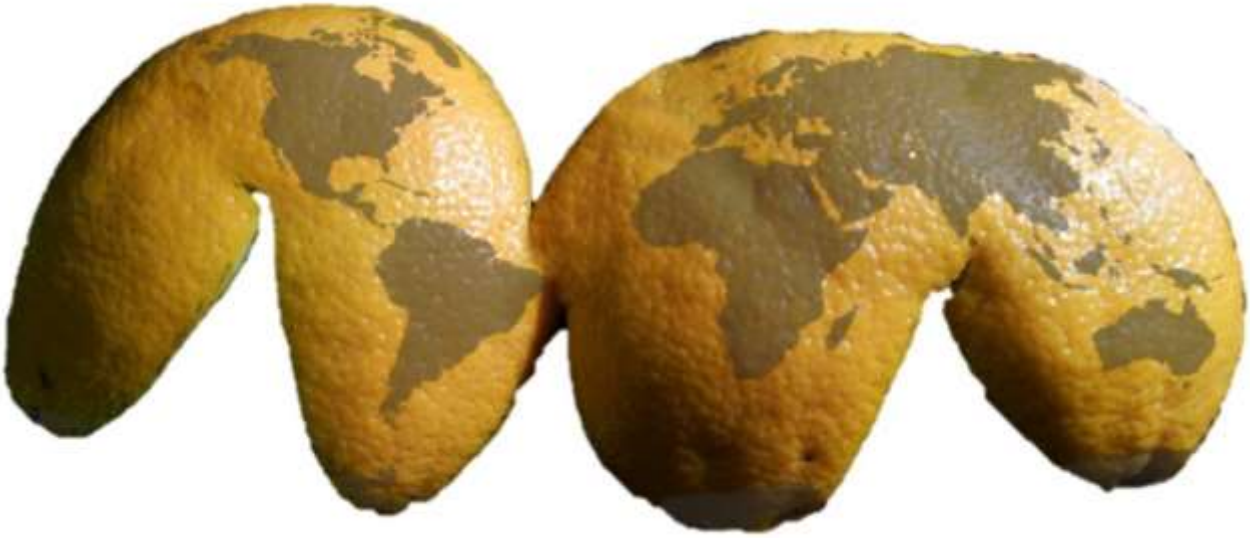
GEOHAB 2021

Marine Geological & Biological Mapping

PROGRAM AND

ABSTRACT BOOK



GeoHab Nodal Conference of Europe and Africa (GNCE&A)

5TH of May 2021

GEOHAB 2021

Marine Geological & Biological Mapping

Europe & Africa Node

5th May 2021

Slot 1	***Chairs*** ***Peter Harris and Federica Foglini***	
9:00-9:15	Swanborn et al.	Mapping geomorphological drivers of mesophotic coral ecosystems around Seychelles
9:15-9:30	Appah et al.	Environmental Controls of Benthic Megafauna Distributions in the Cold-Water Coral rich habitat of the upper Porcupine Bank Canyon, NE Atlantic
9:30-9:45	Price et al.	Fine-Scale Heterogeneity of a Cold-Water Coral Reef and Its Influence on the Distribution of Associated Taxa
9:45-10:00	Curtis et al.	Investigating inter-user variability in seabed image annotation and its impact on cold-water coral monitoring programmes
10:00-10:15	de Oliveira et al.	3D Classification of Cold-Water Coral Reefs: A Comparison of Classification Techniques for 3D Reconstructions of Cold-Water Coral Reefs and Seabed
10:15-10:30	**BREAK**	
Slot2	***Chairs*** ***Fantina Madricardo and Aarno Kotilainen***	
10:30-10:45	Castellan et al.	A simple method to estimate light intensity at seafloor: applications in the study of Mediterranean benthic mesophotic ecosystems
10:45-11:00	Minelli et al.	Semi-Automated Data Processing and Semi-Supervised Machine Learning for the Detection and Classification of Water-Column Fish Schools and Gas Seeps with a Multibeam Echosounder
11:00-11:15	Roche et al.	Quantifying sediment plumes induced by human activities by using MBES and SBES water column data combined with in situ measurement and water sampling: feasible?
11:15-11:30	Vejzovic et al.	Beyond Pretty Pictures: A Methodical Approach For Generating 3D Models Of Hydrothermal Vents In The Subantarctic By Utilising Structure From Motion (SfM)
11:30-11:45	Harris et al.	Exposure of coastal benthic habitats to river-sourced plastic pollution
11:45-11:50	**BREAK**	

Slot 3	***Chairs*** ***Federica Foglini and Hayley Cawthra***	
11:50-12:05	Montereale-Gavazzi et al.	What lies beneath the busiest shipping lane of the world? Stony reefs in the Belgian Continental Shelf: a quantitative mapping approach.
12:05-12:20	Le Bas	GIS tools for marine habitat mapping “made easy”.
12:20-12:25	Deleu et al.	A stable reference area for multibeam bathymetry and backscatter: KWINTE, a dedicated quality control area in the Belgian North Sea
12:25-12:30	Makori et al.	Acoustic Seabed Classification Using the Single Beam Echo sounder System (SBES): A Case Study on the Kenyan Territorial Zone
12:30-13:30	**LUNCH BREAK**	
Slot 4	***Chairs*** ***Fantina Madricardo and Aarno Kotilainen***	
13:30-13:45	Summers et al.	A scalable, supervised classification of seabed sediment waves: using an object-based image analysis approach
13:45-14:00	Hansen et al.	Classification of boulders in coastal marine environments using random forest machine learning on an imbalanced data set from topo-bathymetric LiDAR
14:00-14:15	Yamada et al.	Metadata Enhanced Feature Learning for Efficient Interpretation of AUV Gathered Seafloor Visual Imagery
14:15-14:30	Sañé et al.	Characterization Of Rhodolith Beds-Related Backscatter Facies From The Western Pontine Archipelago (Mediterranean Sea)
14:30-14:45	Barette et al.	Mapping gradients in seafloor characteristics in the Belgian part of the North Sea: preliminary findings and way forward
14:45-15:00	**BREAK**	
Slot 5	***Chairs*** ***Andrea Fiorentino and Fantina Madricardo***	
15:00-15:15	Dorokhova et al.	Landscape mapping and ichnological studies in a deep-water gateway, Discovery Gap, NE Atlantic
15:15-15:30	Wardell	Broadscale Landscape Mapping of the Commonwealth of Dominica and surrounding Islands
15:30-15:45	Leontev et al.	New data about benthic landscapes of the eastern Gulf of Finland (Baltic Sea): first results of ADRIENNE project
15:45-15:50	Hartmann et al.	4S - The EU project to map and monitor shallow water benthic and bathymetry
15:50-15:55	Castle et al.	A broad-scale seabed habitat map for Europe – EUSeaMap 2019 and plans for 2021
15:55-16:05	**BREAK**	

Slot 6	***Chairs*** ***Daria Ryabchuk and Aarno Kotilainen***	
16:05-16:20	Franken et al.	Wadden Mosaic: Understanding the ecological functioning of the subtidal Dutch Wadden Sea
16:20-16:35	D'Urban Jackson et al.	Mapping temperate reef habitats in high energy waters
16:35-16:50	Karpin et al.	Streamlined bedforms of the Western Estonian Shelf - implications for ice-flow reconstruction
16:50-17:00	**Discussions and Closure**	

Mapping geomorphological drivers of mesophotic coral ecosystems around Seychelles

D.J.B. Swanborn[1,2,3], V.A.I. Huvenne[4], S.J. Pittman[5,6], L.C. Woodall[1,3], Nico Fassbender[3], Paris Stefanoudis[1,3]

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2. University of Oxford, Department of Earth Sciences, UK
3. Nekton Foundation, UK
4. National Oceanography Centre (NOC), Ocean BioGeosciences, UK
5. Oxford Seascape Ecology Lab, University of Oxford, UK
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Mesophotic coral ecosystems (MCEs) consist of light-dependent reef communities typically found at a depth range of 30-150 m in clear tropical and subtropical waters. Major knowledge gaps exist in our understanding of the drivers and geographical distribution of MCEs which limit evidence-based conservation and management. Spatial predictive models using terrain variables as predictors of MCE occurrence, however, offer a solution to address geographical gaps in our knowledge and generate insights into ecological relationships, even where detailed biological data are scarce. Predictive models in MCEs have mainly focused on individual species, but as MCEs consist of multiple taxa contributing to the structure and functioning, community-level approaches may provide significant advantages. Knowledge of the patterns in seascape structure behind community occurrence and distribution is particularly relevant for little-explored marine regions, such as the Western-Indian Ocean (WIO), where MCEs are abundant around coastal zones and oceanic islands yet remain understudied.

We combined terrain models derived from high-resolution multibeam sonar with observations of biological communities from submersible-video surveys to classify benthic MCE assemblages and model their occurrence and distribution in four atoll seascapes in Seychelles. Cluster analysis identified four different biological assemblages, and Random Forests (RF) and Boosted Regression Trees (BRT) modelled assemblage-environment relationships of each assemblage type. Best models exhibited good to excellent overall performance with mean absolute error ranging from 2% to 22.9% for RF and from 2% to 24.7% for BRT models. Water depth, distance from shore, terrain rugosity, curvature and slope contributed most to the models. Models were used to produce probability distribution maps that showed distribution patterns for identified MCE assemblages across locations, with high occurrence probabilities linked to complex geomorphological structures.

This study is the first to model and predict biological assemblages across MCE seascapes in the WIO. Our results contribute to a better understanding of the relationship between seascape structure and mesophotic reef ecosystems in this region. We demonstrated that multi-scale bathymetric derivatives perform as reliable predictors for mapping mesophotic assemblages in the WIO and identifying priority habitat. Complex geomorphological structures, including terraces and paleoshorelines, supported high densities of MCE habitat, and we recommend these could be considered priority areas for marine biodiversity conservation.

Environmental Controls of Benthic Megafauna Distributions in the Cold-Water Coral rich habitat of the upper Porcupine Bank Canyon, NE Atlantic

Appah J. K. M.[1], Lim, A.[1,3], Harris, K.[1], O' Riordan R[1], O'Reilly L.[1], Wheeler A. J.[1,2]

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3. Green Rebel Marine, Crosshaven Boatyard, Crosshaven, Co. Cork, Ireland

Submarine canyons support high biomass communities as they act as conduits where sediments, nutrients and organic matter from continental shelves, or carried by along slope currents, are transported into the abyssal zone. The Porcupine Bank Canyon (PBC), located on the Irish continental margin, reveals a complex terrain and variable substrata that affect the distribution of benthic fauna.

Here, ROV based benthic video, Conductivity-Temperature-Depth (CTD) and bathymetric data were assessed to show the effects of environmental processes on the distribution of benthic megafauna throughout the canyon.

Multivariate analysis of the benthic community reveals significant ($0.091 < R < 0.166$, $P < 0.05$) differences in the community structure between the habitats throughout the canyon. Furthermore, the analysis shows that non-coral habitats exhibit more variation in the composition of benthic taxa than coral habitats, with the following taxa most contributing to the structural differentiation: *Leiopathes glaberrima* (12.46%), *Hexadella dendritifera* (10.37%), *Cidaris cidaris* (9.31%), *Aphrocallistes beatrix* (9.33%), Areaosoma fenestratum (9.11%), *Stichopathes cf. abyssicola* (7.39%), *Anthomastus glandiflorus* (4.66%) and *Benthogonea rosea* (3.84%). In addition, bathymetric variables (depth, slope), habitats and sites are the most important environmental drivers that affect benthic taxa distribution in the PBC.

Habitat variability, bathymetry and oceanographic processes most likely control benthic taxa distribution in the canyon. The findings of the current study will inform fishermen on how to responsibly interact with the canyon and can help inform policy makers on the effective management of the cold-water coral (CWC) environment in the PBC.

Fine-Scale Heterogeneity of a Cold-Water Coral Reef and Its Influence on the Distribution of Associated Taxa

D.M. Price[1,2], A. Lim[3,4], A. Callaway[5,6], M. Eichhorn[3], A.J. Wheeler[3], C. Lo Iacono[7], V.A.I. Huvenne[2]

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5. Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK
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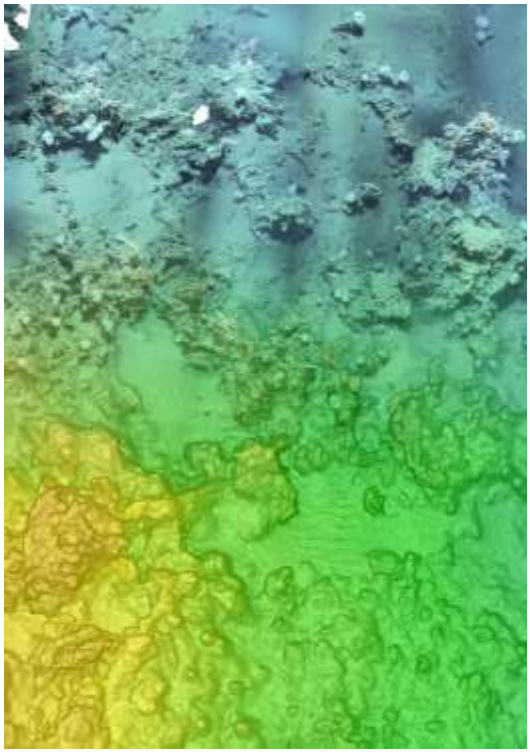
Benthic fauna form spatial patterns which are the result of both biotic and abiotic processes, which can be quantified with a range of landscape ecology descriptors. Fine- to medium-scale spatial patterns (<1–10 m) have seldom been quantified in deep-sea habitats, but can provide fundamental ecological insights into species' niches and interactions. Cold-water coral reefs formed by *Desmophyllum pertusum* (syn. *Lophelia pertusa*) and *Madrepora oculata* are traditionally mapped and surveyed with multibeam echosounders and video transects, which limit the ability to achieve the resolution and/or coverage to undertake fine-scale, centimetric quantification of spatial patterns. However, photomosaics constructed from imagery collected with remotely operated vehicles (ROVs) are becoming a prevalent research tool to map cold-water coral reefs and can reveal novel information at the scale of individual coral colonies.

A downward facing camera mounted on a ROV which traversed the Piddington Mound (Belgica Mound Province, NE Atlantic) in a lawnmower pattern was used to create 3D reconstructions of the reef with Structure from Motion techniques. Three high resolution orthorectified photomosaics and digital elevation models (DEM) >200 m^2 were created and all organisms were geotagged in order to illustrate their point pattern. The pair correlation function was used to establish whether organisms demonstrated a clustered pattern (CP) at various scales. We further applied a point pattern modelling approach to identify four potential point patterns: complete spatial randomness (CSR), an inhomogeneous pattern influenced by environmental drivers, random clustered point pattern indicating biologically driven clustering and an inhomogeneous clustered point pattern driven by a combination of environmental drivers and biological effects. In this presentation we will discuss how reef framework presence and structural complexity influenced inhabitant distribution, as most organisms showed a departure from CSR. These CPs are likely caused by an affinity to local environmental drivers, growth patterns and restricted dispersion reproductive strategies within the habitat across a range of fine to medium scales. These data provide novel and detailed insights into fine-scale habitat heterogeneity, showing that non-random distributions are apparent and detectable at these fine scales in deep-sea habitats.



Investigating inter-user variability in seabed image annotation and its impact on cold-water coral monitoring programmes

Emma J. Curtis[1,2], Jennifer M. Durden[2], Brian J. Bett[2], Blair Thornton[3,4], Veerle A.I. Huvenne[2], Nils Piechaud[2,5], Adrian Bodenmann[6], Jose Cappelletto[6], Subhra Kanti Das[6], Miquel Massot-Campos[6], Henry Ruhl[7], James Asa Strong[2], Jenny Walker[6] and Takaki Yamada[3]

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Long-term monitoring of benthic communities is essential to understand the resilience of marine ecosystems to anthropogenic impact and to assess the effectiveness of conservation measures such as Marine Protected Areas (MPAs). Digital photographs are now widely used in monitoring programmes, where information about the biota is typically extracted through annotation by human experts. Although automated techniques are also in development, these normally require human annotated data for training, making the variability between expert annotations a primary concern for study robustness and comparability.

To investigate inter-user variability and its impact on ecological metrics in the monitoring of cold-water corals, we compare 11 users' annotations of seabed images from the Darwin Mounds Special Area of Conservation (c. 1000 m water depth), and compare two annotation approaches: grid-based estimation and manual polygon segmentation to measure seabed cover. The images were captured using a combined stereo camera and double laser line scanner system (BioCam) integrated into an autonomous underwater vehicle (Autosub6000). The same group of 96 images were annotated in random order by each user using the Squidle annotation platform, with repeated annotation for each of the two annotation methods.

Preliminary results show inter-user variability in the coral cover determined. Cover estimates from images where coral was detected had ranges greater than their respective average cover estimate. An offset was found between the two approaches, with grid-based estimates of coral cover being higher than estimates from manual polygon segmentation. Based on these results, we consider how to reduce this variability in annotation, and how such variability can be considered when comparing studies. We also aim to show how this variability can be used to create a more robust training dataset for automated annotation.

To view the full image set used in this study visit:
https://soi.squidle.org/
Campaign: dy108-109_nerc_oceanids_class
[ID:57]

3D Classification of Cold-Water Coral Reefs: A Comparison of Classification Techniques for 3D Reconstructions of Cold-Water Coral Reefs and Seabed

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3. Escola de Artes, Ciências e Humanidades, Universidade de São Paulo, São Paulo, Brazil
4. Irish Centre for Research in Applied Geosciences, Marine and Renewable Energy Institute, University College Cork, Cork, Ireland

Cold-water corals (CWC) reefs are key components of deep-sea ecosystems due to their complex geomorphology and their role in nutrient supply dynamics. As three-dimensional structural habitats, there is a need for robust and accessible technologies to enable more accurate reef assessments. The use of Remotely Operated Vehicles (ROV) combined with Structure-from-Motion (SfM) photogrammetry represent an effective and non-destructive methodology that yields high-resolution reconstructions of deep-sea environments such as cold-water coral habitats and submarine canyons. The increase of data derived from SfM mapping has led to the necessity for new tools and techniques to aid time-effective and high-quality analysis of large areas.

In this study, three classification workflows [Multiscale Geometrical Classification (MGC), Colour and Geometrical Classification (CGC) and Object-Based Image Classification(OBIA)] were applied to photogrammetric reconstructions of CWC habitats in the Porcupine Bank Canyon, NE Atlantic. In total, six point clouds, orthomosaics, and digital elevation models, generated from structure-from-motion photogrammetry, are used to evaluate each classification workflow. We analysed the classification accuracy results, overall performance and the potential loss of information when using 2D and 3D data.

Our results show that 3D Multiscale Geometrical Classification outperforms the Colour and Geometrical Classification method. Accuracy results varied from 59 to 90% with average of 67.2% in point-clouds. However, each method has advantages for specific applications pertinent to the wider marine scientific community. Results suggest that SfM can contribute to more precise structural analysis of CWC habitats while also providing grounds for temporal and volumetric change detection in CWC reefs. Furthermore, advancing from commonly employed 2D image analysis techniques to 3D photogrammetry classification methods is advantageous and may provide a more realistic representation of cold-water coral habitats.

A simple method to estimate light intensity at seafloor: applications in the study of Mediterranean benthic mesophotic ecosystems

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In the last 20 years, the body of literature about benthic mesophotic ecosystems is strongly increased, together with the awareness of both their biological richness and related ecological importance.

Mesophotic ecosystems host coral, algae, and sponge assemblages constituting complex three-dimensional structures, mainly located between 30 m and the bottom of the photic zone, frequently defined as 1% of the photosynthetically active radiation (PAR).

Although this threshold has been commonly used to define the limit of the photic zone in the past, evidence of macroalgae assemblage (mainly coralline) able to maintain their photosynthetic metabolism up to 0.0005% PAR potentially extend the photic zone deeper than what previously thought. Further information on the bathymetric limits of the mesophotic zone would be of great importance for the environmental characterization and the spatial definition of the mesophotic zone. It is also functional to plan future research and support management plans and conservation measures.

We estimate the quantity of PAR reaching the seabed from 17-year (2002-2018) average surface chlorophyll-a concentration from open-access repository (NASA Ocean Color). By setting the upper border of the Mesophotic Zone at 30m depth and the lower at 0.0005% of surface PAR, the portion of seabed that falls under mesophotic conditions in the Mediterranean Sea is then estimated. Our spatial definition is compared with the distribution of benthic mesophotic assemblages from available literature to test the reliability of the proposed area.

Finally, we analyze the estimated light intensity values in correspondence of 25 mesophotic assemblages along the Italian coasts explored with visual benthic surveys to investigate the influence of light on the taxonomic composition of these mesophotic ecosystems.

Semi-Automated Data Processing and Semi-Supervised Machine Learning for the Detection and Classification of Water-Column Fish Schools and Gas Seeps with a Multibeam Echosounder

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2. Echoview Software Pty Ltd, Australia
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Multibeam echosounders are widely used for 3D bathymetric mapping, and increasingly for water column studies. However, they rapidly collect huge volumes of data, which poses a challenge for water column data processing that is often still manual and time-consuming, or affected by low efficiency and high false detection rates if automated. This research describes a comprehensive and reproducible workflow that improves efficiency and reliability of target detection and classification, by calculating metrics for target cross-sections using a commercial software before feeding into a feature-based semi-supervised machine learning framework (Fig.1). In particular, assuming that targets such as fish schools, gas seeps and noise differ in morphological metrics, scattering degree and behaviour in time, the proposed workflow makes use of Echoview and machine learning techniques to: (i) speed-up the target extraction procedure by drafting a reproducible workflow that can be run automatically in Echoview and embedded in a template that can be efficiently applied to new surveys.; and (ii) classify extracted targets using a pre-trained stacking ensemble machine learning framework. For more detailed information on the ML pipeline the code is available at: http://doi.org/10.5281/zenodo.4621173. It was developed in Python with the support of its Scikit-learn machine learning library.

The method is tested with data collected with a Kongsberg EM2040CD around 2 offshore gas platforms in the Adriatic Sea (Fig.2, left): Survey 1-3 were conducted at site A, while Survey 4 at site B. Once evaluated on the testing Survey 1 dataset, the trained model was saved and used to classify the remaining unseen datasets. It resulted in a sensitive speed-up of target detection and, although uncertainties regarding user labelled training data need to be underlined, an accuracy of 98% in target classification was reached by using a final pre-trained stacking ensemble model.

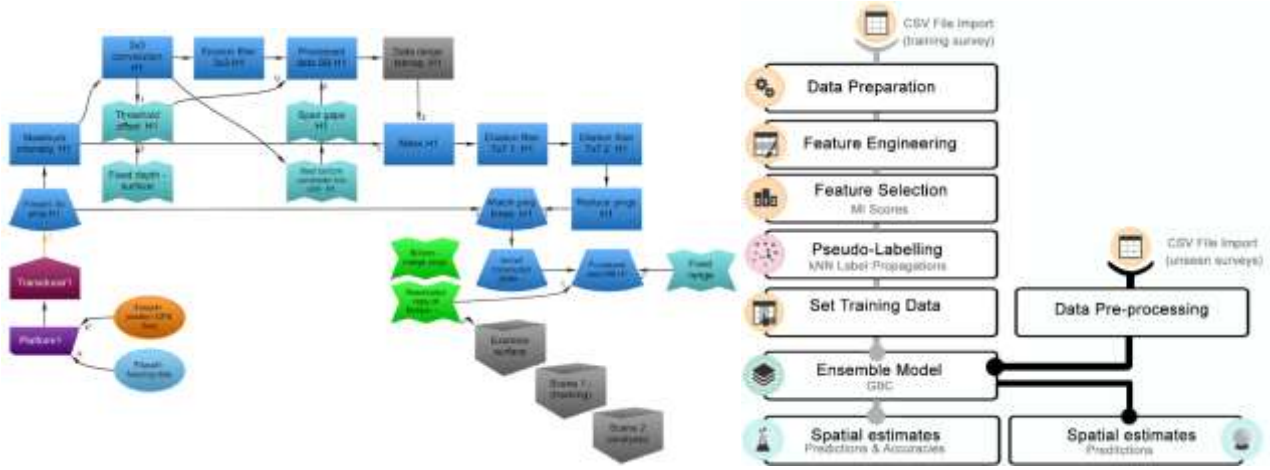

Figure 1. Echoview "Dataflow" window showing the data-processing steps applied to transducer 1 ("H1") (left); machine learning data-processing workflow to train the model before performing predictions on unseen data (right)

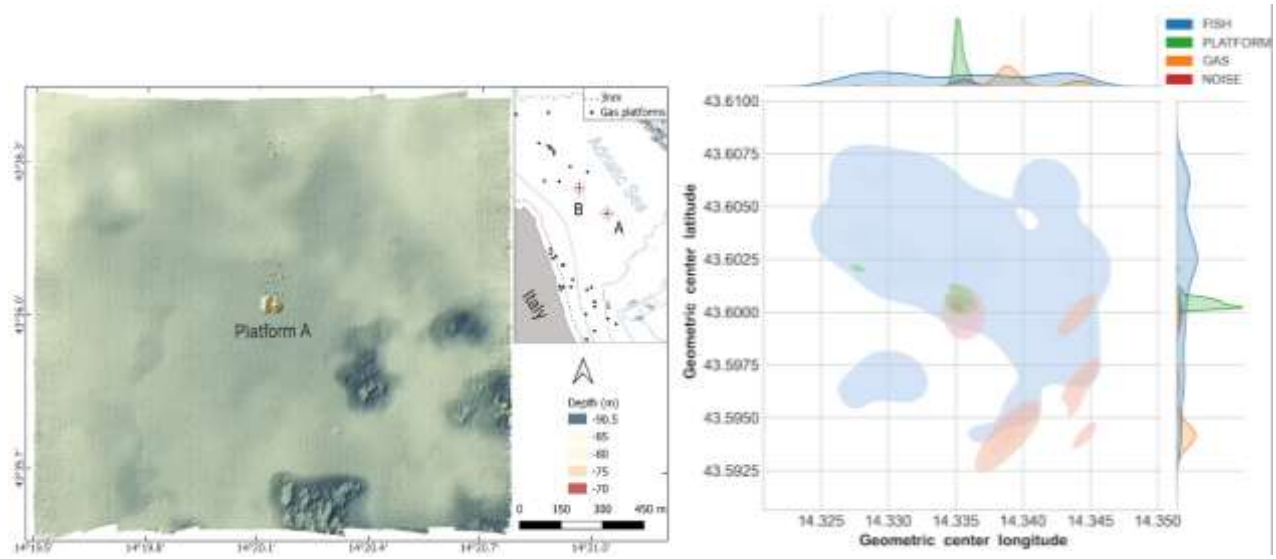

Figure 2. Site A surrounding the gas platform A. The red cross symbols in the locator map highlight the location of two study sites in the Adriatic Sea (left): Predictions on Site A - Kernel Density Estimation plot (right)

Quantifying sediment plumes induced by human activities by using MBES and SBES water column data combined with in situ measurement and water sampling: feasible?

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5. IFREMER, NSE-AS, France

The Belgian part of the North Sea is an area of dense economic activities generating various impacts on the marine environment. Most of these activities are closely monitored, but important questions remain regarding the direct and indirect impact from diversely generated sediment plumes. To the point, human-induced Suspended Particle Matter (SPM) plumes could, including transport and resedimentation, notably modify the habitats within a certain radius around their centre of creation. A clear example are the gravel areas, hosting high biodiversity, that border the sandbanks where sand extraction takes place.

Recently, attempts to evaluate the volume of SPM generated by human activity in real-time by direct field observation, resulted in a series of simultaneous acoustic water column measurements with a Kongsberg EM2040 dual RX multibeam echosounder (MBES) and a Simrad EK80 calibrated single beam echosounder (SBES) onboard the RV Simon Stevin, while tracking different sand dredging vessels and beam trawlers during their activity. Qualitatively, the dynamic observation of polar and longitudinal echograms derived from the backscatter values (Sv in dB/m³), normalized for the volume of water involved, revealed vortices of highly variable Sv levels. These effects can potentially be attributed to SPM plumes from dredging and trawling activities. The development of specific echo-integration algorithms makes it possible to quantify the Sv level within different slant ranges and angular intervals of the water column, as a function of time. Although a substantial part of the swirls of Sv in the upper part of the water column is linked to the propulsion of the research vessel itself, Sv level time series acquired near the seabed made it possible to distinguish between stable Sv levels, characterizing water masses that are not affected by human activity, and intense and fluctuating Sv level phases, linked to the presence of sediment plumes .

Based on in situ SPM concentration measurements from water filtrations and grain size measurements acquired synchronously with the acoustic data, continuous SPM concentrations were derived from acoustic measurements, using a scattering model. Additionally, tidal cycle stationary measurements were conducted at a coastal site where highly turbid and changing waters prevail. On this location, Kongsberg EM2040 dual RX MBES and Simrad EK80 calibrated SBES water column data measurements were combined with in situ measurements by an optical turbidity sensor (Campbel Scientific OBS3 +) and laser scattering and transmissometer (LISST 100C of Sequoia Scientific Inc.). Water samples using Niskin bottles were harvested at regular intervals. However, the spatial distance between the fixed sensors and the in situ measuring and sampling, can reduce the consistency between them and explain the relatively weak correlation that was observed on this location between the SPM concentration and the EM2040D Sv levels.

The sediment plumes generated by human activities at sea are difficult to grasp due to their diffuse nature, implying strong spatial and temporal variability. The results obtained within this preliminary study demonstrate that quantification by scientific measurements at sea should be feasible but highly challenging, requiring suitable logistics, the implementation of dedicated calibrated acoustic devices synchronized with in situ SPM measurements and water sampling. Real-time integration of hydrodynamic data combined with the position of the research vessel and with that of the vessel generating the sediment plume must be considered as well.

Beyond Pretty Pictures: A Methodical Approach For Generating 3D Models Of Hydrothermal Vents In The Subantarctic By Utilising Structure From Motion (SfM)

I. Vejzovic[1], P. Wintersteller[2] (further people involved, in process)

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2. MARUM Center for Marine Environmental Sciences, University of Bremen, Germany

Underwater vehicles such as the Remotely Operated Vehicle (ROV) can be used to acquire visual imagery from remote areas previously hidden in the vast deep ocean. With this high-resolution near-bottom approach we are able to image seafloor features down to a mm-range and to map the benthic habitat of the scene of interest. Here, we present high-resolution 3D models of chimney complexes from the East Scotia Ridge (ESR) by using the SfM approach. Additionally, the 3D models should contribute to a better positional rectification of measurements and bathymetry acquired with the Ocean Floor Observation Bathymetry System (OFOBS).

E2 is one of the nine main segments from the ESR active back-arc spreading centre located west of the South Sandwich island arc in the Southern Ocean. It is one of the two segments with hydrothermal activity. Hydrothermal vents at the ESR were the first to be visually confirmed and surveyed in the Southern Ocean. During an expedition of *RV* Polarstern, the chemosynthetic ecosystems could be observed via the ROV MARUM QUEST. The newly discovered yeti crab (Kiwa n. sp.), as well as other chemosynthetic organisms dominate the chimney complexes.

While conventional 2D photo mosaics provide excellent information to e.g. map and count fauna or flora within its habitat, SfM opens the future to a supportive, high-detailed 3D mapping which allows a better interpretation of the habitat´s geomorphology and geology.

Our approach covers at least three photogrammetric models derived from ROV video footage by implementing the SfM workflow. In a first step, still imagery is extracted from the pre-selected sequences of the ROV video material by using open-source software. A pre-processing of the resulting images enhances the perceptibility of features. The following feature detection and the extraction of a photogrammetric extracted sparse point cloud as the basis of the 3D model is blended with navigation data derived from corrected and post-processed underwater navigation.

The georeferenced 3D models, finally draped with the photo mosaic, will allow to correct for positional mismatches of bathymetry derived by the towed OFOBS. The approach should demonstrate the importance of photogrammetry for these types of analysis.

Exposure of coastal benthic habitats to river-sourced plastic pollution

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European time zone
Non-student presentation

Abstract

Marine litter is a global problem which poses an increasing threat to, ecosystem services, human health, safety and sustainable livelihoods. In order to better plan plastic pollution monitoring and clean-up activities, and to develop policies and programmes to deter and mitigate plastic pollution, information is urgently needed on the different types of coastal ecosystems that are impacted by land-sourced plastic inputs, especially those located in proximity to river mouths where plastic waste is discharged into the ocean. We overlayed the most current existing information on the input of plastic to the sea from land-based sources with maps of coastal environments and ecosystems. We found an inverse relationship exists between coastal geomorphic type, plastic trapping efficiency and the mass of plastic received. River-dominated coasts comprise only 0.87% of the global coast and yet they receive 52% of plastic pollution delivered by fluvial systems. Tide-dominated coasts receive 29.9% of river-borne plastic pollution and this is also where mangrove and salt marsh habitats are most common. Wave-dominated coasts receive 11.6% of river-borne plastic pollution and this is where seagrass habitat is most common. Finally, rocky shores comprise 72.5% of the global coast, containing fjords and coral reefs, while only receiving 6.4% of river-borne plastic pollution. Mangroves are the most proximal to river-borne plastic pollution point sources of the four habitat types studied here; 54.0% of mangrove habitat is within 20 km of a river that discharges more than 1 tonne/yr of plastic pollution into the ocean. For seagrass, salt marsh and coral reefs the figures are 24.1%, 22.7% and 16.5%, respectively. The findings allow us to better understand the environmental fate of plastic pollution, to advance numerical models and to guide managers and decision-makers on the most appropriate responses and actions needed to monitor and reduce plastic pollution.

What lies beneath the busiest shipping lane of the world? S*tony reefs* in the Belgian Continental Shelf: a quantitative mapping approach.

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Stony reefs, referred to as gravel beds in Belgian waters, and collectively referenced as subtidal natural hard substrate biotopes, promote occupancy by rich benthic communities that provide irreplaceable and fundamental ecosystem functions. Reefs are fragile biotopes and represent a global priority target for environmental stewardship. In predominantly sedimentary seafloors, such as for the Greater North Sea region, their ecological relevance substantially increases given the paucity of foundation species. All inherent European directives and conventions mention reefs in some way. However, scientifically validated methodologies for the quantitative spatial demarcation of reef habitats, accounting for their low resistance and resilience to anthropogenic disturbances, are rare. This study presents a minimally invasive benthic habitat mapping methodology for the monitoring of seafloor integrity under the umbrella of Europe's Marine Strategy Framework Directive (MSFD) (see QR code). For a 32 km^2 offshore study site, high-resolution (1 m) multibeam echosounder (MBES) data and optical images by an underwater video drop-frame were acquired, analysed to quantitatively characterise the reefs, and integrated to produce a random forest spatial model, used to predict the continuous surficial distribution of the coarse substrate grain size fraction (% / 1 m^2) with the highest potential for colonisation by sessile epilithic organisms.

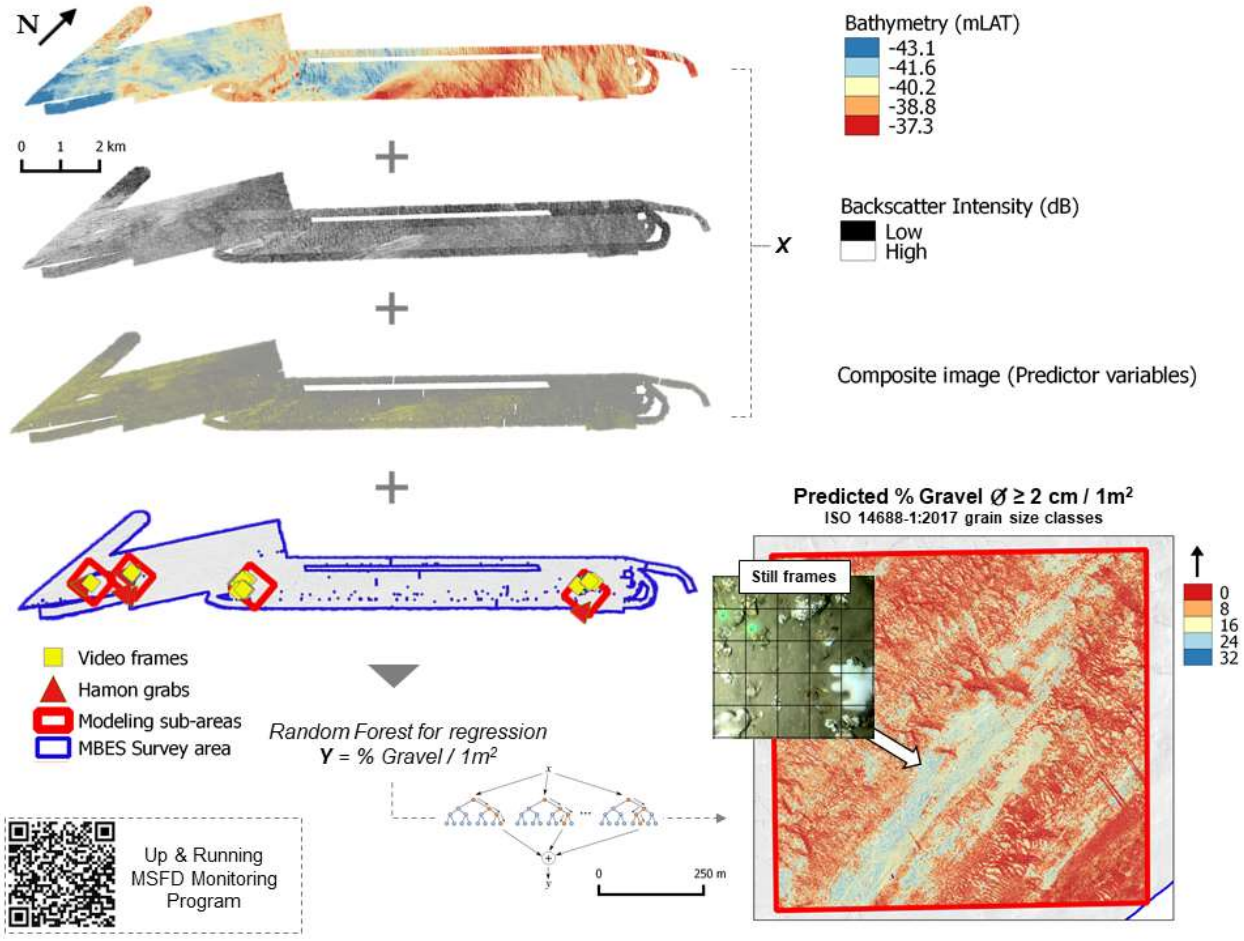

Figure 1 – Schematic diagram illustrating the benthic habitat mapping methodology.

GIS tools for marine habitat mapping “made easy”.

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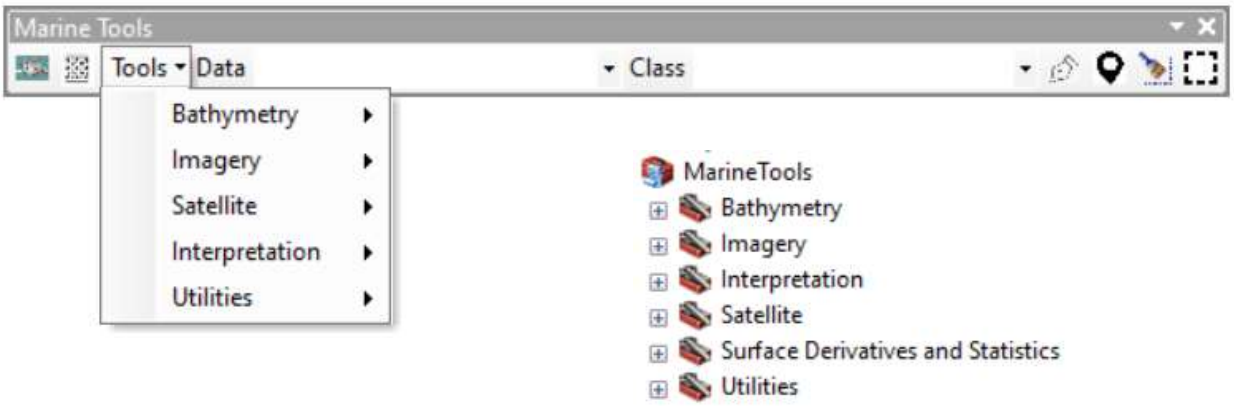
Marine habitat mapping often uses a great variety of data sources. They have to be manipulated in a coherent manner, often by their geographic location and extent, for analysis. However, many Geographic Information Systems (GIS) are primarily designed for terrestrial and human geography analysis. GIS software is often presented as a series of fundamental tools that a user can utilise step by step to produce a required analysis. It is common for some standard analysis techniques to have a series of tools to be chained together to create the required result, but seldom these chains are developed with the marine GIS user in mind.

Presented here is a new toolbar for ArcMap which provides many standard marine habitat mapping techniques. Scientific papers often present new and complex data manipulation techniques which readers may wish to copy using their own data. This has an expectation for users to go through each step individually to produce a result. When results from these steps are gained, users often find it cumbersome to go through the whole process again to alter a parameter or use an alternative data source. Users can write, edit and compile their own code, but this requires a certain level of programming experience and GIS expertise. Having a set of pre-made tools collated and designed for marine habitat mapping will accelerate the users’ progress and allow time for higher level analyses and interpretation. The tools do allow a certain amount of parameter variation and data input changes, to test interpretation sensitivity to changes in input data.

The tools are divided into 5 categories: Bathymetry manipulation, Sidescan, backscatter and photographic imagery operations, Satellite derived bathymetry, Classification and interpretation techniques and Miscellaneous utilities for data handling. Demonstrations of the main functions and their application to example datasets will be given.

The toolbar is available for free download and can be used as a toolbar or toolbox in ArcMap (versions 10.1 to 10.8). Download produces an executable file which, when run, installs all the files for the toolbar and toolbox. Some example datasets are included for testing. Administrative privilege is required for installation.

Available at https://projects.noc.ac.uk/cme-programme/workshops



A stable reference area for multibeam bathymetry and backscatter: KWINTE, a dedicated quality control area in the Belgian North Sea

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Habitat mapping is nowadays increasingly carried out using multibeam echosounders (MBESs). However, the measurements of each operational MBES need to be regularly controlled on a well-known area to validate the quality of both the bathymetry and backscatter. Such a reference area has now been established in the Belgian part of the North Sea (KWINTE) based on multiple high quality hydrographic and research surveys over a coarse-grained and stable seabed with low seabed dynamics.

The importance of such a measurement control area was recognized in the 2020-2026 Belgian Marine Spatial plan, allowing its protection from seabed disturbing activities. The area is open to use for every public or private institute or company wanting to calibrate and evaluate the quality of measuring devices. The reference bathymetric model and backscatter level are available on request. The KWINTE area is ideal for performing a cross check test. The cooperation with the project partners is strongly encouraged by suggesting that users transmit their data collected on the KWINTE area. After a quality control, the new dataset will be integrated into the reference bathymetric model and the backscatter database. All necessary information can be found on the project website: https://www.afdelingkust.be/en/acoustic-reference-area-kwinte

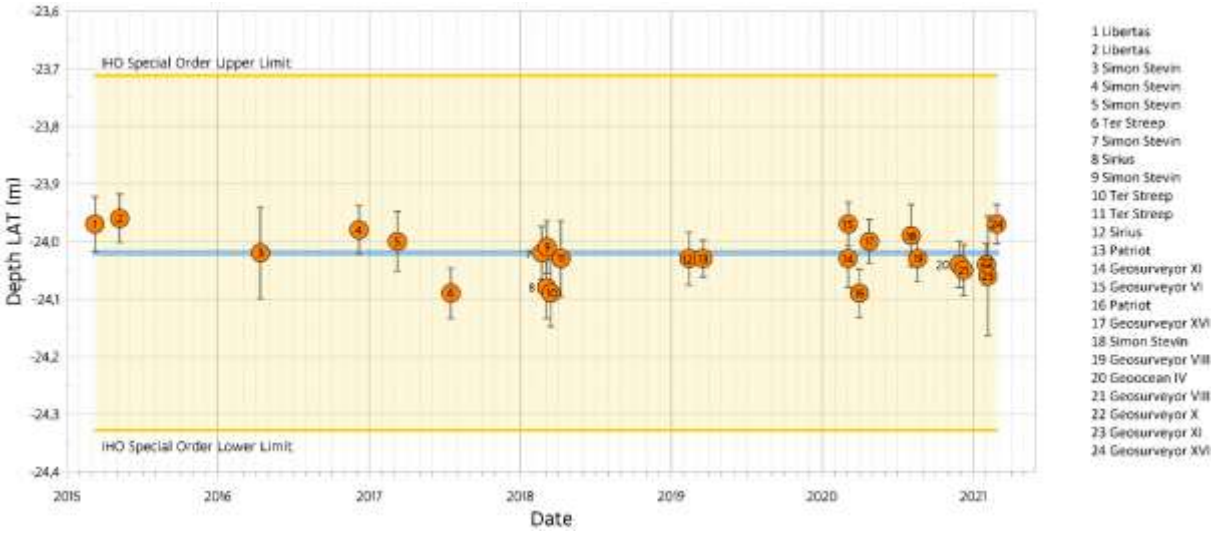

Figure 1 : Bathymetric time series of approved surveys (orange dots: mean depth value of all soundings with 95% confidence error bars; blue line: reference towards the mean depth value of the reference model; yellow line: reference towards the IHO Special Order Limits).

Acoustic Seabed Classification Using the Single Beam Echo sounder System (SBES): A Case Study on the Kenyan Territorial Zone

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The use of acoustic backscatter measurements to classify seabed substrate is an efficient option to rapidly decipher different seabed substrate. Understanding seabed characteristics is important for many disciplines including marine spatial planning, fisheries, geology, oceanography and geo-exploration. Nonetheless, automatic sea bottom classification remains a major problem. This study focuses on the utilization of normal incident acoustic data, to identify substrate types and generate an informative user-defined acoustic-derived seabed map of Kenya's territorial region from Shimoni in the south to Kiunga in the north. Acoustic data was acquired using a single split-beam EK60 echo sounder operable at 38 kHz frequency over 600 km cruise track ranging at depths ranging from 10 - 200 m. Bottom surface backscattering strength (BSBS) from the acoustic echogram was extracted using EchoView software (ver. 9.0) while seabed classification analysis was performed using the inbuilt PCA and K-means clustering analysis within the EchoView sea-bottom classification module. An acoustic seabed map was generated using the Kriging method in QGIS 2.18.18, to interpolate the BSBS values. Four BSBS value classes associated with different substrate types were established. The high BSBS values indicated coarse substrates, whereas low values indicated soft substrates. Regions between Tana River and Sabaki estuary showed a predominance of acoustically low seabed backscatter with a mean ~-9 dB, attributable to the presence of soft muddy sediments. High acoustic backscatter energy of mean~-20 dB was observed along the coastline, attributed to patchy coral reefs and sandy derived substrates along Lamu archipelago to the north and fringing reef formation along the southern coast from Malindi. Although ground-truthing was not applied in this study, the results showed the feasible capability of a single beam echo sounder system (SBES) providing real-time inference of types seabed substrate types.

Keywords
Acoustic, bottom surface backscattering strength, seabed classification, single-beam, substrate, Territorial waters, Kenya

A scalable, supervised classification of seabed sediment waves: using an object-based image analysis approach

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National mapping programs (e.g., INFOMAR and MAREANO) and global efforts (Seabed 2030) acquire large volumes of multibeam echosounder data to map large areas of the seafloor. Developing an objective, automated and repeatable approach to extract meaningful information from such vast quantities of data is now essential. Many automated or semi-automated approaches have been defined to achieve this goal. However, such efforts have resulted in classification schemes that are isolated or bespoke, therefore it is necessary to form a standardised classification method. Sediment wave fields are the ideal platform for this as they are dynamic, form complex morphologies, and are important habitats for various organisms. Here, we apply object-based image analysis (OBIA) to assess and compare the accuracy and precision of 2 multilayer perceptrons, support vector machine, and voting ensemble algorithms across 3 separate study sites. The classifiers are trained on high spatial resolution (0.5 m) multibeam bathymetric data from Cork Harbour, Ireland and are then applied to lower spatial resolution EMODnet data (25 m) from the Hemptons Turbot Bank SAC and offshore of Co Wexford, Ireland. A stratified 10-fold cross validation was deployed to assess overfitting to the sample data. Samples were taken from the lower resolution sites and examined separately to determine the efficacy of classification. Results showed that the voting ensemble classifier achieved the most consistent accuracy scores across the high-resolution and low-resolution sites. This is the first object-based image analysis classification of bathymetric data with significant disparity in spatial resolution. Applications for this approach include benthic environmental energy assessments, a geomorphological classification framework for benthic biota, and a baseline for monitoring of Marine Protected Areas.

Classification of boulders in coastal marine environments using random forest machine learning on an imbalanced data set from topo-bathymetric LiDAR

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Boulders on the seabed in coastal marine environments form an important hard substrate for macroalgae, and hence for coastal marine reefs. Such reef areas constitute important ecosystem services, e.g. storage of organic carbon in macroalgae or “blue carbon” as well as important habitats to fish for living, hiding and feeding. Information and knowledge about boulder locations and geometry in coastal marine environments are often obtained as part of seabed habitat mapping. Usually, seabed habitat mapping is based on geophysical surveys using multibeam echo sounding along with side-scan sonar imaging in combination with biological ground-truthing. However, coastal areas are challenging to map with full spatial coverage due to the shallow water conditions. An alternative is to use airborne LiDAR technology. Topo-bathymetric LiDAR (green wavelength of 532 nm) has made it possible to derive high-resolution data of the bathymetry in coastal zones (e.g. Andersen et al., 2017). This technology can cover the transition zone between land and water, and the time consumption for data acquisition is small compared to vessel borne methods.
The aim of this study was to investigate the possibility of developing an automated method to classify boulders from topo-bathymetric LiDAR data in coastal marine environments with shallow water (<6 m). The Rødsand lagoon in Denmark, where topo-bathymetric LiDAR data were acquired in 2015, was used as test. The classification was done using the random forest machine learning algorithm. The study resulted in the development of a nearly automated method to classify boulders from topo-bathymetric LiDAR data. The data set was imbalanced with a large over-presentation of non-boulder points. To avoid a tendency to classify non-boulder points, combinations of subsampling and classification cost were tested. Different measure scores were used to evaluate the performance, where one of the best results had a classification accuracy on 99%, a weighted accuracy on 41%, recall on 30% and f-score on 21% on the test site. The obtained knowledge about boulder locations can provide important information about the ecosystem services and improved management of the coastal marine environment.

Acknowledgement:
This work is part of the project "ECOMAP - Baltic Sea environmental assessments by opto-acoustic remote sensing, mapping, and monitoring", supported by BONUS (Art 185), funded jointly by the EU and the Innovation Fund Denmark.

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Metadata Enhanced Feature Learning for Efficient Interpretation of AUV Gathered Seafloor Visual Imagery

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Camera equipped Autonomous Underwater Vehicles (AUVs) typically gather tens to hundreds of thousands of georeferenced seafloor images in a single deployment. However, taking full advantage of this growing repository of data is a major challenge for the scientific progress. Although modern machine learning techniques, e.g. Deep Learning, are potentially useful to interpret these images, much of the progress in this field has been driven by the availability of large training datasets of expert human annotations that are available for terrestrial ad satellite imaging applications. Such datasets do not currently exist in the marine domain, and even if they did, it is not clear if the sensitivity of marine images to observation conditions, such as altitude, water turbidity and different illumination sources will limit the utility of such initiatives. Most applications of deep learning to marine imagery have used training datasets that have been specifically generated on a per-survey basis, and although the results are encouraging, the high workload involved in generating dataset specific expert training labels is unlikely to be justifiable in most applications.

To address this issue, we investigate the use of unsupervised feature learning (or representation learning), where lower-dimensional feature vectors are derived from original high-dimensional image data through Convolutional Neural Networks (CNN) without any human annotations. Once the feature vectors of the original images, which keep only useful information to distinguish the habitats and substrates, are obtained, various interpretation techniques such as clustering, contents retrieval, few-shot learning can be efficiently applied.

In this work, we demonstrate autoencoder and contrastive learning-based feature learning techniques specially designed for seafloor visual imagery [1]. The proposed methods can leverage the metadata gathered with the images by AUV, e.g. georeference, water-temperature, saliency. We confirm that metadata-guiding significantly improves the feature learning and demonstrate applications to unsupervised and semi-supervised mapping of habitat, substrate and infrastructure distribution at the Southern Hydrate Ridge (Oregon, USA, 12k images), Darwin Mounds (UK, 20k images) and Tasmania (Australia, 110k images) datasets with validation against human annotation results

[1] Takaki Yamada, Adam Prugel-Bennet, Blair Thornton, Learning Features from Georeferenced Seafloor Imagery with Location Guided Autoencoders, Journal of Field Robotics 38, 52-67, DOI: 10.1002/rob.21961

Characterization Of Rhodolith Beds-Related Backscatter Facies From The Western Pontine Archipelago (Mediterranean Sea)

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Rhodoliths (nodular calcareous red algae) are considered one of the most important bioengineers in the Mediterranean Sea, making rhodolith beds ecologically relevant ecosystems.

On the insular shelf surrounding the western Pontine Archipelago (depth from 43 to 112 m), rhodolith beds were identified through the analysis of an extensive dataset of grab samples and videos to ground-truth the acoustic facies identified on the full-coverage backscatter data. Six acoustic facies (low backscatter, dishomogeneous low-backscatter, dishomogeneous high-backscatter, high-backscatter, rocks and high backscatter, and rocks and medium backscatter) were recognized.

We studied how rhodoliths characteristics (density, morphotype, size and structure) differently influence the backscatter signature. At the western Pontine Archipelago the most representative facies of rhodoliths beds are the dishomogeneous high backscatter, the high backscatter, the high backscatter with rocks and the medium backscatter with rocks.

The obtained results increase both the knowledge on the heterogeneous structure of such ecologically relevant benthic habitat and highlight the use of distinctive acoustic facies for their identification. Finally, the used approach could be considered a useful method for indirect detection and mapping of rhodolith beds.

Mapping gradients in seafloor characteristics in the Belgian part of the North Sea: preliminary findings and way forward

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Over the last 20 years, multibeam echosounder (MBES) bathymetry and backscatter data and sediment samples have been acquired at regular intervals to monitor the impact of marine aggregate extraction in the Belgian part of the North Sea (BPNS). Although very valuable to monitor changes in seabed characteristics, no systematic and repetitive classifications of the seafloor were produced with these data until now.

Anticipating on a next era in multibeam monitoring with the new RV Belgica, a specific approach will be developed to (1) classify gradients in seafloor characteristics based on MBES data acquired at different frequencies and (2) identify gradual changes in seafloor characteristics over time. To achieve this, a detailed characterization of the acoustic, sedimentological, geotechnical and macrobenthic properties of archetypal morpho-sedimentological environments of the BPNS is required.

A preliminary version of the classification approach is already developed and tested on former MBES data acquired at 300 kHz. The approach relies on the hyper-angular cube concept [Alevizos and Greinert, Geosciences, 8, 446 (2018)] and fuzzy classification approaches.

This contribution will illustrate why the concepts of gradients and gradual changes are critical when classifying environments such as the BPNS and how this can be accounted for when classifying MBES data. Subsequently the classification approach and some first classification results will be presented and the following steps of the project will be discussed.

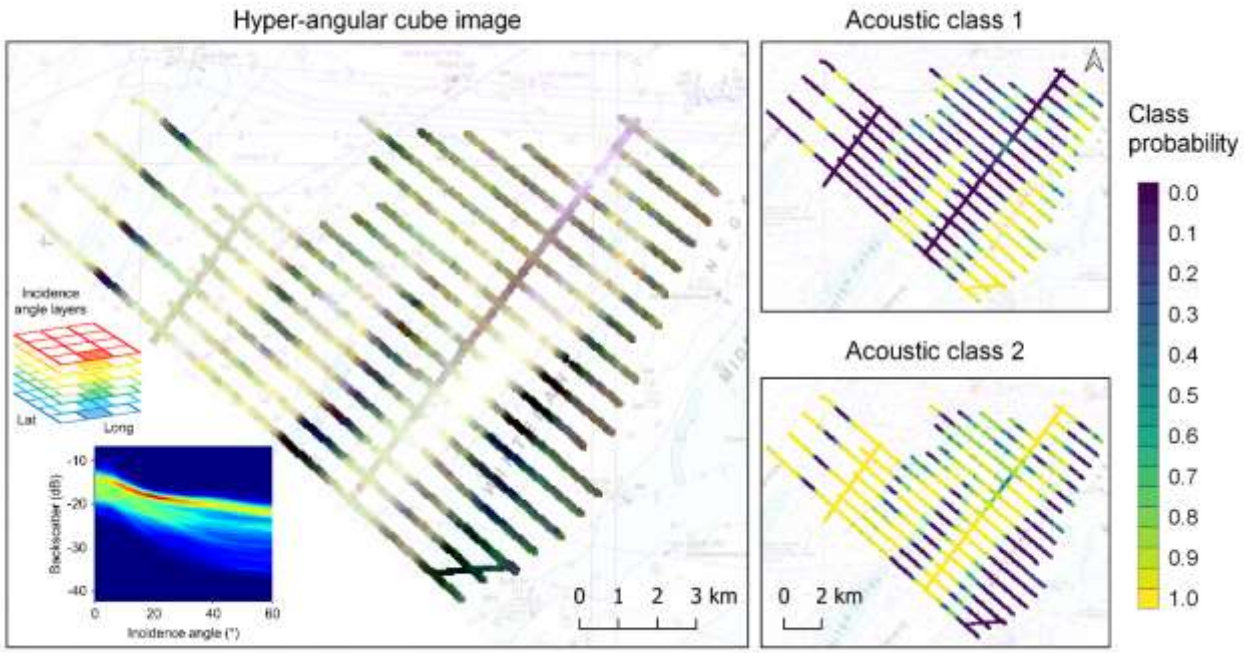

Figure 1. Illustration of the hyper-angular cube image used in the classification, hyper-angular cube concept and angular responses present in the image (left) and the main classification output (right).

Landscape mapping and ichnological studies in a deep-water gateway, Discovery Gap, NE Atlantic

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Landscape and habitat mapping of abyssal environments and studies of their long-time dynamic conditions represent a great challenge (Harris, 2020). Ocean gateways connect abyssal plains and play an important role in the exchange of water, sediment, and biota from one basin to another. The aim of this work is 1) to present landscape mapping of a deep-ocean gateway for characterization of its modern environment and 2) to study ichnofossils in sediment cores to explore the long-time dynamic conditions of the environment. Ichnofossils (or trace fossils) are biogenic sedimentary structures, which are useful for characterizing past endobenthic communities and their living environment. Trace fossils are more sensitive indicators of change in the benthic environment than body fossils (Wetzel, 2010). In the gateway environment, variations of ichnofossil in seabed sedimentary archive may evidence not only environmental condition changes but also spatial variability associated with transit of biota and nutrients from one basin to another, being an underexplored point from the ichnological point of view.

Discovery Gap is a deep-water gateway, located in the ridge of the Azores–Gibraltar Fracture Zone (NE Atlantic, 37^{o} N, 16^{o} W). The gateway connects the Madeira and Iberian abyssal basins and consists of series of narrow gaps and sills, elongated in the SW-NE direction.

Integrated research of Discovery Gap has been done during the 43rd cruise of the R/V *Akademik Nikolaj Strakhov* in October 2019. Bathymetry was obtained by multibeam echosounder RESON SeaBat 7150 (Dudkov, Dorokhova, 2020). Geomorphology characteristic of the study region was described according to benthic terrain classification. It was created using the bathymetric position index, calculated from the multibeam data. Data of the seafloor acoustic profiling, acquired by sub-bottom profiler EdgeTech 3300, were used for the characteristic of the sedimentary conditions. Physical water conditions (water temperature, salinity, oxygen, and silica content) were studied on five stations by a hydrological system, included CTD-probe SBE 19plus and carrousel-type sampler SBE 32.

Three sediment gravity cores were sampled in the southern, central and northern parts of Discovery Gap at depths of 5275, 4737 and 4928 m, respectively. The cores are represented by light brown silty clays with foraminiferal sands and numerous bioturbation structures. The ichnofossil analysis of the cores was carried out based on direct analysis on cores, high-resolution 2-D image treatment, and 2D and 3D CT-scan data (University Veterinarian Rof Codina (Lugo, Galicia)) of the trace fossils.

Funding: RSF (project No. 19-17-00246.), IO RAS (Theme No. 0128-2021-0012).

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Broadscale Landscape Mapping of the Commonwealth of Dominica and surrounding Islands

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The growing human population has caused increased exploitation of the marine environment. A need to appropriately manage and conserve that environment for sustainable use requires knowledge that is not, at present, sufficient in data extent, resolution or understanding. *In situ* data acquisition, processing and interpretation is often expensive and time-consuming and so cannot be a priority for many developing countries. Therefore, the growing body of publicly available datasets and model outputs (e.g. The General Bathymetric Chart of the Oceans (GEBCO) and the Copernicus Marine Service) greatly increases potential research possibilities.

The Commonwealth Marine Economies Programme aims to help the most vulnerable Small Island Developing States to further understand, utilise and protect their marine environment in a sustainable and economically beneficial way. One of the targeted Islands was the Commonwealth of Dominica, where the population mainly lives in coastal towns and is reliant on natural resources, resulting in pressure on the nearshore marine environment and the potential for irreversible marine habitat damage. Little knowledge of the wider Dominican marine environment is available.

Landscape mapping is a top-down method of habitat mapping that uses geophysical and oceanographic data to classify the marine environment based on its abiotic characteristics. These abiotic classifications can then be used to predict areas of ecological and economic importance in previously unmapped regions. The classifications can also be combined with existing biological sampling to expand current knowledge of the marine environment and to prioritise where data collection should occur when financial, social and political goals align.

This method is based on the approach by Hogg et al. (2018) and conducts principal component analysis (PCA) on the available abiotic variables to reduce the data dimensionality and remove collinearity. The optimum number of clusters is determined using the Calinski-Harabasz index (C-H) and the elbow method before *K-means* clustering is conducted to partition the data. The clusters are then mapped by location and each cluster assessed against the original abiotic inputs to determine the characteristics of the cluster.

Here we evaluate the suitability of this method for Caribbean Islands, where *in situ* data is sparse and available data is of low resolution. We discuss the considerations of factor retention for the *K-means* analysis and the conclusions that can be drawn from the resultant broadscale landscape maps.

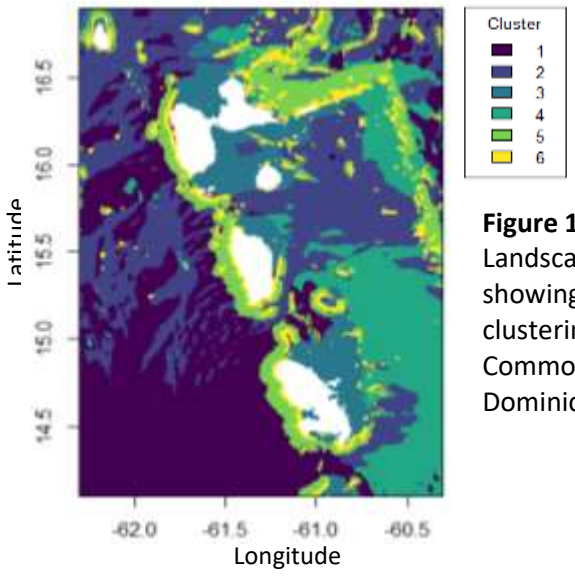

Figure 1. Broadscale Landscape Map showing the K-means clustering of the Commonwealth of Dominica waters.

New data about benthic landscapes of the eastern Gulf of Finland (Baltic Sea): first results of ADRIENNE project

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The Estonia – Russia Cross Border Cooperation Programme ADRIENNE (ER55), launched in 2019, aims to develop a publicly accessible GIS portal that will provide an opportunity to assess the consequences of anthropogenic impact on the underwater landscapes ecosystem of the Gulf of Finland (GoF) under various scenarios (including climate change). Creation of such portal will help in rationalizing the approach to environmental management in this territory and preserve the existing biogeocenosis. Background knowledge and factual data for future modelling are now collecting during analyzing of existing sources (e.g. results of annual geological field work carried out by VSEGEI in 2011–2019 and multibeam echosounder profiling (Teledyne RESON Seabat 8111-H, E208-3F66 Dry MBES system) produced in 2017 and 2019 during the cruises of the R/V Academic Nikolaj Strakhov) and project field work.

The fieldwork stage of ADRIENNE project was carried out during the summer-autumn period of 2019–2020 and resulted into primary database containing information on biotic components' sampling (phytoplankton, zooplankton, benthos, periphyton, macrophytes, fishes), geological sampling (bottom sediments for grain size analysis) supported with measurements of basic hydrophysical (depth, Sechi depth, surface and upperbottom temperature of water), hydrochemical (salinity, pH, Eh, oxygen concentration) characteristics and spatial data from multibeam echosounding and underwater photo- and videodocumenting. Logistics of sampling and spatial location of the points within the key and reference areas were based on the results of geophysical survey of the Eastern GoF conducted in previous years. The total number of localities – 301.

Spatial data analysis results and measurements form specific layers and used in GIS visualization. The dataset of geological and biological data (e. g. nine key areas of full multibeam coverage) provides information for benthic landscape mapping and ecosystem analysis for the entire EGoF. Spatial distribution of studied key areas and sampling sites allows to characterize a variety of abiotic components of benthic landscapes. The easternmost part (Neva Bay) represents limnic salinity (< 0,5 ‰), highly wave exposed, extremely shallow (less than 10 m) conditions, with domination of sandy and boulder bottom substrate (relatively low geodiversity). Benthic communities here are highly impacted by extensive dredging in the Neva Bay. The second part of study area is located within large bays of the southern coast (Kopora Bay and Luga Bay, area around Moshny Island) and can be characterized as oligohaline (0,5–5 ‰), wave exposed areas. More complicated geological structure and wider depth gradient (10–30 m) causes higher geodiversity, including transition from stony photic high wave impacted bottom to anoxic silty-clayey mud bottom. The highest geodiversity characterizes north-western part of the EGoF (Vyborg Bay) with oligohaline (0,5–5 ‰) to mesohaline (> 5 ‰) conditions, very patchy (mosaic) surface sediments distribution and wide spread of Fe-Mn concretion. Western part of study area (around Gogland Island) is located in mesohaline conditions and characterized by the highest depth gradient (20–80 m), patchy sediment distribution, wide spreading of gas-saturated sediments and intense local impact of near-bottom currents.

Preliminary results of the data analysis reveal the ranking of abiotic factors combination from less favorable for benthic fauna development (both abundance and biomass) anoxic silty-clay mud bottom, via more favorable conditions (oxic silty-clay bottom, oxic sandy or stony bottom) to most favorable (oxic mixed sediment bottom, e. g. areas of Fe-Mn concretions growth). Score and numerical data are used for multidimensional statistical analyses aimed to valuating the biota in the space of abiotic and human-mediated parameters. This work is in the process and partly will be represented in the talk.

Acknowledgements: "Estonia-Russia Cross Border Cooperation Programme 2014-2020", project ER55

4S - The EU project to map and monitor shallow water benthic and bathymetry

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1. EOMAP, DE
2. Länsstyrelsen Västerbotton, SE
3. Instituto Hidrografico Portugal, PT
4. Fugro Germany Marine GmbH, DE
5. Smith Warner International Limited, JM
6. Quality Positioning Services; NL
7. National Research Council, The Institute of Marine Sciences (CNR-ISMAR); IT
8. Hellenic Centre for Marine Research (HCMR), GR

Airborne and satellite-based mapping of shallow water bathymetry and habitats has found increased uptake and use for coastal zone management and reporting. Especially the availability of new satellite data and capabilities allow for mapping but also for monitoring the shallow water zone on small to large scales and in high frequency. Still today, the analysis is typically depending on expert interpretation and based on model assumptions which in total hinders upscaling and easy integration of the technique into daily workflows. In order to work on these aspects, a team of academia and industry has formed as the 4S consortium. 4S aims to introduce new advances for the remote mapping technology, which includes – but is not limited to - the development of tools that allow any stakeholder to access and analyze remotely sensed data from the comfort of the desk, and also to work towards whitepapers and guidance. 4S is formed by CNR ISMAR (IT), FUGRO Germany (DE), Hellenic Centre for Marine Research (GR), Instituto Hidrografico (PT), Länsstyrelsen Västerbotten (SE), Quality Positioning Services QPS (NL), Smith Warner Int (JM) and led by EOMAP (DE). This presentation will introduce the concept of the 4S solution and technology behind and provide examples and insights on the online software. We will showcase sensor fusion of aerial and satellite derived data which allows to increase the level of details and improve accuracies, and how continuous satellite derived data provide spatial and continuous information on change of seabed. The prototype of the 4S online tools and interfaces will introduce how stakeholders can access data, perform analytics and generate statistics.
This project has received funding from the European Union's Horizon 2020 research and innovation programme H2020-SPACE-2020 under grant agreement No 101004221

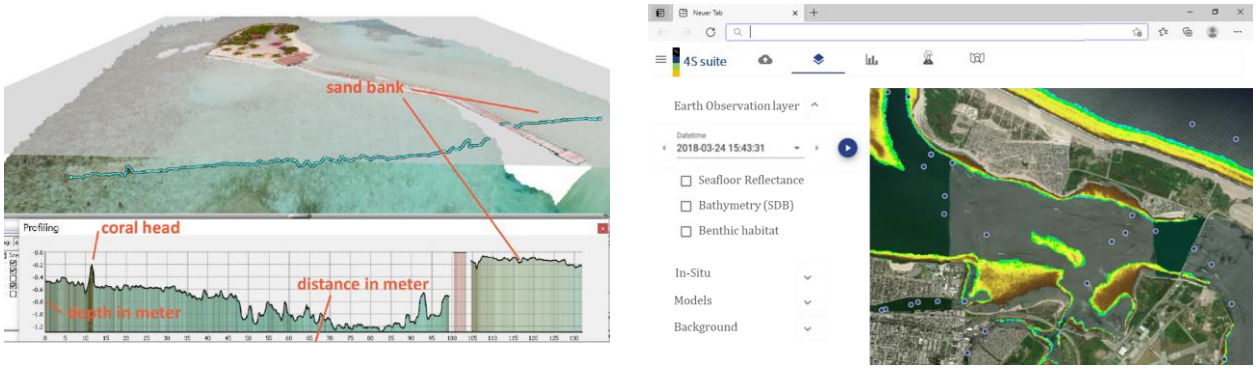

Figure: Left: Seafloor morphology derived from sensor fusion of airborne and satellite data. The bathymetric surface has 9cm spatial resolution and allows to identify the morphology of single coral heads. Right: Preview of the 4S online solution which allows to process, analyze and visualize depth and benthic data based on the innovations of the 4S project.

A broad-scale seabed habitat map for Europe – EUSeaMap 2019 and plans for 2021

1. On behalf of the EMODnet Consortium

EUSeaMap is a free, integrated, multi-disciplinary broad-scale modelled map of physical seabed habitats in Europe created by the EMODnet Seabed habitats marine data initiative. It was first created in 2009 and in its infancy, EUSeaMap only covered the Celtic Seas, Greater North Sea, Baltic Sea and the western Mediterranean, but over the last decade, EUSeaMap has undergone considerable improvement thanks to the growing collaborative efforts of all the European partners involved.

The current version of EUSeaMap (2019) has a geographical coverage that now encompasses all European Seas and its resolution has never been finer. Details of how EUSeaMap 2019 was created can be found in the technical report (Vasquez et al 2020) on the EMODnet Seabed Habitats portal. Habitats are mapped in the Marine strategy framework directive (MSFD) benthic broad habitat types classification as well as the EUNIS 2007 classification system, which are a comprehensive pan-European system for habitat identification, meaning it can be interpreted by most European countries. EUSeaMap has become an integral data source across multiple sectors, including marine research & academia, marine policy & planning and marine infrastructure. Perhaps one of the most important benefits of a full-coverage dataset is the ability for users to undertake regional assessments for high-level reporting purposes – such as MSFD reporting. Detailed use cases of how EUSeaMap has been applied to these different fields can be found on the EMODnet Seabed Habitats portal.

This year, EMODnet Seabed Habitats have plans to improve EUSeaMap even further, firstly by updating the underlying substrate data that feeds into the broad-scale model and, secondly, through the application of the new EUNIS 2019 habitat classification system. These planned updates will aim to keep EUSeaMap at the forefront of resources in the seabed mapping community, and through its free access, will continue to facilitate sustainability in European seas.

Vasquez Mickael, Manca Eleonora, Inghilesi Roberto, Martin Simon, Agnesi Sabrina, Al Hamdani Zyad, Annunziatellis Aldo, Bekkby Trine, Pesch Roland, Askew Natalie, Bentes Luis, Castle Lewis, Doncheva Valentina, Drakopoulou Vivi, Gonçalves Jorge, Laamanen Leena, Lillis Helen, Loukaidi Valia, McGrath Fergal, Mo Giulia, Monteiro Pedro, Muresan Mihaela, O'Keeffe Eimear, Populus Jacques, Pinder Jordan, Ridgeway Amy, Sakellariou Dimitris, Simboura Mika, Teaca Adrian, Tempera Fernando, Todorova Valentina, Tunesi Leonardo, Virtanen Elina (2020). EUSeaMap 2019, A European broad-scale seabed habitat map, technical report. EASME/EMFF/2018/1.3.1.8/Lot2/SI2.810241– EMODnet Thematic Lot n° 2 – Seabed Habitats. https://doi.org/10.13155/74782

Wadden Mosaic: Understanding the ecological functioning of the subtidal Dutch Wadden Sea

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The Wadden Sea is of great ecological importance and supports many species of birds and fish. These species depend on a plethora of benthic invertebrate species living in and on the sediment. While the intertidal mudflats are relatively well studied, the biodiversity and food web structure of the subtidal Wadden Sea is relatively unknown. Yet, information on this subtidal component of the Wadden Sea is essential if we want to understand changes that occur due to climate change, natural and human disturbances. The Wadden Mosaic project aims to shed light on this hidden part of the Wadden Sea. We will map biodiversity and link the benthic communities to habitat characteristics. In addition, we will test the feasibility and effects of possible management actions: i) (re-)introducing hard substrates, ii) facilitating epibenthic shellfish beds, iii) explore restoration possibilities for subtidal seagrass meadows and iv) test the effectiveness of excluding human activities from designated marine protected areas. Here, we will present the first results from a large sampling campaign in which samples were taken throughout the Dutch Wadden Sea with a grid resolution of 1 km, resulting in data from 1394 samples. From each sample we analyzed sediment characteristics; identified, counted and weighted the benthic species; and for the dominant species the stable isotope ratios were analyzed to reconstruct the subtidal food web. Overall, the results from the project will improve our understanding of the ecological functioning of the subtidal Wadden Sea, and predict the effectiveness of management practices aimed at sustaining or increasing biodiversity.

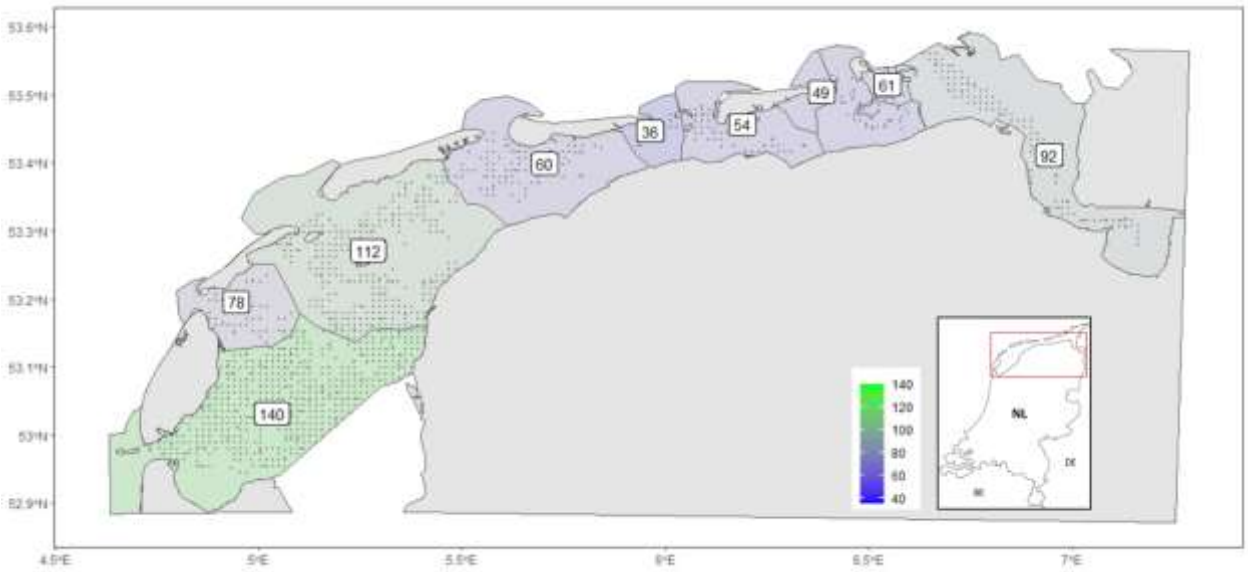

Figure: Observed species richness per tidal basin (numbers) and visualization of all sampling locations (grey dots) in the subtidal Dutch Wadden Sea.

Mapping temperate reef habitats in high energy waters

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High energy marine areas are understudied and less developed compared to lower energy waters but are seeing increased interest and novel pressures from the growing marine renewable energy industry. Temperate reef habitats are commonly found in high energy sites and are listed in the European Commission Habitats Directive Annex 1 for their conservation importance. To understand baseline conditions and monitor interactions, detailed information about the spatial distribution of reef habitats in a development area is needed. High-resolution environmental data used for predictive mapping are often limited to bathymetry, backscatter and their derivatives. However, hydrodynamic energy at the seabed is a critical structuring factor in high energy habitats and is likely to be an important predictor of habitat spatial distribution. We used random forest classification to map potential reef substrate and potential biogenic reef habitat in a tidal energy development area, incorporating bathymetric derivatives and modelled tidally induced seabed shear stress. We mapped potential reef substrate (four classes: sediment (not reef), stony reef (low resemblance), stony reef (medium – high resemblance) and bedrock reef) with mean ± sd overall balanced accuracy of 81% ± 2% and kappa coefficient of 0.62 ± 0.04. We mapped potential biogenic *Sabellaria spinulosa* reef with a balanced accuracy of 72% ± 5%. Tidally induced mean bed shear stress was the most important predictor variable for both predictive models. We tested the influence of backscatter derivatives on models across a subsection of the study area, finding a small but statistically significant improvement for the reef substrate model only. This study generated previously unresolved information on the spatial distribution of potential Annex 1 reef habitats in a tidal energy development area. The outcomes are valuable for understanding spatial ecology and informing environmental management in high energy marine ecosystems.

Streamlined bedforms of the Western Estonian Shelf - implications for ice-flow reconstruction

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Geomorphological studies of the bottom of the Baltic Sea are scarce and very little is directly known about the palaeo-ice flow dynamics in the area. However, recently collected high resolution multibeam bathymetric data reveal direct geomorphological evidence of ice-flow patterns on the Western Estonian shelf.

We report a well-preserved geomorphological record of streamlined bedforms (mostly drumlins), mapped semi-automatically using standard GIS methods. We identify two diverging flow sets (A and B, Figure 1), partially continuing onshore, revealing ice sheet behaviour in the area around the time of Palivere stadial (13.2 kyr BP). The observed ice-flow directions permit refining earlier reconstructions and conclude that there were no significant ice-margin standstills in the area.

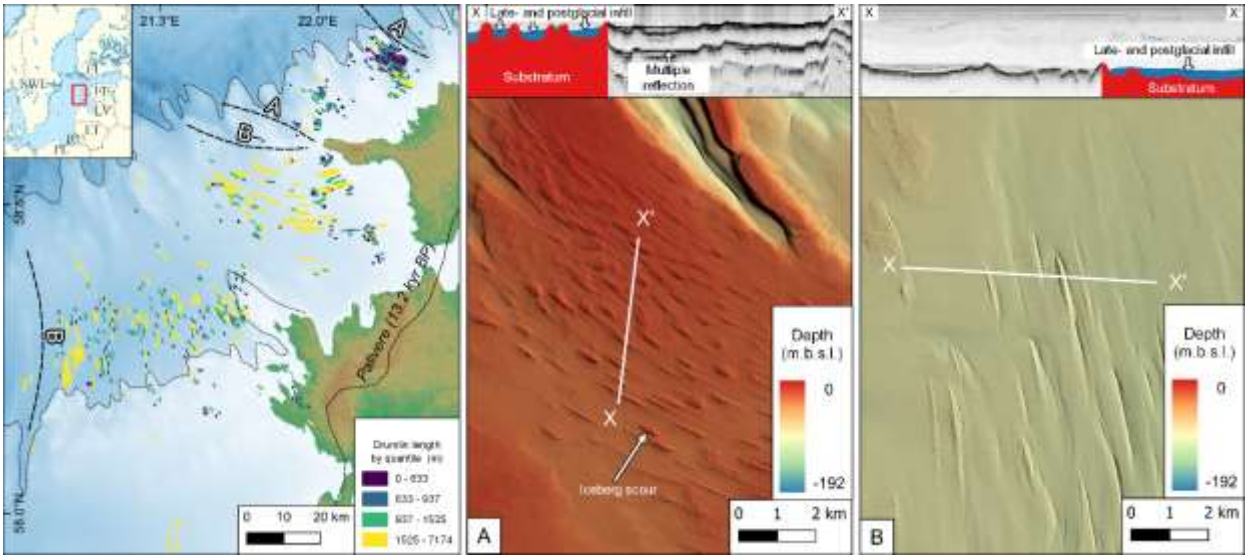

Figure 1. Left: Length and spatial distribution of the mapped streamlined bedforms on the Western Estonian Shelf. Dashed line represents Palivere onshore ice margin location. Middle: example of drumlins from flow set A. Right: : example of drumlins from flow set B.