical and biological characteristic is essential for effective and defensible marine environmental planning and management. The first step in being able to sustainably manage the marine environment is to identify key natural assets (areas of high biodiversity; habitat for commercial species; unique physical and biological features), in particular the location of key ecological features and processes. Baseline data likewise provide foundation information upon which monitoring programs can be developed. Monitoring or repeat surveys is important for detecting change, both natural changes and change due to significant human impacts, as well as changes that may be related to the cumulative impacts of a number of apparently relatively benign pressures.

Natural resource development
Environmental baseline conditions are an important element of offshore industry development proposals as they describe environmental conditions of a permit area prior to any potential impacts related to development and production activities. Baseline seabed data at the regional scale (beyond typically site-specific data coverage) can also assist in the assessment of potential impacts over areas distant from developments. Regional data is also important for indicating seabed conditions and potential geohazards that represent risk to proposed activities, such as drilling and infrastructure development, and in identifying environmentally sensitive areas that could be avoided. Broad-scale seabed baseline information can therefore help industry in cost-effective (and environmentally desirable) investment decisions.

Data management and access
The national-scale management of seabed baseline data, using an international standards based approach across a distributed system of databases, offers the potential to derive maximum benefit from the data. Access to baseline information by government and the public can support the social license of the offshore industry by improving the transparency to the public of government decisions on development proposals. The ability to build regional baseline characterisations provides important context for site specific observations, in particular on the broader significance of ecologically important features (canyons, reefs) that are identified within a relatively small study area. Having access to national baseline data also enables modelling of ecologically important patterns and processes (benthic biodiversity, seabed shear-stress). These derived products can significantly increase the utility of baseline data for a range of end users.

New Techniques for Fine-scale Mapping of Intertidal Environments using Kite Aerial Photography

Mitch Bryson[1], Richard Murphy[1] and Matthew Johnson-Roberson[2]

[1]Australian Centre for Field Robotics, The Rose Street Building, J04, University of Sydney, NSW, 2006, m.bryson@acfr.usyd.edu.au

[2]Department of Naval Architecture and Marine Engineering, University of Michigan, Ann Arbor, MI, USA

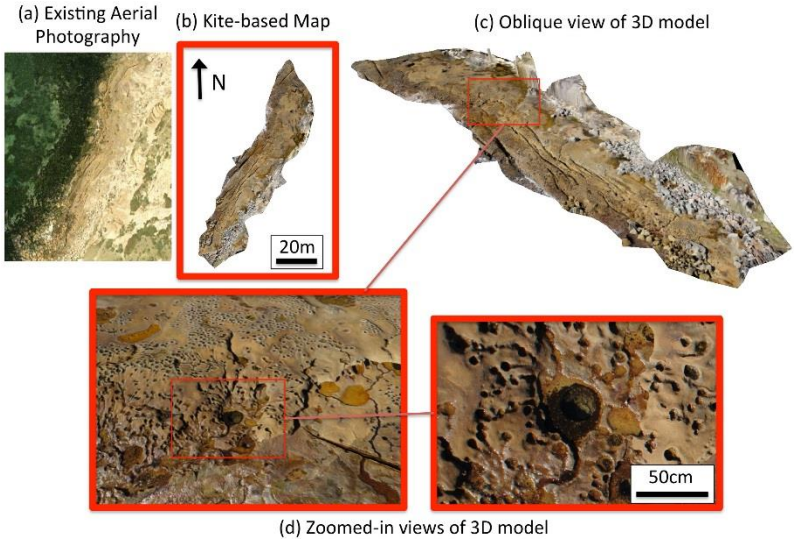

Figure 1: Preliminary results from a pilot study illustrating a high-resolution, photo-textured reconstruction of a rock shore

Plant and animal species that live in intertidal regions such as rocky shores [1] form an important ecosystem that has been studied primarily using in-situ field-based sampling at small spatial scales. Satellite and manned-aircraft remote sensing have also been used to study these habitats at larger scales, although at limited spatial and temporal resolution (greater than 2m per pixel/sample point) and at relatively high costs ($3000-5000US per imagery scene) [2]. In recent work by the authors, a low-cost technique was developed for building high-resolution, geo-referenced image and topographic maps of intertidal regions using kite aerial photography and structure-from-motion image processing [3]. The technique combines consumer-grade cameras and a simple data collection process with state-of-the-art post-processing techniques to produce multi-spectral, 3D photographic maps over hundreds of meters of shoreline with an unprecedented spatial resolution of 5mm per pixel (see Figure 1). In this talk we will present new developments and results in data collection and processing techniques for kite aerial photographic mapping of intertidal environments.

The techniques developed in [3] result in multispectral imagery maps comprising of blue, green red and near-infrared band reflectance data. We are developing automatic imagery classification algorithms that use the multispectral imagery to automatically classify different types of macroalgae to study spatial and temporal variations in coverage at scales not available using existing techniques. The techniques developed in [3] also allow for the reconstruction of fine-scale 3D topography of the rocky shore. From this data we have developed tools for measuring rugosity, slope, aspect (and other related variables) and extract quantitative measurements of sub-habitat geometry (such as rockpools). Our current and future work is focussed on using these environmental and topographic variables over broad spatial scales to study links to ecosystem function, competition and resource usage in the intertidal zone.

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Conservation and management of coralligenous habitat: experience from the BIOMAP Project

Elisabetta Campiani[1], Federica Foglini[1], Simonetta Fraschetti[2], Alessandra Savini[3], Lorenzo Angeletti[1], Valentina Bracchi[3], Frine Cardone[4], Fabio Marchese[3], Francesco Mastrototaro[4], Alessandra Mercorella[1], Serena Palamara[3] , Cesare Corselli[3], Marco Taviani[1], Fabio Trincardi[1] and Angelo Tursi[4]

[1]CNR-ISMAR Via Gobetti 101 40129 Bologna, Italy, federica.foglini@bo.ismar.cnr.it

[2]University of Salento, Dept. of Biological and Environmental Science and Technologies, - Piazza Tancredi, N.7 - 73100 Lecce, Italy

[3]University of Milano-Bicocca, Dept. of Earth and Environmental Sciences, P.za della Scienza 4, 20126 – Milano (Italy)

[4]University of Bari, Department of Biology, Via Orabona, 4 - 70125 - Bari - Italy

Benthic habitat maps represent instrumental tools in supporting the implementation of national legislations (such as the European Habitat and Marine Strategy Framework Directives) as well as new marine management initiatives (e.g., Marine Spatial Planning (MSP) and Ecosystem-Based Management (EBM)) for the marine environment. Coralligenous is one of the most important habitat for the Mediterranean sea recognised as protected habitat in the EC Regulation No. 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea. Different actions have been thus favoured to collect new data on its range of extent and distribution in the Mediterranean and European seas.

BIOMAP Project (Biocostruzioni marine in Puglia, http://www.biomapping.it/index/), promoted by Puglia region, Italy, is a part of the program "PO FESR 2007/2013 – AXIS IV – line 4.4: intervention for the ecological network". It promotes actions in order to map and monitor coralligenous habitats along the Apulian coast (southern Adriatic margin and northern Ionian margin – Mediterranean sea). Acoustic (multibem and side-scan sonar) and video data were collected through a number of oceanographic cruises, to identify and locate coralligenous habitats in 21 Site of Community Interest (SCI) and 3 Marine Protected Areas (MPA).

We produced 59 maps (44 maps at 1:25.000 and 15 maps at 1:10.000) covering the entire Apulian coast, including all SCI and MPAs. Additionally, we mapped deep water sites off shore Bari and Santa Maria di Leuca particularly relevant for protection of deep water white corals. We discovered that Coralligenous habitat covers about 436 Km^2, representing the most relevant habitat within SCI and MPA originally instituted considering only Seagrass occurrences. This knowledge is critical for further conservation measures and for improving the management of Apulian coastal and deep sea areas. Our results are relevant not only for Apulia but for all sites of community interest in the western Mediterranean, highlighting the importance of habitat mapping in improving spatial maritime planning for conservation and protection purposes.

Fish habitat relationships in the Santa Barbara Channel, California USA

Jennifer E. Caselle[1], Mary Young[2], Guy Cochrane[3], Katie Davis[1] and Donna Schroeder[4]

[1]Marine Science Institute, University of California, Santa Barbara, California, 93106 USA, jenn.caselle@ucsb.edu

[2]Department of Ecology and Evolutionary Biology, Long Marine Laboratory, 100 Shaffer Road, University of California, Santa Cruz, California 95060, USA

[3]United States Geological Survey, Pacific Coastal & Marine Science Center, 400 Natural Bridges Dr., Santa Cruz, California 95060, USA

[4]Bureau of Ocean Energy and Management Pacific Region, Camarillo, California, 93101, USA

Effective marine management requires understanding of how local impacts to fish populations affect the regional population. Advances in habitat mapping and suitability modeling enables the prediction of the spatial distribution of species and the factors driving those distributions. While much of this progress has occurred in shallow coral reef habitats, these approaches have been less used in cold temperate, nearshore systems. Here we present results of a study that coupled the distribution of habitats and species habitat affinities using GIS technology to measure species habitat utilization patterns at scales that are commensurate with both ecosystem processes and fisheries management. We used a stratified random sampling design for fish surveys using SCUBA. Habitat maps were compiled from all available sources from the shoreline out to the 20 meter isobath**.** Data types include multibeam sonar, sidescan sonar, and air photos. The habitat classes were reduced to hard or soft bottom. A 100 by 100 meter mesh was used to partition the study area. Because soft bottom predominates in the area, cells were then selected in a stratified random scheme to insure that a significant number of hard bottom sites were included. Using generalized additive models, we found that the abundance and distribution of several important fish species correlated with seafloor substrate, kelp biomass, and depth. For example, the biomass of kelp rockfish (*Sebastes atrovirens*) increases with increases in hard substrate and kelp biomass and decreases with increases in depth. These relationships can be used to extrapolate biomass estimates across the study area, including regions where biomass was not sampled.

Benthic habitat mapping using backscatter angular response, mosaic and bathymetry from multibeam echosounder

Rozaimi Che Hasan[1,2], Daniel Ierodiaconou[2], Alexandre C. G. Schimel[2] and Laurie Laurenson[2]

[1]UTM Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia, rozaimi@ic.utm.my

[2]Deakin University, Centre for Integrative Ecology, School of Life and Environmental Sciences, Faculty of Science and Built Environment, Warrnambool, Victoria, Australia

The effective management of marine ecosystems requires the capability to identify, characterise and predict the distribution of benthic biological communities. Multibeam echosounders (MBES) are increasingly becoming the tool of choice for marine habitat mapping applications. In turn, the rapid expansion of habitat mapping studies has resulted in an increase in the need for automated classification techniques to efficiently map benthic habitats and assess confidence of model outputs and variable importance driving patterns observed. The benthic habitat characterisation process often involves the analysis of MBES bathymetry, backscatter mosaic or angular response with observation data to provide ground truth. However studies that make use of the full range of MBES outputs in the habitat characterisation process are very limited to date.

This study introduces and demonstrates an approach which combines features derived from MBES backscatter angular response curves, bathymetry, backscatter mosaic and their derivatives in a classification process driven by a Random Forests decision tree algorithm using training data from towed video. This approach is applied to a 42 km^2 study area located in cool temperate waters of southeast Australia and encompassing the Discovery Bay Marine National Park, Victoria, Australia. A Reson 8101 was used to acquire full coverage MBES data. This was complemented with 9 acoustically positioned towed video transects resulting in 21hrs of georeferenced underwater towed video footage, covering 56 linear kms of seafloor for groundtruth.

Our methodology combines statistical features that describe the backscatter angular response curves for mid-range incident angles (i.e. mean value, least square slope, skewness and kurtosis) collated from within homogenous segments defined from the backscatter mosaic. These angular response features are then integrated with features derived from the backscatter mosaic (Red, Green and Blue layers of Hue, Saturation and Intensity (HSI) and the Haralick texture features Homogeneity, Entropy and Correlation, calculated from Grey Level Co-occurrence Matrices (GLCM)) and bathymetry data (i.e. complexity, aspect, bathymetry slope, bathymetric position index, maximum curvature and rugosity).

Adding angular response features in the classification process resulted in improving map accuracy from 88.5% to 93.6%. Random Forests also provided insight into the relative contribution of each feature, thereby allowing us to quantitatively determine the relative importance of the angular response features in comparison to the more traditional mosaic and bathymetry features. This capability allowed us concluding that (1) bathymetry and the mean of the angular response were consistently the two most important features in classification process, and that (2) angular response features were consistently more important than features derived from the backscatter mosaic. Further, this capability allowed us to propose a feature-selection process to search for a more parsimonious model, that is, one achieving high accuracy with fewer variables. A model including the four angular response features, the three HSI layers, the correlation texture feature, bathymetry, and bathymetry derivatives complexity and rugosity was found to perform well. This study demonstrated the merits of integrating high-resolution angular response features with bathymetry and backscatter mosaic and their derivatives for benthic habitat mapping applications.

CMECS Biotope Maps for the Southern Salish Sea

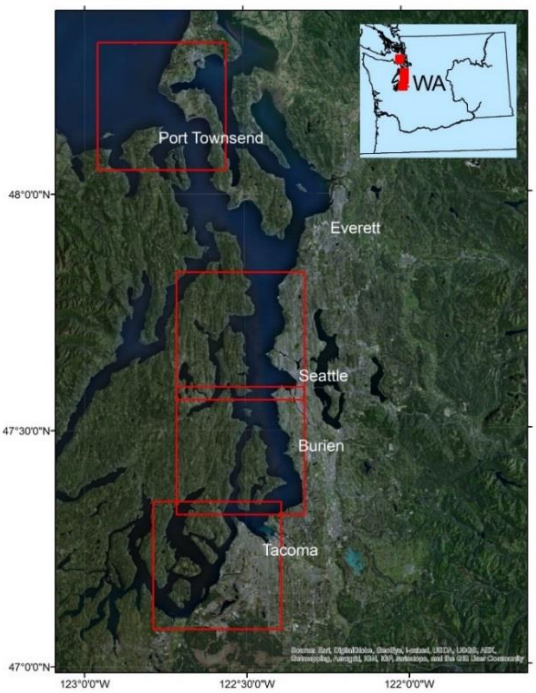
Guy R. Cochrane[1], Megan N. Dethier[2] and Timothy O. Hodson[3]

[1]USGS Pacific Science Center, 400 Natural Bridges Dr., Santa Cruz, CA, 95060, US, gcochrane@usgs.gov

[2]University of Washington, Friday Harbor Labs, Friday Harbor, WA, 98250

[3]Northern Illinois University, Geology and Environmental Geosciences, DeKalb, IL, 60115, US

Recent efforts by the U.S. Geological Survey have used National Oceanic and Atmospheric Administration multibeam sonar data from Admiralty Inlet and south-central Puget Sound, Washington to supervise sea floor video survey, link sea floor geologic data with biotic groups, and generate Coastal and Marine Ecological Classification Standard (CMECS; http://www.csc.noaa.gov/digitalcoast/publications/cmecs) biotope maps. The results are organized into four map blocks (see figure). Physical data on benthic habitat were binned into 1-minute intervals and compiled and matched with time intervals for which the organisms were recorded. Physical data include depth, slope, VRM, BPI, and 6 primary and secondary grain size classes (mud to bedrock). Analyses were done in PRIMER6. In all blocks, correlations existed among physical variables; the strongest relationships were a positive correlation between primary and secondary substrate types, and a negative correlation between depth and primary substrates. Deeper observations tended to have flatter slopes, presumably because the bottom of this fjord is flatter. For each block, biological samples were clustered by their biotic similarity (at a particular statistical level, $p = 0.01$ or 0.005). The combination of substrate type and depth was the best predictor of the biotic assemblages seen in all blocks. For example, one large group was characterized by bryozoans, tubeworms, and other taxa that inhabit stable substrates, and the substrates for the samples in that group were all bedrock and coarse. Another group with clear physical correlates consisted of samples in deep and very deep water with fine substrates, and the biota were characterized by sea whips and their predatory seastars. The best overall predictors of biotic assemblage (substrate type and depth) were used to generate the first CMECS biotope map for the Salish Sea through classification of the individual predictors using the CMECS class divisions and then generating polygons for all 15 possible combinations of the predictor classes, some of which were associated with more than one biotic group.



Quantifying the Discriminatory Power of Benthic Habitat Mapping Technologies

Simon Collings[1], Norm Campbell[1], Gordon Keith[2], Drew Devereux[1] and Boo Davie[1]

[1]CSIRO Computational Informatics

[2]CSIRO Marine and Atmospheric Research

A number of methods and technologies exist for surveying the seafloor, including multibeam echo-sounder (both depth and backscatter data), LiDAR (depth and reflectivity), as well as various passive devices, such as World View 2 (WV2) satellite imaging and airborne hyperspectral cameras. Benthic habitats are of great interest to ocean managers, marine ecologists, conservationists and others who wish to sustainably exploit the ocean's resources.

While many researchers have classified and segmented images from such devices to produce habitat maps, the data from these technologies have not been quantitatively examined to determine the extent to which they enable benthic habitats of interest to be reliably discriminated from one another.

In this presentation, the authors present results from a comprehensive study off the coast of Perth, Western Australia, where we have collected and collated geo-registered multivariate data sets, consisting of WV2 spectral data, aerial photos, LiDAR reflectivity and depth, and multibeam backscatter data, with towed video for ground truth. By examining these data sets collectively and individually using the statistical technique of canonical variate analysis, we provide quantitative results on the suitability of these technologies for reliably discriminating benthic habitats of interest.

The map of marine landscapes of the Cilento, Vallo di Diano and Alburni Geopark

Silvana D'Angelo[1], Floriana Di Stefano[2], Andrea Fiorentino[1], Maria Teresa Lettieri[1], Giovanni Fulvio Russo[2] and Crescenzo Violante[3]

[1]Geological Survey of Italy – ISPRA, Via Brancati, 48, 00144 Roma, Italy, andrea.fiorentino@isprambiente.it

[2]Department of Environmental Science (DISAM), "Parthenope" University of Naples, Centro Direzionale, Isola C4, 80143 Napoli, Italy

[3]Insitute for Coastal and Marine Environment (IAMC), National Research Council (CNR). Calata Porta di Massa, 80133 Napoli, Italy

The Geological Map of the Cilento, Vallo di Diano and Alburni Geopark includes, for the first time in Italy, marine areas. The map was realized at 1:110,000 scale for the entire Geopark, covering a marine area of 460 square kilometers, down to a depth of -100 m. A detailed map of the Marine Protected Area "Santa Maria di Castellabate" was produced at 1:30,000 scale. The seafloor was described according to a classification based on geomorphology, geological composition and dominant organisms.

The cartographic representation is largely based on the morphological features derived by a detailed multibeam bathymetry, completed by geological seabed data resulting from the Italian Geological Mapping Project at 1:50,000 scale (CARG Project). Biological data have been complemented by ROV inspections.

Information has been adjusted to the scale of representation. The main map scale (1:110,000) allows for a general overview of the submerged landscape of the Cilento coast. Approximately 30% of the submerged areas is constituted by hard bottoms. Banks have been mapped distinguishing them according to the grain size of their sediment covers. Hard substrates are seldom represented by rocks directly exposed in the water, since they are covered everywhere by calcareous bioconstructions (coralligenous), which form also on sandy seafloors where algae with calcareous thalli produce lumps of cemented grains (melobesias). On top of them organisms with calcareous skeletons, such as madrepores, serpulids, bryozoans, molluscs settle.

Seagrasses, like *Posidonia oceanica* and *Cymodocea nodosa*, form extended meadows colonizing sandy bottoms down to more than -30 m depth. Deeper than the lower boundary of the meadows, sediments are constituted by organogenic sands and gravels, characterized by calcareous shell fragments of foraminifers, molluscs, bryozoans and serpulids, which inhabit the *Posidonia* meadows. Wherever the sediments covering the rocky substrate are muddier, soft corals (Pennatulacea and Alcyonacea) prevail. Terraces downstepping offshore are covered by sediments of mixed grain size, colonized by *Posidonia* meadows or incrusted by coralligenous organisms.

Submerged plains form in the center of bays bordered by promontories and at river mouths. In these areas sediments are generally fine (sands, muddy sands and silts) and the organisms are mainly fossorious. Sands accumulate in the submerged area exposed to wave action. They are locally characterized by current ripple marks and are colonized by fossorious organisms able to resist to wave perturbation, like cockles (*Donax* spp. and *Chamelea gallina*). The muddy fractions increase offshore and the submerged plains host fossorious "pipebuilders" organisms, such as worms and crustaceans. The plains can be locally covered by *Posidonia oceanica* meadows or, in case of finer sediments, by *Cymodocea nodosa*. Sands can be locally found at greater depths, beyond the muddy plains, as remnants of relict beaches, formed during previous sea level low stands.

The marine protected area "Santa Maria di Castellabate" has been chosen to elaborate an experimental map in order to verify how much detail can be obtained in the description of marine landscapes by increasing the scale of representation. The area, which in the 1:110,000 scale map is represented as a single bank in continuity with the Punta Licosa promontory, covered by mixed sediments, becomes a very diverse zone in the 1:30,000 scale map, with minor banks surrounded by irregular slopes and a variety of biological assemblages.

Seabed characterisation using multibeam sonar angular response curves and a two-stage unsupervised classification technique

James J. Daniell[1], P. Justy W. Siwabessy[2] and Scott L. Nichol[2]

[1]School of Earth and Environmental Sciences, James Cook University, Townsville, Queensland, Australia, james.daniell@jcu.edu.au

[2]Geoscience Australia, Canberra, ACT, Australia

Seabed acoustic backscatter is a complex function of many factors, such as acoustic frequency, incident angle, seabed slope, roughness, grain size distribution, presence of fauna and flora, biological reworking, and volume reverberation. The variation of (discrete) measurements of backscatter over a range of incidence angles for a single seabed type is referred to as its angular response. Angular response is considered an intrinsic property of the seabed and potentially a useful tool for seabed classification. Multibeam sonars acquire acoustic backscatter over an angular sector of between 120-150 degrees. This data, when corrected for seafloor slope, beam pattern, time varying gains, and the area of insonification produce angular response curves for the port and starboard sides of a multibeam swath.

The volume of data acquired by a multibeam sonar in shallow water can be considerable. The presentation demonstrates the application of an efficient, two-stage unsupervised classification technique to cluster a dataset of over 100,000 angular response curves from a survey in the vicinity of Ningaloo Reef, Western Australia. A Self-Organising Map (SOM) is used to provide a manageable summary of the input dataset. Hierarchical Clustering is then used to segment the output from the SOM. Both techniques provide visualization tools to aid the interpretation of classification results. The combination of techniques is shown to be effective at producing detailed maps of seabed composition. These maps can aid geoscience research, habitat mapping, and marine zone management.

Autonomous Habit Classification using Robots

Andrew Davie[1]

[1]CSIRO Wealth from Oceans, Sandy Bay, Tasmania, boo.davie@csiro.au

This work presents a system developed by the author that enables fine-scale benthic classification of habitat using an autonomous underwater robot, and supports other classification methodologies by providing ground-truth and compositional estimates of habitat types.

Fine-scale underwater mapping is expensive to deliver, leading to mapping programmes at odds with the timescales of the processes being studied. Accurate positioning underwater is also expensive resulting in compromise in accuracy that can hide spatial trends. Remote sensing involving the interpretation of aerial and satellite photography is an active field of research, but such methods have limited capability to discriminate benthic habitat beyond shallow depths due to the attenuation of light by the overlying water body. There is a need to determine ground-truth on a fine scale to support larger-scale classifications using more limited spectral data, and for automated techniques to increase accuracy and reduce cost and time required for mapping.

A system for performing unsupervised classification and mapping of benthic habitats using an autonomous underwater vehicle carrying optical spectrometers is presented. The method is insensitive to scale in terms of the level of human input required.

Hyper-spectral data collected by dual optical spectrometers are used to calculate a representation of bottom reflectance spectra that are then un-mixed to produce accurate estimates of the composition and proportions of benthic habitat types, distinguishable to a single species resolution. These un-mixed estimates are distributed over multi-layer classification maps to accept positional uncertainty. These maps represent the types and distributions of benthic habitats.

This capability to autonomously classify and map underwater habitat can complement existing remote sensing techniques. It allows accurate mapping where benthic habitat is obscured from airborne and satellite sensors because of water clarity and depth, and can provide important ground-truth information for other remote sensing methods. The insensitivity to scale opens the door to increased robotic exploration without an associated increase in expert user input.

A Regional analysis of the distribution and abundance of rippled scour depressions along the California coast

Alexandra Davis[1, 2], Rikk Kvitek[2] and Craig Mueller[2]

[1]Oregon State University, Zoology Department, 3029 Cordley Hall, Corvallis, OR 97331, USA, davialex@oregonstate.edu

[2]California State University, Monterey Bay, 100 Campus Center, Seaside, CA, 93955, USA

Rippled scour depressions (RSDs) are coarse-grain sediment features found on continental shelves worldwide that are characterized by long period sand waves (Figure 1) inside of the depressions (0.4m-1.0m depth). Sonar data from the California Seafloor Mapping Project reveal RSDs as common features on the shelf including within marine protected areas (MPAs). While many studies describe RSDs at specific locations, this study is the first to address the spatial distribution of RSDs at the regional scale. The goals of this study were to: 1) quantify the abundance and patterns of distribution of RSDs along the entire California coast, and 2) determine the percentage of rock reef, sedimentary and RSD habitats within state waters, inside and outside of the MPA network. We developed an algorithm-based tool to identify edges of RSDs and differentiate them from other sediment and rocky reef habitat. We then used GIS spatial analysis to quantify the distribution and abundance of RSDs along the coast and test predicted relationships with proximity to rocky reef, depth, and latitude. RSDs make up 3.6% of the shelf compared to 8.4% for rocky reef. RSD percent cover varies significantly with depth and increase with proximity to rocky reef. Because RSDs are a unique habitat found throughout California's MPAs their distribution likely affects the composition and abundance of benthic communities. Specifically, in a companion study to this, remotely operated vehicle (ROV) surveys showed a decrease in faunal richness inside of RSD habitat from surrounding benthic habitat. Surprisingly however, there was a significant increase in the number of young-of-the-year rockfishes and small flatfishes inside of RSD habitat, suggesting RSDs may serve as potential nursery habitat in an otherwise depauperate habitat. So, determining the patterns of distribution and abundance for RSDs on the continental shelf will provide information valuable to the design, monitoring and assessment of California's MPA network mandated by the States Marine Life Protection Act.

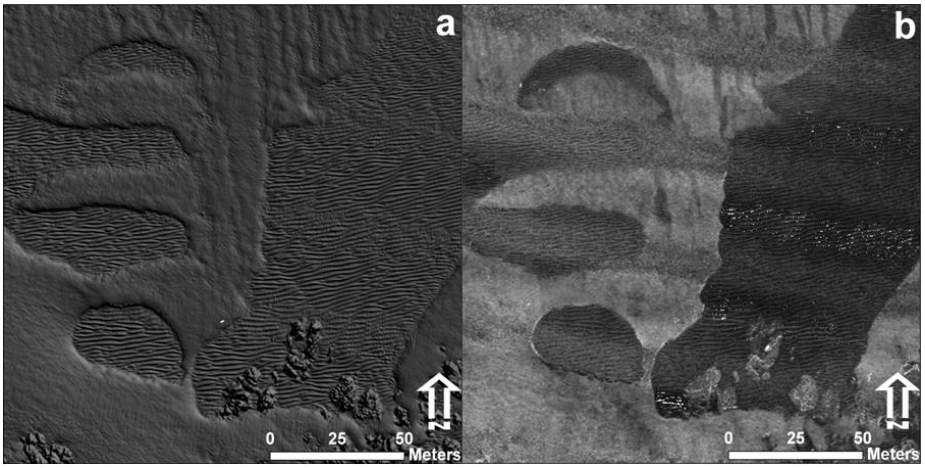


Figure 1: Example image of Ripple-scour Depressions (RSDs) in geophysical data. a) Example of RSDs in a shaded relief digital elevation model (DEM) raster derived from multibeam bathymetry data illustrates distinct depression boundaries and larger-scale sand waves in the RSDs. b) Acoustic backscatter data showing the coarse-grained sediment of RSDs as areas of stronger (darker) acoustic return.

Are classifier ensembles improving prediction accuracy?

Markus Diesing[1] and David Stephens[1]

[1]Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, Suffolk, United Kingdom, markus.diesing@cefas.co.uk

Seabed habitat mapping based on swath acoustic data and ground-truth samples is an emergent and active marine science discipline. Significant progress could be achieved by transferring techniques and approaches that have been successfully developed and employed in such fields as terrestrial land cover mapping. One such promising approach is the multiple classifier system, which aims at improving classification performance by combining the outputs of several classifiers. Here we present results of a multi-model ensemble applied to multibeam acoustic data covering more than 5000 km^2 of seabed in the North Sea with the aim to derive accurate spatial predictions of seabed substrate. A suite of six machine learning classifiers (k-Nearest Neighbour, Support Vector Machine, Classification Tree, Random Forest, Neural Network and Naïve Bayes) was trained with ground-truth sample data classified into seabed substrate classes and their prediction accuracy assessed with an independent set of samples. The three and five best performing models were combined to classifier ensembles. Both ensembles led to increased prediction accuracy as compared to the best performing single classifier (Figure). The improvements were however not statistically significant at the 5% level. Although the three-model ensemble did not perform significantly better than its individual component models, we noticed that the five-model ensemble did perform significantly better than three of the five component models. A classifier ensemble might therefore be an effective strategy to improve classification performance. Another advantage is the fact that the agreement in predicted substrate class between the individual models of the ensemble could be used as a measure of confidence.

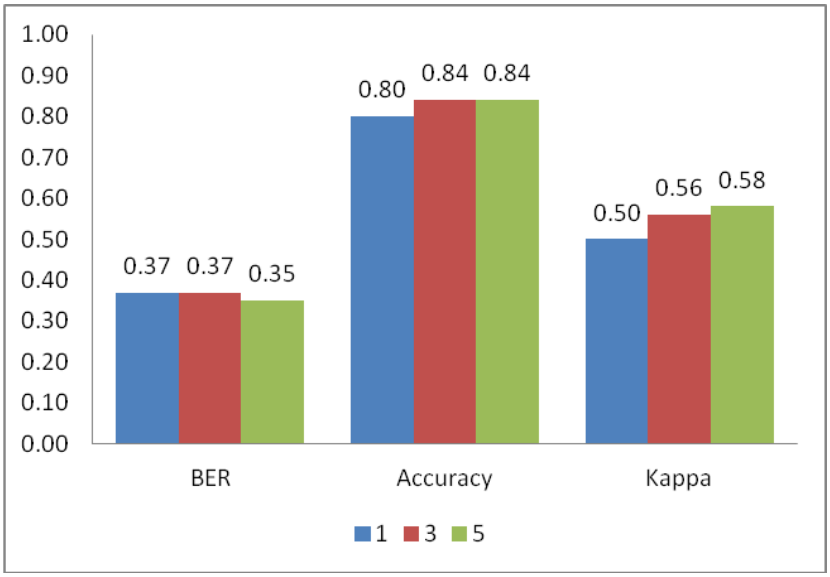


Figure 1. Comparison of accuracy statistics for different model ensembles: 1 – best performing single model (Naive Bayes); 3 – three-model ensemble; 5- five-model ensemble; BER – balanced error rate. Differences in accuracy statistics are not statistically significant at the 5% level.

Use of seafloor stereo-images to validate automatic classification of benthic habitats

Massimo Di Stefano[1] and Larry Mayer[1]

[1]University of New Hampshire, Center for Coastal and Ocean Mapping Joint Hydrographic Center, Durham, NH, US, mdistefano@whoi.edu

Here we present a technique for automatic classification of seafloor data collected during the 2012 HABCAM-V4 cruises led by NOAA, UNH and WHOI a federally funded long term project part of the annual NOAA sea-scallop's survey.

This project will analyze a unique data set that includes simultaneously collected data such as:

- Hi-resolution multi-beam (digital bathymetry and backscatter intensity)
- Seafloor stereo image data (e.g. species and substrate)
- Environmental parameters (e.g. temperature, salinity, water turbidity)

The analysis will be based on an unsupervised spatial clustering (K-means) of a combination of several predictors like morphological features (curvature, rugosity, fractal index, surface area) and backscatter intensity.

The final results will be validated by analyzing the identified classes with a randomly selected subset of underwater photographs for each class.

The seafloor classification map produced is then used as a preliminary "habitat classification" for further classification. It can be reused to define selection-criteria for the underwater images used by automatic classifier or by manual image annotator tools.

Results from this project will also help to define new survey track-lines prior to and during HABCAM surveys.

Towards a seamless national offshore biotope map - progress and challenges in biotope modelling from the MAREANO programme, Norway

Margaret F.J. Dolan[1], Pål Buhl-Mortensen[2], Sigrid Elvenes[1], Valérie K. Bellec[1], Jofrid Skarðhamar[2], Thijs van Son[1], Genoveva Gonzalez-Mirelis[2] and Lilja R. Bjarnadóttir[1]

[1]Geological Survey of Norway (NGU), P.O. box 6315 Sluppen, NO-7491 Trondheim, Norway, margaret.dolan@ngu.no

[2]Institute of Marine Research, P. O. Box 1870 Nordnes, 5817 Bergen, Norway

Norway's first offshore biotope map was published by the national seabed mapping programme MAREANO in 2008 (www.mareano.no). This map was based on multibeam data and video observations from an important fishing bank, Tromsøflaket, in the SW Barents Sea. Together with other MAREANO maps and data highlighting the geology and biology of the 2000 km^2 area, this map provided new information for management. A little over 5 years later, with more than 100 000 km^2 of seabed now mapped by MAREANO, this starting point on Tromsøflaket represents a small fraction of the seabed across which biotope distribution has now been predicted. The biotope map for Tromsøflaket has already been revised (2012) and will be subject to further revision in 2014 in order to align the modelled biotopes with those from neighbouring areas and incorporate newly available oceanographic data.

With a focus on the SW Barents Sea we highlight how the workflow used by MAREANO, and similar to many habitat mapping initiatives worldwide, has provided valuable knowledge about offshore benthic communities and the physical environment they inhabit. We summarise some of the improvements that have been made, as well as some that are forthcoming in MAREANO's biotope modelling work, and we also consider where challenges remain. The physical and biological data gathered by MAREANO is one of the largest integrated datasets in the world, and this offers tremendous possibilities for the development of a seamless national offshore biotope map. However, with diverse topography, oceanography and an area spanning several biogeographic zones, over 1000s of km^2 and with depths ranging from 50 to 3000 m, this is no small challenge.

A Biologically Driven Habitat Map for the Southern North Sea – Where to Draw the Lines?

Anna-Leena Downie[1], Alex Callaway[1], Paul McIlwaine[1] and Koen Vanstaen[1]

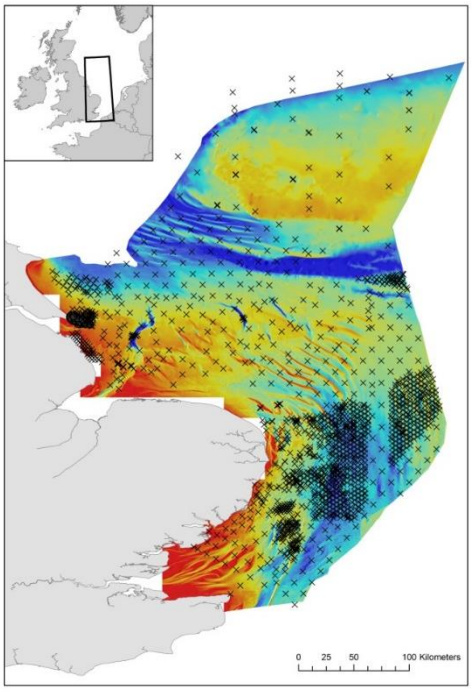
[1]Centre for Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, NR33 0HT, UK, anna.downie@cefas.co.uk

Knowledge of where species and communities occur and which factors limit their distribution is fundamental to both the ecosystem-based management, conservation, spatial planning and the science of the marine environment. Habitat mapping is an exercise in representing the benthic biotopes and communities that occur under specific conditions using all available physical information. If management and planning are to be successful, there is a pressing need to improve the information on where and how to split the abiotic environment into categories that are biologically meaningful. Current broadscale characterisation approaches are often limited to a description of the physical seabed habitats. This lack of biological consideration has potentially large knock-on effect when the maps are used for marine planning, conservation planning or assessments of biodiversity. To produce truly useful maps, we need flexible, ecologically relevant broad-scale maps that take account of the species, communities and their sensitivity.

In our study we show that an ecologically relevant level of biological organisation can be presented in map form with enough confidence to inform planning processes and resource use. To achieve this we combined a large infauna dataset (1752 grab samples) covering the study area with existing environmental layers, including topographical variables derived from bathymetry, substrates and modelled oceanographic variables like tidal power, temperatures and the concentration of labile organic carbon. We used two different approaches to produce maps:

1) an informed top down approach, where the environment was classified by placing splits on the environmental gradient at places where maximum change in biota was observed; and

2) a bottom up approach, where the distributions of key species in communities, defined a priori, were modelled and the most likely communities at each location inferred from the modelled distributions the species.



The results of both methods were compared with existing classification schemes. We make recommendations on which environmental layers are important to incorporate into such maps to ensure they better reflect biological communities. We have also investigated the biotope level diversity in the broader habitat classes we are currently able to map based on available GIS layers. The range in the number and sensitivity of communities in each map category reflects on the use of the maps for the management of benthic habitats and biodiversity.

Spatial heterogeneity in the activity of abyssal megafauna

Jennifer M. Durden[1], Brian J. Bett[2] and Henry Ruhl[2]

[1]Ocean and Earth Science, University of Southampton, National Oceanographic Centre, Southampton, UK

[2]National Oceanographic Centre, European Way, Southampton, UK

Spatial heterogeneity in the diversity and biomass of megabenthos has recently been established in relation to seabed conditions on hills found on abyssal plains. The megafauna of abyssal plains is dominated by deposit-feeding echinoderms that work the sediment along with mega and macrobenthic infauna, leaving traces as evidence of their activity. Heterogeneity in the activity of the deposit-feeding and infaunal mega- and macrofauna was assessed in relation to variation in sediment type and quality, and topography by analyzing photographic transects, bathymetry and sediment cores from locations on the plains and abyssal hills of the Porcupine Abyssal Plain. Lebensspuren (animal traces in sediment) in the photos were categorized, enumerated and measured for fractional seabed coverage. Fifty-seven different types were identified, including feeding and locomotory traces, burrows and feces.

The composition of lebensspuren and coverage of seabed by them differed significantly between abyssal hills and the plain, and was dominated by spoke burrows attributed to infaunal echiurans, and by elasipod tracks attributed to the epifaunal holothuria *Psychropotes longicauda* and *Amperima* sp. Coverage by both was greater on plains than on the hills. The benthic habitat on the abyssal hills differed from that on the plains in terms of slope, sediment particle size distribution and sediment quality (carbonate and lipid composition). An understanding of the spatial heterogeneity of the activity of megabenthic communities improves our knowledge of the factors controlling the abundance, distribution and function of the studied fauna in relation to the benthic environment. This understanding is currently lacking when considering potential human impacts from hydrocarbon and seafloor mining activity that are extending to abyssal depths.

On the Cusp of Big Data Mapping: A Critical Stage for Systematic Image Scoring and Automated Classification

Matt Edmunds[1]

[1]Australian Marine Ecology, 82 Parsons St, Kensington, Victoria, Australia, matt@marine-ecology.com.au

Recent technological developments have made it considerably cheaper and more efficient to collect imagery for larger areas, in the order of hectares instead of square metres. This is largely driven by the development of man-portable autonomous underwater vehicles, stereo video localisation and mapping and small form-factor computing systems. At the same time, advances in computing power, including multi-core and parallel processing, and algorithms, such as object recognition and neural networks, means there is great potential for automated data extraction from the image mosaics. This is a significant step in marine ecology, opening up sources of information on patch dynamics, species interactions and emergent ecosystem properties, as well as moving from sampling to census approaches.

Such technology is likely to be accessible and affordable for most marine scientific organisations within 3-5 years. However, there remains a critical threshold with respect to automated classification resolution and comparability of the data obtained. Automated systems presently require human-scored imagery as training sets, with the quality of the automated outcomes reflecting the quality of the training sets. Although there has been over a decade of development of marine image classification and scoring in selected habitat types, Australia is presently lacking a unified framework for classification and cataloguing of habitats, biotopes, community assemblages and morpho-species.

This presentation outlines some of the habitat and morpho-species classification systems being used to score imagery, along with their pros and cons. Some approaches toward a unified framework are presented, in context with some well-developed international systems such as the CMECS and JNCC habitat classification schema. Key recommendations include: development of a complete hierarchy from high level ecosystem characteristics down to biotopes, morpho-species and species ecological variants; a framework that enables addition of new categories at appropriate levels by all researchers; a framework that facilitates pooling and sharing of data across research projects to bolster information use and machine learning; inclusion of all environments, ecosystems and sensing platforms and resolutions; and a common language and system for describing and cataloguing morpho-species from visual characteristics.

Zonation in Foraminifera microhabitat in the inner shelf adjacent to Ponta Negra Beach, Natal (RN/Brazil)

Patrícia Eichler[1], Luciana Marques[1], Roberto Barcellos[2] and Helenice Vital[1]

[1]Programa de Pós Graduação em Geofísica e Geodinâmica (PPGG), Laboratório de Geologia e Geofísica Marinha e Monitoramento Ambiental, Centro de Ciências Exatas e da Terra da Universidade Federal do Rio Grande do Norte (GGEMMA,CCET,UFRN),Campus Universitário, Lagoa Nova, 59072-970, Natal, RN, Brazil

[2]Departamento de Oceanografia, Laboratório de Oceanografia Geológica, Centro de Tecnologia e Geociência, Universidade Federal de Pernambuco, Recife, PE, Brazil

This study was developed in the inner shelf adjacent to Ponta Negra beach, an important touristic place from NE Brazil. Eighteen sediment samples were collected following the 5 and 10 m isobaths with the main objective to identify the foraminifera habitats present on this area. In the northern part, closer to Potengi estuary, sediment samples have lower $CaCO_3$ content (15,8%) and coastal samples have more $CaCO_3$ showing benthic production. Samples from central part are silicibioclastics, ranging from 30,71% to 39,10% of carbonates, where this kind of habitat are suitable for benthic production from consolidated sediments with lack of terrigenous material. Southern samples from 10m isobaths are biosiliciclastic with $CaCO_3$ ranging from 50,2-55,0% due to the presence of consolidated sediment and biogenic production are the less diverse foraminifera habitat. Coastal sediments are siliciclastics (3,2-19,0%) due to the sandy sediments that accumulate in sand banks in the Ponta Negra cove, this are the most diverse foraminifera habitats. The 5m isobath, where more oxygenated environments with highest silt and clay content are colonized by *Bolivina striatula, Bulimina patagonica, Fissurina laevigata, F. lucida, Lagena striata* and *Miliolinella subrotunda*, whereas samples collected in the deeper regions (10m isobath) with coarser fractions, sandy, with more matter that is organic and $CaCO_3$ are suitable for *Buliminella elegantissima, Cassidulina subglobosa, Discorbis peruvianus* and *Spiroculina depressa.* The foraminifera species *Ammonia tepida, Quinqueloculina lamarckiana, Q. atlantica* and *Textularia gramen* are found in both 5 and 10 m isobath habitats. We have showed that depth and sediment content play important roles on distinguishing foraminifera habitats.

Habitat mapping for establishing Coast to Coast Network of marine protected areas in the framework of COCONET Project: from coastal area to deep sea in the South Adriatic (Italy)

Federica Foglini[1], Lorenzo Angeletti[1], Elisabetta Campiani[1], Simonepietro Canese[5], Simonetta Fraschetti[2], Valentina Grande[1], Elisa Leidi[1], Fabio Marchese[4], Alessandra Mercorella[1], Mariacristina Prampolini[1,3], Alessandra Savini[4], Marco Taviani[1] and Chiara Tessarolo[4]

[1]CNR-ISMAR Via Gobetti 101 40129 Bologna, Italy, federica.foglini@bo.ismar.cnr.it

[2]University of Salento, Dept. of Biological and Environmental Science and Technologies, - Sp. Lecce-Monteroni, Ecotekne, 73010 Lecce

[3]Univerisy of Modena and Reggio Emilia, Largo Sant'Eufemia 19, 41121 Modena, Italy

[4]University of Milano-Bicocca, Dept. of Earth and Environmental Sciences, P.za della Scienza 4, 20126 – Milano (Italy)

[5]ISPRA Institute for Environmental Protection and Research, Via Vitaliano Brancati 48, 00144 Rome, Italy

The aim of the COCONET Project (Towards COast to COast NETworks of marine protected areas from the shore to the high and deep sea) is to identify groups of putatively interconnected MPAs in the Mediterranean and the Black Seas, shifting from local (single MPA) to regional (Networks of MPAs) and basin (network of networks) scales. The identification of physical and biological connections clear the process that govern patterns of biodiversity distribution. This will enhance policies of effective environmental management, also to ascertain if the existing MPAs are sufficient for ecological networking and to suggest how to design further protection schemes based on effective exchanges between protected areas. The coastal focus is widened to off shore and deep sea habitats, comprising them in MPA networks.

In this perspective, the knowledge about habitat distribution and extent is critical for the conservation and the management of the marine system and for designing of networks of effective MPAs at basin scale.

Different key concepts and methods in dealing with marine habitat classifications and mapping have been developed by different disciplines (e.g. marine geologists and ecologists, oceanographers), the aim of this work is to establish an unified approach on the definition of habitats combining multi-scale geological, oceanographic and biological data to homogeneously map habitat distribution at basin scale from coastal areas to deep sea. We focus on habitats included in the Habitats Directive (92/43/EEC), from coralligenous to deep sea white corals, discovered in the South Adriatic Sea, that reveal to be an ideal laboratory because of the variety of habitats and the complexity of the submerged landscape. We will particularly highlight the strict relation between the geological/geomorphological features and the biological component and the need of tools for data integration and management. The maps of habitat distribution at multiple scale will be used as key information for multi scale spatial analysis for the identification of suitable sites in shallow and deep-water area. We will present a case study of site selection algorithm application to provide scenario of protection according to the distribution of habitats.

Mesophotic coral ecosystem geoacoustically derived diversity estimation

Alexander Forrest[1,2], Art Trembanis[2], Brian Keller[2] and Mark Patterson[3]

[1]University of Tasmania, Australian Maritime College, Launceston, Tasmania, Australia, alex.forrest@amc.edu.au

[2]College of Earth, Ocean, and Environment, University of Delaware, Newark, Delaware 19716, USA

[3]Marine Science Center, Northeastern University, 430 Nahant Road, Nahant, MA 01908, USA

Current trends demonstrate coral reef health in serious decline worldwide. Some of the most pristine coral reefs in the Caribbean basin are located in the waters surrounding Bonaire, in the Dutch Caribbean. In many places, the shallow reef systems are further complemented by deeper water coral assemblages known as Mesophotic Coral Ecosystems (MCE). Autonomous Underwater Vehicles (AUVs) were used to collect geoacoustic data of several leeward MCEs at multiple sites in January 2008. AUV swath bathymetry and side-scan sonar data were analyzed for depth (Fig. 1A), slope (Fig. 1B) and rugosity (Fig. 1C). Principle Component Cluster analysis of the side-scan sonar mosaics were used to generate geoacoustic segmentation of the seabed that was then classified using the concurrently collected benthic imagery (Fig. 1D). Although a biological diversity index (e.g. Shannon's diversity index, *H'*) was not estimated directly from the observed taxa, a synthetic biological diversity index, H_{SC}', was created by creating combined weightings of these different parameters (Fig. 1E).

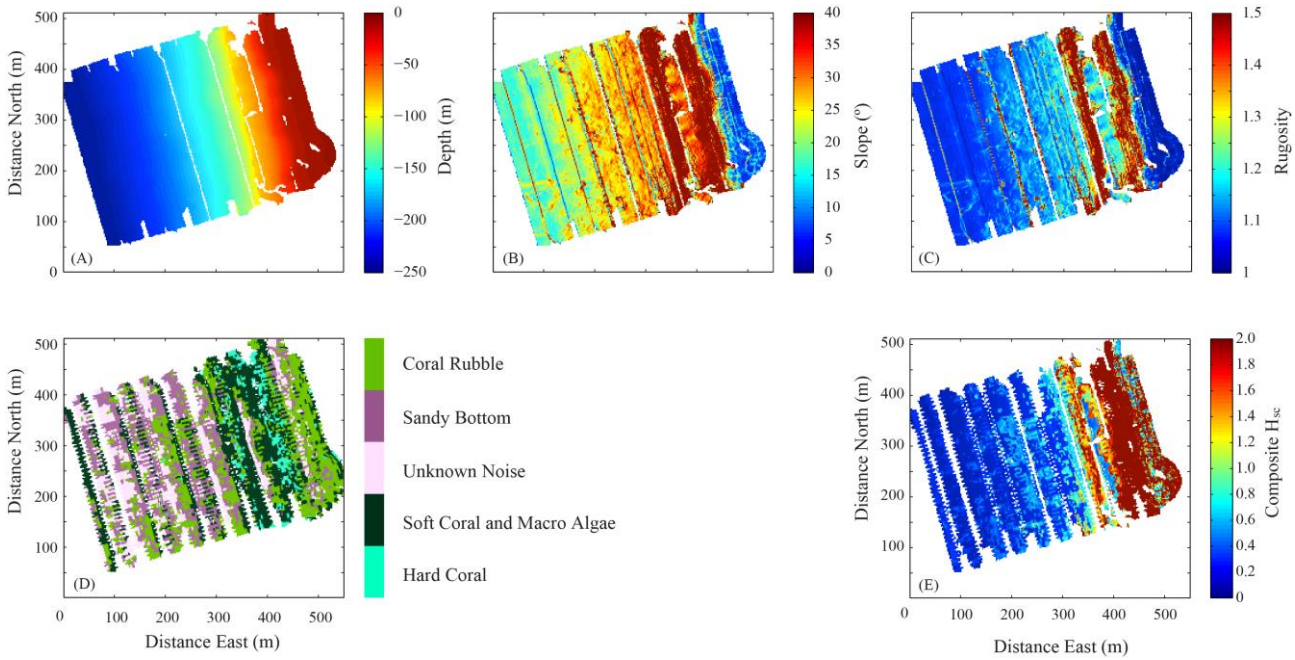


Fig. 1: Synthetic bottom type-diversity index for Nukove Bonaire based on composite summary of bathymetry (A), rugosity (B), slope (C) and acoustic class type (D). Color scale indicates magnitude of synthetic bottom-type diversity index, H_{SC}' (E).

The derived synthetic index is a potentially useful tool in quantifying the diversity of MCEs. Through the use of AUVs, these deep reef structures may be studied much more efficiently compared to using traditional methods such as scuba divers, towed bodies or ROVs. MCEs at Bonaire provide potential refugia for corals and thus a buffer against pressures such as climate change and storms. MCEs throughout the ABC islands (Aruba, Bonaire and Curaçao) and many others in the Caribbean still remain largely unexamined and, as a result, are underestimated and under protected as they often lie below the depth of Marine Protected Areas (MPAs). The developed methodology could see a broad range of application in the assessment of coral reef health.

High-resolution marine geophysical mapping of glaciogenic landforms in Melville Bay off the western coast of northern Greenland

Francis Freire[1] Richard Gyllencreutz[1] Larry Mayer[2] and Martin Jakobsson[1,2]

[1]Department of Geological Sciences, Stockholm University, Stockholm, Sweden, francis.freire@geo.su.se

[2]Center for Coastal and Ocean Mapping, University of New Hampshire, Durham, New Hampshire, USA

A high-resolution marine geophysical mapping, the Vega 2013 Expedition, was undertaken in 2013 to collect the first ever scientific data on submarine glaciogenic features and continental shelf/fjord interactions off Baffin Bay in the western coast of northern Greenland. The mapping expedition used a sail-powered vessel, the Explorer of Sweden, with a mounted Kongsberg (EM2040) and deployed the AUV Gavia with 600/1200 kHz sidescan sonar from Marine Sonic and the GeoSwath interferometric sonar for higher resolution bathymetry data. Processing of the data was carried out using CARIS HIPS/SIPS and QPS Fledermaus software. Erosional and depositional features extracted from high resolution AUV sidescan data are presented. Results show the area to be mostly glacially eroded bedrock with three dominant deep troughs having a north to northwest orientation. Sediment characterization analysis using Geocoder shows that they are infilled with sediments. Smaller fractures and iceberg scours are also evident in the bedrock up to 400 m depth that are oriented north-northwest to south direction which indicate movement of large ice mass southwards to the Labrador sea.

Classification of benthic marine habitats using LiDAR and WorldView-2 imagery

Thomas French[1], Jacquomo Monk[1], Daniel Ierodiaconou[1], Adam Pope[1], David Ball[2], Steffan Howe[3], Arnold.Dekker[4], Janet Anstee[4] and Hannelie Botha[4]

[1]Deakin University, School of Life & Environmental Sciences, Warrnambool, Victoria, Australia

[2]Department of Primary Industries, Queenscliff, Victoria

[3]Science and Management Effectiveness Branch, Parks Victoria, Melbourne, steffan.howe@parks.vic.gov.au

[4]CSIRO Land & Water, Environmental Remote Sensing Group, GPO BOX 1666, Canberra, ACT 2601, Australia

Deakin University and the Department of Primary Industries were commissioned by Parks Victoria (PV) to create two updated habitat maps for Yaringa and French Island Marine National Parks. The team obtained a ground-truth data set using *in situ* video and still photographs. This dataset was used to develop and assess predictive models of benthic marine habitat distributions incorporating data from World-View-2 imagery atmospherically corrected by CSIRO and LiDAR (Light Detection and Ranging) bathymetry. In addition, the team applied an unsupervised classification approach to an aerial photograph to assess the differences between the two remote sensors. This report describes the results of the mapping as well as the methodology used to produce these habitat maps.

This study has provided mapping of intertidal and subtidal habitats of Yaringa and French Island MNPs at a 2 m resolution with fair to good accuracies (Kappa 0.40-0.75). These were combined with mangrove and saltmarsh habitats recently mapped by Boon et al. (2011) to provide compete-coverage habitat maps of Yaringa and French Island MNPs.

The mapping showed that Yaringa MNP was dominated by mangroves, wet saltmarsh and dense Zostereaceae, covering 33%, 29% and 19%, respectively. Similarly, intertidal vegetation and subtidal vegetation (dominated by Zosteraceae) covered 26% and 25% of French Island MNP. However, as a result of turbidity and missing satellite imagery 27% of French Island MNP remains unmapped.

The coupling of WV-2 and LiDAR reduced potential artefacts (e.g. sun glint causing white and black pixels known as the “salt and pepper effect”).

The satellite classification appeared to provide better results than the aerial photography classification. However, since there is a two-year difference between the capture of the aerial photography and the collection of the ground-truth data this comparison is potentially temporally confounded. It must also be noted that there are differences in costs of the data, the spatial resolution between the two datasets (i.e. WV-2 = 2 m and the Aerial = 0.5 m) and the amount spectral information contained in the data (i.e. WV-2 = 8 bands and the aerial = 4 bands), which may ultimately determine its utility for a particular project.

The spatial assessment using FRAGSTATs of habitat patches within Yaringa MNP provides a viable and cost effect way to assess habitat condition (i.e. shape, size and arrangement). This spatial assessment determined that dense Zosteraceae and NVSG habitat classes were generally larger in patch size and continuity than the medium/sparse Zosteraceae habitat. The application of spatial techniques to time-series mapping may provide a way to remotely monitor the change in the spatial characteristics of marine habitats.

This work was successful in providing new baseline habitat maps using a repeatable method meaning that any future changes in intertidal and shallow water marine habitats may be assessed in a consistent way with quantitative error assessments. In wider use, these maps should also allow improved conservation planning, fisheries and catchment management, and contribute toward infrastructure planning to limit impacts on Western Port.

Automated estimation of benthic coverage - a superpixel-based approach

Ariell Friedman[1], Stefan Williams[1] and Oscar Pizarro[1]

[1]The Australian Centre for Field Robotics, University of Sydney, NSW, Australia,
a.friedman@acfr.usyd.edu.au

Benthic image surveys typically involve laborious, manual processing to transform seafloor images into quantitative coverage estimates. With the recent advent and rapid adoption of digital imaging and autonomous platforms, the amount and quality of the imagery has dramatically increased. The human element is a costly, persistent bottleneck in the processing pipeline and the copious influx of survey data is making traditional manual interpretation infeasible. Typically, less than 1−2 % of the collected images end up being selected for detailed analysis, and from that, usually only a subset of 20−50 points within each image are scored to estimate benthic coverage. This results in a tiny fraction of the total amount of collected pixels (on the order of 0.00001%) that get used for science purposes.

We introduce a supervised automated classification framework for estimating benthic coverage (see Figure 1). The proposed framework leverages existing annotation effort to train an automated superpixel-based classifier capable of extrapolating the sparse, human-scored pixels in a subset of images, to every pixel across all the images of an entire survey. Each image is segmented into homogenous superpixels. Superpixels (or segments) help to maintain the delineation of the boundaries between benthic classes and serve to improve the accuracy in coverage estimation. Texture, colour and shape descriptors are then computed for each superpixel and fed through a multi-class support vector machine (see Figure 2).

The results of the traditional point count method and the automated classifier are compared and we show that it is possible to obtain similar results across the hand-scored validation images. The automated superpixel classifier is then used to extrapolate the results beyond the small subset of human-annotated pixels, to every pixel across all the images in the survey. The results are verified through visual inspection and the system is shown to perform well over the unseen data. The proposed framework enables the rapid estimation of benthic coverage over broad extents and fine resolutions, making it possible to reveal spatial patterns that may not otherwise be captured by subsampled data.

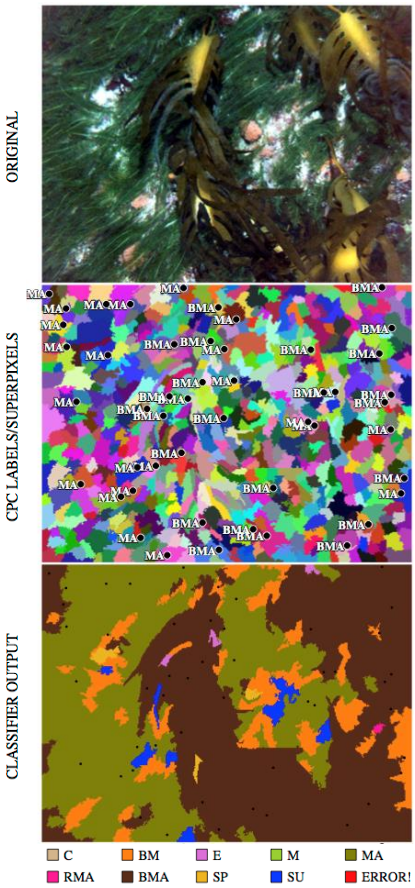


Figure 2 – Example image showing the original image, the training point labels and superpixels and the automated classification results

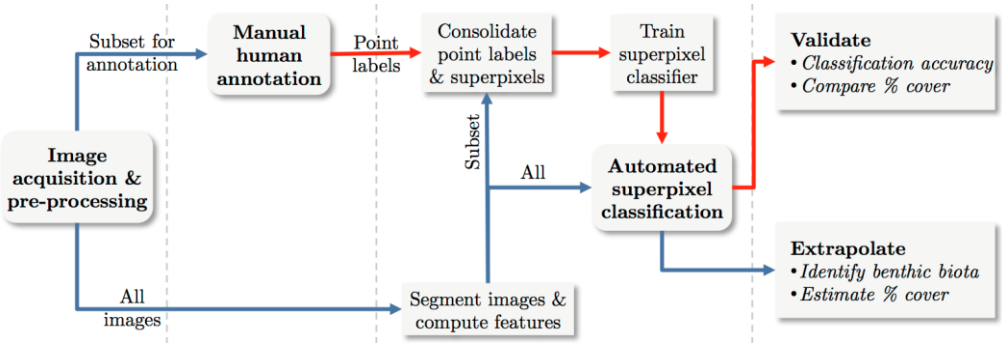


Figure 1 - Flow diagram of the proposed pipeline for sub-image classification of benthic biota. The blue arrows show the flow of unlabelled data and outputs from automated processing steps, and the red arrows show the flow of data that requires manual annotation by a human expert.

Autonomous, large-scale urchin barren mapping with interferometric sonar

Rowan Frost[1], Caitlin Hoey[1], Michael Bell[2], Alexander Forrest[1] and Vanessa Lucieer[3]

[1]University of Tasmania, Australian Maritime College, Launceston, Tasmania, Australia, alex.forrest@amc.edu.au

[2]Defence Science and Technology Unit, Maritime Division, Eveleigh, New South Wales, Australia

[3]University of Tasmania, Institute for Marine and Antarctic Studies, Hobart, Tasmania, Australia

The southern expansion of long spined urchin (*Centrostephanous rodgersii*) into Tasmanian waters will have a negative impact on the two biggest wild fisheries through the creation of urchin barrens. The rock lobster and abalone fisheries were valued at $163 million to the state of Tasmania in 2012 and accounted for 96% of all wild caught production by value (Skirtun, Sahlqvist, Vieira, (2013)). A key to future management of the spread and impact of *Centrostephanus rodgersii* is the ability to produce large scale, semi-automated maps showing current distribution of urchin barrens. The aim of this research is to investigate the application of using interferometric sonar mounted on an Autonomous Underwater Vehicle (AUV) as a method for urchin barren mapping. On the east coast of Tasmania, *Phyllospora comosa* and *Ecklonia radiata* are the most common alga in the depth range predominantly affected by urchins. Both these species form dense canopies up to 2m above the seabed. It is hypothesized in this work that the algal canopy will affect the uncertainty in the bathymetric model generated from interferometric sonar and that this uncertainty can then be used to map potential barren sites.

Initial tests were conducted in Wineglass Bay on the central east coast of Tasmania using *DSTO Gavia* as the observational platform. This vehicle was equipped with a Geoswath plus (500 kHz) interferometric sonar, Marine Sonics 900/1800 kHz side scan, and a Kearfott T-24 inertial navigation unit. This site was chosen as it is part of a long term diver assessment on the impact of *Centrostephanous rodgersii* of endemic reef ecosystems. In total, around 7.4 acres were surveyed in a single deployment lasting approximately 90 minutes in September 2013. Initial data processing was conducted using Caris HIPS/SIPS ver 8.1. A potential classification technique to identify barrens was developed for this data set. This method first utilises the Caris bathymetry associated with statistical error (BASE) surface standard deviation values to classify barrens. It is hypothesised that the combined uncertainty and bathymetric estimator (CUBE) algorithm used to produce the BASE surface will produce a higher uncertainty value in heavily vegetated areas. This method was validated using drop camera imagery at 13 sites within the surveyed area. Good correlation was found with 77% of sites in agreement with predictions based on the standard deviation.

These results suggest that there is potential for the use of interferometric sonar for broad scale macro algae and urchin barren distribution mapping. The use of AUVs allows us to access near-shore regions, which are difficult to assess by other means. Further work needs to be conducted to test the robustness of this methodology on different slope gradients, substrates and vegetation types, but initial results are promising are extremely positive. It is hoped that the ability to perform broad scale urchin barren mapping will in the future play a key role in the management strategies of Tasmania's marine parks and fisheries and be able to be applied to other marine problems involving large scale mapping.

Skirtun, M., Sahlqvist, P., & Vieira,S. (2013). Australian Fisheries Statistics 2012, FRDC project 2010/208, ABARES, Canberra.

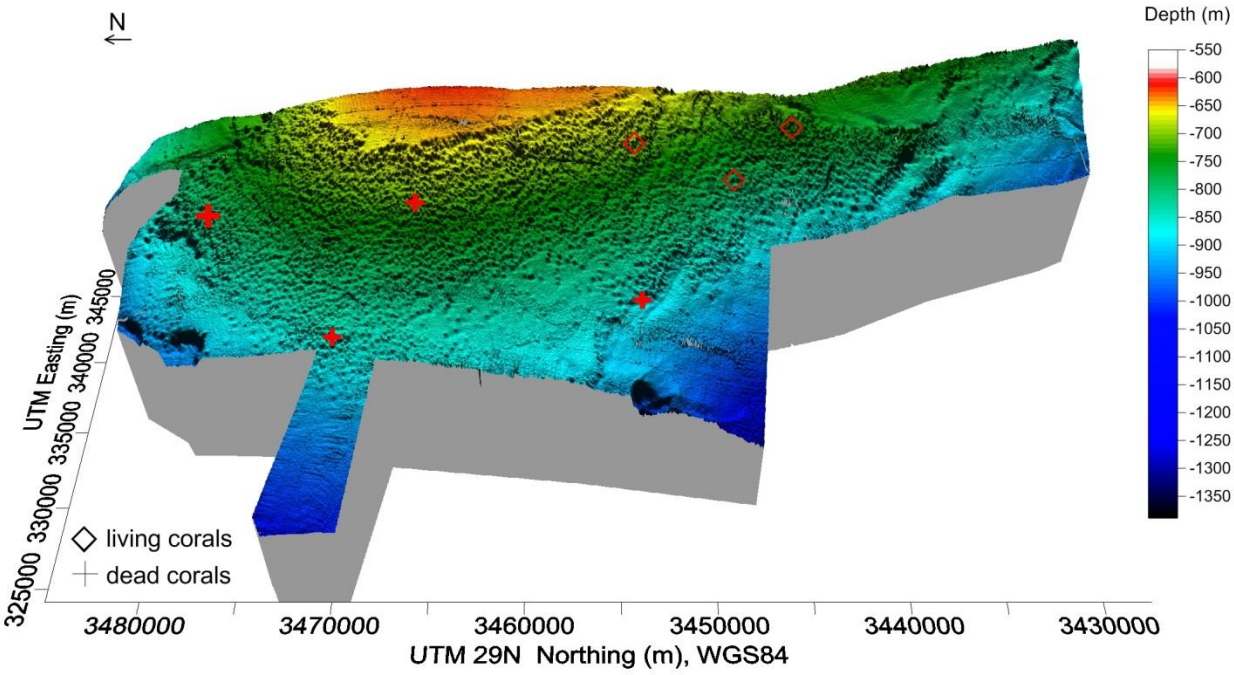
Living cold water corals off Morocco: Water Masses and Bathymetry

Silke Glogowski[1], Peter Feldens[2], Veit Hühnerbach[1,3], Jonas von Reumont[1], Sebastian Krastel[2], Sascha Flögel[1], Wolf-Christian Dullo[1] and Russel B. Wynn[3]

[1]Helmholtz Centre for Ocean Research Kiel (GEOMAR), Kiel, Germany, sglogowski@geomar.de

[2]Institute of Geosciences, Kiel University, Kiel, Germany, pfeldens@geophysik.uni-kiel.de

[3]National Oceanography Centre (NOC), Southampton, Great Britain



A field of cold water coral mounds, 410 km^2 in extension, was discovered offshore Morocco in water depths between 678 m and 773 m. This coral field was investigated with CTD casts, multibeam echo sounder surveys and TOBI backscatter imaging. Ground truthing was done by box coring. Individual mounds comprise living *Lophelia pertusa*, *Madrepora oculata*, *Desmophyllum* sp. and other calcified biota such as bivalves and brachiopods. CTD casts reveal that the coral mounds are located above the Mediterranean Outflow Water (MOW). Temperatures at the coral mound locations where living species were retrieved, ranged between 10.73°C and 9.32°C, salinity between 35.831 g/kg and 35.576 g/kg, density between 27.25 kg/m^3 to 27.37 kg/m^3 and oxygen between 3.04 ml/l to 3.62 ml/l.

These physical properties of the investigated coral mounds are similar to those observed in other regions of the world, including e.g. various sites in the NE-Atlantic and Campeche Bank in the Gulf of Mexico. Individual mounds surveyed off Morocco have a round to elliptical shape and reach heights of up to 12 m, albeit most are elevated between 4 m and 8 m. Maximum height and coral abundance tend to decrease with increasing water depth. The coral mound density has been counted in three different areas of 4 km^2 each. Individual coral mounds were identified based on their slopes. Mound density varied between 14 mounds/km^2 in 700 m water depth, 9 mounds/km^2 in 790 m water depth and 2 mounds/km^2 in 880 m water depth. Multibeam echo sounder and TOBI backscatter data did not show any evidence of bottom trawling or other anthropogenic impact in the newly discovered cold water coral area. Therefore, this area could be seen as unique and serve to establish a potential link between the coral graveyard areas in the Gulf of Cadiz and the live mound areas offshore Mauretania. In memory of the German scientist Eugen Seibold (1918-2013) we plan to propose the name Eugen Seibold Coral Garden for the discovered location.

Geological mapping of the seabed; the role of expert interpretation

Sophie Green[1], Heather Stewart[1], Rhys Cooper[1] and Dayton Dove[1]

[1]British Geological Survey, Murchison House, West Mains Road, Edinburgh, UK. soph@bgs.ac.uk

A wide range of different approaches are now routinely applied to mapping the seabed sediments using multibeam bathymetry data, backscatter and ground-truthing information from grab samples and imagery. These approaches range from traditional expert interpretations made manually (using software such as ArcGIS) by marine geologists, to fully automated schemes applying modelling techniques and machine learning. The relative value of these different methodologies is determined through consideration of the purpose of the map produced, and therefore the necessary resolution, reproducibility and confidence required.

This poster presents examples of seabed sediment, geological and geomorphological mapping on the United Kingdom Continental Shelf, produced using a semi automated and expert interpretation approaches to seabed mapping. The semi automated technique retains expert input from marine geologists whilst semi automating the first stages of the classification using an ArcGIS clustering technique. The studies presented highlight the value of including diverse data, such as geological interpretations of the sub surface and an understanding of an areas geological evolution, for example its glacial history, in order to interpret the present day seabed environment. This is particularly important in highly heterogeneous seabed environments and where novel or unexpected features occur.

Further examples of mapped areas where these methodologies have proved successful include areas of incomplete acoustic data coverage and limited ground truthing data. In these cases it is necessary to apply expert geological judgement in order to extrapolate over broader areas and apply appropriate representation of the associated mapping confidence.

Advocacy and Science – Either, Or, or Both, And The GeoHab Influence

H. Gary Greene[1,2]

[1]Moss Landing Marine Laboratories, Center for Habitat Studies

[2]SeaDoc Society/Tombolo Mapping Lab, Orcas Island, WA USA, tombolo@centurytel.net

Marine benthic habitat characterization and mapping has grown astronomically in the past decade with GeoHab playing no small part in this evolution. The GeoHap community has contributed significantly to the advancement of the science through inventive and progressive thinking along with freely communicating their results in the international forum of GeoHab. However, much more needs to be done by the community, as advocacy groups, policy agencies, and governments are ignoring scientific facts in their environmental deliberations and decision-making. As an example, the agencies responsible for management of the US Pacific coast fisheries, excluding Alaska, have basically decided to govern on advocacy agendas rather than on scientific evaluations. A five-year Essential Fisheries Habitat review that provided new data to evaluate marine protected areas, including fisheries no-take zones, favored subjective advocacy arguments instead of a robust scientific evaluation of new proposals. However, selected industries such as coastal nuclear power plants are using science and habitat characterization as part of their review of seismic hazards, which was propagated by the Fukishima Diichi disaster. What can the GeoHab community do to assure that science is considered on the same basis as advocacy driven agendas and arguments. This, as well as a brief history of GeoHab and its early concerns about such problems will be discussed along with what is working today in regard to habitat characterization and mapping.

Habitat Mapping for Monitoring Seismicity at a Nuclear Power Plant

H. Gary Greene[1], Stuart Nishenko[2] and Marcia McLaren[2]

[1]Moss Landing Marine Labs, Center for Habitat Studies, Moss Landing, CA 95065, greene@mlml.calstate.edu

[2]Pacific Gas & Electric Company, San Francisco, CA

Concerns about the safety of coastal nuclear power plants arose from the earthquake and tsunami that impacted the Fukushima Daiichi power plants three years ago. Many countries have either shut down, or delayed building, nuclear power plants until extensive reevaluations of plant sites can be completed. To date only one nuclear power plant is operational on the US West coast, the Pacific Gas and Electric (PG&E) Company's Diablo Canyon Power Plant (DCPP), and very sophisticated, state-of-the-art geophysical investigations are underway to assess the seismic and tsunami hazards in the vicinity of the plant. Part of these investigations entailed the examination of marine benthic habitats in the nearshore areas adjacent to DCPP to support proposed extensive onshore and offshore seismic-reflection data collection. Permitting agencies require an Environmental Impact Statement that included habitat characterization to evaluate the impact on benthic habitats from placing seismic nodes on the seafloor to receive seismic survey signals, and the placement of Ocean Bottom Seismometers (OBS) and connecting cables to monitor earthquakes in real-time. PG&E initiated an extensive multibeam echosounder bathymetry and backscatter survey to map marine benthic habitats in the vicinity of DCPP to configure potential seismic node and OBS network locations. These data are also being used to develop realistic geoacoustic profiles of the study area to support the 2013 California State Lands Commission Low Energy Offshore Geophysical Permit Program Review. All of these activities set the industry standard for environmental assessments offshore of nuclear power plants, and the industry is closely watching to see the benefits of the outcomes. The application of potential marine benthic habitat mapping in addressing permitting and management agencies requirements for seafloor installations will be discussed along with lessons learned.

Quantifying deep-sea habitats: an cold-water coral example from the FP7 CoralFISH project

Anthony Grehan[1], Laurent de Chambure[2], Alessandra Savini[3], Jean-Francois Bourillet[4], Anna Rengstorf[1], Tina Kutti[5], Jan Helge Fossa[5], Steinunn Olafsdottir[6] and Fernando Tempera[7]

[1]NUI Galway, Ireland, anthony.grehan@nuigalway.ie

[2]LDC_Consult, France

[3]CoNISMa, Italy

[4]IFREMER, France

[5]IMR, Norway

[6]MRI, Iceland

[7]DOP, UAzores

CoralFISH, by studying the interaction between cold-water coral habitat, fish and fisheries, is developing methodologies and tools to support the implementation of an ecosystem-based management approach in the deep-sea. One of the key outputs will be the development of standardised mapping approaches to support classification and quantification of benthic habitats, particularly cold-water corals.

CoralFISH partners have generated new maps of coral habitat settings in six different eco- regions in the oceans and seas of Europe, stretching from Norway to the Azores through to the Ionian Sea. To quantify the extent of coral habitat in each region and to facilitate regional comparisons, an area of approximately 10 km^2 has been chosen as representative of the densest coral cover in each region. Semi-automated geomorphological classification has been applied to each area and ground-truthed using geo-referenced video survey. First-order approximations of coral cover are presented for each region and used as a basis to assess quantitative regional variations in the importance of corals as a habitat constructor.

Measuring uncertainty in multibeam bathymetry data: An analysis of spatial randomness

Zhi Huang[1], P. Justy W. Siwabessy[1] and Vanessa Lucieer[2]

[1]Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia, Zhi.Huang@ga.gov.au

[2]Institute for Marine and Antarctic Studies, University of Tasmania, Australia

In the past two decades, multibeam sonar systems have become the preferred seabed mapping tool. Many users have assumed that multibeam bathymetry data are highly accurate in spatial position. In reality, both vertical and horizontal uncertainties exist in every data point. These uncertainties are often represented as one single measure of Total Propagated Uncertainty (TPU). TPU is important to understand because it affects the quality of products generated from multibeam bathymetry data. To account for the magnitude and spatial distribution of this influence, an objective uncertainty analysis is required. Randomisation is the key process in such an uncertainty analysis. This study compared two randomisation methods, restricted spatial randomness (RSR) and complete spatial randomness (CSR), in an uncertainty analysis of a slope gradient dataset derived from multibeam bathymetry data. CSR regards data error in every grid cell as independent and assumes that the data error varies within a known statistical distribution without any neighbourhood effect. RSR assumes spatial structure and thus spatial auto-correlation in the data.

We present a case study from a survey of the Oceanic Shoals Commonwealth Marine Reserve (CMR) in the Timor Sea, conducted in 2012 by the Marine Biodiversity Hub through the Australian Government's National Environmental Research Program. The survey area is characterised by steep-sided carbonate banks and terraces with abrupt breaks in slope of limited spatial extent. As habitats, the carbonate banks and terraces are important because they provide hardground for diverse epibenthic assemblages of sponges and corals, with their steep sides marking the environmental transition to deeper water, soft sediment habitats.

In this analysis, the data errors in the multibeam bathymetry data were assumed to follow a Gaussian distribution with a mean of zero and a standard deviation represented by the TPU. The CSR and RSR methods were each implemented using a Monte Carlo procedure with 500 iterations. After about 300 iterations, the Monte Carlo procedure converged for both methods. Results for the study area are compared against pre-processed slope data (Figure 1a). The averaged slope gradient from the CSR method is 4.5 degrees greater than the original slope layer, whereas for the RSR method this value is 0.03 degrees. Moreover, the slope layer from the CSR method resolves noticeably less detail than the original slope layer and is an over-simplification of the true bathymetry (Figure 1b). In contrast, the RSR method maintained the spatial pattern and detail observed in the original slope layer (Figure 1c). This study demonstrates that although the uncertainty in multibeam bathymetry data should not be ignored, its impact on the subsequent derivative analysis may be limited. The selection of appropriate randomisation method is important for the uncertainty analysis. When the data errors exhibit spatial structure, we recommend using the RSR method.

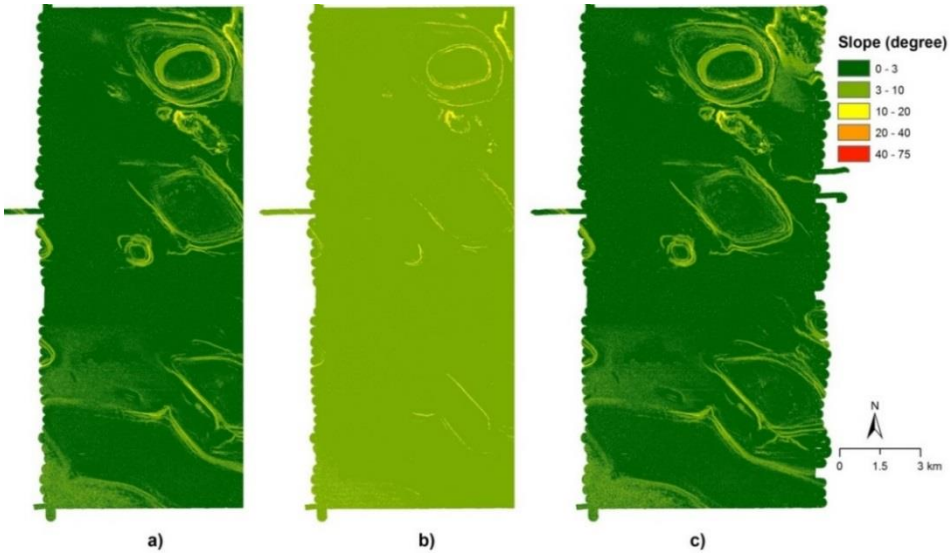


Figure 1: Seabed slope maps for carbonate banks in the Oceanic Shoals CMR, showing: a) slope derived from the original multibeam sonar data; b) the average slope layer from the CSR method, and; c) the average slope layer from the RSR method. All maps are 2 m spatial resolution.

26 years later - revisiting the DISCOL area in the southeastern Pacific, off Peru, for a 'real' long-term environmental impact assessment

V. Hühnerbach[1], J. Greinert[1], G. Schriever[2], M. Haeckel[1], E. Alevizos[1], K. Köser[1] and the RV SONNE/JPIO-Consortium[3]

[1]GEOMAR – Helmholtz-Centre for Ocean Research Kiel, Wischhofstrasse 1-3, D-24148 Kiel, Germany, jgreinert@geomar.de

[2]BioLab Research Institute, Kieler Strasse 51, D-24594 Hohenwestedt, Germany

[3]JPIO-Partners are from Belgium, France, Germany, Italy, Norway, Poland, Romania, Sweden, The Netherlands and United Kingdom

During the DISCOL (Disturbance and Recolonization) experiment in 1989, approx. 11 km^2 of manganese nodule covered seafloor in 4300 m water depth was disturbed with a 8 m wide plough-harrow, a specially designed device that should represent the effects of caterpillar tracks or chains of a self-propelled carrier during potential deep-sea mining operations (however, Mn-nodules were actually not collected and removed). Consequent post-impact studies of the ecosystem were carried out immediately after the disturbance as well as after a period of 6 months, 3 and 7 years. The latter was part of the follow-on research project ATESEPP (Effects of Technical Interventions into the Ecosystem of the Deep Sea in the Southeast Pacific Ocean (see Deep-Sea Research II No 48, 2001).

Although only about 20% of the entire circular experimental area was initially ploughed at the time, immediate effects were noted in surrounding areas where sediments of up to 30 mm thickness, compared to pre-impact baseline studies, blanketed the seabed. Long-term effects on bottom-dwelling biota were not as catastrophic as predicted but benthic species populations appeared to be still impacted when the site was revisited after 7 years.

In order to fully assess the temporal and spatial effect of this extensive deep seabed disturbance, a new, three-month long expedition aboard the RV SONNE is scheduled for spring 2015. During this voyage the latest advances in ROV- and AUV technology for high-resolution seabed mapping and sampling will be applied and compared to previous data.

This is a unique opportunity to document the status of this ecosystem after more than 25 years since the disturbance experiment was carried out.

GLCM or OBIA? Combining the best of both methods to map cold water coral stands in the Rockall area (NE Atlantic)

Veerle A. I. Huvenne[1], Tim P. Le Bas[1], Khaira Ismail[1] and Katleen Robert[1]

[1]National Oceanography Centre, Southampton, UK

Habitats based on the cold-water corals *Lophelia pertusa* and *Madrepora oculata* are some of the Vulnerable Marine Ecosystems recognised by the UN as in need of protection. Mapping and monitoring are necessary to support adequate management. The species are known to occur in the Rockall Trough and on Rockall Bank (NE Atlantic), where they can be found not only in association with large cold-water coral mounds (Mienis et al., 2006), but also in patchy distributions of individual, metre-sized coral stands (Wilson, 1979). To obtain an accurate insight in the spatial distribution of these coral patches, and to map the occurrence of live coral colonies versus dead framework and coral rubble, high-resolution sub-metre pixel resolution acoustic data (sidescan sonar and multibeam backscatter), is needed. Identification and delineation of the coral types in a repeatable and automated way, however, is the main challenge before routine monitoring of these patchy reefs can be carried out. As the corals can mainly be recognised from their image texture, the application of Grey Level Co-occurrence Matrices (GLCMs) to define their signature is a logical approach, that has been successfully applied in proof-of-concept studies (e.g. Hühnerbach et al., 2008). However, also Object Based Image Analysis (OBIA) has been demonstrated to be a valuable approach for backscatter classification (e.g. Lucieer et al., 2011), and could provide advantages.

As part of the ERC project CODEMAP and the UK MAREMAP programme, high-resolution sidescan sonar mosaics (410 kHz, pixel size 20-50cm) were acquired in 2011 at several locations in the Darwin Mound area and on Rockall Bank, using the Autonomous Underwater Vehicle Autosub6000. Following processing with the NOC in-house software PRISM, the data were subjected to various approaches for seafloor classification, in order to map out the occurrences of live and dead coral stands, coral rubble and the different types of surrounding seabed environment. Ground-truthing was provided through ROV video and stills.

Comparisons are made between pure rule-based OBIA, applied to the original sidescan sonar images, and traditional supervised and unsupervised classifications based on 5 derived image texture layers, including GLCM Entropy and Dissimilarity. The former gives the opportunity to create a detailed and customised final map, whereas the latter methods are more objective and perform better at separating terrains with closely similar characteristics, but are computationally intensive. The optimal approach, however, if the computing power is available, might be to combine the techniques, applying a supervised classification to the OBIA-segmented image stack, incorporating the GLCM layers in the analysis.

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Mienis, F., van Weering, T., de Haas, H., de Stigter, H., Huvenne, V.A.I., Wheeler, A. J. (2006). Carbonate mound development at the SW Rockall Trough margin, based on high-resolution TOBI and seismic recording. *Marine Geology*, 233, 1-19.

Wilson JB (1979b) 'Patch' development of the deep-water coral Lophelia Pertusa (L.) on Rockall Bank. J Mar Biol Assoc UK 59:165-177

Swathes of data: Towards a comprehensive map of the NSW Marine Estate

Tim Ingleton[1], Stephen Holtznagel[1], Michael Kinsela[1], Peter Davies[1], Edwina Foulsham[1], Brad Morris[1], Michelle Linklater[1], Alan Jordan[3], Martin Fitzhenry[2], Bruce Coates[2] and David Hanslow[2]

[1]NSW Office of Environment and Heritage 59-61 Goulburn Street, Sydney, NSW, Australia, tim.ingleton@environment.nsw.gov.au

[2]NSW Office of Environment and Heritage, Honeysuckle Drive, Wickham, Newcastle, NSW, Australia

[3]NSW Department of Primary Industry, Port Stephens Fisheries Institute, Taylors Beach, NSW, Australia

Baseline mapping of the seafloor and its character is fundamental to the management of the marine and coastal zone. Benefits include data for modelling of coastal processes and hazards including coastal erosion, storm surge, oil spill response. The data also provide knowledge of marine and coastal habitats as well as resources essential for sustainable resource utilisation, conservation and management. In this presentation we will outline the current state of knowledge of the NSW sea floor examining the extent and quantity of data available for coastal and marine management.

Despite many years of surveying, gaps remain in the overall spatial coverage for the state's coastal waters. Aspects covering the state database around data currency, representation, comprehensiveness and limitations are to be presented. Several of the major estuarine systems eg. Clarence River Estuary, are yet to be surveyed using modern methods and data for some offshore sections is limited to early lead-line soundings. Only a small proportion of the state's subtidal beaches have been mapped using single beam on at least 1 occasion since 1975. While the terrestrial component of the majority of beaches has been surveyed using LIDAR relatively few have been subtidally mapped using techniques such as LADS. A total of 15 %, however, of state waters has been surveyed using multibeam as part of the Habitat Mapping Program. While these surveys focused on reefs at depths of <60m, other broader scale bathymetry indicates areas of "deeper" inner-mid shelf reefs in 70-80, 100 and 120m of water further offshore bordering state waters. These unsurveyed reefs are a key ecological feature flagged during Commonwealth bioregional assessments and reserve planning. Despite the recent increase in effort across the inner shelf, a significant gap exists from 3NM to the shelf edge. With the purchase of a "shallow-water" multibeam onboard the new RV Investigator, greater coverage of shelf habitats is expected.

OEH now runs multiple platforms including jet-skis, a quad bike and sea-going vessels fitted with digital laser scanners, underwater video, oceanographic equipment, single beam and multibeam systems that utilise RTK VRS corrections over 4G network. With technological advancement in both survey equipment and post-processing capabilities increased spatial and temporal coverage of state waters has become possible. We will detail current survey efforts and discuss future priorities for baseline mapping and coastal monitoring.

Automated classification and OBIA of sidescan sonar imagery and multibeam bathymetry to map submarine canyons

Khaira Ismail[1], Veerle A. I. Huvenne[1], Tim P. Le Bas[1] and Katleen Robert[1]

[1]National Oceanography Centre, Southampton, UK, K.Ismail@noc.soton.ac.uk

Submarine canyons are important geological features that incise the continental slope and serve as conduits to the deep abyssal plains. The deep and complex topography, strong currents and occurrence of high turbidity affect the habitat heterogeneity, making canyons potential hotspots for biological activity, with high faunal diversity supported on hard substrata and mobile sediments. However, the high terrain variability makes canyons difficult to be mapped efficiently. Therefore a comparison of different methods to produce robust marine landscape maps is needed to support future marine monitoring programmes.

A combined multibeam and sidescan sonar survey of Whittard Canyon was carried out as part of the EU FP7 project HERMIONE, and the UK OCEANS2025/MAREMAP programme. Within the project CODEMAP, it is now used to generate a landscape map for Whittard Canyon using automated classification and object-based image analysis (OBIA). The aim of this study is to find the most robust, repeatable, and capable method of processing many remotely acquired acoustic data in a more efficient manner.

Three approaches to map the submarine canyon are compared to find their advantages and disadvantages. The first method consists of landscape map generated with pixel-based automated classification using statistical means. The second method uses all available abiotic variables from multibeam bathymetry, backscatter, sidescan sonar and its derivatives as layers to run the OBIA method. And finally the third method is a combination of automated classification and OBIA, using sidescan sonar imagery at a fine scale as a single layer to generate OBIA segmentation, followed by a supervised classification of the segments using training objects.

The results are evaluated using traditional digitization, based on visual assessment of the sidescan imagery and video transects. The advantage of using OBIA is that it allows incorporation of fine scale features into the broad-scale map as image segmentation was carried out on the fine scale sidescan sonar imagery. In addition, the segmentation aspect of OBIA results in a better-resolved boundary between classes, based on features in the imagery instead of a pixelated representation. However, using OBIA as a standalone method is very subjective and its rule-based method is environment-exclusive, i.e. the rule set is only applicable on datasets with the same type of data and covering a similar environment. Automated classification has the advantage of being very objective but the final maps are often pixelated and the boundaries between classes are often too structured.

A multidisciplinary approach to shallow benthic fisheries management integrating bathymetric LiDAR

M. Ali Jalali[1], Daniel Ierodiaconou[1], Adam Miller[2], Jacquomo Monk[1] and Alex Rattray[1]

[1] Deakin University, Centre for Integrative Ecology, School of Life & Environmental Sciences, Faculty of Science, Engineering and Built Environment, P.O. Box 423, Warrnambool, Victoria, Australia, majalali@deakin.edu.au

[2] Department of Zoology, The University of Melbourne, Parkville, Victoria, Australia.

LiDAR for shallow water mapping provides the means for scientists and managers to fill in the "coastal white stripe", allowing for seamless mosaics from terrestrial to marine environments. The resolution afforded by these systems has allowed collection of high-resolution bathymetry and intensity data in often difficult to survey areas. Multiple uses of these costly datasets are desirable as extending applications beyond the initial scope of survey maximizes the value of mapping programs. For commercial benthic resources, understanding the geographical extent of fishable grounds relevant to the scale of targeted exploitation remains a challenge. A potential way to bridge this gap is to integrate geo-spatial data originating from remote sensing systems and spatially explicit fisheries information. In this study we demonstrate how commercial catch and diver survey datasets can be combined with LiDAR-derived seafloor structure using geostatistical approaches to improve stock management of a commercially important mollusc, the black lip abalone *Haliotis rubra* (Leach). Fishery dependent data were used to develop a species distribution model identifying the extents of suitable fishery grounds by combining bathymetric LiDAR data and commercial diver GPS tracks. Spatial patterns in the distribution of fishing activity tended to be clustered, with patterns varying temporally. We examine the integration of this information to evaluate alternative harvest strategies. LiDAR-derived habitat models were also used to determine spatial connectivity of reef patches and test hypotheses regarding the dispersal characteristics of abalone. Population genetic analysis involving the assessment of allele frequencies at 15 polymorphic microsatellite loci indicate extensive gene flow across reef patches and evidence of a single genetic stock spanning more than 1000km of coastline. They also provide insight into the spatial patterns of larval recruitment by combining genetic measures of relatedness within and across LiDAR derived reef complexes. We demonstrate a multidisciplinary approach integrating LiDAR-derived reef extent with genetics, video observations and fisheries data to improve the current spatial management of a commercial important benthic mollusc.

Understanding Mid-shelf Seafloor Evolution Using a Four-dimensional Approach

Elizabeth Johnstone[1], Neal Driscoll[1], John Milliman[2] and Rudy Slingerland[3]

[1]Scripps Institution of Oceanography, University of California, La Jolla, California, USA, lizjo222@gmail.com

[2]School of Marine Science, College of William and Mary, Gloucester Point, Virgina, USA

[3]Dept. of Geosciences, Pennsylvania State University, University Park, Pennsylvania, USA

We used geophysical and analytical tools to map sediment packages and investigate the evolutionary processes controlling mid-shelf deposits in the Gulf of Papua (GoP). Our group acquired data in 2004 as part of a program funded by the National Science Foundation (NSF), which supported several cruises to integrate research from terrestrial mountainous inputs to deep-sea depositional regions. We studied the shelf seafloor at water depths of 20-80 meters to document sediment dispersal from two different types of river systems. Using acoustic methods (e.g., multibeam in Figure A, depth soundings, sub-bottom profiling in Figure B) we imaged several sediment lobes in three-dimensions to understand the processes that sculpted present and past seafloor environments. Sediment cores were co-registered with the lithostratigraphy (Figure C) to ground-truth the seismic data. Chronostratigraphy of sediment cores introduced a fourth dimension. We gained insight on depositional history by radiocarbon dating benthic organisms. Sediment provenance was determined by elemental analysis (Figure C) using X-ray diffraction and fluorescence. These data chronicle environmental shifts caused by changes in sediment supply and available accommodation over the last glacial cycle. Drowned bioherms were also discovered, underlying rapidly accumulated sediment lobes revealing a marked shift in depositional environment. Where sediment accumulation rates were high, they acted as a blanket obscuring past seafloor structures. Conversely, where rates were low, remnant seafloor features were visible on seafloor maps. The dynamic relationship between the terrestrial landscape and oceanographic conditions are driving forces for benthic habitat formation and are altered by the most recent sea level rise during the Holocene. Our results show that sediment discharge and deposition on the shelf is controlled by the storage capacity and native discharge from land, while oceanographic currents control the depositional placement and accumulation rates. We describe two distinct river types that have similar discharge rates. Type I systems have large sediment discharges and traverse low gradient, passive margins, often sequestering large amounts of sediment in their coastal plains during sea level highstands. Conversely, high gradient, active margin rivers (Type II) generally have little onshore storage capacity during highstands. These small, mountainous catchments may dominate during these periods, but may be subordinate to Type I rivers during sea level lowstands. Knowledge on the past and current processes that control sediment output to a shelf is essential to understanding the evolution of biohabitats. Historical deposits provide the structural foundation to benthic marine life, while a balance between nutrient supply and sedimentation rates mediates the maintenance of present-day marine biological environments.

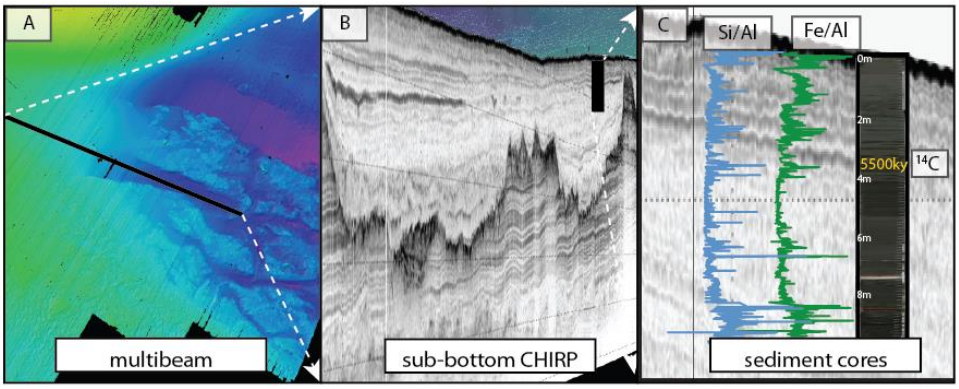


Figure A) Multibeam data from the Umuda channel in the Gulf of Papua. Black line represents location of CHIRP line. Figure B) CHIRP seismic line (vert exag. 75x) with black rectangle representing location of sediment core. Figure C) Jumbo piston core with 14-Carbon date and XRF data shown adjacent to photo.

Quantifying rock fishing hazards using marine and terrestrial LiDAR

David M. Kennedy[1], Colin D. Woodroffe[2], Shauna Sherker[3], Adam Weir[4], Barbara Brighton[3] and Daniel Ierodiaconou[5]

[1]Department of Resource Management & Geography, The University of Melbourne, Parkville, Vic, Australia, davidmk@unimelb.edu.au

[2]Department of Earth & Environmental Sciences, University of Wollongong, Wollongong, NSW, Australia

[3]Surf Life Saving Australia, Rosebery, NSW, Australia

[4]Surf Life Saving New South Wales, Belrose, NSW, Australia

[5]Deakin University, School of Life & Environmental Sciences, Warrnambool, Victoria, Australia

The rocky coast is a very hazardous environment; there were 23 fatalities accounting for 19% of coastal drowning in Australia in 2012-13. Water safety management is now focusing strategies on reducing risk for users of this coastal environment. A critical element of understanding risk is modelling of the hazard, namely the size of waves approaching the shore (hydrodynamics) and the likelihood of them washing across a shore platform (morphological exposure). It has recently been identified that morphological elements of the shore, namely the depth at the front of the platform and the platform elevation are key to quantifying the likelihood of wave overwash. Traditionally field surveying is required to quantify this exposure over large sections of the coast which is often prohibitively time consuming and expensive. The advent of marine and terrestrial LiDAR provides researchers with the capability to quickly and quantitatively map this zone thereby allowing for regional assessments of coastal morphology. In this study we test the utility of integrated marine and terrestrial LiDAR for the assessment the morphological exposure using the rocky coast of Lorne, Australia as a test site. It is found that such datasets are highly valuable for the assessment of hazard, although they still require a significant amount of expert interrogation to delineate the morphological boundaries within the landscape. Future refinement of the model and its application will have important implications for improved public safety.

Integrating multibeam sonar and marine and terrestrial LiDAR data for quantifying coastal geomorphology

David M. Kennedy[1], Daniel Ierodiaconou[2] and Alexandre C. G. Schimel[2]

[1]Department of Resource Management & Geography, The University of Melbourne, Parkville, Vic, Australia, davidmk@unimelb.edu.au

[2]Deakin University, School of Life & Environmental Sciences, Warrnambool, Victoria, Australia

Sediment transport and erosional processes on coastal landforms are concentrated at the interface between the land and sea. Processes of wave breaking can hinder investigations due to an inability to physically access the littoral zone. On rocky coasts landforms evolution occurs over millennial scales which means throughout the Quaternary these coasts have been variably exposed to different sea level elevations and erosion can be concentrated at different elevations than observed today. Investigations of the submarine landscape of rocky coasts therefore require data beyond the intertidal zone and research has been hindered by this inability to accurately image nearshore morphology. In this study we test the utility of terrestrial and marine LiDAR data combined with nearshore multibeam sonar to seamlessly collect data across the land-sea interface. The plunging-cliff landscape of Wilsons Promontory Marine National Park (MNP) in Victoria, Australia is used as a field site, with a composite dataset from +10 m elevation to -90 m depth captured for the 170km^2 MNP. This integrated data set is ideal for quantifying long term landscape evolution. It is found that the morphology of granite-domes is virtually unaffected by erosion at sea level. It appears that evolution of Wilsons Promontory is a very slow process with modern sea level acting only to remove subaerially weathered debris. The size and orientation of the joints within the granite that composed the coast is the primary reason for its resistance. Only where joints are densely spaced (< 2 m apart) or the bedrock is highly weathered can semi-horizontal surfaces form.

Benthic Photo Survey: New Open Source Software for Cost Effective Ground Validation

Jared Kibele[1]

[1]University of Auckland, Leigh Marine Laboratory, Institute of Marine Science, Leigh, New Zealand, jkibele@gmail.com

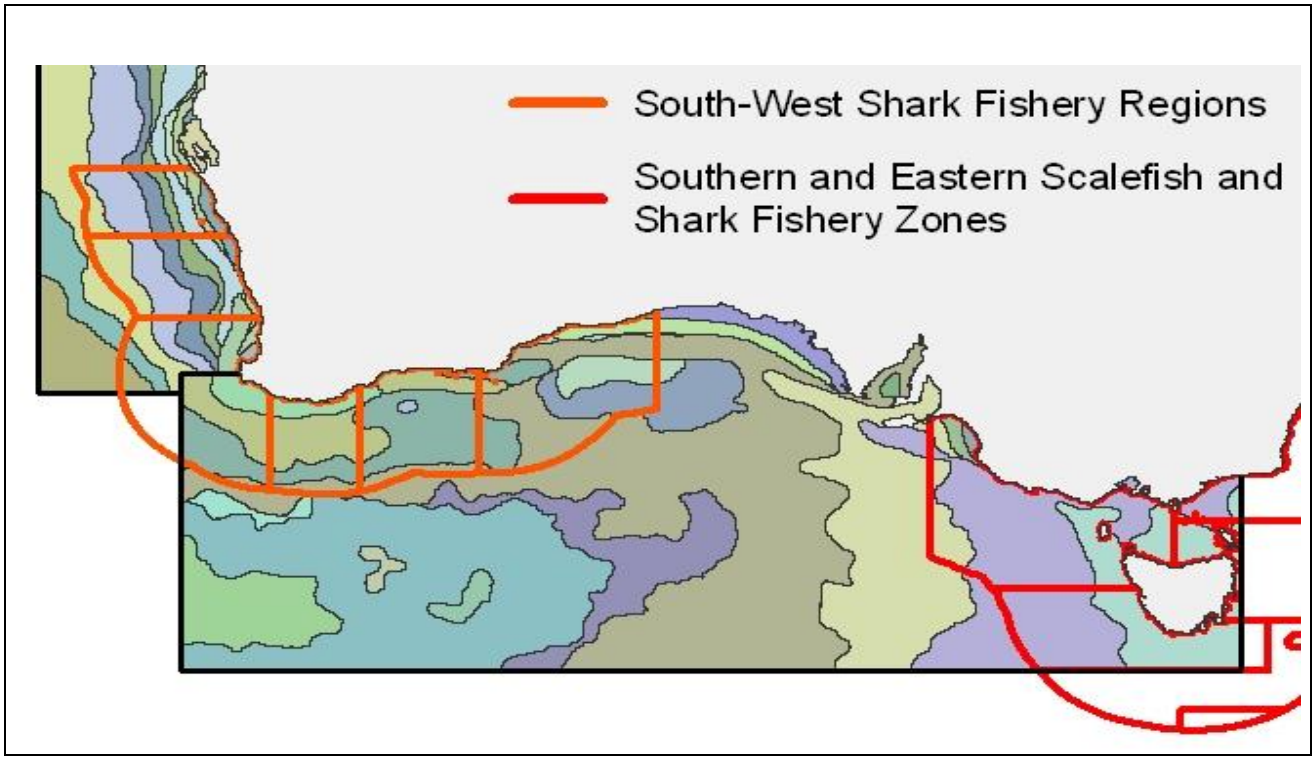
Field based reference data (a.k.a. ground truth or ground validation data) are vitally important in the creation of habitat maps via remote sensing techniques. These data are required for the training of automated classifiers and for the assessment of mapping accuracy. Photo transects have been shown to be an effective means of generating reference data but the complexity of post fieldwork data processing has been an ongoing barrier to their use. In this paper I present a free and open source software (FOSS) application called Benthic Photo Survey (BPS) that has been developed to reduce the cost, complexity and time expenditure required to generate reference data from photo transects. To demonstrate its abilities, BPS has been used to facilitate the classification of WorldView-2 multispectral satellite imagery into a habitat map for a temperate rocky reef in north eastern New Zealand. A QGIS Accuracy Assessment plugin has been created to work in conjunction with BPS and generate an error matrix and measures of mapping accuracy. Additionally, BPS can be used on its own to capture and generate spatial data that are useful outside the remote sensing context, as demonstrated by the use of BPS to map and quantify a die-off of the habitat forming kelp *Ecklonia radiata*. These FOSS tools will help to eliminate barriers to the production of field validated habitat maps and make habitat mapping more accessible to ecologists and resource managers without specialised remote sensing experience and expensive proprietary software.

Characterisation of marine regionalisation using satellite imagery

Adrian Kitchingman[1] and Joseph Leach[1]

[1]University of Melbourne, Parkville, Victoria, Australia, leach@unimelb.edu.au

This study looks at the elements that define a natural boundary and its marine variant. It then aims to quantify and delimit natural marine boundaries from satellite sea surface temperature and ocean colour imagery. The nature and definition of a natural boundary is complicated and often subjective. Natural boundaries often have a fuzzy or zonal nature, can be dependent on and independent from the character of the region which they bound, and have temporal characteristics that occur over a variety of temporal scales. Natural marine boundaries have the added complexity of occurring in three dimensions and of being temporally dynamic throughout the water column. A monthly time-series of MODIS satellite imagery from July 2002 to June 2006 was used in this study. The standardised principle component analysis (sPCA) was used to identify the mean state of identifiable natural process and to quantifying a degree of spatio-temporal (seasonal) dichotomy in detected marine processes. Component images from the sPCA provided a spatial representation of marine phenomena, while sPCA loadings indicated the temporal fluxes exhibited in a given component. Classification of significant sPCA components was conducted to derive regional boundaries. Initially, this was performed in an unsupervised manner using an ISO process. Subsequent classified images were then simplified using a combination of dendrograms and knowledge-based examination. A comparison of these results with similarly derived regionalisation showed that the spatio-temporal representations have the potential to further inform marine spatial management regimes. It was also shown that the delimitation of natural phenomena is feasible and can have seasonal dynamics represented. This provides a potential baseline for near real-time boundary assessments and an addition to adaptive management techniques. Ultimately the results have shown that there is scope for the improved incorporation of marine dynamics into marine spatial management systems.



Comparison of natural marine regions with fisheries management boundaries

Modelling 3-dimensional connectivity at the continental scale: examples from shelf and canyon systems on the northwest margin of Australia

Johnathan T. Kool[1] and Scott L. Nichol[1]

[1]Geoscience Australia, Symonston, ACT, Australia, johnathan.kool@ga.gov.au

As part of Geoscience Australia's commitment towards the National Environmental Programme's Marine Biodiversity Hub, we have developed a fully four-dimensional (3D x time) biophysical dispersal model to simulate the movement of marine larvae over large, topographically complex areas. The model uses parallel processing on Australia's national supercomputer to handle large numbers of simulated larvae (on the order of several billion), and saves positional information as points within a relational database management system (RDBMS). The model was used to study Australia's northwest marine region, with specific attention given to connectivity patterns among Australia's north-western Commonwealth Marine Reserves and Key Ecological Features (KEFs). These KEFs include carbonate terraces, banks and reefs on the shelf that support diverse benthic assemblages of sponges and corals, and canyons that extend from the shelf edge to the continental slope and are potential biodiversity hotspots. We will show animations of larval movement near canyons within the Gascoyne CMR; larval dispersal probability clouds partitioned by depth and time; as well as matrices of connectivity values among features of interest. We demonstrate how the data can be used to identify connectivity corridors in marine environments, and how the matrices can be analysed to identify key connections within the network. Information from the model can be used to inform priorities for monitoring the performance of reserves through examining net contributions of different reserves (i.e. are they sources or sinks), and studying changes in connectivity structure through adding and removing reserve areas.

From the rocky subtidal to the deep sea: Distinguishing habitats using variability in fine-scale benthic features

Myriam Lacharité[1], Anna Metaxas[1], Peter Lawton[2] and Robert E. Scheibling[3]

[1]Dalhousie University, Department of Oceanography, Halifax, Canada, myriam.lacharite@dal.ca

[2]Fisheries and Oceans Canada, St. Andrews Biological Station, St. Andrews, Canada

[3]Dalhousie University, Department of Biology, Halifax, Canada

At the seascape scale (100s of meters to kilometers), spatial variation in fine-scale (centimeters to meters) substrate features (i.e. relative cover of particle grain size) affects the distribution of marine epibenthic communities both because of specific associations with habitat types and the proximity of suitable habitat. Fine-scale variability in substrate features may be manifested in sharp boundaries or gradients. Benthic habitat mapping has typically used boundaries to establish habitat classifications at the seascape scale, which might forego the importance of gradients in determining the spatial patterns, composition and diversity of benthic biological communities. Spatial statistical approaches developed in landscape ecology (such as variograms and one-dimensional autocorrelation) can provide insights into the frequency and magnitude of boundaries along transects in benthic habitats and communities. However, comparisons among habitats using these approaches remain challenging because of the difficulty of quantifying patterns of surficial geology.

Optical imagery, in addition to being used to ground-truth acoustic surveys, captures fine-scale seafloor features. The variability in these features can also be integrated in habitat maps to increase their accuracy. Using digital photographs of the seafloor and a novel approach to quantify fine-scale features, we compare patterns of spatial variability in surficial geology with those in epibenthic biological communities along an inshore-offshore habitat gradient in the Gulf of Maine/Scotian Shelf region (northwest Atlantic). We compare four areas with different geomorphological features using 2 1-km replicate transects in each area: nearshore rocky subtidal zone (60-80 m depth), 2 deep basins on the continental shelf (150-300 m depth) and 1 area on the continental slope (1,350-1,500 m depth).

Preliminary results indicate that spatial variability in fine-scale features (both geological and biological) can be quantified using object-based image analysis of digital photographs of the seafloor. Environments of increasing complexity (i.e. great steepness and frequency in variation of fine-scale features) are associated with greater epibenthic species richness, while environments with more homogenous habitat features are associated with lower epibenthic species richness.

Utilization of multi-beam and video data to classify habitat structure inside and outside a marine reserve to quantify biological response to protection

Alix Laferriere[1], Geoffroy Lamarche[2] and Jonathan Gardner[1]

[1]Victoria University of Wellington, Wellington, New Zealand, Alix.Laferriere@vuw.ac.nz

[2]National Institute of Water and Atmospheric Research (NIWA) , Private Bag 14-901, Wellington, New Zealand 6021

The south coast of Wellington, New Zealand, is situated along the high energy environment of the Cook Strait. The topography is complex with rugose bedrock reefs, rocky outcrops, incisions with rippled sediment flows, post-glacial gravel beds overlain by finer sediments and boulder fields. This complex habitat supports a high diversity of ecologically and economically important species and is distinct from the rest of New Zealand in terms of its community structure. The Taputeranga Marine Reserve was established in 2008 to protect the habitats and species in an area of 854 hectares. A seafloor map for marine reserve siting and spacing as well as setting a physical baseline from which to monitor change was needed. In 2005, through a collaborative effort of multiple stake holders, the nearshore seafloor (approximately 5- 40 m depth) in and adjacent to the reserve was mapped by NIWA. Multi-beam data were acquired using a SIMRAD EM3000D and was processed using CARIS HIPS software and imported into ARCGIS for data analysis and map compilation. 3D views were generated using IVS Fledermaus Pro. After establishment of the Taputeranga Marine Reserve, reserve and non-reserve sites were designated for monitoring. Identifying and describing habitat type and spatial extent are essential in understanding the patterns and processes influencing organismal distribution and underpin the monitoring of change in an environment attributable to the reserve. When habitat is not examined before reserve establishment the natural spatial and temporal variability in the physical environment often confounds the reserve effect. In the austral summer of 2013 and 2014, we utilized the multi-beam dataset to design visual spatial surveys for physical and biogenic habitat classification with the goal of comparing habitat characteristics between reserve and non-reserve sites. The survey consists of a number of drop camera stations on an initially random distribution adjusted to cover all backscatter facies identified on the processed EM3000D dataset. High definition videos were collected at each location for duration of 120 seconds. Videos were reviewed and substrate was classified into a small number of classes including mud, sand, gravel, cobble, boulder and continuous bedrock. Biogenic reef types and macroalgal functional groups were assigned. We present here the compilation of ground-truthing video data and multi-beam data of physical and biogenic habitats for each site and compare the similarities among and between reserve and non-reserve sites. This multidisciplinary and scalar approach produces a robust habitat map to be used to understand the association between substratum type and ecological community, as well as permitting quantification of the conservation outcomes of marine reserve establishment by comparing between reserve and non-reserve sites.

Why do the marine hydrocarbon and mining sector need habitat mapping?

Geoffroy Lamarche[1]

[1]NIWA, Private bag 14-901, Wellington, New Zealand

Worldwide there is rapidly growing interest in offshore minerals and deep sea hydrocarbon resources. A range of environments are at potential risk of the impact of exploration and exploitation. One of the (many) challenges facing management agencies is to facilitate development of operations while ensuring that the environment is not compromised for future generations. Legislation is still developing, and there are only limited regulatory guidelines in place. So in the meantime, what can environmental science provide to help stakeholders to make the right decisions?

We will use the example of the Pegasus Basin, east of New Zealand, where an extensive review of environmental data has been completed and where hydrocarbon exploration is taking place. Pegasus Basin lies entirely offshore and covers an area of ~25 000 km^2. The basin and its boundaries includes a wide variety of morphologies, substrates, and sensitive habitats. Furthermore, this highly varied morphology constantly evolves in response to sea level fluctuation, sediment input and tectonic forcing.

The wealth of bio-chemico-physical data in the Pegasus Basin is impressive. Bathymetry and backscatter data are of use for predictive resource and biodiversity mapping, particularly in the Hikurangi cold seep province on the basin's northwestern margin. Here sensitive habitats have developed in response to specific chemosynthetic environments associate with gas seeps. In addition, derivative spatially continuous datasets, including geomorphic mapping, quantitative backscatter analysis and sediment distribution, enabled us to analyse the geology-biology relationship and characterise benthic habitat of canyon systems bordering the basin. Importantly, since 2011, full water-column backscatter data have been collected which has enabled flares associated with seeps and pockmarks on the seabed to be imaged. All these form Direct Hydrocarbon Indicators (DHIs) which suggest that the basin may contain an active petroleum system, which indeed is of interest to the Oil and Gas sector.

Some nominal benthic habitats and bottom features defined from multibeam data have been ground-truthed using underwater imaging and direct seafloor sampling. Likewise, distribution of megafauna from predictive habitat suitability modelling provide a first indication of likely distributions of whales and dolphins in the region. Finally, wave climate and current models are available in the region.

These comprehensive datasets provide a means to develop multiple habitat-type products for environmental baseline definition, Environmental Impact Assessments, or Ecological Risk Assessment, and is of use to industry, government agencies, iwi and the public at large to make informed decisions.

The automation of multibeam processing and interpretation for habitat mapping

Tim P. Le Bas[1], Khaira Ismail[1] and Veerle A. I. Huvenne[1]

[1]National Oceanography Centre, Southampton, UK. SO14 3ZH, tlb@noc.ac.uk

Multibeam data provide two excellent datasets for the delineation of habitats on the seafloor. Bathymetry maps are usually well calibrated and have calculated uncertainties thus providing a stable base for the start of interpretation. Backscatter imagery, which can provide valuable additional information on seafloor type, is usually less well calibrated and can be very dependent on the survey characteristics and data processing method used.

Backscatter imagery was once discarded due to the poor nature of processing. Fortunately processing software has improved massively over the last few years. However the process is often hidden in a black box and the results have to be accepted as is. Examples will be shown of data processing variations from different software systems, each with their own advantages. In addition, the many levels of interpretation will be explored. The level of subjectivity vs. objectivity is often crucial to the final result and its relevance to the real world. Examples of expert interpretation will be shown and compared to increasingly objective methods of classification, moving through the spectrum of interpretation from manual rule-based Object Based Image Analysis, over supervised classification to fully automated unsupervised classification (see Figure 1).

This presentation aims to review the variations in the many survey characteristics such as navigation, multiple imagery priority and calibration, and will illustrate their effect on the resulting habitat maps. The absence of true backscatter calibration means that the interpretation of the imagery has to adapt to data acquisition parameters. If standardisation of backscatter imagery can be achieved this will aid the automation and speed of processing, and ultimately the interpretation, as the rules for classification could then be refined by the user community.

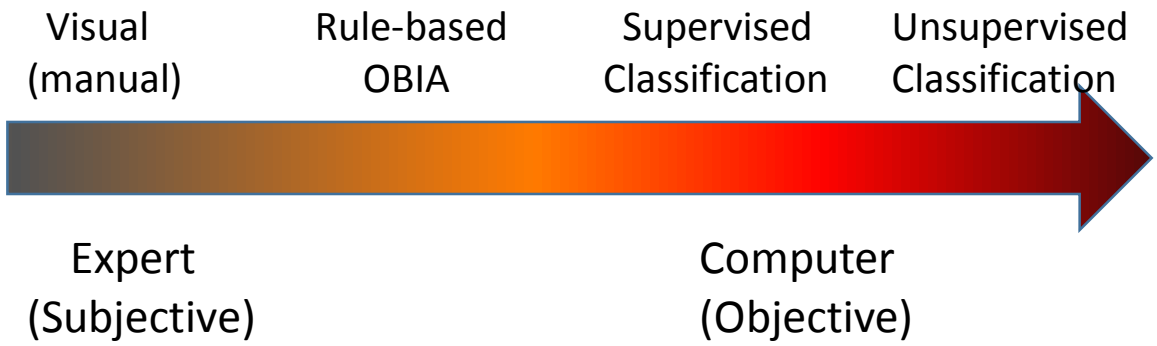


Figure 1. Interpretation spectrum from subjective to objective. The choice often depends on the amount of ground-truth data, the reliability of the data source and its processing.

Application of Novel Hybrid Spatial Modelling Methods to Spatial Prediction of Seabed Sediments

Jin Li[1]

[1]Marine & Coastal Geoscience, Environmental Geoscience Division, Geoscience Australia, jin.li@ga.gov.au

Spatially continuous information of seabed sediments provides important information for seabed mapping and characterisation, prediction of marine biodiversity, and marine environmental planning. Seabed sediment data is available at sampled point locations, so spatially continuous data can only be predicted from the point data. The accuracy of the predicted data is crucial to evidence-based decision making in marine environmental management and conservation. Improving the predictive accuracy is essential, but also challenging, since the accuracy is often data-specific and affected by many factors (Li & Heap 2011 & 2014).

Because of their high predictive accuracy, machine learning methods were introduced by Geoscience Australia into spatial statistics by combining them with existing spatial interpolation methods (SIMs). This resulted in new hybrid methods, with the hybrids of random forest (RF) with inverse distance weighting (IDW) or ordinary kriging (OK) (i.e. RFIDW or RFOK) displaying high predictive capacity (Li & Heap 2014, & Li et al. 2011). However, their applications to environmental variables are still rare. Model selection for RF and the hybrid methods has proven to be necessary and further testing is required. Moreover, model averaging was argued to be able to improve predictive accuracy, but no consistent findings have been observed in previous studies.

In this study, we aim to identify the most accurate methods for spatial prediction of seabed sediments in the Petrel sub-basin, northwest Australia. We experimentally examined: 1) the effects of input secondary variables on the performance of RFOK and RFIDW; 2) whether the performances of RF, SIMs and their hybrid methods are data-specific; 3) the effects of model averaging on predictive accuracy of these methods; and 4) whether additional samples improve spatial predictions of seabed sediments. For RF and the hybrid methods, up to 21 variables were used as predictors. The predictive accuracy was assessed in terms of relative mean absolute error (RMAE) and relative root mean squared error (RRMSE) based on the results of 100 iterations of 10-fold cross-validation.

This study found that:

- the predictive errors changes with the input secondary variables;
- the most accurate model could be missed during the model selection;
- RFOK proved to be the most accurate method;
- the methods are not data specific, but their models are, so the best model needs to be identified;
- model averaging is clearly data specific; and
- contribution of additional samples to the spatial predictions is not apparent.

In summary, model selection is important for identifying the most optimal models for RF and the hybrid methods. Effects of model averaging should also be examined for individual studies. The hybrid methods displayed substantial potential for predicting environmental properties and are recommended for spatial prediction not only in environmental sciences but also in other relevant disciplines. Guidelines are provided in this study for improving spatial predictions of biophysical variables in both marine and terrestrial environments.

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Spatio-temporal Patterns and Controls on Cold Water Coral Reef development: The Moira Mounds, Porcupine Seabight, Offshore Ireland

Aaron Lim[1], Andy Wheeler[1], Agostina Vertino[2], Boris Dorschel[4], Aurelien Arnaubec[5] and Silvia Spezzaferri[3]

[1]School of Biological, Earth and Environmental Sciences, University College Cork, Ireland, alim2389@gmail.com

[2]Department of Geology and Geotechnology, University Milano-Bicocca, Milan, Italy

[3]Department of Geosciences, University of Fribourg, Fribourg, Switzerland

[4]Bathymetry, Alfred Wegener Institute, Bremerhaven, Germany

[5]Positioning, Robotics, Acoustics and Optics, IFREMER, Zone Portuaire de Brégaillon, France

The initiation and development of Cold Water Coral (CWC) reefs, from the colony stage through to coral carbonate mounds is still poorly understood. Our research focuses on small-sized mounds (Moira Mounds, Porcupine Seabight, West of Ireland), considered by Wheeler et al. (2011) as an example of the early-stage growth phase of nearby giant coral carbonate mounds. The western chain of Moira Mounds display a general gradation in mound size, stage of growth and 'vitality' from south to north. Our goal is to combine detailed surface and core features of representative Moira Mounds to understand their evolution and variability in space and time. A broad range of data are utilised including: microbathymetry, ROV video data, high-definition video mosaics, day grabs, box cores, CTD data and CT scans. Further research cruises in 2014 aim to collect longer core material and seismic lines to enhance this data set. With this information, we are constructing a 3D video mosaic of a particular Moira Mound. This will aid us to develop the first total-reef scale habitat zonation model of this kind. Water column, mound surface and subsurface data will give a unique insight to a specific mound. Furthermore, we aim to correlate specific horizons within our cores through this Moira Mound with previously targeted earlier-stage mound surfaces in the local area. This presentation demonstrates a range of work completed to date.

Predictive Ensemble Maps for cold-water coral distributions in the Cap de Creus Canyon (NW Mediterranean). Advantages and limitations

Claudio Lo Iacono[1,2], Katleen Robert[1], Rita Gonzalez-Villanueva[3], Andrea Gori[2], Covadonga Orejas[4] and Josep Maria Gili[2]

[1]Marine Geoscience, National Oceanography Centre, Southampton, United Kingdom, cllo@noc.ac.uk

[2]Instituto de Ciencias del Mar, Consejo Superior de Investigaciones Científicas, Barcelona, Spain

[3]Departamento de Geociencias Marinas y O.T. Universidad de Vigo, Spain

[4]Instituto Español de Oceanografía, Centro Oceanográfico de Baleares, Palma de Mallorca, Spain

Predictive habitat mapping has shown great promise to improve the understanding of the spatial distribution of benthic habitats and is a valuable means to highlight species-environment relationships where field data may be limited. However, how much of what spatial distribution models tell us is true? Although they surely represent an important step forward in process-based ecosystem management, their predictive efficiency is not always tested by independent groundtruthing data. This is particularly true for the deep-sea environment, where sample data are always limited compared to the large extent of the areas to be mapped. Furthermore, the usual paucity of high resolution maps in deep-sea settings makes reliable predictive models even harder to obtain. The aim of this study is to apply and test different spatial models to statistically predict the distribution of three Cold-Water Coral (CWC) species (*Madrepora oculata*, *Lophelia pertusa* and *Dendrophyllia cornigera*) in the Cap de Creus Canyon (NW Mediterranean), based on high-resolution swath-bathymetry data (pixel resolution: 5m) and video observations from the submersible JAGO (IFM-GEOMAR). Presence/absence of CWCs was estimated in each 5m resolution pixel from video imagery. CWCs correspond to a habitat forming deep-sea community, which provide habitat and shelter for a wide range of species, including commercially viable fish. Moreover, submarine canyons act as specific hosting areas for these habitats, owing to their favourable environmental conditions.

Maximum Entropy (MaxEnt), General Additive Model (GAM) and decision tree model (Random Forest) were independently applied to represent non-linear species-environment relationships using terrain variables derived from multibeam bathymetry (slope, geomorphologic category, rugosity, aspect, backscatter). Relevant differences between the three models were observed. MaxEnt gave an outstanding performance for the three species, with the area under the curve (AUC) from the sensitivity-specificity approach between 0.98 and 0.99, and with slope, aspect and rugosity as the most relevant variables responsible for CWC distribution. On the contrary, the presence/absence models (GAM and Random Forest) gave a lower performance, with the considered physical elements having a minor ability to explain CWC distribution. These findings could be partly attributable to the effect of autocorrelation between available samples and also suggest that the addition of oceanographic variables (e.g. current speed & direction) would potentially improve the model performance. Nonetheless, the predicted areas where CWCs should be found with higher probabilities coincided for the three methods when a lower 50 m spatial scale was considered. According to the models, CWCs are most likely to be found on the medium to steeply sloping, rough walls of the southern flank of the canyon, aligning with the known CWC ecology acquired from previous studies in the area.

As a final step, a probabilistic predictive ensemble has been produced merging the outcomes of the three models considered, providing a more robust prediction for the three species. The main insight is that important discrepancies can arise in using different species distribution models, especially when high spatial resolutions are considered. This could in part be the result of the different statistical philosophies behind each of the models. Single models may not always be the most appropriate and definitive option, particularly when a limited number of observations is available. We suggest that a more reliable prediction could be obtained by merging models into spatial ensembles, able to reduce differences and associated uncertainties, showing hence a strong potential as an objective approach in the planning and management of natural resources.

Multi-scale image segmentation of multibeam backscatter data for benthic monitoring

Vanessa Lucieer[1], P. Justy W. Siwabessy[2], Zhi Huang[2] and Keith Hayes[3]

[1] Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 49, Hobart Tasmania, Australia, Vanessa.Lucieer@utas.edu.au

[2] Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia

[3] CSIRO Marine and Atmospheric Research, Castray Esplanade, Hobart Tasmania, Australia

In the last decade seabed classification and mapping has developed as one of the most active areas of marine science. However, the translation of acoustic data into spatial products has been challenged by two important concepts: scale and habitat classification accuracy. Although acknowledged in the habitat mapping literature as being important, these two issues are receiving surprisingly little attention.

Relationships between seabed habitat classes (as objects) and the scales they can be accurately are identified at are explored in this research in the context of mapping for marine protected area assessment where specific seabed geomorphometry classes are required to be accurately identified. The benefits for coupling multi-scale analysis and seabed habitat classes delineated using geomorphometry, are discussed.

To conduct this research we apply a newly automated approach to parameterising multi-scale image segmentation multibeam backscatter data in eCognition™ software. The case study dataset is from the Flinders Island Commonwealth Marine Protected Area; conducted by NERP Marine Biodiversity Hub. This approach relies on the potential of the local variance (LV) to detect scale transitions in backscatter imagery. The tool segments the backscatter and bathymetry data together. It conducts the process iteratively with a multi resolution segmentation algorithm in a bottom-up approach, where the scale factor in the segmentation, namely, the scale parameter (SP), increases with a constant increment. The average LV value of the objects in the two layers is computed and serves as a condition for stopping further iterations: when a scale level records an LV value that is equal to or lower than the previous value, the iteration ends, and the objects segmented in the previous level are retained. Three orders of magnitude of SP lags produce a corresponding number of scale levels. The case study provides an optimal example of an area of complex seabed used to highlight the utility of this approach in objectively mapping reefs and sandy substrate and to develop new techniques for monitoring benthic habitats in complex environments. This tool has a significant potential for enabling objectivity in the automation of GEOBIA analysis for seabed habitat mapping.

One year into the GeoHab Backscatter Working Group: What outcomes?

Xavier Lurton[1] and Geoffroy Lamarche[2]

[1]Ifremer, IMN/NSE/AS – CS 10070, 29280 Plouzané, France, lurton@ifremer.fr

[2]NIWA, 301 Evans Bay Parade, Hataitai, Wellington, New Zealand

The GeoHab 2013 conference featured a workshop about the use of backscatter data provided by seafloor-mapping sonars, especially multibeam echosounders. This one day session of presentations and discussions gathered participants from a range of scientific domains, as well as research engineers, sonar manufacturers and software developers. One outcome of the workshop was the launch of the Backscatter Working Group (BSWG). The purpose of the BSWG is to propose best practice for acquisition and processing of multibeam sonar backscatter data. The BSWG is preparing guidelines and recommendations for sonar manufacturers and software developers. The outcome document entitled "Backscatter measurements by seafloor-mapping sonars: Guidelines and Recommendations" is organized in chapter written by groups of specialist authors affected. The outline was agreed upon at the end of 2013, and a first draft of the complete text, still in progress, is to be completed in time for GeoHab 2014. The chapters of the document are about:

- Background and fundamentals
- Users need
- Backscatter measurements by bathymetric echosounders
- Acquisition best practice guide
- Backscatter processing

with Generalities and Conclusion chapters, and Appendices featuring bibliographic references and terminology index.

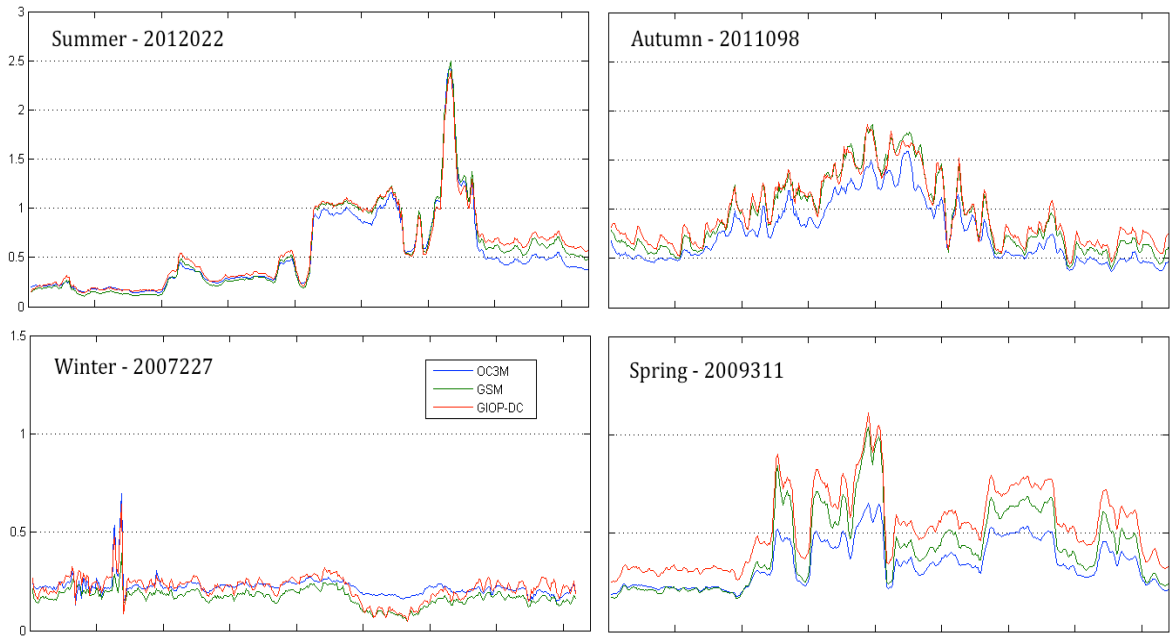
The presentation will include the WG structure and work program, detail of the various chapters, and the main perspectives for the users community, in terms of standardized procedures for calibration, acquisition and processing. A special evening will be dedicated to the working group progress at the Geohab 2014.

Comparison of MODIS-Aqua chlorophyll-*a* algorithms west of Tasmania

Fiona MacGill[1] and Joseph H. Leach[1]

[1]University of Melbourne, Parkville, Victoria, Australia, f.macgill@student.unimelb.edu.au

Marine phytoplankton plays a crucial role in climate change, the carbon cycle and the marine food web. Accurate estimates of phytoplankton, with known uncertainties are required to manage the marine environment. Remote sensing provides an efficient method of monitoring phytoplankton, provided a product of sufficient quality can be retrieved. This product may not be single algorithm but a merged solution for different regions. Ocean colour satellite measurements can provide estimates of marine phytoplankton via Chlorophyll-*a* estimates which can be used to infer phytoplankton biomass. However, the estimations are more challenging in coastal waters, especially in regions which complex oceanographically. West Tasmania's cool temperate rainforest and oceanography form an example of such complex waters for marine phytoplankton retrieval. No global retrieval product performs well in all marine waters and the temporal and spatial consistency between various models is sometimes unclear, particularly in isolated waters. This paper presents an investigation into the consistency and difference between Chlorophyll-*a* estimates for west Tasmanian waters. Three algorithms were used to estimate chlorophyll-*a* concentrations from MODIS-A data: one empirical (OC3M) and two semi-analytical (GSM and GIOP-DC). Data from the four seasons as well as a summer upwelling event were assessed. The average Chlorophyll-a concentration was less than 1 mg/m^3. During spring, summer and autumn, GIOP-DC results were consistently higher than OC3M and GSM, while GSM exhibited the most variability. The three global Chl. retrieval algorithms exhibit similar spatial distribution and seasonal changes. The disparity of Chl. concentration in the coastal waters highlight OC3M simplistic approach to optical complexity compared to GSM and GIOP. The strong Chl. concentration observed offshore may be an indication of interactions with the high nutrient southern ocean or due to complex oceanography of the study.



540km Transect Profile, approximately 100km from the coast Chl. mg/m^3

A comprehensive approach to habitat mapping in extremely shallow water: from acoustic survey to ground-truth

Fantina Madricardo[1], Federica Foglini[2], Aleksandra Kruss[1,5], Jaroslaw Tegowski[3], Philippe Blondel[4], Lukasz Janowski[3] and Marco Sigovini[1]

[1]Instituto di Scienze Marine-CNR, Arsenale - Tesa 104, Castello 2737/F,30122 Venezia, Italy, fantina.madricardo@ismar.cnr.it

[2]Istituto di Scienze Marine-Consiglio Nazionale delle Ricerche, Via Gobetti 101 40129 Bologna, Italy

[3] Institute of Oceanography, University of Gdansk, al. Marszalka Pilsudskiego 46, 81-378 Gdynia, Poland

[4]Department of Physics, University of Bath, Bath BA2 7AY, United Kingdom

[5] Institute of Oceanology Polish Academy of Sciences, Powstancow Warszawy 55, 81-712 Sopot, Poland

Habitat mapping based on acoustic remote sensing methods has rarely been carried in ultra-shallow coastal transitional systems such as lagoons and estuaries. This is due to a number of practical and conceptual issues, including very shallow bathymetries, fine-scale patterns and processes, continuous environmental and biological gradients, high temporal variability and complex water column properties. In this study are presented first results of an extensive survey carried out by a multidisciplinary team of ISMAR- CNR Italy, during 2013, using a Kongsberg EM-2040 DC multibeam system. The survey addressed the entire lagoonal channel network. Although numerous biological studies have been carried out to study the habitats in the tidal flats and salt marshes of the Venice lagoon, the channel seafloor and biota are still almost unexplored. The distinctive features of lagoon channels call for specific operative protocols, both for the acoustic surveys and for ground-truthing. The first results of an acoustic survey will be presented, carried out in a natural tidal channel of the northern part of the Venice Lagoon (water depths from 15 m to less than 1 m). Using the high-resolution bathymetric data (5-cm DTM resolution) a 2D parametric FFT analysis was performed to quantitatively describe the channel seafloor morphology (roughness, dune field wavelength, deposition and erosion areas, etc.). Using the complementary high-resolution backscatter data, a two-dimensional textural analysis was carried out with the Bath TexAn software. A supervised classification of the backscatter data was then performed. As a result, different backscatter areas were identified and several grab samples collected for ground-truthing. The ground-truth dataset and related distinct backscatter areas allow for calibration of the textural analyses and classification of the different substrate types. This characterization of the substrate was then tested with a set of bottom photographs. For this purpose, a specific protocol was developed to address the main issues of underwater photographic surveys include extreme turbidity, strong tidal currents, complex morphology and intense vessel traffic (limiting the times and locations of sampling).

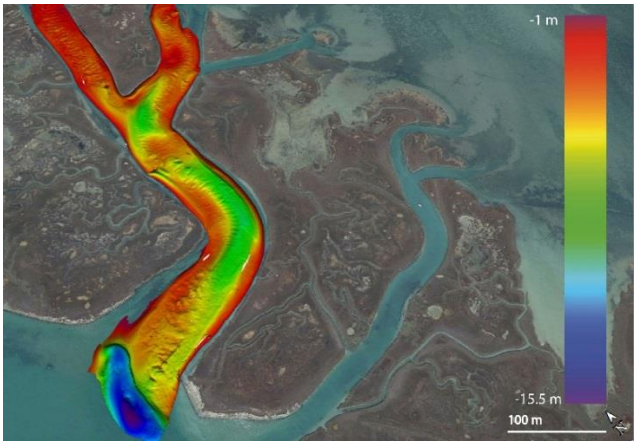


Figure 1. High resolution bathymetry of a tidal channel in the northern Venice Lagoon (5-cm DTM grid) acquired with the Kongsberg EM 2040 DC multibeam system (Google Earth background image).

Linking habitat and biotic patterns improves spatial management in a marine park

Hamish A. Malcolm[1], Alan Jordan[2], Arthur L. Schulz[3], Stephen D.A. Smith[3], Peter Davies[4], Tim Ingleton[4], Edwina Foulsham[4], Michelle Linklater[4], Renata Ferrari[5], Nicole Hill[6] and Vanessa Lucieer[6]

[1]Marine Ecosystems, Department of Primary Industries, 32 Marina Drive Coffs Harbour NSW 2450, Australia, hamish.malcolm@dpi.nsw.gov.au

[2]Marine Ecosystems, NSW Department of Primary Industries, Port Stephen Fisheries Institute, Locked Bag 1, Nelson Bay, NSW 2315, Australia

[3]Southern Cross University, National Marine Science Centre, Charlesworth Bay, Coffs Harbour, NSW 2450, Australia

[4]NSW Office of Environment and Heritage, 59 Goulburn St, Sydney, NSW 2000, Australia

[5]University of Sydney, School of Biological Sciences and Australian Centre for Field Robotics, Edgeworth David Bld, Science Road, NSW 2006, Australia

[6]Institute for Marine and Antarctic Studies Fisheries, University of Tasmania, Private Bag 49, Hobart, TAS, 7001, Australia

The Solitary Islands Marine Park (SIMP) in northern New South Wales, Australia, covers ~720 km^2 of estuarine and continental shelf areas that include rocky reef and unconsolidated habitats up to 17 km from the mainland coast to a maximum depth of 75 m. When established in 1991, there was very limited knowledge of habitats and habitat-biotic relationships in the SIMP, which constrained effective conservation planning. Subsequent mapping of sub-tidal habitats involved aerial photography and single beam sounder surveys, which then facilitated placement of broad-scale diver surveys of fishes, as key surrogate taxa on shallow reefs (<25 m).

In 2006, a swath acoustic mapping program was initiated in the SIMP, with ~35% of the shelf area currently with swath coverage. This enabled higher-resolution mapping of rocky reef habitats, including extensive areas of reef in depths >50 m. Bathymetry and backscatter layers have facilitated selective deployment of Baited Remote Underwater Video (BRUV) to test hypotheses about associations between reef fish and biotic and physical habitat. A Habitat Classification Scheme (HCS) was subsequently refined based on strong correlations with substratum (consolidated, unconsolidated), cross-shelf position (inshore, mid-shelf, offshore) and depth (shallow, intermediate, deep). The HCS was then used to assess the level of representativeness of different biophysical habitats within marine park zones.

Although unconsolidated substratum comprises ~80% of the seafloor in the SIMP, prior to 2011, biotic surveys focused on rocky reefs. More recent BRUV surveys examining patterns of fishes on unconsolidated substrata have found strong correlations with habitat types defined using swath acoustic data. These findings suggest that further refinement to the HCS is required, specifically separating gravel and sand substratum, which can be effectively mapped using backscatter layers.

Predictive modelling of relationships between habitat variables (e.g. from swath acoustic and Autonomous Underwater Vehicle data), and selected reef fishes (from BRUVs) is also being conducted. Preliminary results support the importance of depth as a driver of commercially important species and have shown the strong influence of habitat structural complexity on the relative abundance of trophic groups.

Preliminary systematic planning (using MARXAN) has been undertaken using a combination of habitat (mapped to HCS categories) and fish data. Further refinement of the HCS, and further work on predictive modelling, will enable improved conservation planning to inform future reviews of marine park zoning.

Integrated approach for Habitat Mapping in Wadden Sea and North Sea (Lower Saxony, Germany)

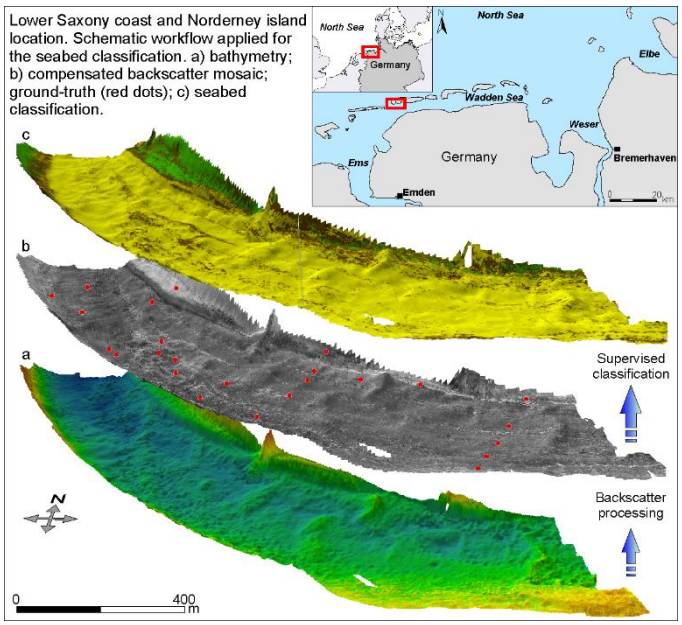
Francesco Mascioli[1], Francisco J. Gutiérrez[2], Holger Dirks[1], Martin Gutowski[2] and Andreas Wurpts[1]

[1]Coastal Research Station, Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency (NLWKN), An der Mühle 5, 26548, Norderney, Germany, francesco.mascioli@nlwkn-ny.niedersachsen.de

[2]Kongsberg GeoAcoustics Ltd., Shuttleworth Close, Gaption Hall Industrial Estate NR31 0NQ, Great Yarmouth, Norfolk, United Kingdom

The Lower Saxony coastal and marine area is a meso-tidal environment, with a maximum depth of about 25 m, including marine waters of North Sea, coastal waters and tidal flats of the Wadden Sea, transitional waters of the Ems, Weser and Elbe estuaries. Abiotic and biotic features are the result of a close interaction between intense natural processes and human-induced actions. The same processes influence the morphology and sedimentary regime, acting in different temporal and spatial scales and controlling the distribution of seabed marine habitats.

In order to implement European Directives, NLWKN is working on a strategy to provide full-coverage habitat mapping using hydro-acoustic methods. The concept aims to supervise the whole mapping workflow, from survey planning to reliable habitat mapping products. The collection of high quality data is guaranteed by an integration of high-standard multi-beam echosounder, multi-beam phase-measuring echosounder, and ancillary sensors. The raw data are processed to obtain high resolution bathymetry and compensated backscatter products that will be used for supervised classification, which will reduce human factor, ensuring repeatability and reliability during the whole process.



Lower Saxony coast and Norderney island location. Schematic workflow applied for the seabed classification. a) bathymetry; b) compensated backscatter mosaic; ground-truth (red dots); c) seabed classification.

An initial assessment has been realized in the western part of Norderney Island. The instruments collected high-quality bathymetric and backscatter data simultaneously. Analysis of elevation data identifies the geometrical characteristics of the main morphological features, like dunes, ripples and bottom roughness.

Bathymetrical data were used for compensating the raw backscatter values. Compensated backscatter was verified and calibrated by grab samples ground-truth, analysed in order to identify sediments and biological features. The combined interpretation of all the morphological, geological and biological features, allowed classifies the different kinds of habitats.

Within this integrated approach, it was possible to map the main abiotic and biotic features of the seabed and relate them to the habitats of a dynamical environment, with productive survey in very shallow areas up to 2-3 meters depth.

Further tests are necessary to optimise the methodology and to calibrate results obtained by different devices and interpretation criteria. To characterise the 3-D habitats distribution and their evolution, an integration of surficial data with subsoil data will be accomplished, using high resolution sub-bottom profiler data calibrated with corings.

SeaSketch: Software as a Service for Marine Spatial Planning

Will McClintock[1]

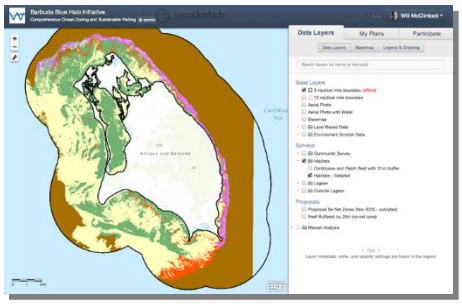
[1]University of California Santa Barbara, Mail Code 6150, Marine Science Institute, University of California, Santa Barbara, CA, 93106-6150, will@ucsb.edu

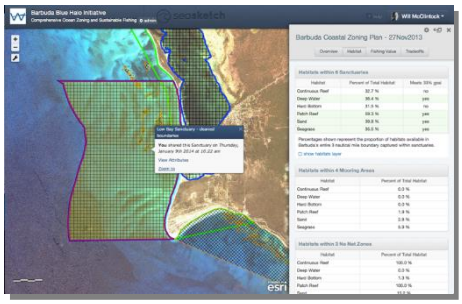
SeaSketch (www.seasketch.org) is software as a service for the collaborative "geodesign" of marine spatial plans (MSP). Currently, SeaSketch is being used for planning marine reserves, aquaculture sites, renewable energy sites, tourism zones, mooring and anchorage zones in New Zealand, the United States, British Columbia, Australia, the Caribbean, Mediterranean Sea, the United Kingdom, and other geographies. Designed primarily for use by non-technical individuals – stakeholders, resource managers, and the general public – SeaSketch allows users to draw ("sketch") prospective plans, receive analytical reports on potential consequences of plans, share and discuss plans with other users in map-based forums.

In this presentation, I will demonstrate how SeaSketch was used throughout 2013 to develop a comprehensive zoning plan for the island of Barbuda (barbuda.seasketch.org). Referencing habitat map derived from a SPOT satellite image, fisheries maps developed in collaboration with local fishers, and biological survey data (e.g., distribution and abundance of conch, lobster and fish), stakeholders authored plans for no-take reserves, mooring and anchorage zones and tourism zones. SeaSketch provided real-time feedback on whether plans met science guidelines for ecosystem protection (based on the habitat maps) and minimizing impacts to fishers (based on the fishing hot-spot maps). Users then shared and debated alternate plans in the map-based forums. The Barbuda Council has used SeaSketch to gage stakeholder support and opposition to plans and the Antiguan government is expected to approve these plans in February 2014.

This relatively simple demonstration of how SeaSketch can be used to rapidly develop marine spatial plans using satellite-derived habitat maps in the Caribbean illustrates two key points. First, habitat maps play a central role in marine spatial planning as the primary means by which scientists (or science-based tools such as SeaSketch) analyse and evaluate prospective marine spatial plans. Second, because SeaSketch projects like the one in Barbuda may be developed within a few hours - including the development of geoprocessing and map services used to analyse and visualize habitat data – the technical barriers to using a geodesign tool for effective MSP processes have been dramatically lowered. If data quality is sufficient, we are now poised to rapidly create stakeholder- and science-driven marine spatial plans on a very large scale.

Given the importance of habitat maps in MSP, and the repeated use of these maps in SeaSketch, I would like to explore how SeaSketch might be used to improve the quality of these maps. As a software service, we can potentially use SeaSketch to host geoprocessing services based on lightweight algorithms for the interpretation of satellite images, depending on computational intensity. Particularly if analytical code is open-sourced, SeaSketch would provide a platform for all interested scientists to scrutinize and evaluate habitat maps derived from this system. Of course, we can also design survey methods using SeaSketch as a means of ground-truthing habitat maps derived from satellite (or other) data. SeaSketch may be used to host survey data (including point counts, transects and associated images and video) and the forums may be used for private or public discussions deliberate how well remote sensed data match observations on the ground





Novelty detection in time lapse image data

Torben Möller[1], Ingunn Nilssen[2,3], Paulo Yukio Gomes Sumida[4], Karin L. Elbers[4] and Tim W. Nattkemper[1]

[1]Biodata Mining Group, University of Bielefeld, D-33615 Bielefeld, Germany, tmoeller@cebitec.uni-bielefeld.de

[2]Statoil ASA, Research, Development and Innovation, N-7005 Trondheim, Norway

[3]Trondhjem Biological Statoil, Department of Biology, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

[4]Benthic Dynamics Laboratory-Instituto Oceanografico da Universidade de Sao Paulo. Praca do Oceanografico, 191-CEP 05508-120, Brazil

Automated detection of changes in underwater images is an important task in the field of benthic habitat monitoring since it can help estimating the stress for the benthic ecosystem. The underlying cause for change in image data can be change in the sensor system (like signal noise or motion of the camera) or short term changes (like moving megafauna) or long term changes or periodic phenomena**.** A system for automated image analysis should be able to recognize which one of the four reasons mentioned before causes the image data to change.

This presentation will show how a statistical model can detect moving megafauna in time laps image data. Moreover approaches will be discussed on how datamining techniques can be used to make an automated system differentiate between different reasons of changes in image data.

A global analysis of the effectiveness of marine protected areas in the face of climate change

Jacquomo Monk[1]

[1]Deakin University, Centre for Integrative Ecology, School of Life & Environmental Sciences, Faculty of Science, Engineering and Built Environment, P.O. Box 423, Warrnambool, Victoria, Australia, jacquomo.monk@deakin.edu.au

Marine Protected Areas (MPAs) are receiving increased attention as a tool to manage, conserve, and augment marine resources. By limiting or preventing fishing and other extractive activities, MPAs have been relatively successful in restoring populations of overharvested marine species (e.g. fish). However, as marine species ranges potentially shift with changing climate it is important to understand how effective will these MPAs will remain in protecting these species. In this presentation I will take a global approach to investigate how effective current MPAs are in protecting the current ranges of IUCN listed marine fishes, and how these are likely to change under future climate change. This research will highlight the importance of considering future changes in species ranges in MPA planning.

Challenges for optimising and integrating systematic marine conservation planning

Cordelia Moore[123], Ben Radford[2], Hugh Possingham[4], Andrew Heyward[2], Matthew Watts[4], Romola Stewart[5], Stephen Newman[6], Euan Harvey[7], Mike Cappo[2], Shaun Wilson[5], Sarah Bignell[5], Jim Prescott[8], Clay Bryce[9], Rebecca Fisher[2], Thor Saunders[10], Ryan Lowe[1], Alexis Espinosa[1], Greg Oliver[11], Linda Abdo[11], Ross Jones[2], Oliver Berry[3], Damian Thomson[3] and Luke Smith[12]

[1]University of Western Australia, Perth, WA 6009, Australia, cordelia.moore@uwa.edu.au

[2]Australian Institute of Marine Science, Perth, WA 6009, Australia

[3]Commonwealth Scientific and Industrial Research Organisation, Perth, WA 6010, Australia

[4]University of Queensland, Brisbane, QLD 4072, Australia

[5]Department of Parks and Wildlife, Perth, WA 6151, Australia

[6]Department of Fisheries Western Australia, Perth, WA 6025, Australia

[7]Curtin University, Perth, WA 6102, Australia

[8]Australian Fisheries Management Authority, Darwin, NT 0801, Australia

[9]Western Australian Museum, Perth, WA 6986, Australia

[10]Department of Primary Industry and Fisheries, Darwin, NT 0801, Australia

[11]INPEX, Perth, WA 6000, Australia

[12]Woodside, Perth, WA 6000, Australia

Balancing marine biodiversity conservation and industry interests can be difficult, particularly in regions that support both important biodiversity values and industry assets. Australia's north west supports some of the world's most pristine and biologically diverse marine ecosystems while also supporting internationally significant oil and gas reserves. With the majority (92%) of Australia's conventional gas resources located in Australia's northwest, and gas production expected to quadruple by 2035, finding the right balance between biodiversity conservation and industry interests is difficult and potentially expensive.

In December 2013 I lead a workshop to examine the state and commonwealth marine reserve network to the north west of Australia. The workshop included representatives from universities, government and industry. During the workshop we examined the representativeness of the current and proposed strict no take areas. With little data available on biodiversity we used the Integrated Marine Coastal Regionalisation of Australia using the proxy of benthic geomorphology. The most vulnerable section of our marine region is the continental shelf (less than 200m depth), where threats to biodiversity are concentrated. Despite this, we found that the majority (75%) of the proposed no take areas were focussed on the abyssal plain (3000-6000m).

To address this we looked to run our own cost benefit analysis to see whether we could find a more representative solution while minimising the impact on industry. We compiled a more comprehensive set of data for the region including more than 600 species distribution models, fisheries catch and effort data and oceanographic models. We then employed an advanced spatial planning tool (Marxan) to investigate where marine protected areas could be expanded to improve representativeness while also accommodating socio-economic interests.

Marine bottom classification with sidescan sonar at National Natural Park Corales del Rosario y San Bernardo (PNNCRSB), Colombia

David F. Morales[1], Jhon Ahumada[2] and Carlos E. Peña[1]

[1]Marine and coastal research institute - INVEMAR, Marine Geoscience Program, Calle 25 No.2-55 Sector Salguero, Santa Marta, Magdalena, Colombia, david.morales@invemar.org.co

[2]University of Cauca, Faculty of Natural Sciences, Exact, and Education, Popayan, Cauca, Colombia

The marine habitats of PNNCRSB have been classified by means of diving observations and satellite image interpretation (Serrano y Quintero, 1992; Quintero et al., 1993, Cendales et al., 2002). These activities have not had enough resolution leaving information gaps in specific areas. Three different areas were surveyed using sidescan sonar (SES 2000 Compact) during 2012. Different mosaics were obtained which was processed using SEHEN software. This software, in development with collaboration of the University of Cauca, is a supporting tool on the sidescan sonar information analysis. SEHEN software did the classification of sea floor on five classes by means of a comparison scheme allowing improving borders and limits of the bottoms previously identified. For the improvement of SEHEN derived data, is necessary a calibration using: i) the expert knowledge and ii) the previous knowledge of the bottoms expected in each region. The obtained classification by means of SEHEN use shows greater bottom discrimination. These changes could be related to changes on grain and biotic composition, requiring later field inspection and further software training. Initially two main substrates were identified at PNNCRSB studied areas: i) substrate related to biogenic sand and ii) coralline bottoms. In detail, using the classification made with SEHEN it was possible to divide five different bottoms: sand, sand with seagrass, coralline formations, coralline patches and coralline formations with debris. A posterior field examination (dive inspection) confirmed that the areas defined by the interpretation of sidescan sonar mosaics are well related with the real structure of the bottom, aiming to contribute on the detailed mapping of bottoms on marine protected areas from Colombia.

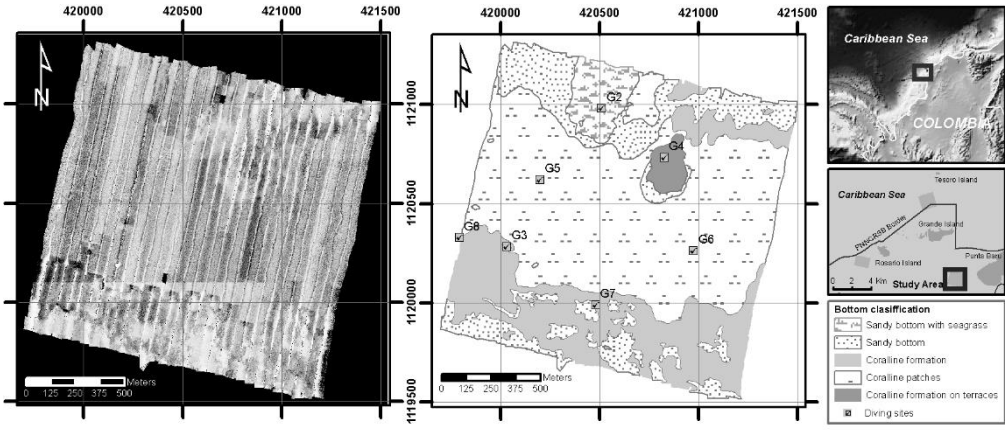


Figure 1. Bottom classification at SE Arena Island (PNNCRSB)

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Opportunistic discovery of gas seep features by industry survey: challenges in multidisciplinary identification, and applications for marine spatial planning

Tamsyn Noble[1], Paul Collins[1], Andrew Griffith[1], Yessica Griffiths[1], Geraint Harris-Bryant[1] and Sarah O'Flynn[1]

[1]Fugro EMU Limited, Morton Peto Rd, Great Yarmouth, Norfolk, United Kingdom, tamsyn.noble@fugroemu.com

In recent decades a growing awareness of marine ecosystem services has vastly increased the onus on industries to minimise environmental impacts, and offshore operators are more frequently required to assess the benthic environment prior to obtaining regulatory consent for developments. Acquisition of these data is critical for mitigation of habitat damage, and aids spatial planning and implementation of conservation measures for habitats which are rare or functionally valuable in a wider spatial context.

Methane-derived authigenic carbonates (MDAC) are biogenic features associated with the seepage of hydrocarbon-rich gas and fluid from sub-bottom strata, also known as cold seeps. Despite ongoing developments in cold seep research, there is a distinct paucity of knowledge regarding the distribution, ecosystem function, and vulnerability of these features. Although the habitat is poorly understood, the EU conferred Annex I conservation status upon 'Submarine structures made by leaking gases', in recognition of their relative scarcity and associated increase in habitat complexity, attachment substrate, chemotrophic primary production, and assemblages of rare and endemic organisms. Whilst high costs and logistical difficulties may limit academic research on MDAC, information acquired in the course of industry surveys may contribute significantly to understanding the distribution, morphology and ecology of these features. The bias of most offshore industry surveys towards areas overlying hydrocarbon reserves may also increase the likelihood of encountering MDAC, particularly in the case of gas hydrates, which are predicted to become a major future hydrocarbon source.

This presentation will focus on the process and challenges of MDAC identification from industry survey data, illustrated by case studies, including mud volcanoes, Arctic ice-scour features, and North Sea pockmarks. Conclusive identification of MDAC is only possible via sampling and carbon isotope analysis, however, this potentially damaging practice generally requires regulatory dispensation, and is not typically appropriate for industry surveys, where most observations are opportunistic. A multidisciplinary approach to MDAC identification and mapping is therefore employed as standard, combining a range of geophysical and biological indicators. Multibeam bathymetry data may be used to identify pockmark features (although MDAC is not exclusively associated with explosive gas release), while side scan sonar data reveals a highly reflective signature returned by concretions, in addition to bubbles in the water column. Shallow gas accumulations, sub-cropping carbonate horizons and venting gases may be observed from sub-bottom profile data. Seabed video and photographic data provide ground-truthing evidence of carbonate concretions, gas bubbles, chemotrophic fauna, and mats of the sulphur-reducing bacteria *Beggiatoa.* Interpretive confidence is dependent on the quality and quantity of corroborating data sources, and offshore survey conditions; the significance of these factors is explored with reference to the case study data.

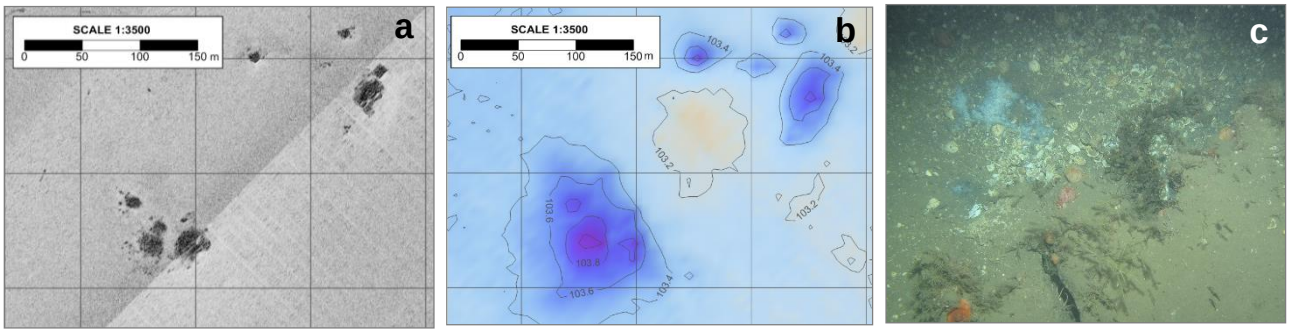


Figure 1: a) Side scan sonar data showing North Sea pockmarks with MDAC, b) corresponding multibeam bathymetry data, c) seabed photograph showing MDAC, shell hash, epifauna and *Beggiatoa* bacterial mats.

Automated Image based Biomass Quantification in Mesocosm Studies

Jonas Osterloff[1], Tim W. Nattkemper[1] and Torben Möller[1]

[1]Biodata Mining Group, Biodata Mining Group, Bielefeld University, 33615 Bielefeld, Germany, josterlo@cebitec.uni-bielefeld.de

Image analysis is a powerful tool to evaluate mesocosm studies in which for example biomass quantification or color changes are examined. Imaging the experiment samples is a comfortable way of conserving results.

Before making a mesocosm study the experimentalist should fulfill specific needs for the later automated image analysis. Having a good working system of automated image analysis is a desirable goal as it makes analyzing images highly reproducible, easier and faster than it can be done by human experts.

From the computer scientist's point of view it is necessary to have a specific amount of images that are comparable to each other in reference to light, rotation of the object and zoom factor.

In the oral presentation different means of dealing with problems that occur when imaging experiment samples are given. From the computer scientist's point of view those problems can be divided into post-solvable and post-unsolvable problems. Those problems are presented by exemplary referring to a stress calc. algae mesocosm study. Suggestions how to avoid problems that cannot be post-solved are presented.

Mapping biomass and habitat of the Northern Demersal Scalefish Fishery, Western Australia

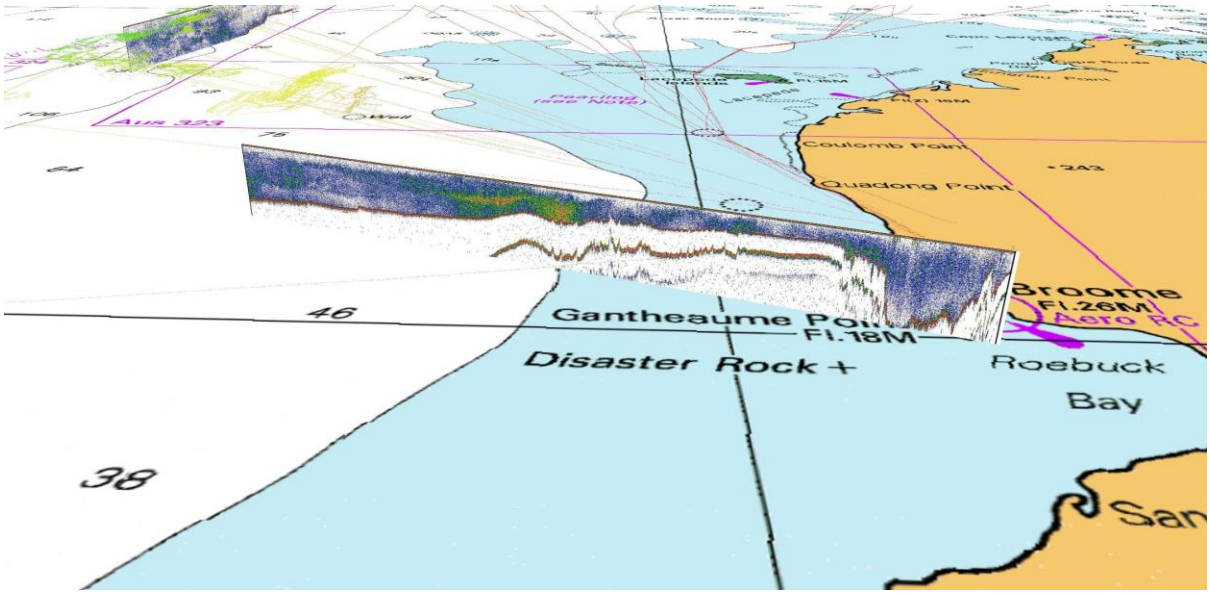
Iain Parnum[1], Miles Parsons[1], Adam Masters[2], Brett Molony[3], Elizabeth Mair[1], Luke Wreyford[1] and Robert McCauley[1]

[1]Centre for Marine Science and Technology, Curtin University, Perth, Western Australia, i.parnum@curtin.edu.au

[2]Kimberley Wildcatch, Broome, Western Australia

[3]Department of Fisheries Research, Government of Western Australia, Hillarys, WA

The Northern Demersal Scalefish Fishery (NDSF) stretches from southwest of Broome to the Northern Territory border in waters off the North West Coast of Western Australia, covering over 200,000 km^2. Target species include red emperor (*Lutjanus sebae*), goldband snapper (*Prisipomoides multidens*), other snappers, emperors and cods. Here, these species are typically demersal, forming assemblages of varying composition. A study is underway that aims to map the seafloor habitat and water-column abundance throughout the fishery using a fishing vessel's 'time at sea'. In April 2012, a multi-frequency single beam echo-sounder (Simrad ES70), with 18, 38, 120 and 200 kHz transducers (38 and 120 kHz being splitbeam transducers) was hull-mounted on the Carolina M of Kimberley Wildcatch. The objective is to examine areas of high commercial effort for relationships with the different acoustic habitats and acoustic biomass. To date over 35,000 km of acoustic data have been collected, together with video ground-truth data of habitat, catch and some of the ones that got away. Maps of bathymetry have been produced using the single beam data for site specific areas, and combined through cokriging with Geoscience Australia's 250 m grid from GeoScience Australia to produce a 200 m grid for the whole area. This paper will highlight some of the findings so far, the advantages/disadvantages of working with industry acquired data and the future plans of the project for the next two years.



Example of single beam echo-sounder data collected in Northern Demersal Scalefish Fishery shown over a chart of the area.

Processing and applications for water column backscatter collected with multibeam sonar systems

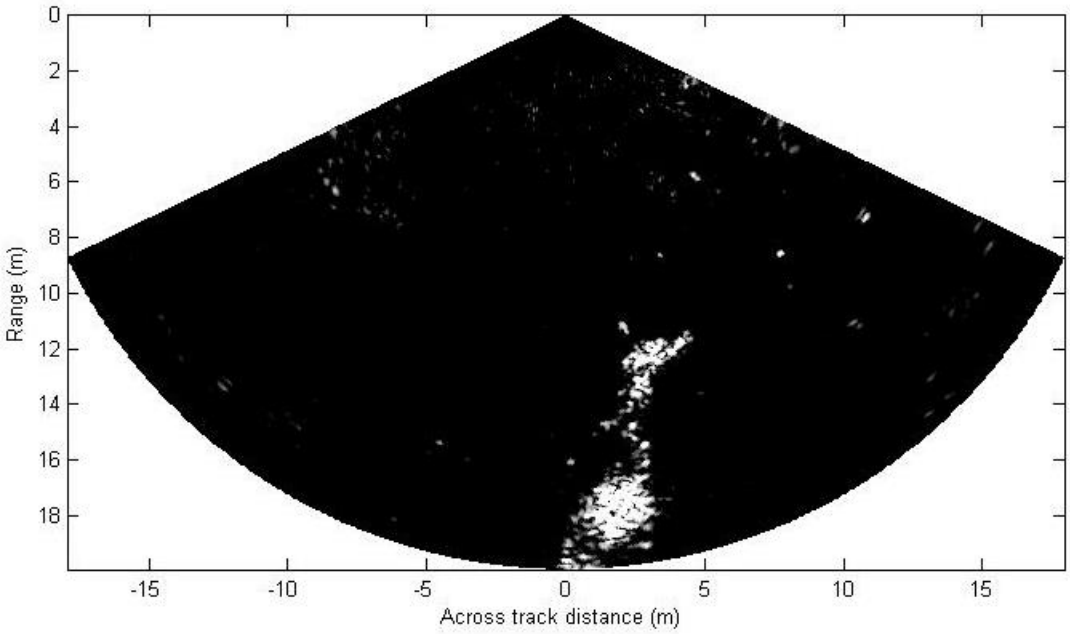
Iain Parnum[1], Miles Parsons[1], Tyler Ellement[1] and Alexander Gavrilov[1]

[1]Centre for Marine Science and Technology, Curtin University, Perth, Western Australia,
i.parnum@curtin.edu.au

Traditionally, multibeam sonar (MBS) systems have been used to collect data to be able to produce high-resolution bathymetry. Advances in hardware have allowed for the collection of the complete time series from each beam within the sonar swath. This, in turn, facilitates the development of new applications of MBS, but with it new challenges in computation and visualisation of the resulting large volumes of data. This talk will present some applications of collecting water column backscatter using MBS, as conducted by the authors, including:

- Fisheries acoustics
- Canopy height estimation
- Turbidity measurements
- Marine mega fauna detection
- Seep detection

The processing pipeline and visualisation challenges are also discussed.



A single ping of water column data from a Reson Seabat 7125 multibeam sonar of a man swimming.

The use of seabed scoured depressions as a proxy for near-seabed flow

Kim Picard[1], P. Justy W. Siwabessy[1], Lynda Radke[1] and Scott L. Nichol[1]

[1]Geoscience Australia, GPO Box 378, Canberra, Australian Capital Territory, Australia, kim,picard@ga.gov.au

The Oceanic Shoals Commonwealth Marine Reserve (CMR) (>71,000 km^2) is located in the Timor Sea and is part of the National Representative System of Marine Protected Areas of Australia. The Reserve incorporates extensive areas of carbonate banks and terraces that are recognised in the North and North West Marine Region Plans as Key Ecological Features (KEFs). Although poorly studied, these banks and terraces have been identified as potential biodiversity hotspots for the Australian tropical north. As part of the National Environment Research Program Marine Biodiversity Hub, Geoscience Australia in collaboration with the Australian Institute of Marine Science undertook a marine biodiversity survey in 2012 to improve the knowledge of this area and better understand the importance of these KEFs. Amongst the many activities undertaken, continuous high-resolution multibeam mapping, video and still camera observations, and physical seabed sampling of four areas covering 510 km^2 within the western side of the CMR was completed.

Multibeam imagery reveals a high geomorphic diversity in the Oceanic Shoals CMR, with numerous banks and terraces, elevated 30 to 65 m above the generally flat seabed (~105 m water depth), that provide hard substrate for benthic communities. The surrounding plains are characterised by fields of depressions up to 1 m deep (pockmarks) formed in soft silty sediments that are generally barren of any epibenthos (Fig .1). A distinctive feature of many pockmarks is a linear scour mark that extends several tens of metres (up to 150 m) from pockmark depressions. Previous numerical and flume tank simulations have shown that scouring of pockmarks occurs in the direction of the dominant near-seabed flow. These geomorphic features may therefore serve as a proxy for local-scale bottom currents, which may in turn inform on sediment processes operating in these areas and contribute to the understanding of the distribution of biodiversity.

This study focused on characterising these seabed scoured depressions and investigating their potential as an environmental proxy for habitat studies. We used ArcGIS spatial analyst tools to quantify the features and explored their potential relationships with other variables (multibeam backscatter, regional modelled bottom stress, biological abundance and presence/absence) to provide insight into their development, and contribute to a better understanding of the environment surrounding carbonate banks. Preliminary results show a relationship between pockmark types, (i.e. with or without scour mark) and backscatter strength. This relationship suggests some additional shallow sub-surface control, mainly related to the presence of buried carbonate banks. In addition, the results suggest that tidal flows are redirected by the banks, leading to locally varied flow directions and “shadowing” in the lee of the larger banks. This in turn is likely to have an influence on the observed density and abundance of benthic assemblages.

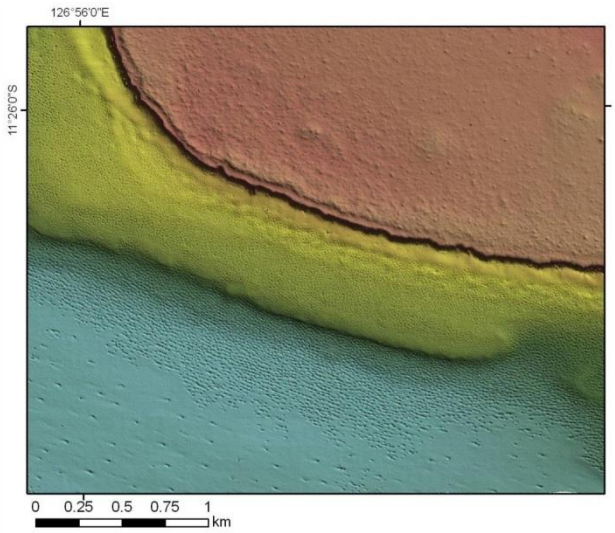


Figure 1: Pockmark field adjacent to a carbonate reef, with scoured pockmarks in the lower left.

Multidisciplinary study of the upper reach of a shelf-indenting canyon (Gioia Canyon, Thyrrenian Sea). Depositional processes and human activity.

Martina Pierdomenico[1], Eleonora Martorelli[2], Federico Falcini[3], Daniela Pica[4] , Giannetta Fusco[5], Giorgio Budillon[5], Pierpaolo Falco[5] and Francesco L. Chiocci[1]

[1]Sapienza University of Rome, Department of Earth Sciences, Rome, Italy, martina.pierdomenico@uniroma1.it

[2]Italian National Research Council, Institute of Environmental Geology and Geo-Engineering (IGAG), Italy

[3]Italian National Research Council, Institute of Atmospheric Sciences and Climate (ISAC), Italy

[4]Università Politecnica delle Marche, Dipartimento di Scienze della Vita e dell'Ambiente, Italy

[5]University of Naples Parthenope, Italy

Submarine canyons are ubiquitous features along continental margins that act as preferential conduits for transfer of water masses, sediments, and organic matter from the shelf to deep basins. The topography and hydrodynamic features of submarine canyons can contribute to increase habitat heterogeneity, promote benthic biodiversity and create biomass hotspots. On the other hand, the enhanced local fishery production often associated with the presence of submarine canyons indenting the continental shelf, expose these environments to intense trawling activity. Furthermore, these canyons may also act as potential pathway for the transfer of pollutant from coastal to deep sea environment.

The Gioia Canyon is a shelf-indenting canyon that extends for about 60 km across the continental slope of the Gioia basin and is intercepted by the Stromboli Canyon at ~1700m depth. The canyon head deeply incise the narrow continental shelf up to water depth of only 5–10 m and is located in front of Gioia Tauro Harbour, the largest terminal for the transhipment of the Mediterranean Sea. In the framework of Ritmare Project (http://www.ritmare.it) a recent oceanographic cruise was conducted, collecting an extensive dataset that includes Multibeam bathymetric and backscatter data, Chirp profiles, grab samples, ROV videos, CTD and ADCP casts. This provides a special opportunity to examine in detail the complex interplay among geological, oceanographic and biological processes occurring in a highly dynamic environment.

Preliminary results indicate active transport of sediment within the Gioia Canyon and its southern tributary, the Petrace Canyon, whose heads incise the littoral wedge up to 150 m from the coastline, thus intercepting the sediment from the northward littoral drift. Furthermore, the canyon heads are located in front of the mouth of two high-energy streams (fiumare) characterized by short and steep courses, torrential discharges with high sediment supply. Sediment transport is mainly suggested by variations and migration of crescent-shaped bedforms within the thalweg at the head of the canyons and by the presence of sand and terrestrial vegetal material in sediment samples from the thalweg at 500 m depth. CTD/ADCP casts indicate increases in near-bottom water turbidity in correspondence of the river mouths and within the thalweg at 200 m depth, where currents of 10-15 cm/s flowing down-canyon are associated with turbidity peaks. ROV videos show predominance of highly bioturbated soft bottoms dominated by pennatulaceans (*Pennatula* spp. and *Funiculina quadrangularis*) and by the hydroid *Lytocarpia myriophyllum*, typically occurring in assemblages with monospecific dominance. However, high density of bottom trawling marks, long-line fishing and littering observed in almost all the ROV videos, together with the conspicuous amount of plastic detritus collected in the sediment samples, indicate intense human impacts in the area that may affect the integrity of the observed habitats. Potential disposal sites of dredged material from the harbour were also detected along the outer shelf and at the canyon margins.

The major research results from the integrated analysis of the multidisciplinary dataset will be presented, focusing on the main processes acting on the seafloor (including human impacts) and their influence on the distribution of habitats and macro-benthic communities.

An assessment of proposed Marine Protected Areas in East Antarctica: A Geoscience perspective

Alix Post[1], Olivia Wilson[1] and Phil O'Brien[2]

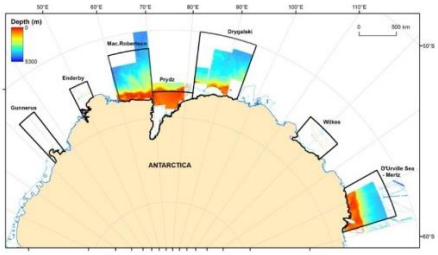
[1]Geoscience Australia, GPO Box 378, Canberra ACT 2601, Australia, alix.post@ga.gov.au

[2]Department of Environment and Geography, Macquarie University, NSW 2109

In 2010, a network of Marine Protected Areas (MPAs) was proposed for the East Antarctic region. This proposal was based on the best available data, which for the benthic regime consisted chiefly of seabed geomorphology and satellite bathymetry data. Case studies from the East Antarctic region indicate that depth and morphology are important factors in delineating marine benthic communities, particularly on the continental shelf. However, parameters such as sediment composition also show a strong association with the distribution and diversity of benthic assemblages.

To support the justification of the proposed MPA network, sediment and bathymetry data were compiled across the East Antarctic region (Post, 2013; Wilson, 2013). The incorporation of sediment properties and higher resolution bathymetry grids (Figures A and B) has enabled a better assessment of the nature of benthic habitats within the proposed MPA network. Based on these physical properties, and in combination with the seabed morphology, we can now distinguish a range of distinct habitats, such as deep muddy basins, scoured sandy shelf banks, ruggedly eroded slope canyons and muddy deep sea plains. In this presentation, we assess the types of benthic habitats across the East Antarctic region, and then determine how well the proposed MPA network represents the diversity of habitats across this margin. The diversity of physical environments within the proposed MPAs suggests that they likely support a diverse range of benthic communities which are broadly representative of the surrounding region. This research has been conducted in support of Australia's Antarctic Science Strategy (Stream 3.4, Protecting Marine Biodiversity) and Geoscience Australia's Marine Bioregional Planning program.

A



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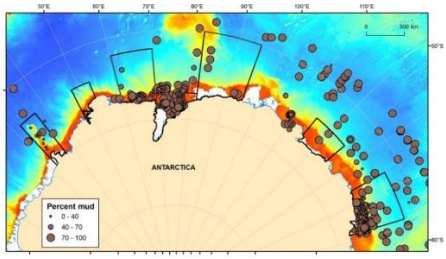

A) High resolution bathymetry grids within the East Antarctic MPAs (Wilson, 2013); B) Distribution of compiled sediment data and values for percent mud across the region (Post, 2013).

Post, A.L., 2013. A compilation of grainsize, biogenic silica and carbonate data from East Antarctica surface sediments. Record 2013/05. Geoscience Australia: Canberra.

Wilson, O. A. 2013. *Bathymetry Compilation for Proposed Marine Protected Area in East Antarctica: Technical Report*. Record 2013/24. Geoscience Australia: Canberra.

Assessment of protection of coral reef ecosystems in Brazil

Robert L. Pressey[1], Morena Mills[2] and Rafael A. Magris[1]

[1]Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland, Australia, rafael.magris@my.jcu.edu.au

[2]Global Change Institute, the University of Queensland – UQ, Brisbane, Queensland, Australia

Brazilian coral reefs, despite their high biological importance and provision of many ecosystem services, have been affected adversely by a variety of anthropogenic activities, especially excessive fish-take and destructive fishing techniques (e.g. Ferreira et al. 2004). Although an extensive portion of these ecosystems is encompassed by marine protected areas (MPAs), most of the protection is provided by large areas in which various extractive activities are permitted (Magris et al., 2013). A refined investigation of whether the existing MPA network comprehensively represents the spatial variation in coral-reef biodiversity also remains to be done. We expand the analyses carried out in a previous study to assess the extent to which MPAs represent more finely delineated coral-reef ecosystems and provide guidelines for a regional conservation plan. High- and very high-resolution satellite images (IKONOS and LANDSAT) were processed to build a coral-reef map that was intersected with bathymetry, boundaries of marine ecoregions, and tidal zones. Combining six geomorphic types (nearshore bank, bank off the coast, fringing, patch, and mushroom reef, and atoll) with four ecoregions (Amazon, Northeastern, Eastern, and Fernando de Noronha and Atoll das Rocas), two depth classes (deep and shallow), and two tidal zones (subtidal and intertidal), we produced a map of 23 types of coral-reef ecosystems. The spatial dataset of our MPA network contained 18 individual protected areas including three levels of protection (4 no-take areas, 4 extractive reserves, and 10 multiple-use areas). Currently, the protection of coral reef ecosystems by no-take areas is very uneven (protection ranged from 0% to 99%; median=0%, mean=28%), with 13 of 23 ecosystems having no coverage (mostly nearshore banks and patch reefs located at north-eastern coast). Conversely, if we consider all MPA categories combined, coral-reef ecosystems showed a high level of protection (8 ecosystems had 100% coverage, median=95%, mean=77%). However, while aiming to integrate conservation and economic activities, MPAs other than no-take areas have not been well implemented. Most lack management plans and their allowance of extractive activities are inconsistent but generally liberal. Our results reflect the bias in distribution of MPA types across different ecosystems. Increasing the effective protection of coral reefs in Brazil is critical, not only to achieve government commitments but also to ensure marine resources are sustained through time. We recommend that a conservation plan for Brazilian coral reefs considers: (i) the expansion of no-take areas for the coral-reef ecosystems identified here, and (ii) more effective implementation of the less restrictive existing MPAs as a way to ensure sustainable management of coral reefs.

References

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Magris RA, Mills M, Fuentes MMPB, Pressey RL (2013) Analysis of progress towards a comprehensive system of Marine Protected Areas in Brazil. Natureza & Conservação 11:81–87

Using multibeam-derived variables to characterise regional patterns in tropical sponge assemblages in northern Australia

Rachel Przeslawski[1], Belinda Alvarez[2] and Scott L. Nichol[1]

[1]Geoscience Australia, GPO Box 378, Canberra ACT 2601, Australia, Rachel.przeslawski@ga.gov.au

[2] Museum and Art Gallery of the Northern Territory, PO Box 4646, Darwin NT 0801, Australia

Australia is increasingly recognised as a global hotspot for sponge biodiversity, with sponges playing key roles in habitat provision, water quality, bioerosion, and biodiscovery. Despite the intense focus on marine resource management in northern Australia, there is a large knowledge gap about sponge communities in this region. This study focuses on shelf environments of the Timor Sea, in particular the Van Diemen Rise and Londonderry Rise which are characterised by extensive carbonate terraces, banks and reefs, separated by soft sediment plains and deeply incised valleys. These carbonate terraces and banks are recognised as a Key Ecological Feature (KEF) in the marine region plans for northern Australia (North and Northwest Marine Regions) and are in part incorporated into the Oceanic Shoals Commonwealth Marine Reserve. To support the management of this marine reserve and its associated KEF, we use new datasets to investigate regional patterns in sponge assemblages and their relationships to seabed geomorphology. To do this, we use sponge assemblage data and multibeam-derived variables (depth, backscatter, slope, geomorphic feature) from seven survey areas located on the Van Diemen Rise (four sites) and Londonderry Rise (three sites), spanning approximately 320 km in an east-west direction. The dataset was collected during three collaborative surveys undertaken in 2009, 2010, and 2012 by Geoscience Australia, the Australian Institute of Marine Science and the Museum and Art Gallery of the Northern Territory as part of the Australian Government's Offshore Energy Security Initiative and the National Environmental Research Program Marine Biodiversity Hub. All surveys returned geophysical, biological, geochemical, and sedimentological data. Benthic biota were collected with a benthic sled across a range of geomorphic features (bank, terrace, ridge, plain, valley) identified from high-resolution multibeam sonar. Sponges were then taxonomically identified to 350 species, with the species accumulation curve indicating there may be over 900 sponge species in the region. Sponge assemblages were different between the Van Diemen Rise and Londonderry Rise, as well as between individual banks in the same area, indicating that different suites of species occurred at regional (east-west) and local (between banks) scales. Relationships between sponges and other multibeam-derived variables are more complex and warrant further research. The current study will help: i) facilitate integrated marine management by providing a baseline species inventory; ii) support the listing of carbonate banks of the Timor Sea shelf as a Key Ecological Feature, and; iii) inform future monitoring of marine protected area performance, particularly for areas of complex seabed geomorphology.

Linking patterns and processes on a tropical sediment-starved shelf: Insights from cluster analysis on physical and geochemical variables

Lynda Radke[1], Jin Li[1], Grant Douglas[2], Rachel Przeslawski[1], Scott L. Nichol[1], P. Justy W. Siwabessy[1], Janice Trafford[1] and Tanya Whiteway[1]

[1]Coastal, Marine and Climate Change Group, Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Lynda.Radke@ga.gov.au

[2] CSIRO Land & Water, Private Bag No.5, Wembley, WA 6913

Geoscience Australia undertook seabed mapping surveys in the eastern Bonaparte Gulf in 2009/2010 to deliver integrated information relevant to marine biodiversity conservation and offshore infrastructure development. The survey objectives were to characterise the physical, chemical and biological properties of the seabed, document potential geohazards and to identify unique or sensitive benthic habitats and collect baseline information on these habitats. Different clustering methods were applied to a 124 sample dataset comprising 74 physical and geochemical variables which describe organic matter (OM) reactivity/quantity/source and (bio-) geochemical processes relevant to biodiversity. Infauna data were used to assess different groupings because they are an important food source for epibenthic crustaceans and fish and purveyors of ecosystem services including nutrient cycling and mineralisation. Clusters based on physical/geochemical data discriminated infauna better than geomorphic features. Major variations amongst clusters included grainsize and a cross-shelf transition from sediment authigenic Mn and As enrichments (inner shelf) to sediment authigenic-P enrichment (outer shelf) which relate to energy levels and sediment oxygen status. Clusters comprising raised features had the highest reactive OM concentrations (e.g. based on low chlorin indices and C:N-ratios, and high *k*) and benthic algal $\delta^{13}C$ signatures. Surface area normalised OM concentrations higher than continental shelf norms were observed in association with: (i) low $\delta^{15}N$, inferring *Trichodesmium* input; and (ii) pockmarks. The pockmarks are shown to impart bottom-up controls on seabed chemistry and cause inconsistencies between bulk and pigment OM pools. The geochemical data and clustering methods provide insight into ecosystem processes which influence biodiversity patterns in the region. Low Shannon-Wiener diversity occurred in association with low porewater pH and evidence for low sediment redox status and high energy levels, while the highest beta-diversity was observed at euphotic depths. Pair-wise ANOSIM results for infauna are brought together in a summary model which highlights the influence of the clusters on beta diversity.

Arctic Nearshore Sediment Dynamics from High-Resolution Phase Measuring Bathymetric Sonar Data: bathymetry, backscatter imagery and seabed classification

B. Radosavljevic[1], F.J. Gutiérrez[2], H. Lantuit[1] and M. Gutowski[2]

[1]Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Telegrafenberg A43, Potsdam 14473, Germany

[2]Kongsberg GeoAcoustics Ltd., Shuttleworth Close ,Gapton Hall Industrial Estate, Great Yarmouth, NR31 0NQ, United Kingdom

Carbon-rich permafrost coasts in the Arctic are subject to rapid erosion, causing vast quantities of carbon and sediments to enter the nearshore. According to many climate models, the Arctic will experience disproportionate warming in coming decades. One of the consequences will be increased coastal erosion, as the open water season lengthens. The release of carbon raises a number of questions ranging from the impact on local ecosystems, to potential climate change feedbacks. Due to the size and remoteness of arctic coasts, relatively few studies addressed the question of carbon transfer into the Arctic Ocean. These studies rely on remotely sensed data which means that the submarine portion of the coast, the processes and storage potential remain largely unknown. The Coastal Permafrost Erosion project by the Alfred Wegener Institute aims to answer some of these questions by quantifying erosion and characterizing eroded material for the whole coastal tract in the vicinity of Herschel Island, Yukon Territory, Canada. In this study, we describe the investigations of nearshore sediment and carbon dynamics carried out as part of the project in 2012 and 2013. The objective of the study is to establish a baseline dataset on bottom sediments, and gain insight into transport processes, pathways, and sinks.

The Kongsberg GeoAcoustics GeoSwath Compact 500 kHz phase-measuring bathymetric sonar system was chosen for the study. It is optimal for shallow water (<50 m) and delivers high-resolution, co-registered bathymetry and sidescan imagery. The bathymetric data provided insight into physical processes such as ice gouging (Fig. 1), while sidescan mosaics delivered a map of sediment distribution (Fig. 2). The side scan data was processed, mosaicked and classified using GeoTexture software, which turned out to be the optimum tool for these tasks as it compensates beam spreading, absorption, vessel motion (roll) and incident angle (local slope). Bathymetric data were processed using Kongsberg GeoAcoustics GS+ software and gridded at 0.5 m resolution.

Through the compensated backscatter imagery, we identified areas where fine sediments are deposited and carbon may be stored. The classified image was validated by grain size parameters from the benthic grab samples with a very high degree of correlation. A significant portion of the released carbon is particulate organic matter which is transported along with the sediment. Elemental analyses of the grab samples revealed that organic carbon may account for up to 9% of the bottom sediment. We also found that the shoreface is subject to intensive ice gouging. Finally, we found that the sediment distribution in the nearshore is related to terrestrial features being eroded, e.g. cliffs, or valleys.

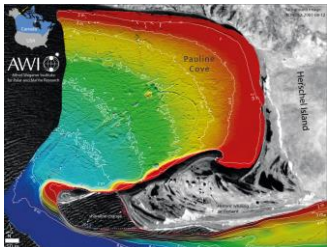

Figure 1. A close-up view on the bathymetry of Pauline Cove, Herschel Island. The linear features result from ice keel grounding on the sea bottom.

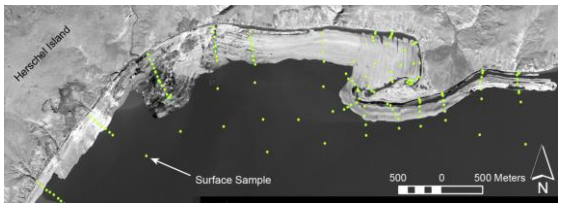

Figure 2. Backscatter data was used to map sediment distribution and validated by extensive surface sampling.

Wave-driven exposure as a surrogate for benthic habitat distribution

Alex Rattray[1,2], Daniel Ierodiaconou[2], Jacquomo Monk[2], Rozaimi Che Hasan[3] and Tim Womersley[4]

[1]University of Pisa, Department of Biology, Via Derna 1, Pisa, Italy, alex.rattray@for.unipi.it

[2]Deakin University, Centre for Integrative Ecology, School of Life & Environmental Sciences, Faculty of Science, Engineering and Built Environment, P.O. Box 423, Warrnambool, Victoria, Australia

[3]Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia

[4]Water Technology, 15 Business Park Drive, Notting Hill, Victoria, Australia

Exposure to hydrodynamic energy is one of the fundamental variables of the coastal environment and has been well demonstrated to play an integral role in the life histories and evolutionary biology of the organisms that live there. Despite the evidence linking the distributional ecology of marine taxa to their hydrodynamic environment there are few studies that explore the application of these variables for local-scale (10's -100's km^2) predictive distribution modelling. Acoustic habitat mapping uses sonar-derived variables as proxies to describe the range of physical conditions that define the realised niche and subsequent distribution of benthic species and assemblages. The role of wave exposure on habitat distribution is often only indirectly considered through associations with water depth and seafloor aspect. In shallow coastal zones the effect of wave energy is locally modified by factors such as coastline geometry and bottom topography. It is therefore unlikely that depth and orientation of the seafloor are fully indicative of structuring effects of wave exposure on benthic communities. A spectral wave model was developed for a site at Cape Otway, the major coastal feature of western Victoria, Australia. Comparison of models implemented using the Random Forests algorithm established that significantly more accurate estimations of habitat distribution were obtained by including a fine-scale numerical wave model, extended to the seabed using linear wave theory, than by using acoustic proxies alone. Variable importance measures showed that the exposure variable was most influential in discriminating habitat classes containing the canopy forming kelp *Ecklonia radiata*, a foundation species that affects biodiversity and ecological functioning on shallow reefs across temperate Australasia. This study demonstrates that hydrodynamic models reflecting key environmental drivers on wave exposed coastlines are important in accurately determining distributions of benthic habitats.

Abiotic surrogates for temperate rocky reef biodiversity: implications for Marine Protected Areas

Matthew J. Rees[1], Alan Jordan[2], Owen F. Price[1], Melinda A. Coleman[3] and Andrew R. Davis[1]

[1]University of Wollongong, School of Biological Sciences, Wollongong, New South Wales, Australia, mjr849@uowmail.edu.au

[2]NSW Department of Primary Industries, Locked Bag 800, Nelson Bay, Australia

[3]NSW Department of Primary Industries, Narooma, Australia

In response to rising concerns over continued marine biodiversity loss, global development of marine protected areas (MPAs) has been pursued as an effective conservation strategy. However, decisions on MPA location, configuration and size have often been driven by social, economic or political processes rather than on available ecological knowledge. Therefore, in the absence of a firm ecological foundation, current MPAs may not be achieving their stated conservation objectives, potentially providing a false sense of protection. The issue with establishing MPAs using defined biodiversity criteria stems from constraints and costs involved in acquiring species and community-level biological data over broad (100's m-km) geographical areas. An alternate approach adapted from terrestrial reserve design is the use of surrogates, such as abiotic measures, to indirectly identify representative areas of biodiversity and infer the boundaries for protected areas. In this study we examined the potential of remotely sensed abiotic measures as surrogates for the abundance, diversity and community composition of temperate rocky reef fishes and sessile invertebrates. We used high-resolution bathymetric side-scan sonar imagery to quantify abiotic measures of rocky reef habitat and examined the relationship between abiotic measures and (1) sessile invertebrate abundance, (2) sessile invertebrate species richness, (3) total fish abundance, (4) fish species richness, and (5) Monacanthidae abundance using generalized additive mixed models (GAMMs). We chose GAMMs as the preferred statistical analysis to account for the spatial autocorrelation present in our data. We found a strong positive relationship between abiotic measures and sessile invertebrate abundance and diversity ($r^2 > 0.64$). By far the most important predictor was vertical relief within a 75 m radii seascape surrounding the faunal survey. Overall, abiotic measures were poor predictors of total fish abundance ($r^2 = 0.175$) and fish species richness ($r^2 = 0.276$), with minimum adequate models producing low explanatory power. Monacanthids exhibited a strong positive relationship with abiotic variables ($r^2 = 0.385$), with increased abundance associated with greater depth and distance from soft sediment. In conclusion, remotely sensed abiotic measures were important predictors in describing the spatial patterns of sessile invertebrate abundance and diversity and Monacanthid abundance. In contrast, abiotic variables were poor predictors of total fish abundance and diversity. Our results highlight the potential of habitat as a useful, cost-effective surrogate to determine areas of conservation value for certain temperate rocky reef assemblages. This information is valuable for future MPA development and design.

Observed Variability in Seafloor Acoustic Backscatter During Repeat Surveys in Portsmouth Harbor, NH, USA

Glen Rice[1,2], Thomas C. Weber[2], Larry G. Ward[2], John Heaton[2], Carlo Lanzoni[2] and Eric Bajor[2]

[1]National Oceanic and Atmospheric Administration, 24 Colovos Road, Durham, New Hampshire, USA, glen.rice@noaa.gov

[2]Center for Coastal and Ocean Mapping / Joint Hydrographic Center, University of New Hampshire, 24 Colovos Road, Durham, New Hampshire, USA

The Center for Coastal and Ocean Mapping at the University of New Hampshire conducted repeat surveys over the same survey track for seafloor acoustic backscatter. One of the purposes of these surveys was to observe variability in the backscatter statistics associated with different seafloor types in order to further our understanding of seafloor backscatter measurements, and also for the purpose of creating a 'standard line' that could act as a backscatter reference for other hydrographic survey systems. Surveys were conducted weekly in the mouth of the tidally dominated Piscataqua River in New Hampshire, USA, over an eight month period. Higher frequency sampling was also conducted to observe backscatter variability within a single tidal cycle. Each survey was conducted with the same 200 kHz Simrad EK60 split-beam echo sounder mounted at a 45 degree angle to vertical. In addition, the EK60 acoustic response was checked against the same 38.1mm tungsten carbide reference sphere to track measurement consistency. The survey track passed over many different types of seafloor, both with and without bedforms, and with different compositions such as fine sand with shell hash, coarse sand, gravel, and outcropping bedrock. Some areas included macro algae or epifauna which may change with the season or in response to storms. These different areas were examined and compared to assess the consistency of the observed seafloor backscatter over the course of this study. While previous work using uncalibrated multibeam echosounders has suggested that some of these areas are changing over time on a scale of days, preliminary results suggest that seafloor backscatter, as observed with this echo sounder, is very stable in most of the study area. For example, the total variation over the 8 month period is approximately 1.7 dB for all data at a site within a known sand wave field; fifty percent of all data from this same site is within 0.3 dB of the average. Excluding any biological influence, gravel or rock areas might be expected to produce stable backscatter over time, but it was not expected that changing bedform fields would show similar stability. These preliminary results suggest that even though there may be changes in individual realizations of the seafloor in the study area in response to tidal currents or other forcing functions, the statistics of the seafloor roughness and volume scattering that are relevant to the acoustic response are stationary on long time scales. In the light of our preliminary work in this area, these results raise questions regarding how changes in seafloor characterization and backscatter might be observed depending on the instruments that are used and the processing techniques that are applied.

Finding the hot-spots within a biodiversity hotspot: Fine-scale biological predictions within a submarine canyon

Katleen Robert[1], Daniel O.B. Jones[2], David Van Rooij[3] and Veerle A.I. Huvenne[2]

[1]School of Ocean and Earth Science, University of Southampton, Southampton, UK, kr2r11@soton.ac.uk

[2]National Oceanography Centre, Southampton, UK

[3]Renard Centre of Marine Geology, University of Gent, Gent, Belgium

Submarine canyons are complex geomorphological features that have been suggested as potential hotspots for biodiversity. However few canyons have been mapped and studied at high resolution. In this study, the four main branches of Whittard canyon, Northeast Atlantic, were mapped using multibeam and sidescan sonars to examine which environmental variables are most useful in predicting regions of higher biodiversity. The acoustic maps obtained were complemented by 13 remotely operated vehicle (ROV) video imagery transects at depths ranging from 650 m to 4,000 m. Over 100 hours of video were collected, and used to identify and georeference megabenthic invertebrates species present within specific areas of the canyon. Both general additive models (GAMs) and random forests (RF) were used to build predictive maps for megafaunal abundance, species richness and biodiversity. Vertical walls were found to harbour the highest diversity of organisms, particularly when colonized by cold-water corals such as *Lophelia pertusa* and *Solenosmilia variabilis*. GAMs and RF gave different predictive maps and external assessment of predictions indicated that the most adequate technique varied based on the response variable considered. By using ensemble mapping approaches, results from more than one model were combined to identify vertical walls most likely to harbour a high biodiversity of organisms or cold-water corals. Such vertical structures were estimated to represent less than 0.1% of the canyon's surface. The approach developed provides a cost effective strategy to facilitate the location of rare biological communities and guide further sampling efforts to help ensure that appropriate monitoring can be implemented

Multiscale analysis of information content: How much information is lost and which scale should be used?

Katleen Robert[1], Daniel O.B. Jones[2] and Veerle A.I. Huvenne[2]

[1]School of Ocean and Earth Science, University of Southampton, Southampton, UK, kr2r11@soton.ac.uk

[2]National Oceanography Centre, Southampton, UK

Questions of scale are recurring in ecology and pixel size is one of the basic considerations of remote sensing. At too coarse a resolution, important features driving ecological processes might be missed, while at too fine a resolution, stochasticity can make identifying relationships difficult. Although there is no single appropriate scale at which to study a system and each scale can provide information regarding different processes, in many cases, particularly in deeper environments, a single resolution is often chosen arbitrarily due to data acquisition, time or cost limitations without the knowledge of how this choice affects the information acquired. Or in other words, we do not know how much information is lost by acquiring or processing data to a particular resolution.

As part of the CODEMAP project, three areas of Whittard Canyon, NE Atlantic, were mapped at fine resolutions (1m) using an ROV, while the broader canyon was also mapped at lower resolution (50m) using a ship-borne multibeam system. The area had also been mapped as part of the Irish National Seabed Survey (INFOMAR) at a third resolution (100m). Three ROV video transects were further collected to examine spatial patterns in megabenthic invertebrate density and diversity (1/D). Using information theory metrics, we examined how the entropy (the amount of information needed to encode the signal) and mutual information content (MIC, a measure of the information gained on signal *X* after measuring signal *Y*) changed across scale for both geomorphological and biological characteristics. MIC was also used to quantify how much information on the biological signal was acquired by examining the bathymetric (and derived environmental descriptors) signal.

Using both raster grids and triangular irregular networks (TINs), we found that the normalized entropy of the morphological characters such as depth, slope and aspect decreased with increasing pixel size while bathymetric position index (BPI), roughness, terrain ruggedness index (TRI) and all biological characteristics increased. For all environmental and biological descriptors MIC decreased quickly until 20m pixel size, but more gradually thereafter. The bathymetry-derived environmental descriptors from the raster grids influenced biological characteristics over a range of scales, but similar trends were observed for both density and diversity. At the finer scale roughness, TRI and flow direction influenced biological characteristics, while slope and depth had an impact at medium scales and finally BPI had an influence only at the broader scale.

We discuss the implication of these results for the broader study of this canyon and suggest that such an information theory approach based on a fine-scale examination of a small area can provide information upon which broader-scale surveys can be designed as well as help tease out the relative importance of processes occurring over various scales.

Modelling fine-scale HELCOM HUB underwater biotopes in a shallow Baltic Sea archipelago

Matti Sahla[1,2] and Annica Långnabba[1]

[1]Natural Heritage Services (Metsähallitus), P.O. Box 475, FI-65101 VAASA, Finland, matti.sahla@metsa.fi, annica.langnabba@metsa.fi

[2]University of Turku, Department of Geography and Geology, FI-20014 TURUN YLIOPISTO, Finland

As a result of past and present severe anthropogenic pressure, the Baltic Sea ecosystem is continuously subjected to effects of eutrophication, pollution, and biodiversity loss. With nine countries bordering the sea, management of the Baltic has long been further complicated by the lack of a common understanding and definition of its underwater biotopes. Existing biotope definitions, including the EU Habitats Directive and an array of nationally developed classification systems, have most often been focused on rare or important biotopes, leaving large areas of the sea undefined as a consequence. To bridge this gap, HELCOM published a report in 2013 on its newly developed HUB underwater biotope and habitat classification system (Balt. Sea Environ. Proc. No. 139). HELCOM HUB was designed based on biological data from the entire Baltic Sea area, taking into account various environmental variables. The data-driven HUB classification system is hierarchically structured, allowing classification down to different ecologically relevant levels depending on scarcity, quality and reliability of the input data. Clear split-rules have been defined between and within levels, in order to delineate in total 328 different biotopes covering all benthic environments.

The aim of this study was, firstly, to explore the applicability of HELCOM HUB to a set of national inventories data, consisting of over 12 000 analysed drop-video recordings collected from a Finnish coastal area during the years 2006–2013. Data points were numerically classified in MS Excel, in accordance with the HUB system regarding substrate type and dominating macroscopic species assemblage. The chosen area for the study, the Kvarken Archipelago, is a part of a UNESCO World Natural Heritage Site, and is characterised by its shallow moraine landscape and continuous isostatic land uplift. A unique mix of marine and fresh water plants and animals is encountered due to the highly brackish water and varied geography, and a total of 95 HUB biotopes were recorded in this study. Secondly, with spatial data coverage of the classification results ranging from good to sparse, we produced a HUB biotope map (Fig. 1) of the area through predictive modelling in GIS. The process underlined the need for area-specific environmental predictor variables, such as bathymetry, substrate type, photic depth, and depth-attenuated wave exposure, in order to attain nationwide whole-coverage biotope maps of the coastal underwater environment.

Our study emphasises the general functionality and applicability of HELCOM HUB to inventory and monitoring data, through the successful classification of a region as geologically and biologically diverse as the Kvarken Archipelago. Furthermore, the fine-scale patterns of the HUB biotope map make it a well suited tool for aiding both local and regional marine spatial planning and environmental monitoring. Developing methods for modelling HUB biotopes can therefore be of great importance both nationally and internationally, facilitating in particular the implementation of the EU Marine Strategy Framework Directive (MSFD).

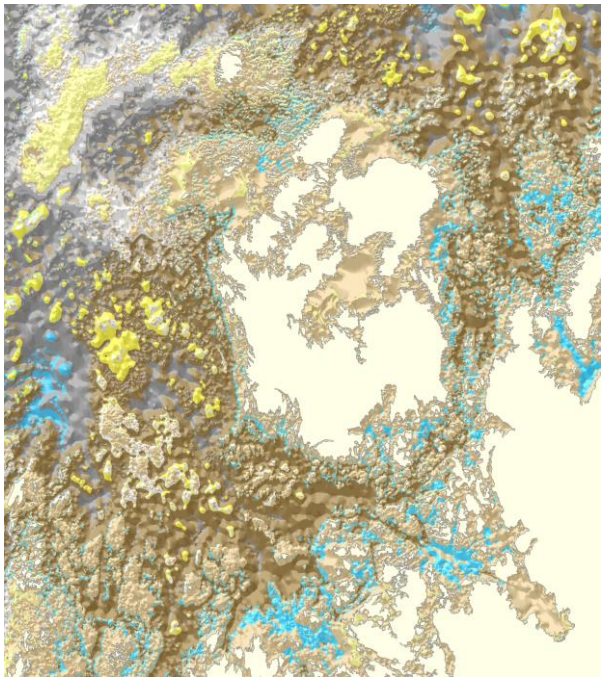

Figure 1. Modelled HUB-map of the Kvarken Archipelago

Acoustic seafloor mapping and geomorphological characterization of Coralligenous habitat in the northern Ionian and southern Adriatic Seas (western Mediterranean)

Alessandra Savini[1], Valentina Alice Bracchi[1], Daniela Basso[1], Fabio Marchese[1], Serena Palamara[1], Lorenzo Angeletti[2], Elisabetta Campiani[2], Giovanni Chimienti[3], Federica Foglini[2], Simonetta Fraschetti[4], Francesco Mastrototaro[3], Marco Taviani[2], Fabio Trincardi[2], Angelo Tursi[3] and Cesare Corselli[1]

[1]University of Milano-Bicocca, Dept. of Earth and Environmental Sciences, P.zza della Scienza 4, 20126 – Milano, Italy, alessandra.savini@unimib.it

[2]CNR – ISMAR Via Gobetti 101 40129 Bologna, Italy

[3]University of Bari, Department of Biology, Via Orabona, 4 - 70125 – Bari, Italy

[4]University of Salento, Dept. of Biological and Environmental Science and Technologies - P.zza Tancredi, 7 - 73100 Lecce, Italy

The coralligenous build-ups are positive structures, formed by the overlapping growth (in dim light conditions) of organism with calcareous skeletons (especially encrusting coralline algae), that thrive in the temperate Mediterranean Sea. They are always very complex in structure and allow the development of several kinds of communities. Therefore, according to Ballesteros (2006), a Coralligenous Habitat (CH) should be considered more as a submarine landscape or community puzzle rather than a single community. Various definitions have been used to characterize the variety of coralligenous build-ups that forms CH (e.g.: columnar crustose coralline algal build-ups, algal reefs, banks, coralligenous atolls …), although only few of them were thoroughly described through seafloor mapping data (Bonacorsi et al., 2012; Bracchi et al., *in press*).

Here we report preliminary results obtained from the integrated analysis of acoustic (multibeam and side-scan sonar) and video data, acquired to characterize CH in 21 Sites of Community Interest (SIC) and 3 Marine Protected Areas (MPA) of the Apulian continental shelf (southern Italy, Mediterranean Sea), for a total of 1017 Km^2 of survey area.

In Side-Scan Sonar mosaics, the explored coralligenous build-ups generally showed a distinctive texture, due to their rigid, cavernous and hard framework. As well imaged also by multibeam data, they spread out as positive-relief structures, occurring on the seafloor as isolated blocks (from roughly 1 m to few meters in diameters) or field of blocks and as wide tabular ridges with several metres of lateral continuity. Three main meso-habitats (sensu Greene et al., 1999), dominated by such coralligenous build-ups, were distinguished: 1) Mosaic of coralligenous and *Posidonia oceanica*; 2) Coralligenous; 3) Mosaic of coralligenous and coastal detritic.

Further studies will be necessary to obtain a complete characterization of the different geomorphological expression associated to the occurrence of CH, nevertheless our preliminary analysis suggest that inherited continental shelf morphologies coupled with present-day processes strongly control their extreme morphological variability.

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Multibeam water-column data: show me those plants!

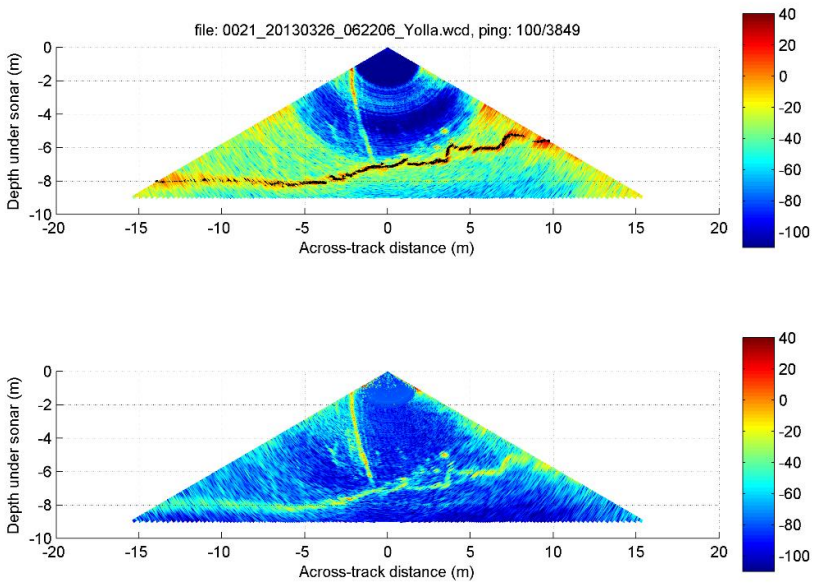
Alexandre C. G. Schimel[1] and Daniel Ierodiaconou[1]

[1]Deakin University, School of Life & Environmental Sciences, Warrnambool, Victoria, Australia, a.schimel@deakin.edu.au

The Giant kelp (*Macrocystis pyrifera*) is the largest of all brown algae and one of the fastest-growing organisms in the world. Individuals extend from the rocky seabed on which they are attached all the way to the surface, holding vertically in the water column with the help of gas bladders that develop along the stipes at the base of each blade. When in large numbers, forests of giant kelp become a significant shallow-water habitat for many marine species that feed on them or depend on them for shelter or preying. The recently developed capability of Multibeam sonar to record and image the acoustic signal backscattered by targets in the water-column below and sideways from the vessel on which it is mounted constitutes an original and unique opportunity to effectively detect and rapidly map these important habitats. This paper presents an original research aiming at exploring this opportunity using a Kongsberg EM2040C Multibeam sonar.

The study site is a Giant kelp forest located off the Hopkins river mouth in Warrnambool, Victoria, Australia (38.405°S, 142.503°E). A pilot survey was undertaken to acquire acoustic water-column data over a control setup. Fourteen Giant kelp individuals were harvested from the forest, measured, weighted and then arranged in a 4x4m quadrant over an area originally devoid of plants, thus constituting an artificial patch of a dense forest. Subsequently, half of these individuals were removed from the test site, thus constituting a low density forest patch. Over a hundred Multibeam data files were then obtained over these patches using different frequencies (200, 300 and 400kHz) and pulse lengths (very short, short and medium CW pulses). Matlab algorithms were developed to read these data, reduce the level of the sidelobe artefacts in the water-column, detect the acoustic signal backscattered by the plants and compute their backscatter energy level and distribution. This processing methodology was applied to the pilot survey data in order to assess which settings are better suited to quantify Giant kelp biomass and distribution.

The potential application of this methodology to repeated surveys of the natural Giant kelp forest through the year would allow monitoring of habitat changes over time. Comparison of such results with hydrographic modelling of wave and current exposure and water quality has the potential to yield new insights into kelp ecology.



Predicting reef fish species richness and abundance for Ningaloo Reef, Western Australia

Ana M. M. Sequeira[1], Camille Mellin[2], Hector Lozano-Montes[3], Matthew Vanderklift[3], Russ Babcock[3], Jessica Meeuwig[1] and M. Julian Caley[2]

[1] UWA Oceans Institute, School of Animal Biology and Centre for Marine Futures, University of Western Australia M470, 35 Stirling Highway, Crawley, Western Australia 6009, Australia, ana.sequeira@uwa.edu.au

[2] Australian Institute of Marine Science, PMB No.3, Townsville MC, Townsville, Queensland 4810

[3] CSIRO Marine and Atmospheric Research, Underwood Avenue, Floreat Park, Western Australia 6014, Australia

Management strategies to conserve and manage coral reef fish species such as the implementation of networks of marine protected areas are highly dependent on our understanding of the key processes that establish and maintain spatial patterns of biodiversity. Using seven years (2007-2013) of reef fish transect data, we developed predictive models of coral reef fish species richness and abundance for Ningaloo Reef, Western Australia. We also replicated similar models developed for a well-studied reef system (Great Barrier Reef; Mellin *et al.*, 2010) and tested the predictive ability of these models for Ningaloo Reef.

Our models exploited a range of spatial and environmental predictors including distance-to-domain boundaries and both biotic and abiotic factors. These were collated across a 0.01° grid at a national scale as part of the National Environmental Research Program Marine Biodiversity Hub (NERP; http://www.marinehub.org/).

The most important predictors of fish abundance for Ningaloo Reef were distance to reef slope and depth, and prediction maps show increasing abundances with increasing distance from shore. For species richness, sea surface temperature had the largest effect and predictions show scattered areas where species richness is expected to be greater, particularly in the southern sections of Ningaloo Reef.

Our work provides an indicative map of the spatial patterns of common biodiversity indicators for Ningaloo Reef, and provides significant understanding of the applicability of established models to new reef systems. It also indicates ways in which these models may be fine tuned to increase their predictive power.

Home is Where the Habitat is: Using Habitat Suitability to Inform Fish Survival

S. Kalei Shotwell[1], Jodi L. Pirtle[1], Mark Zimmermann[2], Jane A. Reid[3] and Nadine Golden[3]

[1]Ted Stevens Marine Research Institute, Auke Bay Laboratories, Alaska Fisheries Science Center, NMFS, NOAA, 17109 Point Lena Loop Road, Juneau, Alaska, USA, 99801, Kalei.Shotwell@noaa.gov

[2]Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, Seattle, Washington, 98115

[3]Pacific Coastal and Marine Science Center, U.S. Geological Survey, 400 Natural Bridges Drive, Santa Cruz, California, USA 95060

Estimating recent recruitment or annual reproductive success in fish populations is one of the more daunting tasks in fisheries population modeling primarily due to the lack of data on the critical early life history stages of fish and the limited knowledge of the underlying processes influencing recruitment during these stages. Often the approach to improving this situation is to identify the dominant drivers of changes in recruitment based on a conceptual model for a given species and then integrate a set of reasonable proxies for these processes within a population model. Generally, the set of predictor variables represent biophysical measures of oceanography, prey, competitor, and predator fields that influence the species. One field that is often not included in improving estimates of recruitment is the suitability of habitat at the end of the critical period and how encountering preferred habitat could be a regulator of early life survival.

In this case study, we characterize the preferred habitat for a set of focal groundfish (bottom-dwelling) species in the Gulf of Alaska and explore the most appropriate use for this information as a final step in determining early life survival. This project is part of a larger integrated ecosystem research program (http://www.nprb.org/gulf-of-alaska-project) with the main objective to identify and quantify the major ecosystem processes regulating recruitment strength of the focal species. To that end, we first collected and validated available bathymetry and sediment data from a large variety of sources and then generated high resolution surfaces that correspond to the geographic extent of the settlement stage for each species. Multi-scale terrain analysis was then performed on these surfaces to generate a suite of benthic predictor variables to evaluate species-specific habitat suitability. We also analysed these variables at different grid resolutions to assist with matching the appropriate terrain scale to a particular region of settlement (e.g. nearshore versus continental slope).

Given the paucity of observations for these early life history stages, we developed a presence-only habitat suitability model using maximum entropy (MaxEnt) modeling for each species. Model evaluation was performed using cross-validation techniques and prediction maps of the best model were created for each species. We then examined the spatial scale of covariation of the best predictor variables for each species to provide information on the appropriate spatial scale that these suitability maps should be averaged when combining with other influential ecological processes for a given species. We consider an example of the spatial overlap between individual based model (IBM) trajectories and the habitat suitability predictors of a given species and provide recommendations on combining the two survival indicators.

In the future we plan to incorporate the habitat suitability information into the population models for these groundfish species to help inform recruitment. The estimate of suitable habitat for these early life stages along with results from IBMs could be used to generate recruitment estimates that can be incorporated as another survey index within the population model. Management strategy evaluations may also be employed to test the influence of potential bias in the habitat suitability model given the presence-only methods. These habitat suitability techniques may be applied to other life history stages and utilized for estimating other population parameters within a population model such as vulnerability to different fishing gear types and habitat-specific fish growth.

Modelling the past, present and future distribution of macrofauna species in the Jade Bay (North Sea, Germany)

Anja Singer[1,2], Ulrike Schückel[1], Melanie Beck[3], Heiko Westphal[4], Andreas Wurpts[4] and Ingrid Kröncke[1]

[1] Senckenberg am Meer, Marine Research Department, Südstrand 40, 26382 Wilhelmshaven, Germany, anja.singer@senckenberg.de

[2] University of Bremen, INTERCOAST Research Training Group, Leobener Strasse, 26359 Bremen, Germany

[3] Institute for Chemistry and Biology of the Marine Environment (ICBM), Department of Microbiogeochemistry, Carl von Ossietzky University, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg, Germany

[4] Coastal Research Station - Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency, An der Mühle 5, 26548 Norderney, Germany

Species distribution models (SDMs) are applied to predict changes in the distribution pattern of 10 characteristic macrofauna species in the Jade Bay (North Sea, Germany) in response to expected environmental changes due to climate change and harbour effects. The Jade Bay is a tidal basin with a total area of approximately 160 km² that is affected by environmental changes such as temperature increase and sea-level rise. In addition, since 2008, the construction and maintenance of Germany's first deep-water harbour (JadeWeserPort) with draughts up to 16.5 m tide-independently is affecting the benthic habitats. 5 different SDM algorithms (MAXENT, GAM, ANN, RF and MARS) will be compared by using the R package 'biomod2'. The species-specific distribution for 2009 is predicted based on 12 high resolution (5m*5m) environmental grid layers. Results for past distribution scenarios will be compared with historical macrofauna data from the 1930s and the 1970s. For the future distribution scenarios, regional climate scenarios for the years 2050 and 2085 will be used to predict the effects of 1) ongoing sea-level rise 2) increasing winter water temperatures 3) increasing mudflats 4) increasing sediment volume and 4) extending seagrass beds on the distribution of the 10 characteristic macrofauna species.

Seabed Habitat Mapping of Darwin Harbour, Northern Australia: Using Acoustic and Optical Data to Classify Hard and Soft Seabed

P. Justy W. Siwabessy[1], Maggie Tran[1], Zhi Huang[1], Scott L. Nichol[1] and Tanya Whiteway[1]

[1]Geoscience Australia, GPO Box 378, Canberra, Australian Capital Territory, Australia, justy.siwabessy@ga.gov.au

Darwin Harbour is the primary sea port for northern Australia, for which accurate information on the seabed is critical and required by multiple stakeholders. These stakeholders include the offshore energy industry, the fishing industry, and government authorities responsible for managing the harbour, in particular, the Port Authority. Darwin harbour is macrotidal with large areas of shallow (<10 m) subtidal and intertidal flats, dissected by bifurcating channels with localised areas of hardground. These hardground areas provide substrate for epibenthic communities. To support the informed management of Darwin Harbour, Geoscience Australia (GA), in collaboration with the Northern Territory Department of Land Resource Management (DLRM), the Australian Institute of Marine Science (AIMS) and the Darwin Port Corporation, conducted a multibeam survey of the harbour in 2011 on board *MV Matthew Flinders*. This was followed in 2013 by a physical sampling (sediments and video) survey by GA in collaboration with DLRM on board *MV John Hickman*. This paper presents results from those surveys with a focus on techniques used to produce a spatially continuous map of the harbour floor showing the distribution of hard and soft substrate types.

The Darwin Harbour surveys acquired multibeam sonar data (bathymetry and backscatter) across 180 km^2 gridded to 1 m resolution, 61 seabed samples and 35 underwater video observations to map and classify the seabed into habitats. Primary geomorphic features identified in Darwin Harbour include channels, banks, ridges, plains and scarps. Within the study area, acoustically hard substrates are associated with hard ground and relatively coarse seabed sediments. The hard grounds (rock, reef and coral gardens) are found mostly on banks and often overlain by a veneer of sandy sediment. In contrast, acoustically soft substrates are associated with fine sediments (mud and fine sand) that form the plains and channels.

A seascape analysis was used to classify the seabed, incorporating information from multibeam data, underwater video characterisations and seabed hardness predictions. We used the Iterative Self Organising (ISO) Unsupervised Classification technique to combine the information from five variables (bathymetry, slope, rugosity, backscatter and probability of hard seabed (*p*-rock)) to form a single seabed habitat classification. The *p*-rock variable was derived by comparing the angular backscatter response of known areas of hard seabed to all other angular backscatter responses. We found that six habitat classes were statistically optimal based on the distance ratio measure. These six classes are related to a unique combination of seabed substrate, relief, bedform, presence of a sediment veneer and presence of epibenthic biota and rock/reef (hard substrate).

The results presented here demonstrate the value of acoustic data for the characterisation of the seabed substrate that provides key habitats for benthic biota. This study also highlights the utility of the *p*-rock variable for habitat mapping at the level of distinguishing areas of hard seabed from soft sediment areas. The resultant seabed habitat maps are being used by the Northern Territory DLRM to inform ongoing management of Darwin Harbour, with additional mapping planned for offshore areas and adjacent harbours in the region.

Using an integrated sampling approach to understand benthic biotopes in an Antarctic coastal marine environment

Jodie Smith[1], Philip E. O'Brien[2], Jonathan S. Stark[3], Glenn J. Johnstone[3], P. Justy W. Siwabessy[1], Iain Parnum[4] and Martin J. Riddle[3]

[1]Geoscience Australia, GPO Box 378, Canberra, Australian Capital Territory, Australia, jodie.smith@ga.gov.au

[2]Macquarie University, Department of Environment and Geography, Sydney, New South Wales, Australia

[3]Australian Antarctic Division, Kingston, Tasmania, Australia

[4]Centre for Marine Science and Technology, Curtin University, Bentley, Western Australia, Australia

The value of integrated high-resolution data sets in understanding the marine environment has been demonstrated in numerous studies around the Australian margin, however this approach has rarely been applied to studies in East Antarctica. An integrated approach was applied to a survey in Antarctica which utilised a multibeam sonar system, underwater video and sediment sampling to aid the understanding of seabed character and benthic biotopes in the coastal waters of the Vestfold Hills, near the Australian station of Davis.

The Vestfold Hills is one of the largest ice-free areas on the East Antarctic coast. The coastal area is a complex of small islands, embayments and fjords. High-resolution bathymetry and backscatter data were collected over 42km^2 to depths of 215 m. Epibenthic community data and *in situ* observations of seafloor morphology, substrate composition and bedforms were obtained from towed underwater video. The new high resolution datasets reveal a mosaic of rocky outcrops and sediment-filled basins.

Analysis of the datasets was used to identify statistically distinct benthic assemblages and describe the physical habitat characteristics related to each assemblage, with seven discrete benthic biotopes identified. The biotopes covered a range of habitat types including shallow coastal embayments and rocky outcrops, which are dominated by dense macroalgae communities, and deep muddy basins which are dominated by mixed invertebrate communities. Transition zones comprising steep slopes provide habitat for sessile invertebrate communities. Flat to gently sloping plains with a thin sandy cover on shallow bedrock are relatively barren.

The relationship between benthic community composition and environmental parameters is complex with many variables (e.g. depth, substrate type, longitude, latitude and slope) contributing to differences in community composition. Depth and substrate type were identified as the main controls of benthic community composition, however, depth is likely a proxy for other unmeasured depth-dependent parameters such as light availability, frequency of disturbance by ice, currents and/or food availability. Sea ice cover is an important driver of benthic community composition, with dense macroalgae communities only found where ice-free conditions persist for most of the summer. The bathymetry data shows iceberg scouring is common, however, scouring does not appear to impact benthic community composition in the study area.

This is the first study that has used an integrated sampling approach to investigate benthic assemblages across a range of habitats in a coastal marine environment in East Antarctica. This study demonstrates the efficacy of using multibeam and towed video systems to survey large areas of the seafloor in Antarctica where marine sampling is often logistically difficult and to collect non-destructive high-resolution data in the sensitive Antarctic marine environment. The multibeam data provide a physical framework for understanding benthic habitats and the distribution of benthic communities.

This research provides a baseline for assessing natural variability and human-induced change across the coastal marine environment (Australian Antarctic Science Project AAS-2201), contributes to Geoscience Australia's Marine Environmental Baseline Program, and supports Australian Government objectives to manage and protect the Antarctic marine environment.

How useful are abiotic surrogates for mesophotic reef biodiversity?

Tim Stevens[1], Sarah Richmond[1] and Ryan Pearson[1]

[1]Griffith School of Environment and Australian Rivers Institute, Gold Coast campus, Griffith University, Queensland 4222, Australia, t.stevens@griffith.edu.au

Biodiversity of marine areas beyond the reach of conventional diving technology (>30m) is poorly known, yet subjected to increasing stresses from expanding recreational and commercial fishing, minerals exploration and other anthropogenic influences. In part, this is because detailed surveys or these areas are logistically complex and expensive. There is a conspicuous gap in our knowledge of warm-temperate mesophotic (c.30-150m) reefs, which is of particular concern given the initiatives to establish Australia's National Representative System of Marine Protected Areas (NRSMPA). Typically, the lack of detailed biological data is addressed by using abiotic surrogates for patterns of biodiversity, for instance in planning marine protected areas or other management measures. However, the efficacy of these surrogates varies from place to place, and is often not quantified at the scale used by MPA designers and managers. We surveyed and classified benthic and nektonic assemblages of continental shelf mesophotic rocky reefs from 30 to 85m at four locations spanning c.120km of coastline, using combination of towed HD video and BRUVs. We related the patterns of benthic and fish assemblage structure to commonly used abiotic surrogates to assess their effectiveness in representing the observed biodiversity. Five distinct benthic biotopes were defined, characterised primarily by abundances of gorgonians, sponges, kelp, and urchins. There were also distinct subdivisions within the fish assemblage, but these did not align with the benthic biotopes. In both cases patterns of biodiversity were relatively poorly predicted by conventional abiotic surrogates such as depth, substrate type, relief, water temperature and salinity, proximity to the coastline, shelf break and river mouths (R^2 < 38%). We included ecological process variables (scavenging and herbivory rates) and a measure of recreational fishing pressure, which improved the fit for benthos, but not for fish assemblages.

Capability of multibeam backscatter data to discriminate between temperate water habitats and substrates

Sira Tecchiato[1], Iain Parnum[2] and Lindsay Collins[1]

[1] Department of Applied Geology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia

[2] Centre for Marine Science and Technology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia, I.Parnum@curtin.edu.au

Multibeam echo-sounder data were used to map shallow water geomorphological features and the spatial distribution of benthic habitats of two shallow (<30 m) embayments of the Midwestern Australian coast. The main identified geomorphic features include, limestone reef systems and hardgrounds, as well as extensive uncolonised sand features such as sand bars, sand sheets and rippled sand flats. Sediment sampling and analyses have revealed that carbonate sediment predominates, with fine sand dominating the <10 m deep areas close to shore and increasing grainsize moving offshore. Underwater imagery was used to ground truth the acoustic data, and has shown that seagrass meadows and macroalgal communities are the dominant biota. The trend observed at Geraldton is that seagrasses are limited to <10 m depth and colonise sheltered areas close to shore, and macroalgal communities are common in higher energy areas on the coastal platform edge. An analysis of the distribution of substrates and associated habitats has shown that seagrass meadows are mainly developed on hardgrounds blanketed by highly consolidated fine sand, and macroalgal communities commonly colonise shallow limestone reefs and hardgrounds with a mixed medium-coarse shallow sand cover.

The capability of the multibeam echo-sounder backscatter data to discriminate between seagrass meadows, macroalgal communities and sandy substrate was evaluated and the acoustic response from the seabed could be better explained by considering together biota type and substrate characteristics. In fact, it is well documented that backscatter strength is directly proportional to sediment grain size and surface roughness. It is also well known that large surface roughness and high acoustic impedance associated with hardgrounds and gravel dominated substrates produce high backscatter levels. In contrast the acoustic scattering from seagrass and macroalgae is poorly understood compared to rock high backscatter levels and sediments. Speculated reasons for high backscatter levels from marine flora include gas bubbles, foliage and dense root structure.

The combined characterisation of sediment types, substrate geomorphology, substrate characteristics and biota cover provided a comprehensive description of the benthic habitats investigated in this study which has been shown to match the acoustic response of the seabed. Uncolonised sandy substrates are the most easily discernible habitats, as they retain the lowest relative backscatter strength values measured with differences associated to the varying grainsize. Macroalgae and seagrass communities show similar relative backscatter strengths, and colonise hardgrounds with diverse but shallow and consolidated sediment cover. These habitats cannot be mapped separately by applying automated classification algorithms to a raster of angle independent backscatter levels but a different acoustic response from these habitats was evident when observing the backscatter versus incidence angle curves, known as angular response curves. Finally, a mixed sand, seagrass and macroalgae habitat class was also analysed and occurred on a range of substrate and sediment types, although the general nature of sediment cover at Geraldton is shallow and consolidated. This habitat has shown a similar acoustic response to macroalgal communities and seagrass meadows, reducing the accuracy of the habitat map generated by applying automated classification algorithms to a raster of angle independent backscatter levels.

Marine Metapopulation Persistence: Connectivity Modelling Reveals Key Biological and Physical Drivers

Eric A. Treml[1], John R. Ford[1], Kerry P. Black[1] and Stephen E. Swearer[1]

[1]Department of Zoology, University of Melbourne, 3010 VIC, Australia, etreml@unimelb.edu.au

The persistence and dynamics of marine metapopulations is dependent on many factors, including the spatial structure of habitat patches, life-history characteristics, demographic processes, connectivity through the dispersal of propagules, and spatiotemporal patterns in disturbance. Although we have made significant advances in our understanding of these individual factors, developing an integrated approach to studying this complex process from reproduction, through dispersal, and to the successful recruitment and survival of individuals has been difficult. Using the southern hulafish (*Trachinops caudimaculatus*) population in Port Phillip Bay, Victoria, we present an empirically-based metapopulation network model of this system. We present data on population demographic and vital rates, describe our connectivity modelling approach, and show how a global sensitivity analysis was used to quantify the impact of i) life histories, ii) demographics, iii) dispersal, and iv) the physical seascape, on the spatial structure of metapopulation dynamics and persistence. We show that the competency window during the early life stage largely determines the strength and extent of connectivity as well as the metapopulation growth rate, yet the location and timing of propagule release determine the importance of each subpopulation in the persistence of the metapopulation.

Exploring our marine geological resources in the fifth dimension: About 3D voxels, 4D impact models and uncertainty

Vera Van Lancker[1], Lies De Mol[2], Guy De Tré[3], Denise Maljers[4], Tine Missiaen[5], Jan Stafleu[4], Dries Van den Eynde[1] and Sytze van Heteren[4]

[1]Royal Belgian Institute of Natural Sciences Operational Directorate Natural Environment, Gulledelle 100, B-1200 Brussels, Belgium, vera.vanlancker@mumm.ac.be

[2]Federal Public Service Economy, SMEs, Self-Employed and Energy Continental Shelf Service, Koning Albert II-laan 16, B-1000 Brussels, Belgium

[3]Ghent University, Faculty of Engineering, Department of Telecommunications and Information Processing. Database, Document and Content Management, St.-Pietersnieuwstraat 41, B-9000 Gent, Belgium

[4]TNO – Geological Survey of the Netherlands, Princetonlaan 6, 3584CB Utrecht, the Netherlands

[5]Ghent University, Faculty of Sciences, Department of Geology. Renard Centre of Marine Geology, Krijgslaan 281, B-9000 Gent, Belgium

Mineral and geological resources can be considered to be 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 management of these invaluable and sought-after resources is not possible. Comprehensive knowledge on the distribution, composition and dynamics of geological resources therefore is critical for developing long-term strategies for resource use. For the Belgian and southern Dutch parts of the North Sea, such strategies will be worked out in the project TILES (Belgian Science Policy, 2014-2017). Particularly, TILES has the ambition of:

(1) Developing a decision support system (DSS) for resource use. This DSS contains tools that link 3D geological models, knowledge and concepts, providing information on present-day resource quantities and distribution, to numerical models of extraction-related environmental impact through time. Together they quantify natural and man-made boundary conditions and changes to define exploitation thresholds that safeguard sustainability on a multi-decadal time scale.

(2) Providing long-term adaptive management strategies that have generic value and can be used for all non-hydrocarbon geological resources in the marine environment.

(3) Proposing legally binding measures to optimize and maximize long-term exploitation of aggregate resources within sustainable environmental limits. These proposed measures feed into policy and associated monitoring plans that are periodically evaluated and adapted (e.g. EU Marine Spatial Planning and EU Marine Strategy Framework Directive).

Extensive analyses of data- and interpolation-related uncertainties, and of the propagation of these uncertainties in data products such as maps and GIS layers, form the backbone of the DSS. This is a necessary step in producing data products with confidence limits, and critical to detecting ‘true’ seabed changes in environmental monitoring. Using a dedicated subsurface viewer, a suite of data products will be viewable online. They can be extracted on demand from an underlying voxel (3D pixel) model. Each voxel will be assigned with values for geological, environmental and decision-related parameters, including uncertainty. The flexible 3D interaction and querying, enabled by TILES, will be invaluable for professionals, but also for the public at large and for students in particular. It will herald a new age in assessing cross-border impacts of marine exploitation activities.

Use of Wave Glider monitoring for assessing changes in habitat integrity

Vera Van Lancker[1], Matthias Baeye[1], Dimitris Evangelinos[2], Dries Van den Eynde[1], Ilse De Mesel[1] and Francis Kerckhof[1]

[1]Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Gulledelle 100, 1200 Brussels, Belgium, vera.vanlancker@mumm.ac.be

[2]MSc Marine and Lacustrine Science and Management (Oceans & Lakes) Ghent University, Krijgslaan 281, S-8, 9000 Gent, Belgium.

In Belgium, far offshore sandbanks are targeted for exploitation of huge quantities of sand, mainly for coastal defence works. Over a surface area of 46 km^2, up to 2.9 million m^3 can be taken over 3 months, with a maximum of 35 million m^3 over a period of 10 years. Large vessels can be used extracting 12500 m^3 per run. As a comparison, present-day yearly extraction levels for the entire Belgian part of the North Sea only recently surpassed 3 million m^3, the majority of which was extracted with vessels of 1500 m^3. South of this new concession zone, a Habitat Directive area is present, hosting ecologically valuable gravel beds. From an environmental management perspective, it is critical to assess smothering of habitats due to multiple and frequent depositions from dredging-induced sediment plumes. Furthermore, changes in seafloor integrity and hydrographic conditions need quantification, two key descriptors of marine environmental status within Europe's Marine Strategy Framework Directive.

State-of-the-art instrumentation (from RV Belgica) was used, measuring the 3D current structure, turbidity, depth, backscatter and particle size of the material in the water column, both in-situ and whilst sailing transects over the sandbanks. In the Habitat Directive Area, gravel bed integrity (i.e., epifauna; sand/gravel ratio; patchiness) was measured as well, both acoustically, as well as visually. Most innovatively, an autonomous surface vehicle was deployed (Wave Glider®, Liquid Robotics Inc.) for 22 days or 39 rounds around the extraction site. 25 extraction events took place during this period. The payload of the platform included a surface fluorometer, measuring chlorophyll a and a proxy of turbidity, as well as an Acoustic Doppler Current Profiler.

The presentation will focus on the results of the analyses of the Wave Glider data. The continuous data series allowed capturing temporal and spatial patterns in turbidity increases, and correlating these with naturally- and human-induced processes. Overall, turbidity increases were dynamic, changing rapidly over time and space, though a well-delineated sediment plume was identified resulting from the aggregate extraction activities. The detection was local and rather ephemeral, though sinking and deposition were observed three hours after the last dredging activity, at 8 km away from the source, as propagated by the dominant current. Simulations on the dispersion of the plumes showed the likelihood of sediment deposition in the Habitat Directive Area. Sampling and observations along the gravel fields showed an enrichment of fines, already mixed with the coarser substrate. These fields are richest in biodiversity in the trough of barchan dunes. It is hypothesized that the morphology of these steep dunes induces the formation of eddies that preferentially trap fines. Follow-up is needed to evaluate to what extent a smothering process can be revealed that would lead to a degradation of the gravel bed integrity.

Marine Habitat Mapping along the Shelf around the Abrolhos Archipelago - Brazil

Laura S. Vieira[1], Alex C. Bastos[2] and Leila L. Longo[3]

[1]Federal University of Espírito Santo, Department of Oceanography, Vitória, Espírito Santo, Brazil, laurasilveiraoc@gmail.com

[2]Federal University of Espírito Santo, Department of Oceanography, Vitória, Espírito Santo, Brazil

[3]Federal University of Espírito Santo, Department of Oceanography, Vitória, Espírito Santo, Brazil

The Abrolhos Shelf (Bahia-Brazil) is well known for encompassing the most important coralline reefs in the South Atlantic, with high levels of endemism and unique mushroom-shaped coralline pinnacles. The Abrolhos National Marine Park is situated in the northern-central part of the shelf, including the Abrolhos Archipelago, formed by five small islands. A comprehensive study of marine habitat distribution has already been performed for the entire shelf. Herein, our objective is to investigate marine habitat distribution within the Archipelago Shelf. The study has carried out *in situ* seafloor sampling and marine acoustic mapping of the area between the islands of the Abrolhos Archipelago. Different substrates were defined by using both geophysical and ground-truth sampling. Acoustic images were obtained using a 500kHz side scan sonar (SSS). Ground truth consisted of van-Veen grab and scuba dive sampling. Samples were processed to determine grain size, composition and associated biological diversity. Side scan data was processed to produce a full-covered sonographic mosaic.

Four sonographic patterns were identified and, from this classification, two types of substrates were defined for the archipelago shelf: reef substrate and unconsolidated carbonate substrate. In the western portion of the study area, unconsolidated coarse sediments were observed, intensively represented by calcareous algae forming rhodoliths, as well as by fringing reefs bordering the islands of Sueste and Siriba. On the other hand, in the central and eastern portions of the shelf, fine sediments are observed surrounded by the typical geomorphological feature of Abrolhos, the isolated reef structures known as "chapeirões" (coral formations with significant growth and mushroom-shape, and its worldwide distribution being restricted to the shelf in question). Chapeirões or pinnacles are not observed along the central region.

Adjacent to the Sueste island, to the south, reef banks are observed. These are characterized by coalesced isolated pinnacles (coalescence chapeirões tops). In general, the unconsolidated substrate represents the large majority of the total area, around 93%, leaving only 7% for reef substrate. Potential habitats were defined based on the classification of seabed types. Associated benthic communities are being investigated in order to discuss the relationship between seabed types and benthic biodiversity. On the other hand, Abrolhos is famous for its reef fish community, so mapping the submerged reef areas is a very important result for managing the National Park. Finally, the habitat map produced herein is a very important tool for planning and managing the Abrolhos National Marine Park, as this area is the main touristic attraction of the Park.

Habitat distribution in sediment-starved and sediment-dominated coastal environments: examples from southern-eastern Tyrrhenian margin, Italy

Crescenzo Violante[1] and Marinella De Lauro[1]

[1]Institute for Coastal and Marine Environment (IAMC), National Council Research (CNR), Calata Porta di Massa, Napoli, Italy, crescenzo.violante@cnr.it

River discharge and local bathy-morphological features mostly control sediment supply in coastal temperate marine environments, with important ecological implications. Sediment-starved conditions typically occurs off low-relief rocky coasts with no or very poor hydrographic network where shallow and/or outcropping bedrock occurs at seafloor. They characterize also the top of structural highs and seafloor reliefs occurring at different scales both in shallow settings and offshore. In such areas mostly of the sediment is produced *in situ* by high biogenic activity resulting in relatively thin mixed siliciclasic/carbonate sedimentary covers.

High biogenic carbonate production occurring in sediment-starved environments provide important benthic habitats characterized by calcareous formations of biogenic origin including the Coralligenous and other calcareous bio-concretions, as well as significant amount of organogenic sediments entirely composed of remnants of calcareous organisms. In term of biodiversity, the Coralligenous is considered as the second ecosystem in the Mediterranean. It forms organogenic buildups mainly produced by accumulation of encrusting algae supporting a variety of benthic organisms including the well-known red coral (*Corallium rubrum*) and some hundreds of invertebrate and algal species. The species dominating the coralligenous seascape are encrusting calcareous algae, sponges, cnidarians, bryozoans and tunicates.

On the contrary, sediment-dominated coastal settings are characterized by low energy, gently sloping shelf areas composed of soft bottoms with seaward decreasing sediment size. Such environments typically occur off alluvial plains where sediment aggradation strictly relates to fluvial dynamics. Sediment aggradation occur also in a wide range of coastal marine environments, including coastal embayment and in the lee of islands or submerged barriers. In all these cases, high rates of sediment supply produces benthic habitat heavily contrasting with those provided by sediment-starved conditions.

Benthic habitat occurring in sediment-dominated settings are characterized by thick sequences of sandy and muddy deposits inhabited by invertebrate communities living in or on the sediments. The species dominating the gently sloping shelf seascape are both deposit feeders such as holothurians, echinoids, gastropods and suspension feeders (e.g., bivalves, ophiuroids and crinoids).

Benthic habitat characterized by both sediment-starved conditions and high sediment supply widely occur along the southern Italy coastal areas and are often included in Marine Protected Areas (MPA). The reported examples include the Santa Maria the Castellabate MPA, the Cilento coasta area and the Tyrrhenian Basilicata in the Gulf of Salerno, the Ionian Basilicata in the Gulf of Taranto, the Capri Island and the Punta Campanella and the Regno di Nettuno MPAs in the Gulf of Napoli, and the Graham Bank in the Sicily channel.

Monitoring Seabed Character and Habitats of a Tropical Shallow Shelf, NE Brazil.

Helenice Vital[1], Jorge Eduardo Lins Oliveira[2], José Garcia Junior[3], Tatiana Leite[2], Mary L. S. Nogueira[1] and Iracema Miranda da Silveira[4]

[1]Programa de Pós Graduação em Geofísica e Geodinâmica (PPGG), Universidade Federal do Rio Grande do Norte (GGEMMA,CCET,UFRN),helenice@geologia.ufrn.br, Campus Universitário UFRN, Lagoa Nova, PO Box 1596, 59072-970, Natal, RN, Brazil RN, l

[2]Departamento de Oceanografia, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil RN

[3]Recursos Pesqueiros, Instituto Federal de Ensino, Tecnologia e Ciência do Rio Grande do Norte, Macau, RN, Brazil RN

[4]Museu Câmara Cascudo, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil RN

Environmental monitoring and mapping was developed on the continental shelf adjacent to Potiguar Basin, an important area of exploitation of hydrocarbons resources located on northeastern Brazil. This tropical shelf is characterized by its narrow wide (average 40 m) and very shallow waters (average 60 m depth), which presents the transition from a dominantly siliciclastic inner shelf to a carbonate system offshore. Field sampling was carried out during 4 cruises, in dry and wet seasons, to monitoring and mapping the sediments, morphologic features and associated biological habitats. Results indicate that biological communities are controlled by substrate and light level. Fine- to medium-grained siliciclastic sands, mainly composed by quartz occur inner shelf, while coarse bioclastic gravel dominated the outer shelf. The transition from mid- to outer shelf, around 25 m depth is marked by alignments of submerged outcrops, composed of carbonate cemented sandstones and grainstones, covered by seaweeds, rhodoliths and sponges. Dominant ictiofauna is represented by *Haemulon aurolineatum*, *Pomadasys corvinaeformis*, Dactylopterus *volitans* and Haemulon *aurolineatum*. Mollusca, Crustacea and Annelida are the predominant invertebrate communities.

Benthic Terrain Modeler: Interpreting the Bathymetric Environment

Shaun Walbridge[1], Dawn J. Wright[2], Matt Pendleton[3], Jennifer Boulware[4], Bob Gerlt[2] and Dave Esslinger[3]

[1]Esri, 35 Village Road Suite 501, Middleton, Massachusetts, USA, swalbridge@esri.com

[2]Esri, 380 New York St, Redlands, California, USA

[3]NOAA Coastal Services Center, 2234 South Hobson Av, Charleston, SC 29405

[4]PeopleMatter, 466 King Street, Charleston, SC 29403

The Benthic Terrain Modeler (BTM) is a collection of ArcGIS-based tools for analyzing and classifying the benthic environment. These tools include the creation of bathymetric position index (BPI) grids[1], standardized BPIs, slope, aspect, and rugosity from an input bathymetric data set. Additionally, terrain classification scripts allow users the freedom to create their own zone and structure classifications and define the relationships which characterize them.

The BTM tools transform digital elevation data into a classified product used in both research and natural resource management. However, the tools are general enough that they can be used on any digital elevation data. The inclusion of easily customizable terrain classification allows investigators and managers to create terrain maps in a variety of environments for a broad range of intended uses.

The tools have attracted an audience which use it for a variety of goals. The simple interface, extensive help, and a step-by-step tutorial lend BTM to teaching applications and an introduction to techniques for elevation analysis. In resource management applications, BTM is often used to infer zone and structure classifications for unsampled locations, by creating classifications based on known observed locations and combining them with collected bathymetry. BTM is also used by environmental modellers[2] who use it to produce environmental covariates for regression models, in order to make species habitat predictions. The tools support a variety of useful terrain analysis algorithms. These include the Vector Ruggedness Measure[3], the ratio of surface area to planar area[4] (both of which are to characterize surface roughness or rugosity), trigonometrically transformed aspect, depth statistics (mean, standard deviation, variance) which can be computed at multiple scales, and plan / profile curvature to measure the slope of slope.

BTM[5] has been actively developed since 2005, and the current release, v3.0, has been modernized for the current version of ArcGIS, and actively supported in ArcGIS versions 10.0 and later. Using a Python toolbox, all code (including model parameters and settings) can be easily edited and managed, allowing a simple interface to recreate the “wizard” experience of the earlier version. Classification dictionaries, which used to require a custom authoring environment and produced XML documents, can now be created directly in spreadsheet software, and the tool now directly reads Excel Spreadsheets and CSV files along with the older XML format. BTM is also now open source, with both its code and collaboration facilitated through GitHub. This newly introduced version of BTM provides a series of graphical menus to access the tools via a Python Add-In, along with a Python toolbox which allows the tools to be embedded in scientific workflows. Additionally, each script is stand-alone, and can be embedded into Python applications, or used interactively with an environment such as IPython[6]. Finally, the project now includes an extensive testing framework, which enables reproducible results necessary in many scientific applications.

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Mapping habitats with satellites: state of the technology and worldwide examples

Magnus Wettle[1], Knut Hartmann[1], Marcus Bindel[1], Andreas Muller[1] and Thomas Heege[1]

[1]EOMAP GmbH, Earth Observation and Mapping, Sonderflughafen Oberpfaffenhofen, Friedrichshafener Str. 1 D-82205, Gilching, Germany

For the past several decades, considerable research and development has been directed at deriving bathymetry and mapping benthic cover - two key components in defining marine habitats - using satellite image data. The first generation of approaches to deriving bathymetry from satellite data used so-called empirical methods. Although relatively easy to implement, these methods require already known depth information for the study area. By contrast, second generation, so-called physics-based methods, require no a priori information, and can in principle therefore be applied to any location worldwide for which suitable image data is available . In practice however, most physics-based methods are in the research and development stage, with few such applications able to deliver robust and accurate bathymetry products in a timely manner.

The preponderance of studies on mapping benthic cover from satellite imagery use one or more supervised classification techniques in order to group image pixels into meaningful ecological assemblages. This requires either known study area information or expert knowledge by the user. A further important limitation is that the water column depth and water column optical properties at any given location in the image will influence the signal, thereby adversely impacting the classification results.

Here, we present the results of the physics-based method MIP (Modular Inversion Processor) for estimating bathymetry and mapping benthic cover that has been successfully used in over 10 studies worldwide, including such diverse locations as the North Atlantic, the British Virgin Islands, the Mediterranean, the Arabian Sea, the Caspian Sea, the Mexican Maya coast, and the entire Great Barrier Reef. For the bathymetry, comparison against airborne and ship-borne field measurements reveal typical accuracies of within 10-20% (CE90) of validation data (Figure 1).

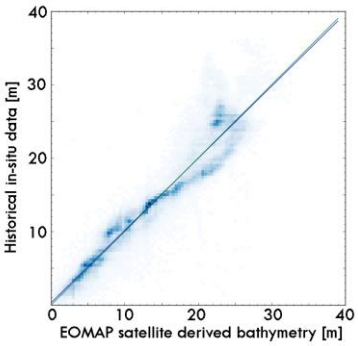

Figure 1. Example comparison of derived bathymetry and validation data

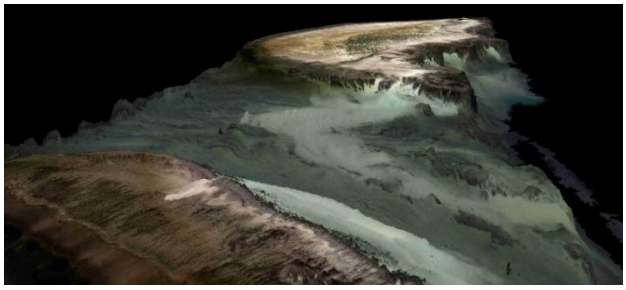

Figure 2. Example from the Great Barrier Reef of the physics-based seafloor reflectance product draped over the derived bathymetry

The MIP is a coupled approach: it uses the derived water depth information to calculate the confounding effects of the water column on the satellite signal. From this, the reflectance, or colour, of the seafloor is produced. This is the equivalent of acquiring a satellite image of the seafloor with the overlying water column removed (Figure 2). This allows for benthic classification routines to be implemented with considerable more accuracy. We submit that the most effective satellite-based benthic mapping solution to date is to deliver this seafloor reflectance product to specialists in the benthic assemblages of the given study area. Indeed, this is the approach taken in a recent mapping project on the Mexican Maya coast, where a seafloor habitat baseline is being successfully mapped over a 5000 square kilometer area by the Mexican National Commission for Knowledge and Use of Biodiversity, using the MIP-calculated seafloor reflectance image.

Marine spatial science at work: Practical examples of various habitat mapping techniques in Western Australia

Kristin Wouters[1], Dinesh Tuladhar[1] and Philip Kindleysides[1]

[1]BMT Oceanica Pty Ltd, PO Box 462, Wembley WA 6913, kristin.wouters@bmtoceanica.com.au

BMT Oceanica, a Western Australian consultancy specialising in marine and coastal environmental services, has completed numerous projects involving marine mapping applications using a range of remotely sensed data, including high resolution satellite and aerial imagery, sidescan backscatter data and multibeam bathymetric data. In particular, benthic primary producer habitat (BPPH) and seagrass meadow mapping projects have been completed for Western Australian nearshore marine areas. Since the outcomes of these projects were instrumental in the environmental approvals process and for BPPH change calculations, they required a high positional and thematic accuracy. To achieve this accuracy, and in a cost-effective manner, we applied advanced feature extraction and classification methods using spectral or acoustic data most suited for mapping features at a particular resolution over a given area.

Typically, methods employed by BMT Oceanica's specialist remote sensing and GIS team included supervised classification approaches facilitated by ground truth data from classified video and diver observations, object-based segmentation to extract image objects, as well as spatial interpolation methods.

BMT Oceanica has successfully used sidescan backscatter and multibeam-derived bathymetric data to extract seagrass meadows off the coast of Perth and southwest WA in areas too turbid or deep to target with traditional remote sensing imagery. In clear shallow water areas, we have used high spatial resolution aerial imagery in combination with ground truthing interpolation methods for long-term repeat monitoring of large-scale seagrass meadows off Cockburn Sound, WA. For the assessment of BPPH losses/gains off Fremantle, WA, 8-band WorldView-2 satellite imagery was utilised to allow for improved spectral separation of habitat classes. We have also employed satellite imagery successfully to map benthic habitats and reef over remote areas, such as off northeast WA.

BMT Oceanica has a number of studies underway to test the capability of multibeam-derived bathymetric variables and high spectral resolution satellite imagery – potentially in conjunction with water column removal approaches – to improve the extraction of fine-scale habitats based on their spectral response and topography.

Future developments at BMT Oceanica include trialling a wider array of imagery types and sources suited to benthic habitat mapping, such UAV imagery, and advanced segmentation and classification methods. We are also exploring approaches for benthic feature extraction and classification from multibeam backscatter data.

Spatial and temporal persistence of giant kelp (*Macrocystis pyrifera*) along the Central Coast of California, USA

Mary A. Young[1], Kyle Cavanaugh[2], Li Erikson[3] and Curt Storlazzi[3]

[1]University of California at Santa Cruz, Ecology and Evolutionary Biology, Santa Cruz, California, USA, maalyoun@ucsc.edu

[2]Smithsonian Environmental Research Center, Edgewater, Maryland, USA

[3]United States Geological Survey, Pacific Coastal and Marine Science Center, Santa Cruz, California, USA

Rocky reefs in many temperate areas worldwide serve as habitat for canopy forming macroalgae (e.g. kelp) and these structure forming kelp forests often serve as important habitat for numerous species. Along the Pacific coast of North America from Baja California to Central California, giant kelp (*Macrocystis pyrifera*) is a common canopy forming marine alga. *M. pyrifera* has a patchy distribution throughout its range and this patchy distribution is believed to be caused by a number abiotic and biotic phenomena including the effects of currents, temperature, substrate, depth, swell intensity, size of kelp patches, nutrient availability, and many more. As a foundation species that provides food and habitat for a wide range of species including marine invertebrates and fishes, understanding the distribution and persistence of *M. pyrifera* throughout its range is important to understanding the community dynamics within the kelp forests. Using kelp biomass data derived from LANDSAT imagery, we focused on the Central Coast of California to determine what environmental variables are significant in explaining the distribution and persistence of *M. pyrifera*. The data derived from the LANDSAT imagery provided a 30m resolution time series of kelp biomass from 1984 to 2011, which were converted into annual and seasonal (winter/spring and summer/fall) persistence values based on the presence or absence of kelp. The resulting season-level and annual-level persistence layers were then combined with a suite of environmental variables to determine those variables responsible for the distribution and persistence of *M. pyrifera*. The variables used in this study included geomorphic structure variables derived from multibeam bathymetry data (depth, slope, rugosity, topographic position, substrate type), patch-based variables derived from the spatial kelp data (patch size, distance to patch edge, proximity to outside or inside edge of patch), and high-resolution spatial maps of wave orbital velocity. To associate kelp persistence with the environmental variables, generalized linear mixed models (GLMMs) and generalized additive mixed models (GAMMs) incorporating spatial correlation structure were used. The best models were then chosen based on AIC and deviance explained. We found that kelp persistence tends to increase in areas with higher complexity rocky habitat, high topographic relief, larger kelp patches, and toward the center of the kelp patch. On the other hand, kelp persistence has a significant negative relationship with wave orbital velocities and increases in depth. This study helps to further our understanding of how the variation in the environment affects the persistence of a foundation species along the California coast with implications for the management of many of the recreationally and commercially important marine species that use these kelp forests for habitat, food, and nursery grounds.

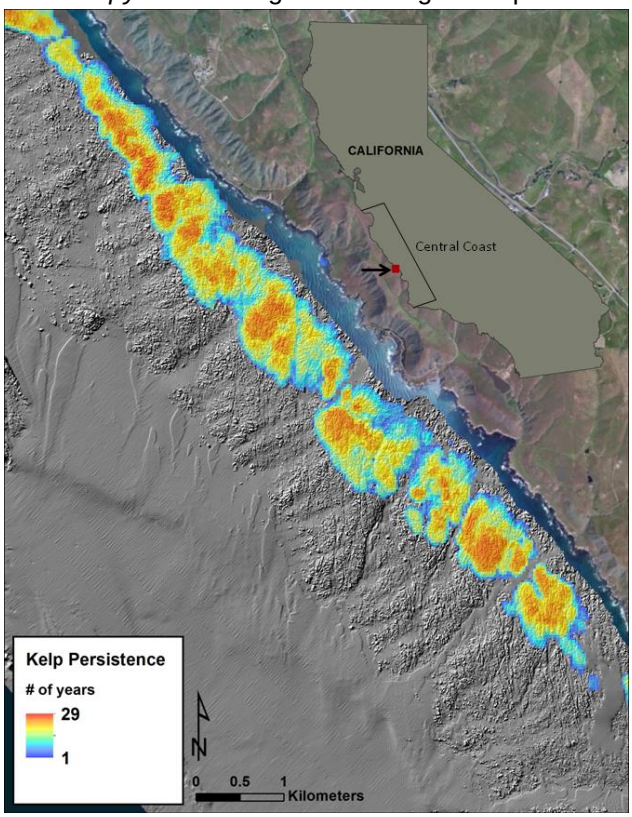

Fig. 1: Annual persistence of kelp overlaid on a 2m resolution shaded-relief image of the seafloor along a small region of the Central Coast of California.

Innovative monitoring tools to define Good Environmental Status of Coralligenous habitats

Paula A. Zapata-Ramirez[1], Carla Huete-Stauffer[1], David Scaradozzi[1], Michele Marconi[1] and Carlo Cerrano[1]

[1]Università Politecnica delle Marche, via. Brecce Bianche – Monte Dago, I-60100 Ancona, Italy, p.a.zapata@univpm.it

Sustainable management and exploitation of coralligenous bio-constructions is one of the most important concerns of the last decade throughout the Mediterranean basin. Their importance has been recognised under different international, European and national conservation frameworks (e.g. Habitats Directive; European Water Framework Directive). In particular, coralligenous environments are recognized as protected habitats in the EC Regulation No. 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the region. One of the main goals of the Marine Strategy Framework Directive (MSFD) is the establishment of a monitoring programme and protocols for ongoing assessment and regular updating of targets by 15 July 2014. Therefore, MSFD offers a crucial opportunity to test and validate novel monitoring approaches to the investigation on marine biodiversity and to develop programs of measures designed to achieve or maintain a Good Environmental Status (GES) by 2020 and that ultimately may be used as indicators. Consequently, the specific aims of this study were to test the potential of remote sensing techniques to map and to identify the environmental variables that influence the distribution of coralligenous environments. Here the case study of the Portofino MPA is reported. We applied acoustic and optical methods to provide insights on the distribution and other properties of coralligenous environments, to further generate outputs useful for informed decision making for managers when prioritizing areas (e.g. deciding the protection level). To achieve this aim we assessed the capacity of the Benthic Terrain Model data for discriminating different structures in coralligenous habitats. We investigated the effectiveness of the model and the geophysical substrate properties such as depth, slope, aspect, rugosity, and geomorphic zones, for detecting the location of known coralligenous communities in the MPA and to forecast new undescribed areas. Multi-beam sonar data were used in combination with optical data, collected during the ground truthing sampling. We generated three-dimensional reconstructions from stereo images to characterise the habitat composition and that help us to understand the spatial layout of seafloor features obtained by the acoustic information. Results show that this approach provides both high-resolution, full coverage surveys of selected areas that can be precisely revisited during monitoring activities as well as broader scale features of the terrain, such as surface roughness, slope and aspect that provide notion of the habitat structure and regarding sea floor integrity. In addition, optical information help us examine the correlations between populations and underlying bathymetric processes that determine their distribution. The results presented here fit the aims of MSFD by generating spatial mapping of coralligenous environments, building a key baseline for their monitoring and to define GES. The presented methods are simple and cost-effective becoming an optimal solution for extended monitoring by the combination of innovative and new tech tools.

How distance to reef and distance to soft sediment influence the structure of fish communities

Richard Zavalas[1], Daniel Ierodiaconou[1] and Jacquomo Monk[1]

[1]Deakin University, School of Life & Environmental Sciences, Warrnambool, Victoria, Australia, rz@deakin.edu.au

The influence of hard substrata and soft sediment habitats on the distribution and structure of demersal fish assemblages remains poorly defined for temperate continental shelf environments. The spatial distribution of transitioning fish assemblages between reef and sediment needs to be defined in order to properly assess the influence of seascape variation on fish-habitat associations. Through the use of high-resolution Multibeam Echosounder (MBES) and LiDAR spatial datasets we assessed distance to hard substrata or distance to soft sediment at a range of sample sites in four Marine Protected Areas (MPAs) of south-eastern Australia. Baited Underwater Video (BRUV) observations of demersal fishes were used to estimate species abundances, richness and biomass through length measurements. This information was integrated to assess at what distances ranging from 0 – 1500 m substrata type was influencing fish assemblages. Assemblage structure of demersal fishes was influenced by distance to dominant reef, with spatial transition between reef and soft sediment communities evident at distances up to 550 m from reef and 100 m from soft sediment. The transition gradients of assemblages differed at all four MPAs sampled and were driven by those fish species exploiting a wider range of substratum types. Species with similar functional traits displayed similar influences of distances to reef within habitat transition areas, such as reef 'centric' herbivores occurring at a smaller range from reef than other higher order species. Our analyses are useful for estimating at what range substrata type influences 'whole' assemblages and individual species. This information can be used to inform at what range seascape variation derived from high resolution spatial datasets should be considered for purposes such as habitat suitability modelling at community and species level. Therefore, further contributing to an ecosystem based approach to inform conservation and management objectives.

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