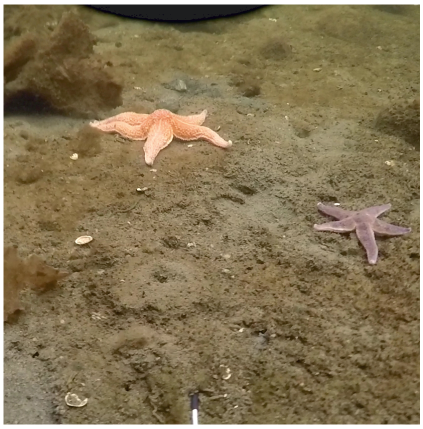
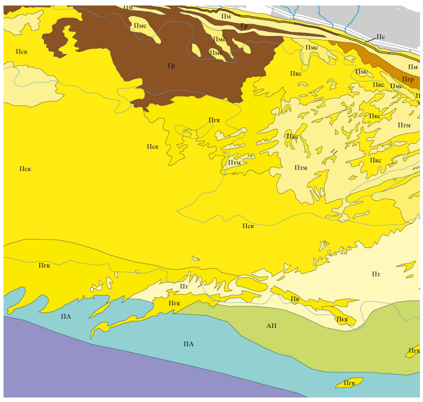
Saint-Petersburg • Russia
May 13-17, 2019

GEOHAB 2019

Marine Geological & Biological Habitat Mapping





ABSTRACTS

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MARINE GEOLOGICAL AND BIOLOGICAL HABITAT MAPPING

ABSTRACTS
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The book contains the abstracts for presentations from the Annual International Conference "GeoHab 2019 – Marine Geological and Biological Habitat Mapping" (May 13–17, 2019, St. Petersburg, Russia). The presentations are devoted to study and mapping of different types of habitats – from coastal and shallow water to shelf, deep-sea and coral habitats, geological and biological features of seeps and hydrate, interactions between oceanographic processes and habitats, mapping, planning, and impact assessment for ocean energy, sustainable development of marine minerals' extraction, submerged landscapes and archeology.

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Dear Colleagues!

Allow me to welcome the GeoHab International Conference participants
to the A.P. Karpinsky Russian Geological Research Institute (VSEGEI)

Our Institute is a successor of the Geological Committee (GeolCom), the first state geological institution of Russia, founded by Decree of Emperor Alexander III of January 31, 1882. At this time, geological surveys were organized in many countries of the world, whose main task was to compile geological maps of their states.

At present, VSEGEI is an institution within jurisdiction of the Federal Agency on Mineral Resources of the Ministry of Natural Resources and Environment of the Russian Federation. The main task of the Institute is compiling geological maps and atlases, sets of state geological maps of the Russian Federation and its continental shelf at scales of 1:1,000,000, 1:200,000 and larger.

Since its establishing, the Geological Committee of Russia have paid great attention to international cooperation. In particular, GeolCom was the initiator and organizer of the 7th International Geological Congress, which was held in St. Petersburg in 1897.

VSEGEI continues and develops this tradition. In recent years, in the course of the international cooperation, Atlases of geological maps of a new generation of 1:2,500,000 and 1:5,000,000 scales of the Circumpolar Arctic, Northern, Central and East Asia, and the CIS countries were prepared that ensured the successful integration of our country into the international system of digital geological mapping. In April 2019, the Commission for the Geological Map of the World at UNESCO issued the Tectonic Map of the Circumpolar Arctic – the result of the work of geological surveys, national academies of sciences of the Arctic states. In cooperation with the Geological Survey of Norway, the Tectonostratigraphic Atlas of the Barents Sea was compiled.

St. Petersburg is a sea city and therefore one of the VSEGEI activities is marine geology. Specialists of our institute have compiled geological maps of the seabed of the Russian Gulf of Finland. In 1980–1990s, VSEGEI performed a state geological survey of the seabed of the Gulf of Finland, including the Neva Bay. The results of the geological survey are summarized in the Atlas of Geological and Ecological-and-Geological Maps of the Russian Baltic Sea, published by VSEGEI in 2010. Since 2011, studies under the program of the federal state monitoring of the geological environment of the seabed and coasts in north-west Russia have been carried out at VSEGEI. Every year, specialists from the institute perform marine geological and geophysical studies in the White, Baltic and Barents Seas. During the monitoring, numerous shows of active hazardous geological processes were identified: underwater landslides and subsidence of the seabed, vast areas of gas-bearing sediments, outflows of groundwater and gases, oxygen-free zones and areas of high radioisotope concentrations.

The most important results on the Baltic Sea geology we obtained in the course of joint studies in the Gulf of Finland with specialists from the Geological Survey of Finland. Since 2009, Russian-Finnish investigations are being conducted in Quaternary geology and paleogeography of the post-glacial stage of evolution of the Gulf of Finland. In 2012–2014, our scientists worked under two projects of the cross-border cooperation program "Southern Finland – Russia" ENPI. Within the framework of the TOPCONs project, sea landscapes of the Gulf of Finland were mapped for the first time.

Since 2014, VSEGEI has been participating in the international project on compiling the unified geological map of European seas (EMODNET-geology). Our specialists have compiled geological maps of the Baltic, Barents, White and Caspian seas.

Dear friends, it is a great honor for us to host GeoHab, the largest international forum. GeoHab conferences provide an opportunity to be acquainted with the most recent global achievements in marine geological mapping and interdisciplinary studies and to show the results of the latest projects. The synergy arising from scientific communication during the GeoHab conferences leads to the broadening of international ties, elaboration of new joint international research projects and enhancing scientific cooperation between countries.

In conclusion, I would like to wish all the conference participants to gain every success in their work.

Oleg Petrov,
VSEGEI General Director

PO1. A centralized access point for marine habitat spatial data: The EMODnet Seabed-Habitat portal

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Since 2008, when the first preparatory action for EMODnet (EC contract no. MARE/2008/07) started, the main objective of this EMODnet task was to fill the critical gap in the environmental spatial data availability. This objective was partially reached during the project by producing the first consistent broad-scale seabed habitat map for European waters, available on line since 2010, covering the Western Mediterranean Sea, the North Atlantic sea and the Baltic Sea.

During the second EMODnet Seabed Habitats (ESBH) project (EC contract no. MARE/2012/10), the seabed habitat modelled map was extended so that they now cover all European basins, building on the method with enhanced validation.

All these products, together with all the input layers needed to produce the models (i.e. light, salinity, energy are freely disseminated online through the ESBH portal (http://www.emodnet-seabed habitats.eu).

Starting from this first step, where the portal was providing the results of the projects activities, during the second phase the approach of make freely available seabed habitat maps has been complemented with the collation of habitat maps from surveys or other analyses.

This new section represents an important improvement of the ESBH portal as, in this way, the end user can get not only a broad modelled information of the seabed habitat distribution at European scale (mostly about presence of broad-habitat *sensu* MSFD) but, in some areas, also more detailed information (at different scale).

During the current phase (phase III, 2017–2019) the project is still improving the products freely available through the portal by collating and disseminating ground-truth habitat point data from surveys and individual habitat models.

The content of the website is now strongly improved: from a relatively common portal where find

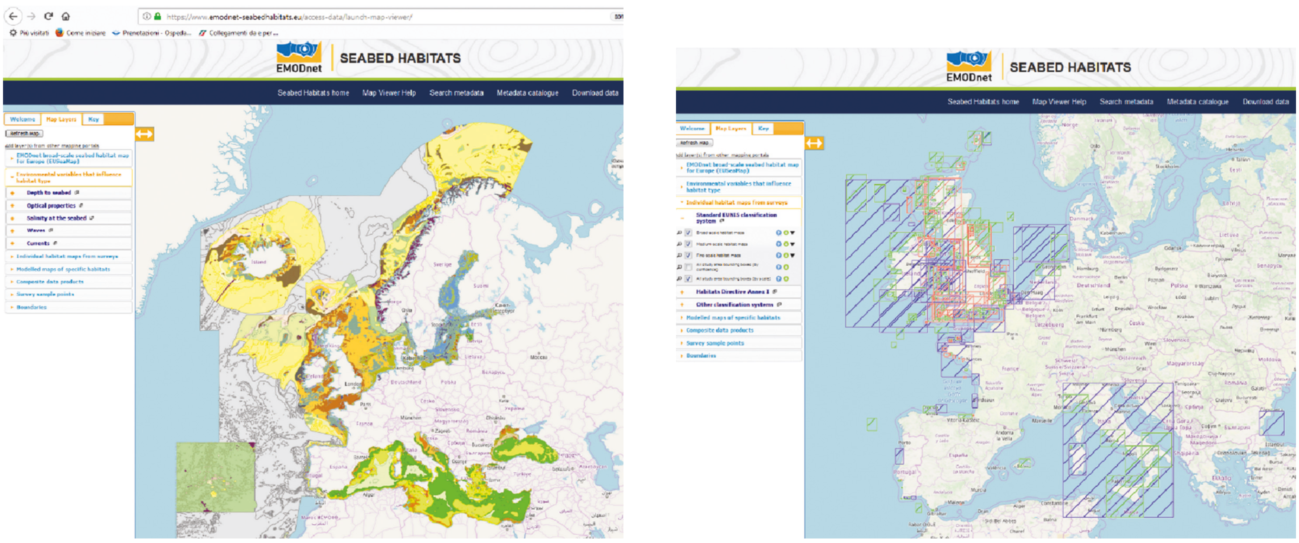

Figure 1. The ESBH portal map viewer

the final product of a project to something more complex and really unique: provide a standardized, centralized and free access point for habitat spatial information at a European scale.

As there is no single point of access to point records of seabed habitats, biotopes, communities and/or biocoenoses (hereafter all referred to as "habitats"), this work will fill a critical gap in the availability of such information. Furthermore, the possibility to access all these different seabed-habitat information using the same portal, is a very interesting novelty for both technical and non-technical stakeholders.

Through the map viewer section of the portal (https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/) the end-user can visualize, query and download a very huge number of spatial data that are briefly described below.

The broad-scale habitat map: a full coverage broad-scale habitat map has been produced for the European waters. This map, also known as EUSeaMap, aims to describe the environmental conditions occurring at the seabed that are known to influence the distribution of plant and animal communities. The modelled map was created by applying specific set of rules (selected and defined for each sub region) for the combination of environmental input layers (light, energy, seabed substratum, depth, oxygen and salinity). Where possible, the marine section of the European Nature Information System (EUNIS) habitat classification scheme was used.

The survey habitat sample points: this section hosts habitat data in the broadest sense. In fact, habitat data can encompass all the levels of detail covered by hierarchical systems such as EUNIS but also other regional and or national classification systems. A specific database was developed to internally host and manage the collected data in a secure and robust system, allowing full workflows for data ingestion and validation, and provision of data in a standardized format. In further efforts to standardize the recording of habitat point information, ESBH have been working closely with peers to upload national and international habitat classification systems into online machine readable vocabularies, providing a consistence single source of reference for habitat definitions. The project has already had success in adding the UK, OSPAR list of threatened and/or declining habitats and HELCOM HUB classification systems into online vocabularies and is continuing to work towards uploading further classification systems. The project also aims (where possible) to make use of existing data schemas and infrastructure to make the data available, namely the Ocean Biogeographic Information System (OBIS). In this scenario, the ESBH portal will pilot the use of machine-to-machine connections to harvest European habitat point data from OBIS, as well as providing links with any associated species occurrence data available via the EMODnet Biology portal.

***Individual habitat map from survey*:** a library of over 600 habitat maps have been collated to date. These maps span the extent of the Northeast Atlantic Ocean, Baltic Sea, Mediterranean Sea and Black Sea. The maps are in themed categories: EUNIS maps, Annex 1 Habitat maps, OSPAR habitats, broadscale predictive maps and Essential Ocean Variables. The maps are fully INSPIRE compliant. All maps can be freely downloaded from the ESBH portal along metadata and confidence scores for each map.

Products available in the web portal can be used for many purposes like MSFD assessment, regional convention activities, MPA evaluation and impact assessment. To date over 600 habitat maps from across Europe, over 120,000 ground-truth habitat data and over 11,000,000 km^2 of modelled habitat map are available. More than 28,000 downloads were completed in 2018 with the majority of requests for the EuSeaMap (broadscale physical habitat map for European Seas), the habitat maps from surveys, and for the environmental input variables.

Share data within the framework of this most wide-ranging and long-term pan-European seabed habitat web portal is really easy and can help to increase visibility and longevity of collected data. The international scientific community and the data owners can contribute to this European initiative becoming EMODnet Associated Partner (http://www.emodnet.eu/emodnet-associated-partners) or simply contacting the EMODnet Seabed Habitat helpdesk.

S3O1. Quantitative Mapping of Rhodolith Beds Using Multibeam Backscatter Data

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This study aims at showing the potential of acoustic backscatter mosaic obtained from Multibeam Sonar System (MBSS) to map rhodolith cover variation along rhodolith beds. Researches have been successful in acoustically identify rhodolith beds [1, 2, 3]. However, to quantitatively map the seafloor rhodolith cover using MBSS backscatter is a new approach.

High-resolution MBSS data were acquired on April 2018, in the Marine Protection Area Costas das Algas, located in the Espírito Santo continental shelf. Three areas were selected based on preterit data, totalizing 73km² of data acquisition. The MBSS data were processed on Caris Hips and Sips 9.1.7 software, and three georeferenced backscatter mosaics were created. On June 2018, 80 videos of the seafloor were collected in the areas. These videos were analyzed on the Coral Point Count with Excel Extension Software and used to provide seafloor type and percentage of rhodolith cover in each station.

The data were segmented into classes based on backscatter intensity variation and ground truth information. As a final result, we identified three seafloor classes related to rhodolith in different densities: low rhodolith coverage (inferior to 25 % of rhodolith), moderate rhodolith coverage (between 25 % and 35 % of rhodolith), and high rhodolith coverage (greater than 35 %). Classes associated with unconsolidated sediment, bio-concretions and red algae genus *Peyssonnelia* were also identified.

The methodology used in this work is an efficacious tool to map benthic habitats and to detail nodules distribution across a rhodolith bank. It can be used to improve spatial management of marine systems, and to monitor and protect vulnerable marine ecosystems.

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S5O1. A new Mediterranean Cold-Water Coral Province?

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Eight cold-water coral (CWC) provinces have been identified in the deep western and central basins of the Mediterranean Sea to date [1], In general, CWC established under a bottom current regime of high intensity with the Levantine Intermediate Water (LIW) mass as the main factor controlling their basinal distribution.

Exploration of the southern Ligurian and northern Tyrrhenian Seas in the frame of the Italian Marine Strategy Framework Directive in 2016 and

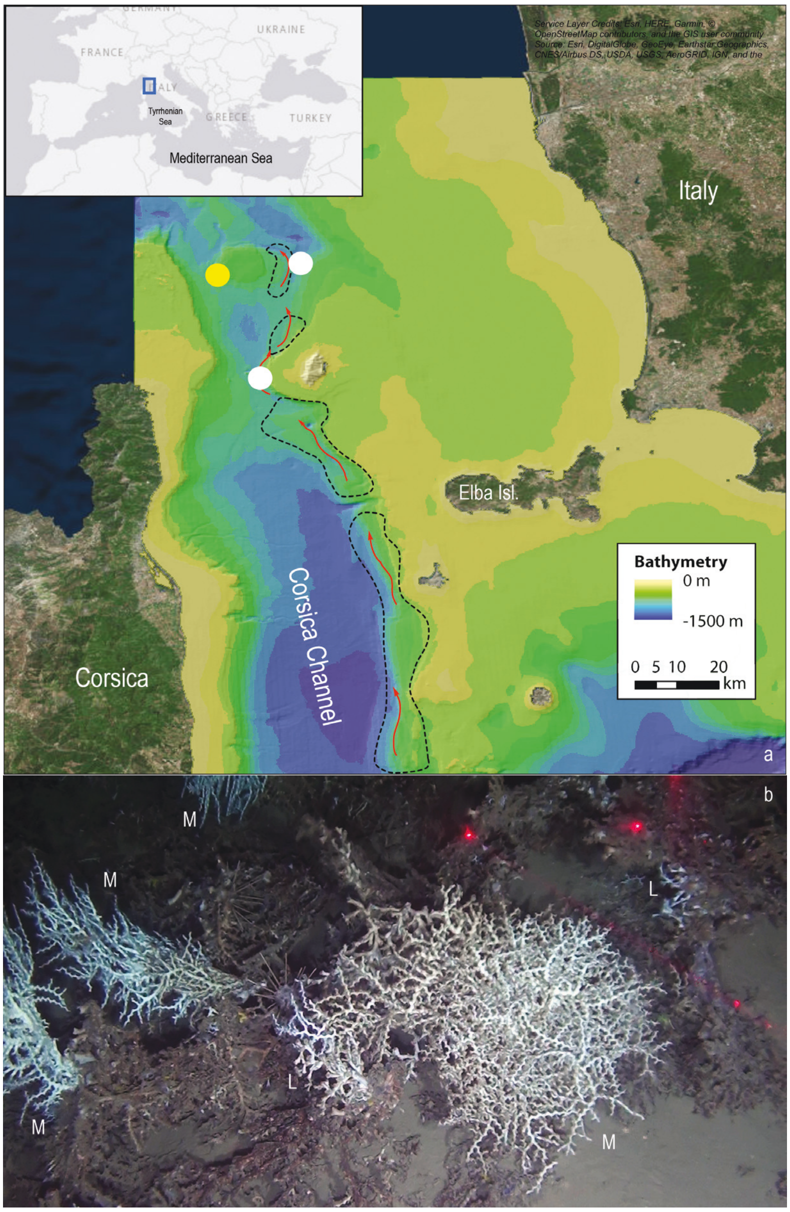

Figure 1. Study area: a) Bathymetric map of the Corsica Channel and its location in the Mediterranean basin (inset), displaying the LIW trajectory (red arrows); dashed lines represent contouritic drifts (modified form [4]); white dots mark the sites explored by ROV, while the yellow dot refers to the buried *Madrepora*-mound from [2]. b) Underwater image of one CWC mound at ca. – 430 m: M = *Madrepora oculata*, L = *Lophelia pertusa*. Laser beams spacing = 20 cm

2017, resulted in the discovery of well-developed live CWC presence in the eastern side of the Corsica Channel (Fig. 1a). Over 25 mounds have been identified off the Tuscan Archipelago through multibeam bathymetric mapping at depth of 400–430 m, with dimensions ranging from 70 to 330 m, achieving maximum heights of 25 m. Two such mounds were explored in detail by means of Remotely Operated Vehicle, revealing thick coral growth (Fig. 1b) with a predominance of the branching scleractinian *Madrepora oculata* as main frame-builder, and subordinate *Lophelia pertusa*. The solitary species *Desmophyllum dianthus* and *Javania cailleti* add to the biodiversity here, which accounts for at least 50 macro- and megabenthic species. Habitat mapping of the site was performed using the Adelie software.

In consideration of the remarkable surface (ca. 3.4 km^2) covered by living corals, their density and healthy appearance, and discontinuity with other major CWC occurrences in the Mediterranean Sea, we propose that this area represents a distinct CWC province. This new CWC Province is located off the Tuscan Archipelago in a sector already known for the presence of pre-modern CWC mounds [2]. Thus, a prolonged CWC regional presence is testified here, beginning in the post Younger Dryas [3], although not necessarily continuous.

Noticeably, well-developed contourite drift systems developed in the Corsica Channel since the Middle Pleistocene [4]. The co-occurrence of CWC-mounds lends support, therefore, to the observation that a strict link exists between contourite drifts and coral growth at depth [5].

This research is part of the Italian Marine Strategy Framework Directive Programme and the DG Environment programme IDEM (grant agreement No 11.0661 /2017/750680/SUB/EN V.C2).

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S3P1. TRANSHAB: Coast to Deep Habitat Mapping

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There is growing demand for descriptive and predictive cartographic rendering to understand and govern at best the maritime domain. Among the most salient services to the society, benthic habitat mapping (HM) of the submerged territory contributes to (i) evaluate biological and geological resources, including their inventory, (ii) supply information at aptly justifying guidelines and directives for the management of the maritime space, (iii) improve a refined appreciation of the submerged cultural heritage. Standard methodologies applied to habitat mapping depend both on the approach and aims of the different disciplines at work on a specific goal, and on the technology involved that is necessarily dictated by constraints of physiographic settings. Coastal studies, for instance, make large use of SCUBA-diving operations, whilst the study of the offshore is largely based upon ROV, AUV and various acoustic approaches.

In definitive, there is not a standard approach at present to tackle habitat mapping independent of goals and operational spatial scales. We propose, therefore, to launch the informal initiative TRANSHAB. This initiative aims at first to discuss, and establish after, unified protocols and procedures in marine habitat mapping, applicable to any particular situation and opened to the entire HM community.

A first operative step to evaluate options could be through experimental transects which radially traverse the coastline to its offshore, intercepting habitats along a geographic continuum. This experiment would disclose dissimilarities in the mapping approach, explore operational and technological potentialities, recognize pitfalls, thus paving the road to find consensus solutions and prepare uniform guidelines. For practical reasons, the TRANSHAB approach should be limited at the beginning to territorial and EEZ waters in consideration of the difficulties in the high-seas below bathyal depths.

The habitat mapping of the coastline from the intertidal zone to the shallow depth should be performed through walking the shore and snorkelling, giving then way to SCUBA diving deeper or to miniaturized devices. Manned and unmanned underwater technologies will be responsible for mapping beyond the SCUBA reach. By large, instruments equipping the operative teams shall provide comparable geo-referenced data, what likely requires the design and/or adaptation of existing technologies to fit swimmers and SCUBA-divers and their supportive devices such as boats and scooters.

This research is part of the EU IDEM Project.

ABSTRACT GUIDELINES

1. A two-page limit will be enforced, so all text and figures must be within this limit.
2. You can insert one Figure (color in .pdf version; black and white or greyscale for printed version).
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S3O2. Rhodolith bed distribution: two modelling approaches to map the continental shelf seabed using acoustic data

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In the Mediterranean Sea, Rhodolith beds are considered habitats of conservation interest according to the EC legal framework for the marine environment (EC Council Reg. 1967/2006, EU Dir. 92/43/EEC, EU Dir. 2008/56/EEC) and by the UNEP-MAP Action Plan on marine vegetation. The knowledge of the spatial distribution and extent of the seafloor is particularly crucial for habitats requiring specific protection efforts. To date, the availability of an accurate, high-resolution scale and recent cartographic dataset of sensitive seabed habitats, such as Rhodolith beds, is one of the most critical aspects in the study of the marine environmental status. This aspect is very important where human activities such as fishing pressure strongly affect the seabed like the shelf area.

In general, for the production of habitat maps, two well separate phases are needed: the data collection and the data processing. In the elaboration of habitat maps from surveys, the first phase is dramatically demanding strongly increasing the cost of the process. Conversely, in the modelled maps, the first phase is shorter while the data processing takes the majority of the effort. For these reasons, the use of models to produce habitat maps is often chosen to cover wide areas with acceptable costs.

In this study, two different modelling approaches to predict seafloor habitat were applied by elaborating data collected using indirect methods such as multibeam bathymetry and acoustic backscatter (MBES), together with analyses of the images collected by ROV.

Data presented in this work were collected in the Tuscan Archipelago in June 2013, within the framework of a research project on Rhodolith beds funded by the Italian Ministry of Agriculture, Food, Forests and Fisheries Politics – Fisheries Direction. A total of 50 km^2 of Multibeam bathymetric data were collected with a Kongsberg-Simrad EM2041 system operating at a frequency of 400 kHz at an average speed of 6 knots. The average swath width was about 150 m and a swath overlap was maintained during the acquisition. Bathymetry and backscatter data were processed with CARIS Hydrographic Information Processing System (HIPS) and exported as raster with a cell size of 1 m. ArcGIS 10.1 software (ESRI inc) was used to aggregate the collected data to a broader 4m resolution; furthermore, the following bathymetric-derived layers were estimated: slope, roughness and bathymetric position index (BPI) and morphological features (a further derived variable in which BPI and slope values are combined). A total of 15 geo-referenced underwater video transect were recorded and a frame every 10 seconds was extracted. An image analysis of these frames was carried out in order to classify the seafloor and the following five different substratum classes were identified: Rhodolith beds coverage = >50 %, Rhodolith beds coverage < 50 %, sediment, mixed substratum and hard bottom.

The first tested modelling approach is a supervised method based on traditional/general statistical elaborations which needs a strong control by the modeller (expert judgement to decide step-by-step the threshold applied to each environmental variable interval). The second one is a GAM based approach in which the expert judgment contribution is not relevant. All the statistical analysis were run using R software and the probability maps were created in using ArcGIS.

Method 1: supervised approach using general statistics parameters

Each substratum class occurrence was statistically compared with the other variables using the Newman-Keuls test. The test confirmed that all subsets are significantly different (p value < 0.05). The basic statistics of backscatter showed a linear correlation between the percentage of Rhodolith beds and the acoustic response suggesting a prevailing role of this variable for modelling this habitat. The Backscatter typical range for each substratum classes was identified. Roughness and morphological features were then considered in order to reclassify each pixel in 5 “confidence” levels of presence per each substratum. All the obtained layers were summed

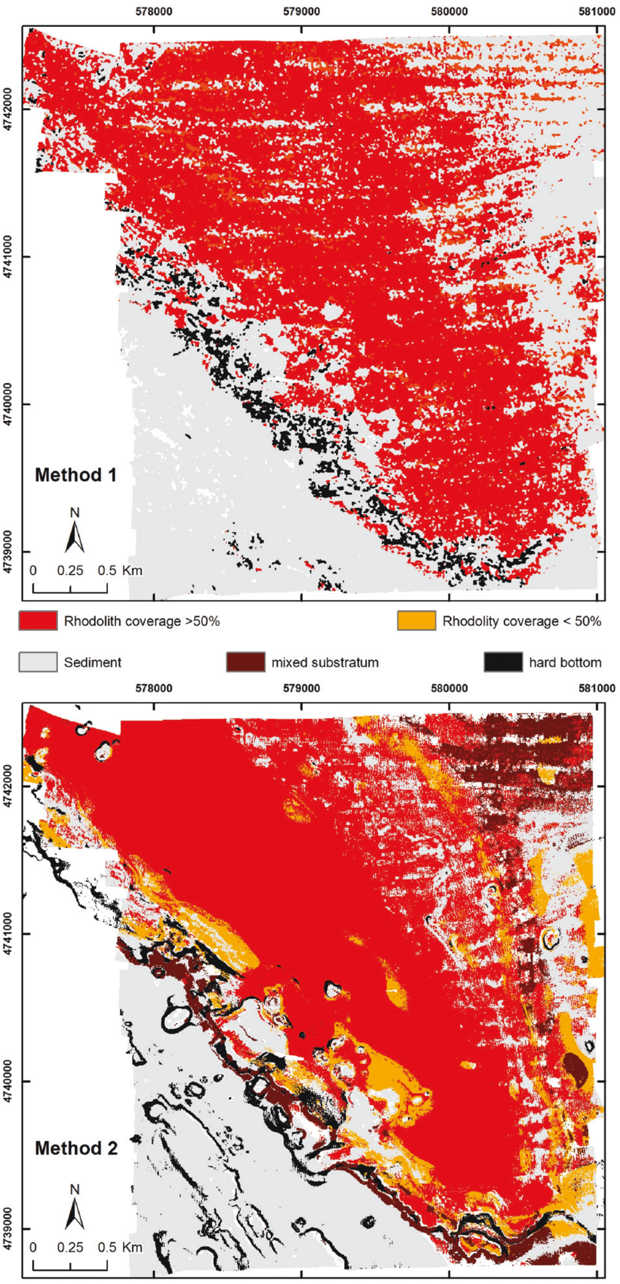

Figure 1. Modelled map outputs using the two described approaches

and a modelled map of the substratum was created by taking into account bathymetry, slope intervals and confidence. The comparison between the modelled map and the ground-truth shows a good correlation between the calculated pixel attribute and the corresponding seabed habitat detected by the ROV.

Method 2: unsupervised approach using general additive models (GAM)

Each substratum class was tested with different GAM models in order to individuate the best one in terms of deviance explanation and number of environmental variables used. The predictive accuracy was then applied and evaluated on the test dataset using: i. the threshold-independent Receiver-Operating Characteristic (ROC) plot; ii. the estimation of the area under the Receiver Operating Characteristic curve (AUC). The optimum probability threshold for model was individuated and the relative threshold, which gave the best data test correctly classified, was selected. The model was then used to assign a predict value and relative standard errors to each cell of the study area. This procedure, applied to each substratum class, provided four substratum probability layers that, summed together, allowed to create the prediction map of the study area. Since very few ground-truth data lie on hard bottom, it was not possible to run the GAM for this substratum class and, for this reason, the presence of this class was estimated based on the morphological feature values as calculated in the method 1. In case of pixel with multiple assignation (i.e. more than one model predicts the presence of a substratum class), the final assignation was based on the distance of the fit value from the threshold calculated by the ROC plot. Finally, a three classes confidence map, based on the model standard errors and the number of presence occurrence estimated within the same pixel, was created in order to highlight the consistence of the model.

The two modelling approaches provide relatively similar distribution of Rhodolith beds prediction maps confirming that both the methods are valid for this purpose (see figure below). However, the second approach is less influenced by the modeler experience and provides a more objective and replicable map. On the other hands, in case of few ground-truth data availability, the GAM approach could not be applied, as happened for the hard bottom in this exercise. More generally, the combined MBES/ROV approach tested in this study allows to investigate wide areas in a relatively short time. The described modelling approaches could be improved by using other environmental variables influencing Rhodolith bed distribution (i. e. light and energy at sea bottom).

S3O3. Classification of potential mesophotics coral reefs habitats on a South Atlantic oceanic island based on Benthic Terrain Modeler (BTM)

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Mesophotic coral reef habitats, occurring at depths of 30 to over 150 m, represents the deep continuum of adjacent shallow coral reefs about which little is known [1]. The objective of this study is to analyse the seabed geomorphology of an oceanic island at the South Atlantic, to assess the geodiversity of the area, specially the potential occurrence of mesophotic coral reefs. The analysis was supported by Benthic Terrain Modeler (BTM), which uses a combination of derived terrain attributes (BPI-Benthic Positioning Index, slope and depth), and a decision table containing definitions and thresholds appropriate to the data input, to enable a characterization of geologic types and benthic biotic communities. Results from the BTM analysis revealed twelve seabed classes highlighting the great geomorphic diversity of the area. Mapped classes included: Plains shallower than 30m (13.74 %), plains deeper than 30m (41.66 %), depressions (2.44 %), gentle slopes (19.93 %), steep slopes (1.76 %), flat ridge tops (8.91 %), rock outcrop highs (2.03 %), local boulder/pinnacles in depressions (0.25 %), local boulder/pinnacles on slopes (1.56 %), local boulder/pinnacles on broad flats (0.20 %), local depressions (7.30 %) and scarps/cliffs (0.14 %). Based on field survey the potential mesophotics coral reefs habitats occur in the folowing seabed classes: gentle slope, flat ridge tops and local depressions.

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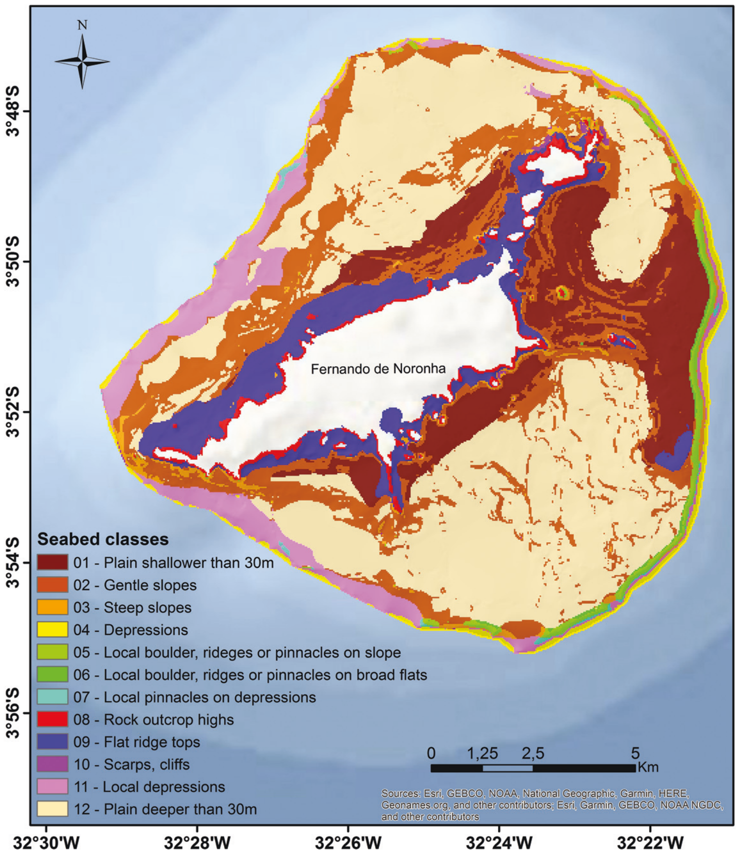

Figure 1. BTM output from the study area

S6O1. Benthic Habitat of Mud Volcanos Associated with the Queen Charlotte Transform Margin of Northern British Columbia, Canada and Southern Alaska, USA

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A 150 km linear series of mud volcanos located on the continental slope that crosses the international border between Canada and USA lie in approximately 1000 to 1300 m of water and are associated with the major tectonic plate margin between the Pacific oceanic plate and the North American continental plate, defined as the Queen Charlotte transform fault zone. The volcanos provide hard substrate habitats on a soft sediment slope. The hard substrate is manifested as carbonate slabs located in and around active gas vents at the crest and upper flanks of the volcano. The organisms associated with this mixed indurated habitat are primarily governed by depth and chemistry. Methanogenic chemosynthetic communities consisting of *Phreagena soyae* clams, *Solemya* spp. mussels, a *Vestimentiferan*-like tubeworm, and *Beggiatoa* spp. bacterial mats are the dominant chemosynthetic organisms. Anemones, shrimp, encrusting sponge, deep sea corals (Anthomastus spp.), demosponge, serpulid, glass sponges and ophiuroids make up the sessile and epi-fauna, while the Thornyhead rockfish *Sebastolobus* sp. and the deep water sole *Embassichthys bathybius* are present. Prominent gas vents, seen on echosounder and multibeam profiles, may serve as proxies or indicators for the presence of similar communities along this "leaky" margin.

P1. EMODnet Geology:
attributes and standards of geological events in submerged areas

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The European Marine Observation and Data Network (EMODnet) is a Project promoted by the European Commission in the frame of the Blue Growth, aiming at the collection and harmonization of existing marine data. It is subdivided into several Lots: Bathymetry, Geology, Biology, Chemistry, Physics, Seabed Habitats and Human activities. The Geology Lot, realized by a Consortium of European Geological Surveys, underlies other Lots, particularly Seabed Habitats which strongly rely on substrate information. Data mapped by various national and regional mapping projects and recovered in the literature, are freely available through a dedicated portal (http://www.emodnet.eu/) displaying digital maps harmonized at different scales, from 1 : 1,000,000 to 1 : 100,000. EMODnet Geology requires the compilation of a number of layers subdivided into Work Packages (WP), regarding seafloor sediments grainsize, sedimentation rates, Quaternary geology, pre-Quaternary geology and stratigraphy, coastal behaviour, geological events, mineral resources.

The Geological Survey of Italy is Partner of the Consortium and Leader of WP6 "Geological events and probabilities", which includes earthquakes, volcanoes, landslides, tsunamis, fluid emissions and Quaternary faults. Datasets consist of shapefiles representing each kind of event. One of the main objectives is the interoperability of data, in order to offer more complete, error-free and reliable information and to facilitate exchange and re-use of data even between non-homogeneous systems. Metadata and available information collected during the Project is displayed on the Portal (http://www.emodnet-geology.eu/) as polygons, lines and points layers according to their geometry (see Fig. 1 below).

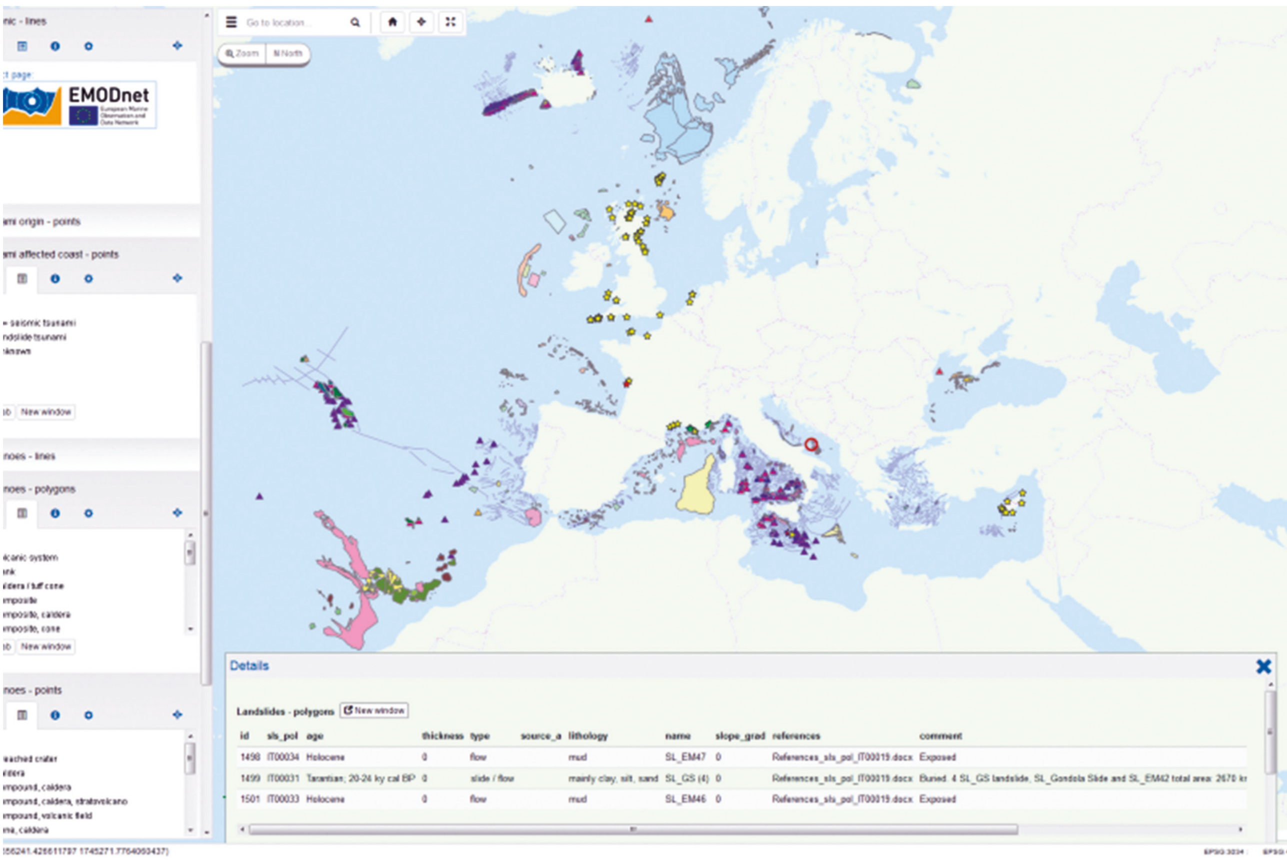

Figure 1. EMODnet Geology Portal: visualization of WP6 "Geological events"

The elaboration of WP6 guidelines to compile the shapefiles and attribute tables was aimed at identifying parameters that should be used to characterize events and any additional relevant information. Particular attention has been devoted to the definition of the Attribute table in order to achieve the best degree of harmonization and standardization according to the European INSPIRE Directive (https://inspire.ec.europa.eu/). Due to the diverse geological settings of European sea areas it was necessary to elaborate a comprehensive and detailed pattern of Attributes for the different features. Submarine slides have been characterized by type of movement, material involved (lithology), volume, thickness, slope, age and source area. Volcanic centers were complemented by information on their morphological and activity types, age of activity, chemical composition, eruption frequency, height, volcanic district and the presence of fluid emissions. Mud- volcanoes and fluid emissions of non-volcanic origin are characterized by type, height, region, composition, morphological and activity types, age of activity. Attributes listed for tsunamis are: date, type, cause, run-up, intensity, affected coast. Faults active during the Quaternary were taken into account.

The systematic collection of data concerning geological events has allowed the Geological Survey of Italy to produce an Atlas of Italian volcanic seamounts and a compilation of data on fluid emissions in the Italian submerged areas (to be published in the future). As a potential application of the data collected within WP6, the Geological Survey of Italy, in cooperation with other Italian public institutions, is working at an update of the structural model of Italy for submerged areas, whose last version dates back to 1992.

S3P2. Mapping submarine glacial landforms on the South Orkney Islands shelf (Weddell Sea, Antarctica)

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The 150-km-wide continental shelf surrounding the South Orkney Islands (SOI) in the NW Weddell Sea (Fig. 1) was significantly shaped during repeated advances and retreats of ice caps on the SOI starting from the late Miocene [5]. Sub-bottom profiling revealed presence of buried glacial landforms on the SOI shelf down to ~ 54 m below sea floor [3]. Several glacial troughs and the mid-shelf break mark the maximum extent of ice grounding, which was first approximated with the 200 meter isobath [6]. Later improvements to bathymetric data suggested that grounded ice reached 250–300 m [4], and 300–350 m water depths [2].

In March 2018, detailed multibeam survey was performed on the SOI shelf as part of the 63rd Russian Antarctic Expedition onboard the RV "Akademik A. Karpinsky" (PMGE). This ship is equipped with a hydrographic system (including the Atlas Hydrosweep MD-3/30 multibeam echosounder) that is compliant with the IHO S-44 Order 1a survey standards. The shipboard hydrographic group included a FIG/IHO/ICA Category A certified hydrographer. Survey planning and raw data acquisition were performed using the HYPACK/HYSWEEP software. Data processing and gridding were done in the QPS Qimera package (QPS kindly provided a limited time software copy for the duration of the cruise).

The area mapped represents a ~1500 sq. km polygon in the Signy Trough area (Fig. 1). The multibeam survey was conducted along 43 profiles (parallel to the long side of the polygon), spaced at

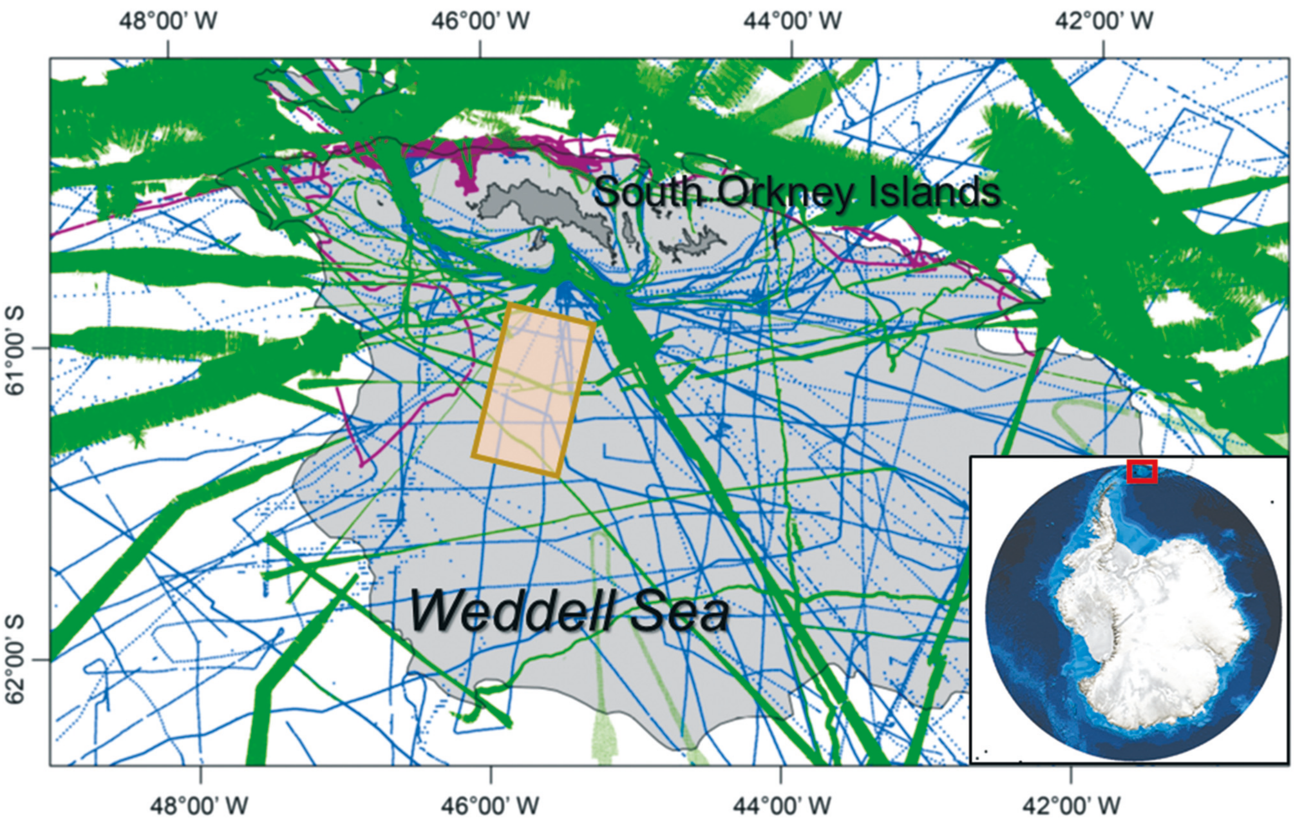

Figure 1. Spatial extent of bathymetric data available for the South Orkney Islands shelf: single-beam data — blue lines, multibeam data — green polygons (figure from the 300m resolution bathymetric compilation [2]); multibeam data of the 63rd Antarctic Expedition collected in 2018 (full coverage and 30m grid available within the brown polygon). Inlet map shows the study area in the NW Weddell Sea, Antarctica (basemap is IBCSO [1]).

750 m to ensure enough overlap between swaths. Bathymetric maps available for the SOI shelf comprise a ~ 500 m resolution circum-Antarctic IBCSO grid [1] and a 300 m regional grid based on the 1986–2012 multibeam surveys [2]. The 2018 multibeam data allow us to compile a bathymetric map with a 30 m resolution grid (water depths in the survey area range from 180 to 400 m), which significantly improves the existing visualization of sea-floor morphology and provides details on smaller scale glacial landforms (e.g. moraines, ice channels, plough marks etc.). ESRI ArcGIS ArcMap software will be used for further surface analysis to produce aspect and slope maps, which will allow 1) to describe the depth and shape of the Signy glacial trough in greater detail, as well as 2) to determine the orientation of surficial moraine systems and, hence, to infer the directions and thickness of paleo-ice streams.

Interpretation of the detailed multibeam data, aiming to reconstruct Quaternary paleoenvironments and ice dynamics on the SOI shelf, will be fulfilled along with analysis of multichannel seismic lines crossing the studied area (including the lines collected during this cruise) and all other literature information.

This study is supported by the Russian Foundation for Basic Research (grant no. 19–05–00858).

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S1O1. Bioherms of Peter the Great Bay. Distribution and prospects of study

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Marine bioherms, also called “oyster banks” or “oyster reefs”, were studied during the monitoring work in 2014–2018. Bioherms looks like correct dome-shaped form up to several tens of meters at the base and up to several meters high. These forms of relief are common in shallow water. The bioherms are folded with shell detritus in the upper part by about 30 %, while the remaining 70 % of bioherm are composed of compressed silt. In addition, the oyster banks of Peter the Great Bay are populated at this time not with oysters, but with completely different types of mollusks (bowardi arch, sea cockerel), so the name “oyster bank” is very conditional. The age of sediments from the lower part of bioherm is 8–10 thousand years [Vyshkvartsev, 2010].

Oyster banks in Peter the Great Bay are most common in the shallow part of the Amur, Ussuri and Posiet gulfs. It should be noted that numerous studies have shown that the occurrence of the distribution of marine bioherm to gas outlets in the bottom layer of water [Vyshkvartsev, 2010; Lein, 1989; Boulegue, 1987; Vogt, 1994], which suggests that the source of development of these bioforms may be local gas inflows to the bottom surface, forming, ultimately, a nutrient medium for the local fauna. Thus, since it is possible to raise the question of the existence of correlations between the spread of degassing zones of bottom sediments and accumulations of bioherms, and the flow of gas may be related to tectonic activity, it can be assumed that the development phases of bioherms have an indirect connection with local tectonic activity.

The report was based on works carried out by the State Company “VNIIOkeangeologiya” within the framework of monitoring the geological environment of the shelf in the waters of Peter the Great Bay, Sea of Japan. It summarizes the research data for 2014–2018, which includes both information obtained during geophysical surveys and bottom sampling. Also, this report cover the prospects for studying of modern and buried bioherms.

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S1O2. High Arctic habitat mapping in Svalbard — challenges & preliminary results

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Svalbard is an archipelago covering 61 022 km^2 in the high Norwegian Arctic (74–81° N, 10–35° E) in the northwestern Barents Sea. The largest islands, Spitsbergen and Nordaustlandet, cover more than 85 % of the archipelago. The climate is arctic, but due to the West-Spitsbergen current it is much warmer than the latitude would indicate, particularly on the west coast. Meanwhile, the northern and eastern coasts of the archipelago are under the influence of more arctic water, brought in from the polar basin by the East-Spitsbergen current. About 60 % of the islands are currently glaciated with outlet glaciers calving icebergs into the sea in several fjords.

Svalbard, like much of the Arctic, is currently experiencing rapidly changing climate. Besides direct environmental changes linked to warmer air and sea temperatures, the changing climate may also lead to an increased human activity in the Arctic e.g. fisheries and transport. To meet the challenges of sustainably managing these changes, ocean management bodies have expressed a need for increased knowledge of the benthic ecosystems around the Svalbard archipelago. Kongsfjorden on the west coast and Rijpfjorden on the northeast coast of the archipelago have been defined as important reference fjords, representing an already impacted and a relatively pristine Arctic fjord, respectively.

To address this need for knowledge of the benthic ecosystems, the Norwegian seabed mapping programme MAREANO, has begun mapping selected areas on the continental shelf west and north of Svalbard. Multibeam surveys were undertaken in 2016–2018 and followed by a sampling cruise in 2018 collecting data for geological, biological and chemical analysis and map product development. The two reference fjords of Kongsfjorden and Rijpfjorden were the focus of the 2018 sampling cruise. Both the main fjord (>30 m deep) and the shallow coastal water (< 30 m depth) were mapped with respect to substrate and habitats. Here we focus on the shallow water surveys in this challenging coastal environment. We present highlights from the cruise, including operational considerations, field observations of the geology and habitat. We also outline follow-up work and present the substrate maps for each fjord.

S1O3. Marine mine tailings disposal in Stjernsundet, North Norway

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Sibelco Nordic's mine at Stjernøy, North Norway, disposes mine tailings into the fjord Stjernsundet (see Fig. 1 below). Nine million tons have been disposed since 1962. The tailings, discharged at the shore line in the bay of Lillebukt, comprise c. 85 % fine silt to medium grained sand (0.01–0.5 mm). Upon discharge of the mine tailings into the fjord, they are redistributed by slides and density currents along major channels with pronounced levees [1]. Multibeam echosounder data show sand waves in the channels, while seabed samples and cores document sand ripples and layers of mud between the sand layers. Mud accumulates outside of the channels on the seabed in Lillebukt and as a thin veneer along the shores to the east and west. The bathymetry data show partly buried slide escarpments and slide deposits, while smaller slide scars are evident in the levees. Three slide events in the tailings are documented of which the most recent occurred 9th October 2017. Comparison of bathymetry data collected in 2016 and 2018 show changes in bathymetry in the channels of +/- 3 m. Slides are partly initiated along fine-grained layers and caused by hyper-sedimentation. From 60 m depth, one single channel continues down to 100 m, where the sediment transport is along a gully in the steep (45º) bedrock slope down to c. 400 m depth. A sand-dominated submarine fan is deposited at the foot of the slope, extending to c. 463 m depth. Bathymetric data, seismic data and core analysis show that the fan has a radius of up to 1500 m and covers an area of c. 1.5 km^2. Comparison of bathymetry data collected in 1998 and 2016 shows that a major part of the tailings disposed of in that 18-years period (4 million tons) have accumulated on the submarine fan.

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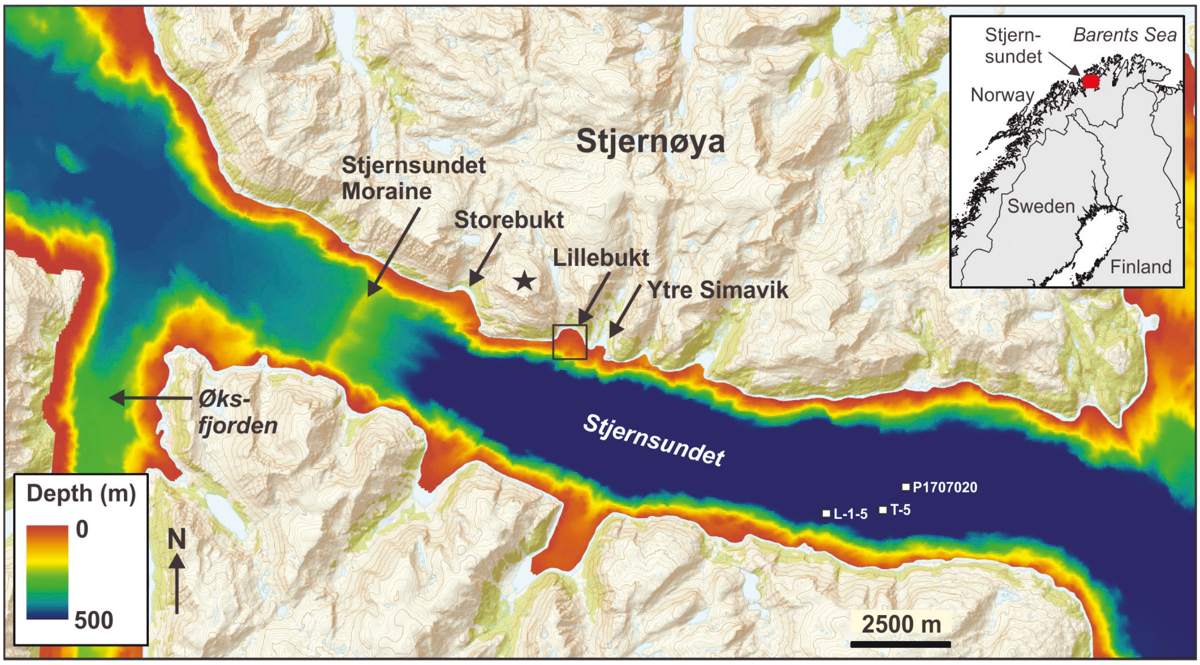

Figure 1. Coastal profile dynamics

S3O4. Testing the application of synthetic aperture sonar for seafloor habitat mapping

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Ocean mapping technologies continue to advance, and the introduction of Synthetic Aperture Sonar (SAS) is an emerging seafloor-imaging technique that provides ultra-high-resolution imagery for both bathymetry and backscatter data sets at superior coverage rates. SAS has primarily been used for military applications to date (e.g. target detection on the seafloor), but offers far wider potential benefits in other non-military applications due to the very high resolution data (e. g. 3 cm horizontal resolution). Results from a collaborative project between the Applied Oceans Research Group (AORG) at the Nova Scotia Community College and Kraken Robotic Systems Inc. (Kraken) will be presented. Test data sets were collected using the Kraken KATFISH actively-controlled towed vehicle fitted with the SAS system in the vicinity of Halifax Harbour and the Bedford Basin, Nova Scotia, Canada. Following post processing of the SAS bathymetric and backscatter data sets, ground-truthing was conducted using an underwater ultra-high definition subsea camera system mounted on a drop camera frame. A variety of data segmentation and classification routines were applied to these data sets to evaluate the utility of the SAS imagery for surficial geological and benthic habitat mapping applications. The implications of the ultra-high acoustic data resolution are discussed in the context of the mapping methodology, and the spatial scale of the interpreted thematic maps. The results demonstrate the significant, potential benefits that ultra-high resolution SAS data can offer this field of research.

S1PO1. Spatial and temporal variability of trawl marks in the area of Dogger Bank (German Exclusive Economic Zone, North Sea)

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Environmental risk assessment and spatial management due to fishing pressure are important topics, especially to relatively small sea regions with high human impact. To monitor fishing activities, usually VMS (vessel monitoring system) and logbook data are combined from which fishing intensity maps can be deduced. In the North Sea these maps have a spatial resolution of roughly 0.05°*0.05°, thus information about small-scale effects is missing. Higher spatial resolution could be achieved by considering trawl marks that temporarily remain in the sediment due to bottom-contacting fishing gears. To evaluate the persistence of trawl marks and therefore the impact on benthic habitats in terms of frequency and intensity, we started comparing VMS-based small-scale swept area estimates with trawl marks that we observed in high resolution hydro-acoustic data.

Data acquisition was conducted in the scope of the German seabed mapping program "SedAWZ", which is supported by the Federal Agency for Nature Conservation (BfN) and the Federal Maritime and Hydrographic Agency (BSH). The northernmost part of the German Exclusive Economic Zone including the natural conservation area Dogger Bank was mapped with hydro-acoustic devices: using side scan sonar, multibeam echo sounder and parametric echo sounder almost 1500 km² of seabed sediments were recorded in 2016 and 2017. Sediment types in the area were determined from backscatter data, which were verified with grab samples and underwater video observations.

Trawl marks were classified considering backscatter intensity and their morphology to assess their stability, from which different stages of age could be derived. The main controlling factors are grain-size, water depth and the used trawling gear. Moreover, the swept area based on VMS data was correlated with the swept area calculated from mapped trawl marks. The given data clearly display annual to monthly changes in fishing activity. It turns out, that in-situ observations only show a small proportion of the trawled area, but it sheds light on how long trawl marks persist under specific environmental conditions. The new approach of combining trawl track analysis, sediment composition and hydro-acoustic mapping provides important information for the future analysis of trawling impacts on the seafloor, especially in areas where the physical forcing and bedload sediment transport varies.

S8O1. Bottom nepheloid layer within the redox barrier on the Gdansk-Gotland Sill (the Baltic Sea)

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The Gdansk-Gotland Sill is located in the South-Eastern Baltic, separating the Gdansk Deep from the Gotland Deep. Its mean depths are 85–87 m; a moraine is exposed at the seafloor or overlapped by a thin layer of modern (Holocene) sediments. According to [1] the wave-shaped relief of the Gdansk-Gotland Sill originates from elongated furrows, which were formed on dense late Pleistocene glacial deposits and basically are and ice-keel relict ploughmarks, which stopped to occur during the Ancylus Lake stage. Another feature of the Gdansk-Gotland Sill is the fact that here halocline reaches the bottom, favoring nutrient accumulation. The Gdansk-Gotland Sill area is also known for ferromanganese crusts development, according to [2] the quantity of them reached 5–16 kg/m^2. Along with small sedimentation rates all these makes the Gdansk-Gotland Sill a highly special type of habitat, for instance, the macrobenthic communities within this area were depleted last several years and consisted almost exclusively from Polychaeta.

The bottom nepheloid layers formation should include both the bottom current and unconsolidated fine sediments. So, the main feature about bottom

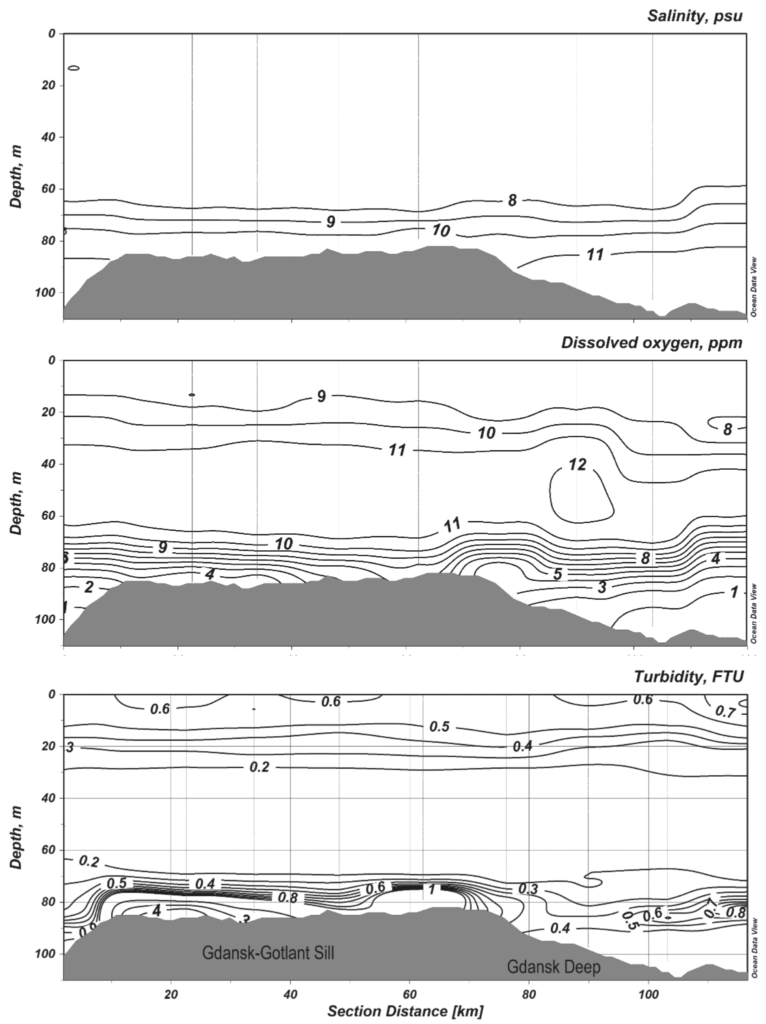

Figure 1 Hydrological conditions during the survey.

nepheloid layers is that the concentration is generally highest close to the bed and decreases upwards.

The 43-rd cruise of the r/v "Akademik Boris Petrov" (August 2018) revealed the appearance of the anoxic conditions in the Gdansk Deep, which was for the first time for the XXI century [2]. The hydrological conditions of the survey were generally common for the Baltic Sea summer. The upper mixed layer (9–15 m thick) above the seasonal deepen sharp thermocline (20 m deep), the cold intermediate layer and the halocline, but both the Gdansk Deep and the Gotland Deep bottom salinity is less than 12 psu (see Figure 1 below, salinity section). The dissolved oxygen (Idronaut 316 Plus probe) level experiences drop to 3 ppm at 80–90 m depth, coinciding with the halocline (see Figure 1 below, dissolved oxygen section) and the bottom of the Gdansk-Gotland Sill. At the same time, in the Gdansk Deep, to the south from the Sill, the oxygen depletion reaches its peak, changing oxygenic conditions to hydrogen sulfide presence.

The Idronaut 316 Plus turbidity (FTU) probing showed a nepheloid layer, located at roughly 80–90 m depth (see Figure 1 below, turbidity section), which is intermediate nepheloid layer for the Gdansk Deep ant the bottom nepheloid layer for the Gdansk-Gotland Sill area. At the same time, the very maximum of turbidity was not located near bottom, as it should within a bottom nepheloid layer. It is known for the Baltic Sea, that suspended particulate matter formation is possible within the border between oxygen and non-oxygen conditions due to bacterial activity and particulate Fe/Mn formation [3]. The suspended matter samples, collected from maximum turbidity zone, appeared to have reddish color, specific for particulate Mn. The scanning electronic microscopy of these samples from the Gdansk Deep has shown the biogenic (bacterial) origin Mn particles.

After all, we observed not the aforementioned "common" bottom nepheloid layer, but the particular conditions which appear to be favorable for Mn-forming bacteria. The habitat of these bacteria is narrowed to the thin layer of alternation oxidizing conditions to reducing.

Acknowledgements.

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S8O2. Probabilistic seafloor classification using multispectral acoustic backscatter and hydrodynamic modelling: Case study of Delgada submarine canyon, USA

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Active submarine canyons are rare worldwide due to sea level rise following the last glacial maximum. However, active canyons do occur in areas of rapid tectonic uplift and coarse sediment (gravel) delivery to the shore. Recent research suggests that submarine canyon-induced wave refraction alternatively causes sheltering the canyon head from longshore transport and focuses wave energy into shoreface gullies, which could trigger density currents that exit to the deep sea [1]. We have used sedimentary provenance, hydrodynamic modeling, and repeat multibeam sonar surveys to suggest, at Delgada Canyon in northern CA, USA, that submarine canyon bathymetry and sediment inputs from coastal creeks and bluffs have profound influences on nearshore wave transformation, gravel beach dynamics, and the mass balance and spatial storage patterns of mixed sand-gravel-cobble littoral sediment [1]. The strong likelihood of offshore gravel deposits would further support the hypothesis that the canyon promotes offshore transport of terrestrially sourced material.

To this end, we present results from a multi-frequency (a.k.a 'multi-spectral') R2Sonic 2026 multibeam survey of the canyon headwall and nearshore area (5 incident frequencies simultaneously), tributaries and main axis (3 incident frequencies, down to a depth of ~200 m), conducted in collaboration with R2Sonic in October 2018. Acoustic seafloor sediment maps have been created from acoustic backscatter calibrated to sparse ground-truth observations of sediment from ponar grab and mini ROV dives, and using numerical hydrodynamic model outputs to constrain sediment predictions. To do so, we modify the probabilistic graphical seafloor classification framework proposed by [2] to utilize heterogeneous inputs consisting of both point observations of sediment and field observations of individual sediment-class-likelihoods based on average modelled bottom shear stress in the 12 months prior to the survey. The result is a physically more realistic seafloor sediment map than using bed observations alone.

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S1P1.Observations of water column multispectral acoustic backscatter over migrating dunes: Case study of Colorado River in Grand Canyon, USA

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Previous researchers have suggested that quantifying and visualizing flow and sediment in rivers is possible using a stationary high-frequency multibeam sonar [1][2] but this has not before been demonstrated from a moving vessel, nor at multiple incident frequencies. While the discriminatory power of multispectral backscatter is explored and exploited for seafloor habitat and geological mapping, there is a concomitant interest in the use of multispectral multibeam backscatter for quantitative measurements of flow and suspended sediment.

We present observations from a multi-frequency ('multi-spectral') R2Sonic 2024 multibeam survey of the Colorado River in Grand Canyon, conducted in collaboration with R2Sonic in February 2019. The unique dataset consists of several hours of repeat multibeam surveys over a defined reach of the Colorado River. The section of alluvial channel is quasi-trapezoidal in shape and the bed is composed mostly of fine and medium sand [4]. The suspended sediment is a mixture of clay, silt and sand. The survey reach starts at USGS gaging station 09404208, from which sediment samples were collected at discrete times throughout the survey. Full water-column and bed backscatter were collected simultaneously over multiple frequencies between 170 and 700 kHz while the sand dunes on the bed deformed and migrated downstream. These data were collected for the 2019 R2Sonic Multispectral Backscatter Competition. The full dataset also consists of supporting measurements from: 1) a 600 kHz Acoustic Doppler Current Profiler, consisting of periodic cross-stream transects at the upstream and downstream extents of the reach; 2) periodic vertical profiles of suspended sediment concentration and grain-size using a P-61 time-integrated sampler; and 3) a calibrated cross-sectional average measurement of suspended sediment concentration and grain-size at 15 minute intervals using a multi-frequency array of single-frequency side-looking acoustic-Doppler profilers, estimated using the techniques proposed by [4]. The 4D multispectral water column backscatter data has been collected and made freely available for the purposes of stimulating research into 1) rendering the backscatter in order to visualize the spatio-temporal evolution of flow and suspended sediment fields, and 2) estimating suspended silt/clay and/or sand concentration and/or grain size from features extracted from the backscatter data.

Disclaimer

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the US Government

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S7P1. Updates and highlights of the South African offshore mapping programme

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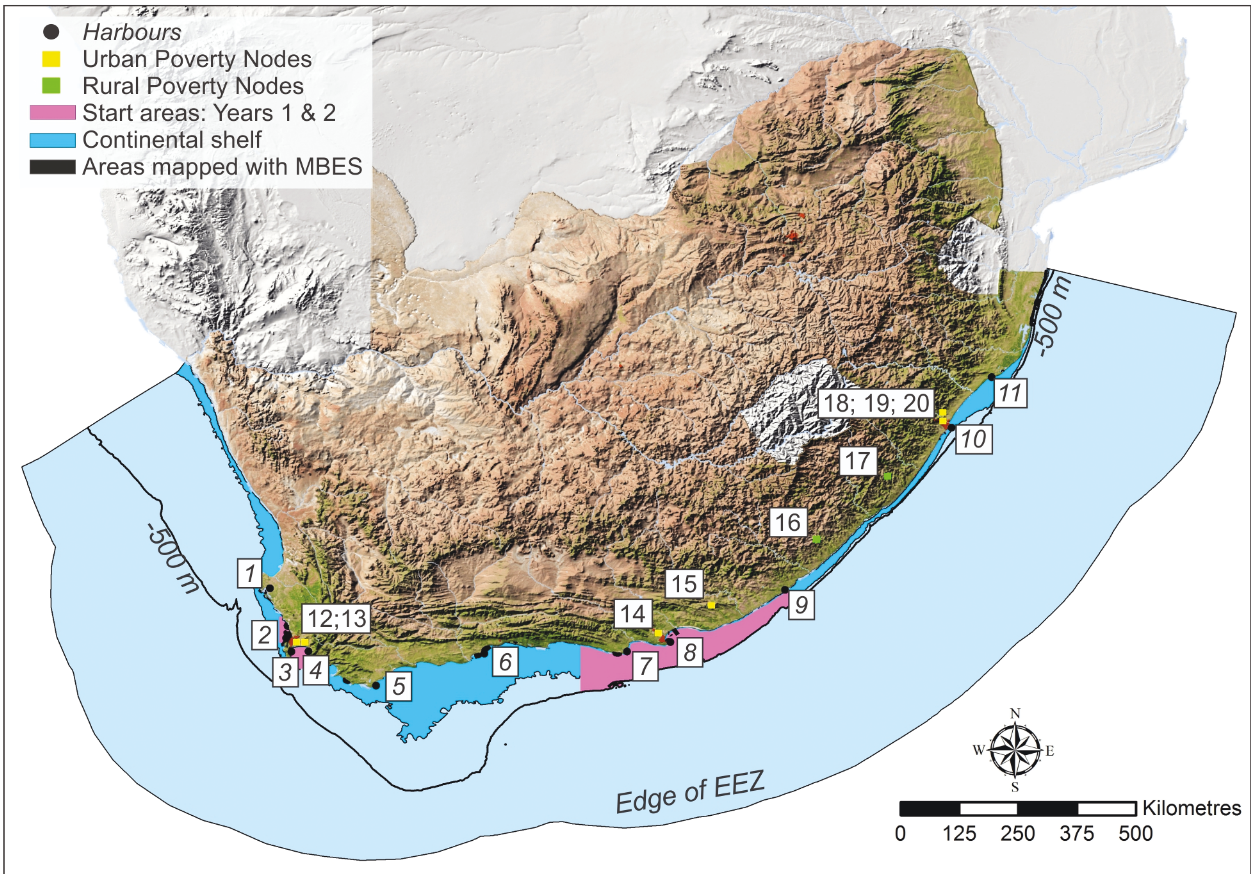
The South African offshore area is larger than the onshore region, and will be more than doubled if the Extended Shelf Claim is ratified by the United Nations. The Council for Geoscience (CGS)' marine geoscience programme has an overarching objective to boost the South African blue economy. This project aims to create a high-resolution onshore-offshore map of South Africa which seamlessly spans from the coastline to the outermost edge of the offshore territory. The marine geoscience programme will map the entire Exclusive Economic Zone (EEZ) with full coverage, using a suite of vessels designed for a range of ocean depths and applying five marine geophysical methods. These techniques include multibeam bathymetry, side-scan sonar, marine magnetics, medium-penetration sub-bottom profiling and gravity.

South Africa's rich and productive coastal waters support tens of thousands of jobs, with coastal goods and services estimated to contribute 35 % to South Africa's Gross Domestic Product. Preliminary economic analyses suggest a R 5 to 7 billion



1: *Saldanha Bay Harbour*; **2:** *Cape Town Harbour*; **3:** *Simon's Town Harbour*; **4:** *Gordon's Bay Harbour*; **5:** *Struis Bay Harbour*; **6:** *Mossel Bay Harbour*; **7:** *St Francis Bay Harbour*; **8:** *Port Elizabeth Harbour*; **9:** *East London Harbour*; **10:** *Durban Harbour*; **11:** *Richard's Bay Harbour*; **12:** Mitchell's Plain; **13:** Khayelitsha; **14:** Motherwell; **15:** Mdanshane; **16:** O.R. Tambo; **17:** Ugu; **18:** Inanda; **19:** kwaMashu; **20:** Ntzuma.

Figure 1. The South African coastal and offshore environment

[~US$ 400,000,000 — 500,000,000] boost in direct economic benefits to maritime industries through the completion of an offshore mapping programme, and these projections were based on the continental shelf which comprises only 15 % of the EEZ. Marine and coastal resources are important as they represent both a source of food and have enormous potential for economic development through both tourism and industry.

Outcome

Mineral resource mapping and promotion of environmental stewardship on South African coasts to boost the Blue Economy

Key objectives

1. To enhance economic growth through research on the coast and continental shelf of South Africa and, in turn, to boost the Blue Economy
2. To effectively plan adaptive strategies to address threats to infrastructure and the coastal community; tighter constraints on the rates of sea level rise are vital

Here, we provide data outputs from parts of the Western and Eastern Cape continental shelf, where our work has commenced. Thus far, our research focusses on seafloor structures, benthic habitat mapping and heritage resources.

S7O1. A submerged terrestrial landscape in southern South Africa: geological and soil maps for the Last Glacial Maximum

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The South African Cape South Coast is bordered by one of the broadest continental shelves in Africa. Quaternary sea levels have been significantly lower than at present for ~90 % of the last 900 ka, exposing a terrestrial ecosystem on what is now the submerged portion of the Palaeo-Agulhas Plain. Past work has hypothesised a contrast in character of this submerged landscape. We demonstrate, through the application of marine geoscientific techniques and a culmination of 8 years of work on the continental shelf, that the submerged landscape was a unique terrestrial environment and that there is no exact modern-day analogue in the region other than a small (~70 km^2) area located at the edge of the Agulhas Plain near Cape Agulhas. We describe the geological deposits and projected soils for each lithological substrate type, as well as geological and soil maps for average glacial conditions during Marine Isotope Stage (MIS) 2: the Last Glacial Maximum (LGM). We show major contrasts in the geological, topographic and edaphic nature of the landscape from the onshore to the offshore. The submerged shelf is dominated by more fertile soils compared to the dissected onshore belt where there are acidic soils. The expansion of this plain is coupled with enhanced fertility, exaggerated floodplains, meandering shallowly incised rivers and a mobile deposit of unconsolidated sediment available for dune construction. Mesozoic sedimentary deposits crop out near the surface on this current-swept shelf and fertile soils derived from siltstone and shale bedrock are prominent when the coast is up to 64 km distant from the modern shoreline at its maximum point. Beyond this, weathered limestone dominates the substrate sequences on the Agulhas Bank/outer shelf. Sea level reached a maximum depth of 130 m BMSL during MIS 2 and wetlands and floodplains were present. Broad, shallowly incised rivers carved the low-relief coastal plain. The geological record suggests that laterally extensive floodplains were infilled and overspilled with sediment into the incised channels. Extensive dunefields, extending up to 10 km inland from their associated palaeoshorelines, covered much of the emergent shelf. Sedimentary bedforms may have obstructed or slowed drainage as suggested by leached palaeosols and carbonate mixing observed in petrographic thin sections. The data show a low-relief "plains" landscape, which contrasts strongly to the topographically complex and largely infertile contemporary coastal foreland.

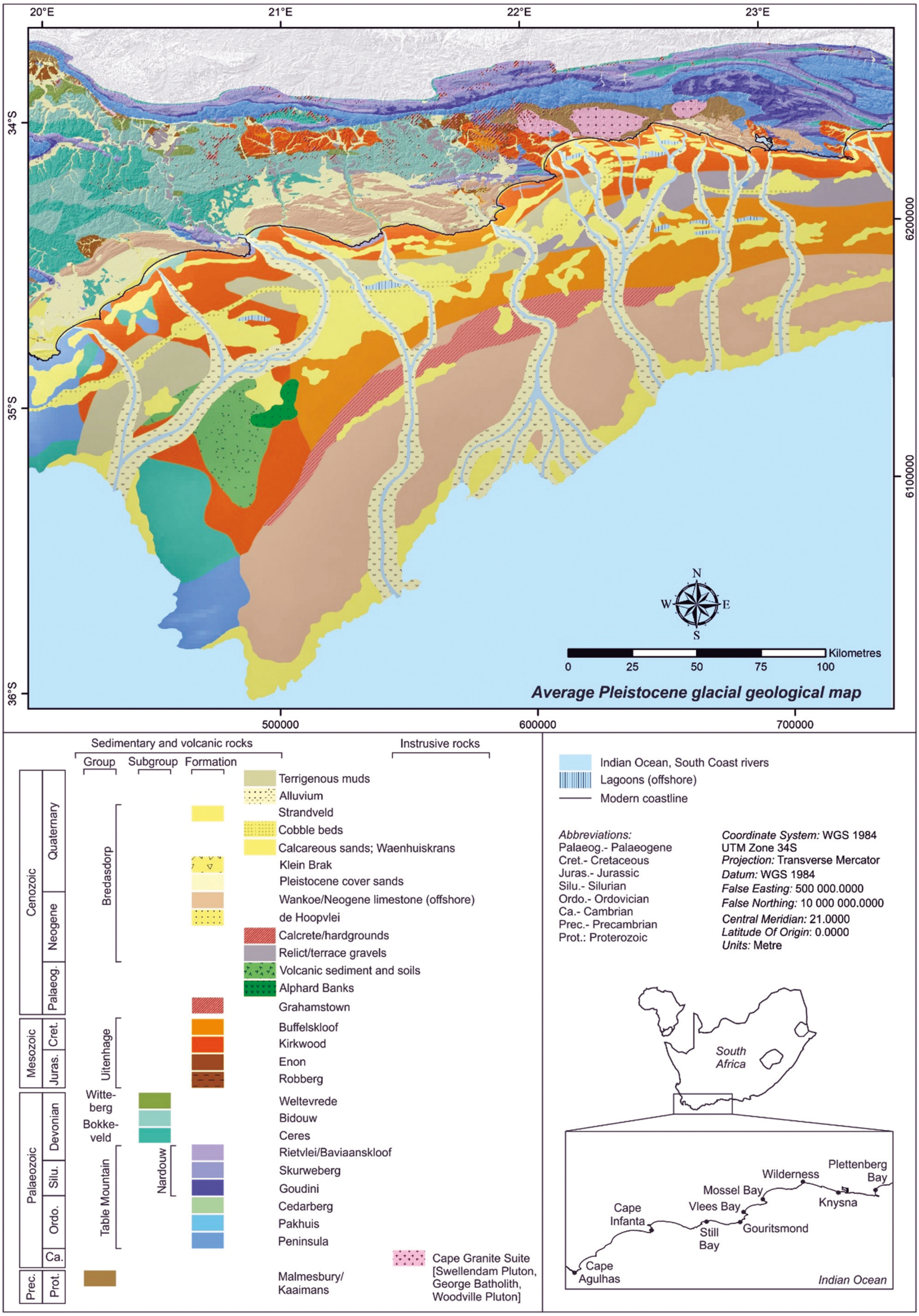

Figure 1. Geological map of the Last Glacial Maximum

S3P09. Inertial Multibeam Sidescan Sonar and Multibeam-Multiswath Echosounder as Adaptive Backscatter Imaging Systems

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Backscatter imaging systems are, usually, optimized for pre-defined tasks: high resolution sidescan are devoted to detection purpose, lower resolution systems are used for large area mapping and seabed classification applications, and multibeam echo sounders are dedicated to reach the best bathymetric performances. Adaptive imaging systems are, on the other hand, designed to be able to modify their insonification geometries and processing algorithms. This approach may be very valuable to optimize and adapt the performances of the imaging systems according to the environment conditions variabilities and navigation stability and operational needs.

We will illustrate the benefits of such an approach for backscatter imaging considering two adaptive systems examples: "inertial multibeam sonar system" and "multibeam multiswath echosounder". An inertial multibeam sonar system is a sidescan sonar composed of the four keys elements: a large emission aperture, a multiple receiver antenna, integration of an inertial navigation units and an adaptive processing algorithm [1]. The processing parameters can be tuned so as to produce the best image resolution and quality from incoherent to full coherent synthetic aperture processing [2], [3]. The second adaptive backscatter imaging system we will focus on, is a multibeam multiswath echosounder [4]. It is composed of a two linear antenna array arranged in a conventional Mills Cross geometry. Each antenna can transmit and/or receive and the emission beam can be steered electronically. Benefits of multiswath backscatter imaging will be evaluated, and especially the perspective on seabed classification upon anisotropic seafloor textures.

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S3O5. Geological and biological mapping of deep-sea hydrothermal vent fields based on observations using ROV

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Deep-sea hydrothermal vent fields can be considered as the meeting point of unique chemosynthetic biological communities and exciting hydrothermal mineralization presented in various morphological types. Variable geological structures provide specific landscapes where habitats are distributed under the fluid temperature and geochemistry control.

Bio- and geodiversity as well as zonality of distribution of both biota, hydrothermal chimneys and other geological structures can be described within a hydrothermal field based on high-resolution bathymetry and video/photo profiling by Remote Operating Vehicle (ROV). We used observations made with ROV Victor 6000 (IFREMER, France) during the French-Russian SERPENTINE project [1] at the Ashadze-1 field, 13°N, Mid-Atlantic Ridge as a case study for demonstration of the comprehensive detailed mapping of the hydrothermal vent site. Some detailed maps and description of the biological community of Ashadze-1 based on black & white and coloured images were published earlier [2]. The aim of the present study is (1) to describe geological features of the field in more detail and (2) to summarize biological and geological data in the context of modelling and assessment of potential mining impact.

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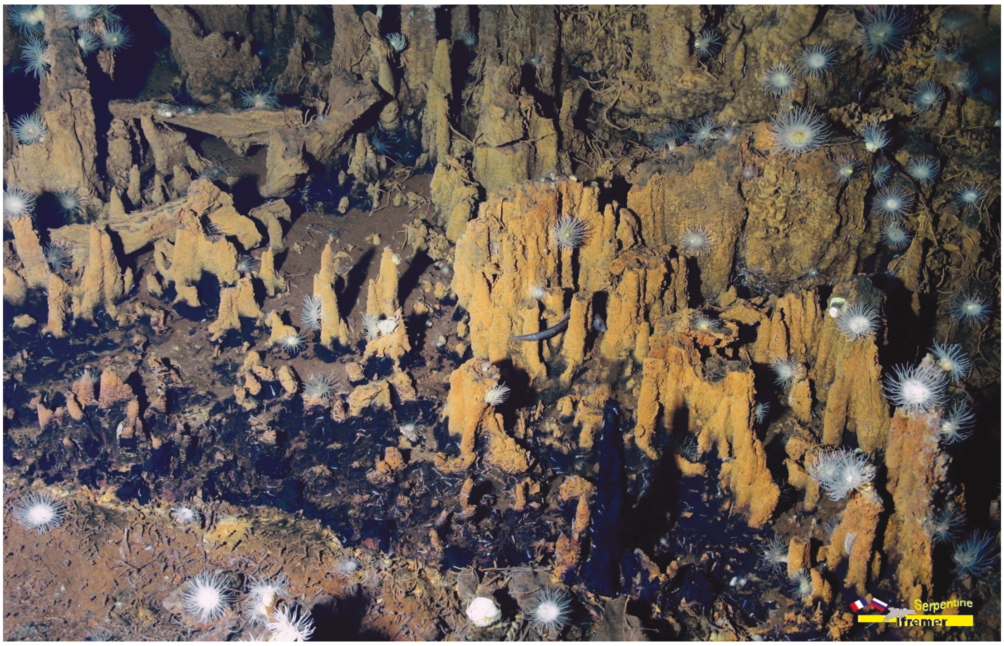

Figure 1. Ashadze-1 hydrothermal vent field, weakly active site with combination of different geological structures (sulphide chimneys, crusts, metalliferous sediments) and hydrothermal vent fauna (anemones, chaetopterid polychaetes, shrimps etc.).

S1P2. Conditions affecting carbon storage in mangrove leaves at Katunggan It Ibajay (KII) and Bakhawan Eco-parks, Kalibo Aklan

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Mangrove forests play a big role in mitigating climate change contributed by carbon emissions by storing carbon above and below-ground. This study aims to estimate carbon content in mangrove leaves of Sonneratia alba, Rhizopora sp., and Avicennia sp. Leaves were collected and then exposed to different conditions (exposed to air and submerged in water) for three months at the Bakhawan and KII Eco-parks. Total organic carbon (TOC) content was determined using Loss on Ignition method. When compared to TOC values of fresh leaves obtained from a previous study, those submerged in water had higher organic carbon content. For both areas, leaves submerged in water showed higher %TOC compared with leaves hung in air. The difference in %TOC between submerged leaves and leaves hung in the air is 0.41 % in Bakhawan and 0.26 % in KII. Submerged leaves have higher %TOC probably due to resorption from the carbon-enriched water brought by runoff. For leaves in both conditions (exposed to air and submerged in water), Rhizopora had the highest TOC (0.23 %), followed by Avicennia sp. (0.22 %) and Sonneratia alba (.17 %). Results also showed that the average %TOC of submerged and air-control leaves for the KII Eco-park (0.31 %) was higher than Bakhawan Eco-Park (0.17 %). This may be due to KII Eco-park being the more mature forest with larger vegetation biomass, and greater net productivity as more plant litter is produced. The overall mean litter (from the litter trap) in KII Eco-park (90.85 g/m) is also one order of magnitude higher than at the Bakhawan Eco-park (1.30 g/m). Results indicate that the ability of mangroves to store Carbon is site- and species-dependent.

S3PO1. Mapping in support of Marine Protected Area designation and management: a 'back-to-front' story

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The UK is currently completing the third and final tranche of UK Offshore Marine Conservation Zone (MCZ) designations, to address deficiencies in existing MCZ coverage. MCZs — a type of Marine Protected Areas — are a tool to help achieve Good Environmental Status in UK waters under the EU Marine Strategy Framework Directive. In the UK, social and economic impacts must be considered during MCZ site selection and designation. Following the Irish Sea Conservation Zones project's 2011 recommendations for MCZ sites in the Irish Sea, the Northern Ireland (NI) fishing industry raised objections regarding the potential impact the proposed sites could have on access to historic fishing grounds, primarily focussing on the *Nephrops norvegicus* (Dublin Bay Prawn, 'scampi') fishery. The NI fishing industry was encouraged by the UK Government to propose alternative MCZ sites to fill existing gaps in the MCZ network (e. g. covering specifically subtidal mud habitat) while minimising potential impact to the industry. Following a review of available habitat data and Vessel Monitoring System (VMS) data, reflecting fishing effort, an alternative MCZ site was proposed colloquially known as "Queenie Corner" [1].

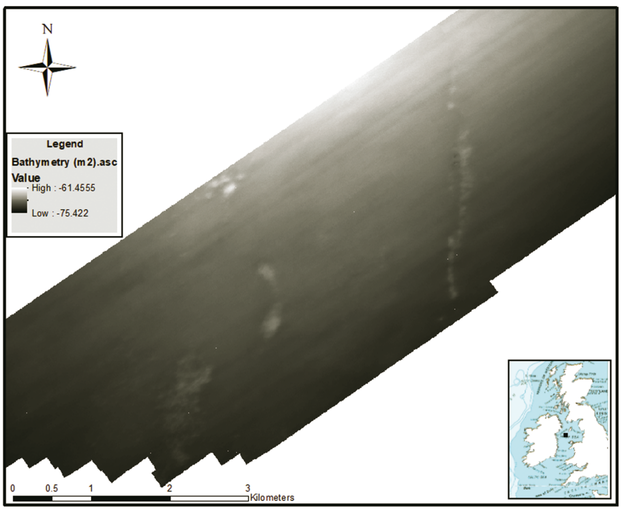

Figure 1. Section of "Queenie corner" proposed Marine Conservation Zone multibeam bathymetry with potential gas doming features

There were some existing data within "Queenie Corner" that could be used to assess its suitability for designation (video and grab data), where the presence and extent of the feature of interest — in this case subtidal mud broadscale habitat — could be inferred. However, to increase confidence in the site's suitability further data were required to allow derivation of a habitat map. This was crucial to making the case that this site may be a truly suitable alternative MCZ to those previously proposed. To that end, multibeam echosounder data were collected over three surveys in 2016, 2017 and 2018 as part of a collaboration between Geological Survey Ireland/INFOMAR and AFBI to generate 100 % remote sensing coverage of the 146 km^2 site. The site ranges in depth from -61 m to -112m, and lies beneath a known oceanographic front at the eastern border of the western Irish Sea mud patch. Although particle size data collected by grab sample indicated that all samples within the site could be considered as EUNIS category A5.3 "Sublittoral mud" [3], and video data showed the same habitat (with *N. norvegicus* and other burrows), the multibeam data revealed additional seabed features. These were broadly linear 'mounds' with 0.5 m–2 m vertical relief compared to the surrounding seabed (see Figure 1). There is evidence of methane derived authigenic carbonate in the western Irish Sea [2, 4] and seismic profiles in the vicinity have shown gas blanking. Targeted ground-truthing planned for April 2019 will enable further classification of these features, which may be gas doming, and may represent a different ecological habitat to the surrounding bioturbated mud.

Currently "Queenie Corner" is being formally considered for MCZ designation (decision expected summer 2019) as a 100 % 'subtidal mud' habitat, meaning that the site would contribute 146 km^2 of this habitat to the UK MPA network, which will almost reach the target required for the UK's Irish Sea waters. However, with the availability of these additional multibeam data, a modification to the features that this site could protect may be required. This work highlights the pivotal role multibeam data plays in understanding and identifying feature presence and extent, and the benefits of acquiring 100 % multibeam coverage data.

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S2P2. Cooperative Seafloor Mapping of the South-central California Outer Continental Shelf

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Recent mapping of an area of the outher continental shelf off south-central California was accomplished through a cooperative agreement of three federal agencies, titled "Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS)". The collaboration targets deepwater areas off of California, Oregon, and Washington that are of interest to managers of living resources, offshore energy, and mineral resources. This study area is tectonically active, with growing folds and thrust faults that have implicatons for regional earthquake hazards in a predominanly strike-slip tectonic region, has petroliferous strata that have been developed for petroleum resources, and is of interest for a floating wind-farm because of the reliably high wind energy in the region. Mapping occurred in August and September of 2018. Approximately 5000 km^2 of multibeam echosounder data and 2800 km of high-resolution multichannel seismic reflection data were collected simultaneously using the National Oceanic and Atmospheric Administration (NOAA) hydrographic research vessel *Rainier*. The mapping was carried out by all three of the EXPRESS collaborating US Federal agencies: NOAA, the Bureau of Ocean Energy Management (BOEM), and the U. S. Geological Survey (USGS). This was the first use of USGS seismic reflection systems on a NOAA ship. The data show extensive pock-mark fields that had been previously observed near by, fault offsets of the seafloor, tilted strata, scarps with relief on the order of 100 meters on a bank in the study area called the Santa Lucia Bank, and other features of interest for regional assessment of habitat and hazards with implications for the placement of a wind farm. Products planned include CMECS geoform, substrate, and biotic component maps, surficial geology and geologic structure, and sedimentary processes models. Final analysis will be done after an EXPRESS ROV and coring cruise in 2019 that will include collaboration with the Monterey Bay Aquarium Reasearch Institute (also a member of the EXPRESS cooperative).

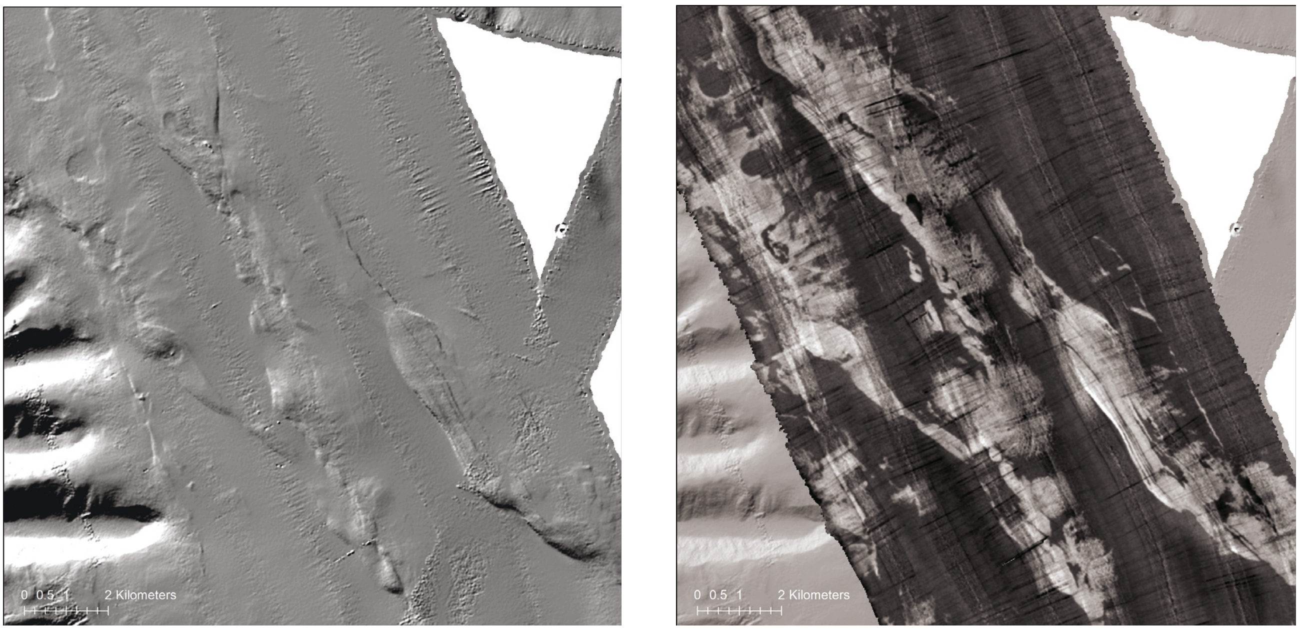

Figure 1. Santa Lucia Bank MBES data images, hillshade left, backscatter intensity right. Ridges and scarps likely formed by recent folding and faulting provide potential rocky habitat in the study area

S1PO2. Mapping tropical coastal social-ecological systems using unmanned airborne vehicle (UAV)

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The coastal ecosystems provide significant services, such as food provisioning, tourism, or coastal protection [1, 2], that has the potential to attenuate ocean-climate hazards exacerbated by sea-level, cyclone/storm intensity, and demography increases. The protection ensured by tropical ecosystems is all the more crucial that population is very vulnerable to global changes. The evaluation of the natural-based coastal protection requires a very high resolution (VHR) mapping of ecosystems, such as mangrove forests, seagrass meadows and coral reefs. The primary objective of this work is to quantify the ability of a consumer-grade red-green-blue (RGB) sensor mounted on unmanned airborne vehicle (UAV, [3]) to map the structural complexity of intertwined terrestrial human exposure and vulnerability with three major shallow water ecosystems offering protective adaptation through wave attenuation. The agility of the DJI Mavic Pro UAV permitted to survey coastal socio-ecosystems in 2018 over Mayotte Island (Indian Ocean) at 150 m altitude with several dozens of 4K georeferenced and overlapped RGB photographs using a mission planning application (DJI GS Pro). The image processing included alignment, point cloud creation and densification, mesh construction, digital surface and orthomosaic models (Fig. 1, Agisoft). Models were rasterized with a 0.1-m pixel size, providing predictors for mapping purposes (habitat classification and biophysical response regression).

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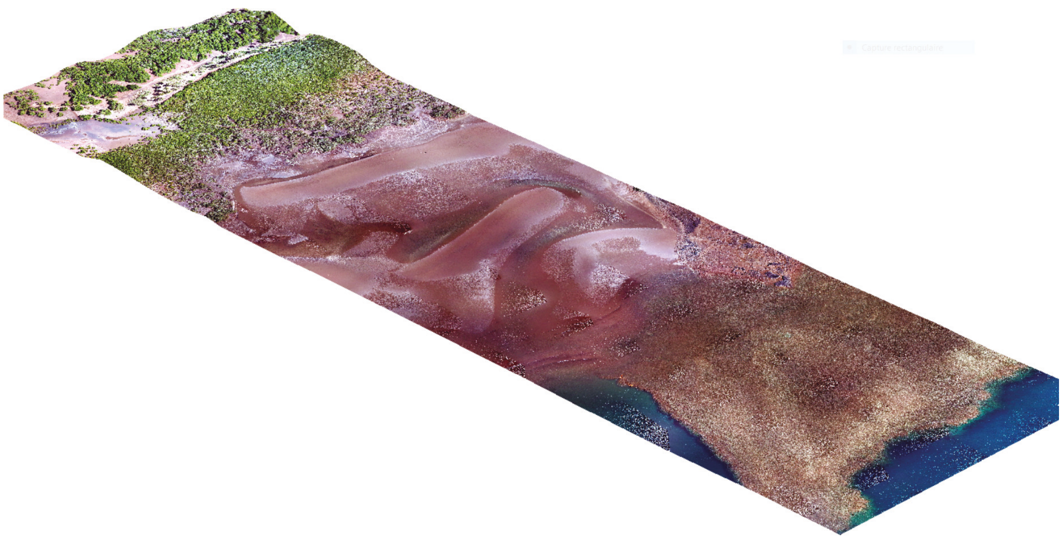

Figure 1. Natural-coloured orthomosaic draped over digital surface model, derived from the structure-from-motion technique applied to an airborne UAV survey over a coastal socio-ecosystem in Mayotte Island (Indian Ocean)

S8O3. Hydrodynamic connectivity between reefs habitats on an oceanic small insular shelf*

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Connectivity among reefs habitats has been identified as a critically important factor in resilience, specifically in regard to recovery from disturbance [1]. In this work, we investigated the potential hydrodynamic connectivity on a small oceanic insular shelf (Fernando de Noronha Island located at the South Atlantic Ocean) by tracking simulated larval releases from representative reef locations. Output from Delft3D FLOW numerical model was used to drive a particle-tracking model considering the direction and intensity of the simulated ocean currents. The results show dominant westward transport with distinguish trajectory pattern over the windward and leeward island side. Particles released on the leeward side shows a circular pattern of transport with higher residence time over the insular shelf. At the windward side, particles are either transported to oceanic waters or to the leeward side. The results suggest lower hydrodynamic connectivity between the leeward and windward reef habitats (see Fig. 1 below).

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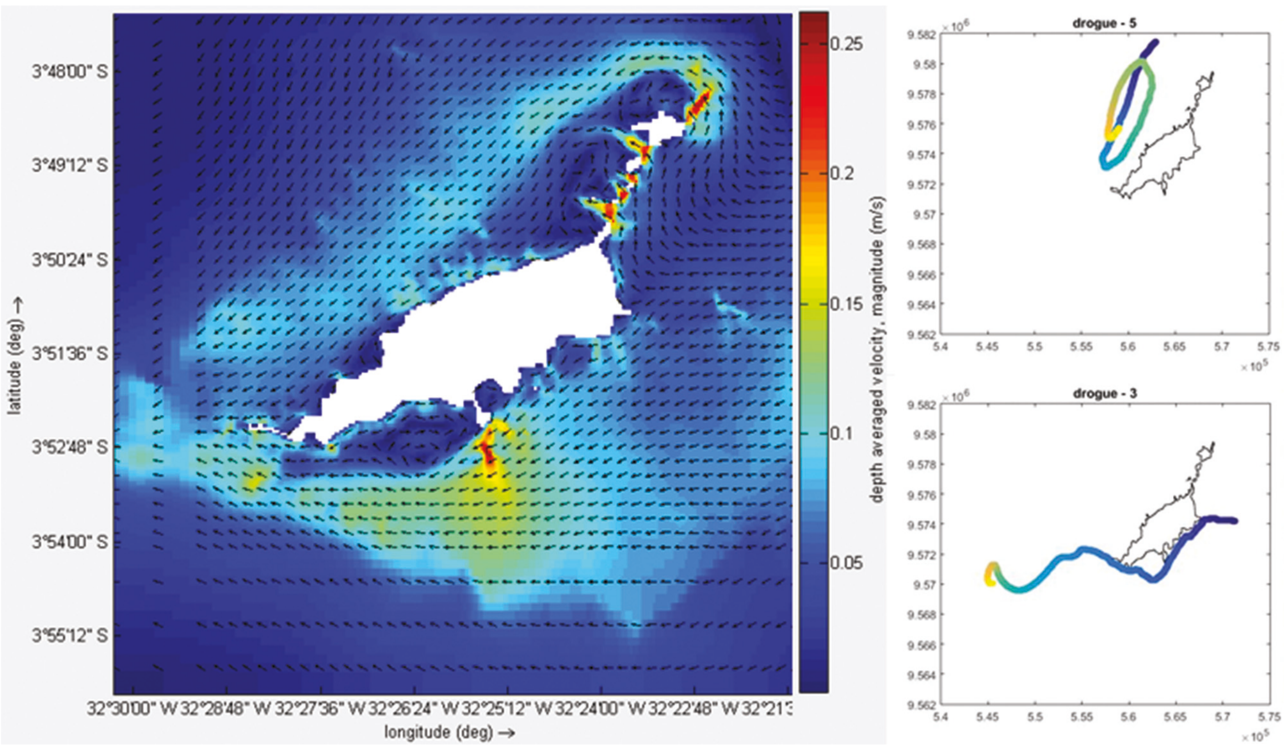

Figure 1. Output from hydrodynamic numerical model and particle-tracking model

S2O1. Geomorphological and Geological Constraint Mapping for Renewable Energy Development in the Irish Sea

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The energetic wind regime and relatively shallow water depths of the Irish Sea make it an ideal location for the development of offshore wind turbines. However, the area has a complex Quaternary history of ice-sheet dynamics, Holocene marine transgression and modern day hydrodynamics. As a result, vagaries exist regarding the complexity of sub-surface conditions in the Irish Sea and contemporary geomorphology and seabed dynamics. The fiscal implications of poor background knowledge regarding ground conditions before construction are well demonstrated by previous projects [1].

The EASTWIND project is based in the Irish Centre for Research in Applied Geosciences (iCRAG) and aims to bring together academic researchers and industry consultants in order to address the following research question: What are the key seabed characteristics and sedimentary process affecting potential offshore wind deployment in the Irish Sea? We aim to answer this question by delivering a set of mapping products and geotechnical assessments in order to help de-risk the future deployment of infrastructure related to offshore renewable energy. To deliver these products and assessments, EASTWIND primarily uses high-quality seabed mapping data gathered as part of the Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) programme including multibeam echosounder, derived backscatter and sub-bottom profiling.

Based on these data, and others, we are developing a geomorphological map for the Irish sector of the Irish Sea to characterise the seabed based on standardised nomenclature [2].This will act as a baseline for current and future Quaternary geology studies also. In addition, we identify and characterise a number of geohazards and geotechnical constraints that are common to offshore development including shallow gas, overconsolidated sediments, underconsolidated sediments and mobile sediments [3].

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S1O4. The distribution and biodiversity of horse mussel biogenic reefs in the Bay of Fundy

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Pockets of dense aggregations of horse mussels are known to exist in the Bay of Fundy and are thought to be areas of high biodiversity compared to that of surrounding habitats [1]. Previous research has found correlations between these aggregations (often referred to as reefs) and long narrow flow-parallel bedform features, but theories on the origin of these features vary [2][3]. This study takes a multi-scale approach using broad scale multibeam echosounder (MBES) data and fine scale biodiversity patterns to interpret the formations and functions of these systems. Broad scale MBES data will be used to assess the distribution of these habitats and their relationship with the flow-parallel bedforms using seafloor video and derived terrain variables in a species distribution modelling approach (MaxEnt). Fine-scale biodiversity patterns are assessed from seafloor video through imagery analysis to characterize benthic assemblages. Additionally, Structure from Motion (SfM) methods are used to generate high resolution Digital Elevation Models (DEMs) from the high-resolution underwater video data to measure fine-scale environmental characteristics of the seafloor (eg. Roughness, surface complexity, curvature, etc.) both on and off the reefs. Results from this study will help to better understand the distribution and biodiversity of these habitats, and will facilitate decisions around marine spatial planning, protection and monitoring of these areas.

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S1P3. Pseudo stalactites of Capo d'Otranto caves (Puglia, Italy) as a relevant information in habitat mapping for conservation and management purposes

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Italian national Marine Protected Areas (MPAs) are created to fulfil the three key functions of the marine conservation (conserve marine biodiversity, maintain / restore productivity and contribute to economic and socio welfare of local populations). Zoning is the first step to establish new MPAs and it is their primary reference for the management [4, 9]. ISPRA has been charged by the Italian Ministry for Environment Land and Sea Protection (IMELS) to complete the preliminary studies for the establishment of the MPA of "Capo d'Otranto-Grotte Zinzulusa e Romanelli-Capo di Leuca" located in Salento Peninsula (Puglia).

Coastal marine caves are one of the main environmental characteristics, worthy of protection [8], of the study area. Due to this reason an inventory of coastal marine caves has been made through the analysis and re-elaboration of the dataset of the Regional Register of the Natural and Artificial Caves of Puglia Region [2]. A bibliographic survey was carried out for each of the identified caves in order to obtain useful information for their characterization.

A table of attributes has been associated with the GIS mapping, containing:

• Georeferenced coordinates;

• Morphology/planimetry (number of marine entrances and/or air openings, possible presence of an emerged surface);

• Freshwater sources, pseudo-stalactites and other particular geological elements;

• Presence of fossils;

• Presence of benthic populations (in particular Bryozoans, Cnidarians, and Lithophyllum spp.);

• Presence of ichthyofauna;

• Historical presence of the monk seal.

Some caves of Capo d'Otranto, remarkably, show typical calcareous bioconstructions [6] called pseudo stalactites. These formations uniformly cover the ceiling and the side rock walls of some caves (Lu Lampiùne, Lu Fauceddhu, Tau-Manhattan, Zinzulusa), in the most sheltered parts, usually far from the entrances, showing varying levels of development (from a few cm to about 2 m). They have the same elongated and hanging look of the stalactites of mineral origin and reach the length of two meters, with a diameter of approx 40 cm. The shape is roughly conical, with a circular or elliptical section, but in some cases they are very flat, with the larger side displaced horizontally, closer to the entrances of the caves. Their peculiarity is that (unlike the common stalactites of karstic origin) they tend to develop towards the centre of the cavity; very often diagonally, or even horizontally when they start from the bases of the sidewalls. They have no parts of chemical-concrete nature, because made up exclusively of an overlap of biogenic structures (essentially calcareous tubules of Serpulids, mainly the marine tubeworm *Protula tubularia* [1]). The particular shape of these pseudo stalactites is due to the apical growth of the Serpulids and to the necessity of these organisms to reach out to the water with greater turnover and richer nourishment, following the opposite direction of the dominant current (Fig. 1).

The presence of these characteristic bioconstruction, linked to a particular geological environment, is a valid reason to consider these caves as important geo-site to be included in the Italian Geosites Inventory [5].

The definition of the zoning proposal of the new MPA will be drawn through a spatial analysis based on maps relating to the different environmental and socio-economic values of the study area. The zoning, in turn, will be the basis for the definition of more in-depth management measures for the future MPA [7], improved also with the stakeholders' involvement.

Presence and the location of the caves characterised by these relevant geological features are one of the main environmental aspects of the studied area and, in association with other significant biological aspects and the socio-economic issues, are key elements for the GIS spatial analysis that will allow to define the first zoning proposal of future MPA.

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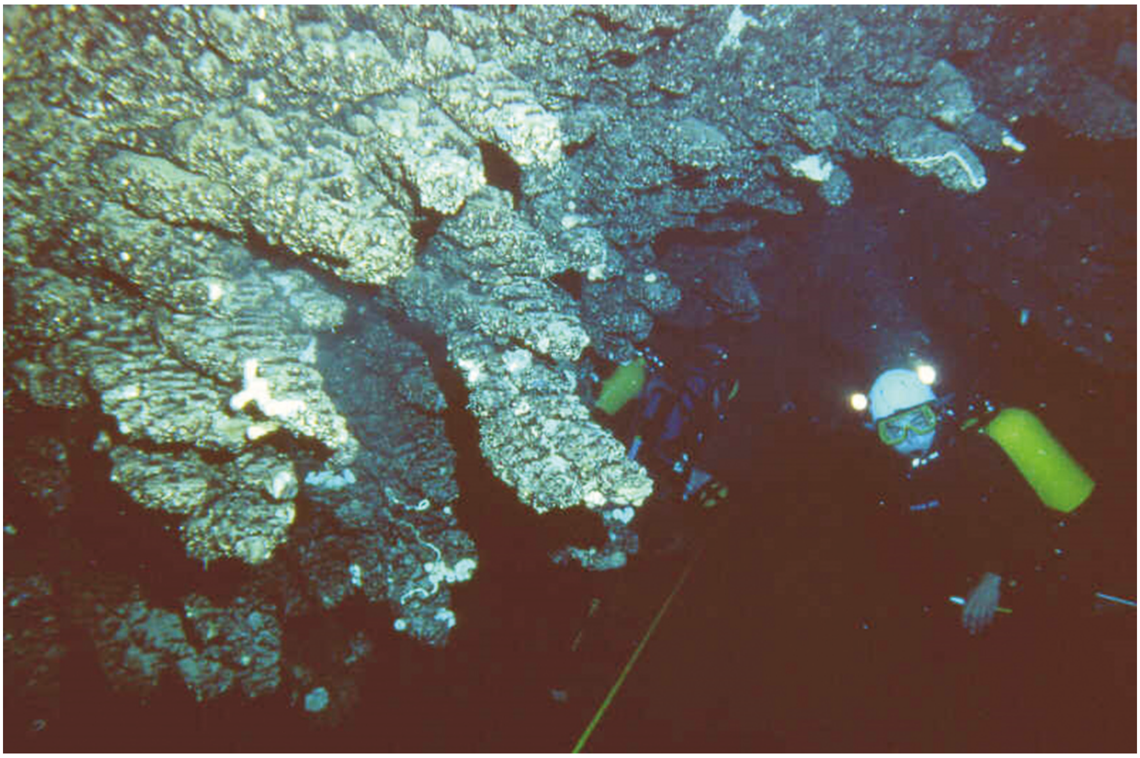

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S5O2. Mapping benthic respiration rates in the cold-water coral reef, the Mingulay Reef

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The Mingulay Reef located off the West Coast of Scotland, has the ecosystem engineers *Lophelia pertusa* and *Spongosortites coralliophaga* as the resp. dominant substrate forming coral framework and sponge. Predictive models and maps of cold-water coral habitats are useful to understand the factors that control the distribution and function of these organisms. There is increasing evidence that cold-water coral communities are regions of intensified carbon cycling, and depending on certain organisms' biomass it is expected to find spatial variation within and between a reef's respiration activity. In this study, the surface area of the dominant coral *L. pertusa* and the sponge *S. coralliophaga* were calculated from Mingulay Reef 1 images and converted to estimated biomass values. The environmental variables that control the variation in coral and sponge biomass were explored and used to create a predictive map. The aim of this study is to be advancing our understanding of the complexity, i. e. the variability and distribution of cold-water coral community metabolism, by mapping the spatial distribution of respiration activity within a cold-water coral reef.

S1P4. Bathymetry in Magdalena Region, Colombian Caribbean

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Coastal areas are studied due to their economic, ecological and social importance and their vulnerability to anthropogenic pressure. Therefore, bathymetric studies are very important to know the geomorphology, hydrology and sedimentology, fishing, storm and tsunami, mineral exploration, ecology, hydrodynamic models (Sutherland et al., 2004) and regional development of harbors. The objective was to assess by hydroacoustics the bathymetric characteristics in shallow and deep waters in Magdalena region, Colombian Caribbean Sea. The acoustic survey was carried out onboard in a small vessel at which a scientific echo sounder Biosonics DTX with a 38 kHz transducer. The depth ranged between 8.54 and 876.82 m (mean 336.19 ± 217.46 m). Five zones were identified according to bathymetric characteristics. 1) Palermo- El Torno swamp; 2) Animas Bank; 3) Aguja Canyon off Santa Marta; 4) Tayrona Canyons is the deepest zone; and 5) Buritaca (Fig. 1).

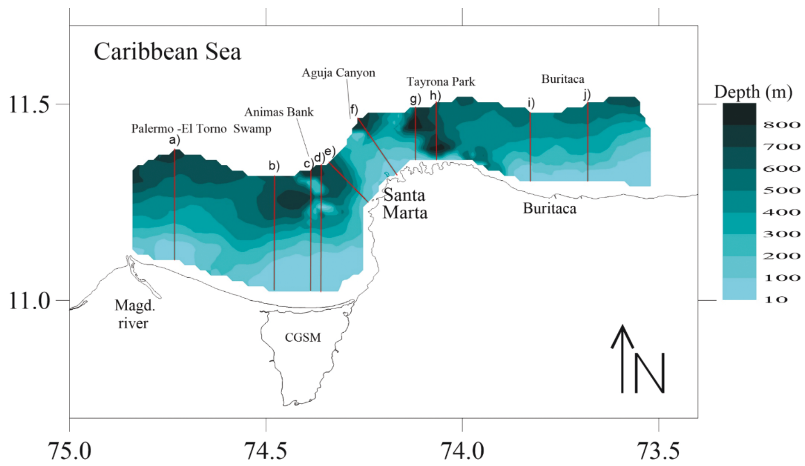

Figure 1. Spatial distribution of bathymetry in the Magdalena region.

S8O4. Coupling underwater acoustic and image surveys to correlate bedform's microhabitats and ocean processes

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The deeper and central part of the Great South Channel (North Atlantic) is characterized by a narrow sediment-starved area with the presence of sparse Large, Straight, Isolated (LSI) bedforms. In a relatively high energetic seabed, under the influence of a strong tidal regime, these LSI bedforms have been documented to act as collectors of fine sediments thereby creating a complex pattern of diverse substrates which are highly correlated with the hydrographic regime and the bedform's shape. The fauna in the area surrounding the bedforms was also found to be organized in consistent, microscale patchiness.

In this work we perform a detailed analysis of bathymetry and backscatter data combined with co-registered stereo-images of these LSI bedforms. By relating the distribution of marine life with the scale-dependent landforms we test the hypothesis that morphology has a direct influence on the spatial distribution of benthic species, shedding light on the geological processes that maintain the LSI bedforms, as well as the ecological processes they maintain.

S1O5. Phasing in use of the "Nature in Norway" (NiN) system for classification and description of nature in the marine environment — experiences, challenges and international relevance

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Marine habitat mapping in Norway has to date been conducted according to various project-based standards and classification systems (nature type/habitat/biotope). Mapping according to "Nature in Norway" (NiN) — the new Norwegian standard for describing and classifying ecological variation — is currently being phased in for the marine environment with the ambition that NiN will be tried and tested, ready for practical use from 2020. Although the first version of NiN (which spans terrestrial, freshwater and marine environments) was published in 2009 and significantly revised in 2015, there has been relatively little focus on marine mapping at the ecological system level (meso-mega-habitats) until 2017, when the first pilot project for mapping according to NiN was initiated in Søre Sunnmøre, Western Norway. Further revisions to NiN will be made during the period 2019–2022 with the aim of updating NiN theory, the type and attribute systems, and practical mapping guidelines to make this an effective standard for mapping of the marine environment. Project-specific mapping instructions will also be needed to supplement the generic NiN guidelines. With this in mind it will also be important to raise awareness of NiN over the coming years, not only among those involved in practical mapping, but among project leaders, management authorities and other end-users involved in defining marine mapping projects.

Here we present and discuss experiences from the pilot project and related projects with relevance to NiN (e. g. MAREANO); development of guidelines for practical mapping according to NiN; strengthening of NiN for marine areas through a marine expert group and the NiN scientific advisory board. We also outline the ecological concepts behind NiN and highlight potential international relevance of the concepts and applications by highlighting synergies and differences between NiN and existing habitat classification systems used in other parts of the world (e. g. EUNIS, CMECs).

S1P5. Acoustic survey of the sea bottom landscapes with high archeological potential in the South-Eastern Baltic Sea (Russian sector)

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Significant changes of the coastline took place on the early stages of the Baltic Sea evolution in Late Pleistocene to Early Holocene about 14–9 ka BP. Lake and sea stages of the Baltic alternated driven by eustatic sea level changes and isostatic land movement [1]. During that period sea level of the South-Eastern Baltic was changing multiple times in 20–53 m range below modern level [2]. Vast coast territories which were possible settled were submerged and could hide archeologic artefacts until now. Besides the Baltic has intensive marine traffic from surrounding European countries and were area of military actions. Until now sunk vessels which are valuable archeological monuments are weak studied and documented. We presenting collected archival material, new geoacoustical surveys and underwater video of the sea bottom landscapes with high archeological potential (Fig.1). These areas are recommended for further study with the aim of finding of new cultural heritage objects.

The study was done with a support of BalticRIM project.

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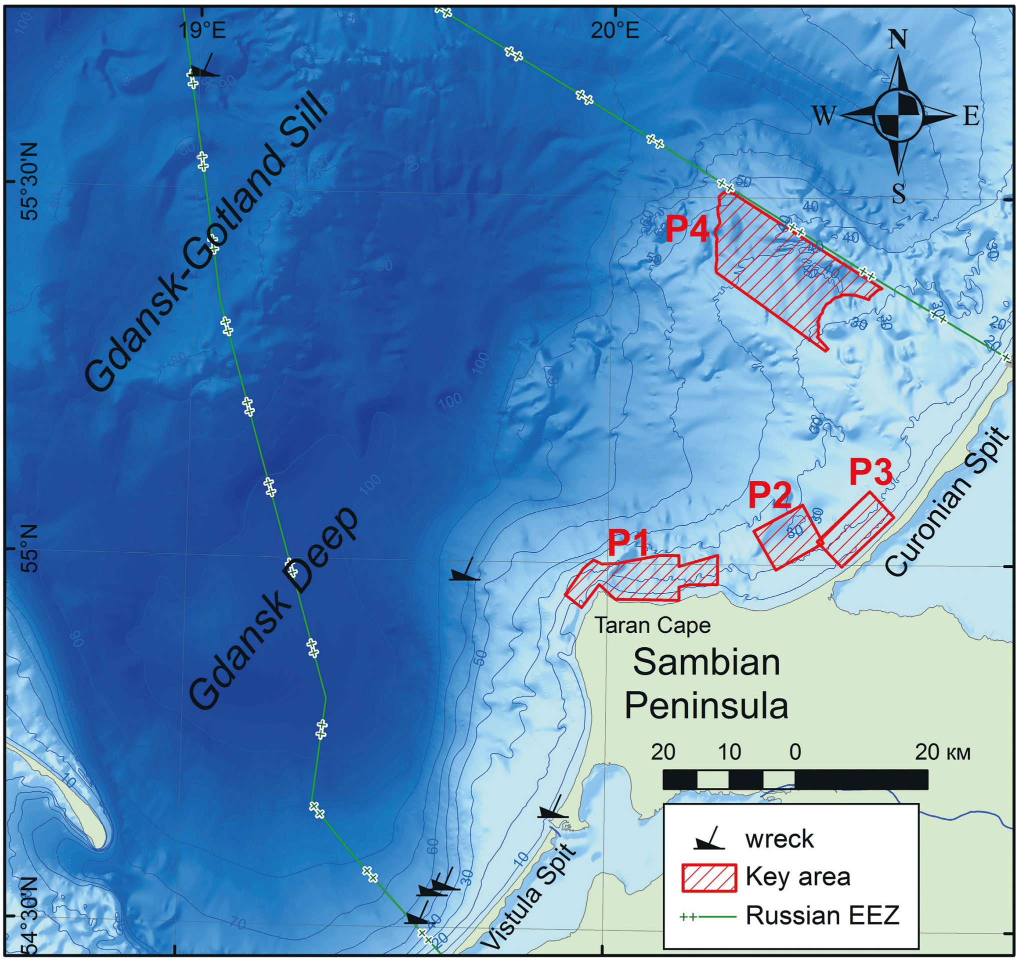

Figure 1. Key geoacoustical survey areas with high archeological potential and wrecks

S1P5. Broad-scale and fine-scale abiotic mapping of the bottom landscapes of the South-Eastern Baltic Sea (Russian part)

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The new landscape maps are obtained for the Russian sector of the South-Eastern Baltic Sea in the broad- and fine- scales on the base of modified methods of the European's projects the BALANCE and EUNIS. Public meso-scale maps of substrate type, near bottom water salinity and temperature, photic zone and ice cover were used for broad-scale mapping. The fine-scale mapping is made on the base of field data. The geophysical investigations were carried out in 2013–2016 using the single- and multi-beam echosounders, swath bathymetry and side-scan imaging systems. Surface sediments were sampled for the sonogram interpretation. The archive data of ABOIRAS, JSC «Sevmorgeo», VSEGEI and Museum of the World Ocean were also used. Bathymetric Position Index (BPI) was

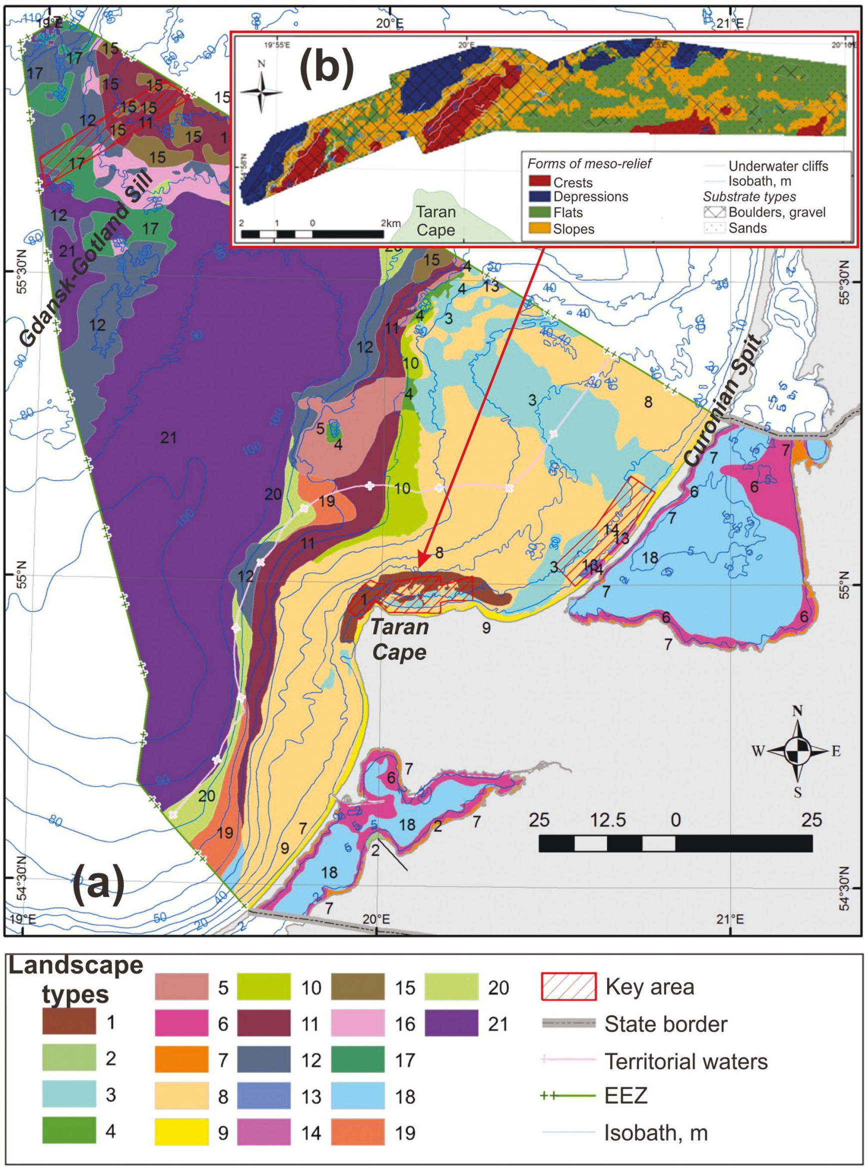

Figure 1. Broad-scale bottom landscape map of the Russian sector of the South-Eastern Baltic Sea (a). Example of fine-scale landscape map on the Taran Cape (b)

calculated on the base digital elevation model for definition of meso- and micro-forms of relief. Bottom landscape maps were composed by union of BPI and substrate type defined according to side-scan sonar images.

The 21 types of bottom landscape are distinguished in the broad-scale (Fig. 1a). The most perspective landscapes for the creation of the Marine Nature Conservation Areas (MNCA) are described further.

A relatively large and variable landscape #1 was studied in details on the key area near the Taran Cape (Fig. 1a). It is represented by two different areas. The first one is characterized by flat bottom with sands of different grain size, and the second one is slopes with sand, boulder and gravel (Fig. 1b). Coarse grained deposits mark Pre-Quaternary outcrops. Relict submerged coastal cliffs of 1–10 m high are unique feature of the area. Underwater cliffs are interesting not only from the paleogeography point of view, but also as they are special elements of the bottom landscape with increasing population and biodiversity of bottom community. Hard substrate with boulders and gravel is favorable for growth of rare plants attached to the bottom and invertebrates (mussels, crustaceans). Relict cliffs must become a Marine Nature Conservation Area (MNCA) as Natural Monument because it is important source of information for reconstruction and prediction of the sea level variation related to the global climate changes.

The landscape types #13 and 14 (Fig. 1a) have the smallest area and located in the near shore zone off the south part of the Curonian Spit on the depths of 5–15 m. The landscape is characterized by high variability, which was one of the reasons for choosing it as key area for fine-scale mapping. There are unique folded hard clay outcrops on the depths less than 15 m. The clays ("lagoon marls") are extruded muds of the paleolagoon of the Littorina Sea [1, 2]. The clays are unique bottom oasis where the numbers of benthic organism species sharply increase in contrast to almost lifeless adjacent extensive sand areas. The main criterion for the creation of MNCA is protection of the marine ecosystem. Relict lagoon marl outcrops are nature monument, object for the scientific studies and for underwater tourism. Because the aquatic area joins to the coast of the Curonian Spit National Park it should be included in it.

The third key area on the Gdansk-Gotland Sill (Fig. 1a) is interesting for the palaeogeographic reconstructions because of ploughmarks presence on the seafloor. They can give valuable information on water current directions on the early stages of the Baltic Sea. Besides this area is characterized by variable substrate of glacial till and is transit zone of water exchange between Gdansk and Gotland Basins. It plays important role in the near bottom oxygen saturation and development of benthos.

The work was supported by the state assignment of IORAS № 0149–2019–0013.

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S1PO3. Recent sediment dynamic in the coastal zone of the South-Eastern Baltic Sea (Russian sector)

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Substrate type and sediment dynamic play critical role on benthos distribution in the coastal zone. Regionalization based on measurement of sediment dynamic might provide an objective basis for predicting the spatial and temporal nature of benthic habitats.

Coastal zone of the Russian sector of the South-Eastern Baltic Sea is characterized by complex sediment dynamic, mainly conditioned by wave processes and wind direction. At the same time it is known, that the extensive zones of bottom in the coastal zone (depth < 30 m) were formed during the evolution of the Baltic Sea and are relict.

The aim of this study is to present sediment dynamic map in the coastal zone of the Russian sector of the South-Eastern Baltic. For this purpose two sedimentological parameters were combined: critical shear stress velocities and geomorphological features expressed in bathymetric position index (BPI).

Detail map of surface sediment types is needed for the calculation of critical shear stress velocity. The new sediment map (1 : 200 000 scale) was developed on the base of sonar profiling and grain-size data, acquired by ABIORAS and VSEGEI in 2006–2016 in study area. Archive data were also

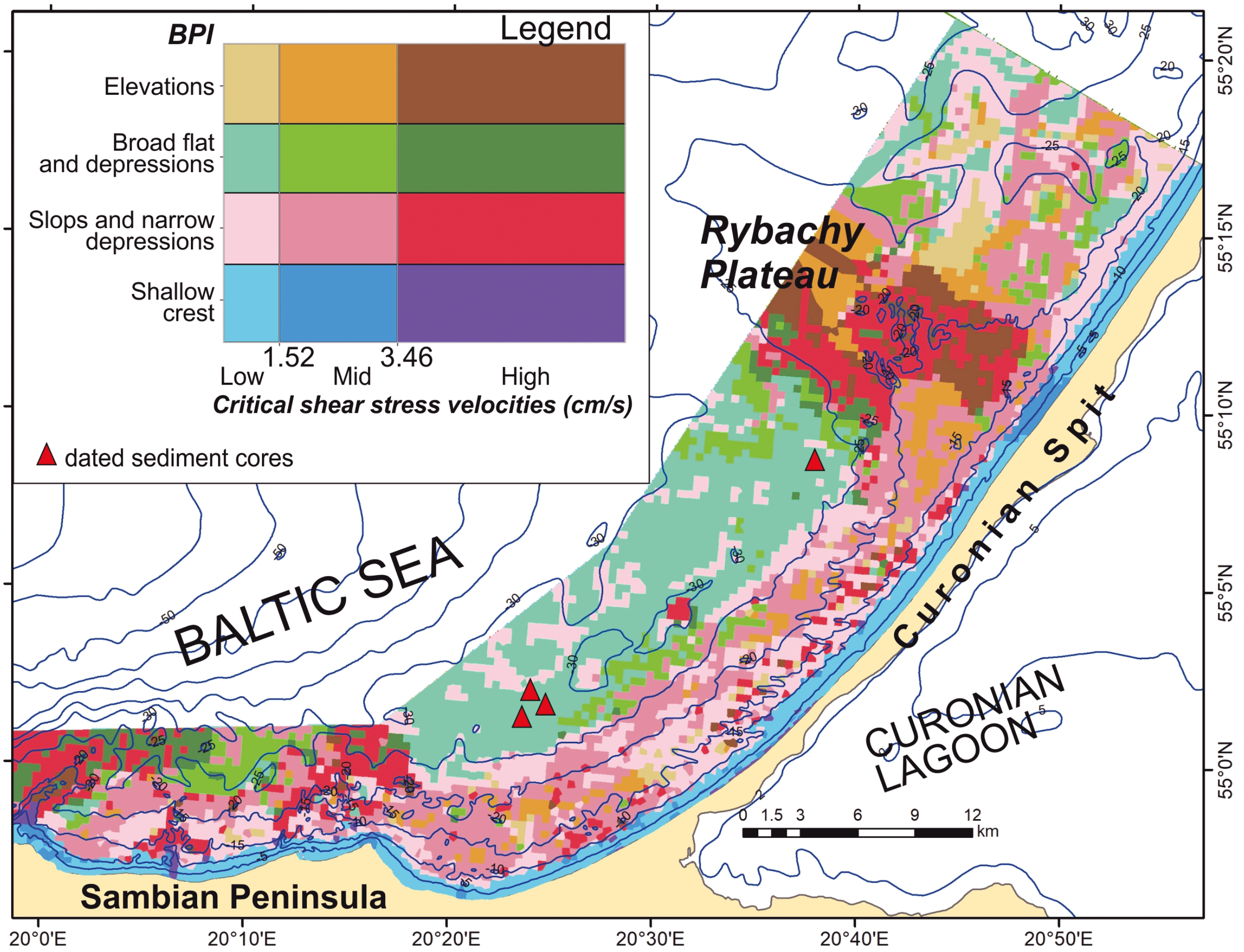

Figure 1. Sediment dynamic map of study area

used. Critical shear stress velocities were calculated from sediment distribution data on the base of Shields and Hjulström diagrams. The critical erosion current speed was transformed to the critical shear stress velocity by the quadratic friction law. The mean diameter for the critical shear stress velocity was defined from the grain-size analyses and distributed by the grid according to sediment map. BPI was calculated by standard procedure from navigation maps bathymetry. Eight AMS radiocarbon dates of four sandy sediment cores (water depth 26–28 m) were also used for the interpretation of results.

Created surface sediment map reveals new features of sediment distribution in the study area and well correlates with previous maps. The twelve sediment dynamic zones are distinguished as a result of combination of critical shear stress velocities and BPI (Fig. 1). It is shown that high critical shear stress velocities are associated with rough bottom (slopes and narrow depressions) and bottom elevations. Flat bottom and broad depressions mainly coincide with low critical shear stress velocities.

The shallowest zone from the foreshore to 10 m depth is characterized by low critical shear stress velocity values, except cape areas of the Sambian Peninsula, south part of the Curonian Spit and Rybachy Plateau. For the underwater sea slope of the Sambian Peninsula the rough relief is common. The sea bottom consists of several sediment cells with boundaries in cape areas accompanied by high critical shear stress velocities and low velocities in the central parts of the bights.

Zone of slopes and narrow depressions with high critical shear stress velocities is elongated along the Curonian Spit at the depths of 10–25 m. The sediments of this zone are not involved in modern dynamic processes during calm weather, when wave velocities are weak to erode sediments. During strong storms coarse sediment material from this zone can transport shoreward. The flat depression with low critical shear stress velocity values is located seaward up to 30 m depth. Here sandy sediments are relict, formed during low sea level stand. However due to high mobility (low critical shear stress velocities) the sands may be redeposited during extreme storms. This assumption is confirmed by AMS dates according which sandy sediments on 5–35 cm below bottom surface are younger than 1950.

The study was done with a support of the state assignment of IO RAS (Theme No. 0149-2019-0013).

S1P7. Mapping Rocky Coastal Landscapes in Northern Lake Ladoga around the islands of Raipatsaari and Lussikainluoto

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The study of underwater landscapes is necessary as base for water protection measures and competent economic activities in the waters of Lake Ladoga. The underwater natural complexes of the lake are still poorly studied. The Institute of Limnology (IL) has studied the underwater landscapes of Lake Ladoga since 2013 using modern and innovative methods and equipment. In particular, aerial photography from an unmanned aerial vehicle (UAV) was applied [3] providing insight to underwater landscapes to 4 m depth. The remote-operated unmanned underwater vehicle (ROV) Limnoscout-230, created in the IL, was successfully tested in 2017–2018 and proided video profiles of the lake bottom [2].

The purpose of this study was to estimate and to map the underwater landscape elements in the coastal zone of islands Raipatsaari and Lusikainluoto situated in northern Lake Ladoga. The study was conducted in May 2018 over an area of 200 000 m^2 with water depth reaching a maximum of 26 m.

An example of lakebed mapping is shown in Figure 1. Large rock fragments, boulders and rubble occupy the largest part of the investigated lakebed. Their maximum extent is in the bays around the islands. At the capes and along shores with a straight coastline, this facies is more narrow. On rocky surfaces and large stones seston is deposited and sponge and periphytic algae actively develop. In turn, these contribute to the development of a rich fauna of zooperiphyton. The large area of underwater bedrock outcrop is divided into two categories: close to the lake surface, subaerially exposed at low water level (so called "ludas" — small islands without vegetation), and deep (found at water depths up to 15 m). The detection of ludas localization is important for the study of an important component of the Lake Ladoga biota, the Ladoga ringed seal [4].

Within the underwater rock outcrops in the northern part of the study area, sandstones of probably Riphean age are exposed on the lakebed (Fig. 2). These outcrops occur from 11–14 m water depth. The sandstone is underlain by Archean and Proterozoic basement [1].

Small areas of the lakefloor are covered with fine gravel; this facies is typical in narrow shallow straits with water depths from 3 to 8 m. The accumulation of organic matter in such areas contributes to the creation of suitable conditions for the development of macrophytes. During the period of research, young plants that began to grow were found within this facies. This facies hosts the maximum occurrences of large bivalves (Unio and Anadonta) and juvenile fish.

Sand occurs over a large area, especially in deep parts of the lakefloor. At shallow depths (5–7.5 m) the sand shows no sign of ripples. Ripples appear in the sand at a depth of 8 m and occur to a maximum depth of 25 m. The ripple crest lines extend in the NE-SW direction. As depth increases, the organic debris (of plant origin) accumulated between the ripples also increases. The sand facies hosts the highest concentration of fishe. At great depths we also met

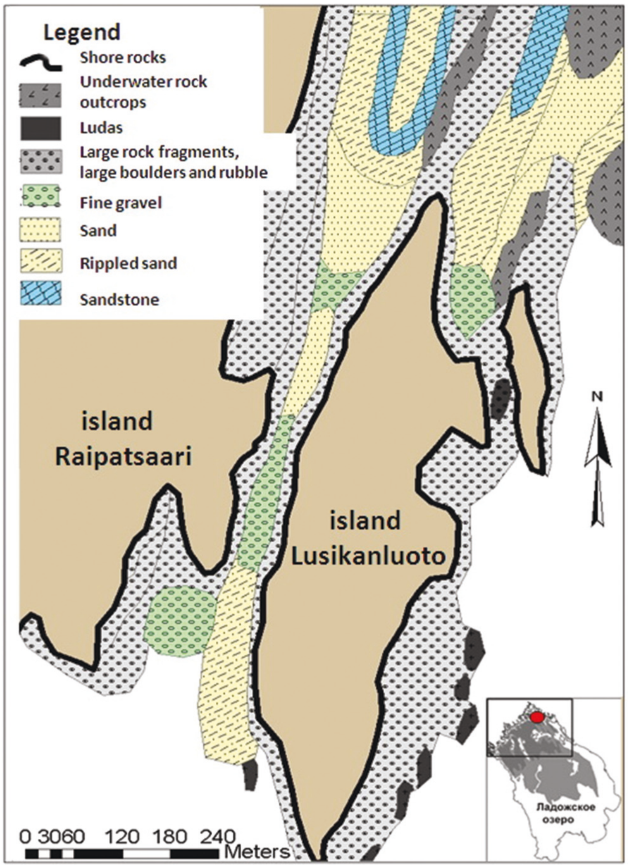

Figure 1. Scheme of underwater landscape facies distribution

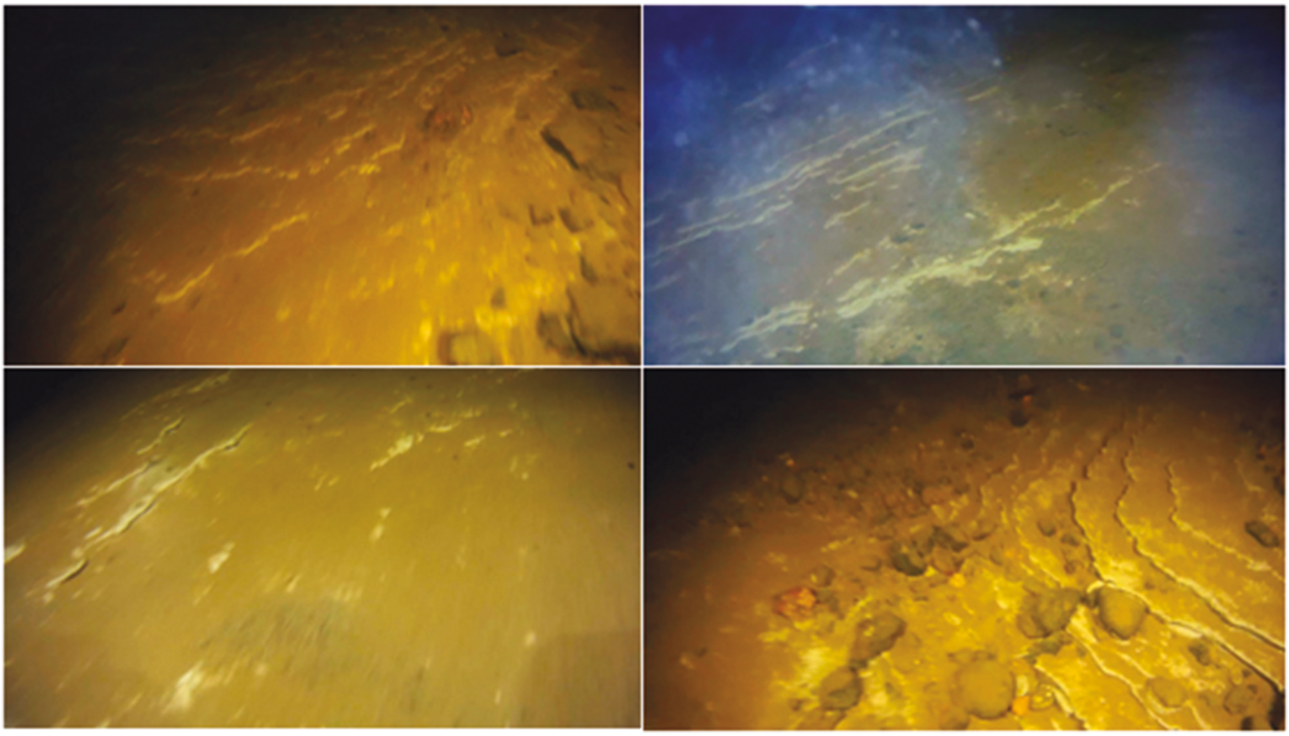

Figure 2. Facies of underwater sandstone outcrops

amphipods and traces of their activities at the bottom.

The study of underwater landscapes of northern Lake Ladoga has resulted in the mapping of types and distribution of underwater facies. The application of aerial and underwater photography and videogarphy will be continued as this project matures.

The work was performed within the framework of the state assignment of the Institute of Natural Sciences of the Russian Academy of Sciences on the subject № 0154–2019–0001 “Comprehensive assessment of the dynamics of the ecosystems of Lake Ladoga and the water bodies of its basin under the influence of natural and anthropogenic factors”.

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S3O6. Benthic habitat mapping using Underwater Hyperspectral Imaging

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Underwater Hyperspectral Imager (UHI) utilizes high color sensitive information in the visible light (380–750 nm) reflected from objects of interest (OOI) [1]. The camera system has been integrated on a range of ROVs (Remotely Operated Vehicles) as well as HUGIN class AUV (Autonomous Underwater Vehicle) for seafloor mapping in many scenarios from habitat mapping, coral classification and pipeline inspection. The system also features a regular video camera and the ability to process and save external navigation data (position, altitude, depth) time-synchronized with the UHI images, which is used for geocorrection and integration in Geographic Information Systems (GIS).

In this study, we present results from a seabed mapping survey spanning 15,400 m^2 using 14 ROV-runlines. The survey focused on detecting and identifying benthic organisms and subsequently perform a habitat classification. Spectral reference libraries were generated using optical signatures extracted from select OOIs (crustaceans, echinoderms and cnidarians). The hyperspectral classification Spectral Angle Mapper (SAM) was used to process and assign classes to each pixel in the dataset to the closest match. The results were verified and exported to geographic shapefiles. Using ArcGIS, total number of species were summarized and patterns in distributions identified.

Standard seabed mapping is performed using video interpretation, the results of which can vary significantly between operators. Using hyperspectral classification, we can move beyond subjective and categorical classification towards simplified, automatic counting of individual organism which provides a higher resolution dataset for geospatial analysis.

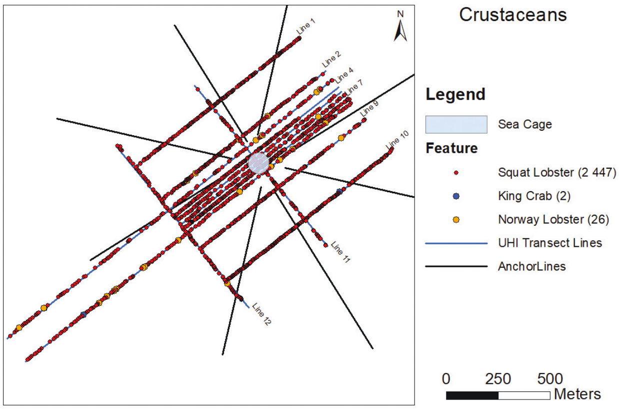

Figure 1. Map of the survey area showing all classified crustaceans. Each point represents one classified individual organism

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S1O6. Connecting the dots: distribution and productivity of nearshore rocky outcrops influences ecologically important connectivity between kelp forests and sandy beaches

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Connectivity between ecosystems is strongly affected by the distribution, condition and dynamics of donor and recipient ecosystems. In the Southern California Bight (SCB), USA, submerged rocky outcrops support highly productive giant kelp (*Macrocystis pyrifera*) forests across a strong spatial gradient in SST and marine productivity (Fig. 1a). Kelp forests respond significantly to wave disturbance, sediment dynamics and oceanographic conditions. Most kelp forest primary production is exported as drift kelp. The major recipients of this bounty are sandy beaches whose biodiversity and ecological functioning depend on these highly variable energy subsidies. Kelp forests and beaches are highly connected ecosystems, yet how that relationship varies across spatial gradients in nearshore rock outcrops and environmental conditions is unknown. In this study, we explored how the distribution and persistence of kelp patches along the California Channel Islands within the SCB may contribute to inputs of drift kelp to adjacent sandy beaches and affect biodiversity of these recipient ecosystems.

We hypothesized that sandy beach ecosystems adjacent to larger and more persistent kelp forests support higher diversity and abundance of primary and secondary consumers, including intertidal macroinvertebrates, surf-zone fishes, and shorebirds. We used a combination of datasets from field surveys and remote sensing to investigate the role of spatial variation in kelp forest abundance and persistence on recipient beach ecosystems. We found evidence of strong spatial variation in giant kelp subsidies to sandy beaches with abundance (cover) varying over an order of magnitude (0.1–4.0 m^2/m) across island beaches (Fig. 1b). The species richness of kelp dependent biota also varied by an order of magnitude (2–23) across our study sites with the highest values at sites with more drift kelp. Our results suggest spatial variation in the distribution and persistence of kelp forests (and rock outcrops) may be a predictor of beach biodiversity. The spatial connectivity between kelp forests and sandy beaches represents a key ecological pathway and can help inform marine spatial planning. Since kelp forests within marine protected areas (MPAs) often show increased persistence compared to unprotected forests, biodiversity of nearby beaches may serve as a potential indicator of MPA performance.

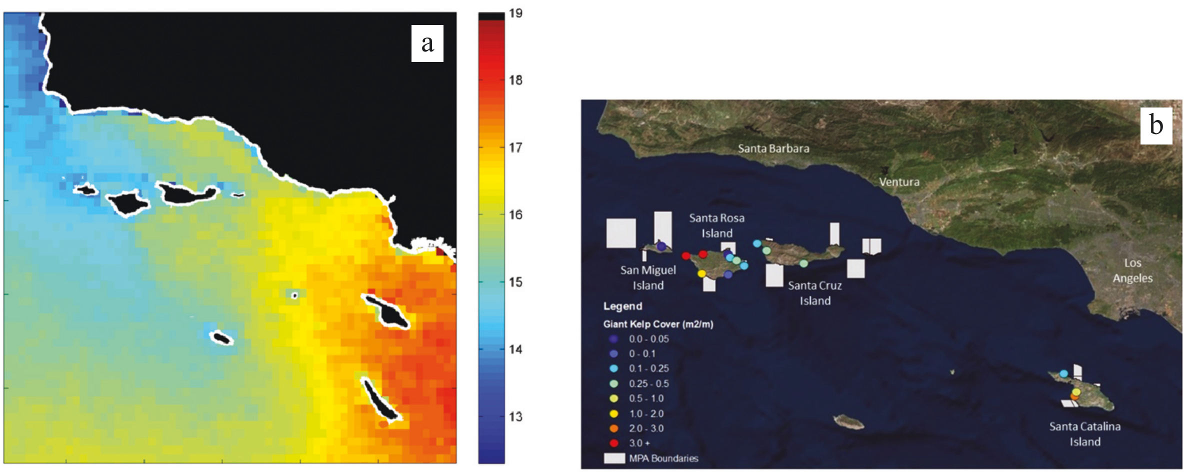

Figure 1: a) sea surface temperature gradient (˚C) in the Southern California Bight b) sampling locations of sandy beach ecosystems in the California Channel Islands. Site color represents mean cover of kelp wrack. MPA boundaries shaded in grey

S1P8. Monitoring Intertidal Oyster Reefs in Florida using an Unmanned Aerial System

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In Florida, eastern oyster (*Crassostrea virginica*) reefs are very important economically and provide a range of essential ecosystem services (*e. g.*, pollutant filtration, shoreline erosion control). However, these services along with the commercial and recreational fisheries the reefs support are threatened. There has been an estimated 66 % decline in eastern oyster reef area along Florida's northwestern coast since 1982 [1]. This decline occurs along a vastly undeveloped coastline, presenting an opportunity to study the spatial and temporal dynamics of a system without excessive human-induced change. However, sampling oyster reefs is very challenging. Reefs need to be accessed by boats, they are in intertidal and shallow waters, and are difficult to assess (*e. g.*, live/dead counts) without going on them directly and potentially causing harm. These challenges make oyster reef monitoring costly in terms of financial, human, and time resources. This study explores the use of high-resolution imagery collected with an unmanned aerial system (UAS) off the coast of Cedar Key, Florida, as a method to address these concerns. UAS provide a relatively inexpensive method to collect large amounts of data on intertidal reefs at a very high spatial resolution. Such data can then be used to characterize reef spatial dynamics and monitor changes. The spatial resolution of UAS imagery allows for analysis at the scale of the individual oyster, unlike imagery captured from aircraft or satellite imagery.

A quadcopter UAS was flown at low altitude above multiple reefs in a way to capture imagery with significant overlap between transect lines. The imagery was used to produce an ortho-mosaic and a digital terrain model (DTM) for each reef. Quadrat sampling was also performed directly on the reefs to collect ground-truthing data: the amount of live and dead oysters was counted within each quadrat. A series of terrain attributes (*e. g.*, rugosity, slope) was derived from the DTM. Then, Geographic Object-Based Image Analysis (GEOBIA) was used to extract live oyster counts and densities from the ortho-mosaic. GEOBIA was applied in a Python programming environment using raster attribute tables [2]. Image mosaics were segmented into objects, and each object was summarized based on its spectral, topographical and structural components, which were then used to classify each object into one of four classes: live oyster, dead oyster, surrounding reef elements (*e. g.*, substrate), and shadow. The number of live and dead oysters on each reef was then calculated based on the GEOBIA results and was compared to field transect data to assess classification accuracy. Additionally, in-lab visual counts were conducted on each original image mosaic to quantify differences across field results (*i. e.*, pre-processing), in-lab visual counts (*i. e.*, post-processing), and GEOBIA (*i. e.*, semi-automated counts).

This poster presents visual preliminary results of the application of GEOBIA. These results will be used as the main input for a seascape ecology analysis in which seascape metrics such as patch cohesion, connectance, and nearest neighbor indices will be computed using the FRAGSTATS statistical software [3]. Demonstrating the potential of UAS imagery to produce accurate live oyster counts will be valuable to future restoration projects and management efforts, as it has the capability of assessing the status of reefs in an expedient and inexpensive manner.

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S1PO4. Submarine landscapes of shallow-water Fe-Mn concretions fields of the Eastern Gulf of Finland (Baltic Sea)

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Ferromanganese concretions in the eastern Gulf of Finland (EGoF) achieve the highest levels of abundance (up to 150 kg/m^2) and variability found in shallow-water environments. The total weight of Mn-rich spheroidal concretions in the Russian sector of the gulf is calculated to be more than 6 million tonnes. The spheroidal concretions contain on average 33.8 % MnO_2, 20.2 % Fe_2O_3 and 2.7 % P_2O_5. The high rates of concretion growth (about 0.014 mm/yr) can be explained by bacteria activity. Due to the very intense processes of concretion formation the areas of their occurrence are characterized by a specific landscape. A field with abundant concretions lies to the north of Moschny Island. Here a multidisciplinary survey in 1995 included geological, hydrochemical and biological studies onboard the R/V *Professor Logachev.* Comparison of the data collected during that cruise shows essential differences between benthic assemblages collected in 1995 and 2017.

During the cruise of the R/V *Academic Nikolaj Strakhov* (19–25 of July 2017), a key area in the EGof located to the north of Moschny Island, was studied using a multibeam echosounder (MBES) (Teledyne RESON Seabat 8111-E208–3F66 Dry MBES system) and an EdgeTech 3300-Hm sub-bottom profiler (with Discover Sub-Bottom v3.36). Geological sampling and a submarine video survey within study area were undertaken by VSEGEI in 2017 and 2018, using box-corers and gravity corer (45 sites). Biological sampling was conducted in during the July-August 2018 cruise of the R/V *Academic Boris Petrov*. Samples were taken at 8 stations with a Van Veen grab (0.1 m^2), then sieved with seawater (0.36 mm mesh size) and fixed in a buffered 4 % formaldehyde solution. Further processing with identification to the species level was performed in the laboratory, using an MBS-10 or Motic-SMZ143 stereo microscope. The organisms of each species/group in every sample were weighed with an accuracy of up to 0.0005 g, and numbered. The abundance and biomass of each species/group of organisms per square meter were calculated. For compilation of the benthic landscape map, the BalMar classification (with modifications) [1] was used according to algorithm described in [2]. The study area is characterized as mesohaline (salinity 5–7.5 per mil) and it is exposed to wave impact, but the seabed is beneath the level of wave impact (10 m) as well as beneath photic zone (0 to -6 m). Joint analyses of biological and geological data revealed some important abiotic factors control the benthic assemblage distribution, thus for compilation of the benthic landscape map, the layers of see-bed map and Quaternary map were used.

Deep parts (> 45 m) of sedimentary basins are characterized by low abundance and biomass of macrozoobenthos represented by two species — alien *Marenzelleria arctica* (Polychaeta) and native *Monoporeia affinis* (Amphipoda). The lowest total macrozoobenthos abundance (30 ind./m^2) and biomass (0.37 g/m^2) are observed in an anoxic sand area inhabited only by *M. arctia*. Within the periphery area of clayey mud accumulation with oxic condition dominating, quantitative development of macrozoobenthos remains relatively low in abundance (90 ind./m^2) and biomass (0.85 g/m^2).

Medium values of benthic invertebrate total abundance (400–600 ind./m^2) and biomass (3.4–10.4 g/m^2) were obtained from samples collected within tops of the submarine moraine ridges, represented by boulders and hard clay covered with sandy-gravel from depths of 20–45 m, in oxic conditions. These habitat types are associated with streamlined moraine linear ridges up to 1000 m long, 100 to 170 m wide and 15–20 m high, well-defined in bottom relief, and a relatively bathymetrically high submarine pla-

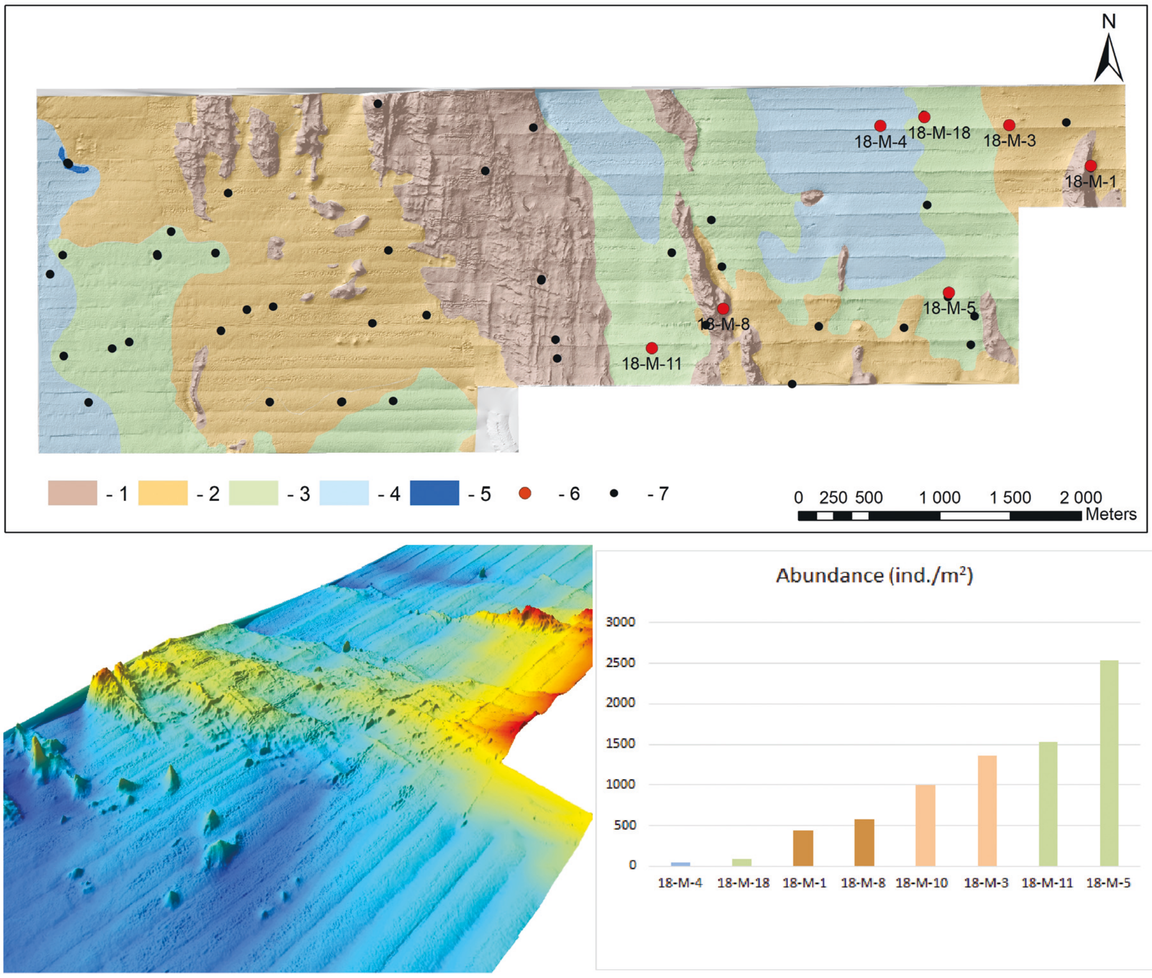

Figure. Map of submarine benthic landscapes of the Gof bottom to the north of Moschny Island. 1 –medium energy circalittoral mixed sediment bottom with Fe-Mn concretions; 2 — medium energy circalittoraloxic sandy clayey mud with spheroidal Fe-Mn concretions bottom on the erosion surface of hard clays; 3 — medium energy circalittoraloxic sandy clayey mud bottom with discoidal Fe-Mn; 4 — low energy circalittoraloxic mud bottom; 5 — low energy circalittoral anoxic mud bottom; 6 — geological sampling sites; 7 — biological sampling sites.

teau with De Geer moraines (0.5 to 2.0 m high, 8 to 10 m wide, and up to 1300 m long rhythmic parallel ridges spaced from 50 to 150 m apart) on top. *M.arctia* (dominant)*, native Saduria entomon* (Isopoda)*, Limecola balthica* (Bivalvia)*,* and *M.affinis* (Amphipoda) were identified.

The most favorable conditions for benthic invertebrates (with total abundance of 1000–2530 ind./m^2 and biomass of 11.6–145.9 g/m^2) are a mixed sediment substrate. Bottom sediments here are represented by an admixture of sandy silts, silty-clay mud, gravel and pebbles, with a gyttja oxic silty-clay layer (3–5 cm) on top. Typically this substrate contains Fe-Mn concretions of different shape and size. The benthic community is the most diverse and contains *M. arctia*, *L. balthica* (dominant), *S. entomon, M. affinis, Oligochaeta, Jaera albifrons* (Isopoda)*,* and *Gammarus zaddachi* (Amphipoda). thebenthic landscape can be subdivided into two subtypes, one subtype with less total abundance and biomass of macrozoobenthos in areas of dense Late Pleistocene clays outcropping, and the othet with higher abundance and biomass within areas of low-sedimentation rates of soft Holocene mud.

Acknowledgements:

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S1P8. Mapping of bottom assemblages in the South-Eastern Baltic Sea, Russian EEZ

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The economic development strategy of the Kaliningrad region provides for various types of exploitation of marine resources, including the further development of off-shore oil and gas production/transportation, the mining of sandy material, the construction of new ports and harbors, more intense recreational use of the coastal zone, which leads to an inevitable increase the impact on the ecosystem in the coming years.There is an urgent need to predict the direction of biota transformation under the cumulative effects of changing anthropogenic and natural drivers, as climate change. However, the biota of the South-Eastern Baltic has not been studied enough to provide a basis for the such forecasts. One of the evident knowledge gaps is a lack of any spatial representation in regard of zoobenthos.

In the Russian EEZ, various types of a comprehensive geological mapping have been performed, some attempts have been made to classify and map the underwater landscapes [1] however, the latter absolutely do not take into account the biological characteristics of the diversity of species, communities and habitats and thus cannot fundamentally serve the goal of marine ecosystem resources sustainable use. The given study is aimed to present the current distribution of zoobenthic assemblages in the borders of Russian EEZ in South-Eastern Baltic Sea communities of the Russian part of the Southeastern Baltic in 2000–2014 are considered. The location, composition, and structure of zoobenthos communities were studied and mapped.

Data collected during IORAS research cruises in 2001–2018. Two or three replica per sitewere sampled by Ocean grab (0,25 m^2),Van-Vin grab (0,1 m^2). Samples were treated in accordance with standard methods [2]: washed out on the mesh (0.4 mm^2), fixed with 4 % neutral formaldehyde, identified to a species level when possible, wet weight and numbers of every taxa per sample were determined. Benthic assamblages were discriminated based on Bray-Curtis similarity index and rank abundance plot for biomass data.

In the study area ca.80 macroinvertebrate species and taxa not identified to a species level (Hydrozoa, Oligochaeta, Chironomidae, Harpacticoidae and Turbellaria) were recorded. The highest species and assamblages diversity was recorded at the area of the boulders or pebbles fields distribution (Taran Cape area, the north coast of the Sambian Peninsula, the root part of the Curonian Spit) and at the lagoon marl extrusions along the Curonian Spit. The species diversity of macrobenthos was low at the areas of distribution of fine and different grain sized sand.

Classification procedures (Bray-Curtis similarity) and rank plots analysis let to recognize seven bottom macroinvertebrate assamblages (communities) in the EEZ area below the 70 m isobath: *1Mytilus edulis + Limecola (Macoma)balthica + Amphibalanus improvisus, 2 Mytilus edulis, 3 Mya arenaria, 4 Limecola (Macoma) balthica, 5 Amphibalanus improvisus + Limecola (Macoma) balthica, 6 Marenzelleria spp., 7 Cerastoderma glaucum* in the area of interest. (Figure 1).

Community, dominated by *Limecola (Macoma) balthica* occupies the largest part of the study area. This community is spread at the different types of sediments at the depths from 10 to 80 m. Species composition of this community changes along with a changing sediment type and depth, four variations of *M. balthica* assemblage were identified: (MbMnHd) — *Limecola (Macoma) balthica + M. neglecta + H. diversicolor;* (MbHd) — *Limecola (Macoma). balthica + H. diversicolor;* (MbCg) — *Limecola (Macoma) balthica + C. glaucum.* An average, for the whole study area, value of benthos biomass in this community is not very high — 69,4 ± 11,4g·m^{-1}, but in the areas with the most favorable set of condition for the dominant species it could reach 100–150 g·m^{-1}.

Community, dominated by*Mytilus edulis,* was found at the different type of hard bottoms: boulders-gravel beds around the Taran Cape, at fields of coarse sediments with crusts along the North coast of the Sambian Peninsula and at the Curonian-Sambian Plateau, as well as at the area of distribution of so called «ancient lagoon mud» (the lagoon marl extrusions) in shallow zone along the Curonian Spit. Three variation of *M. edulis* community were recorded: (MeCvMa) — *M. edulis + Corophium volutator + M. arenaria;* (MeAi) — *M. edulis + A. improvisus;* (MeMa) — *M. edulis + M. arenaria*. It is the most productive zoobenthos community at the study area, biomass could reach 6000,0 g·m^{-1}(mean 996,6 ± 233,5).

The community with a predominance of *Mya arenaria* is located at the shallow zone, up to 15–

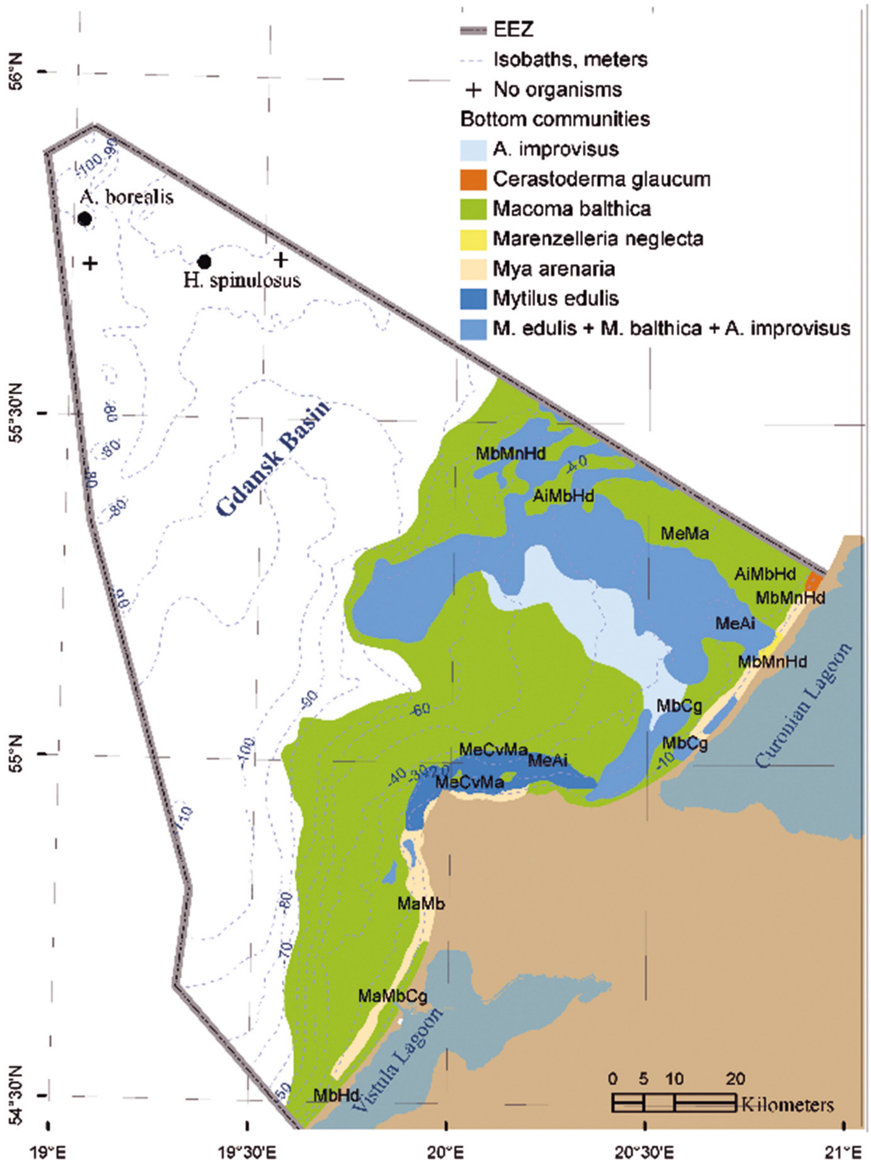

Figure 1. Map of benthic assemblages' distribution up to 70-meters deep based on data of 2001–2014

20 m depth along the coastline and is not cover a large bottom area in comparison with two above mentioned ones, but one of the most productive in the study area — with a biomass up to 1000 g·m^{-1} (mean 458,4 ± 154,7). Depending on local condition, three variation of the Mya community were identified: (MaMnHd) — *M. arenaria + Marenzelleria spp. + H. diversicolor;* (MaMbCg) — *M. arenaria + Limecola (Macoma) balthica+ C. glaucum;* (MaMb) — *M. arenaria + Limecola (Macoma) balthica.*

Bottoms, deeper than 80 m, up to 120 m, could be inhabited by a typical sub-halocline deep-water community, rather poor, with the dominance of polychaetes *Scoloplos armiger* and *Bylgides sarsi*, and priapulid *Halicryptus spinulosus* accompanied by a few meiobenthic ostracods and harpacticoids, or represent anaerobic 'benthic desert' without macrobenthos, depending on the oxygen conditions. Biomass is not exceed few grams per square meter.

Thus, in the Russian EEZ in the South-Eastern Baltic Sea, seven zoobenthos communities were recognized in the whole area up to 70–80 m depth. The most productive are *Mytilus edulis* and *Mya arenaria* communities. The community of *Limecola balthica* is the most wide distributed and is covering the largest area. Below the 80 m isobath only one community, leading by *S. armiger* and *B. sarsi* or its depleted derivates, could be found.

Acknowledgements:

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S1O7. Use of a commercial drone to map ecological and geomorphological post-bleaching changes ongoing in shallow coral reef environments in Faafu Atoll, Republic of Maldives

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High biodiversity coral ecosystems characterize the Republic of Maldives. These are extremely fragile and subject to profound alteration due to global climate changes, sea-surface temperature (SST) warming events, ocean acidification, and anthropogenic pressures such as fishing overexploitation, land reclamation and mass tourism.

In 2016 coral reefs worldwide were affected by an extensive coral bleaching event caused by anomalous high STT. The overall percentage of bleached corals recorded across the Maldives was 73 %. Bleaching affected mainly branching corals of the Acropora genus, the principal reef corals form in Maldivian reefs. After the event, the recorded mortality was higher than 80 %. The deterioration of the natural environments will affect the life of Maldivian people significantly. Coral reefs support a wealth of ecosystem goods and services that extend across the provisioning of food resources, through cultural and tourism benefits, to shoreline protection. A few months after the bleaching event, the coral reef environments have entirely changed their composition and structure. Our study aims to monitor, map and quantify these changes through time using high-resolution drone images and Structure-from-Motion techniques.

Using a consumer-grade drone (DJI Phantom 4), we collected images over different parts of shallow coral reef environments near inhabited, uninhabited and resort islands in Faafu atoll. The surveys took place from February 2017 (a few months after the bleaching event), twice a year until November 2018. The collected data were processed using photogrammetry software to obtain dense point clouds, digital terrain models (DTM) and high-resolution (≈5 cm) orthomosaics. These models were post-processed using GIS software and Object-Based Image Analysis (OBIA) algorithms.

Due to the high spatial resolution of the data we were able to map the shallow coral reef environments at habitat patch scales (centimetres to meters) distinguishing between growth forms of colonies. From the comparison of the maps through time we highlighted and quantified the changes ongoing in the post-bleaching coral reef environments in terms of benthic composition and 3D structures.

Our results show that during 2017 and 2018 the monitored areas lost diversity in terms of coral assemblages and 3D structural complexity; this has led to a progressive flattening of certain parts of the coral reefs. This degradation process affected species richness and abundance and can also threaten the integrity of the islands with a consequent increase of the shore erosion rates.

S1P10. Multispectral acoustic angular backscatter measurement and analysis using tilted EK80 wide band transceiver

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The measurement of backscatter angular response by multibeam echosounders (MBES) for characterizing homogeneous areas of seabed reflectivity at large scales is acknowledged to be an effective method, as the sediment angular response is intrinsically linked to its properties. Nevertheless, the angular response is also dependent on the acoustic frequency.

The frequency dependency is mainly a consequence of different seabed roughness at the scale of the sonar wavelength and of different levels of sediment volume scattering due to a higher signal penetration at lower frequencies [1]. Thus a clear understanding of the sediment-acoustics relationship is a necessary step for the analysis of the backscatter strength over a wide range of frequencies/wavelengths.

However, in order to cover a frequency range of more than one octave, which is perceived as a minimum for a multifrequency analysis, a combination of at least two MBES systems is needed. Besides, most MBES available on the market are not calibrated for absolute backscatter strength, making it difficult to compare measurements from different MBES, and even on the same MBES at different frequencies.

Fortuitously, the recently released Simrad EK80 single-beam echosounder (SBES) can cover a wide frequency band using several modular transducers. Additionally, this echo-sounder can be fully calibrated using a known frequency-dependent sphere target. As a result, it is usable as a reference sensor for measuring the absolute backscatter response vs angle and frequency needed for further cross-calibration of MBES. We present here a multispectral analysis of seabed backscatter intensity using data from an EK80 SBES with four transducers deployed over four homogeneous areas in the Bay of Brest (France) with different sediment types. The SBES transducers were tilted at incidence angles from zero to 70° to form the seafloor angular response at different frequencies ranging from 45 kHz to 450 kHz (Fig. 1). The calibration procedure for the reference SBES, the survey configuration, some scattering statistics and a preliminary analysis of the wavelength effect on the backscatter angular response are presented and discussed.

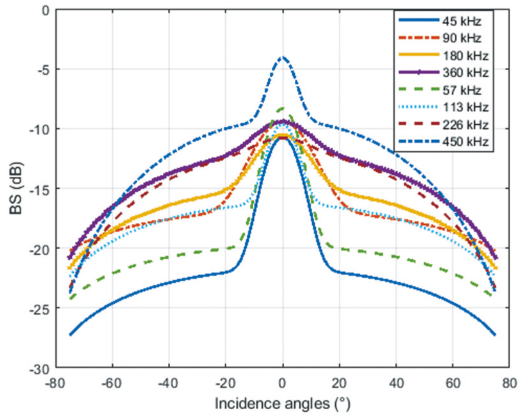

Figure 1. Fitted model of the calibrated EK80 angular backscatter measurements for the "Rascass" area at different frequencies

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S8O5. Biogenic features in the Geological Map of Italy

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The Italian continental shelf is mostly characterized by terrigenous, siliciclastic sediments delivered mainly by rivers, whereas carbonate deposits are less common. Sediments are locally characterized by a high bioclastic component, while a few relevant biogenic features are evidenced by remote sensing. Biogenic carbonate deposits deriving from the accumulation of calcareous plankton have also been detected at a few sites drilled by the DSDP [3][4].

Several kinds of biogenic deposits are represented in the Geological Map of Italy (CARG Project). Deposits are distinguished by age, depositional environment, sediment grainsize and composition and are represented accordingly. A specific symbol for each feature has been established by the Geological Survey of Italy in the Guidelines for surveying and representation.

Seagrass meadow and coralline build-up are the more prominent features, which can be represented either by polygons or by isolated overprinted symbols, depending on their extension. Seagrass can be further subdivided into *Posidonia oceanica* and *Cymodocea nodosa* by specific symbols, wherever these two species have been recognized.

Non-tropical carbonate sedimentation has been identified on the shelf in isolated areas surrounding islands such as the Egadi and the Pontinian Islands [1]. The high-energy hydrodynamic regime around the islands and the lack of significant river runoff prevents the deposition of muddy sediments. The organogenic sedimentation in these sites is essentially made up of carbonate, medium- to coarse-grained sands and gravels of maerl & praline facies [2]; this latter can be represented in the CARG geological maps by a dedicated pattern.

Bioclastic deposits are represented by polygons characterized by patterns combining the symbols for biogenic components and those for grainsize. Additional patterns have been provided in order to distinguish bioclastic deposits originated by bioherm dismantling.

Even when bioclasts are not common, information on the organisms recovered in the deposits is reported in the Legend of the Map and/or in the accompanying Explanatory Notes.

Moreover, the geological maps of the CARG Project are complemented by the associated more detailed database. By combining data on biogenic features, sediment distribution and geomorphological elements contained therein, it is possible to contribute to the study of living assemblages with the aim to better define and characterize different habitat settings.

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S1O8. Mangrove colonization as a result of high sedimentation in a man-made river: a case study in the Jaro Floodway, Iloilo City, Philippines

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The Jaro Floodway is 4.8 km long and 82 m wide and was constructed to divert floodwater from the Jaro River to the Iloilo Strait. It was completed in 2011 and designed to protect against a 20-year return [1]. However, this large-scale anthropogenic disturbance may pose a threat to the nearby mangrove forest. To evaluate the effect of the floodway to the areal extent of the mangrove forest, Landsat 5 (2000, 2004, 2006, and 2010) and Landsat 8 (2014, 2016, and 2018) images from WRS Path 114 and WRS Row 53 were acquired from the USGS Global Visualization Viewer. Geometric correction was performed on all of the images using 20 ground control points from topographic maps available from the National Mapping and Resource Information Authority (NAMRIA) with a root mean square error of < 30 m. The images were then clipped to the area of interest bounded by 122.5836ºE, 10.7487ºN and 122.5982ºE, 10.7361ºN. Masking was performed to reduce data volume and increase overall classification accuracy by reducing land cover types and spectral variation [2]. Principal component analysis was conducted and a threshold value of 0.03 was set to the 1st principal component band to remove water. The normalized difference vegetation index was then calculated from the masked near infrared and red bands, and a threshold value of 0.25 was used to remove non-vegetated areas. K-means clustering, an unsupervised classification scheme, was applied to the 2nd masked images. Clustering was set to output 10 classes, which were manually grouped into three thematic classes, namely, water, non-mangrove, and mangrove areas. The calculated mangrove cover before the floodway was constructed is 11.62 (2000), 8.11 (2004), 7.21 (2006), and 9.73 ha (2010). Mangrove cover then increased in the succeeding years measuring 13.88 (2014), 20.08 (2016) and 38.84 ha (2018). The decrease in mangrove cover from 2000 to 2006 is attributed to the conversion of fishponds. On the other hand, the general increase from 2010 to 2018 is attributed to a combination of factors such as high sedimentation and mangrove planting efforts by the government. The contribution of mangrove rehabilitation efforts could not be quantified due to the absence of any documentation from the government on when they started planting mangroves, where they were planted, and how many hectares have already been planted. Regardless of this data gap, it is apparent that sedimentation played a major role in the increase of mangrove cover. Sedimentation and mangrove colonization are closely related as seen in other deltas in the world [3]. The construction of the Jaro Floodway lead to the formation of a new delta on which the mangroves currently thrive. Sediment accretion resulted in the gradual shallowing of the water column up to the optimal depth for mangroves and accretion also allowed the area to be more accessible to coastal managers. Historical images from NAMRIA also showed that the mouth of the Jaro River shifted westward from 1953 to 1988, which resulted to the formation of a delta and an increase in mangrove cover from 7.01 to 43.83 ha.

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S3O7. Exploring the Perth Canyon deep-sea habitats

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The Perth Canyon is a V-shaped incision located 50 km offshore the southwest Australian continental shelf in the southeast Indian Ocean. This large submarine feature extends from a depth of ~200 m to the abyssal plain at ~4000 m. The Perth Canyon was explored for the first time by means of a Remotely Operated Vehicle (ROV) in March 2015, during cruise FK150301 aboard the R/V *Falkor*, with a focus on deep-sea coral communities, and anthropogenic-driven changes. High-resolution bathymetric data were acquired using Kongsberg EM 302 and 710 multi-beam echo sounders. The multibeam mapping program firstly focused on the ROV dive sites, then was expanded to cover unmapped zones across the region (McCulloch et al., 2017). The multi-beam echo-sounder data was processed using CARIS HIPS and SIPS 7.0 software. A digital terrain model (DTM) was generated at 20 m resolution for the entire canyon, and at 10 m resolution for the ROV dive areas.

A total of nine transects using a Sub-Atlantic Comanche 2000 m ROV were conducted at six distinct locations encompassing the head to the mouth of the canyon, and on the northern shelf plateau (Fig.1). The dives traversed the generally featureless muddy canyon floor, along near vertical walls, and onto the canyon rim. ROV imaging revealed typically massive and well-bedded Late Paleocene to Miocene sedimentary units, variably lithified but mostly friable.

The ROV surveys revealed localized, patchy occurrences of mega- and macro-benthos in the depth range of ~680 to ~1800 m, including corals, sponges, molluscs, echinoderms, crustaceans, brachiopods, and worms (Trotter et al., 2018). The settlement of large benthic sessile organisms is mostly limited to indurated substrates and typically along the canyon walls. Noticeably, solitary (*Desmophyllum dianthus*, *Caryophyllia* sp., *Vaughanella* sp., and *Polymyces* sp.) and colonial (*Solenosmilia variabilis*) scleractinians were sporadically distributed along the walls and under overhangs, and along the canyon's rim. Soft and calcified (*Corallium*) gorgonians, bamboo, and proteinaceous corals were present. Extensive last glacial coral graveyards comprising colonial (*S. variabilis*) and solitary (*D. dianthus*) scleractinians, were discovered at two disparate sites between ~690–720 m, on the northern plateau, and 1560–1790 m, deep within canyon.

This multi-disciplinary study characterized the canyon environments and habitats, documenting localized occurrences of mega- and macro-benthos, and providing evidence that the canyon is currently essentially inactive.

S1P11. Some Practical recommendations for averaging acoustic backscatter strength

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Averaging samples of acoustic backscatter signal is a necessary step for both acquisition and processing, including analysis, of underwater acoustic data, particularly those acquired by multibeam echosounders (MBES). In MBES, samples of backscatter strength (BS) are normally registered in decibels (dB), in the form of a time-series (snippets), or in the form of one single value per beam. The BS is proportional to the square of the observed amplitude *x*, expressed in dB as . So, averaging a set [*x*] of backscatter observations implies the averaging of squared amplitudes. Additionally, the probability density function (PDF) of a set [*x*] of backscatter amplitudes usually follows a Rayleigh law, in case of time-series samples, and moves towards a log-normal distribution, in case of one single value per beam. These results can be directly observed in multibeam data and can be reproduced during statistical simulations. Although the mathematically correct way of averaging BS samples is by averaging squared-amplitudes, we will discuss four different approaches:

1. Directly averaging squared amplitudes....... $10log_{10}\langle x^2\rangle$
2. Averaging amplitudes and shifting .... $20log_{10}(\langle x\rangle) + offset$
3. Averaging dB values and shifting........... $\langle 20log_{10}(x)\rangle + offset$
4. Calculating the median and shifting......... $Median(x) + offset$

Approach #1 follows a squared-Rayleigh (Exponential) distribution and directly gives the correct average. Approach #2 follows a Rayleigh PDF and #3 a Log-Rayleigh PDF. The averages calculated by #2 and #3 give biased values, and the calculated averages must be shifted by statistical offsets (+1.0 dB for #2; +2.5 dB for #3). Approach #4 does not imply any underlying distribution, as the ascending order of amplitude values or dB values are the same. Nevertheless, the median of a Rayleigh-squared PDF is also displaced with respect to its mean (+1.6 dB).

Given enough samples and applying the proper offsets, all four approaches will provide similar results, give or take some statistical fluctuations. However, in actual MBES data, backscatter samples are often contaminated by random noise and high-amplitude scatterers, causing the results of the four approaches to differ considerably (up to 20dB!), depending on the amount of noise, the number of scatterers and number of samples (Figure 1). So, in this case, we can give the following recommendations for averaging acoustic BS samples:

1. The direct averaging of squared amplitudes should be avoided. Although this calculation is mathematically correct, it severely contaminated by noise and high-amplitude scatterers. The calculation errors are higher for low backscatter values;

2. Averaging amplitudes should also be avoided, as it is also severely contaminated by noise and scatterers. This average does not follow the same PDF as the average of squared amplitudes, so it should be shifted by a statistical offset. Nevertheless, the actual difference between these averages

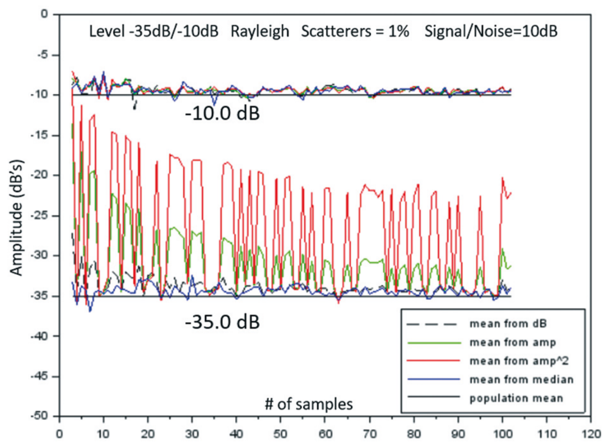

Figure 1 — Statistical simulation of seafloor Rayleigh Distributions. Note that different approaches for calculating the average backscatter diverge in the presence of noise and high-amplitude scatterers

is not consistent and is not predictable, depending on the noise level, the number of scatterers, and on the underlying PDF. The calculation errors are higher for low backscatter values;

3. The average of dB values does not follow the same PDF as the average of squared-amplitudes, so it needs to be shifted by a statistical offset. The actual difference between these averages is not consistent and is not predictable, depending on the underlying PDF, the noise level and the number of scatterers. However, with enough samples, this average is seldom more than 2.5 dB away from the correct value. The errors have a weak dependency on backscatter level, but are significantly higher for a small number of samples;

4. The median should be the preferred calculation method. It is a robust measurement, weakly affected by the noise level, the number of scatterers, and the number of samples. Similarly, the median must be shifted in order to estimate the correct mean value, by an offset only dependent on the underlying distribution.

S1P12. An integrated approach for benthic and fish fauna monitoring by remotely operated vehicle (ROV) and acoustic technology (MBES/SSS)

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The installation of a regasification plant in North-Eastern Adriatic Sea (Italian territorial waters) started in late 2008 and ended in fall 2009. Located offshore the river Po delta, on sandy bottoms, its base was protected from erosion by a rocky belt (10 m width) covering all sides. In 2010 an artificial reef (Technoreef® restocking modules) was also installed 1.1 nautical miles S-W the plant, as a compensation measure to fishermen.

A general monitoring plan was carried out before, during and after the installation to study the effects of this off shore platform on the surrounding environment. A georeferenced base for all the monitoring activities was realized, by means of seafloor acoustic mapping (multi-beam echo sounders, MBES; side-scan sonar, SSS) performed in 2006 (before the installation), 2009 (during) and 2012 (after), over an area of 5 nm^2 around the platform. Acoustic data allowed to identify several natural rocky outcrops in the study area, so the monitoring plan included those natural hard substrata in addition to the artificial one (rocky belt and Technoreef® modules).

From 2010 to 2015 epimegabenthic species and fish fauna were then investigated by means of a Remotely Operated Vehicle (ROV), equipped with a transponder to couple the observations with position in a GIS environment.

Information on species type, number of individuals or abundance class and timestamp on videodives were noted and stored in a database. Timestamp (date-hour-minutes) of both the trasponder and the observation files was used as a common column to link the video observations to position; the resulting file was then displayed on a grid, built for each monitored site, and a spatial join was finally run to attribute the observations to each cell of the grid interested by the passage of the ROV itself.

The coupling of ROV data with transponder information allowed to highlight spatial differences not only between but also within artificial sites. At the Technoreef® site, for example, it was possible to discriminate a different colonization pattern of *Phallusia mammillata* (Cuvier, 1815) with respect to module type, represented by an abundance gradient from the inner part of the field — where small modules were deployed — to the outer side of the installation, composed by medium (two-level) to big (three-level) elements and antitrawling structures (Fig. 1).

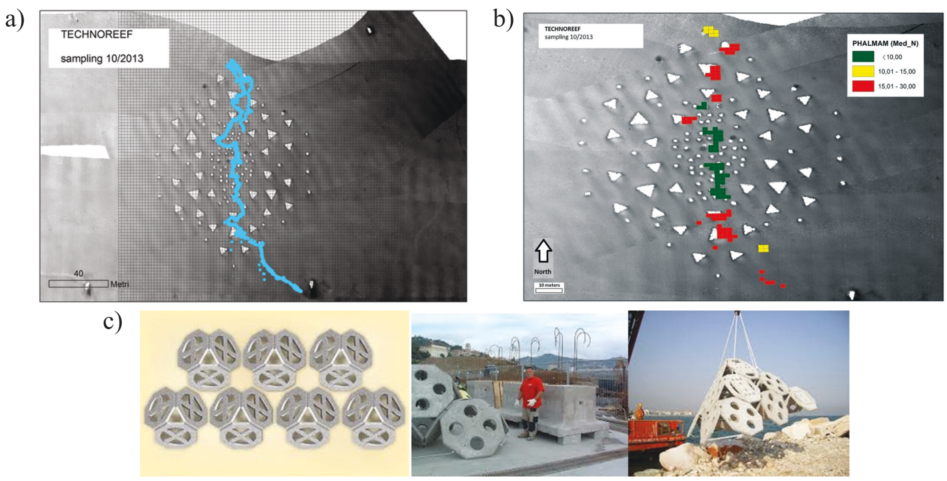

Figure 1. Technoreef® site: integrated results by acoustic mapping and ROV dives. a) ROV route on October 2013 survey; b) Spatial distribution of *P. mammillata*, where it is possible to observe that the species' abundance is not homogeneous over the artificial reef; c) from left to right, elements of the artificial reef: small modules, two-level module plus some antitrawling structures, three-level module

S2P2. Application of Unmanned Aerial Vehicles (UAVs) to density measurements of the noble pen shell *Pinna nobilis* (Linnaeus, 1758) in the Venice Lagoon

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There is a growing interest in the ecological science field on the use of remotely piloted aircraft systems, commonly known as “drones”, as they greatly improve our ability to collect high-resolution spatial data at repeated intervals, eliminating the need (at least at reduced spatial scales) for expensive traditional flights [1].

In the Venice Lagoon the presence of *Pinna nobilis* (Linnaeus, 1758), the biggest bivalve endemic species of the Mediterranean Sea, is known since the end of the 18th century, reported by the abbot — and biologist — Giuseppe Olivi [2]. In the lagoon *P. nobilis* colonizes either deep zones — where the pen shells live unseen, always under the sea water level — or shallow substrates, locally called *velme*, where the natural tidal cycle periodically expose the shells to open air during low tide. On the *velme* the colonies are strictly associated to seagrasses — *Cymodocea nodosa* (Ucria) (Ascherson, 1870), *Zostera marina* (Linnaeus, 1753) and *Z. noltei* Hornemann — and during low tide the individuals are easily visible and accessible (Fig. 1).

Considering exposition of pen shell colonies, presence of seagrasses, low cost of consumer grade UAVs and possibility of data collection with high frequency the aim of this study was to test the pros and cons of the use of drones in the collection of spatially explicit data (georeferenced videos and photos) as an intermediate acquisition level between field work and satellite, applied to the distribution and density estimates of *P. nobilis* in a tidal environment like the Venice Lagoon.

A shallow site near the city of Chioggia (Venice Lagoon, Italy), characterised by a dense colony of *P. nobilis* among a seagrass meadow composed by *C. nodosa*, *Z. marina* and *Z. noltei* was then identified as our case study.

Starting from the calibration of the surface viewed by the camera of the drone when oriented 90° degree to the terrain, measures were performed at different flight altitudes (5, 10, 15 and 20 m). Pen shell density was both manually measured on a known surface (2 different transects of 40 m^2) and through several overlapping flights, with density

Figure 1. A) *velma* during low tide; B) pen shells exposed; C) A specimen among seagrasses during high tide

counts made from single video frames (400 m^2 at 10 m height). Results were finally compared in terms of density measurements, space variability, surface covered/min.

As it was predictable, manually collected density data were higher (1.8 times) than those resulting from UAV flights, mostly due to small individuals hidden below the seagrass leaves, but space variability of the measure acquired with the two techniques resulted similar. On the other hand, the surface covered per time unit was strikingly on the side of UAVs: 560 m^2/min (10 m altitude flights) vs 1 m^2/min (manual transect).

An integration of field work and drone flights could then provide valuable data, balancing the precision on a very small spatial scale of the manual transect with the possibility to explore wide surfaces and the advantage to reach areas which may not easy — or impossible — to sample.

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S5O3. EXpanding Pacific Research and Exploration of Submerged Systems: A Campaign to Map Critical Data Gaps in the Northeast Pacific

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Building on the success of prior work, National Oceanic and Atmospheric Administration, Bureau of Ocean Energy Management and United States Geological Survey have begun a new campaign: Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS). This campaign hopes to fill critical data and habitat gaps offshore of California, Oregon, and Washington in the Northeast Pacific by leveraging mapping platforms across multiple agencies and Nongovernmental Organizations. EXPRESS will also work with the co-occurring West Coast Deep Sea Coral Initiative, which seeks to improve the understanding of this resource along the U. S. West Coast and will invest over 2 million dollars in this effort over the next two years. Multiple EXPRESS missions have already launched including a mission to map the waters around Santa Rosa Island in Southern California and an effort in the Olympic Coast National Marine Sanctuary. Moving forward, EXPRESS will use the Integrated Ocean and Coastal Mapping Program and the Seasketch tool to plan for upcoming acquisition missions and coordinate priorities between agencies.

S6O2. Geomorphometric characterization of pockmarks by using semi-automated method

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Pockmarks are seabed depressions developed by fluid escaping at the seabed, most notably gas such as methane. In some pockmarks, structures of methane-derived authigenic carbonate (MDAC), produced below the seafloor by microbial oxidation of the seeping gases [1], can be exposed at seabed offering shelter for many species. Active pockmarks can also support a unique community of chemosynthetic organisms such as the gutless nematode *Astomonema southwardorum* [2], only known to occur at Scanner Pockmark in the North Sea. Additionally to their importance as areas of significant biodiversity, mapping of pockmarks is important for different reasons: *1)* assisting towards the detection of hydrocarbon resources, *2)* revealing areas where carbon sequestration is not possible due to the potential leakage of the targeted reservoir, and *3)* representing areas prone to present geozahard risks (e. g. gas venting, slope failure) for seabed infrastructures.

The substantial increase of multibeam data available allowed the identification and morphological characterisation of a vast number of pockmarks, in many marine and lacustrine environments. However, the manual mapping of these features can be extremely time-consuming and subjective. Several different semi-automated methods to map pockmark have, therefore, been developed. Including the ArcGIS-based toolbox developed by the British Geological Survey that recognises, spatially delineates and morphometrically describes seabed features including pockmarks [3]. These tools allowed the mapping of diverse pockmark fields in an efficient and consistent, from the North Sea to the Gulf of Mexico, including pockmark fields within areas with the highest density of pockmarks known in the world, *i. e.* the Barents Sea [4] and the northwest Australian continental shelf [5]. By combining the statistical analysis of extracted morphological parameters with the geological and oceanographic knowledge of individual areas, multiple interactions that explain the pockmark form and distribution have been revealed.

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S1O9. An Improved Understanding of Multispectral Multibeam Echosounders: Towards 3D Sediment Classification Based on Multispectral Backscatter and Bathymetry

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Multispectral backscatter data have indicated the potential for increasing the discrimination between different seabed environments (e. g. [1], [2], [3]). According to the acoustic theory, three main reasons cause the frequency dependency of scattering: 1) relationship between acoustic wavelength and seabed roughness, 2) transition between dominating scattering regimes (Rayleigh to geometrical scattering) and 3) increased volume scattering due to signal penetration [2]. The latter plays an important role, in particular for fine sediments, with respect to the typical frequency range of modern multibeam echosounders (MBES) (100–400 kHz). However, in case of sediment layering or large vertical heterogeneity an affect other than the three mentioned above can also become important, i. e. the observed frequency dependency of scattering may result from the ensonification of different sediments at different depth due to an increased signal penetration with decreasing frequency.

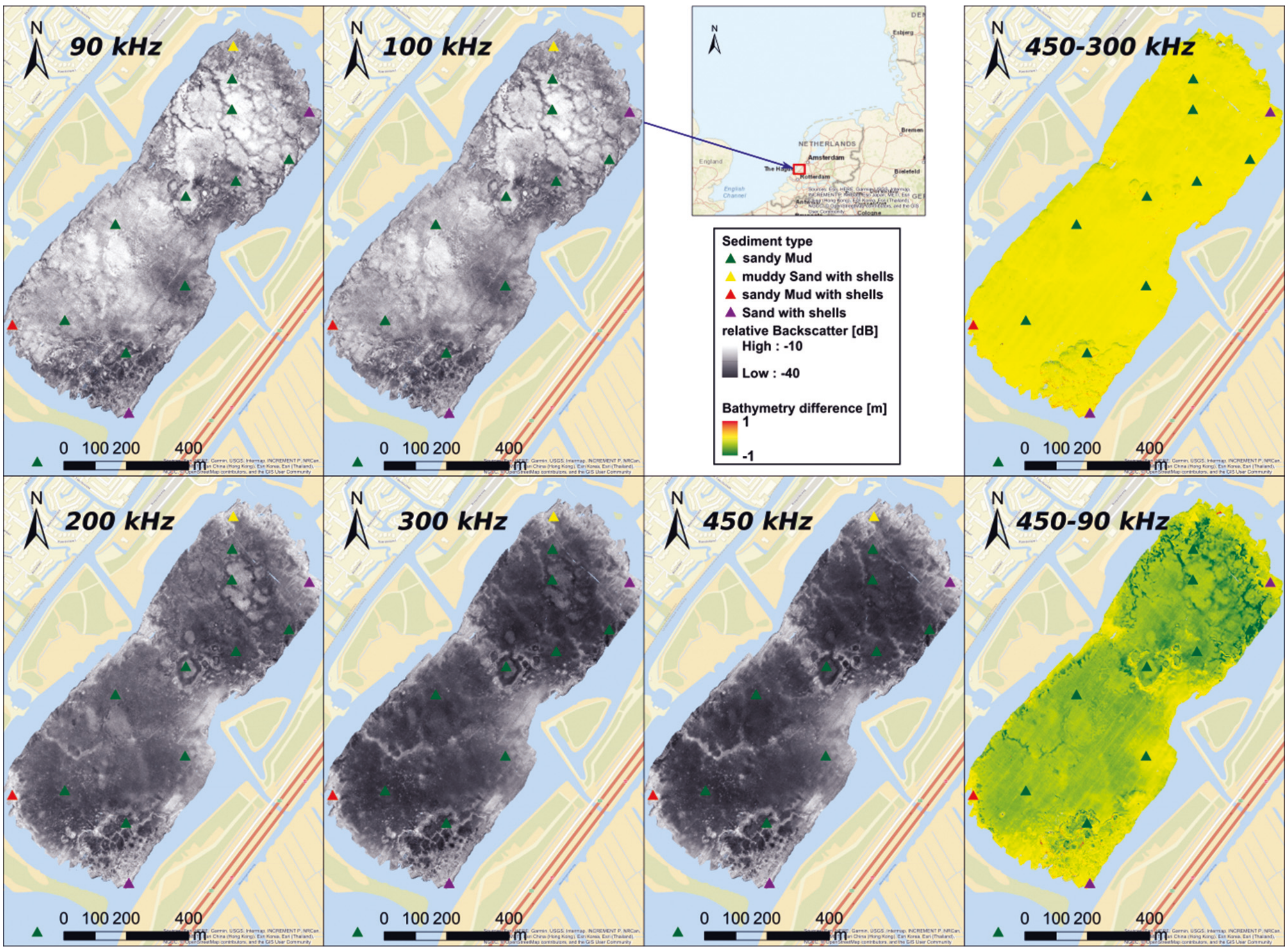

Figure 1. Multi-frequency backscatter maps (90, 100, 200, 300, 450 kHz) and bathymetry difference maps (450–90 kHz and 450–300 kHz) from the Vlietland Lake, The Netherlands. The spatial resolution is 1 m by 1m

In this study we investigate the signal penetration per frequency with respect to sediment properties as well as their influence on the measured backscatter. To this end, we acquired a multi-frequency backscatter dataset (90, 100, 200, 300, 450 kHz) with an R2Sonic 2026 MBES in a freshwater lake in the Netherlands. The lake is a former sand pit used for the extraction of sand. Van Veen grab samples and video footage indicate that the sediments range from mud to sand partly combined with freshwater mussels.

Varying signal penetration depths for different frequencies and different sediment compositions are observed, as indicated by the different vertical position of the bottom detection per frequency. The bathymetry maps differ up to 110 cm for the most separated frequencies in the finest sediment (mud) (see Figure 1). Based on model predictions for the bathymetry uncertainties, accompanied by a detailed investigation of the data, it is found that the bathymetry difference per frequency is significant. The analysis of the backscatter along with the ground truth data and interpretation of the geological setting indicate that the detected bottoms at different frequencies correspond to different sediment layers. The backscatter at 450 kHz represents the seabed properties from the surficial seabed for the entire range of sediments. The backscatter at 90 kHz and 100 kHz correspond to the surficial seabed for sandy sediments and muddy sediments with a large layer thickness. In case a sand layer exists below a thin mud layer (< 110 cm), the backscatter is dominated by the sand layer. To account for the attenuation loss (absorption and scattering) in the upper subsurface layer, in particular for the lower frequencies, we propose a correction term to retrieve the accurate backscatter, corresponding to the sand layer.

These results provide promising opportunities to correlate multispectral backscatter to depth and therefore to produce a 3D map of the surficial seabed and the upper subsurface. Furthermore, the results indicate the potential to use multispectral MBESs as a supporting tool for detecting fluid mud layers.

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S1O10. Optimization of side-scan backscatter to allow sorted bedform monitoring in the German Bight, North Sea

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Monitoring sorted bedforms can provide information on sediment budget estimation, which is important to understand the changes in bedform habitats. Temporal changes of bedforms have been studied in the German Bight. However, the reported results of these studies were impaired by high uncertainties of positional errors incurred by towed side-scan and geo-referencing of images. In this study, improvement in the spatial accuracy of side-scan mosaics was achieved, which allowed monitoring of bedform boundary oscillation.

Offshore surveys were conducted in November 2017 and March 2018 in a small area in the German Bight, using Edgetech 4200 Side-scan sonar and EM710 Multibeam system. Backscatter images from side-scan were rectified using a surface digital terrain model from multibeam data. The georeferenced mosaics were used to extract bedform boundaries, which were analyzed using the Digital Shoreline Analysis System (DSAS) tool. The DSAS tool provided an estimation of the magnitude of change along the sorted bedform boundaries. In addition, changes in bathymetry and sediment volume were calculated using the multi-beam bathymetric data. Results were verified with grain-size analyses and underwater video footages. The short-term change monitoring provided an estimation of the net boundary movement and change in sediment volume of sorted bedforms, which can assist in environmental monitoring.

S3P3. Habitat Geological Survey at Nanji island of Zhejiang Offshore, China

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The relationship between marine organisms (fish, shellfish, etc.) and benthic environment has become a research hotspot which also has attracted more and more attention from government departments. In August 2018, we chose the coasts along Nanji Island of East China Sea as an study case area to carry out the habitat geological survey. Nanji Island is located in Wentai Fishing Ground, which belongs to Zhoushan Fishing Ground and has abundant biological species. Local fishermen call it Shellfish and Algae Paradise.

For our survey, 70 surface sediment samples and related hydrological data were collected in Nanji Island, and 175 stations of seabed photographic survey were conducted in August 2018. Different stations showed the different characteristics in sediment types, hydrological turbidity and seabed images. The detailed results show that: (1) The distribution of fish in the coastal zone less than 50 m depth was closely related to water depth, water temperature, turbidity, dissolved oxygen, chlorophyll content and sedimentary environment. Fish mainly lived in reef areas where shellfish and algae were flourishing, and fishing was also active. However, there are fewer macro organisms in muddy seabed areas. This is of great significance for marine environmental monitoring and fishery management. (2) The application effect of submarine camera technology in coastal zone was poor, which was mainly affected by high turbidity water and high plankton water, and its light transmittance was poor. (3) High turbidity water mainly occured near the sea bed. Based on CTD data and video information estimation, there was a layer of high turbidity near the bottom of the coastal zone. The layer thickness was about 3 m and the light penetration was less than 10 cm, which made the higher suspended sediment concentration and the worse transmittance in this layer. (4) The high chlorophyll content in the thermocline indicated that the phytoplankton was flourishing in the thermocline, but the turbidity data showed that the magnitude of the thermocline changes little compared with that of the surface water. Coupled with CTD data and video information, we found that the thermocline position was mainly affected by plankton, and the transmittance gradually deteriorates. (5) For the coastal zone of muddy sediments, the advantages and disadvantages of the camera system should be fully taken into account in the eco-environmental geological survey. At the same time, the submarine camera Survey need to be combined with other survey methods. Otherwise, it is difficult to obtain better data for underwater camera.

S1P13. The first results of the semiaquatic vegetation mapping in the Russian part of the Vistula and Curonian Lagoons, Baltic sea

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The Curonian and Vistula Lagoons are the largest shallow lagoons of the Baltic Sea. These lagoons are separated from the Baltic Sea by a stable sand barriers — Vistula and Curonian Spits. The Curonian Spit is a protected area, UNESCO World Heritage Site. The whole Polish part of the Vistula Lagoon together with the Vistula Lagoon have been acquired as Natura 2000 area. There are still no published data on the area of semiaquatic and submerged plants communities of the Russian part of Vistula and Curonian lagoons of the Baltic Sea.

In the Curonian Lagoon the processes of overgrowing with aquatic plants are most pronounced over last decade when the reed belt has become visually apparent. The scarce data on macrophytes communities spatial distribution do not allow to estimate the temporal dynamics of aquatic vegetation., to outline typical, anthropogenically undisturbed and unique plant communities. A preliminary estimation of aquatic plant communities areas in the Curonian and Vistula Lagoons is the aim of the study.

The field works was carried out in summer season of 2013–2014 and 2017–2018. Mapping was conducted on land and and from a motorboat. Gebotanical descriptions and GPS tracking of plant communities were done ***in situ***, then GPS tracks along the borders of the plant associations were digitized using route crawls and analysis of satellite images from Google Maps service.

It was found, the reed communities (*Phragmitetum australis subpurum, Phragmitetum australis purum*) and communities with lake reeds (*Scirpetum lacustris purum, Scirpetum lacustris phragmitetum*) are dominate in coastal biotopes. *Potamogetonetum perfoliati subpurum* and *Potamogetonetum pectinati purum* appear to be dominating between the water communities.

In the Vistula Lagoon the pattern of aquatic vegetation distribution is fragmented-belt type. In the Primorsk Bay and along the Vistula spit the overgrowth are more intensive. The width of the reed belt varies from 10–50 m to 150–200 m. Submerged vegetation occupies vast areas in a shallow water up to 1.8 m depth, where *Potamogeton perfoliatus* belt can reach up to 200 m width. The areas covered by macrophytes communities in the Vistula Lagoon were calculated basing on the composed map.

According to preliminary estimation, the area covered by submerged vegetation amounts 11,877596 km^2, by semi-aquatic vegetation — 15, 657145 km^2, which together makes 5.86 % of the total area of the Russian part of the Vistula Lagoon.

In the Curonian Lagoon the semi-aquatic vegetation is well pronounced over the lagoon coastal zone, excluding some sections of the Curonian Spit and has a typical belt distribution. The width of the reed belt varies from 25 to 70 m, but somewhere at the east coast can reach 400 m. The width of the lake reed belt is less, reaching 10–20 m.

In some parts of the eastern and southern shores plant communities are distinguished by a maximum species diversity and represent little-modified type of aquatic vegetation, valuable both because on their regional typicality and the presence of rare hydrophytes as *Nymphoides peltata, Nymphaea alba.*

The area, occupied by the protected *Nymphoides peltata* (Red Book of the Kaliningrad Region) was mapped and calculated, it amounted to 28,384 m^2. Three sections of the west coast occupied by plant communities also were mapped. The coverage of area by *Phragmites australis* (13,9 ha), *Scirpus lacustris* (0,38 ha), *Nuphar lutea* (0,07 ha) communities was estimated.

The identified valuable plant communities and habitats on the southern shore of the Curonian Lagoon are located in a close proximity to a partially submerged archaeological site, a medieval settlement. Both biotopes and an archaeological site need in a certain level of conservation measures, on the one hand, and are promising in terms of the development of specialized tourism. After completion of the studies, this section of the lagoon and coast is supposed to be recommended for the creation of a small protected area, MPA, promising in the framework of the Blue Growth concept

The field works were supported by the project # R64 BalticRim, data analysis was done with a support of the state assignment of IO RAS(Theme No. 0149–2019–0013)

S1P14. Monitoring sediment transport along the Israeli continental shelf with high resolution multibeam data

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The Israel Oceanographic and Limnological Research (IOLR) started an annual sediment monitoring program in 2017. The aim is to evaluate the amounts of sediment transport (erosion and deposition) along the Israeli continental shelf, and to assess the influence of marine infrastructures on sediment transport and marine habitats.

The monitoring comprises an annual survey aboard the IOLR operated R/V Bat-Galim. The survey includes multibeam seafloor mapping, 3.5 KHz Chirp sub-bottom profiling and sediment sampling along 8 transects across the shelf from WD 10–100 m. Depending on water depth, the Kongsberg EM2040 multibeam yielded horizontal resolution of 0.25–1.0 m and vertical resolution of several centimeters. The combination of high-resolution bathymetric and backscatter data enables us to analyze sediment transport, erosion and accumulation. We present preliminary comparison results between the 2017 and 2018 campaigns. Subtraction of the bathymetric map of 2017 from the 2018 shows patterns of sediment accumulation and erosion along the coastline parallel Kurkar ridges (Calcareous sandstone rocky ridges). We measure changes of up to +/–0.8 m in the vertical axis. The backscatter data shows variations between hard and soft cover and enables spatial analysis of sediment composition of the continental shelf. The sediment trends along man made interferences is very dominant especially in shallow water (less than 30 m). The results are the first stage towards full quantitative classification. We plan to develop a data catalogue (i. e. ‘acoustic library’), integrate multi frequencies, and use in-situ validation. The methodology is expected to assist in estimation of changes to the seafloor habitats of the Israeli continental shelf. This methodology has significant importance for the government sector decision making as well as for the academic sector.

S1O11. Habitat mapping of *Macrocystis pyrifera* in nearshore coastal southern Otago

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Anecdotal evidence describes the presence of large *Macrocystis pyrifera* (*M. pyrifera*) kelp forests along the southern Otago coastline which are now no longer present. There are many different hypotheses why these kelp forests have disappeared but most attribute the loss to an increase in sedimentation in coastal waters due to the downstream effects of gold mining, agriculture, industrialisation, and urbanisation[1]. Anecdotes describe kelp forests that supported *Jasus edwarsii*, *Haliotis iris, Evechinus chloroticus* and *Odax pullus*[1,2]. Anecdotal evidence such as this, has been shown to be important for inferring historical conditions when there are no long term data sets available[3]. Natural fluctuations and disappearance of entire beds is not uncommon in well studied Californian kelp beds[4], however, it is important to determine if *M.pyrifera* forests along the Otago coast disappeared due to anthropogenic implications such as discharged waste waters, agriculture or mining or if it is attributed to natural changes such as El Nino cycles, storms, and rainfall[4,5]. By understanding the drivers of loss we are better informed to restore these once productive ecosystems.

This project aims to investigate the distribution of *M.pyrifera* along the southern coast of Otago from Green Island to the Clutha River. There are three key questions and objectives of this project, (1) determine the historic extent of kelp forests along the coast south of Green Island (2) estimate potential periods of change and their triggers, (3) determine and quantify the presence of potential habitat that may remain in the study area. The study design as such will then be divided into answering these three components, (1) interviews, sounding sheets and satellite/photo imagery of the coastline to record historic growth, (2) interviews, Otago Regional Council river discharge data, and Otago Coastal Hazard Reports to determine periods of change and triggers, and (3) multibeam and dive surveys to record areas where habitat may still be suitable to *M.pyrifera* growth.

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S3P4. Geomorphological classification of the benthic structures for the coastal protected area Costa dos Corais — northeast Brazil

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The seabed habitats, a crucial part of marine ecosystems, have high biodiversity and shelter several species of great economic importance. A first step in studying these habitats is to recognize the properties of the seafloor. The aim of this study is to perform a geomorphological classification for a sector (1,103km²) of APA Costa dos Corais, which is a conservation unit for sustainable use, extremely relevant to the preservation and management of the Brazilian coast [1]. With great morphological complexity, this area has positive and negative features (reef banks of various origins, channels, among others) [2]. This study was performed from a single-beam echosounder bathymetric data set. The geomorphological analysis was conducted from the Digital Bathymetric Model (DBM) and its derivatives (slope and Benthic Positioning Indexes), through the Benthic Terrain Modeler (BTM) extension, with the support of a decision table containing definitions and thresholds. Twelve benthic structures (Figure 1) were recognized: Plain inner (2.20 %), Plain middle (51.49 %), Plain outer (26.11 %), Gentle slopes (1.04 %), Steep slopes (0.09 %), Depressions (6.09 %), Local pinnacles on slope (0.07 %), Local pinnacles on plain (3.14 %), Rock outcrop highs (0.64 %), Flat ridge areas (8.83 %), Local pinnacles on depressions (0.27 %) and Scarps (0.01 %). The occurrence of these benthic structures highlight the heterogeneity of this unit conservation. The recognized plains were calculated according to the classification which divides the Pernambuco continental shelf into Inner shelf (limited by the 20 meter isobath), Mid Shelf (from 20 to 40 meters' depth) and Outer Shelf (beyond 40 meters' depth) [3]. In relation to submerged channels previously mapped [4], the following benthic structures were mapped: Depressions, Gentle slopes, Steep slopes and Local pinnacles on plain and on depressions.

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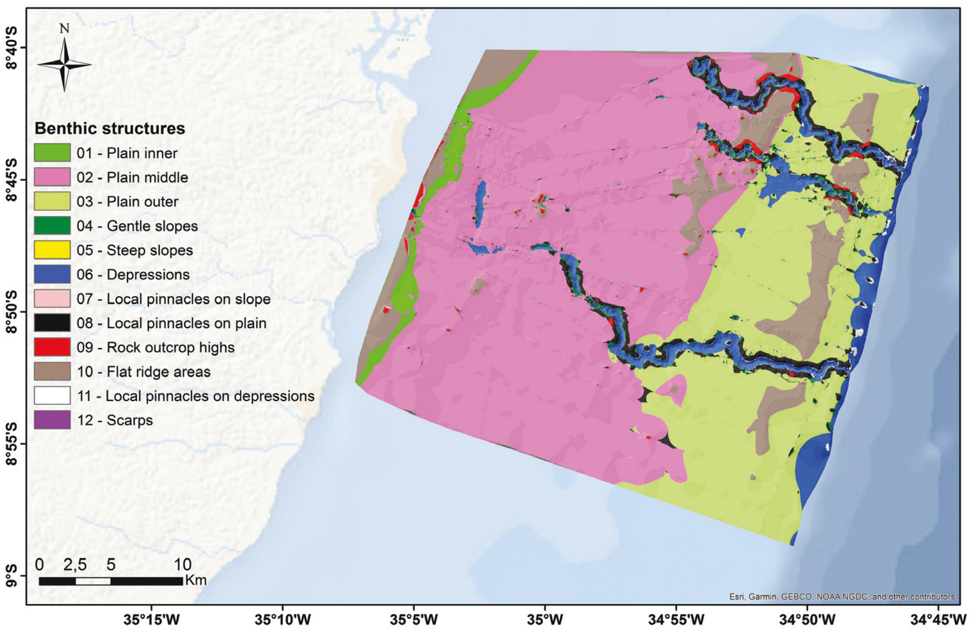

Figure 1. BTM output from the study area

S1O12. Acoustic Characterization of Seabed Sediments Around an Artificial Reef in Pozos Colorados, Colombian Caribbean

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Artificial reefs are used for fish aggregation and also function as marine protected areas, improving the quality of ecosystems. Therefore, it is important to understand the type of habitat around artificial reefs to assess their effectiveness as a conservation measure. The objective of this study was to characterize sediments using acoustics methods around an artificial reef in Pozos Colorados, Colombian Caribbean. A Biosonics DTX scientific echosounder with a split beam transducer of 38 kHz was used. The survey design used coast-parallel and coast-normaltransects, spaced every 25 m. Around the artificial reef, sediment was sampled every 5 m. Analysis of characteristics of sediment type was carried out using Visual Habitat software. A total of 152521 acoustics records were obtained. The depths varied between 1.07 and 48.76 m (mean 12.55 m). In the analysis of bottom types, fine sands showed a 37.9 % frequency, followed by medium sand (21.0 %), very fine sands (20.4 %), coarse sands (18.2 %) and mud (2.6 %). Around of artificial reef the predominant sediment was mud.

S3O8. Observations of a Dynamic Bedform Sub-Tidal Forage Fish (Pacific Sand Lance, *Ammodytes personatus*) Habitat Using a Submersible

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The Pacific sand land (*Ammodytes personatus*) is a critical forage fish for a variety of mammals, birds and fish including minke whales and salmon as it preys upon zooplankton and acts as an energy transfer species from the lower trophic levels to the higher ones. Pacific sand lance (PSL) seeks refuge and overwinters in sand wave fields consisting of dynamic bedforms (Fig. 1). It prefers loosely packed, well-aerated, well-sorted, medium- to coarse-grain sand that it can easily burrow into. Such geomorphic features as active dynamic bedforms provide such preferable habitats for this forage fish and depend on specific and unique oceanographic processes that can maintain the habitat's morphology and grain sizes. Understanding these processes is essential in forecasting alteration or destruction of such features, including changes the may be brought about by sea level rise. Using the five-person submersible *Cyclops* 1, we recently examined a well-studied sand wave field in the San Juan Archipelago of Washington State, USA, which has been reported to at times harbor up to 12 million PSL (Fig. 1). Observations, video recordings, and photography from this vehicle allowed us to

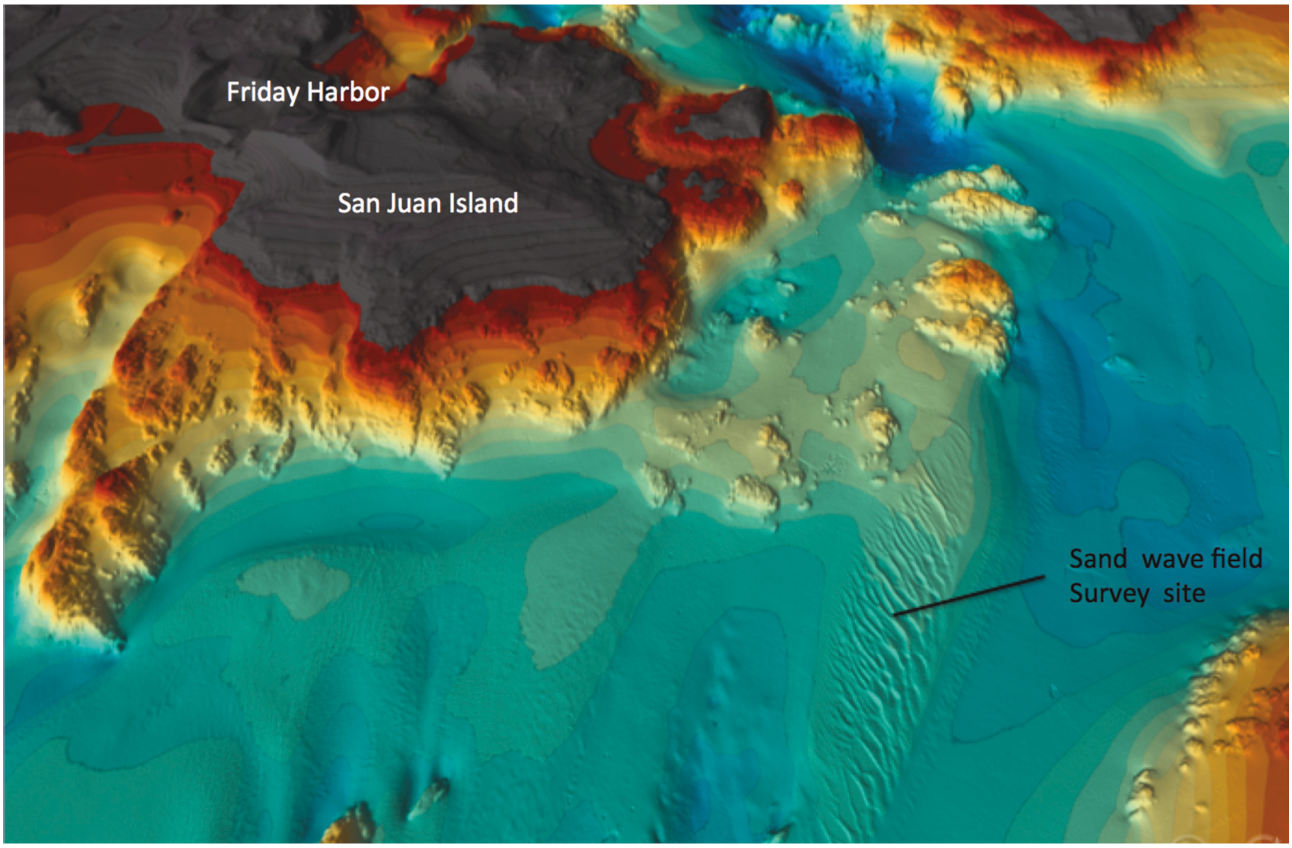

Figure 1. Dynamic bedforms (sand wave field) located in the San Juan Archipelago, Washington State, USA and a sub-tidal habitat for the forage fish Pacific sand lance that was examined using the submersible *Cyclops 1*.

Figure 2. Pacific sand lance exiting their refuge within the sand waves of the San Juan Channel sand wave field as observed from the submersible *Cyclops 1*.

assess modern seafloor processes that can be used along with fish and sediment sample data to determine physical preferences this fish needs to sustain its population (Fig. 2). Changes in the seafloor current regime, sediment source, and anthropogenic disturbances can critically alter a PSL habitat.

S3O9. Permafrost distribution in the Quaternary sediments of the Kara Sea

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In the southern part of the Kara Sea, submarine permafrost has been well studied by geophysical methods [1, 2] and penetrated by shallow drilling. Presence of the frozen strata is assumed from geophysical data in shallow waters, including area around the Taimyr Peninsula. The northern part, in contrast, shows a low preservation of submarine permafrost. As is known, permafrost develops to a greater extent in areas that have not been covered with ice sheets. Near glaciers, permafrost may develop either fragmentarily or completely absent. There are no frozen structures near the edge of the continental shelf around the islands of Severnaya Zemlya. Frozen strata are present in shallow water if they are distributed on adjacent land. It is assumed that poor permafrost preservation in the northern Kara Sea is associated with the expansion of the Atlantic waters. In the south, in shallow water near the Yamal and Taimyr Peninsula, the frozen strata were flooded in the Late Holocene, and therefore their preservation is still significant.

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S1P15. Shallow drilling experience in shallow waters of the Eastern Arctic seas

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VNIIOkeangeologia has a UMB-130 offshore drilling complex (multi-track drilling rig) comprising: ANB-50 drilling pump unit, bottom frame, elevator for lowering and lifting the drill shell, bottom frame winch, winch for the drill shell, PBS-127 drill string, set of core-boring and drilling tools. The UMB-130 complex is manufactured and operated in close cooperation with the Donetsk National Technical University (DonNTU). In 2006, the complex was used for geological surveys in the Chukchi Sea from the sea tug "Shuya" [1, 2]. In 2007 the complex used for Laptev Sea cryolithozone study with the R/V "Ivan Petrov". Wells in the Chukchi Sea have drilled the Holocene marine silts and Neogene sediments (see Fig. 1 below), Laptev Sea wells reached pre-Holocene lake sediments. The experience with this complex showed the possibility and performance of its use for marine geological exploration, especially for the Arctic seas.

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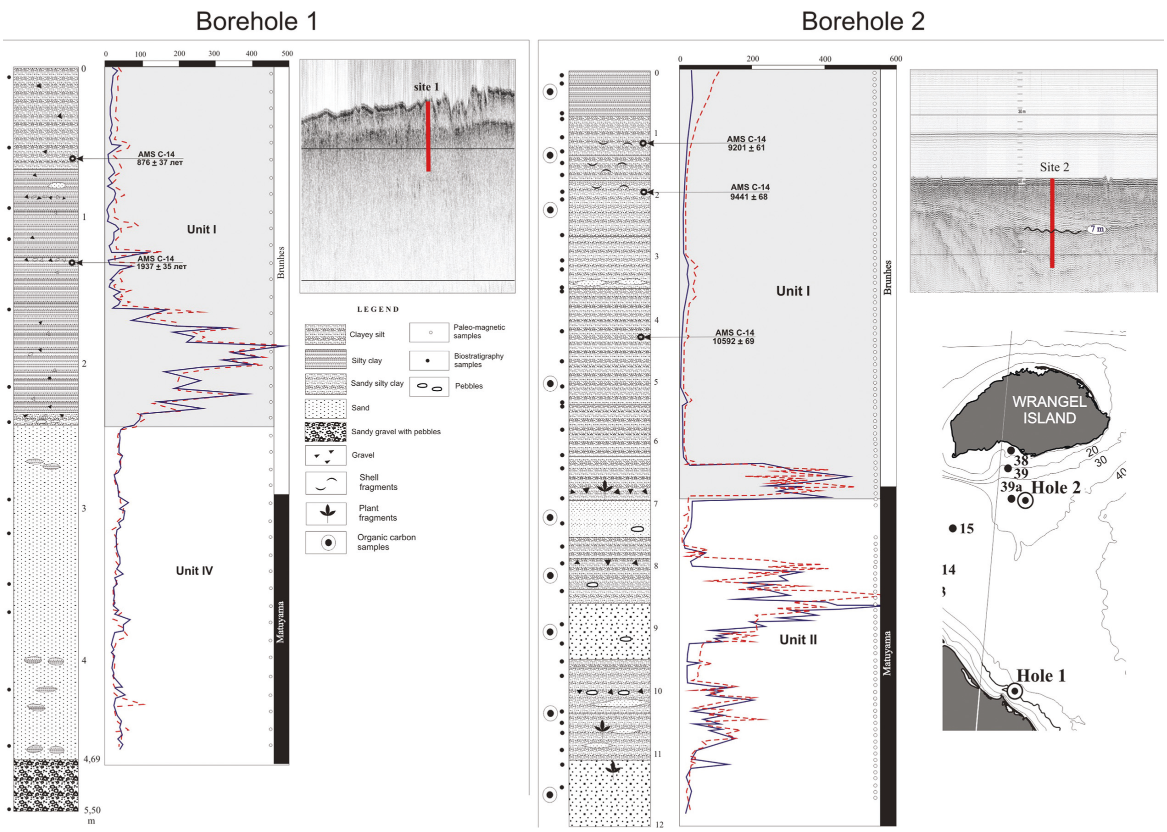

Figure 1. Chukchi Sea boreholes

S6O3. High-Resolution mapping and Remotely Operated Vehicle Observations of the Largest Cold-Seep Barite Deposits Discovered to Date

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During the course of mapping surveys with an autonomous underwater vehicle of the San Clemente Fault, offshore northern Baja California, the largest deposits of cold-seep associated barite documented to date were discovered in the vicinity of the fault. While it is known that smaller barite deposits exist further north along this fault, the present study reveals massive newly found outcrops. The high-resolution maps resolve their small-scale morphology, their large geographical extent and their spatial distribution with respect to the fault. These features, at a depth of 960 to 1300 m, are not detected in bathymetric grids obtained via surface ship multibeam mapping surveys. Detailed bathymetry (1 m × 1 m × 0.25 m grid resolution) was obtained for a 6 km long x 1.9 km wide area intersected by the San Clemente Fault. This previously unmapped morphology consists of numerous closely spaced quasi–circular to elongated mounds of 10–30 m planar dimensions that rise up to 11 m above the surrounding seafloor. This rough topography occupies up to 50 % of the seafloor on a 30–45 m high and at least 1,100 m long ridge, and it is also observed along outcrops of truncated strata elsewhere in the mapped area.

A subsequent remotely operated vehicle dive show that the mounds consist of steep sided blocks of dark-varnished authigenic barite. Active barite precipitation is manifested as white porous friable spires of euhedral to sub-euhedral sub-millimeter weakly cemented crystals, that emerge from the sides or tops of massive older deposits, or as white porous precipitates that fill fissures within blocks of previously deposited barite. The spires coalesce at their base, but branch laterally and upwards culminating into fingers that are topped by microbial mats. The upward thinning spires morphology and microbial mats occurrences atop the spires are consistent with aggradational growth due to precipitation from upward flowing solutions. Live *Lamellibrachia* tubeworms are found in association with the fissure-filling barite precipitates, which occasionally surround and engulf them, attesting to the geologically fast growth rate of authigenic barite in this environment. d^{34}S values of barite sulfate (22.4 to 27.5 ‰) are slightly higher than seawater's value indicating that most sulfate is of seawater origin and that precipitation of barite in the fresh deposits is taking place at or close to the seafloor. ^{87}Sr/^{86}Sr ratios range between 0.708220 to 0.70898, suggesting a contribution of Sr from older marine sediment. The lack of enrichment in metal sulfides argues against a hydrothermal Ba source. Barium budget considerations indicate that the barium inventory in the sediment column down to the bedrock appears to have been sufficient to account for the volume of barium concentrated in the surface barite deposits.

Mapping surveys were also conducted along a shorter section of the San Clemente fault, south of the Navy Fan. In addition, a 9 km^2 area along the San Diego Trough Fault south of the US-Mexico border was mapped and visited in an ROV dive. In the three mapped regions, sub-bottom chirp profiles indicate that barite precipitation occurs where strata, truncated and uplifted by the fault, has thin or no sediment drape allowing for Ba-rich solutions flowing along bedding planes to mix with seawater sulfate at the seafloor interface.

While scattered occurrences of barite have been previously reported in the California Borderland, the massive extent of these deposits is surprising. Moreover, as these mounds at 960 to 1300 m water depth, which are so distinctive in the high-resolution bathymetry, are not resolvable in surface ship multibeam-generated bathymetry (20 m grid resolution), their presence has gone undetected. Thus, the full extent of these deposits remains unknown.

S7O2. Coastal Landscapes and Humans in the Baltic Sea Area during the Holocene

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The Baltic Sea basin and its coasts allow in an exceptional manner to study the effect of climate driven eustatic sea-level change on a non-uniformly governing earth crust in its vertical movement. Glacio-isostatic uplift of the Baltic Shield and parts of the Russian Platform is compensating the climatically controlled postglacial sea-level rise, so that regression, i. e. advancing coastlines, determine the development of (uplifting) paleo-landscapes in Central and Northern Scandinavia. Along the subsiding belt surrounding the Fennoscandian Shield in the South and the Southeast, the eustatic sea-level rise and land subsidence even reinforce each other and lead to transgression, i. e. permanently retreating coastlines so that landscapes along the southern coasts of the Baltic Sea experience continuous inundation starting with the Littorina transgression, ca. 8 ky BP. This inundation has lead to a belt of submerged landscapes accompanying the southern Baltic coast from West to East. Along with permanent flooding, wind-driven waves lead here to coastal erosion and counter-clockwise sediment transport forming the typical sandy spits which separate lagoons from the open sea. These sandy bars have at some places protected the coast against wind wave driven coastal erosion so that in particular in the South-West submerged coasts preserve as “fossil landscapes” the former terrestrial environment keeping the morphological features and remains of vegetation cover. In transition zones between the uplifting North and the subsiding South, the influence of eustatic sea-level rise is replaced stepwise by crustal uplift during the Holocene leading to a change from transgression to regression and correspondingly special coastal landforms which can be studied exemplarily at the Gulf of Finland and Gulf of Riga and in particular at the Estonian coast [2]. Changing climate, coastal processes and differences in the societal response from prehistoric to modern communities are highly correlated in the Baltic area during the last millennia [1]. Since the final retreat of the Fennoscandian ice shield during Early Holocene, hunter-gatherer communities have been living along the respective Baltic Sea shores where they deployed access to marine resources and to fluvial-marine transportation and communication routes [3]. Adjusted to the type of coasts these communities developed different strategies in the response to the changes in the coastal environment determined by climatically controlled eustasy, atmospheric circulation, and glacio-isostatic adjustment. Before the Neolithic revolution — (shift from hunting and gathering to farming societies), the socioeconomic systems were strongly dependent on the shift of coastlines requiring a down-slope migration in case of coastal advance and up-slope when coasts retreated landwards. After the Neolithic shift to farming societies the sensitivity changed to climate-ruled atmospheric parameters such as temperature and precipitation influencing agriculture. Another historical modification refers to the impact of the socio-economic system onto the climate, geo- and ecosystem. Before the Neolithic revolution the societies did just react passively by adjustment of socio-economic parameters to climate variation or changes in geo- and ecosystem. But, the economic and technical development in the course of the Neolithic revolution, later technical developments and finally industrial revolution enabled the humans to influence actively first of all directly the ecosystem by deforestation and agricultural activities and later on the geo-system by coastal constructions and finely the climate driven seal-level rise by greenhouse gas emission.

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O1. GeoHab Atlas of seafloor geomorphic features and benthic habitats — status report and synthesis of the volume

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The second edition of the *GeoHab Atlas of seafloor geomorphic features and benthic habitats* includes 6 revised and updated introductory chapters, 53 case study chapters and a final chapter on synthesis and lessons learned. All chapters have been accepted and forwarded to Elsevier for production of the volume. The case studies covered areas of seafloor ranging from 0.2 to 500,000 km^2 (average of 16,670 km^2) and a broad range of geomorphic feature types. The mean depths of the study areas ranged from 1.5 to 8,000 m, with about half of the studies on the shelf (depth <120 m) and half on the slope and at greater depths.

In terms of environmental condition, there is a skewed distribution of studies across the four naturalness categories with most habitats classed in the "very good" (n = 20) and "good" (n = 24) condition categories. Only 8 studies classified their study area as being in a "poor" condition and none were classified as being in "very poor" condition. The majority of case studies (n = 34) concluded that the condition was steady, eight case studies reported a declining condition and only two case studies assessed the condition of their study area was improving. The confidence of the estimates

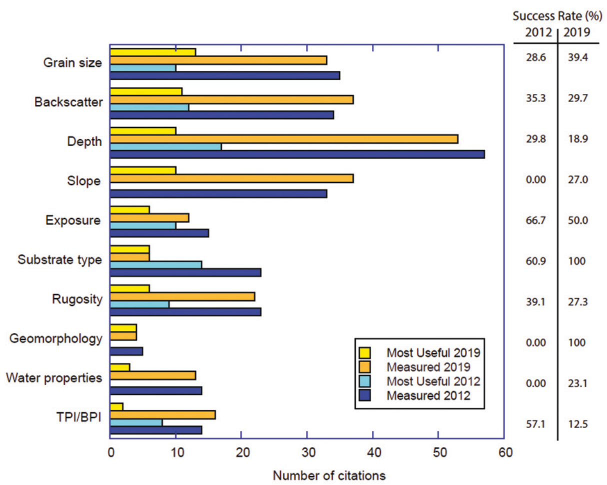

Figure 1. Surrogates measured versus those found to be useful in 2012 and 2019 editions

for condition and trend were more evenly spread between high (n = 15), medium (n = 21) and low (n = 10).

The 53 case studies in the 2019 edition are in addition to the 57 case studies included in the 2012 edition, making a total pool of 110 case studies that can be used for statistical analysis of various aspects of habitat mapping programmes. In the 2019 edition, sediment grain size/composition was found to be the most useful surrogate for benthic communities in the most studies (n = 13), followed by acoustic backscatter (n = 11), water depth (n = 10), slope (n = 10), wave-current exposure (n = 6), substrate type (n = 6), seabed rugosity (n = 6) and geomorphology/TPI (n = 6). These results were very similar to those reported in the 2012 edition, apart from seabed slope, geomorphology and water properties, which were reported to be not useful in 2012 [1] but were found to be useful in 2019 case studies (Fig. 1). The top two surrogates in terms of success rate (percentage of times found to be useful divided by the times measured) are substrate type and exposure, which is the same in both the 2012 and 2019 editions.

Of the many purposes for mapping benthic habitats, four stand out as being preeminent: 1) to support government spatial marine planning, management and decision-making (n = 30); 2) to support and underpin the design of marine protected areas (MPAs; n = 19) and fisheries reserves (n = 10); 3) to conduct living and non-living seabed resource assessments for economic and management purposes (n = 16); and 4) to conduct scientific research programs aimed at generating knowledge of benthic ecosystems and seafloor geology (n = 11). The results suggest that governments and regulators generally view habitat mapping as a useful means of measuring and monitoring change. In terms of the perceived clients and users of habitat maps, most authors considered marine conservation (n = 39) and fisheries (n = 21) to be the biggest users of habitat maps.

A gap analysis (i. e. geomorphic features and habitats not included in the case studies) illustrates that whereas estuarine, shelf, and slope (canyon) habitats are well represented in the case studies, deep ocean (abyssal — hadal) environments were described in only a few case studies. Geographically, about two-thirds of the case studies were from waters around western Europe and North and South America, whilst the margins of the continents of Africa and Asia were not well represented in the case studies (Fig. 2).

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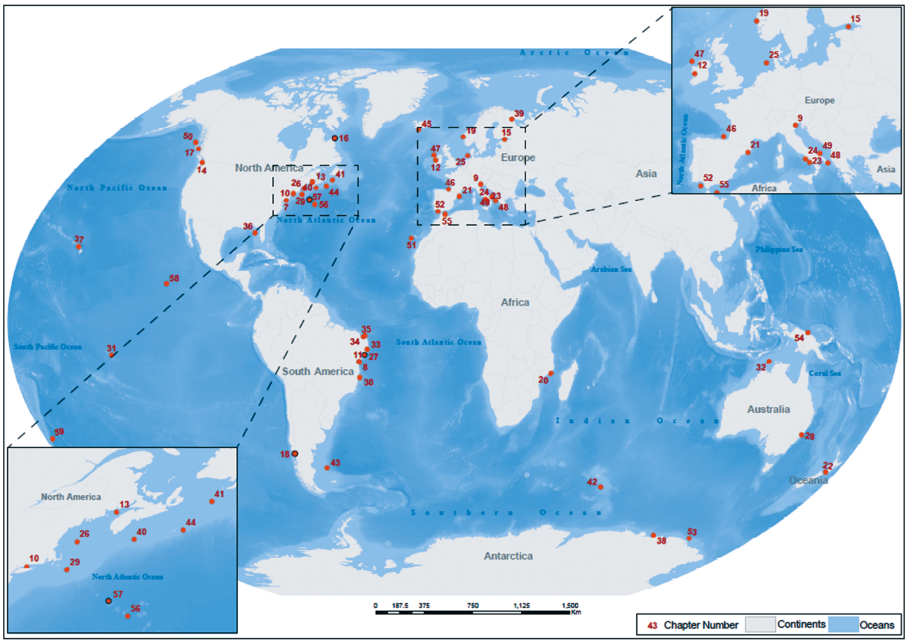

Figure 2. Map of case studies included in the 2019 edition

S1PO5. Morphodynamic processes in the German Wadden Sea (SE North Sea) visualized using time-series aerial photographs

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The Wadden Sea is the largest tidal-flat system on Earth. It stretches along the Dutch, German and Danish coasts of the SE North Sea and harbors a multitude of rare and protected organisms that live in balanced habitat and foodweb systems. However, anthropogenic coastal protection measures and more natural environmental change have already begun to introduce instability into a system that was in a dynamic balance for most of the Late Holocene.

This study focusses on the Sylt/Rømø Basin (SRB, Fig. 1), a 400 km2 tidal basin at the German-Danish border. It is cut off the neighboring tidal flats by man-made dams to the north and the south. To the west, Sylt and the Danish island Rømø form barrier islands that allow the formation of extended back-barrier tidal flats zigzagged by channels. The water depths outside the channels range between 0 and 2 m. As a result, large areas can neither be investigated using boats and ships nor on foot. Hence, aerial photos were used for scientific investigations.

Annual series of aerial photographs allow to observe long-lasting processes such as change of large bedforms and sediments. Even more information allow time-lapse movies produced out of the time-series aerial photographs. The movies not only make even small change very clear, they also provide information on the direction of change and collateral effects.

In the working area 16 years of annual aerial photographs were investigated. The results reveal mobile subaqueous dunes (in this case: large intertidal sandwaves), along-shore and other sediment-transport processes, dynamic change in the position of larger sand bodies and tidal channels. The whole tidal basin reveals import of sand in particular in its shallowest regions. There are areas (sometimes covered with mussel banks) that are increasingly affected by sand that can even be observed to creep upslope -out of the channels- in some places.

The increasing transport of sand along the west side of the island of Sylt into the SRB is very likely related to beach replenishments along the west coast of Sylt that are carried out to fight coastal erosion ever since the 1970ies.

Figure 1. The Sylt/Rømø tidal basin located at the German-Danish border (North Sea)

S8PO1. A Very High Resolution Geomorphological and Habitat Mapping Investigation of the Northern Paleovalley, English Channel (La Manche)

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The causes for Late Quaternary separation of Britain from continental Europe are a debated issue. Researchers have suggested that the opening of the Dover strait was caused by a catastrophic spillover of a proglacial lake ~450 ka ago. The spillover is thought to have caused a megaflood event into the subaerial English Channel that produced a drainage system and erosional features, amongst which the Northern paleovalley [1], [2] is a prominent example. An alternative theory suggests that the breaching and erosion of the region was incremental, as opposed to catastrophic, and thus dictated by fluvial erosion during lowstands and tidal activity at highstands [3].

As part of the ongoing monitoring efforts of Offshore Overfalls Marine Conservation Zone (MCZ), the R. V. Cefas Endeavour collected high resolution multibeam bathymetric (1 m) and backscatter (0.5m) datasets over an area coincident with the Northern Paleovalley (Figure 1). These were ground-truthed against 32 sampling stations, where high definition videography data and Hamon grab sediment samples were acquired. Taking advantage of these new datasets, we aim to investigate the sedimentary and geomorphological features of the Northern Paleovalley in the greatest detail to date, determining the presence or absence of meso and micro geomorphological "forms". These forms may then be correlated to the macroscale studies which have been carried out in the past, helping to further unravel the history of the English Channel [1].

Following on from the detection of microscale and mesoscale forms, we will undertake topographically driven habitat mapping of the paleovalley. These maps will be created using object-based image analysis of both the bathymetry and backscatter datasets, in conjunction with ground-truthed habitat

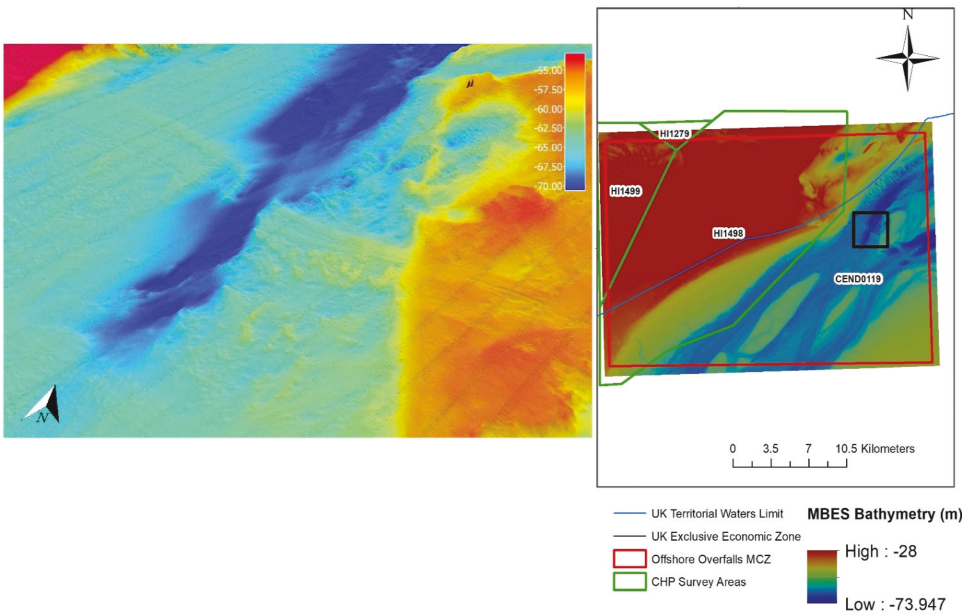

Figure 1. Plate A shows a 3D presentation of portion of the data collected, with Plate B presenting an overview of the whole MBES data collection area (CEND0119 cruise). The blue area in plate A illustrates the central glacio-fluvial drainage channel [1], and the orange-red area to the right is a partial presentation of 'teardrop' island structure. The linear feature running through the image is the Wight-Bray fault [4], trending West to East through the study area

data and predictive modelling using supervised learning algorithms. We will then use these maps to ascertain the relationship between those epifaunal communities observed, and the broad-scale geomorphology present across the paleovalley system.

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S1O13. How to evaluate marine protected areas using GIS -data? — Case study from Finland

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In many cases marine protected areas (MPA) have been established with limited information on underwater environments [1]. During the last decade mapping efforts done along the Finnish coast have considerably increased the amount of species data. Efforts to map human activities at sea and in drainage basins has improved the quality of human pressure data [2]. Recent species and human pressure data allows us to evaluate the effectiveness of Finnish MPA network.

We aim to evaluate marine protected areas by identifying the most important ecological values and analyzing the relevant legal framework. In Finland there are eight often overlapping types of protected areas that differ in protection goals and measures. We have analyzed the legal constraints of each protected area type and connected the regulations to human activities at sea. We use spatial data of Natura 2000 habitats, modelled HELCOM HUB biotopes and species distribution models for individual important species or taxonomic groups. Also, the level of human pressures affecting MPA's are taken into account by cumulative human pressure modelling. We use aerial images to visually detect dredging, jetties, wave breakers and other coastal constructions to complement human activities data. Initial results show a tenfold difference in reported dredging compared with aerial image interpretation.

We evaluate the extent of conservation areas in relation to distribution of ecological values. We calculate per conservation area statistics that include modelled and detected species/biotope occurrences. Also, human pressure index will be calculated for each protected area. We aim to identify the ecological values that are not under sufficient protection in the current MPA network and legislation. Our results will be compared with the Zonation (conservation planning software) analysis recently carried out in Finnish coastal areas [3].

This study will also be the basis for proposing future actions for enhancing the effectiveness of MPA management in Finland. Our experiences can be used in planning field inventories to fulfill the needs of MPA network evaluation process. We hope that our work will serve as an example for the

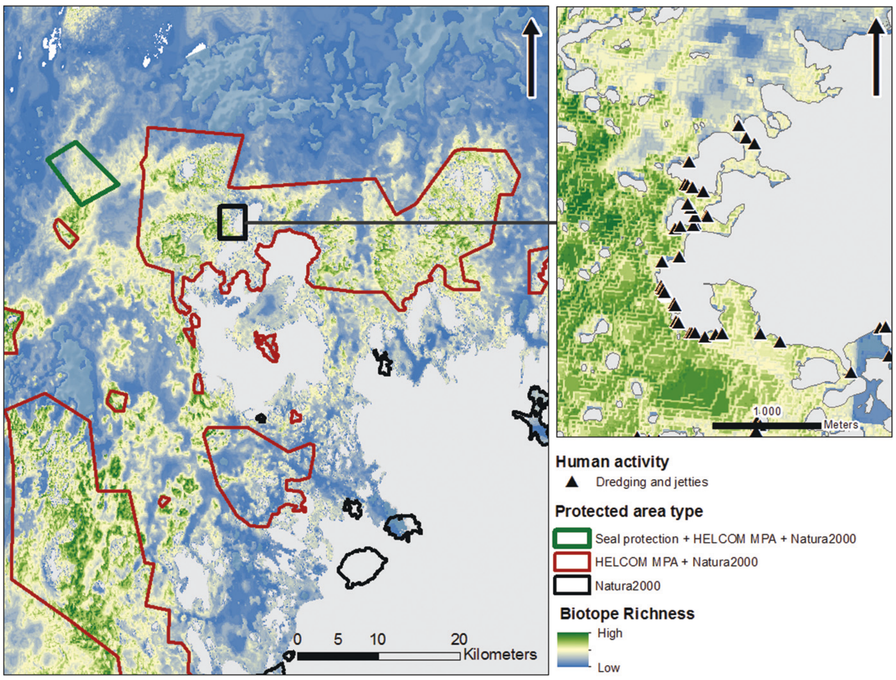

Figure 1. Biotope richness in relation to protected areas and some coastal human activities

international community on how to implement spatial data in evaluating MPA effectiveness.

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A1O14. Citizen Science Drones for monitoring coastal change

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The development and refinement of new technology to address increasingly complex research questions and global challenges for monitoring marine coastal environments (e. g. climate change and biodiversity loss) is increasing rapidly.

Recent advances in low-cost unmanned aerial vehicle (UAV) technology and spatially accurate positioning systems now allow for the collection of centimetre resolution aerial imagery and topography suitable for assessing change in coastal ecosystems [1,2]. The Victorian Coastal Monitoring Program (V cmP) aims to provide communities with information on coastal condition, change, hazards, and the expected longer-term impacts associated with climate change that will support decision making and adaptation planning. Central to the success of the V cmP are the community groups (citizen scientists) working in conjunction with institutions to co-invest in coastal monitoring projects at both regional and local scales.

We present a citizen science coastal monitoring program, integrating low cost UAVs and smart target technology, for high resolution, spatially accurate coastal monitoring. The data collected can be used to assess changes in volume, topography and extent of beach sands and foreshore morphology using structure from motion processing. The program has engaged 14 groups across the state of Victoria that have been provided with training, equipment and support to maintain regular time series of key locations across the state with over 100 coastal datasets collected in the first year of operation. We will discuss the challenges and triumphs of implementing a citizen science drone program.

The data is available to the community groups, land managers, and consultants online in an easy-to-use online portal. The approach allows rapid assessment of changes in the volume, height and extent of sediment and other features without the need for high-powered computers or knowledge of GIS software. We also demonstrate adoption of the citizen science approach for monitoring coastal habitats such as intertidal reef systems. The portal can provide downloadable data as geo-rectified orthomosaics and Digital Surface Models for integration with other GIS software and analyses. To access the data portal, please visit:

Website: https://www.propelleraero.com/
Email: v cmp@deakin.edu.au . . . .

Password: propellerv cmp

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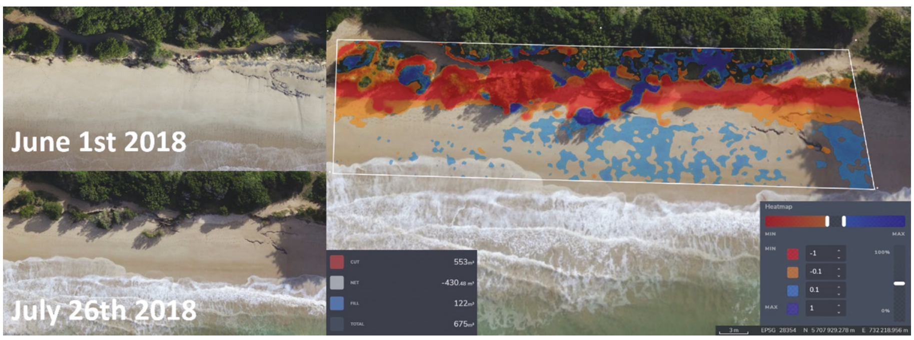

Figure 1. UAV derived coastal change analysis example from the web portal

S3P5. Habitat mapping techniques to assess marine landslide susceptibility in European Seas: preliminary results

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In planning infrastructures addressed at the exploitation of marine energy resources, such as submarine pipelines, extraction wells, or marine current turbines, as well as in the management of policies for submerged areas, knowledge of the seabed is essential. Very detailed studies are required in the design phase, but an overview of the seabed geology can be useful in the programming phase. Bathymetry and slope might be easily available, whereas other relevant data, such as geological structures and events that affect seafloor stability, are difficult to obtain.

The European Marine Observation and Data Network (EMODnet) Project responds to the need of providing freely available harmonized data in European Seas. The EMODnet Geology Lot includes information at different scales, from 1 : 1,000,000 to 1 : 100,000, on seafloor sediments, bedrock layers, coastal processes, geological events and mineral resources which can be downloaded from the dedicated Portal (http://www.emodnet-geology.eu).

As leader of the workpackage "geological events and probabilities", the Geological Survey of Italy is elaborating a model to assess the qualitative probability (or susceptibility) of occurrence of a hazardous event. The first step has been a landslide susceptibility test.

To date, several models have been tested for the study of the susceptibility of landslides; however, almost all of them concern land areas of limited extension, where important variables for modelling, such as lithology, distance from faults, land use and vegetation index, could be easily obtained [1] [2] [6]. In the case of the map of susceptibility of European seas the extension of the area, the difficulty of seabed surveying, and the lack of a homogeneous and distributed knowledge on key parameters such as lithology and presence of faults, has limited the model to the use of bathymetry, from the EMODnet Bathymetry Portal (http://www.emodnet-bathymetry.eu), and morphological parameters that can be extracted from it.

A well-known statistical methodology for habitat mapping was chosen for this study: the maximum entropy modeling, for which an open source software (MAXENT) developed by the Center for Biodiversity and Conservation at the American Museum of Natural History [5] is available. MAXENT works with presence-only data, i. e. with sighting data of specimens of the studied species, and with a set of environmental layers which, in the case of marine habitat mapping, are generally bathymetry and associated morphological parameters. In our case, the presence data used were derived from the inventory of underwater landslides at 1 : 250,000 scale of the EMODnet Geology Project. The original inventory contains 2,963 features subdivided into points, lines and polygons which, after selection and transformation operations, generated a presence dataset of 2,428 landslides distributed across all European seas. Eighty-five percent of this dataset was used for model training, while the remaining 15 % was used for testing. A set of 31 environmental layers, at different spatial scales, was generated using bathymetry, and 50,000 background points were extracted from this set to be used to train the model. The environmental variables were then subjected to an interactive selection process, which took into account their collinearity and their actual contribution to the model. As a result of the selection, it was decided to maintain only the two variables with the largest contribution to the model: slope (contribution of 81.7 %) and bathymetry (contribution of 18.3 %). Statistics show that the model, with an Area Under the Curve (AUC) of 0.91 for both training and test data, performs much better than the random prediction (AUC = 0.5) and that the test data confirm the model's prediction of accuracy.

The output of the model, an estimate of the probability of occurrence from zero to one [4], was classified with a threshold value obtaining a map with two values: susceptible/non-susceptible to landslides (Figure 1). The threshold value chosen is the one that maximises training sensitivity plus specificity [3], corresponding to a percentage of the area predicted as susceptible equal to 18.8 % and to an omission rate (landslides not predicted), calculated on the test data, equal to 13 %.

Although the map still needs to be analyzed in detail, and the model still needs a tuning phase, it is possible to see that it is consistent with the inventory of landslides of EMODnet Geology, and

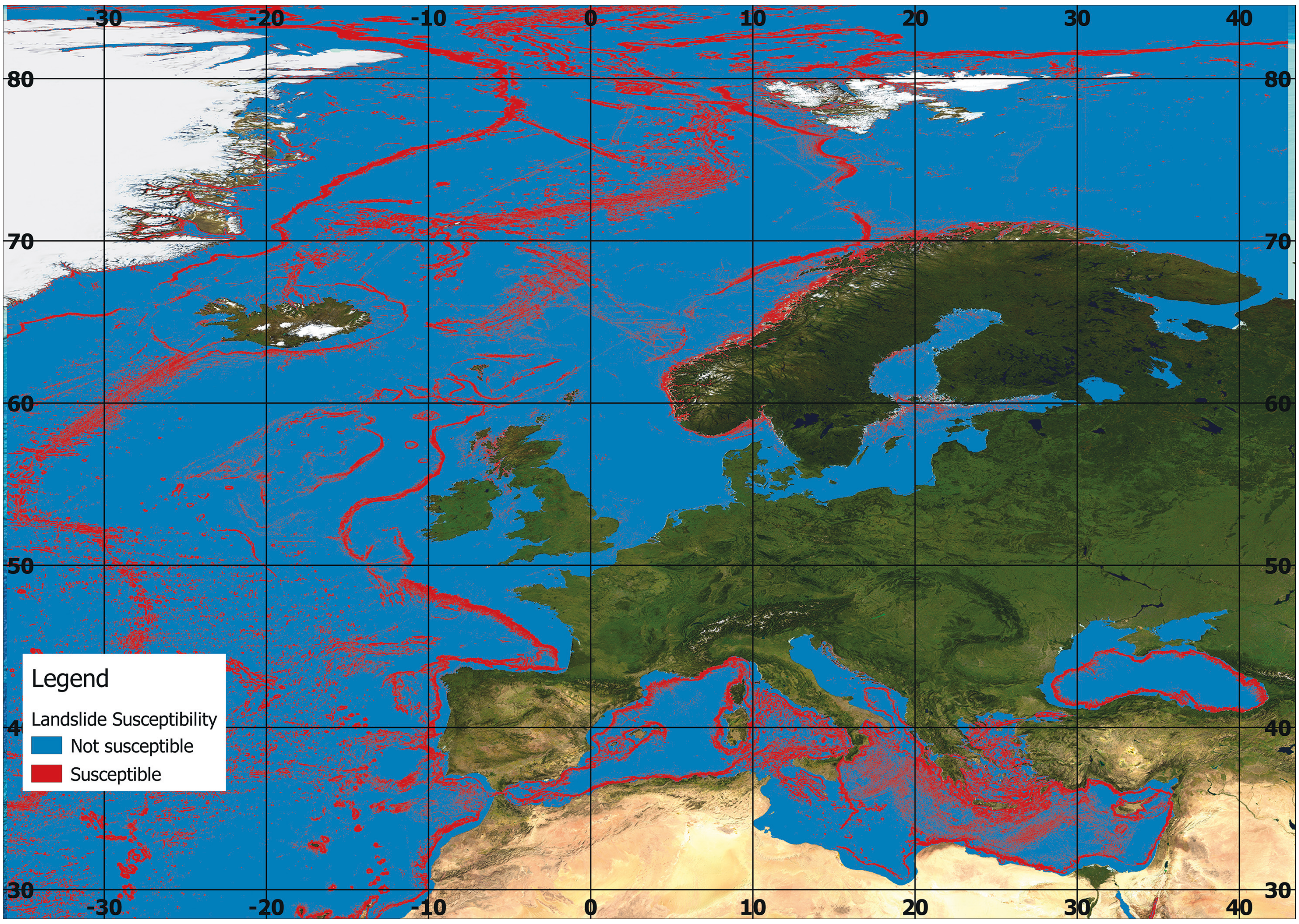

Figure 1. Landslide Susceptibility Map

correctly identifies the largest structures that can generate landslides. Once published on the EMODnet Geology Portal, the susceptibility map of submarine landslides will provide an innovative tool to be applied in the planning of operations on the seabed, such as infrastructures necessary for the exploitation of marine energy resources.

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S1O15. Benthic Habitat Mapping of the Rowy Site in the Southern Baltic Sea Based on Multi-Frequency Multibeam Echosounder Dataset

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Benthic habitats of shallow euphotic zones in the nearshore areas may be recognized and determined based on measurements from multibeam echosounder systems. Especially recently developed equipment allows acquiring high-resolution data in the shallow water environments [1, 2]. This study presents results of predictive benthic habitat mapping based on multibeam echosounder data and ground truth samples. Hydroacoustic data were collected at two working frequencies using a multibeam echosounder NORBIT iWBMS (model STX). Ground truth samples included sediment grabs and underwater videos from ROV. The main goal of this study is determination of different properties of backscatter intensity for classification of benthic habitats in the southern Baltic Sea utilizing image processing, including statistical and textural features of multi-frequency multibeam echosounder data. Developed semi-automatic workflows allowed to recognize high biodiversity and determine six classes of benthic habitats within the Rowy site. Some of them, such as red algae on a boulder substratum have a unique value within the Polish coast of the Baltic Sea. The method presented herein benefit from pixel-based and object-based approaches of image processing. In this study were utilized 35 secondary features of multibeam bathymetry and backscatter for each frequency. Four methods of supervised classification were tested and evaluated giving good results of accuracy assessment. Two results performed well for specific classes of habitats, so they were combined increasing overall and kappa accuracy statistics [3]. This study shows, that performance of multi-frequency multibeam echosounder dataset with a proper selection of secondary features may be significantly higher in comparison with a single-frequency multibeam echosounder dataset.

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P2. EMODnet Geology marine minerals data for European seas as an indication of associated endemic species dispersal

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The European observation and data network comprises eight active lots that collect marine environmental data and make these data freely available online. One of the eight environmental themes, Geology, contributes to understanding historic and current marine geology environments and events. These include: seabed substrate, geology and geomorphological features on the seabed, costal behaviour, geo-hazards, drowned landscapes, marine minerals, raw materials and hydrocarbons on and beneath the seabed.

EMODnet Geology has reached the end of its third phase. Over the course of eight years, the project has grown significantly. Together partner agencies have successfully collected and standardised marine geological information across all European Sea basin areas. Geological data and information have been systematically harmonised by thematic work-package leaders into data products. All data products have been made available through the EMODnet Geology open source web portal. Data products continue to evolved and diversify. Here we show that information on marine mineral occurrences can also be used as a proxy for locating certain habitat types.

It has been well established that mapping and understanding seabed substrate is an important factor in habitat mapping. So to is identifying processes like hydrothermal venting, that result in mineral accumulations on the seabed. As these environments also sustain unique endemic biological environments. EMODnet Geology Minerals data maps 12 different types of marine minerals, some of which are identified as unique habitats. By mapping these we can map the geographical dispersal of endemic marine habitats related to known mineral occurrences in European Sea Areas.

S3PO2. Initial results from TOSCA, the first detailed geological and biological survey of the Charlie-Gibbs Fracture Zone Spreading Centre

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The oceanic crust forms about 60 % of the Earth's solid surface and is largely generated by volcanic activity at mid-ocean ridges. Segmentation of the mid-ocean ridges results in strike-slip motion that is accommodated at seismically active conservative plate boundaries called transform faults. These fundamental structures dissect the Earth's crust, segment the mid-ocean ridge system and form bathymetric scars that connect the margins of every ocean basin. Little is known about how transform faults form, accommodate plate motion, affect the nature of the oceanic crust and interact with seawater. Once considered simple strike-slip faults, we now recognise transform faults as key components in the evolution of the oceanic lithosphere and in shaping the Earth's surface.

The research expedition Tectonic Oceanic Spreading at the Charlie-Gibbs Fracture Zone North East Atlantic (TOSCA) took place in 2018. A targeted high resolution multibeam, seismic reflection profiling, gravity coring, ROV media and physical sampling campaign; TOSCA successfully surveyed an area comprising the short order spreading centre between the Charlie-Gibbs double fracture zone. Including highs to the east and west where huge variations in elevation within the relatively confined survey area accommodate a range of geomorphology, habitats and conduits for oceanic current circulation.

Here, we report initial results from the TOSCA survey on the largest transform fault zones in the North Atlantic, the Charlie Gibbs Fracture Zone. Where, in contrast to crust generated by normal seafloor spreading, we find the sea floor between the double transform faults is devoid of volcanic material. Instead, it is formed by tectonic uplift, serpentinisation and exhumation of mantle rocks. We hypnotise that intrusive isolated plutons of magma are simultaneously being deformed and metamorphosed by high-strain ductile shear. Relocation of detachment faulting and extensional rifting between the transform faults, results in a line of massifs that extend across the North Atlantic. We propose that this process of crustal accretion is common within oceanic transform faults. Significant chemical and thermal exchange between the ocean and crust results in metal accumulations and methane release. Evidence shows a thriving deep-sea benthic habitat close to the Charlie-Gibbs North High Seas OSPAR MPA where the seabed and the subsoil remain unprotected.

S4O1. Distribution and drivers of ferromanganese concretion bottoms in the Baltic Sea

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Ferromanganese concretions are found on soft sediment bottoms both in the deep sea and coastal sea areas. Due to containing high concentrations of iron, manganese, phosphorous, and rare earth elements, the economic resource potential of these seafloor mineral deposits has attracted attention for decades. Despite their widespread occurrence in shallow sea areas, considerably more research effort has been invested into studying deep-sea nodules, probably because shallow water concretions have been considered both geochemically and economically less interesting. While mineral concretions are known to exist in many parts of coastal sea areas, specific information on their spatial coverage, and significance for marine ecosystems is still lacking. However, as ferromanganese concretion bottoms are included as a habitat type in the HELCOM underwater biotope and habitat classification system for the Baltic Sea, information on their spatial extent is needed to further examine their role for marine ecosystems.

In this work, we estimated the spatial variability and potential drivers of FeMn concretions in Finnish marine areas in the northern Baltic Sea. We used an extensive data set (~150,000 observations) collected in the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). This data forms an exceptional basis for understanding the occurrence of FeMn concretions in shallow shelf areas. Our aim is to provide new insights into the spatial extent of FeMn concretion bottoms and further examine their ecological importance as a potential habitat type.

S1O16. Mapping and classification of habitats in the Mediterranean Levantine Basin based on combined biotic and geomorphological methods

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Israel's Ministry of Energy recently re-opened Israel's Exclusive Economic Zone (EEZ) in the Mediterranean Sea for oil and gas exploration activities (approximately 26,500 km^2 at water depths up to 2100 m). This was based on a Strategic Environmental Assessment (SEA) for which habitat mapping of the EEZ was required. The chosen methodology relied on combining two approaches. The biotic approach used taxonomic assemblage characteristics of the faunal communities, while the geomorphological approach used visual observations, morphological and geophysical analysis of the seafloor, to define habitat or biotopes boundaries.

This presentation concentrates on the hard substrate habitats and their spatial extents, which were determined using geo-morphological and geophysical methods. To that aim, we combined observations from several methodologies: direct observations (diving and ROV robot surveys); high-resolution aerial photography; high-resolution multibeam bathymetry and backscatter; GIS surface analysis and shallow seismic data.

Results are a map and a GIS layer of 65 habitats of the Israeli EEZ based on the compilation of the soft and hard substrates using both the biotic and the geomorphological approaches. The habitat map is a dynamic updating database: definition of new habitats and re-evaluation of existing habitat boundaries are under routine update based on newly acquired data from verified sources (e. g. newly published studies, ROV dives, seafloor sampling, monitoring activities).

The compiled habitat maps have been formally adopted by other authorities in Israel as the basis for government-based maritime activity and planning (Ministry of Interior, Nature and Parks Authority and others). This development of a multi-method mapping of the EEZ habitats have had an outsize importance on the economic and marine environmental policies of Israel's government.

S1PO6. Habitat suitability modelling of sessile organisms by photogrammetry on the subtidal rocky shore in Otsuchi Bay, Japan

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Sessile organisms are main components of biotic communities in subtidal rocky shores. However, terrain conditions favorable for sessile organisms has not been assessed on the subtidal rocky shore. The purpose of this research is to construct the fine 3d models of rocks by photogrammetry, and to elucidate the relationships between terrain attributes of rocks and the distributions of dominant sessile organisms, a barnacle *Balanus trigonus* and an ascidian *Halocynthia roretz.*

A field survey was conducted on the subtidal rocky shore in Otsuchi Bay on November 11, 2018. 100–200 photos and videos were taken at each of five rocks of approximately 3×3 square meters from various angles by scuba-diving. The point cloud models were obtained by Sfm photogrammetry algorithm and converted to the mesh models. The data of the positions of *B. trigonus* and *H. roretz* were put into the 3d mesh models. On each mesh of the 3d models, the four terrain parameters concerning rock surface were calculated: height from the surrounding meshes, slopeness, orientation and roughness of surface.

Five 3d models for the rocks were obtained with the millimeter scale resolution, and organisms with about 1 cm in diameter could be distinguished in the models. However, some surfaces on the gutters and the underside of overhangs were not restored to the 3d models. The distributions of *B. trigonus* and *H. roretz* were largely overlapped. Response curves of variables by Maxent model suggested that the influence of height from surroundings and orientation on the distributions of both species were larger than slopeness and roughness. Specifically, those two species were highly associated with the high position and shore-facing orientation of the rocks. This indicates that the distributions of the two species may relate to the food availability; current velocity is higher on the upper side of the rocks and backside face against wave direction, resulting in a large supply of suspended particles.

The present study demonstrated the usefulness of the fine 3d models for analyzing the relationship between terrain attributes and the distribution of sessile organisms.

S1O17. Mapping geomorphological features and seafloor sediments on the Western Estonian Shelf

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Estonian Maritime Administration (EMA) is regularly implementing routine hydrographic surveys within Estonian territorial waters. Since 2012, research vessel Jakob Prei has surveyed more than 10 000 km^2 mostly in the Western Estonian Shelf area using Teledyne Reson 7125 SV2 multibeam sonar. Over 40 000 km of seismo-acoustic reflection profiles have been recorded alongside the bathymetric data using 2–9 kHz high definition chirp sub-bottom profiler made by Meridata company, Finland. Conducted to at least IHO S44 survey order 1a, this high resolution multibeam data is being used primarily for navigational and cartographical purposes to ensure the safety of shipping.

The bathymetric data analysis was carried out in an open-source software SAGA GIS based on a grid size of 5 m. Utilizing various morphometric methods including calculation of slope and topographical position index revealed previously undescribed bottom details, such as ice-keel ploughmarks, drumlin fields as well as other seafloor glacial landforms. Combined with seismo-acoustic reflection data this has resulted in a major improvement over previous geomorphological mapping efforts.

A dense network of collected seismo-acoustic reflection profiles will furthermore enable to identify sediment acoustic units along with their spatial extension and thickness, as is formulated in research aims of an ongoing doctoral project. This will hopefully become a significant step towards a systematic Baltic Sea basin-wide stratigraphic classification.

S1P16. Challenges of border crossing marine underwater inventories in very shallow coasts — case study from the Northern tip of Bothnian Bay

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Marine species and habitat inventories have been systematically conducted since 2007 in the northern Bothnian Bay on the Finnish side in a national inventory program (VELMU). On the Swedish side, no systematic inventory of underwater nature has been conducted. Now both countries are working on their national marine spatial plans, but The availability of data is sparse as well as co-operation between the countries

The northern part of the Bothnian Bay is divided between Finland and Sweden, but only the border river Tornio is managed jointly. The area shares an archipelago with two marine national parks and a multitude of similar challenges. The area is very unique and rich in biodiversity and the nature values are high. At the same time, there are a multitude of human pressures and challenges to consider. The species move and human impacts spread throughout the area indifferent to administrative borders.

In order to manage the joint sea area in a sustainable and knowledge-based way, a co-operation project, Seamless Mapping and Management of the Bothnian Bay (SEAmBOTH) was started with Finland and Sweden as partners (2017–2020). In the project we combine pre-existing data, conduct additional biological and geological surveys and harmonize methods, habitat classifications and nature value interpretations. The aim of the project is to create seamless maps and models which cover the whole project area. The end products of the project can be used for managing the sea area in a sustainable way on both sides of the border.

The cross-border cooperation and joint management of sea areas is an everyday issue in many countries. The best practices and methods from this project can benefit cross-border cooperation around coastal countries anywhere.

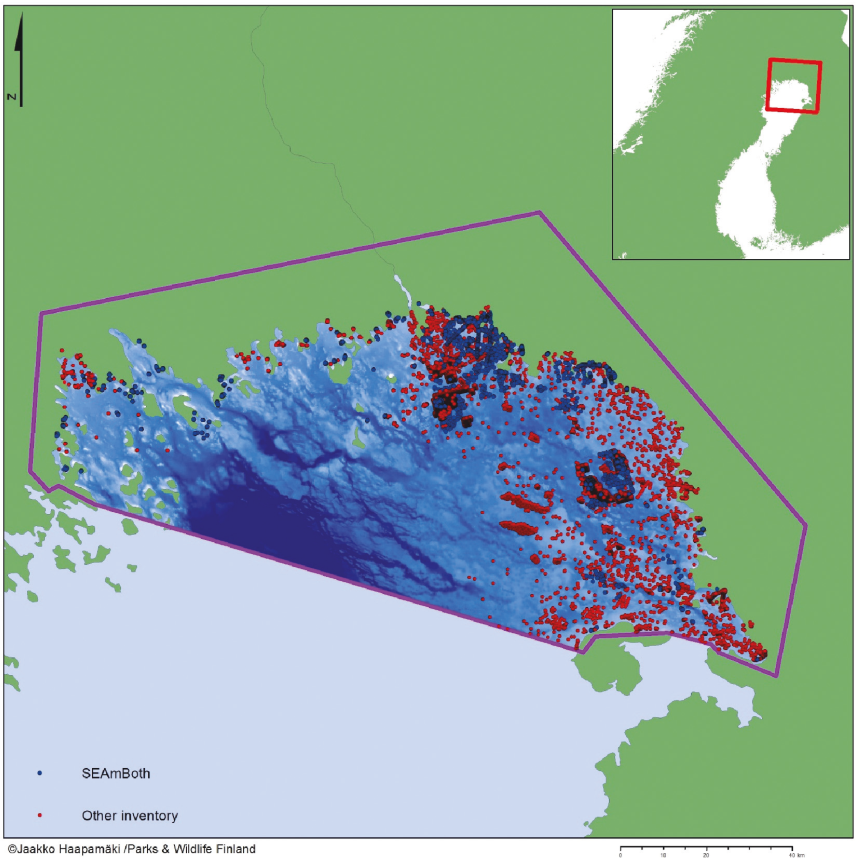

Figure 1. Biological underwater inventory points collected at the SEAmBOTH project area in the northern tip of the Baltic Sea. The area is divided between Finland and Sweden. Blue sample points were collected during the two years of project and red inventory points represent national or other inventories in the area (Jaakko Haapamäki, Metsähallitus)

S1O18. Rapid Coastal/Shallow-Water Mapping with World's First Airborne Multibeam Bathymetric Lidar Mapping System

Rada Khadjinova, Don Ventura

Airborne lidar bathymetry systems have helped streamline coastal and shallow water mapping programs throughout the world. Despite the technology's advantages, however, contemporary systems have long been challenged to meet the data density and point accuracy requirements of many government agencies. Relatively high-energy output systems have sought to penetrate the water column sufficiently to create useable coverage to a depth where traditional acoustic technology can achieve parity in terms of efficiency (swath width) and cost per unit area. In so doing, they have typically created data densities that do not meet International Hydrographic Organization (IHO) standards for target detection on an initial pass and therefore fail to meet IHO Order 1a criteria. The advent of the lightweight 'topobathy' systems, combining the 532 nm green laser of a bathymetric system with a topographic lidar design approach (low-power output, high density data), partially addresses some of the limitations of the 'deepwater' systems but at the expense of water penetration and consistent coverage, making their utility limited in areas of marginal water clarity and variable bathymetry. Fugro has sought to address these limitations and, in partnership with system manufacturer Arete, has adopted a completely new design paradigm and created the world's first multibeam bathymetric lidar, the Fugro Rapid Airborne Multibeam Mapping System (RAMMS). RAMMS is now an operational system and realizing the design goals which were set to attain accurate bathymetric data at a density exceeding that required to achieve IHO Order 1a and the associated target detection criteria. This presentation describes the benefits of this technical approach, how it differs from contemporary bathymetric lidar technology and the considerable advantages it provides to the enduser.

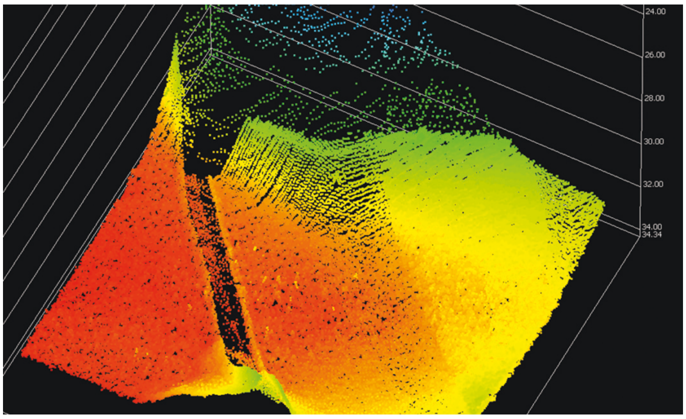

Figure 1. RAMMS data overlying SHOALS (2.5 KHz)

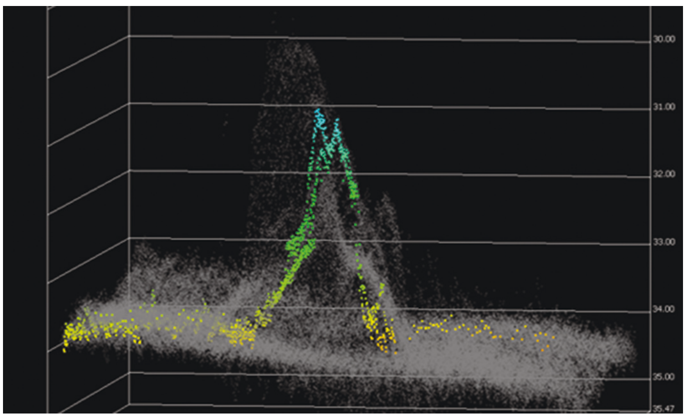

Figure 2. RAMMS point cloud (grey) vs. SHOALS on target feature

P3. Multiscale seabed substrate data for European Seas — EMODnet Geology

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Seabed substrate is one of the key elements shaping the physical structure of benthic habitats. Thus seabed substrate data is essential for various purposes including marine management, conservation and research. With increasing marine and coastal anthropogenic activities, and resulted threats/challenges, there is urgent need for easily accessible and reliable data on marine environment.

The EMODnet (European Marine Observation and Data network) Geology project collects and harmonises marine geological data from the European sea areas to support decision making and sustainable marine spatial planning. The partnership includes 39 marine organisations from 30 countries. The partners, mainly from the marine departments of the geological surveys of Europe (through the Association of European Geological Surveys-EuroGeoSurveys), have assembled marine geological information at different scales from all European sea areas, which have been compiled together within three, subsequent projects running since 2009. European countries have traditionally conducted their marine geological surveys according to their own national standards and classified seabed substrates on the grounds of their national classification schemes. These diverse, national clas-

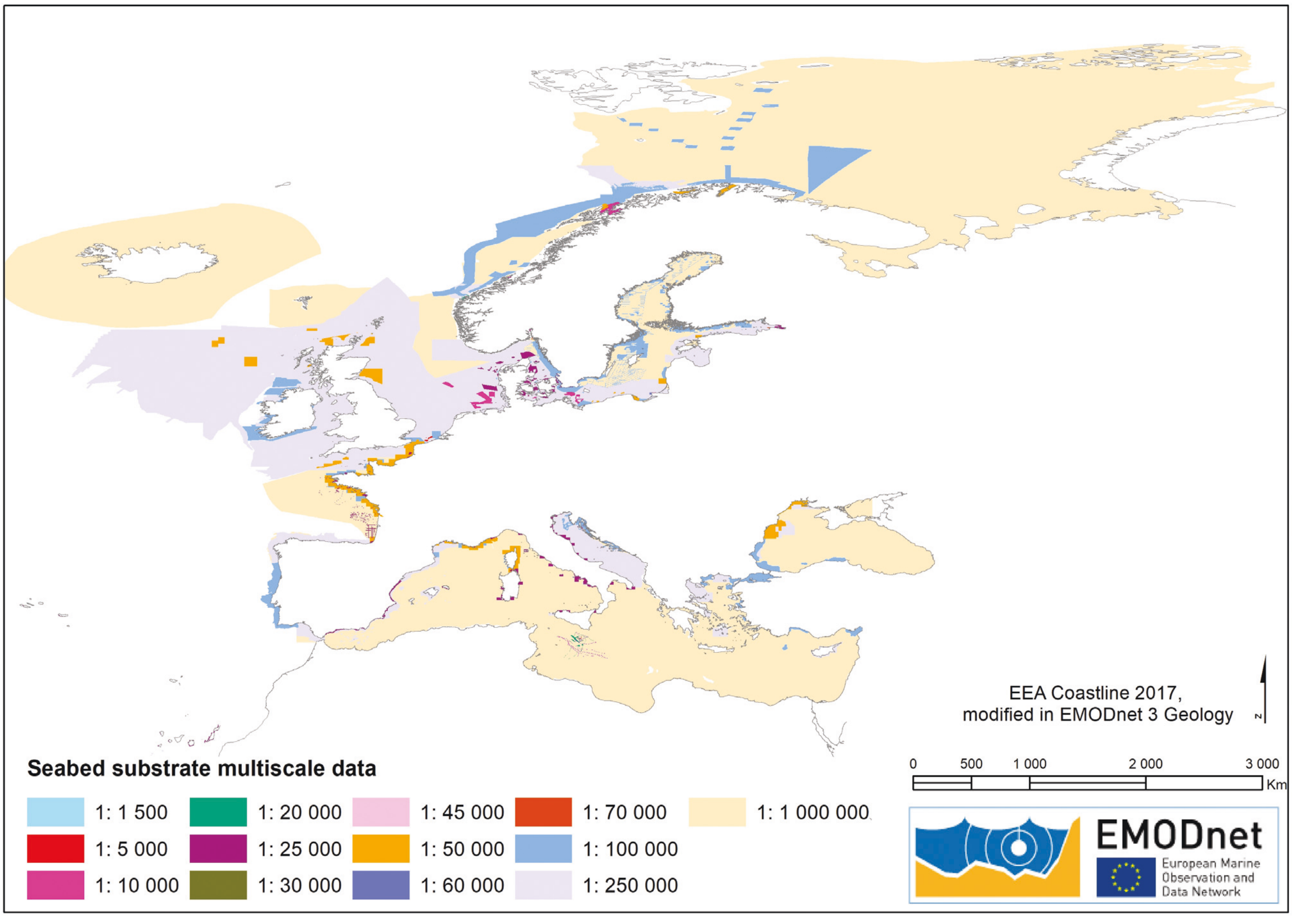

Figure 1. EMODnet Seabed substrate multiscale data coverage

sifications are harmonised into a shared EMODnet schema using Folk's sediment triangle with a hierarchy of 16, 7 and 5 substrate classes. The data tells the seabed substrate composition from the uppermost 30 cm of the sediment column and where necessary, the existing seabed substrate classifications (of individual maps) have been translated to a scheme that is supported by habitat mapping initiative, EUNIS.

The latest EMODnet 3 Geology project started in 2017, and it collects data at 1 : 100 000 scale or finer. The gathered fine scale (more detailed than 1 : 100 000) seabed substrate data vary between 1 : 1 500 and 1 : 70 000, but data at 1 : 25 000 and 1 : 50 000 scales are the most common (see Fig. 1). This high resolution data includes 11 different scales and their coverage is fragmented. Here we present the first version of EMODnet seabed substrate multiscale product that was published in the spring 2019. The multiscale dataset include EMODnet seabed substrate maps at scales of 1 : 50 000, 1 : 100 000, 1 : 250 000 and 1 : 1 000 000. The smallest cartographic units within the dataset are 0.01 km^2 (1 hectare), 0.05 km^2 (5 hectares) 0.3 km^2 (30 hectares) and 4 km^2, respectively.

The small scale (i. e. broad scale) data describes the seabed substrate at a general level only making it suitable for the decision-making, research and large-scale marine spatial planning. More detailed scale data, however, are needed for planning local constructions like wind farms or dredging, as well as for habitat mapping purposes. Detailed data also enables the recognition of areas with great seabed diversity, and provides the important, specific information on the features easily lost in broader scales. On the other hand, it is possible to produce coherent, more general data for the large scale planning on the basis of the more detailed one. Multiscale dataset helps to highlight the sea areas with the largest data gaps and provides available and the most suitable data on the spot, at different scales for different purposes. EMODnet Geology data products are available via https://www.emodnet-geology.eu/_.

The European Marine Observation and Data Network (EMODnet) is financed by the European Union under Regulation (EU) No 508/2014 of the European Parliament and of the Council of 15 May 2014 on the European Maritime and Fisheries Fund.

S1PO7. Benthic landscape mapping of submerged end-moraine ridge slope in Vyborg Bay (Eastern Gulf of Finland, Baltic Sea) based on multibeam echosounder dataset

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Bottom relief of the Eastern (Russian) part of the Gulf of Finland (Baltic Sea) is generally relatively smooth. The most dissected bathymetry and, consequently, the highest geodiversity are observed in the areas of submerged glacial features development. One of such area located in Vyborg Bay was studied using a multibeam echosounder (MBES) (Teledyne RESON Seabat 8111-E208–3F66 Dry MBES system) and EdgeTech 3300-Hm sub-bottom profiler (with Discover Sub-Bottom v3.36) during the cruise of the R/V *Academic Nikolaj Strakhov* (19–25 of July 2017). Thirty-nine lines of MBES and SBP tracks (total length is 164 km) were run to provide coverage of 9 km^2. Data collection and primary processing were undertaken using the PDS2000 v3.7.0.47 processing software. Geological sampling and submarine video survey within study area were undertaken by VSEGEI in 2018, using box-corers and gravity corer (15 sites). Biological sampling was conducted in frame of 43-rd cruise of the R/V *Academic Boris Petrov* (July-August 2018). Samples of macrobenthos were made with a Van-Vin grabber (18 kg additional loads, capture area 0.1 m^2). Samples were washed with seawater from a circulation pump on a capron sieve (0.4 mm mesh size). Large or fragile organisms were removed immediately during washing to avoid damage and fixed. The residue from the sieve was fixed with buffered 4 % formaldehyde. Animals were identified to the species or group level with stereomicroscope Motic SMZ 143, numbered and weighted using the VT-500 torsion balance with an accuracy of 0.0005 g. (wet weight). Compilation of benthic landscape map was undertaken using same principles as described in [2, this volume]. Study area is characterized as mesohaline (salinity 5–7.5 per mill), it is exposed to wave impact, but the bottom surface are located beneath the level of wave impact (10 m) as well as beneath photic zone (0– –6 m).

Bottom morphology of study area controlled by the >4300 m long curved relatively high (10–20 m) and wide (70–200 m to 300–1000 m) ridge, oriented roughly NE–SW to SE–NW (65° to 100°) with the steeper (10° dipping) southern and gentler (3–4°) northern slopes interpreted as an end-moraine; and several the 1000 m long, 100 to 170 m wide and 15 to 20 m high SSE–NNW (160°–170°) oriented elongated linear oval-shaped ridges interpreted as streamlined moraine ridges and classified as drumlins [1]. Tops of submarine ridges (depth <20 m, wave and current impact high energy) are composed mainly on boulders, biological information (Mussels+Barnacles+Polyps+vagile invertebrates) from these habitats received just from analyses of videosurvey.

Mixed substrates (silty-clayey mud with high content of sand particles, gravel and Fe-Mn nodules) on the moraine ridges slopes and peripheral areas of sedimentary basins (depth 20–45 m) are the most favourable for the benthic invertebrates (with total abundance of 1350–5350 ind./m^2 and biomass of 17.6–120.5 g/m^2). Macrozoobenthos here is the most diverse and contributed by — alien *Marenzelleria arctia* (Polychaeta) and aborigine species: *Monoporeia affinis* (Amphipoda), *Saduria entomon* (Isopoda), *Limecola balthica* (Bivalvia), *Gammarus zaddachi* (Amphipoda), Oligochaeta, *Jaera albifrons* (Isopoda). It is interesting to mention that the highest benthic animals's abundance (4600–5350 ind./m^2) corresponds to the areas of active growing Fe-Mn concretions.

Clayey mud substrates of low energy oxic areas of sedimentary basins (> 45 m) are characterized by low abundance and biomass of macrozoobenthos represented by two species — *M. arctia* and *S. entomon*. The lowest total macrozoobenthos abundance (60 ind./m^2) and biomass (0.06 g/m^2) are observed in anoxic areas and contributed by *M. arctia* only.

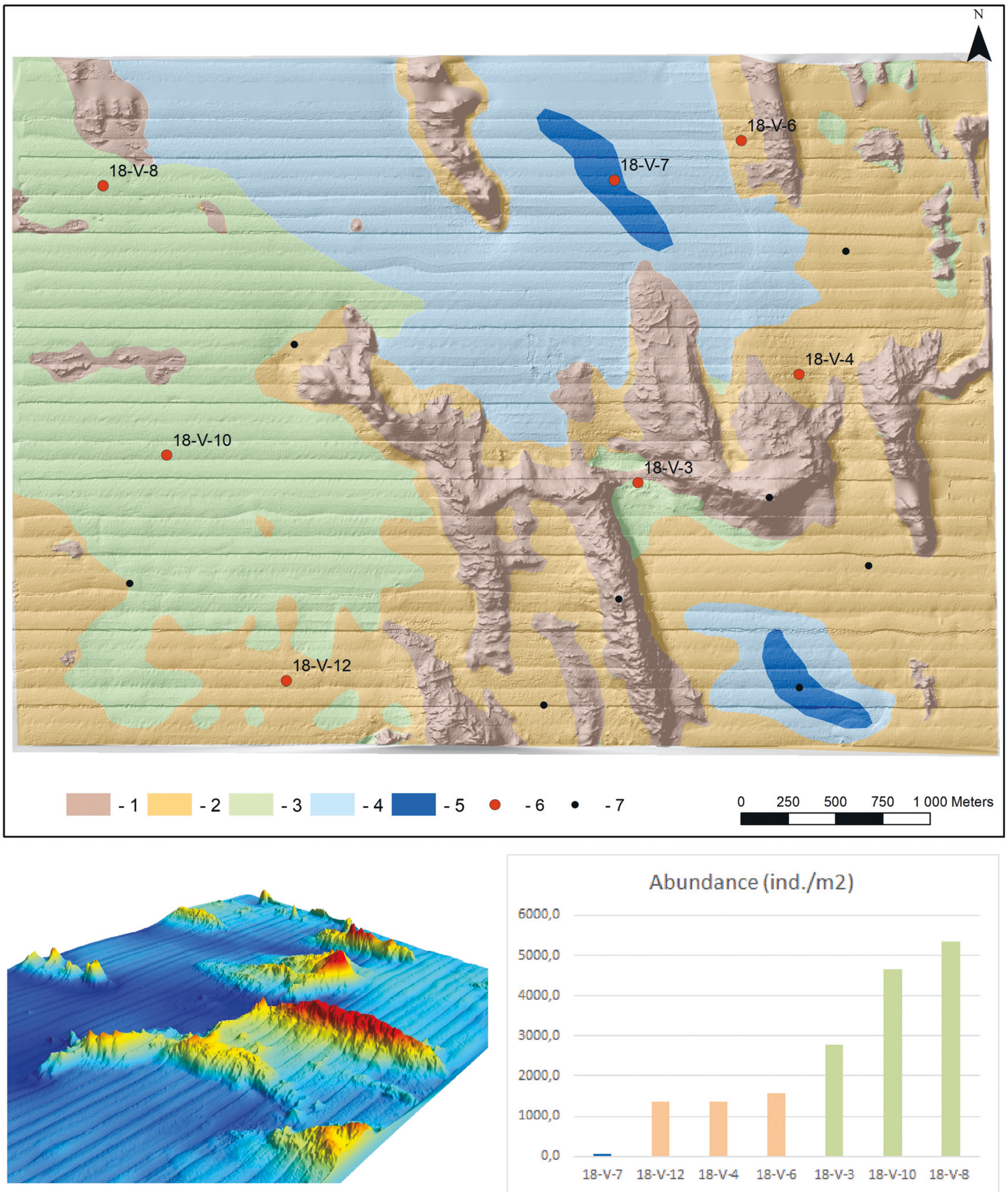

Figure. Map of submarine benthic landscapes of the Vyborg Bay bottom.
1 — high energy circalittoral boulder hard bottom; 2 — medium energy circalittoral oxic sandy clayey mud with Fe-Mn concretions bottom on the erosion surface of hard clays; 3 — medium energy circalittoral oxic sandy clayey mud bottom with growing Fe-Mn concretions; 4 — low energy circalittoral oxic mud bottom; 5 — low energy circalittoral anoxic mud bottom; 6 — geological sampling sites; 7 — biological sampling sites.

Acknowledgements:

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S1O19. Threatened habitat types in the Baltic Sea

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Benthic habitats are an essential part of functional and healthy Baltic Sea ecosystems. However, over the past decades anthropogenic activities have altered marine environments worldwide, and pose great challenges to sustainable marine management. Ecosystem based management (ESBM) is an effective method for ensuring the sustainable use of marine resources and health of the seas. The ESB m requires a large amount of accessible and reliable information on the marine environment, including seabed geology and biology. Information on threatened habitat types is an important indicator when monitoring the status of marine ecosystem and biodiversity.

The second assessment of threatened marine habitat types in Finland was conducted between 2016 and 2018 [1]. The Baltic Sea marine habitats were classified according to the HELCOM Underwater Biotopes (HUB) classification [2] with some modifications. The second assessment of marine habitat types in Finland was based on IUCN Red List of Ecosystems Categories and Criteria [3]. The new, large datasets on marine species and habitats collected e. g. in projects like FINMARINET, TOPCONS, SEAmBOTH, and in the VELMU Programme (The Finnish Inventory Programme for the Underwater Marine Environment), including more than 160,000 observation points from the Finnish sea and coastal areas, were used in the assessment. The assessment was carried out by a group of national experts from the universities, research institutes and authorities. The assessment was coordinated by Finnish Environment Institute.

The assessment listed a total of 42 Baltic Sea habitats, of which 10 were estimated to be threatened and 4 to be Near Threatened [4]. However, 14 habitat types were classified as Data Deficient, which shows that our knowledge of underwater marine habitats is still incomplete.

Eutrophication is still the most important threat to underwater marine habitats in the Baltic Sea. It was considered to be the most significant cause of deterioration for almost all threatened, or Near Threatened marine habitats, such as seafloor habitats of common eelgrass. Dredging and other marine construction activities have been especially detrimental to the unionid (river mussel) habitats in river mouths, as well as the charophyte habitats in sheltered inlets and closed bays/ flads. Other major causes for the threatened marine habitats include marine traffic and acidification. In the future, climate change is expected to exacerbate the eutrophication of the Baltic Sea. In addition, in the long run, a decrease in the salinity of the seawater may significantly change the ecological communities. The warming of the climate is already evident, for example, in shorter ice seasons. Thus, the sea ice was also considered a threatened habitat, as it is indispensable for the ringed seal as well as to micro-organisms living on and within the ice.

Considerable efforts have been made to improve the environmental status of the Baltic Sea, and in some areas the quality of water and underwater environment is improving. However, the processes restoring the marine ecosystem are slow, and climate change decelerates the healing process. To achieve good results and ensure the future health of the seas we need more information and long-term political commitment.

The programme of measures for the development and implementation of the marine strategy in Finland sets out ways to reduce the nutrient load and alleviate the impacts of marine constructions. In order to reconcile coastal human activities and protect threatened marine habitats, various measures are needed, such as increased protection/ marine protected areas, control of small-scale dredging, as well as taking the threatened habitats into account in management and marine spatial planning.

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S6O4. Genesis of Athigenic Carbonate Concretions and Crusts in Pockmark Fields on the Laptev Sea Outer Shelf

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Authigenic carbonate concretions in Holocene shelf sediments (*C15* pockmark field, 76º46' N and 125º50' E, depth 71 m) and carbonate crusts (or blocks) in sediment–water interface (*Oden* pockmark field 76°53' N and 127°47'° E, depth 63 m) in the Laptev Sea were first researched by authors (Fig. 1). The studied pockmark fields are located within the Laptev Sea rift system [1]. Cold methane seeps with bubble methane emission, microbial mats, methanotrophic bacteria and symbiotrophic tubeworms, and methane-derived authigenic carbonates (MDAC) were observed at two sites. We studied the composition, morphology, macro- and microstructure of carbonate crusts and concretions. The participation of methane carbon in authigenic carbonate formation was proven. The MDAC cement formed with Mg-calcite. We revealed that MDAC can deposit and growth (concretions) in the upper sediment layer in modern marine conditions. The multistage formation of carbonates in concretions was determined. However, the formation of MDAC crusts in the sediment–water interface in modern sedimentation oxidative conditions in the Laptev Sea is not possible [2]. We argued the assumption of the predominantly thermogenic origin of methane which participated in the formation of carbonate crusts in the sediment–water interface as a result of the decomposition of gas hydrates during the warming period in Holocene of about 10.5–8.5 ka [3].

Carbonate concretions (*C15* pockmark field). We revealed the structural varieties of Mg-calcite and aragonite. It was shown that organic matter played an important role in the formation of carbonates, i. e., in the formation of sedimentary–diagenetic Mg-calcite. The value of methane as the second source for carbonates formation was estimated. We found that methane-derived Mg-calcite accounts for 17–35 % of concretion material. The $\delta^{13}C$-C_{carb} value of MDAC concretions varied from –24 to –23 ‰ VPDB. This isotopic composition suggests that Mg-calcite was produced during diagenesis by the microbial degradation of isotopically light organic matter in the host sediments with the involvement of carbon dioxide formed via oxidation of methane. This is also seen from $\delta^{13}C$-C_{org} values of carbonate concretions with an anomalously light isotopic composition (from –44.5 to –88.5 ‰ VPDB) due to the very slow process of microbial anaerobic methane oxidation.

Carbonate crusts (blocks) (*Oden* pockmark field). The isotopic composition $\delta^{13}C$-C_{org} of MDAC crusts (–34.6 ± 0.04 ‰ VPDB) was significantly depleted in the heavy ^{13}C isotope compared with organic matter in bottom sediments (–27.7 ± 0.06 ‰ VPDB). The $\delta^{13}C$-C_{org} value of MDAC indicates the participation of methane carbon in the organic matter formation of the crusts. Methane carbon is also involved in the formation of isotopic light carbon of carbonates. This is especially seen on the example of crusts samples with a smaller participation of clastic and clay minerals in their composition ($\delta^{13}C$-C_{carb} reached –40.2 ‰ VPDB). Unlike the concretions of the *C15* pockmark field, carbonate crusts of *Oden* pockmark field were most likely moved from the area of their formation to the place of current location. We revealed significant differences in the mineral and chemical composition of clastic and clay particles cemented in crusts and contained the surface layer of bottom sediments hosted the crusts. It is difficult to assume the site of the MDAC crusts formation since the knowledge of carbonate formation in the Siberian Arctic seas is still very insufficient. Due to the lack of significant variability in the oxygen isotopic composition $\delta^{18}O$ (4.1–4.7 ‰ VPDB) of the crusts, we may assume that the marine conditions were close to the modern sedimentation conditions in the Laptev Sea by the time of MDAC crusts deposition. The crusts were formed possibly into quite deep bottom sediment layer (not in the sediment — water interface) at that time and then they were moved to the seabed surface in further geological periods. The source of abiogenic methane involved in the formation of the crusts is most likely thermogenic methane coming from the fracture zones located

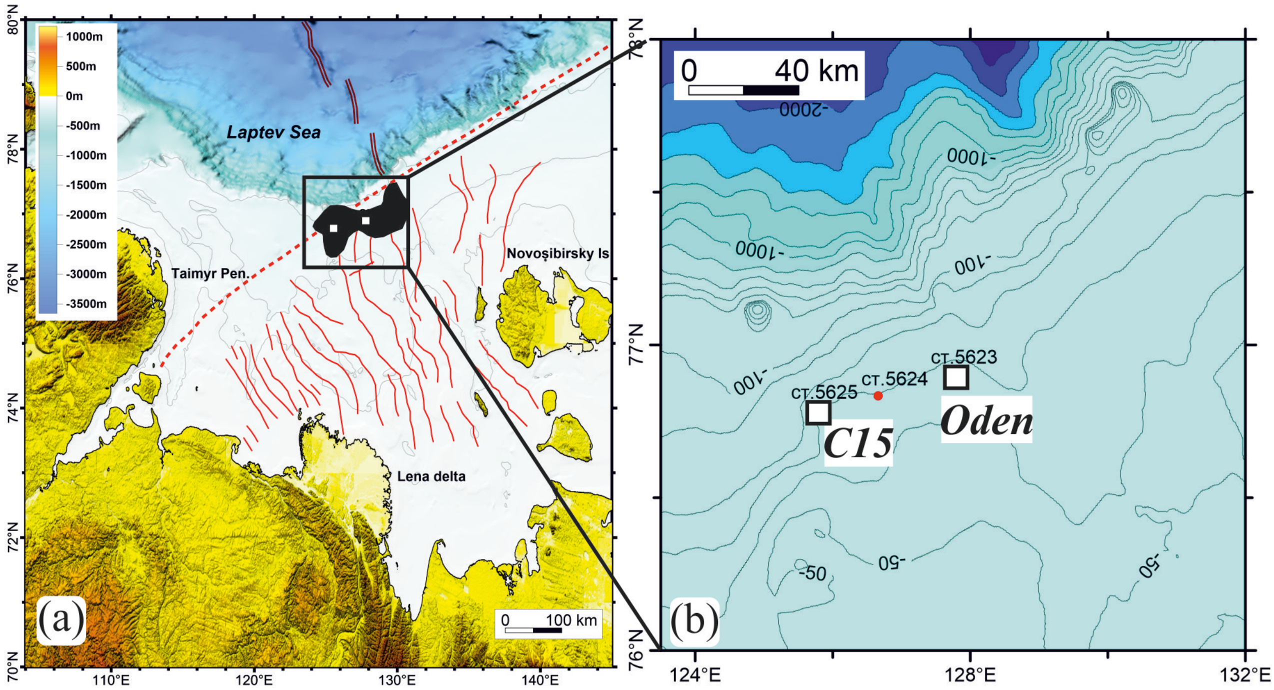

Figure 1. The location of studied sites (white squares). (a) cold methane seep area (black spot, data from [4]) and the Khatanga–Lomonosov fracture zone (dashed line, data from [1])

close to the studied sites. It is the Laptev Sea rift system and the Khatanga-Lomonosov fracture zone [1]. The thermogenic methane was established in bottom sediments of a number of the Arctic seas at 72°–79° N [2]. We suppose that the main carbon source of the carbonate crusts was the carbon of thermogenic methane that supplied to the seabed surface as a result of the methane gas hydrate dissociation during interglacial epochs, the closest of which dates about 10 ka [3].

MDAC formation in the Arctic shelf seas serves as a biogeochemical filter that reduces the flux of methane from bottom sediments into water column and finally methane emission. The detailed study of U-Th age of MDAC crusts and concretions on the East Siberian Arctic shelf should be a further research problem. This is important for solving issues of authigenic carbonate mineralization and reconstruction the intensity of methane-containing fluids in different geological epochs in the Arctic.

The researches were carried out during 63th and 69th cruises of RV *Akademik Mstislav Keldysh* in 2015 and 2017 respectively with the support of state budget (financing of marine expeditions) and RSF project No. 18–17–00089. This work was done in the frame of state task no. 0149–2019–0007.

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S4P1. Crystallization of the ikaite ($CaCO_3*6H_2O$) in the recent sediments of the Russian Arctic shelf

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The sediments of the Arctic shelf virtually do not contain authigenic carbonates due to the specific geochemical composition of pore waters and low temperatures, which increases the solubility of carbon dioxide. Their rare occurrences are related to various biogeochemical processes, e. g. methane oxidation [2, 3], or organic matter destruction [4]. In this line, ikaite ($CaCO_3*6H_2O$) holds a special place. This phase of calcium carbonate can nowadays crystallize in the marine/lacustrine environment only at temperatures close to the freezing point of water, but high content of dissolved phosphorus increases its stability conditions [1, etc]. At the temperatures above 4–6^{o}C ikaite decomposes into water and calcite [1, 5], resulting in the formation of glendonites pseudomorphs. We report results of study the mechanisms of formation of the ikaite found in bottom sediments of the Kara, Laptev and Chukchi Sea. Detailed mineralogical, geochemical and isotopic studies were conducted. The increase in alkalinity is mainly due to the decomposition of organic matter, however, anaerobic oxidation of methane is almost always present as an additional source of bicarbonate-ion.

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S3P6. Geomorphic features and benthos in a deep glacial trough in Atlantic Canada

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The Laurentian Channel is a deep glacial trough located in Atlantic Canada, extending >1500 km from the St. Lawrence Estuary to the shelf edge between Nova Scotia and Newfoundland. The channel acted as a major conduit of ice-stream flow underlying the Laurentide Ice Sheet during the last glaciation event in North America. The impact of glaciation on the seabed is suggested by the presence of iceberg scours and circular depressions (pockmarks and iceberg pits) attributed to disturbance caused by grounded moving icebergs. The outer Laurentian Channel close to its entrance at the shelf edge has been designated as an Area of Interest (AOI) for the establishment of a Marine Protected Area under Canada's Oceans Act. However, baseline information on the composition and distribution of benthic biota in relation to seabed features was lacking. Here, a benthoscape map of the outer Laurentian Channel along its eastern escarpment (51–497 m depth) was generated using geomorphic features mapped with multibeam sonar (density of iceberg scours and pockmarks/iceberg pits, depth and slope) and ground-truthed with surficial geology samples and underwater imagery. Individual surrogates and mapped patterns were compared to faunal patterns (infauna and epifauna) derived from the ground-truthing. Maximal infauna richness and abundance occurred along the escarpment of the Channel, generally decreasing with increasing depth. Both depth and density of pockmarks/iceberg pits influenced community composition. Some benthoscape classes had close associations with distinct infauna, but diffuse patterns were mostly observed. Epifauna — namely sea pens — were most abundant at the confluence of multiple benthoscape classes. This study provided a contextual overview of the composition of the benthoscape and associated fauna in the Laurentian Channel AOI, which is necessary to establish a sound monitoring program in this potential marine closure.

S1P17. Bridging the gap between the environment and history: archaeological fieldwork in the Jussarö archipelago, southern Finland

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Assessing the formation processes behind a cultural phenomenon requires a consideration of the environmental conditions. A ship trap is an underwater archaeological phenomenon, where the environmental conditions create a potential hazard for seafaring. However, the act of a shipwreck is always dependent also on social and cultural factors. The main goal for the joint archaeological fieldwork of Metsähallitus Parks & Wildlife and the Finnish Heritage Agency, under the Interreg Baltic Sea Region program financed project BalticRIM, was to explore a ship trap in the Jussarö archipelago of southern Finland, where several 18th C shipwrecks have been discovered. During the fieldwork, the size and limits of the ship trap were determined through an underwater survey with a side scan sonar and one new wreck was discovered. Determination of ship traps can be used in marine spatial planning to assign areas of high underwater marine cultural heritage values.

The underlying reasons for the creation of a ship trap were examined with a ship trap index model, a theory that is still being developed in a separate project in the University of Helsinki. It was speculated that shipwrecks are located on the seafloor in certain depths according to environmental factors such as wave action and surrounding skerries etc. The aim of the work was to study this relationship between environmental factors and wreck locations with a mathematical model, for which data was gathered from the Finnish Heritage Agency's Database (found online at www.kyppi.fi) and from the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). We also carried out exploratory analysis on the relationship between shipwreck density and the environmental factors, which may have a role on wrecking accidents and geographical locations of the wrecks. The results are preliminary, but could be used to guide further studies within the field.

For these analyses all the known wrecks along the Finnish coast found in the Database were included. The wrecks were used to calculate density of wrecks within a 2 km radius using the Heatmap tool in QGis. The values from the density maps were then linked to each wreck in order to produce a variable showing how densely individual wrecks had other wrecks within the surrounding 2 km.

The Jussarö archipelago has been known since the 17th century as an area where compasses show wrong due to the high magnetite content in the iron in the bedrock. This natural phenomenon has added a cultural layer to the folklore adding intrigue towards the many shipwreck accidents in the area. It is another indication that the environmental factors can help explain historical events and can guide our understanding of the archaeological remains.

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S6O5. Quantitative ocean-column acoustic imaging over the Calypso hydrothermal vent field, Bay of Plenty, New Zealand. First results from the R. V. Tangaroa QUOI Voyage

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The mapping of fluids and bubbles seeping at the seafloor of our oceans is a challenge at the forefront of acoustic science, because in part of the potentially high economic value and huge environmental significance of gas seepages. It undoubtedly has relevance to geological processes and benthic biodiversity.

The aim of the July 2018 TAN1806-QUOI (Quantitative Ocean-Column Imaging using hydroacoustics) voyage on RV *Tangaroa* was to improved methods to characterise bubbles in the water column originating from cold gas seeps and hydrothermal vents. The 20-day voyage focused on the Calypso Hydrothermal Vent Field (CHVF), ca. 15 km SW of Whakaari-White Island volcano which is well known for such active seafloor features. Six experiments were designed:

(1)………………………………… Calibration and cross calibration of two multibeam and six wideband split-beam echosounders systems (SBES) centered around 18, 38, 70, 120, and 200 kHz;

(2)………………………………… Multibeam surveys with 75 % and 95 % swath footprint overlap on natural seeps and bubbles generated using a synthetic seep generator (aka bubble maker), allowing us to model the angular response of seafloor and water-column backscatter, and sidelobe interference;

(3)………………………………… A multi-angle survey over synthetic and natural bubbles using a hull-mounted pan & tilt swivelling device;

(4)………………………………… A horizontally looking SBES for lateral observation of bubble streams;

(5)………………………………… A 5 days passive acoustic recording at the northern CHVF;

(6)………………………………… Video footage, sediment and water samples for signal validation.

The different frequency bands show strikingly different acoustic responses demonstrating the potential of multi-frequency and wideband data for analysis of gas bubbles. Correlating acoustic frequency responses with physical parameters (depth, temperature, salinity) will enables us to estimate bubble-size distributions and flux rates (rising speed). When coupled with video observations and water sample analysis, these methodologies enhance our ability to model gas flux for discrete areas of seafloor. Preliminary results show potential for the development of automated methods to extract estimates from water column acoustic data in real time.

The survey demonstrated that acoustic means can be used to differentiate spatially coincident gas bubbles (here methane and CO2). Such methods could be applied to other targets such as freshwater streams.

S3PO3. The Nippon Foundation-GEBCO Seabed 2030 Project: Update from the South and West Pacific Region

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Recognizing the poor overall resolution of the world ocean's bathymetry, GEBCO and the Nippon Foundation have joined forces to establish the Seabed 2030 Project, an international effort with the objective of facilitating the complete mapping of the world ocean by 2030. The aim of Seabed2030 is to empower the world to make policy decisions, use the ocean sustainably and undertake research based on detailed bathymetric information of the Earth's seabed. Seabed2030 initiative supports the United Nations Sustainable Development Goal (SDG) 14, which is "*to conserve and sustainably use the world's oceans, seas and marine resources*", and will contribute to the UN *Decade of Ocean Science for Sustainable Development (2021–2030)*.

The Seabed 2030 Project is established in four regional data assembly and coordination centers (RDACCs). The South and West Pacific centre is based in Wellington and has responsibility over an 123,000,000 km^2 wide region from South America to Australia (50° S–10° N) and the NW part of the Pacific Ocean to 50° N. The region includes the world's deepest trenches, internal seas, politically contested areas, EEZ from Small Islands Developing States (SIDS) and from some of the largest countries on Earth and covers some of the most remote regions of the planet where bathymetric data originate from existing ship tracks that are spaced up to 100 km apart.

RDACCs are responsible for assembling databases of cleaned bathymetric data, which will be merged into a global product by a global centre, as well as developing protocols for data collection and tools to assemble and attribute appropriate metadata as it assimilates regional grids using standardized techniques. The Centres are responsible for identifying data gaps and opportunities for new data collection, including the facilitation of new mapping endeavours through coordination of ongoing activities among stakeholders in the region. Regional Mapping Committees, groups of regional experts, were established to work with the Centre in identifying data sources, including those that are not currently in publicly available databases, and seek to make these data available. The data resolution (essentially from multibeam echosounders) will be

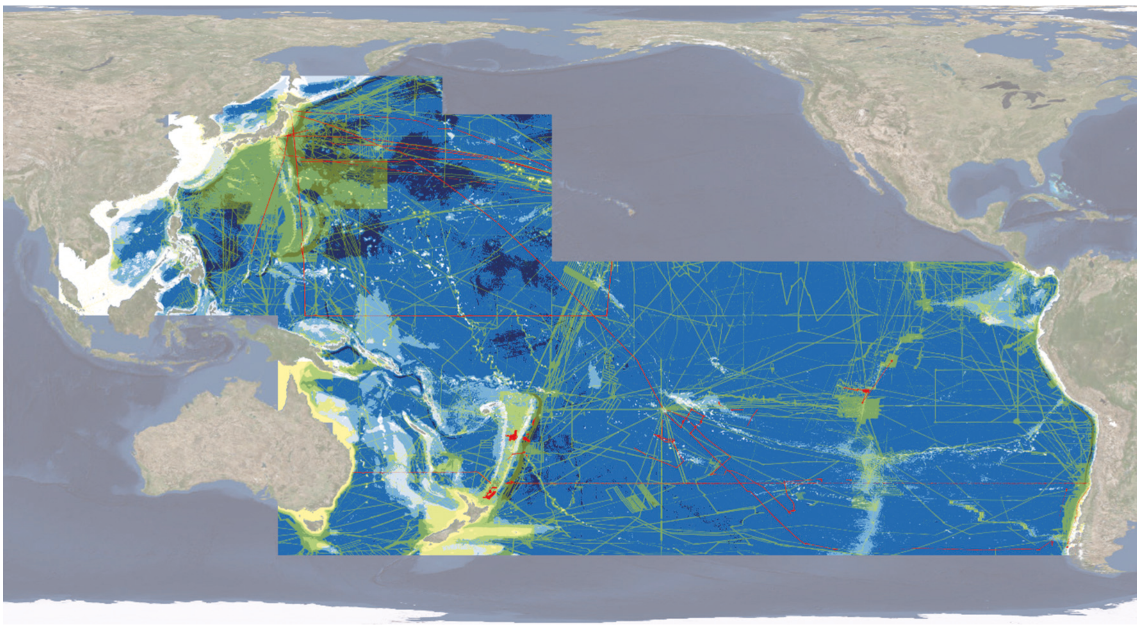

Figure 1. The extent of the South and West Pacific Centre of the Seabed 2030 Project. The yellow shadings represent the data added to GEBCO_2014 [1] for the 2019 release.

depth dependent. Seabed 2030 will consider the seafloor "mapped" if at least one sounding falls in a grid cell of the size of 100, 200, 400 or 800 m for the respective water depth range of 0–1500 m, 1500–3000 m, 3000–5750 m and deeper than 5750 m.

The Centres will encourage and help the development of new and innovative technologies that can increase the efficiency of seafloor mapping, including crowd sourcing, and thus make the ambitious goals of Seabed 2030 more likely to be achieved.

The GEBCO 2019 release includes new data from high-resolution depth models for the Great Barrier Reef and Northern Australia, several multibeam datasets sourced from JAMSTEC and the Alfred Wegener Institute, and the updated New Zealand Bathymetry compilation. We are aware that many bathymetric datasets remain unidentified and one major task in 2019 will be to complete a gap analysis in our region which will require to include information on all academic, government, navy and industry data acquired in the South and West Pacific, regardless of whether these data are readily accessible.

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S3P7. Potential Shallow to Deep Megahabitats along the Brazilian Equatorial Margin

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The Brazilian Equatorial Continental Margin on its northeast portion was analyzed in terms of geomorphometry based on a 2.5 km resolution bathymetric grid using the Benthic Terrain Modeler (BTM). This spatial analysis generated Seabed Classes that indicates the potential occurrence of distinct Megahabitats in terms of relief heterogeneity (Fig. 2). Twelve seabed classes were grouped into eight Megahabitats defined also based on sedimentary facies data, when available. The

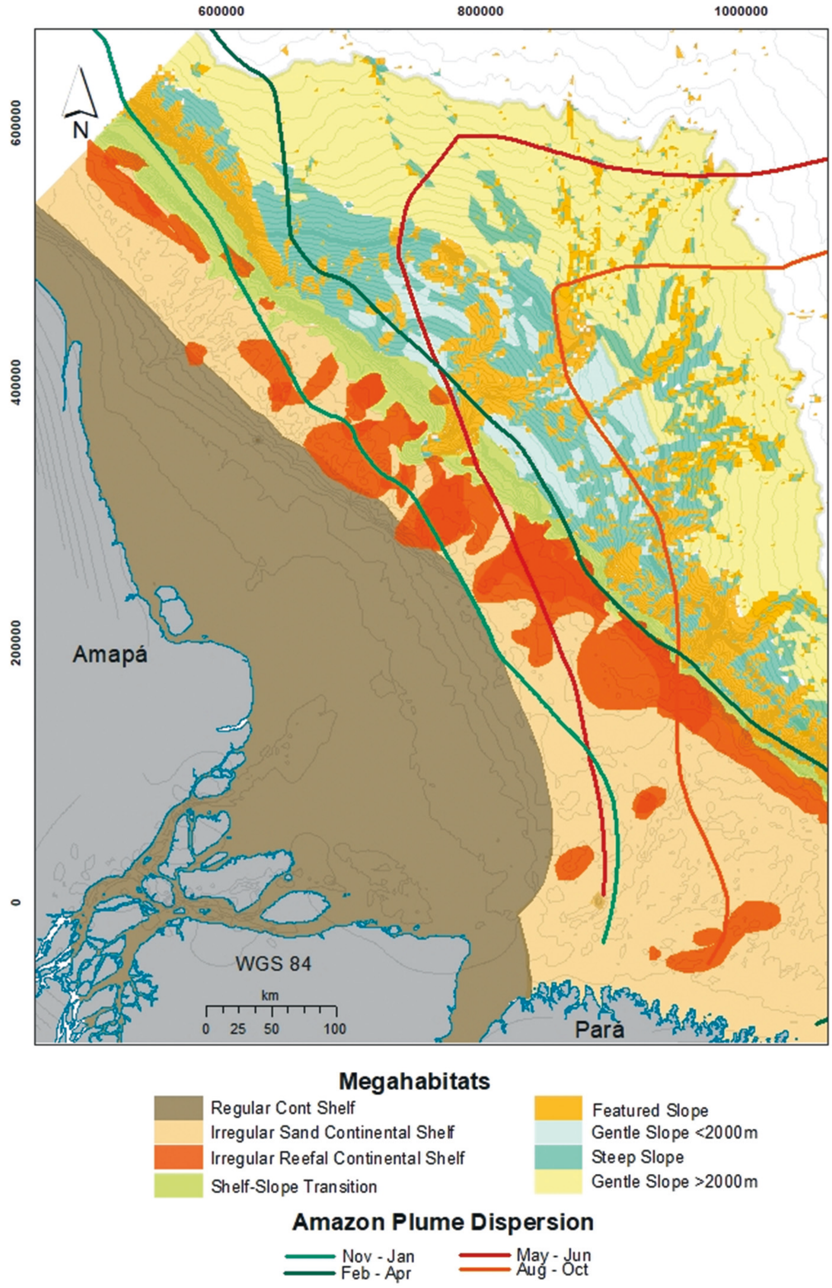

Figure 1: Brazilian Equatorial Margin Potential Megahabitats and Monthly Amazon Plume Dispersion. Target area where Reefal structures were mapped (black circle)

main Amazon plume depocenter along the Inner and Mid Shelf reveals the continuous influence of the plume forming a muddy and smooth deposit (Regular Mud Continental Shelf Megahabitat) (Fig. 2). The Continental Shelf that is not influenced by the riverine discharge and sediment accumulation is rough and characterized by either sand — sand waves and tidal ridges (Irregular Sand Continental Shelf Megahabitat) or carbonate — rhodoliths beds (Irregular Reefal Continental Shelf Megahabitat) (Fig. 2). The Shelf-Slope Transition Megahabitat (Fig. 2) presents a geomorphometric distinction along three designated sectors in terms of shelf break zone depth and slope curvature. Sector 3 presents Outer Shelf Edge and the Ridges together and this target area was where high resolution (5 m) acoustic mapping showed mesophotic reefs- between 110 and 210 m water depth reaching maximum height of around 20 m (Alucia Amazon Cruise — July 2017). Sector 2 presents no defined shelf-break only the Shelf Edge class, which is associated with long-term sediment accumulation and formation of the Amazon Fan. Sector 1 does not present the Outer Shelf Edge Class, only the Ridges, showing valley incised channels in the shelf, i. e., it is a very erosive area with main sediment bypass and carbonate sedimentation). Finally, the slope megahabitat is vastly diverse because of the occurrence (Featured Slope Megahabitat — FSM) or absence of features depressions, i. e., canyons or ravines. The megahabitats without features are: Shallow Gentle Slope Megahabitat (SGSM) — shallower than 2000 m water depth; Steep Slope Megahabitat (SSM) and Deep Gentle Slope Megahabitat (DGSM) (Fig. 2). This current work is significant once it characterizes on of the areas in Brazil that represents a current dilemma due to the presence of reefal structures and its closeness with potential exploratory blocks.

S1O20. Groundtruthing with video imagery and drones for shallow water habitat mapping

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Environmental mapping in shallow water (less than 50 m) is a goal often required by land-based authorities in decisions for coastal development. Surveying with multibeam bathymetry and backscatter data give an understanding of the morphology and its substrate. Object Based Image Analysis (OBIA) can be used on the acoustic data to produce a segmented thematic map and a statistical classification. However groundtruth data must be obtained to convert these class-ifications into real world characterisations of the habitats. In very shallow water (less than 5m) multibeam systems become economically unviable. For these areas, imagery from unmanned autonomous vehicles (UAVs or drones) are now routinely acquired, if water conditions allow.

A multibeam survey was acquired off the south east corner of Tanna, Vanuatu. With this data we used the RSOBIA software [1] to identify the acoustically distinguishable classes. We then developed a random stratified groundtruthing plan. The plan ensured that all areas had a sample point and larger areas had multiple sample points. Using the plan of survey points and a mini-ROV we collected 277 groundtruth videos in one week of survey (about 6 stations per hour). A small number of sediment samples were also collected (about 1 in 7 locations) using the grab on the front of the ROV.

The drone photographs had 90 % overlap and thus two outputs were created. Firstly a photo mosaic was compiled with centrimetric resolution (flying at 40m). Secondly a three-dimensional surface was created using the "structure from motion" technique and was tied down to real bathymetry using a few known depth points collected by hand.

Using a combination of multibeam data and the drone 3D mosaic a full bathymetric map. The habitat map was created using the interpretation of the ROV video and the drone photography. Classification of the video imagery was then used to identify the acoustic classes. Several issues arose; two interpreters were tasked to independently classify each site and there was not full agreement on interpretation, and secondly there was some uncertainty with exact station location due to boat drift and where exactly the ROV first made visual contact with the seafloor. A method to reduce this uncertainty will be presented and the full habitat map that was created.

Tanna (Vanuatu) is home to the active volcano Mt Yasur, and is very accessible to tourists and therefore valuable to the local economy. The volcano is known for its regular spectacular and persistent strombolian activity

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S2O2. Advancements to Multibeam Backscatter Mosaicing to Improve Automatic Seabed Classification

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As we have begun to have a better understanding of the impacts that marine activities have on the marine ecosystems, the importance of quality marine habitat maps has become critical in supporting decision making at the scientific, commercial and policy levels. One of the primary inputs for a marine habitat map is a compensated backscatter mosaic. Classifying the mosaic into areas of similar backscatter intensity results in a representation of the boundaries between different seabed sediment types. The automatic classification process is however highly dependent on a quality backscatter mosaic, and any issues with the mosaic such as the presence of artifacts, poor contrast or low signal to noise ratio, can all compromise the fidelity of the classification.

Teledyne CARIS is actively working on significant improvements in the SIPS Backscatter engine, specifically addressing artifact issues related to gridding and the Angular-Varying Gain (AVG) corrections. The current beam-based gridding algorithm is being replaced by a method more suitable for time-series and multisector data and less prone to interpolation artifacts. The per-line AVG correction is also being adapted to become area-based, therefore reducing the line overlap effect.

This presentation will describe these changes and include case studies demonstrating how the mosaic quality and automatic classification results are improved.

S5O4. To Each Its Own: Contrasting Fine-Scale Environmental Preferences of Cold-Water Coral Species in the Northwest Atlantic

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The Northwest Atlantic waters off the Canadian East Coast are home to a wide variety of cold-water coral species [1]. The last 20 years of investigation of cold-water coral habitats in this area have been driven by data availability; most research focused on testing species-environment relationships using regional data [2] or finer-scale data limited to specific characteristics of the environment (*e. g.*, geological features) [3]. In July 2010, a series of ROV dives were performed at The Gully, the Flemish Cap, and the Orphan Knoll, during which high-resolution bathymetric, video, and chemical and oceanographic data (*e. g.*, conductivity, nitrogen saturation, pH, plume anomaly) were collected. This dataset provides a comprehensive characterization of cold-water coral habitats in terms of biological, chemical, and physical components of the environment. ROV transects covered about 120 km at depths ranging from 200 to 3,000 m deep. A total of 19,969 corals were identified on the video, and a series of terrain attributes (*e. g.*, slope, rugosity, topographic position) were derived from the bathymetric data.

Top-down and bottom-up approaches to habitat mapping [4] were used to characterize potential habitats and identify coral species-environment relationships. First, correlation and principal component analyses were performed to reduce the number of variables available for mapping habitats. Oxygen concentration, salinity, temperature, depth, rugosity, topographic position and aspect (*i. e.*, easterness and northerness) were selected as uncorrelated variables that were the most representative of the environment in those locations and at that scale. Those variables were used in a multivariate clustering algorithm with pseudo-F statistics to identify potential habitats, and in MaxEnt to identify and quantify species-environment relationships.

The accuracy of the habitat maps resulting from the application of the top-down approach ranged from 62 % to 70 %. Those maps enabled the identification of potential habitats and geomorphic features that were spatially associated with specific coral species. Most species were found in topographic highs or areas of higher seafloor rugosity, and, with a few exceptions, areas of lower oxygen concentration. *Keratoisis* sp., *Chrysogorgia* sp. and *Nephtheidae* sp. were generally found in the deepest, coldest waters. The bottom-up approach yielded relatively robust models (mean AUC from 0.82 to 0.99) and showed that the distribution of different species and genus is driven by different factors: some are more influenced by chemical conditions (*e. g.*, oxygen concentration and salinity explained 75 % of *Keratoisis* sp. distribution), some by physical conditions (*e. g.*, rugosity and northerness drove 81 % of *Desmophyllum* sp. distribution), and others by a combination of different types of conditions (*e. g.*, depth, northerness, oxygen concentration, rugosity, and temperature all contributed to a relatively important proportion in explaining the distribution of *Acanella arbuscula*). Our results highlight that cold-water coral habitat suitability may depend on a fairly complex set of characteristics, perhaps more complex than generally thought. They also show the importance of studying species-environment relationships at the highest possible taxonomic resolution, and the potential of high spatial resolution data to appropriately capture the fine-scale, local conditions preferred by corals.

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S4P2. Multibeam and video data applied to Seabed Mapping in the Rio Grande Rise, SW Atlantic

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The deep sea represents a unique environment on earth but still studied to small extent. With increasing interest in mining activities for ferromanganese crusts, several expeditions were carried out by the Geological Survey of Brazil (CPRM) to the Rio Grande Rise (RGR) since 2009. It represents a large feature on the SW Atlantic Ocean, extending approximately 1000 km from the Brazilian coastline, surrounded by abyssal basins. An extensive hydrographic survey was done onboard the Brazilian Navy vessel NHi Sirius (H–21) using a Kongsberg multibeam echosounder (30 kHz), covering a 45,000 km2 area, with depths ranging between 550 m on the plateau and 2775 m in the canyon, resulting in surface models with 50 m resolution (Fig. 1). At least in three other expeditions camera surveys were employed for seabed identification and detailed habitat studies using ROV, TV Grab, towed camera and the Japanese submersible Shinkai 6500. Based on supervised classification, the slope and backscatter intensity were used as parameters to segment the entire area. Video analysis of the RGR helped to identify the surface and divide into four substrates types: Consolidated sediments; Pelagic sediments; Ferromanganese crusts and Rock outcrops/sediments (Fig. 1). Each of these environments has a singular characteristic regarding the colonization of organisms (epibenthic fauna) and the occurrence is intimately associated to the kind of substrate. The most common taxa observed in the RGR are Cnidaria, followed by Porifera and Echinodermata. The crusts are almost always flat and populated by sessile organisms, interspersed by points where there are thin layers of sediments, holes and cracks. It has been observed that currents acting on these sites cause erosion below the crust layer. The basaltic outcrops on the canyons are interposed by areas of soft deposits. There is evidence of older sediments that were exposed due to gravitational movements. A sponge garden was found mimicking the visual habitat of coral gardens [1] in an outcrop, the first documented worldwide to be dominated by the rigid species. In the northeast region of the RGR there is a field of mega pockmarks, with a diameter of up to 10 km. In these

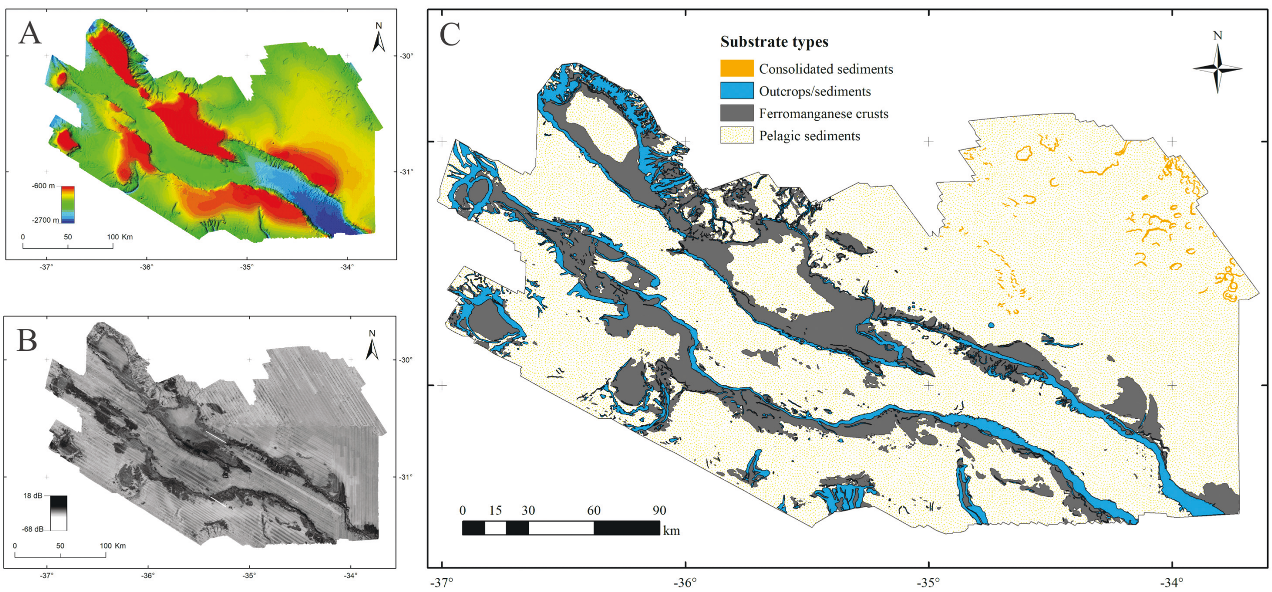

Figure 1. Rio Grande Rise: bathymetry (A); backscatter intensity (B) and substrate types (C) — (consolidated sediments; pelagic sediments; ferromanganese crusts and rock outcrops/sediments)

places no crusts or outcrops are observed, only pelagic sediments and some carbonate rocks produced from methane gas exudation. Current ripples, sediment waves and furrows are present in areas with unconsolidated pelagic sediments, basically composed of foraminifera, nanofossils, and other debris. Communities of molluscs and crustaceans predominate in these environments, and less frequently species of ceriantus, Hexactinellid sponges, Pennatulacea black corals, and fishes. A cluster analysis over species observation performed in different oceanographic stations during the PROERG Amb I & II (2018) cruises [2], has revealed that regions containing the same sort of substrate, bathymetric occurrence and under the action of the same deep current show great faunistic similarity. In fact, the deep currents dynamics should influence the distributions of species in these environments. By physical ways, interacting in the larval dispersion and promoting the colonization of distant areas, or trophically transporting nutrients and particles by advection, favoring biological occurrences in determined regions. The substrate predictive map is extrapolated to a very large area, which can give an overview of the main environments. Other small-scale variations observed in video were not considered.

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S1PO8. Structural insights into the western branch of the Saldania Belt through the marine geology of Table Bay, South Africa

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Table Bay encompasses one of the key, coastal urbanised nodes around the coastline of South Africa, yet its seafloor has never been geologically mapped. The purpose of this investigation was to investigate a ~170 km² area using the highest possible resolution, marine geophysical techniques to chart and understand the seafloor of Table Bay as part of a larger regional study. Full seafloor coverage of both multibeam bathymetry and sidescan sonar were achieved within the study area. This investigation has revealed that the seafloor of the bay is composed almost exclusively of Neoproterozoic,

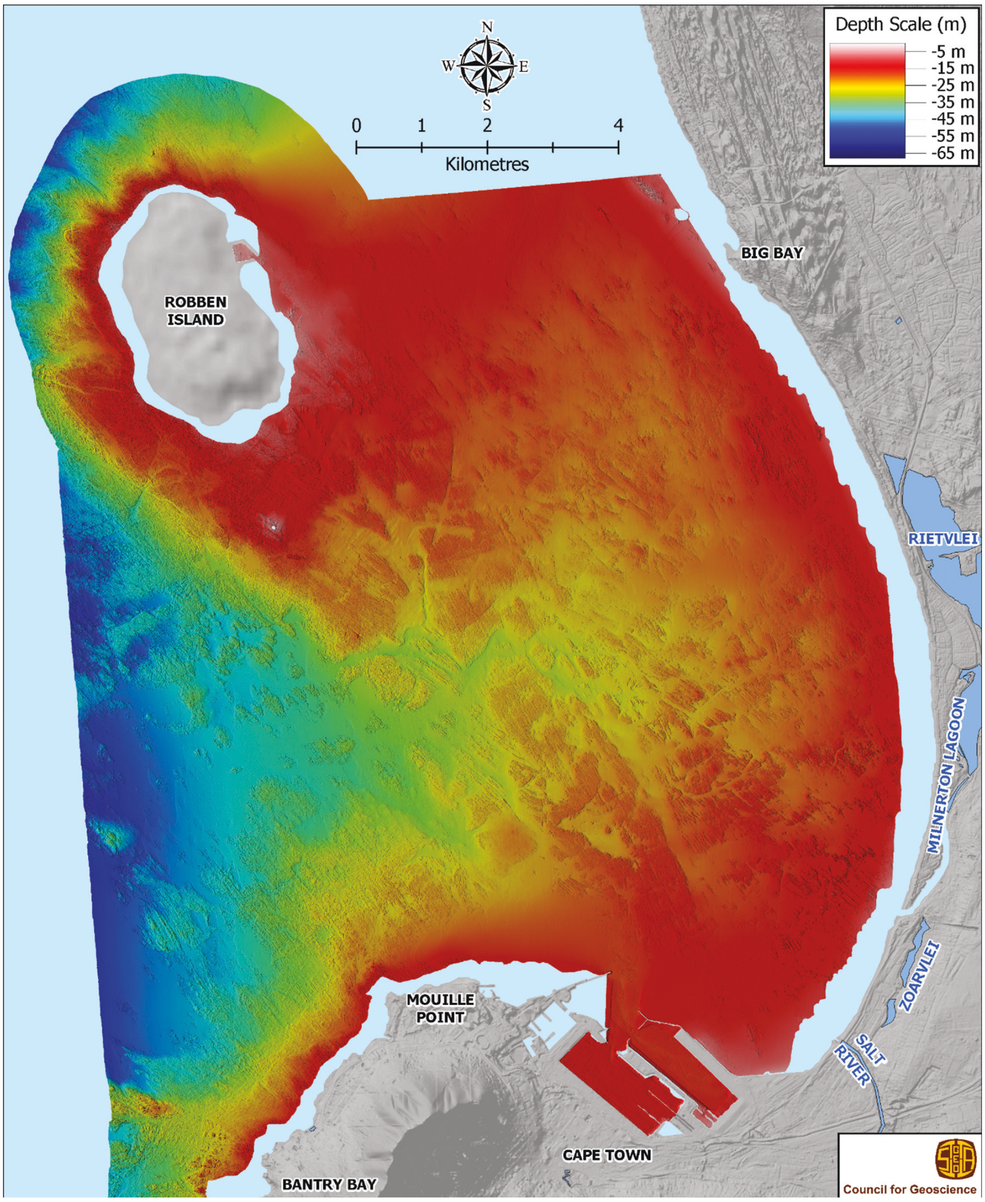

Figure 1. Colour-shaded relief, multibeam bathymetric chart (without contours) of the study area. 10 m Coastal DEM provided courtesy of City of Cape Town

Tygerberg Formation (Malmesbury Group) rocks, which display structures that clearly demonstrate the nature of its deformation dynamics. Acquisition of marine magnetic data have helped to delineate complexity within the Cretaceous, False Bay Dolerite Dyke Swarm.

Whereas outcrops of the Malmesbury Group are scarce above-water, we demonstrate that the seafloor of Table Bay is an ideal locale to gain insight into the Neoproterozoic deformation of the Western Saldania Belt, and to assist in contextualising these structural events at a more regional scale. There is evidence of long straight limb, tight hinge megafolds which plunge in a northwesterly direction. Marginally more competent units within the core of a megasyncline explains the preservation of Robben Island and the formation of box and kink folds west of it. Bedding truncation and a large northwest trending erosional gully support the existence of regional fault which has been named the Table Bay Fault, in the southeast portion of the bay.

In all, these data have helped demonstrate how detailed offshore geological mapping can complement sparse onshore data.

S7O3. High-resolution acoustic surveys for underwater archaeological research in shallow water: a case study from the Lagoon of Venice, Italy

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The Lagoon of Venice (Italy), together with the historical city of Venice, is a UNESCO World Cultural and Natural Heritage. The lagoon origin is the origin of the lagoon is set around 6000–7000 yrs BP, when the lagoon started to form as a consequence of the Flandrian marine transgression, with the sea maximum ingression flooding the alluvial palaeo-plain that occupied the northern epicontinental Adriatic shelf. The first human remains in the lagoon area date back to the upper Paleolithic age (50,000–10,000 BC) [1] and the lithic remains found in Altino (a roman town at the northern edge of the lagoon) show that the first settlements date back to almost 7000 years ago[2]. The islands within the northern Lagoon have been inhabitated since Roman times and up to the Medieval Age and sites that go back to Roman imperial times are now well documented in the northern part of the lagoon [1, 3, 4]. Many other archaeological sites are likely to be submerged or buried under the lagoon seafloor.

The shallowness of the lagoon, however, for a long time prevented the use of underwater acoustics that, in general, can help to extensively and efficiently explore the bottom and sub-bottom for new archaeological discoveries. In this study, we present the results of the application of the most recently built sub-bottom profiler and multibeam systems to archaeological studies showing that they can achieve very high performances also in very shallow waters. In particular, we highlight the possible discovery of buried archaeological features and of ancient roman road in correspondence of an old coast line now submerged (see Fig. 1 below). The results can give a new insight in the underwater archaeological research in the area.

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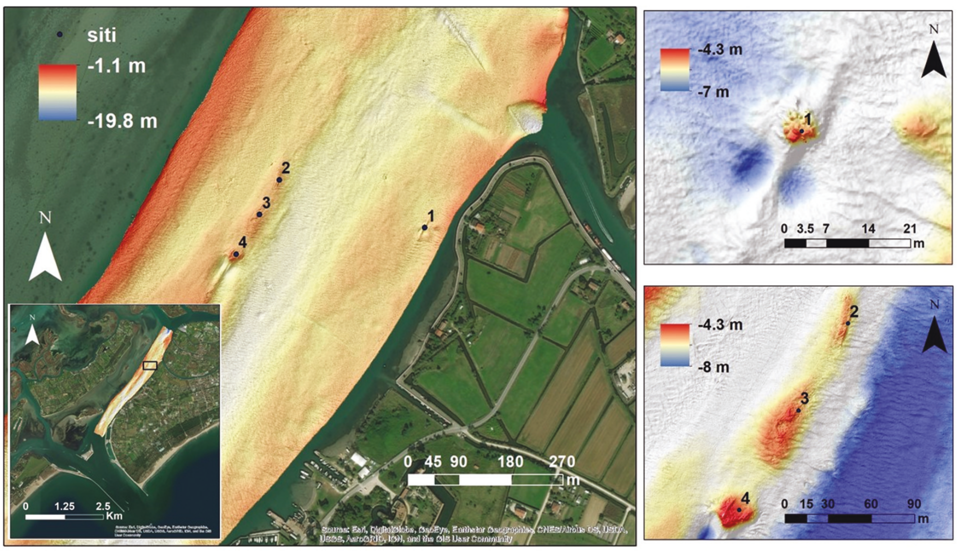

Figure 1. Alignment of anthropogenic structures in the Treporti Channel in the Lagoon of Venice

S1P18. Linking shallow water benthic habitat distribution and dynamical physical variables: case study from the Venice Lagoon, Italy

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Coastal and transitional environments are highly populated and valuable areas providing crucial ecosystem services. The management of these areas calls for a deeper understanding of their functioning also in view of climate change and relative sea-level rise. The recent advances in the field of benthic habitat mapping in very shallow water allow for a new description of the habitat distribution in these environments. However, the relationships between physical parameters, hydrodynamics and benthic habitat distribution in these areas are still not completely understood.

With the aim of filling this knowledge gap, in this work we combine the benthic habitat maps obtained in the Venice Lagoon (Italy) and the related physical parameters and hydrodynamics.

High resolution multibeam data and seafloor samples collected in the Venice Lagoon tidal network in 2013 provided benthic habitat maps of the almost unexplored tidal channel seafloor with unprecedented detail. The main benthic habitats were classified following the scheme proposed within the European project COCONET (*Towards COast to COast NETworks of marine protected areas*) adapted for the Venice Lagoon environment.

A 3D high resolution finite element model was applied to obtain the hydrological variables (current velocity, water level, salinity and temperature) for the whole lagoon and to estimate the characteristic transport time scales. For a study area in the northern lagoon, we investigated the relationship between the tidal channel benthic habitats mapped in 2013, the seafloor terrain attributes and the hydrodynamic regime. In this work, we present the preliminary results of our research in the framework of a long term project supporting an ecosystem based management of the lagoon.

S1P19. High archeological potential underwater areas of South-East Baltic Sea, Russian EEZ

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Southeast part of the Baltic Sea is still remaining little covered by underwater archaeological research, related to the Pleistocene/Holocene boundary. This is one of the reasons why any regional strategies of the economic and cultural development and usage of territorial waters and the coastal zone resources do not take into account the archaeological objects that could be flooded during the geological history of the Baltic Sea.

Underwater areas of a high archeological potential were determined, basing on five reconstructions of paleo-shorelines and buildups, formed 10,500–6,500 years ago. As a basis were taken seashore paleo-reconstruction of Baltic Ice Lake (10500 BP) and Yoldia Sea (10000 — 9500 BP) [1] and seashore paleo-reconstruction 9500 BP, 8200 BP and 6500 BP [2].

Formerly, a set of characteristic geographic features suitable for temporary camps and human settlements was determined. The following geographic objects and territories were accepted as the sites most convenient for settlement, fishing and wind protection: paleo-estuary and adjoining coasts; areas of bays, deeply penetrated into the land; crenellated shoreline areas, small islands with accumulative coasts, situated not far from the main land; spits. Then, such the objects were highlighted on the paleo-shoreline map of every time periods. Each allocated area was attributed to one of the 3 categories of archeological potential (high, middle, low) depending on the individual characteristics of the geographical object found on the reconstruction maps. Twenty-two zones were allocated.

Then, maps of paleo-shorelines for 5 periods, with allocated and areas of archaeological potential, were combined by superposition principle, using ArcGis software. In some cases, areas of archaeological potential from different time periods overlapped with each other. For such cases, zones of the highest archeological potential were allocated. Most of zones of high archeological potential are situated north-eastward the Sambian Peninsula and along the Vistula Spit within 40 m isobath. The scheme of distribution of the areas with different potential in regard of probability to find the prehistoric settlements and other imprints of human being at the Pleistocene/Holocene transition.

During the field season 2018, first sonar surveys at zones of high archaeological potential in accordance with schematization made, were conducted in Russian EEZ South-Eastern Baltic Sea. Results are being discussed.

Acknowledgements:

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S1PO9. Sediments and bedforms mapping of the Lower Saxony Wadden Sea and North Sea (Germany)

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The implementation of HD 1992/43/EEC, WFD 2000/60/EC and the most recent MSFD 2008/56/EC Directives strongly encouraged governmental agencies and research institutes to start seabed-mapping programs and addressed the scientific research towards new technologies, tools and methods. Within this context, the Coastal Research Station of NLWKN is carrying out a long-term program to map subtidal areas of the Lower Saxony coastal and marine waters, adopting a methodological approach aimed to increase objectivity and repeatability of results [1] and producing new data on the subtidal habitats [3].

The study area is one of the world's largest tidal system encompassing a multitude of transitional zones between land, marine and estuarine environments. The geological and geomorphological setting is closely related to the Late Quaternary evolution of the North Sea, controlled by glaciations, sea-level changes and actual morphodynamic processes [2]. The seabed is mainly made of Holocene sandy to silty-sandy sediments and peat layers. They overlay Pleistocene glacial and fluvial deposits, made of sands, rocks and boulders, locally outcropping in small areas in the North Sea and in the deepest sectors of the Wadden Sea tidal inlets [4].

Even though existing maps provide a good broad-scaled representation of the sediments distribution, they were interpolated from grab-samples data, so lacking of resolution and tending to under-represent the hard-substrates. The ongoing mapping program provides full-coverage detailed sedimentological data and new geomorphological information, by means of swath-bathymetry systems, sub-bottom profiler and validation samples. The methodological approach integrates bathymetric,

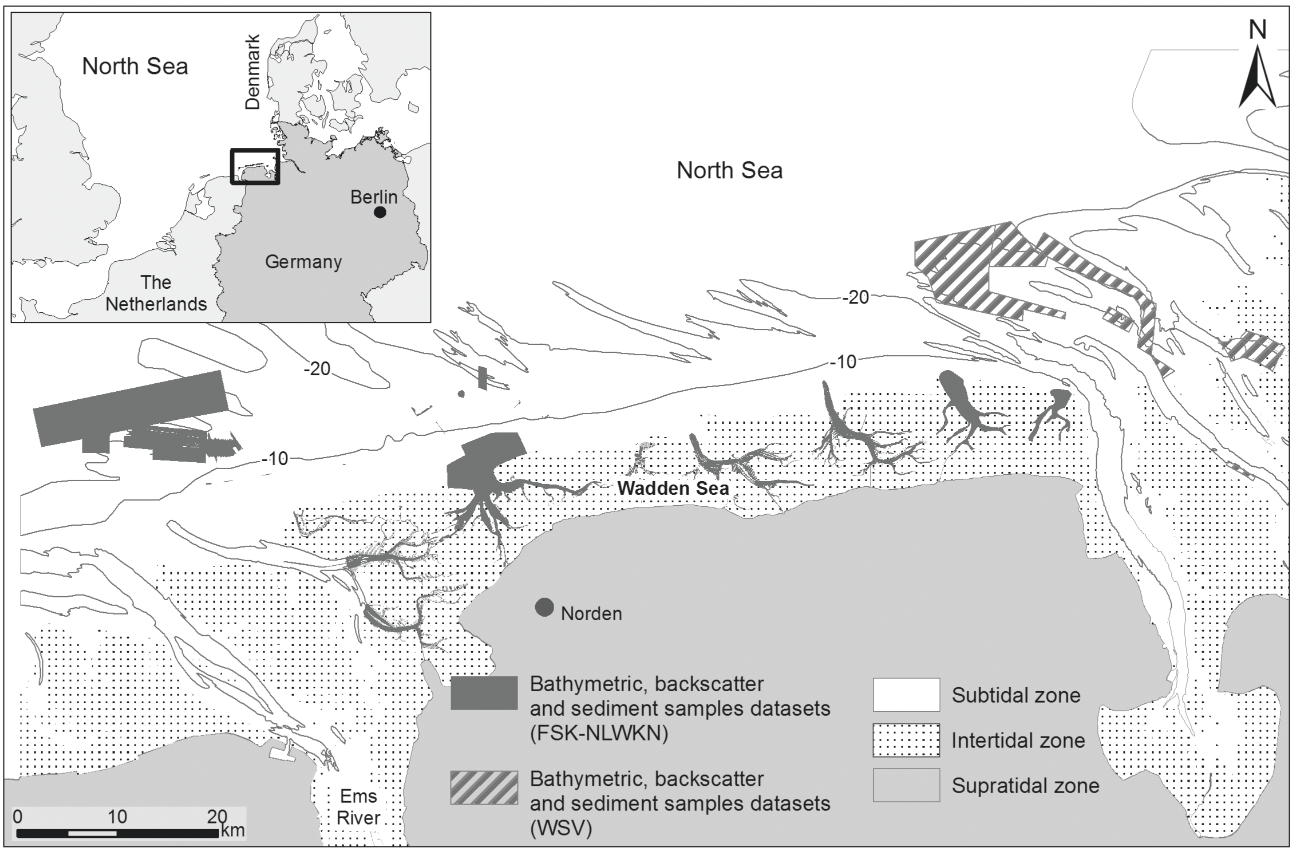

Figure 1. Surveyed areas and datasets

backscatter and stratigraphic information to characterize bedforms and substrates. Bathymetrical and seabed imagery are interpreted using geomorphometric and object-based image analysis, by means of ArcGIS® tools, to increase the objectivity and produce reproducible results.

Resulting maps outline common sedimentological and geomorphological feature across all the observed Wadden Sea tidal inlets, which are made of fine sandy sediments and narrow outcrops of peat layers on the main tidal channels slopes. Both erosive and depositional geomorphological processes are present, represented by several orders of scarps, mainly connected to alternations of hard-substrates and unconsolidated sands, and medium to very large sand waves. In the North Sea area, new detailed data about hard-substrates outcrops have been collected and mapped. Shore-connected very large structures and different orders of sandwaves reveal intense active geomorphological processes, triggered by a complex combination of waves and tidal currents, resulting in huge sediment mobilization.

In conclusion, the mapping programs provides new detailed geological-geomorphological information of a very dynamic coastal area, using repeatable and objective methods. The combination of different datasets and tools allows the quantitative analyse of the complex subtidal morphology, the correlation of bedforms and substrates, the characterization of abiotic features. Resulting products will be further developed for habitat mapping purposes and morphological and hydro-dynamical modelling.

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S5PO1. Automatic Classification of Reef structures: Comparing different techniques

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Reef habitats are excellent case studies to test the use of automatic classification tools of the seabed. Their distinct morphology and high backscatter patterns provide unique characteristics for undoubted map results. Here, we applied two supervised techniques based on different data input as well as distinct algorithms, to classify a reef area. The two models were: the ArcGIS toolbox — the Benthic Terrain Modeler (BTM), a morphometric model based on spatial analysis from bathymetric grids derivatives; and an object-based image segmentation using e-Cognition software, in which input is the backscatter mosaic from a Side Scan Sonar (SSS). The use of these two distinct classifications did not aim to compare its effectiveness, but it was focusing on which technique would better identify and define the extension of reefs in the study area. The aim was to analyze potentialities and limitations of both techniques — using them as a complement — to semi-automatize seabed classification through multibeam bathymetry and SSS data. The analysis was accomplished based on a dataset acquired on the Abrolhos Continental Shelf (East Brazilian Continental Margin), where reef pinnacles, reef banks and rhodoliths banks were observed. Distinct reef types were mapped, including pinnacles, low relief reef banks and an irregular relief reef banks. Even though there is a similarity in terms of reef area measurements, the object-based image segmentation provided a more detailed differentiation among the reef types, making this technique more efficient when comes to distinguish reef structure. It is also important to note that the SSS-based classification did not manage to distinguish seabed types within the inter-reef area. In this case, the morphometric analysis was more efficient. It is important to emphasize that the complementary application of both techniques for classifying geophysical data converge for a better seabed classification. The object-based image segmentation can improve the classification if bathymetry and backscatter are combined.

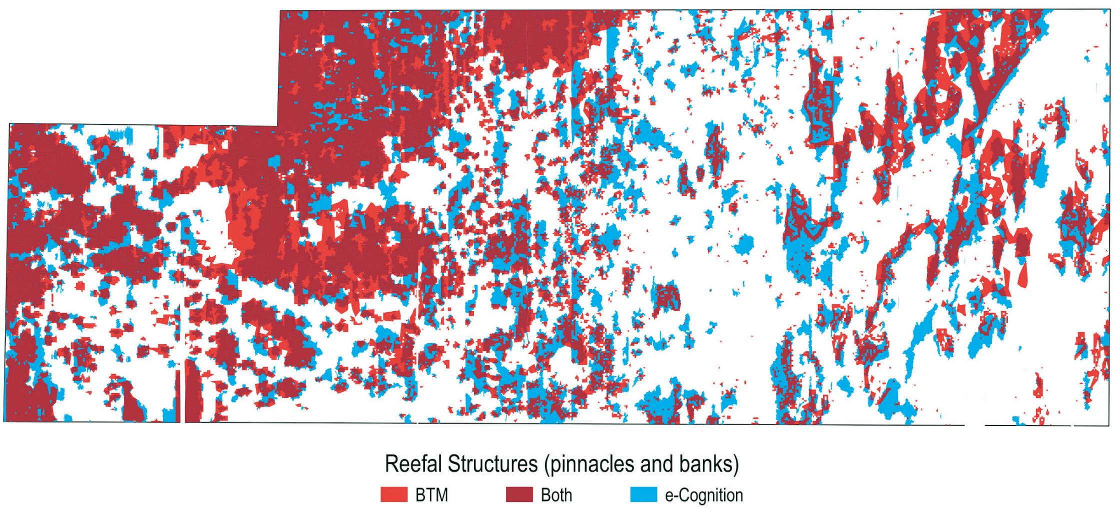

Figure 1. Compilation of the reef classification results by the two techniques, as well as the overlap of both

S6O6. Issues of using data on seabed communities to assess biofouling level of underwater mining complexes

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Offshore field exploration with a use of underwater mining complexes (hereinafter UMC) imposes technological challenges to ensure the process safety. From a wide variety of natural and technology-related risks involved in operations (3, 6), this article highlights one of the most common biological threads — biofouling. Following today's trends of increasing offshore oil and gas exploration, biofouling becomes an issue of great current interest (1).

The only UMC operating in Russia in Okhotsk Sea (Kirinskoye field) from 2013 lacks data on biofouling. Some research on impacts of marine fauna on constructions has been done on the Shtokman field in the Barents Sea (ссылка?). Limited data are available on biofouling of oil platforms for the shelf of Okhotsk Sea.

Evaluations of impacts of biofouling remain significantly underestimated in the Russian literature. Shevchenko with co-authors (6) show rather conservative approach considering biofouling one of the reasons of UMC failure in the Kirinskoye field. Our research revealed that actual reasons for events leading to failure in that case could have been upon ice conditions and earthquakes, but unlikely biofouling.

Kirinskoye gas condensate field was discovered in 1992 as a single exploratory well. It is associated with an anticline, which is a part of Kirinskaya anticlinal zone UMC of the Kirinskoye field is located 29 km offshore from the east coast of Sakhalin Isl, at the water depth of approximately 90 m. Bottom sediments are formed by homogeneous sand with some float stones and silts. A mound of approximately 400x600 m widths and 1.5–2 m height was formed in the central part of the field directly above anticlinal zone as a result of fluid migration. Pockmarks and gas seeps were found on the mound and in the surrounding seabed areas.

Surface water temperatures during the Piter Gaz, LLC cruise in summer 2011 varied from 10,0 to 12,8 °C. Near-bottom water temperature reached — 1,2 °C. Salinity was measured as 28,0 to 31,1 ‰ for the surface waters and 32,9 to 33,1 ‰. for near-bottom waters.

According to NPF DIEM 146 species of aquatic organisms were found on silted sands within the lower sublittoral zone. Three groups of invertebrates contributed the most to biodiversity of macrobenthos, those were: polychaete worms, crustaceans (dominated by amphipods) and mollusks. Crustaceans (amphipods, cumaceans, and others) and polychaetes predominated in numbers. Sea urchins were dominant in total biomass.

Megabenthic assemblages in the area were previously studied under the framework of environmental impact assessment (EIA) (NPF DIEM, 2010), and by Piter Gaz, LLC in 2010–201 during the complex engineering surveys using remoted operated vehicles (ROV). The ROV SeaEye Falcon DR 12135 and "Comanche" ROV were used. Video recordings were studied in detail by the Marine research centre of Lomonosov Moscow State University (hereinafter LMSU MRC) team. A qualitative analysis of the distribution of the megafauna was carried out [2, 4, 5].

It should be noted that a direct comparison of benthic data collected via bottom grabbing and video recording is not accurate. The results of the video survey allow estimating the spatial distribution and density of the large, easily-spotted, often mobile fauna, while the bottom sampling is used to estimate the abundance, biomass and diversity of macrozoobenthos, much smaller (0.5). — 5 cm) and most often infaunal (inhabiting the bottom sediments). There are also methodological challenges in carrying out species identification for video recording.

Less than 20 species of megabenthos were determined during the survey. Significant patterns of distribution of animals in the examined area were not revealed; their distribution is mostly random or, perhaps, depends on sediment. Thus, there are large areas where sea urchin *Echinarachnius parma* is absent, although it dominates in the area in general. Also, there was no difference between the megabenthos near the gas seeps and its background state, probably due to tolerance to local increases in gas concentration. In general, megabenthos of the studied area is relatively poor and

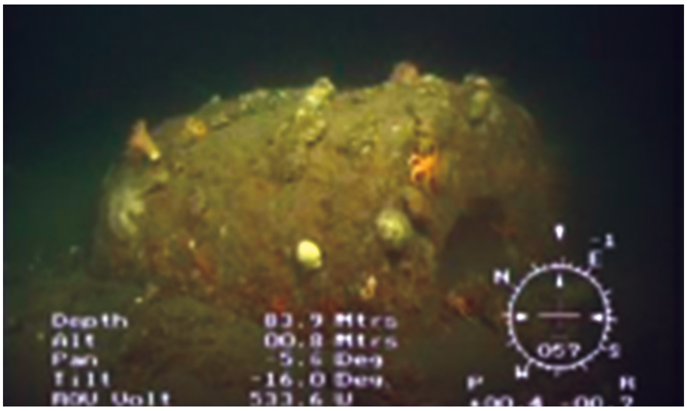

Figure 1. Part of the blowout preventer, diameter about half a meter. The following are visible on its surface: hydrozoans, bryozoans, sea star Henricia sp., gastropode Buccinum sp. And their eggs, hermit crab Pagurus sp., anemone *Stomphia coccinea* (?), decapode *Hyas coarctatus*

not very abundant. However, even in such conditions any anthropogenic objects become the centers of megabenthos attraction and biofouling due to the shortage of hard ground (see Fig. 1 below).

Biofouling communities includes both fouling, attached forms, such as hydroids or Actinia, and associated free-living forms (decapod crustaceans Hyas sp. and Pagurus sp., starfish Henricia sp., gastropods of the genus Buccinum). Species found in fouling communities almost do not differ from the background state.

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S3O10. Breaking down borders: How the sharing of datasets and removal of hard classification schemes result in valuable new products

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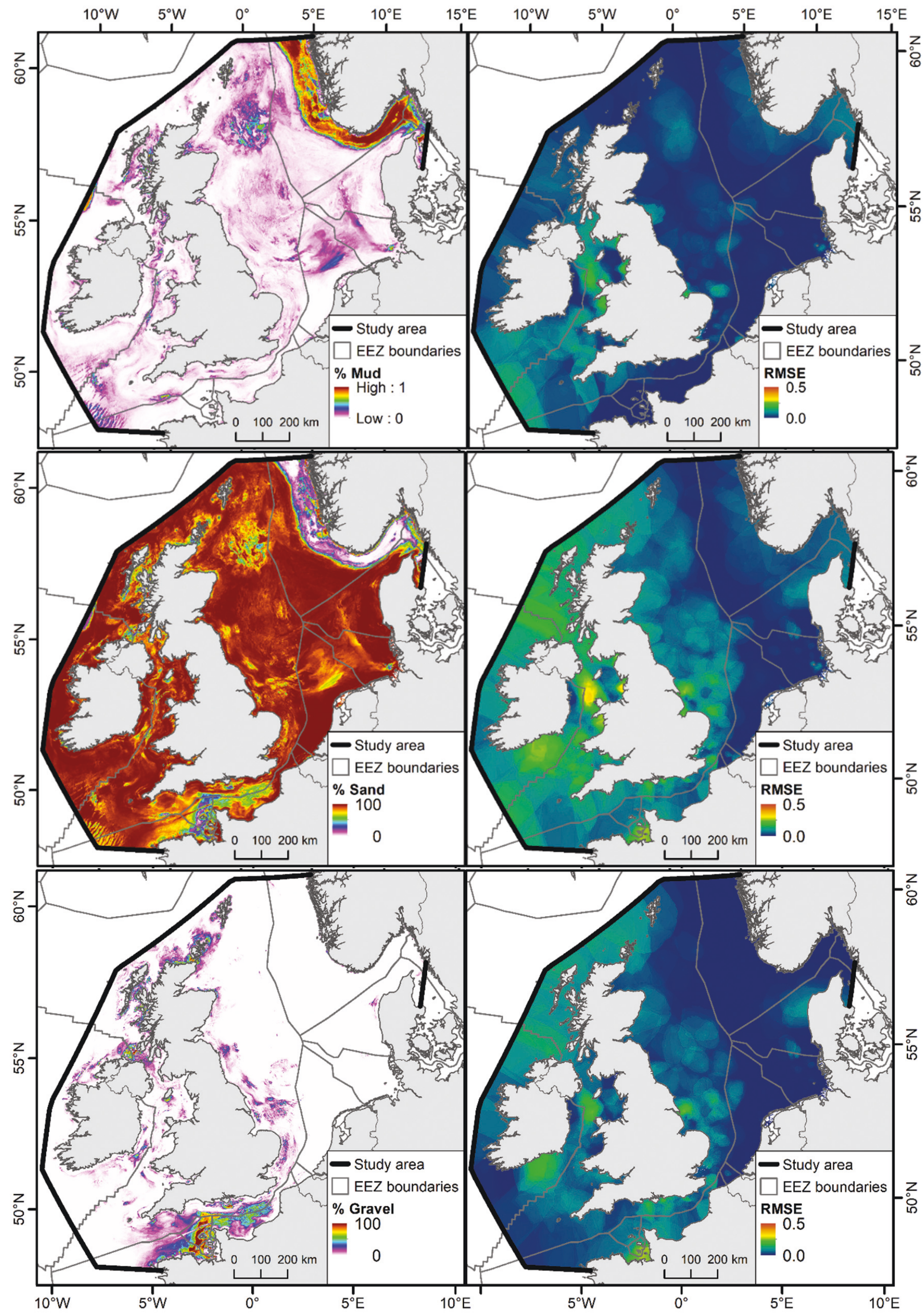
Application of thematic mapping techniques to model the distribution of seabed habitats has been widely applied for decades. In the case of mapping seabed sediments, the classes are typically defined by grouping together samples with similar grain sizes based on the relative fractions of mud, sand and gravel. This was logical considering sediment samples were generally recorded in the field and maps generated from those samples involved a large component of expert interpretation. Increasingly sediment samples are being analysed using more quantitative techniques that measure the frac-



Modelled spatial distributions of the sediment fractions of mud, sand and gravel for the north-western European continental shelf. Each map pane on the right is the associated spatial error for that sediment fraction

tions and statistical models can then be applied to map the distribution of different sediment types. However, despite the uptake of advanced statistical models, these are still predominantly being applied to predict a simplified number of predefined sediment classes.

Using sediment classes for mapping can be problematic. For example, sediment compositions often straddle class boundaries meaning samples from areas that are acoustically and ecologically similar may be split into different classes due to small differences in the relative abundance of sediment components. Furthermore, different classification schemes are not necessarily related, meaning that different maps generated for a similar area may not be comparable if different classification schemes were used and it is almost impossible to back-process to the original samples. Thankfully mapping sediments using sediment classes is not necessary, as sediment modelling techniques can be applied to the original sediment fraction data to predict each fraction separately. Stephens and Diesing[1] showed how these methods could be applied, modelling an area of the North Sea and UK continental shelf.

This study updated their maps, improving the extent and resolution to cover the entire north-western European continental shelf to a resolution of 1/8th arc minute (approximately 100–200 m within the study area). The maps produced are to date the highest resolution quantitative sediment composition maps that have been produced at a sea-basin level. This was possible due to the collation of historical sediment datasets by the European Marine Observation and Data Network (EMODnet) partner organisations, through the release of increasingly fine resolution EMODnet-bathymetry data and improvements in regional wave activity and tidal current models, both of which were observed to be important predictive layers for predicting sediment distributions. In addition, the modelling methodology has been refined, reducing some of the potential sources of error.

In this presentation we also discuss how mapping sediments in this way may produce maps of greater value, as any classification scheme could be applied subsequently. Further, we explore how spatial confidence and accuracy maps can be applied to both quantitative and categorical data to improve map use.

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S1P20. Spatial distribution of threespine stickleback in relation to habitat characteristics, Kandalaksha Bay of the White Sea

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The threespine stickleback (*Gasterosteus aculeatus* L.) is one of the most studied fish worldwide, being a popular model in evolutionary and behavioral research. In the White Sea this species quickly grew last two decades and currently is the most abundant fish of the sea playing an important role in the ecosystem. To study this role, it is crucial to have quantitative data on stickleback distribution. However, such data are very limited because stickleback does not have commercial significance. The absence of quantitative data on distribution of stickleback and its abundance prevents our understanding of a changes mechanism either in the populations of this species and in the whole White Sea ecosystem.

Stickleback density was studied at 11 sites located in different parts of the Kandalaksha Bay of the White Sea. Sampling was done in spawning period (15–30 June) of 2010 and 2018. This is the period of maximum abundance of stickleback in inshore zone and thus we assume that in this period we take into account all spawning individuals in the population. Samples were collected with a 7.5 m-long beach seine with wings 1.5 m high, a mesh-size of 5 mm on the wings and 1 mm in the cod-end. The haul length was 30 m. The catching area of the gear was 120 m^2, and the catching efficiency was accepted to be 0.6. The abundance of stickleback was estimated in terms of number individuals per square meter and per kilometer of shoreline.

A depth was estimated at a distance of 30 m from the shoreline, a slope was measure as a ratio of depth to distance from the shoreline. The density of eelgrass *Zostera marina* and fucoid seaweeds was assessed visually using a subjective ranking system. Types of bottom were visually subdivided into rocks, boulders, gravel, sand, mud and their combinations. Also, we measured a potential wave exposure. Based on the type of vegetation, type of bottom and wave exposure we subdivided the entire shoreline in four typical habitats: (i) eelgrass beds, (ii) fucoid beds, both these habitats were associated with relatively steep slopes; (iii) shallows with sandy or stony bottom spread out to one kilometer from the shoreline with usually scarce vegetation and (iv) rocks associated with relatively steep slope and high wave exposure. This classification was based on our own field observations and analyses of maps and images from Google Earth 6.1. The length of each habitat was estimated using Google Earth 6.1 at a scale of 200 m per cm.

The northern coast of the Kandalaksha Bay, from the mouth of the Varzuga River to Cape Turii, is a vast sandy or gravel littoral heavily exposed to waves (habitat type iii). This coast is definitely unfavorable for stickleback spawning. Fish in this habitat, is even found at all, were solitary with average density up to 0.3 ind/m^2. The coast from the west of Cape Turii to the top of the Kandalaksha Bay has many inlets and islands, which are well protected from the waves, and, as a rule, favorable for the stickleback spawning. These are mainly narrow stony littoral with abundant fucoid brown algae and insignificant presence of some eelgrass (ii). In these habitats, the average number of spawning stickleback was 4.2 ± 1.7 ind/m^2 in 2010 and 12.5 ± 3.3 ind/m^2 in 2018. The southern coast of the Kandalaksha Bay is characterized by a high degree of ruggedness and has a plenty of well isolated inlets with typically stony sandy habitats with fucoid thickets (ii). There are also vast areas, particularly in the inner parts of bays, where dense eelgrass beds are present (i). Stickleback density considerably varies in the eelgrass beds. In the areas with dense seagrass abundance of stickleback approached up to 78.0 ± 4.4 ind/m^2 in 2010 and 135 ± 21 ind/m^2 in 2018, but in beds with lower density of eelgrass stickleback density was lower — 4.7 ± 2.2 ind/m^2 and 16.1 ± 1.8 ind/m^2 in 2010 and 2018 respectively. Thus, the density of stickleback is positively correlated with density of eelgrass. In turn, the density of the eelgrass increases with a decrease in wave exposure, i. e. the most abundant eelgrass beds are located in well protected inlets. As a rule, the density of stickleback in fucoid habitats is lower than in the eelgrass and positively related to the slope.

Based on average density of stickleback in different habitats and on the spatial distribution of these habitats, we estimated the absolute abundance of stickleback in the Kandalaksha Bay. In 2010 the total abundance was equal to 215 million individuals, and in 2018 — 1 billion. There are two possible non-alternative explanations of the inter-annual differences: (1) during years 2010–2018, stickleback steady increased its abundance due to more and more effective utilization of potential spawning habitats of the White Sea, or (2) the differences are caused by natural fluctuations of stickleback abundance due to the changes of environmental factors (for instance, winter temperatures). Currently, we do not have enough information to prefer one of those explanations.

Therefore, in this study we described distribution patterns of stickleback on inshore area of the Kandalaksha Bay based on analysis of coastal habitats. Density of stickleback considerably differs in each of four types of identified habitats, and information on the length of shoreline occupied with each habitat and respective average density of stickleback allows to estimate its total abundance, which was almost five-fold higher in 2018 in comparison with 2010. The most important spawning habitat for stickleback is dense eelgrass beds in closed inlets, which likely create the best conditions for a growth and protection of juvenile stickleback. The area of this critical habitat likely limits abundance of threespine stickleback in the White Sea.

S3PO4. Mapping the geomorphology of Perth Canyon

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Perth Canyon is Australia's second largest submarine canyon. It covers ~1500 km^2 and extends from the shelf break (~170 m depth) to the foot of the continental slope (~4700 m) (Figure 1). The vast size of the canyon drives upwelling near the canyon head, which drives ecological productivity and supports a lucrative fishing industry. While the canyon is situated only 50 km offshore from a major regional centre, its genesis and stability are not yet understood. A new 20 m resolution bathymetry grid was developed using data acquired in 2015 by the Schmidt Ocean Institute, and reveals a complex arrangement of ridges, gullies, escarpments and blocks. These units collectively define multiple mass movement features along the length of the canyon, which individually span water depths up to 2000 m. More ambiguous features are also situated along the canyon floor, and subsurface information is required to understand their internal morphology and interactions between basement lithology and canyon processes.

We present a new two-stage marine geomorphology mapping approach, which embraces and extends the scheme of Dove et al. (2016). The surface morphology of the seafloor is first mapped using bathymetric data and derivatives (e. g. slope) and geomorphology (genesis and composition) is subsequently mapped where additional datasets (e. g. seabed samples, seismic) and expertise are available. Using this approach, we have mapped and interpreted the genesis of the remarkable seafloor units that comprise the Perth Canyon system to better understand the canyons genesis and stability.

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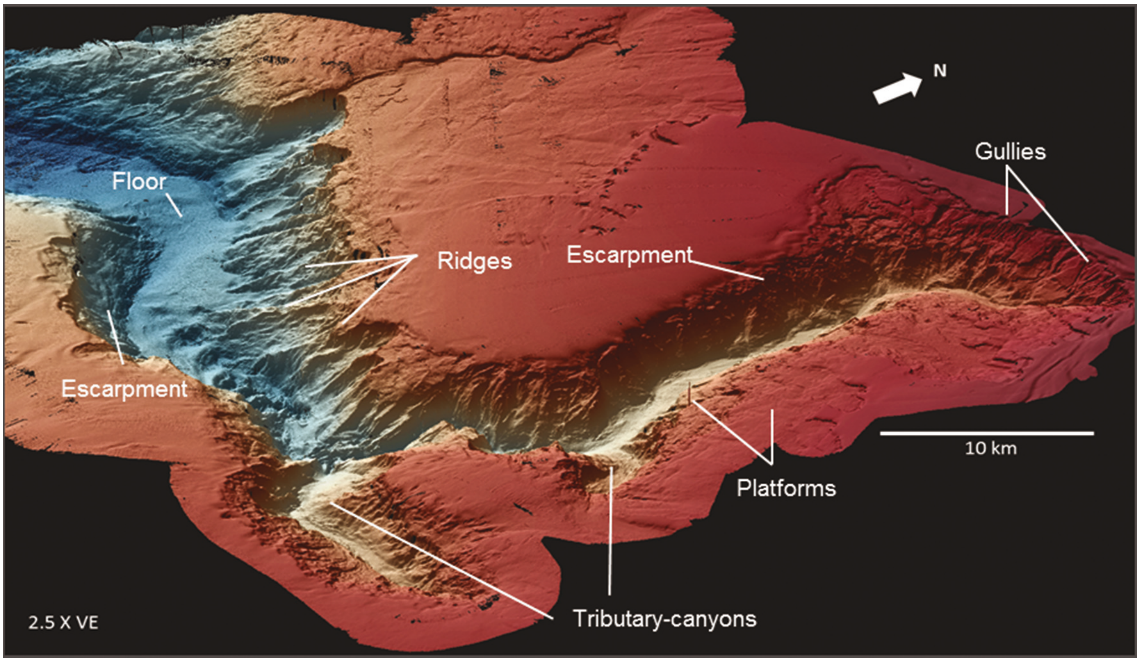

Figure 1

S1PO10. Submarine landscapes of gas-saturated sediment fields of the Eastern Gulf of Finland (Baltic Sea)

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The vast areas of gas-saturated sediments are one of the typical features of the Eastern Gulf of Finland accumulation basins. Research of gas-saturated sediment field located to the east of Gogland Island (e. g. geological sampling (65 dites), sub-bottom and side-scan sonar profiling, study of methane content in sediments and near-bottom water, isotopic research) has been undertaken annually by VSEGEI since 2017. During the cruise of the R/V *Academic Nikolaj Strakhov* (19–25 of July 2017) the area was covered by multibeam and sub-bottom profiling survey, using the multibeam echo sounder SeaBat 8111 (operating frequency 100 kHz). This survey was accompanied by acoustic profiling using EdgeTech 3300-Hm sub-bottom profiler (the frequency range is 2–10 kHz, the pulse length is 20 ms). Biological sampling was conducted in frame of 43-rd cruise of the R/V *Academic Boris Petrov* (July-August 2018).

Abiotic factors controlled the benthic invertebrates within the study area are much more complicated comparing with other areas of EGof [1, 2]. Study are is located at the depth 20–80 m (the deepest part of the Russian part of EGoF), below photic depth and out of wave impact, it is characterized by mesohaline conditions. Relatively bathymetric high parts of the bottom are represented by moraine ridges (with boulders, pebble and gravel on top), which are partly covered by Pleistocene clays. On the top of one the ridges, located in eastern part of study area (water depth 60–68 m) 10 crater-like structures were found range. Several craters are doubled; some of them are concentrated as a chain. Craters' diameter reaches 120 meters, a relative depth is up to 4 m. Some of them are partly buried under the recent marine muds. The sediment samples and submarine video has shown that the bottom surface here is covered by continuous layer of ferromanganese irregular crusts and large (up to 12–15 cm in diameter) flat concretions.

Sedimentary basins of the area filled with silty-clayey Holocene mud. According to acoustic profiling analyses, the major part of accumulative area is characterized by development of gas-saturated sediments and anoxic conditions one the sediment-water boundary. Within some areas according to submarine video-survey results, on thick white bacterial mat are observed, which make such areas totally azoic. Methane content in upper sediment layer varies from 40000 to 314000 ppm. Surface of gas-saturated sediments crossed by elongated runnels (up to 2000 m long and about 5 m relatively deep) and rear small (10–25 m in diameter) pockmarks. Besides, a long curve runnel (more than 4 km long and up to 10 m deep) is located to the east of round-shape bank, and most probably has a contourite origin. Despite the maximal depth of the contourite channel bottom, surface sediments are represented by clayey mud with high sand content and (in some samples) spherical Fe-Mn concretions up to 1–2 cm in diameter.

Due to complicated abiotic conditions the benthic invertebrates distribution here is not so easy to explain comparing the other Gof key areas [1, 2]. Benthic community of the most part of submerged moraine ridges consists of *Monoporeia affinis* sp. (Amphipoda) (dominant), *Marenzelleria arctica sp.* (Polychaeta), *Saduria entomon* (Isopoda), Oligochaeta (medium abundance, abundance of 300 ind./m^2, biomass of 4.5 g/m^2). Areas of Fe-Mn crusts developmets are characterized by similar species set and abundance (280–470 ind./m^2, biomass of 1.3–7.5 g/m^2) — (*M. arctia*, Oligochaeta, *Limecola balthica*, *M. affinis*).

Areas of non-sedimentation conditions (mixed substrates with alternation of low accumulation and periodical erosion along peripheral parts of sedimentary basins) is most favorable for the benthic invertebrates (M. *arctia, L. balthica, M. affinis, S.entomon*, Oligochaeta), but within study area the abundance are lower (960–1350 ind./m^2) while the biomass is more diverse (8.0–213.5 g/m^2) comparing with the more eastern part of the EGof (abundance 1000–5350 ind./m^2, biomass

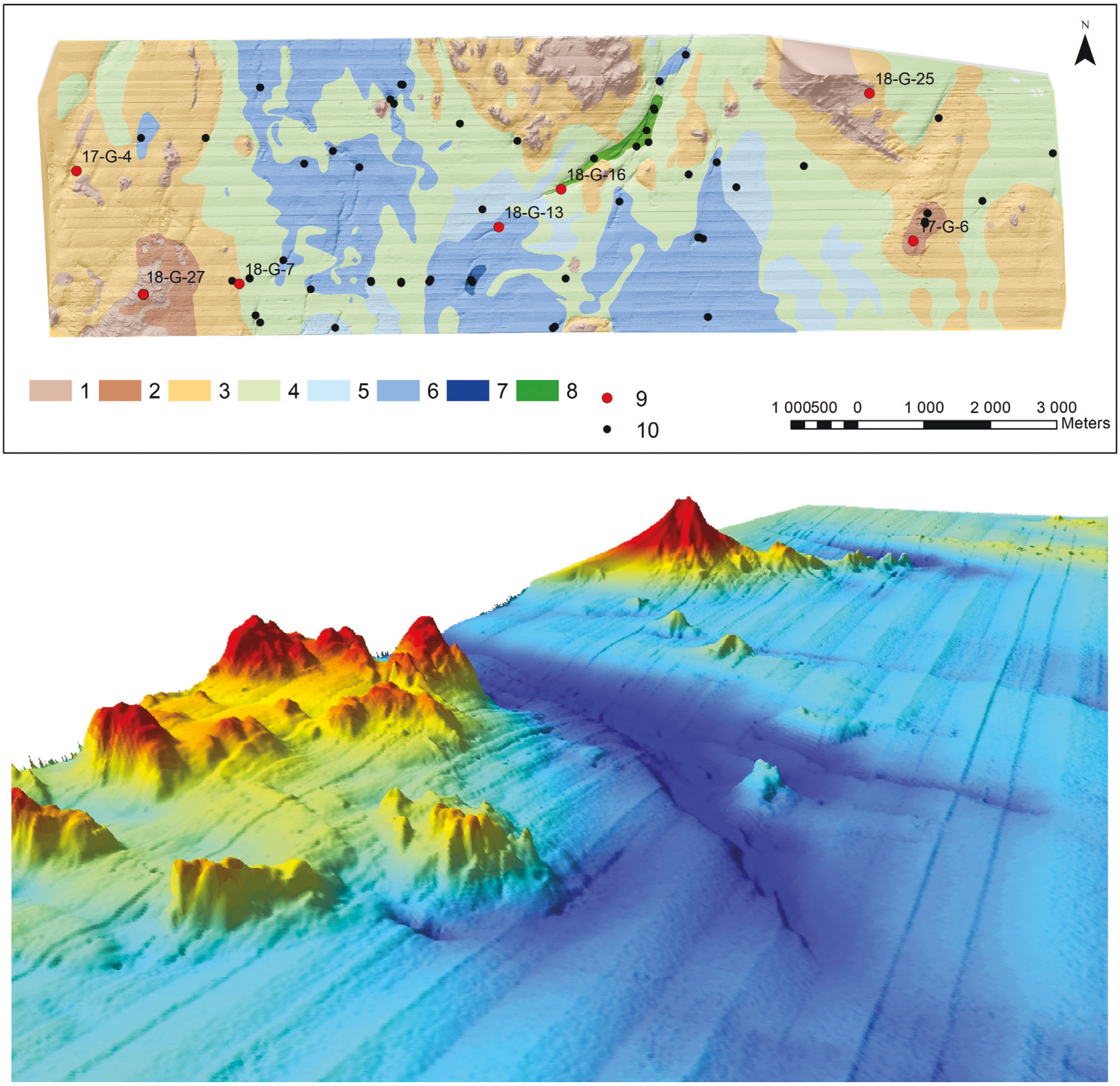

Figure. Map of submarine benthic landscapes of the Gof bottom to the east of Gogland Island.
1 — medium energy circalittoral hard or mixed sediment bottom with Fe-Mn concretions; 2 — medium energy circalittoral mixed sediment bottom with large Fe-Mn crusts; 3 — medium energy circalittoral oxic sandy clayey mud with Fe-Mn concretions bottom on the erosion surface of hard clays; 4 — medium energy circalittoral oxic sandy clayey mud bottom; 5 — low energy circalittoral oxic mud bottom; 6 — low energy circalittoral anoxic mud bottom; 7 — low energy circalittoral totally anoxic mud bottom; 8 — high energy circalittoral oxic mud bottom of submarine channels; 9 — geological sampling and video sites; 10 — biological sampling sites

11.7–120.2 g/m^2 [1, 2]). The sites located on the same substrate and oxic conditions but on the bottom of contourite channels are characterized by extremely low benthic invertebrates abundance and biomass (30 ind./m^2, and 0.47 g/m^2 respectively) and dwelled just by *M. arctia* and *S. entomon*. Anoxic surface of gas-saturated sediments are azoic or has a low benthic abundance and biomass (70 ind./m^2, and 0.46 g/m^2 respectively) of *M. arctia* and *S. entomon*.

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S2O3. Spatial Characterization of Seabed Environment and Properties for the Development of Ocean Energy in Sweden

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Identification and quantification of seabed environmental conditions and geotechnical properties in finding safe and environmental sustainable areas for installations of ocean energy are presented, using information produced from marine geological mapping. Several physical parameters are identified of importance in analyzing environmental conditions and planning designs, in addition to the suitability of different installation techniques for different areas on Swedish seabed. Existing as well as new information derived from geological mapping can be translated in proposed way and be used for ocean energy engineering and environmental analyses purposes, in both overview planning and detailed site mapping. Presented categories and spans of the environmental and geotechnical values for the different parameters have the possibility to be improved as new data are produced from future mapping. The data presented here has the high value of being incorporated into multi-criteria evaluations for optimal site selection of different offshore installations. Examples of weighting the parameters in finding suitable locations for installations and cables routes are performed.

S3P8. Paleogeographic conditions on the dried shelf of the Kara Sea during the Last Glacial Maximum

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This paper presents the reconstruction of the paleogeographic and paleoclimatic conditions of the north of Western Siberia region for the time of the Last Glacial Maximum (LGM) (about 25–12 ka). In this period was a maximum regression of the paleobsin of the Kara Sea to the modern depth of 120 m and limited distribution of ice sheets. This is also confirmed by our many years of research in this region [1].

To illustrate the spatial distribution of paleogeographic and paleoclimatic conditions, the authors compiled a schematic map (see Fig. 1 below) of the paleogeographic conditions of the Kara Sea region for the LGM.

We collected data of the $\delta^{18}O$ isotope content of elementary ice wedges (i. e. formed presently) and compared with the air temperature data of the nearest weather stations. This allowed to construct calibration curves [2]. According to the equations obtained, winter paleotemperatures of air were taken using the data of the isotopic composition of syngenetic ice wedges. Summer temperatures were estimated by stations located presumably in the same bioclimatic zones and having close values of winter temperatures.

Reconstruction show that, there was widespread freezing and formation of low-temperature permafrost in the north of Western Siberia region in LGM. This was facilitated by low air temperatures. Decrease of average annual air temperatures compared to modern values was 6–8 °C.

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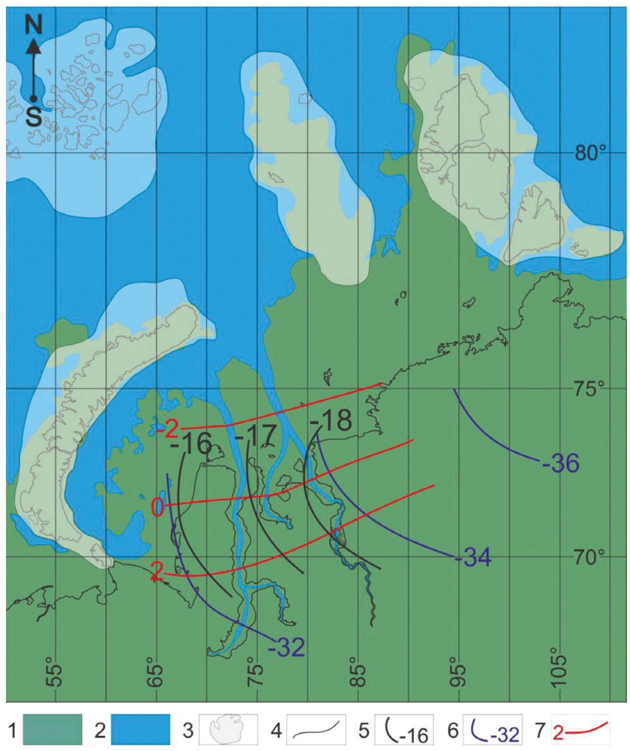

Figure 1. Schematic map of the paleogeographic pattern during the Last Glacial Maximum (25–12 ka). 1 — territory with subaerial conditions (land), 2 — territory occupied by the sea (subaqueous regions), 3 — areas covered by glaciers, 4- modern coastline, 5 — reconstructed average annual air temperatures, 6 — reconstructed winter air temperatures, 7 — reconstructed summer air temperatures

S3O11. Mapping shelf paleovalleys as mesophotic habitats

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The Espírito Santo continental shelf (ESCS) was analyzed through geomorphometry analysis, sediment cover and video-imaging, emphasizing the area of two paleochannels located in the central part of the shelf — APA Costa das Algas paleochannels and Vitória paleochannel. These channels represent important features in the shelf and due its complex morphology (variable slope, roughness and sediment grains), they can lead to distinct mesophotic habitats (deeper than 30 m).Using a 150 m resolution bathymetric grid generated from Inverse Distance Weighting (IDW) interpolation, it was possible to obtain topogaphic parameters through the Benthic Terrain Modeler (BTM).The model resulted in 8 geomorphological zones in the shelf bottom: flat bottom (from 0 to 0.2º),rough bottom (from 0,21º to 0,81º), shallow crest (below –26 m), deep crest (above –26 m), depressions, shelf break, valley bottom and valley flanks. This classification was combined with the present sedimentology in order to distinguish the different habitats of the shelf, resulting in 17 habitat classes. In order to better characterize the seabed and benthic habitats in the paleovalley areas, high resolution images of the seabed were obtained in 94 sites using a drop camera. Sampling stations were distributed between the margins and central portion of the paleovalley. The images showed a varied sediment cover, besides a diverse benthic community, mainly along the submerged channel flanks. Moreover, an extensive rhodolits bed dominates the central and outer shelf portions, bordering the valleys and enriching biodiversity. The combination of all the data allowed to find discrepancies between the two sets of paleochannels, The Vitória paleochannel, is shallower with a gentler slope and less roughness than

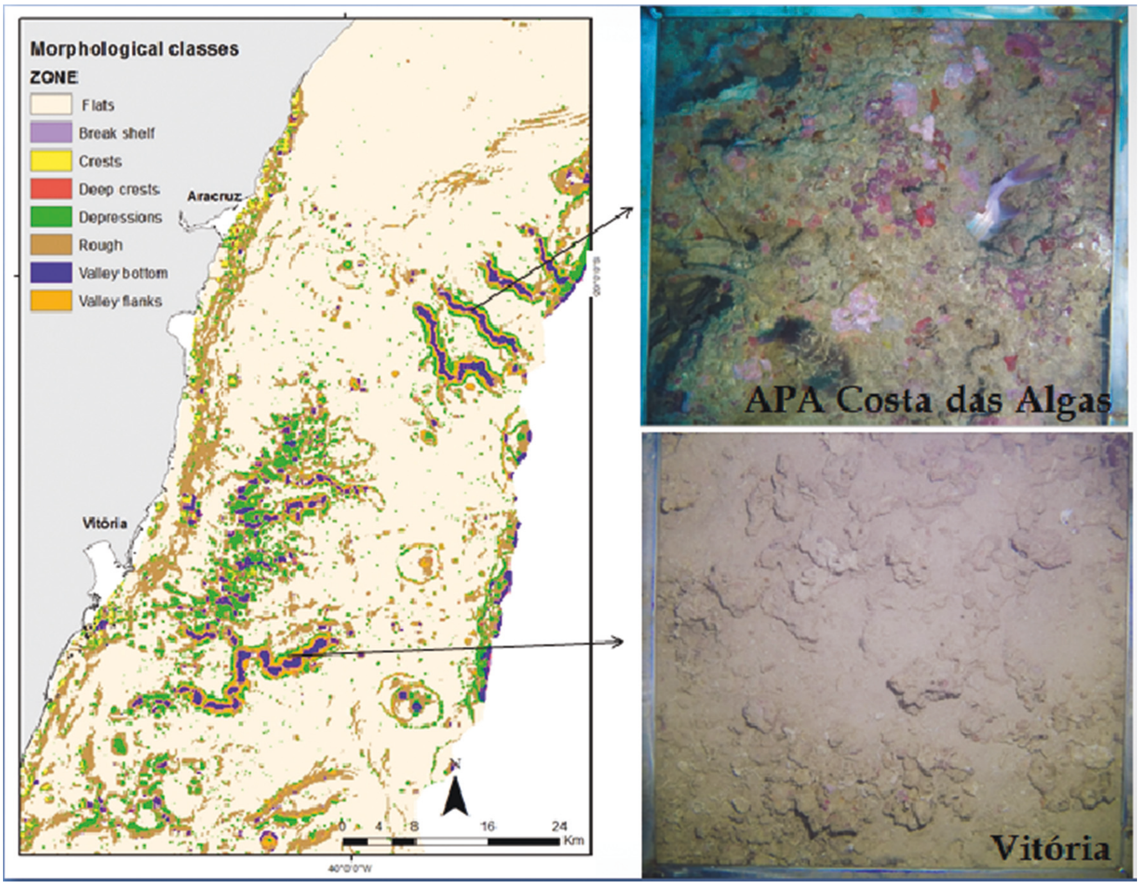

Figure 1. BTM zones (left) and the different kind of organisms in each channel (right).

APAs paleovalleys. In terms of habitats, it presented finer sediments and smaller visible organisms (as bryozoa, ascidians and smaller algae).The APA Costa das Algas paleochannels showed steeper slopes and higher roughness, being covered by coarser sediment. In these channels reefs habitats were observed with corals, macroalgae, sponges, bryozoans and ascidians.When tested if ocurred correspondece among the BTM geomorphologies and our background images, it was obtained a correlation of 79,5 %. Analysing the combination between the BTM zones and the sedimentary classes, 60 % of the resulting habitat classes coincided with the images. Thus, the model proved to be effective in the geomorphological classification, being able, when combinated with a trueground method, to recognize the paleodrainages here studied as mesophotic habitats.

S1O21. Case studies of geo- and biodiversity of underwater landscapes in the eastern Gulf of Finland (Baltic Sea): is anything interesting across brackishwater lightless areas?

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According research carried out along most of Finnish and Russian eastern Gulf of Finland (EGoF) aquatic territories and directed to reveal thresholds for driving forces's underlying identification of underwater landscape types [1], the large-scale spatial mosaic of underwater landscapes estimated by abiotic conditions and structure of macrozoobenthos is statistically dependent on position of a given area in salinity gradient and in gradient of factors, contributing vertical zonality in habitats distribution as well as on archipelago effect.

Three case studies [2–4] are resultant from multidisciplinary RV *Academic Nikolaj Strakhov* (July 2017) and *Academic Boris Petrov* (July-August 2018) surveys [2–4]. They also serve for approbation of integrative approach established thereafter [1] and for provision basic information on geography (values of physical and chemical paraments in water along profiles and measured above and in benthic sediments), geology (morphology, substrates, and their dynamics) and on macrozoobenthos characteristics (taxonomical content and quantitative development) and habitat number and distribution at three relatively study areas situated at depth below 20 m in the vicinity of big islands (Moshny, Gogland) or group of islands (Beriozovye archipelago) (Figure). It is aimed to fill in gaps in our knowledge on underwater EGoF's landscapes not included either to previous study [1] or submission to GeoHab atlas 2-nd edition [5]. Selection of these polygons has allowed to exclude from our consideration salinity, vertical heterogeneity, temperature and other macro- and mezoscale driving forces those determine general distribution of underwater landscapes mosaic in EGof [1] (the polygons are situated below photic zone in mesohaline conditions below the halo- and thermoclines, at approximately similar distance from shores) and to concentrate at local peculiarities: structure of bottom sediments and their heterogeneity; prevalence of accumulation and transit of sediments; specific geological structures (e. g. moraine, Pleistocene clays, runnels and craters); physical and chemical processes (e. g. gas (methane) production and ferromanganese concretions formation).

Each area the abiotic conditions and macrozoobenthos settlements are variable within and between them. The Gogland polygon is the most geologically heterogenous [2], totally 8 typical bottom habitats with peculiar abiotic conditions and macrozoobenthos assemblages are revealed according to BalMar classification therein, while Vyborg [3] and Moshny [4] polygons are represented by only 5 habitats each. Total number of underwater typical habitats for all three polygons reaches 11, three of these are present at all three polygons (*Medium energy circalittoral oxic sandy clayey mud with Fe-Mn concretions bottom on the erosion surface of hard clays; Low energy circalittoral oxic mud bottom; Low energy circalittoral anoxic mud bottom*), one (*Medium energy circalittoral mixed sediment bottom with Fe-Mn concretions*) are present in two — Gogland and Moshny areas, while 7 of 11 were revealed only at one of polygons. In Gogland polygon there were four "original" habitats (*High energy circalittoral oxic mud bottom of submarine channels; Medium energy circalittoral mixed sediment bottom with large Fe-Mn crusts; Medium energy circalittoral oxic sandy clayey mud bottom; Low energy circalittoral totally anoxic mud bottom*), in Vyborg — two (*High energy circalittoral Boulder hard bottom; Medium energy circalittoral oxic sandy clayey mud bottom with growing Fe-Mn*) and in Moshny — one (*Medium energy circalittoral oxic sandy clayey mud bottom with discoidal Fe-Mn*).

As it has been shown by underwater videorecording and quantitative sampling of macrozooben-

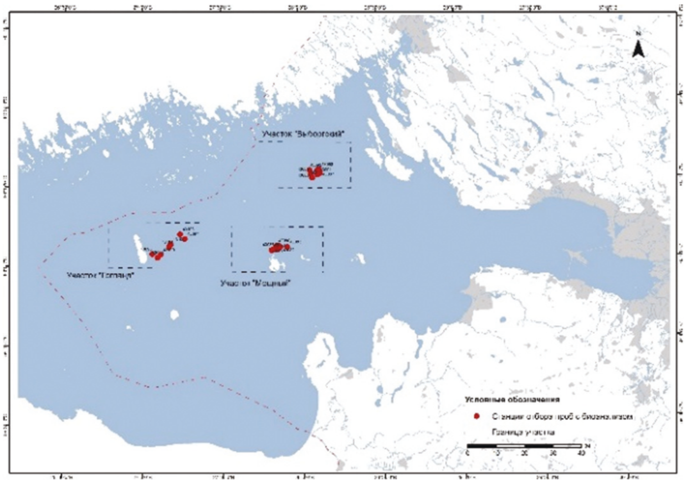

Figure. Position of polygons investigated in 2017 and 2018 years, see also figures in [2–4]

thos applied alone or in combination of both [2–4] the only habitat — *Low energy circalittoral totally anoxic mud bottom* is azoic in sense of macroinvertebrates and life there is represented by bacterial mats only. Opportunistic non-indigenous habitat-engineering spionid polychaete *Marenzelleria arctia* is established now along the whole EGOf and herein [2–4] it demonstrates dominant (rarely subdominant) position in macrozoobenthos including anoxic habitats due to its mode of life and capacity to anaerobic metabolism. Vagile aborigin opportunistic isopod *Saduria entomon* also common in everywhere. Aborigine *Limecola balthica* (Bivalvia) and *Monoporeia affinis* (Amphipoda) get dominance or subdominance at oxygenated mixed and muddy sediments. Peryphyton (one habitat in Vyborg polygon) is typical for the EGof and it is contributed by zebra mussel, barnacles, hydrozoans and vagile invertebrates. Total macrozoobenthos abundance (below 100 ind./m^2 (*low*); 100–1000 ind./m^2 (*medium*) and above 1000 ind./m^2 (*high*)) distribution was similar for all three polygons (with some uncertainness for more heterogenous Gogland polygon) and looks to be dependent on type, heterogeneity and dynamics of bottom sediments (substrates): the *low* grade is characteristic to homogenous anoxic and oxic muds with increase to *medium* at boulders ridges, partly covered by sand and (*medium and high*) at oxygenated mixed sediments lied on the heterogenous layer consisting of sands, gravel and Fe-Mn concretions. Some decrease is registered at mixed sediments lied on dense clays. The *high* grade is registered also at fields of Fe-Mn concretions at the phase of active growth with the highest value for macrozoobenthos s. str. of 5300 ind./m^2.

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S5O5. New discoveries of deep water coral and sponges identified in the North-east Atlantic, offshore Ireland

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A three year assessment of Irelands' Annex 1 Reef habitat to determine the extent of offshore reef habitat has entered its final year of data acquisition. The project funded by the Marine Biodiversity Scheme of the European Maritime and Fisheries Fund (EMFF) Operation Programme 2014–2020 has undertaken two deep-water surveys within Ireland's EEZ since 2017. The surveys using the Marine Institute's *Holland 1* ROV equipped with HD video have mapped reef habitat in water depths ranging from 500 m to just under 3000 m.

In 2018 the survey area extended 500 km along the continental margin south-west of Ireland and 250 km along the eastern flank of the Rockall Bank. In total 120 km of seabed were surveyed over 52 transects. Bathymetric data acquired under Ireland's national seabed mapping programme INFOMAR was reviewed to identify areas of Annex 1 reef habitat associated with seafloor features including canyons, escarpments and carbonate mounds. INFOMAR is the Department of Communications, Climate Action and Environment funded national seabed mapping programme, jointly managed and delivered by Geological Survey Ireland and the Marine Institute. This data combined with fisheries data and information on existing Annex 1 reef habitat was used to inform the site selection.

During the survey high definition ROV video recorded a number of novel species and habitats within Irish waters. Initial findings suggest that several coral species observed are recorded for the first time in Irish waters including two species of black coral (in the genera *Telopathes* & *Stauropathes*) and a species of Octocoral called *Corallium* which forms a distinctive, rigid exoskeleton. Another black coral specimen, also thought to be of the genus *Stauropathes* appears new to science and has never been documented before. The coral species were found at the continental margin of the Porcupine Bank. Rare specimens of large hydroids were recorded as were Relicanthids previously only seen in the Pacific. Finally, areas of potential 'sponge reef' resembling unusual accumulations of living and dead sponges forming a complex habitat for associated species, were observed in video from the Rockall Bank. Such formations are rare and have previously only been recorded in Canadian waters.

Verification will require further investigation, which is underway. The findings underline how much remains unknown about our deep water species, where they exist, and the habitats they form. These remarkable discoveries highlight the importance of high resolution bathymetric data to underpin the identification of seabed features for the assessment of reef habitat. A better understanding of the distribution of offshore reefs is imperative to promote good fisheries management and protect biodiversity in support of the EU Habitats Directive.

S3PO5. Essential shark habitat discovered within a Special Area of Conservation in theNorth-east Atlantic, offshore Ireland

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Assessing Irelands' Annex 1 Reef habitat has been the focus of a study funded under the European Maritime and Fisheries Fund's Marine Biodiversity Scheme (2014–2020). The EU Habitats Directive requires that member states introduce a range of measures for the protection and monitoring of the conservation status of habitats and species listed in the Directive. This project has undertaken annual deep-water surveys since 2017 using the Marine Institute's *Holland 1* ROV equipped with HD video to observe biogenic and geogenic reef formations and biological associations within Irelands EEZ. Bathymetric data acquired under Ireland's national seabed mapping programme INFOMAR was analysed to target areas of interest. INFOMAR is the Department of Communications, Climate Action and Environment funded national seabed mapping programme, jointly managed and delivered by Geological Survey Ireland and the Marine Institute.

There are currently six designated offshore Special Areas of Conservation (SAC) varying in depths from 400 m to 1600 m. In 2018 a survey in one such SAC observed a large school of several thousand blackmouth catshark, *Galeus melastomus*. Below this school, thousands of mermaids' purses (egg-cases) were deposited on a bed of fragmented stony coral habitat at a depth of 750 m. It is believed the cold-water coral framework forms a suitable habitat upon which the sharks deposit their eggs. This is the first time such a nursery habitat has been identified by ROV. Species of crab, sea-urchins and starfish were also observed at the site. This suggests that stony coral such as *Lopheila pertusa* forms an important biogenic reef and essential fish habitat after it has died. In addition, nearby healthy coral reef (also *Lophelia pertusa*) may act as a refuge for shark pups once they hatch. Of further note was the observation of a rare Roughskin sail shark, *Oxynotus paradoxus* in association with the site and potentially foraging on the egg-cases. Both shark species are listed as deep-water species of interest for fisheries managers of the North East Atlantic Fisheries Commission (NEAFC) and for environmental protection purposes. Although *Galeus melastomus* is relatively abundant in the North Atlantic, it is of interest to fisheries managers as it is an important bycatch species. *Oxynotus* is listed as "Near Threatened" on the Irish red list, and otherwise data deficient in European waters. Ongoing monitoring of the site could yield further data that would support Ireland's reporting obligations under the Marine Strategy Framework Directive (MFSD) Descriptor 1 (Biodiversity), OSPAR and the Habitats Directive. The data are currently being processed in support of an ICES data call on Vulnerable Marine Ecosystems and will input directly into national obligations under the MSFD and Marine Spatial Planning Directive. This remarkable finding highlights how little is known about the ecology and biology of deep-sea sharks, where they exist and the habitats they utilise.

S1O22. Comparison of stone detecting strategies in terms of scientific and stakeholder purposes

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The demand for efficient stone detection techniques of stony areas (reefs) in the marine environment increased in the last years. This is especially important for seafloor areas with a patchy distribution of stones in an otherwise sand-dominated milieu. These hard substrates are hotspots of marine biodiversity; especially for benthic communities. For fishes, marine mammals and birds stony areas are important breeding and feeding places. Current research projects are dealing with the stone distribution and density to investigate e. g. species-habitat interactions. On the political level detailed distribution maps are relevant for resource assessments, coastal management and protection conventions.

The detection of stony habitats in sublittoral environments is still a considerable challenge in spite of modern high resolution hydroacoustic techniques. Object detection on the seafloor is commonly done on the basis of hydroacoustic backscatter intensities recorded with e. g. sidescan sonar and multibeam echo sounder. Single objects such as stones can generally be recognized by the acoustic shadow behind the object. For small areas single objects can be easily identified manually; for large scale mapping automated techniques are required which are still under development.

We collected a set of hydroacoustic data on the German continental shelf to compare and discuss the following approaches to detect and demarcate stony habitats:

- manual detection on backscatter mosaics
- automated detection on backscatter mosaics using machine learning techniques
- seismo-acoustic approach (sediment echo sounder, sidescan sonar)

S7P2. The paleo Elbe River: 10.000 yrs after flooding

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The submerged valley of the paleo Elbe River forms one of the most prominent structures of the German North Sea (~1.000 ha). The valley developed to its present form during the Weichselian sea-level lowstand (130 m below present). Melt waters that discharged in north-westerly directions along the Scandinavian Ice Sheet fed the paleo Elbe at that time. During the Holocene the valley drowned in the rising sea.

We will present an area-wide high resolution map of the seafloor (~1,600 km²), high-resolution shallow seismic data and sediment coring data along the paleo Elbe River to explain historical process of sedimentary valley infill and coastal evolution with the successive Holocene sea level rise. At the eastern levee of the valley (which belongs to a nature conservation area) complex sequences of glacio-fluvial and sub-glacial deposits are still present at the seafloor surface. The glacial deposits, consisting mainly of coarse sediments (such as coarse sands, gravel and boulders) are a unique habitat of the otherwise sandy North Sea. The new backscatter map highlights a much higher heterogeneity and complexity in sediment and habitat distribution as assumed before. The presence of only relative thin and patchy Holocene marine fine sand layers indicates strong hydrodynamic processes. Shallow seismic data show the base of the paleo Elbe valley and conspicuous internal seismic reflectors above the base, inclined in northeastern direction. Core data indicate a change in current regime and the development from a terrigenous towards a marine environment.

S3PO6. Submarine Permafrost Dynamics Along the Arctic Shelf Edge

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Exploration in the Canadian Beaufort Sea offshore of the Tuktoyaktuk Peninsula has revealed a remarkable coalescence of seafloor morphologic features. Submarine pingos, pockmarks, and slope-parallel deformation ridges align in bands rimming the shelf edge and uppermost part of the continental slope. The slope is associated with multiple slide scar headwalls, which in places start at 150 m water depth (mwd), but with increased depth merge into one gigantic regional slide scar, creating a more than 100 km wide continuous slide scar below 1200 mwd. In addition, scattered active mud volcanoes penetrate through the continental slope. To understand the development of these features, nine sites were investigated utilizing an Autonomous Underwater Vehicle (AUV) to provide 1-m resolution bathymetric grids and Chirp profiles, supplemented by sediment cores and Remotely Operated Vehicle observations. These morphological features all have geohazard implications, which may be unique to Arctic continental margin settings.

Four unusual environmental factors pre-condition the sediment dynamics here. First, during the sea level lowstand associated with the last glaciation the exposed shelf experienced ~–20 °C mean annual ambient temperatures, which resulted in substantial permafrost formation. Models and observations indicate some areas of the Beaufort Shelf are still underlain by a >600 m thick wedge of relict ice-bonded permafrost and methane hydrate down to >1000 m depths. This wedge of relict permafrost is inferred to extend out to the glacial shelf edge (~120 m) and its boundary is coincident with the distinctive topography. The postglacial marine transgression imposed a large thermal change in the sediment as the mean annual sea bottom temperatures are ≥-1.8°C. This thermal disturbance is still propagating into the subsurface, stimulating the decomposition of both permafrost and terrestrial gas hydrate at depth, which liberates water and methane. Second, the bottom seawater temperatures that impinge on the seafloor at the shelf edge in the Beaufort Sea are <–1.4 °C, cold enough to refreeze brackish pore water within near seafloor sediments. Third, pore waters sampled in 50 sediment cores taken from 90 to 1000 m water depths in this area freshen with sub-bottom depth, indicating the shelf edge and upper slope associated with this dynamic seafloor environment are pervasively bathed in brackish waters. Fourth, rapid sediment accumulations occurred on the slope during the ice ages.

Submarine permafrost decomposition and in-sediment brackish water refreezing in proximity to the seafloor result in the formation of distinct morphologies. The uppermost part of the continental slope in the Beaufort Sea within a band typically between 100 and 200 mwd is characterized by numerous circular topographic domes (i. e., pingos), that are up to 10 m high and ~50 m in diameter, occurring in places at a density of ~6 per km^2. Contour parallel lineations and ridges >1km long and <3 m high are also present and separated by rotated blocks of presumed Holocene age sediments. Circular topographic depressions (i. e. pockmarks), up to 20 m deep, occur at a density of ~1 per km^2, within this band. As the submarine permafrost under the shelf undergoes decomposition, buoyant brackish groundwater is hypothesized to migrate along its base, to emerge at the shelf edge and refreeze when it encounters the colder seafloor. As a result, sediment deformation caused by intra-sediment ice growth in less than 200 m water depths has uplifted the seafloor and created the numerous pingos and deformation ridges. Depressions result from sediment settling following thaw consolidation, collapse, and gas escape along the outer edge of the decomposing relict permafrost. Repeat mapping (2013 and 2017) shows that the deformation is on-going.

The heads of the slide scars on the slope are evidence for retrogressive failures that propagated up-slope over variable distances. However, the headwall scarps stop where the shelf edge permafrost is encountered. These slides have developed along sediment surfaces that were >30 mbsf within glacial marine deposits. Downward extrapolation of measured pore water chloride gradients indicates the widespread occurrence of brackish waters at the depth of the failure surfaces. These sediments were deposited under marine conditions but have been since flushed with brackish waters. Flushing was documented as flow at seafloor springs emanating from the slide scars, and as active fluid expulsions atop mud volcanoes. Both observations point to overpressured conditions. Overpressure and changes in pore water salinity reduce the bounding strength between clay particles, preconditioning these sediments for failure. Lack of sediment consolidation due to rapid sedimentation during glacial periods is inferred to be an additional factor for poor sediment stability, as observed in other glaciated margins where large sediment failures have occurred.

S5O6. Exploring the link between terrain complexity of deep-sea coral mounds and species assemblages

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Small mound features 3 m high and 50–150 m in length occur on the interfluves between the Dangaard and Explorer canyons, North-East Atlantic [1]. The mounds are situated within the Canyons Marine Conservation Zone (MCZ), designated for the presence of "deep seabed" and "cold-water coral reefs". The mounds are predominantly comprised of coral rubble: to date no live cold-water corals (CWC) have been observed. The interfluves of the MCZ (and hence also the coral mounds) are subject to trawling pressure, with the morphology of the mounds differing between the interfluves. Trawling acts to modify seafloor morphology by reducing terrain complexity. A species assemblage comprised of '*Ophiuroids and Munida sarsi associated with coral rubble'* has previously been described from a limited data set covering the mounds [2]. This classification relates to '*coral rubble zone'* described from other settings, where coral rubble assemblage has been found close to live coral reef [3]. Understanding if the mounds support reoccurring species assemblages that are distinct from those on the surrounding seabed and from those next to live coral reefs, and establishing the role of terrain complexity as environmental driver is fundamental to effective habitat mapping and management of these features.

This study aims to study the link between species assemblages, sediment characteristics and morphology of the mounds at the two interfluves, and to ascertain if there is a 'threshold' terrain complexity below which mound-specific species assemblages no longer occur. Data were collected during (1) the JC125 expedition funded by the ERC CODEMAP project (Starting Grant no 258482) and the NERC MAREMAP programme, and (2) the JC166 expedition funded by the CLASS project (Grant no NE/R015953/1). Autosub6000 AUV high-resolution sidescan sonar and sub-bottom profiler data and ROV *Isis* HD video data were acquired to characterise the sediments, morphology and megabenthic species assemblages of the mound provinces. Species assemblages were identified from the video data. Sidescan sonar image texture indices were calculated and multivariate analysis implemented to explore the relationship between sediment characteristics, terrain complexity and species assemblages.

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S1O23. Geological and geomorphological elements that form shelf benthic communities

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This presentation considers the leading role that geological and geomorphological elements play in the formation of various types of demersal and continental shelf benthic communities. Recent tectonic processes control the nature of coastal seafloor relief and the composition and distribution of bottom sediments. Tectonic uplift resulted in the construction of extensive shallow water geomorphology in the form of local ridges and depressions that trend orthogonal to the coastline (fig. 1a).

Two basic types of natural bottom complexes are identified that exhibit characteristic habitats and communities of aquatic organisms. One such complex consist of bedrock outcrops and the accumulation of the eroded detritus (fig. 1b). The other is a combination of the main types of natural bottom

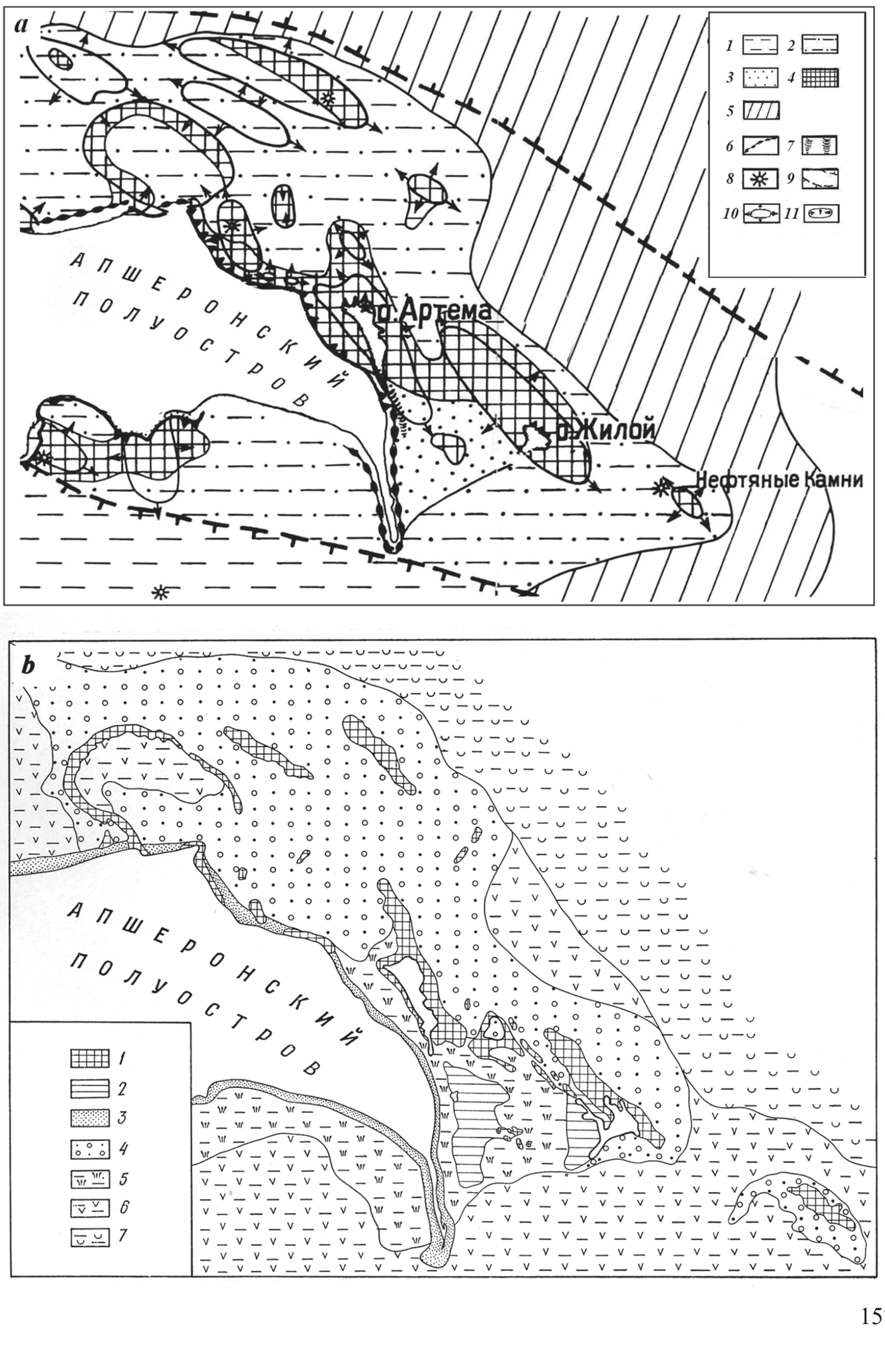

Fig. 1. **Seafloor maps showing the interconnection of geomorphologic and landscape-bionomic features within the Absheron Archipelago [1]:**
a **— Geomorphological map. Legend: *1* — accumulative (depositional) plains, *2* — abrasion-accumulative (erosional-depositional) plains, *3* — nearshore accumulative (depositional) areas, *4* — abrasion (erosional) ridges, *5* — lower shelf accumulative (deeper, non-wave depositional) plains, *6* — coastal sand ramparts, *7* — sand bars, *8* — mud volcanoes, *9* — seaward extension of the Greater Caucasus mega-anticlinorium, *10* — seafloor expression of active anticlinal uplift, *11* — inverted landforms confined to local synclines.**
б **— Landscape-bionomic map. Legend: *1* — abrasion-sculptural (eroded-scoured) features with sessile benthos, *2* — plains covered with lithified crust containing communities of red algae, *Mytilaster* and *Balanus communites*, *3* — coastal ramparts, *4* — sandy-shell plains with nektobenthonic communities of *Isopoda*, *Amphipoda*, Cumacea, *5* — muddy-sand plains with sea grass community at depths of 2–5 m, *6* — muddy plains with community of pelophilic infauna *Cerastoderma lamarcki*, *Abra ovata*, *Pyrgula*, *Nereis diversicolor*, *Oligochaeta*, *Hypania* at depths greater than 10–15 m, *7* — muddy plains with Dreissena rostriformis community at depths of 15–20.**

complexes that forms complex abrasive-accumulative (erosional-depositional) seascapes. Natural bottom complexes (rock exposures and facies) form a system of horizontal and vertical morphological units [4].

The experience in using aerial photography for complex study and mapping of the seabed in shallow waters is discussed (fig. 2) [1]. The important role of using modern space data and methodology in these studies will also be noted [2, 3].

The results of this marine study is described in an article on ,the benthic landscape-bionomic types of the Absheron Archipelago [5].

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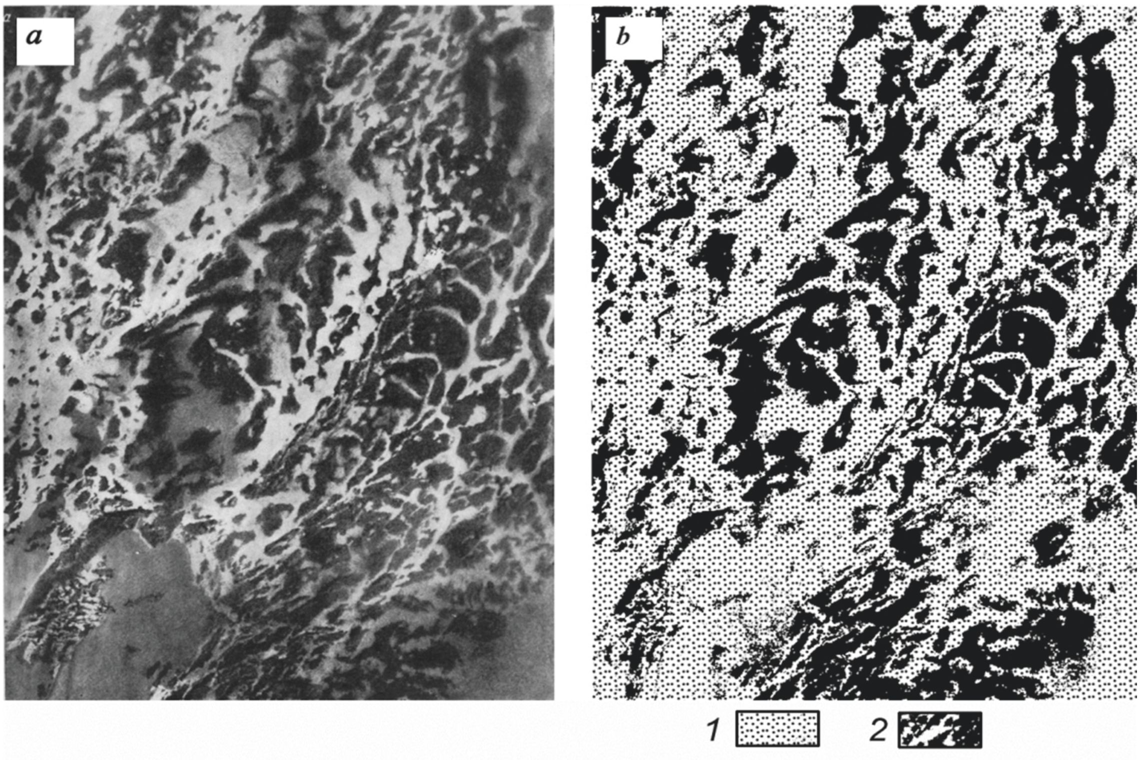

Fig. 2. **Abrasion-sculptural (erosional-scoured) features with communities of sessile benthic organisms occupying an exposed anticlinal fold: *a* — air photo (m-b 1 : 15 000): dark areas of the image correspond to ridges overgrown with red algae *Ceramium elegans* and bivalves *Mytilaster* and *Balanus*; light areas represent sand and shell sediment; *b* — map of facies: *1* — facies of sand and shell sediment, *2* — ridges with communities of sessile benthic organisms**

S1P21. Bionomic principle of zoning of large marine ecosystems

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Bionomic principle is based on the statement that the natural complex of any rank simultaneously is an unit of biogeographical zoning of ocean.

G. Hempel and K.Sherman [1] proposed the concept of Large Marine Ecosystem (LME). M. Spalding with colleagues developed the global system of regionalization of the World Ocean, which includes 12 realms, 62 provinces and 232 ecoregions [5]. In this system, the lowest unit is the ecoregion — a large water area, as a rule, the whole marine basin analogue of physical — geographical country of continent. The principles of creating the hierarchical system of ecoregion subdivisions are discussed in this paper. Biomes at the local (topological), regional, sub-oceanic and oceanic levels might be described in broad terms. The lowest level of biomes are consistently included in higher-rank biochores.

Any natural complex in the ocean and associated communities of hydrobionts represent a single whole, the development of which was carried out in certain conditions of latitudinal zonality, vertical zonation and was controlled by azonal geological-geomorphological factors. A three-row level system of units of regional dimension is proposed [3]. The units of zonal differentiation include belts, zones (latitudinal) and provinces. The system of units of vertical biogeographic differentiation includes stage, belt and zone. The system of azonal units consists of ocean sectors, marine basins, regions, districts.

The lowest and the initial unit of zoning of the ecoregion is the underwater landscape, is a water area, characterizing by a common plan of the geological structure, defined the regularities of the bottom relief and formation a modern geological facies, homogeneity of the hydrometeorological regime, the originality of the composition and distribution of benthic communities [2]. Underwater landscapes are distinguished by the unity of zonal, vertical and azonal characteristics. The position of each landscape and, accordingly, the bionomic area should be determined in a system of three coordinates simultaneously.

The principles of construction the hierarchical system of units — from global to regional ones — are discussed on the example of the Barents Sea, which one is accepted as a large marine ecosystem [4].

The Arctic Ocean and its seas belong to the Arctic belt, which is divided into two zones: Polar-Arctic and South-Arctic ones. In the Arctic belt, the natural conditions change not only in the latitudinal, but also in the longitudinal direction. As the distance from the Atlantic Ocean there is a natural increase in continental climate. In the Barents Sea, the Arctic zone is divided into the Barents Sea Arctic and the Barents Sea Subarctic provinces. Its main central part lies in the Subarctic province. The South-Western part of the sea, most heated by warm Atlantic waters, belongs to the extrazonal Barents Sea province of the boreal zone.

Vertical differentiation takes into account changes in conditions with depth. The properties of vertical zones in the Barents Sea depend on the natural province in which they are formed. Seasonal changes in the hydrometeorological regime, depending on the balance of solar radiation, are significant in the surface zone. In the bottom zone, the thermal regime is determined by provincial conditions. In the same latitudinal zone, the observer, moving from littoral to sublittoral, can observe the change of fauna from boreal to Arctic area.

Azonal differentiation occurs out the causal relationship with the zonal features of the ocean nature. Against the general background of geographical zoning, the distribution of life on the sea floor is controlled not only by the properties of water masses, but also by the geological structure, relief and deposits. Geological structures of different scales and the nature of tectonic movements contribute to distinguishing of bottom natural complexes. It is proposed to use the geomorphological zoning scheme as the basis for the subdivision of the Barents Sea [6]. The definition of the two Barents Sea landscapes is given below.

Underwater landscape of coastal zone of the Kola Peninsula (the Murmansk shore) corresponds to: 1) the sculpture relief formed on the Kola monoclonal characterizing by a rapid increase in depth towards the open sea (the South-Western geomorphological region); 2) the boreal zone of the extrazonal Barents Sea province, influenced by the warm North Atlantic Current, with a predominance of rich boreal fauna; 3) the shelf stage, upper belt, the littoral with *Fucus vesiculesus*, *Laminaria digitata* and the sublittoral with *Alaria esculenta*, *Chorda tomentosa*, *Odonthalia dentate.*

Underwater landscape of the Pechora Sea corresponds to: 1) the Pechora Flat, the accumulative relief formed on underwater continuation of the Russian Platform, characterizing by a slow increase in depth towards the open sea (Kan-in-Pechera geomorphological region); 2) the Subarctic of the Barents Sea province; 3) the shelf stage, middle belt, with dominating communities of bivalves (*Ciliatocardium ciliatum, Macoma calcarea, Serripes groenlandicus*) in sandy-mud deposits.

Bionomic zoning of large marine ecosystems is essential for monitoring, rational use and protection of marine biological resources at different hierarchical levels.

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S3O12. Characterising marine benthic habitats on the South African continental shelf using geophysical tools

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Development of a method in benthic habitat mapping is currently being conducted in South Africa by the authors, using Table Bay and Cape St. Francis areas in the Western and Eastern Cape respectively, as case study sites. We are developing a benthic habitat classification method to bridge the disciplines of marine geophysics and biological science. If the method can be refined for two contrasting bioregions and, study sites located in different oceanographic and geological settings, we anticipate that it can be applied across the South African continental shelf. We are processing backscattered acoustic waves from data acquired on the continental shelf to predict benthic distributions of biota based on the seafloor geology. We present our results from the Table Bay dataset, which has been classified using a number of statistical algorithms and computer programs. The backscatter data collected was classified using Analytical Range Analysis (ARA), a tool within Fledermaus Geocoder Toolbox (FMGT), and was able to calculate the sediment distribution in Table Bay area. Machine learning uses statistical techniques to give computer systems the ability to learn, without being explicitly programmed. These statistical techniques are a relatively new method of working with scientific data (since the 2000's), and have been used to classify the geophysical data. Decision Trees (DT), Random Forests (RF), Support Vector Clustering (SVC) and K-means clustering were a few of the computer algorithms compared. The backscattered wave signals will be classified using these algorithms and linked to the type of benthic species that is most likely to inhabit that environment, as the intensity of the backscattered wave signals are dependent on the type of benthic species present. Underwater video and grab samples will be a few of surficial mapping techniques used to bridge the gap between the collected data and the interpreted data to create accurate and reliable benthic habitat maps. This study thus aims to develop a predictive tool that classifies both geological (geophysical and sediment data) and biological data into benthic habitat maps using machine learning techniques.

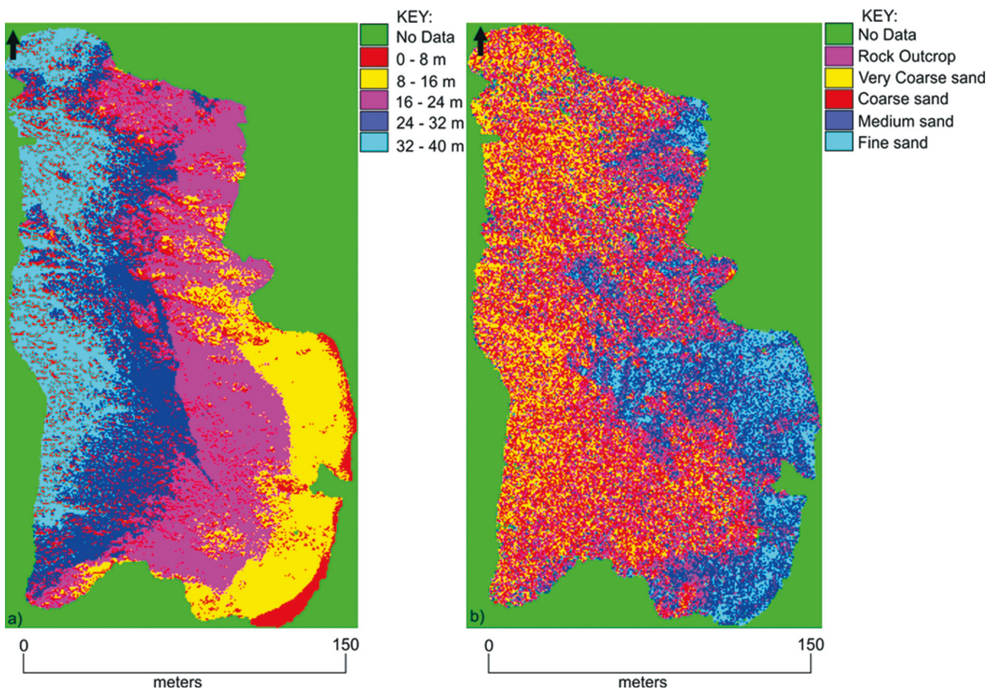

Figure 1. a) Models of the bathymetry (left) and backscatter data (right) from Clifton Beach, South Africa. The pixels within each image are clustered into groups of similar attributes. The bathymetry image showing areas of similar depth and the backscatter image showing sediment classes

S3O13. Field trials of Multi-vehicle Adaptive Robotic Surveys for Sea-floor Mapping and Characterization

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Multiple lines of research have to come together to demonstrate habitat mapping and benthic cover estimation using adaptive robotic surveys. In this paper we report on a few of these strands including: high resolution seafloor imaging from traditional AUVs and Lagrangian drifters, automated interpretation of seafloor imagery, and adaptive sampling guided by the uncertainty in predictions of benthic cover.

High resolution seafloor imaging from mobile autonomous platforms has become a valuable tool for habitat classification, stock assessment and seafloor exploration. This abstract addresses the concept of joint seafloor survey planning using both navigable and drifting platforms, and presents results from an experiment using a bottom surveying AUV and a drifting Lagrangian camera float. We consider two classes of vehicles; one which is able to self propel and execute structured surveys, and one which is Lagrangian and moves only with the currents. The navigable vehicle is the more capable and the more expensive asset of the two. The Lagrangian platforms is a low cost imaging tool that can actively control its altitude above the seafloor to obtain high quality images but cannot otherwise control its trajectory over the bottom. When used together the vehicles offer several scenarios for joint operations. When used in an exploratory manner the Lagrangian float is an inexpensive way to collect images from an unknown area. Depending on the collected images, a follow-on structured survey with the navigable AUV can collect additional information. When used simultaneously the drifting float can guide the AUV trajectory over an area. When both platforms are equipped with acoustic tracking and communications the AUV trajectory can be automatically redirected to follow the Lagrangian float using one of many patterns. This capability allows for surveys that are potentially more representative of the near bottom oceanographic conditions at the desired location. Results where both platforms were used as part of a coral habitat monitoring project are included.

Machine learning research offers flexible and powerful approaches that can use observations of different scales and modalities to construct predictive models with meaningful representations of uncertainty. Beyond providing a sense of the quality of the models, these representations can guide further collection of observations to improve predictive capabilities. The traditionally-resource constrained problem of generating habitat maps from full coverage acoustic multibeam data and targeted optical surveys can be viewed through the lens of machine learning and adaptive sampling. We have investigated the use of techniques in machine learning such as deep learning methods, Gaussian Processes and Dirichlet-Multinomial regressors to generate habitat maps and to suggest where further sampling would be most useful.

We present results based on surveys performed in Australia using ship-borne multibeam sonar and precisely georeferenced imagery collected with Autonomous Underwater Vehicles (AUVs).

Based on these experiences we reflect on successes, ongoing challenges, future research directions for advanced autonomy for robots operating near the seafloor. We also discuss areas potentially ripe to transition from research to operational capabilities.

S1O24. Acoustic Fish Aggregation Around an Artificial Reef in Pozos Colorados, Colombian Caribbean

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Artificial reefs were installed inside a Marine Protected Area (MPA) in Pozos Colorados Bay to improve fisheries management. Artificial reefs are used to enhance fish aggregation and can function as an MPA, improving the quality of the ecosystem. Therefore, it is important to know the effectivness of artificial reefs to improve the biomass of fisheries resources as a conservation measure. The objective of this study was to assess the aggregation of fisheries resources by acoustic methods around an artificial reef in Pozos Colorados. We undertook the survey using a Biosonics DTX scientific echosounder with a split beam transducer of 38 kHz. The survey design consisted of coast-parallel and coast-normal transects spaced every 25 m. Sampling of fish was carried out at a 5 m pacing around the reef. We found ahigher fish aggregation near the artificial reef, suggesting that the reef is acting as a nursery area with possible spillover to nearby fishing areas. This artifical reef protected area can be used by fishermen for eco-tourism through SCUBA diving as an alternative to fishing.

S3O14. Slope environments of the East Antarctic margin: Influence of geomorphology, substrates and oceanographic processes on benthic communities

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The seafloor of the Antarctic upper continental slope is a dynamic and varied environment, shaped by the interplay between geological, oceanographic, glacial and sedimentary processes over long and variable time periods. Oceanographic processes include the export of dense shelf waters, upwelling of Circumpolar Deep Waters and strong along-slope flow and mixing associated with the Antarctic Shelf Front. These features can enhance the productivity of the surface waters and influence the food supply and deposition of sediment at the seafloor. Oceanographic and glacial processes have influenced the development of a complex slope morphology characterised by dense gully networks, rugged submarine canyons and broad sediment ridges.

This study draws on case studies from the East Antarctic margin to understand the processes that drive the modern distribution of benthic biota on the upper slope. These studies illustrate how the composition of seafloor benthic communities are shaped by oceanographic, glacial and sedimentary processes. Flow of dense shelf waters through shelf-incising canyons off the George V margin influences the occurrence of dense hydrocoral communities [1, 2] (Figure 1), while variations in gully

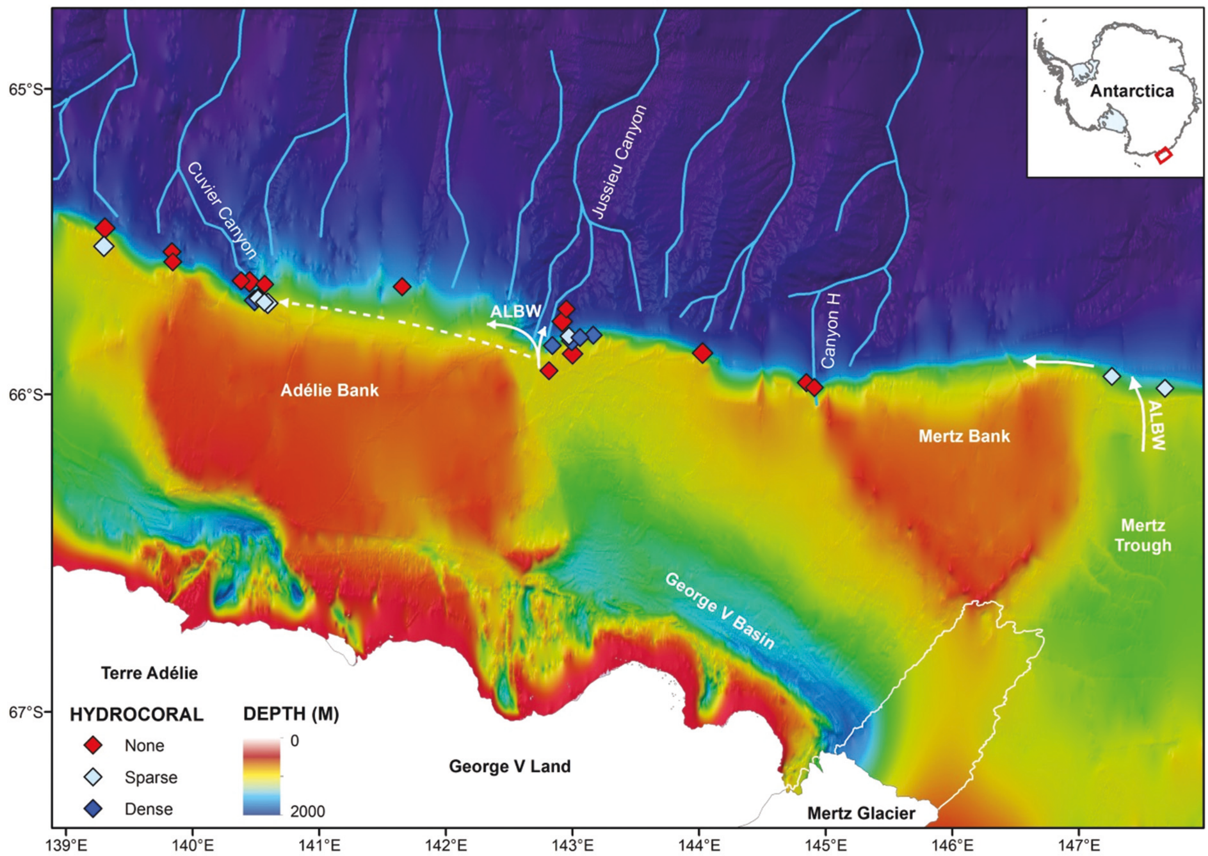

Figure 1. Distribution of hydrocoral communities on the George V slope, Antarctica. Canyon thalwegs are shown by the blue lines. ALBW is Adelie Land Bottom Water. Modified from [2]

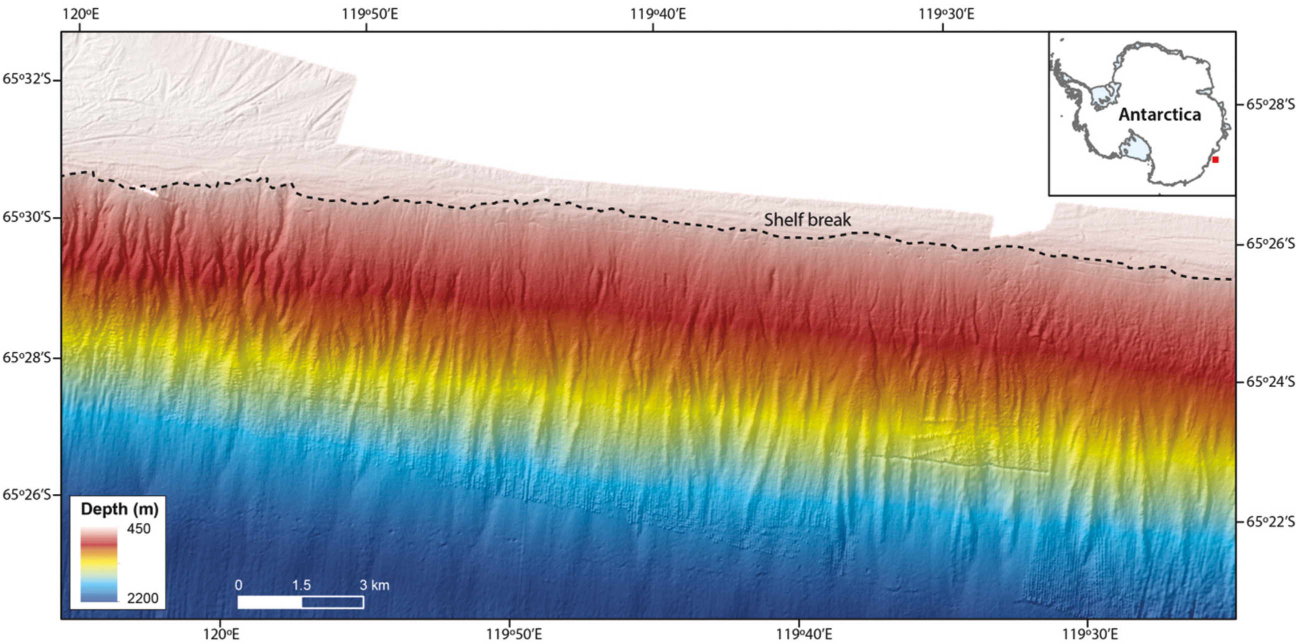

Figure 2. Gullies on the Sabrina upper slope, Antarctica. Gullies become smoother and longer from east to west

morphology on the Sabrina upper slope (Figure 2) creates heterogeneity in the occurrence and diversity of sessile suspension feeders and mobile fauna. The upper slope provides a unique setting for understanding how benthic biota respond in a dynamic environment.

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S3PO7. Mapping seafloor geomorphology and habitats: The influence of scale

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Our knowledge of seafloor bathymetry varies considerably, depending on mapping effort and depth. For large areas of the oceans we rely on satellite data, which varies in resolution from 15 min (~500 m, SRTM15_plus [1]) to ~10 km (GSFM [2]), providing a generalised view of seafloor features. Areas with sufficient ship-track data allow the compilation of satellite and ship-board data, providing better constrained and higher resolution data (e. g. 500 m, International Bathymetric Chart of the Southern Ocean [3]). Dedicated multibeam surveys produce seafloor bathymetry at 1 to 400 m resolution, depending on water depths up to 5750 m, however, for much of the world's oceans multibeam surveys are restricted to relatively small areas.

So how does the scale of observational data affect our assessment of seafloor geomorphology and habitats? The aim of our research is to determine the optimum resolution required to adequately map geomorphic features, and particularly those that provide potential benthic habitats. We assess the detection of seamounts from the Heard and McDonald Islands region from bathymetry datasets ranging from 10 m to 1.85 km resolution. We use steep seabed slopes to infer hard substrates from nearshore and continental slope datasets, and test the effect of data resolution on our assessment of these habitats. We analyse heavily iceberg scoured regions from the outer Antarctic shelf at various data resolutions, and finally use terrain analysis tools to assess mapping of key habitat features at a range of scales. These analyses show that the optimal ratio between the scale of analysis and data resolution varies according to the complexity of the environment. Mapping scales should be optimised based on geomorphic complexity to ensure that benthic habitats can be adequately and confidently mapped.

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S5O7. Living Cold Water Corals Surrounded by Fishing Grounds in Blanes Canyon (NW Mediterranean)

Pere Puig[1], Claudio Lo Iacono[1,2], Ruth Durán[1], Jordi Grinyó[1], Stefano Ambroso[1], Fabio De Leo[3], Marta Arjona-Camas[1], Sarah Paradis[4], Albert Palanques[1] and ABIDES cruise team

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During the ABIDES Project, 20 ROV dives were conducted along the Catalan margin (NW Mediterranean) targeting heavily exploited continental slope fishing grounds, with the aim of exploring the impact of bottom trawling activities on surface sediments. During the 7 dives conducted in Blanes Canyon, Cold Water Corals (CWCs) were discovered at several locations, always associated with the presence of exposed rocky outcrops. The occurrence of living CWCs in this canyon had not been documented before, and represented an unexpected finding. The most developed CWC community was found at the canyon head region on a steep (i. e., vertical and overhanging) canyon wall at the western canyon flank (Fig. 1). This wall spanned from 650 to 500 m depth and was covered by large colonies of *Madrepora oculata* and *Lophelia pertusa*. Dense aggregations of the solitary coral *Desmophyllum dianthus,* the black coral *Parantipathes larix* and the oyster *Neopycnodonte zibrowii* were also observed on this wall. Deeper surveyed areas within the canyon revealed the presence of large isolated colonies of *L. pertusa* at depths ranging from 765 to 864 m, and small colonies of *M. oculata* observed in most dives, being found as deep as 680 m. The detailed spatial distribution of the fishing pressure in Blanes Canyon indicates that these CWCs communities are completely surrounded by active fishing grounds. The indirect impacts of bottom trawling on CWCs by smothering (i. e., exposing them to elevated fluxes of poorly nutritive resuspended particles) might have unforeseen consequences., For example, CWCs may be prevented from expanding their range and colonizing other suitable areas within this canyon, or they may even perish. The deep-sea fisheries being conducted in Blanes Canyon and on the Catalan continental slope are similar to the fisheries along the entire Mediterranean margin. Therefore, other deep CWC communities already found (or yet to be discovered) in trawled submarine canyons might be facing the same impacts.

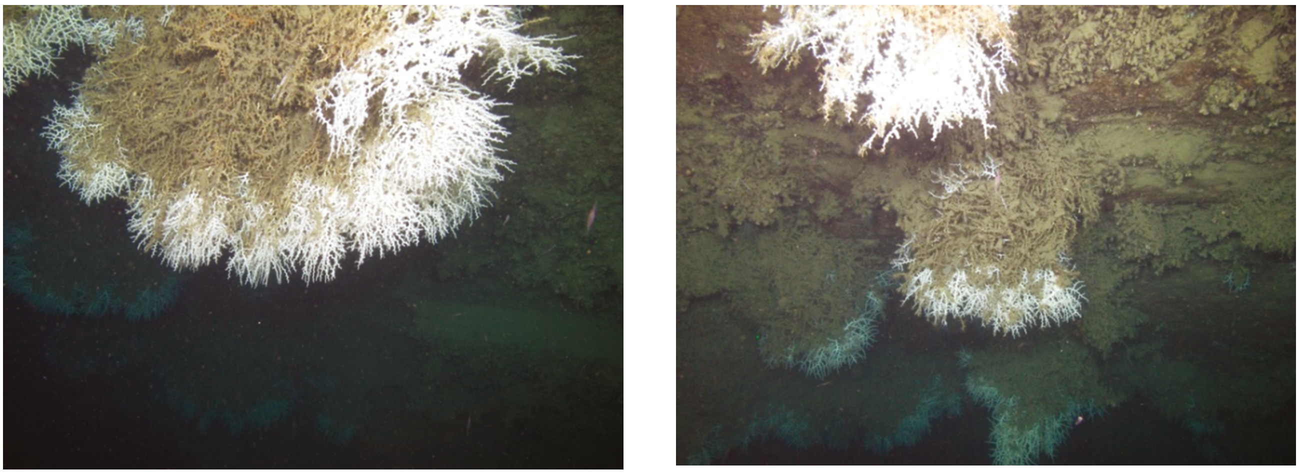

Figure 1. Images from the CWC canyon wall recently discovered at the head of Blanes Canyon. Note the amount of sediment deposited on top of the CWC colonies, presumably caused by resuspension from nearby bottom trawling activities

S1PO11. Rocky reef habitats: new findings in the central Tyrrhenian sea (Mediterranean sea)

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As part of an environmental survey aimed at the identification and characterization of marine sites suitable for the potential controlled spill into the sea of sediments coming from port dredging, ISPRA, on behalf of the Port Authority of Civitavecchia, Fiumicino and Gaeta, has carried out environmental investigations in an area off the southern coast of Lazio (Central Tyrrhenian Sea).

The study included geophysical surveys and characterization of the seabed from a physical, chemical and biological point of view.

The geophysical investigation performed through Multibeam and SSS, highlighted several morphologically elevated structures (pockmarks); in addition, a survey with ROV was also conducted, which emphasized the presence of CE interest species and habitat whose conservation requires, in the Mediterranean sea, the possible designation of special areas of conservation (Annex 1 Habitats Directive 92/43 / EEC).

In this paper we reported, for the first time in the investigated area, the habitat 1170, with the specificity of being inserted in an environment with low biodiversity; moreover, the discovery of this habitat did not allow permission to discharge sediments at the sea.

S1P22. Influence of Delta Dynamics on Fishing Grounds

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Modern coastal subaqueous deltas are very important habitats for marine species, and often are the locations of fishing grounds. Thus, understanding the variability of sea bed sedimentation at these areas can be of great importance for managing fishing activities. The goal of this work is to show and discuss the temporal and spatial variability of seabed dynamics on the continental shelf adjacent to Doce River mouth and how it may impact the benthic habitat. This region coastal/marine area comprises distinct Marine Protect Areas and was severely impacted by the Fundão dam failure in November of 2015.

Five campaigns were carried out during the 2013 (January, May, July and October) and 2014 (January). Sediment samples were collected in 31 stations between 10 and 40 m water depth. Grain size distribution and bulk density were determined. The meteoceanographic conditions were evaluated before and during the field campaigns.

The results show a dynamic environment that responds rapidly to changes in oceanographic conditions, such as wave and wind forces. In January 2013, higher values of mud (>75 %) were localized at the south of the river mouth up to 30 m deep, together with low bulk density values. Sandy bottoms dominated in water depths greater than 30m. In May 2013, the mud deposit extended to the north of the river mouth (no more than 20 m deep) and the sand facies were found in front the river mouth in shallow areas. In July 2013, mud facies became more widely distributed reaching isobaths of 30m, both south and north of the river mouth. Sand facies were only found at water depths greater than 40 m deep. During this campaign, the bulk density values were higher than the previous campaign demonstrating that a consolidation process took place. By October 2013, the mud facies had retreated and were found mainly near the 20 m isobaths. The bed bulk density remained high (>1200 kgm^{-3}). In January 2014, higher mud contents appeared again at the south of the river mouth, reaching 30 m water depth. The bulk density values became lower again (1100–1200 kgm^{-3}) located to the south of the river mouth. When the river fluxes and wind patterns before and after the campaigns were analyzed, it was apparent that the locations of the mud or sand deposits are related to the wind direction and intensity and the river flux.

Based on these results we conclude that the sedimentation process plays a role in habitat distribution. The study area is a shrimp fishing ground and depending the climatological conditions of the year and river flux, the shrimp habitat extents can be influenced and the fishing ground location can change. These changes can affect local economic activities. Sediment dynamics knowledge can help the fishing community to deal with these changes.

S3O15. Continental Shelf Habitats off a Large South American Metropolis: Salvador City, Eastern Brazil

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The continental shelf of Salvador city (CSS) faces the third largest metropolitan area of Brazil (2.7 million inhabitants). The CSS has a total area of 460 km2, is narrow, about 8km wide, and shallow with the shelf break starting at 50–60 m. The circulation is tide and wind-driven. A number of human uses are practiced at the area including domestic waste outfalls, disposal of dredged sediments from major port facilities, artisanal fisheries, dive tourism. The CCS is characterized by an uneven topography with high and low regions usually oriented obliquely to the shoreline.

This work represents a major effort to integrate previously produced data conveying it in a geohabitat map to be used in planning, monitoring and conservation efforts of the marine environments of the Salvador Metropolitan area. There were used information from Nautical Charts from the Brazilian Navy Admiralty; 205 km of chirp sub-bottom profile and 174km of sidescan sonar surveys; 463 sediments samples, collected in a regular grid, at a 1km interval, analyzed for texture and composition; 21 samples for macrozoobenthos fauna analyses collected at seven stations representative of major bottom types; vídeo and photo taken during autonomous dives; maps of fishing grounds and data of fish landings at the Santana Port; hydrodynamic modeling results from Environmental Impact Assessments. All data were integrated in GIS (Ar cmap), for spatial analysis and map preparation.

Based on the integration of available data five major geohabitats can be defined for the CSS region (Figure 1):

Littoral Sands (LS) — Sediment is composed mostly of quartz sand with a few bioclasts (mollusks and echinoderm). It is subjected to high wave energy levels. Because of its proximity to the shoreline is it exposed to urban pollution deriving from pluvial drainage and small rivers emptying the area, especially during the rainy season (winter). Abundance, diversity, and richness of the macrozoobenthos at this habitat are the lowest, as 83 % of all organisms are Polychaeta, followed by Crustacea (9 %) and Mollusca (8 %).

Sand Bank (SB) — Clean quartz sands exposed to high wave and tidal energy levels characterizes this habitat. Despite the high energy levels (tides and waves) on this habitat, there is an increase in abundance, diversity, and richness of the macrozoobenthos compared to the LS habitat, possibly favored by the presence of microhabitats such as sand dune troughs. The macrozoobenthic community is comprised of Polychaeta (47 %), of Mollusca (40 %), Echinodermata (12 %) and Anfioxo (1 %). The exclusive presence of *Amphioxes* and *Platelmints* at the SB and CS probably indicates that the SAB also acts as a trap to the dispersion of other benthic organisms.

Channel Sands (CS) — It is covered with clean quartz sands and local patches of bioclastic gravels whose major constituents are echinoderm, mollusk, and bryozoan fragments. abundance, diversity, and richness of the macrozoobenthos are a little higher when compared to the SB habitat, probably because of a greater heterogeneity offered by the bioclastic gravel patches [1]. Major taxa include Polychaeta (49 %), Mollusca (23 %), Crustacea (14 %), Echinodermata (8 %) e Cephalocordata (6 %) and in small quantities, the Pantopodas, *Pycnogonida,* and Platyhelminthes.

Hard Bottom (HB) — At this habitat, bioclastic gravelly sands composed predominantly by fragments of coralline algae, bryozoans and echinoderms cover the sea floor. It exhibits the highest macrozoobenthos abundance and along with the CS have the highest diversity and richness of the study area. The taxa found is composed of Polychaeta (50–51 %), Crustacea (36–28 %), Mollusca (13–20 %), and Echinodermata (1 %).

Muddy Bottom (MB) — Major bioclastic components of the sediment are mollusks and foraminifera. Carbonate content reaches up to 87 %. Organic matter content varies from 0 to 2.99 %.

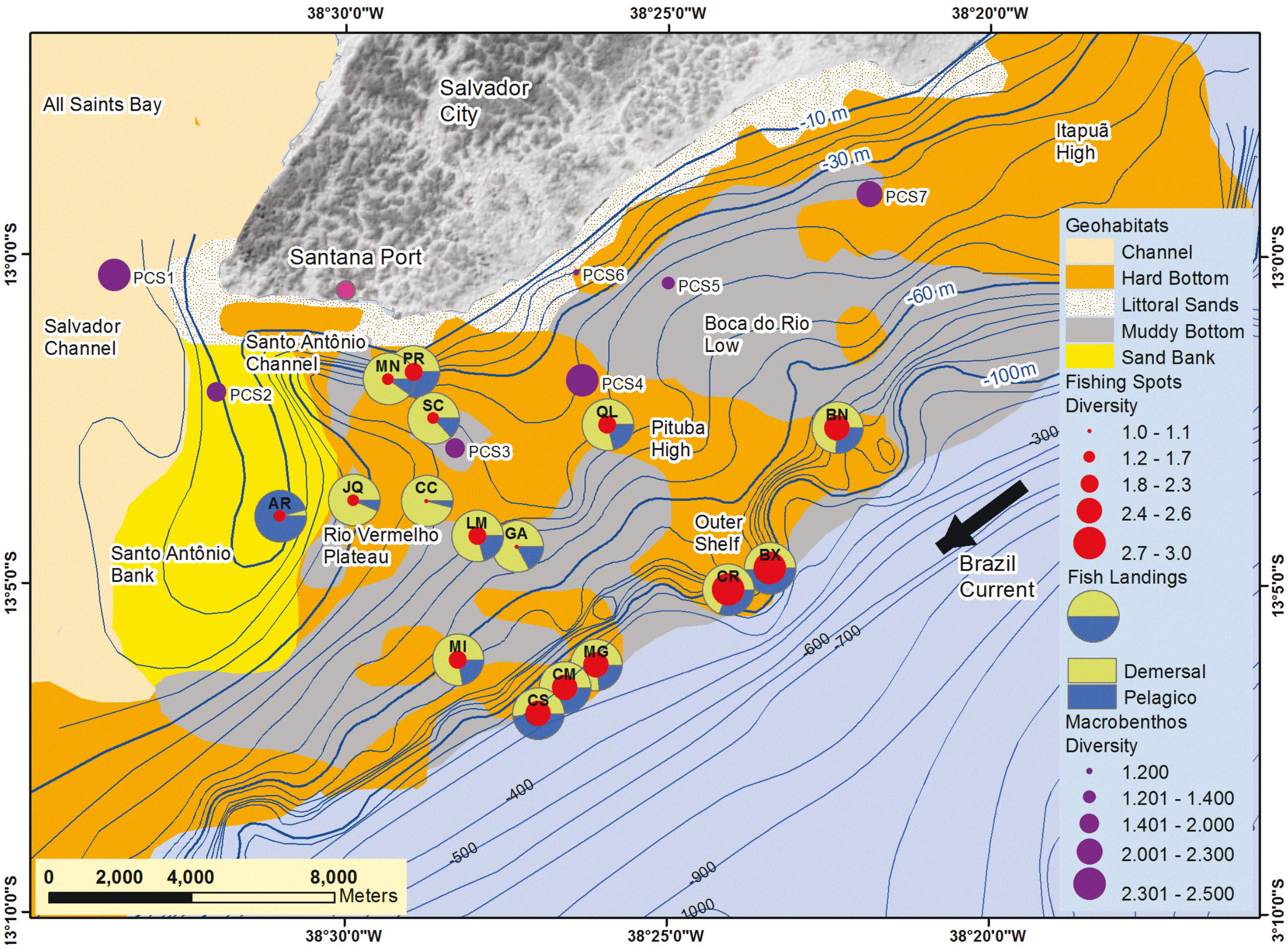

Figure 3 — Geohabitats at the Continental Shelf off Salvador city. Also shown are: (i) Shannon-Winner diversity index of macrobenthos comunities and fish landings at the Santana port and (ii) relative proportions of demersal and pelagic fishes for each fishing spot. Fishing spots: Manilha (MN), Arthemids (AR), Jiqui (JQ), Caçuça (CÇ), Prima (PR), Quebra Linha (QL), Baixios (BX), Coroa (CR), Manguinhos (MG), Caminho Miguilinho (cm), Caminho Simão (CS), Gameleira (GA), Leme da Barca (LM), Sucuriatiba (SC), Bor noite (BN), Mar das Ilhas (MI). Isobaths in meters. From 10 to 80 m isobath interval is 5m

biological indices are relatively low. The macrozoobenthos sampled, shows the dominance of Polychaeta (69–76 %), followed by Mollusca (16–11 %) and Crustacea (15–12 %), and Echinodermata (1 %).

The proportion of the demersal and pelagic species identified at the Santana port landings from 1997 to 1999 and the diversity of the fisheries are also presented in figure 1. Fish species of demersal habits represent 74.5 % of the total landings for the study period. These species are captured at fishing spots located at the Hard Bottom habitat. Pelagic fishes representes 25.3 % of the catches. Migratory oceanic species are captured predominantly at the outer shelf — shelf break in association with the HB habitats. Regarding biomass, the pelagic species are greatly more relevant, than the demersal species, because of their larger body size. Species with benthic habit represent only 0.15 % of the catches.

At the study area, substrate type and energy levels are the best predictors of benthic habitats.

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S1O25. Underwater landscapes of the Velikaya Salma Strait (Kandalaksha Gulf of the White Sea): formation, structure, and biota

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Velikaya Salma Strait is a part of fiard [1, 2], typical of features associated with Kandalaksha Bay of the White Sea [3, 5]. Bathymetry, subaquatic landscapes, and sediment were investigated within an area of 35.12 km^2, at depths ranging from 10 to 120 m by means of geophysical, geological, and visual observations. The set of geophysical methods utilized included multibeam echo sounding, side-scan sonar surveys and continuous seismoacoustic profiling. Geophysical data were "groundtruthed" by geological sampling and visual observations conducted by remotely operated vehicles (ROV). In addition, sediment grab samples, trawling samples, and ROV observations were collected to describe the composition and distribution of macro- and megabenthos. This combination of methods used for complex sea-bottom studies resulted in the first large-scale mapping and classification of benthic habitats on a typical glaciated shelf. Dominant physical parameters of bottom landscapes were evaluated along with the examination of their structure and hierarchy and the analysis of the relationship between environmental parameters and macro- and megabenthic communities' spatial distribution.

The main abiotic factors that form sea-bottom landscapes are the block-like structure of the Archean crystalline basement, moraine surfaces, bathymetric heterogeneity, and sediment composition and facies. Sediment ranges from pebble and boulder to sand and mud. Tidal currents that are influenced by bathymetry (dissected bottom relief) are the primary controlling process of modern sedimentation.

On the hierarchical level of "habitat types" [4], eight regions and twenty-two subregions were identified based on differing physical parameters such as geological cross-sections, meso- and microrelief forms, sediment composition, and sedimentary processes, and mapped at a scale of 10^3 to 10^6 m^2. The differing "habitat types" are based on uniform bathymetric gradients, which is disturbed in areas increased fragmentation of the basement, on mesoforms of glacial and relict gravitational relief (slumps), and zones of the highest and lowest modern sedimentation. Each region and subregion has an individual set of elementary facial units.

Inner structure of habitat types is determined by a combination of small-scale relief features, recent sediment composition, and facies type. Typical sizes of landscape units tend to decrease from 10^4–10^5 m^2 to 10^3–10^4 m^2 with increase of relief complexity. The minimum mapping scale for landscape units (microrelief), with similar (nearly homogeneous) sediment composition comprises the smallest areas, mapped at 10^1–10^2 m^2, and lie within the most heterogeneous (complex) localities of relief.

The depth and the content of sand and mud fractions in sediment significantly affect distribution of the macrobenthos. The community dominated by *Galathowenia oculata* and *Chaetozone setosa* occurs on muddy sediment while *Macoma calcarea – Scoloplos acutus* communities occupying more sandy areas. Correlations between abiotic factors and the composition of the communities are consistent within landscapes of smooth bottom relief, but less consistent on heterogeneous sites because of variable sea-bottom currents, sediment composition. and species distribution.

The most important factor for the distribution of megabenthos is sediment composition. The community of *Balanus balanus — Ascidiacea gen. sp.* tend to inhabit sandy sediments (silty sands, fine sand, sandy-pebbles) and the community of *Mysis oculata* and *Urasterias lincki* occurs on fine sediment with a high silt ratio. Heterogeneity of the benthos communities reflects general patterns in sediment composition influenced by age of deposition and modern seafloor sedimentary processes.

Uncertainty in relations between benthos and their environment seems to be typical for glacial shelves of complicate bottom relief. Predictable changes in benthic communities occur usually on larger spatial scales along more extent gradients of factors (such as depth, temperature, salinity etc.). In scale of our study, high density of samples on complicate relief detects mostly the meso-scale patterns in a single or several benthic associations.

This work is part of the project funded by the Arctic Research Center (Rosneft Corporate Research and Engineering Division). The authors thank the teams of LMSU CMR, LMSU SDAC and SPLIT for acquisition of field data and assistance in data interpretation. Special thanks also go to N. A. Pertsov White Sea Biological Station of Faculty of Biology, Lomonosov Moscow State University, for the support in the survey. Part of the data generalization was done with financial support of the Ministry of Education and Science of the Russian Federation (RFMEFI60717X0187, AAAA-A17-11711167004409) and RFBR (18-05-00303, 18-05-60053, 19-05-00966).

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S1P23. Evolution of the fiord-skerries shores in the vicinity of the Nikolai Pertsov White Sea Biological Station (Kandalaksha Bay) based on large-scale geomorphological mapping

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Mosaic-like morphology resulting from lithologic dynamics creates a fractional landscape structure along the shores of Kandalaksha Bay, White Sea, Russia. Landforms (landscapes) of the coastal zone were studied in high resolution using an unmanned areal vehicle (UAV), bathymetry, and sediment samples.. This study evaluates the topographic relief of the transition zone between the seabed and the land, one of the most difficult tasks of marine geomorphology and landscape science. Students of the Faculty of Geography at the Nikolai Pertsov White Sea Biological Station are introduced to the methods of integrated geomorphological mapping focused on the seabed, coastal zone, and seaside land. The purpose of this presentation is to report upon the student's studies focused on the identificaton of transformation mechanisms that shape the seabed in the coastal zone and to determine the trends in the development of coastal Landscapes. The study area covers the Yeremeyevsky threshold with adjoining parts of the Rugozerskaya Bay and the Velikaya Salma Strait, as well as their shores of the Kindo Peninsula in the south and Velikiy Island in the north.

On the northern coast of the Kindo Peninsula tacheometric, geomorphologic, and UAV aerial photography surveys of the coastal strip were carried out. A bathymetric survey was performed in the Rugozerskaya Bay, the Velikaya Salma Strait, and the Kislo-Sladkoe Lake. The grain size analyses of sediments obtained from the sea and lake bottoms, dried tidal flats , beaches, and coastal terraces were also undertaken. On the Velikiy Island geomorphological transects and profiling were conducted. A combined digital elevation model (DEM) of the coast and the bathymetry (Fig. 1) with corresponding geomorphological maps and detailed orthophoto images of key sections were compiled. To create the DEM, approximately 120,000 depth measurement points (tachometric survey data) on 34 ha of the coastal strip along the northern coast of the Kindo Peninsula and topographic maps of 52 ha of islands and coastal strip along the southern shore of Velikiy Island were used.

A significant part of the seabed is occupied by structural-denudation (bedrock erosion) and glacial landforms. As a result of the continued uplift (1–4 mm/year [2, 4]) of the coast the shallowest (bathymetric highs) on the seafloor are gradually elevated to within the wave impact zone. In the coastal zone, these features undergo significant erosion from wave action, tidal currents, fast ice, and biogenic processes manifesting in dramatic changes of the morphological characteristics and the composition of sediments [1, 3]. The nature of the transformation of the seabed relief and the mechanisms for the extension of the coast are not the same for straight and skerry (moraine) coasts. Rectilinear shores are the geomorphologic expression of tectonic coastal uplift. Coastal accumulative forms of relief are rarely formed. Sea bays and straits of the skerry coasts transform into meromictic lakes and lagoons. The emergence of small accumulative features (e. g., bars, dunes) can accelerate the separation of these bodies of water from the sea within a time span of 150–200 years.

The authors are grateful to the N. A. Pertsov White Sea Biological Station of Faculty of Biology, Lomonosov Moscow State University, where the work was done. The authors thank the students who participated in the field work and primary data processing. The works were carried on the projects AAAA-A16–116032810089–5 and AAAA-A16–116032810094–9 with the support of the RFBR (19–05–00966).

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S1O26. Using mapping data to assess the status of a key species in the northern Baltic Sea

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The habitat forming brown macroalgal species *Fucus vesiculosus* and *F. radicans* (hereafter *Fucus*) are key species of the rocky shores in the brackish northern Baltic Sea. While *F. vesiculosus* is quite common, the endemic *F. radicans* occurs mainly in the Bothnian Sea. In the 1980s, there were several reports describing a rapid decline of *Fucus* in many areas. This raised concerns on the loss of ecosystem functions and biodiversity, as many other species use *Fucus* as food, shelter and as nursery grounds. Despite the importance of the species, there are only some local studies that have examined its general status since the major declines were reported.

The comprehensive marine datasets collected during the Finnish Inventory Programme for the Underwater Marine Nature (VELMU) and in mapping projects on Åland Islands, allowed the assessment of the current status of *Fucus* on a larger scale. We first identified surveyed potential sites for *Fucus* occurrence, i. e. sites with ≥10 % hard substrate and enough light to allow *Fucus* growth. We then related the actual occurrences of *Fucus* in survey data to the potential sites, to produce maps of *Fucus* occurrence rate, using a division to marine areas used in the status assessments related to the Water Framework Directive. We further tested the effects of environmental variation and water quality on both the occurrence rate and the lower limit of *Fucus*, to find out whether the occurrence patterns can be related to e. g. eutrophication.

Our results show that in general the status of *Fucus* is better in the Gulf of Bothnia than in the Gulf of Finland, both in terms of occurrence rate and depth distribution. Despite high potential for *Fucus* growth in the outer Archipelago Sea, the status there is very poor, which may be related to e. g. high grazing pressure. As a whole, the bad status of *Fucus* in the Archipelago Sea is worrying, as with the future climate change the area is expected to be the key area for *Fucus* distribution within the Finnish marine area [1]. Of the environmental variables, Secchi depth showed positive effects on both *Fucus* occurrence rate and depth penetration, although the positive effects were less profound in higher salinities. Also salinity had positive effects on both *Fucus* variables, and higher exposures allowed *Fucus* to occur in deeper waters. We found little direct impact of nutrients (N-tot and P-tot) on the occurrence patterns. Instead, it seems that the eutrophication effects are seen in *Fucus* occurrence patterns through changes in the Secchi depth. Furthermore, many inner archipelagoes and near shore areas along the Finnish coastline have today a poor potential to host *Fucus,* as little suitable hard substrate exist in these areas, most likely due to general eutrophication development.

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S4O2. Bathymetric and backscatter stability assessment of the Flemish banks area based on repetitive multibeam echosounder measurements

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Stretching out over tens of kilometers, with peaks near the water's edge, a height of up to twenty meters, and bounding swales where water depths can reach 30 to 40 m, the tidal sandbanks are major features of the Belgian part of the North Sea (BPNS). Four groups of sandbanks are distinguished according to their position and orientation with respect to the coastline (Fig. 1). In this restricted marine area, which is subjected to increasing human pressure, sandbanks reveal antagonism between environmental and economic points of view: they are dangerous for navigation but they certainly contribute to coastal protection; they shelter particular habitats that deserve to be protected, but as an unique and valuable sand reserve they are the object of a growing sand extraction industry.

What do we know about the stability of these sandbanks? Historical large-scale analysis of sandbank shifts derived from hydrographic charts suggests changes between stable and dynamic phases [1]. The shifts are extremely variable from one sandbank group to another [2]. A complex mechanism of maintenance of the tidal sandbanks, related to the hydrodynamic and sediment transport regimes, has been recognized, and explains their stability over the long term [3, 4, 5].

The presented case study provides some additional elements to answer the question of sandbank stability. The stability of the Flemish Banks is evaluated based on bathymetric and backscatter measurements carried out annually since 2009 as part of the continuous monitoring of sand extraction. Depth and reflectivity are measured across the entire area of the Flemish banks, along parallel reference lines perpendicular to the sandbanks (Fig. 2) using a multibeam echosounder (MBES Kongsberg

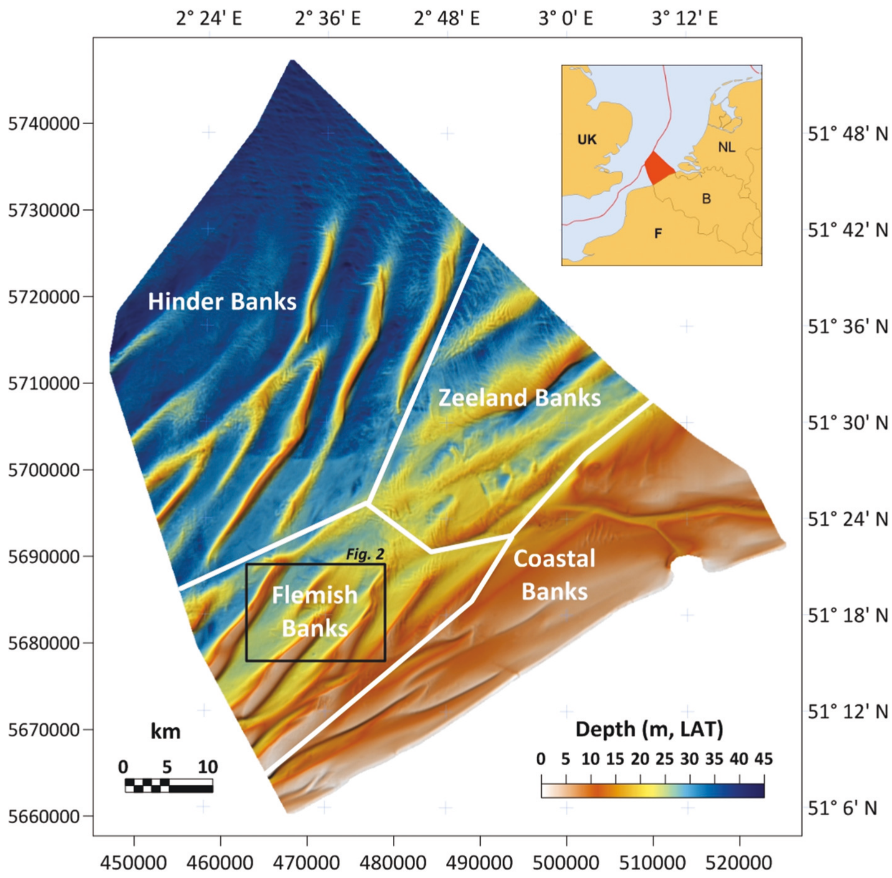

Figure 1. Belgian part of the North Sea, Bathymetry and Sandbanks groups

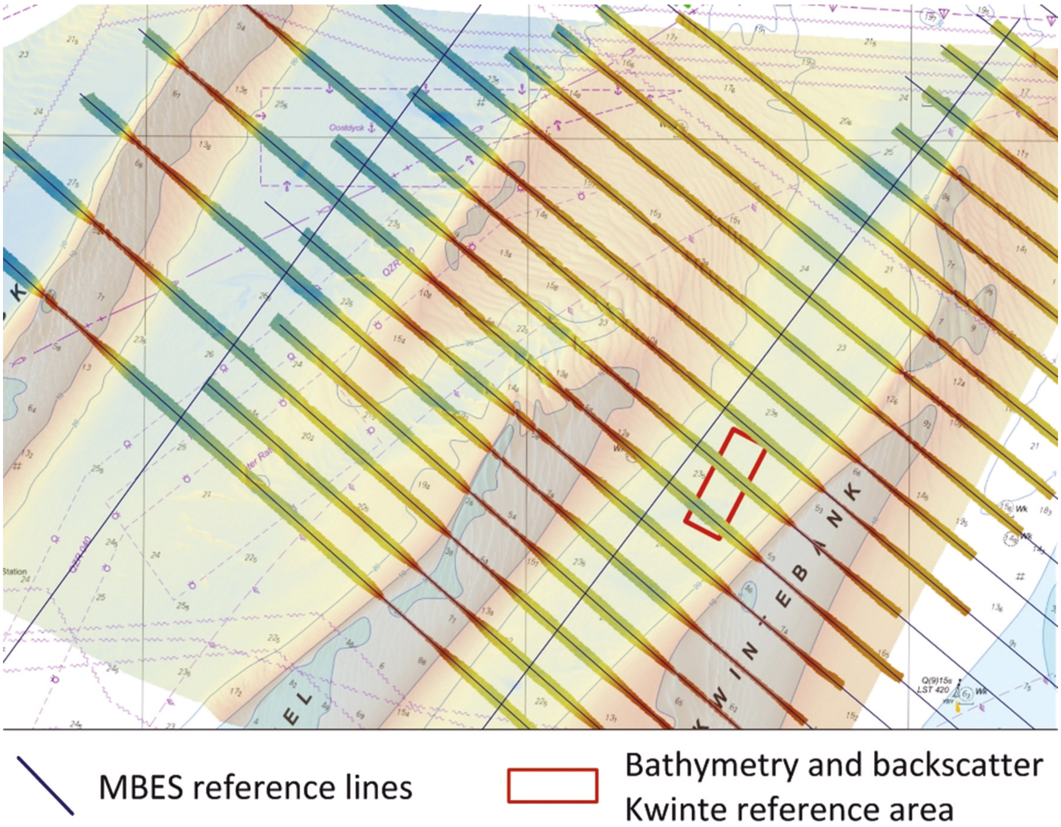

Figure 2. Part of Flemish Banks area (black rectangle in Fig. 1). MBES reference lines are surveyed each year. The Kwinte reference area is used to control the bathymetry and the backscatter accuracy and stability. Background: Hydrographic chart 102 "Frans-Belgische Kust van Duinkerke to Oostende" Vlaamse Hydrographie December 2018; Reference DTM of sand extraction Zone 2 FPS Economy; Survey 1608 RV Belgica EM3002d 22–23/02/2016

EM3002d 300kHz). The presence of tracks across the main acoustic reference area of the BPNS in all surveys, makes it possible to correct the bathymetric biases caused by systematic errors, and to control the stability of the backscatter measurements for each survey [6]. By coupling the bathymetric measurements with data from the Electronic Control System (EMS) installed on each dredging vessel, it is possible to distinguish between impacted areas and areas that are not subject to sand extraction [7]. In these undisturbed areas, the variance of the bathymetry and the backscatter is a priori natural. The controlled dataset allows us to identify the main geomorphological and sedimentological trends in the Flemish banks area.

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S1O27. The eastern Gulf of Finland (Baltic Sea) landscapes — brackish water estuary under natural conditions and anthropogenic stress

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The eastern Gulf of Finland (EGoF) of the Baltic Sea was investigated in 2012–2014 (TOPCONS project) to reveal the structure and forces driving the formation of benthic landscapes. Broad scale environmental and biological (macrozoobenthos) data were collected using remote sensing data, geological and biological fieldwork methods, and processed with multivariate statistics. The resultant series of Geographic Information System (GIS) maps included benthic marine landscapes maps, based on associated environmental variables and benthic assemblages. Hydro-optic and hydrologic conditions in conjunction with salinity and topography, determine the current spatial distribution of nine major benthic landscapes in EGof [1].

Detailed studies of three key areas, representing different (contrasting) abiotic conditions, typical for the EGof were undertaken. These are — Kurortny (nearshore bottom of northern coastal zone) (Figure 1), Vyborg Bay (to north-west on Berjozovy Archipelago), and Kurgalsky (eastern slope of Kurgalsky Reef). Mapping was based on multibeam echo sounding survey (EM-3002 Kongsberg multibeam echosounder with acoustic frequency of 300 kHz), side-scan sonar mosaicking (cm2, C–MAX Ltd, with acoustic frequency of 325 kHz), sediment and biological sampling and video survey (microROV "Super-GNOM", modernized by GoPro HD HERO2 video-camera).

For compilation of detailed scale maps the BalMar classification (with modifications) was used [2]. For each key area the series of maps (e. g., Benthic Terrain Model, generalised bottom substrate map, map of substrate type mobility, map of photic zone, map of hydrodynamic impacts) were compiled. The basic abiotic factors, used for marine landscape mapping were 1) salinity [1]; 2) wave exposure; 3) photic depth; 4) near bottom hydrodynamics (wave and current impact); 5) substrate type [2]. Combination of these layers with results of abiotic and biotic data analyses resulted in compilation of benthic landscape maps.

In terms of photic/aphotic conditions, the assemblages in photic zone (0 — -6 m) are dominated by macrophytes, both vascular plants and macroalgae (green filamentous algae *Cladophora* sp., the peter.mitchell@cefas.co.uk key macrophyte species for freshwater portions and up to 2–4 psu). In areas with higher salinity (partly in Vyborg Bay and Kurgalsky cape and westward) the key seaweed species is brown algae *Fucus vesiculosus.* Nectobenthic native and non-indigenous invertebrate species are associated with sea weeds (e. g. *Gmelinoides fasciatus, Pontogammatrus robustoides, Gammarus tigrinus* (Amphipoda)*)*. Their specific distribution corresponds to their salinity requirements. Below — 6 m and down to the accumulative planes, invertebrate assemblages (periphyton and macrozoobenthos) are predominant.

At stony bottom sites, periphyton (fouling) is dominated by non-indigenous sessile invertebrates. Sediments (e. g., sands, silts) and mixed bottoms (hard/soft) are inhabited by macrozoobenthos s. str., consisting of infaunal and epifaunal mobile species. Composition of dominant groups in macrozoobentos is different in different salinity zones. Role of dominant freshwater taxa (Chiromonidae and Oligohaeta) decreases seaward and brackish water species dominate with invaders *Marenzelleria sp. (*Polychaeta), *Potamopyrgus antipodarum* (Gastropoda), aborigine *Saduria entomon* (Isopoda), *Monoporeia sp.* (Amphipoda), and *Limecola baltica* (Bivalvia) moving in. It is remarkable that previously lifeless anoxic/hypoxic areas are now settled by *Marenzelleria sp*.

Sufficient variability in quantitative development of the most abundant periphyton species (and

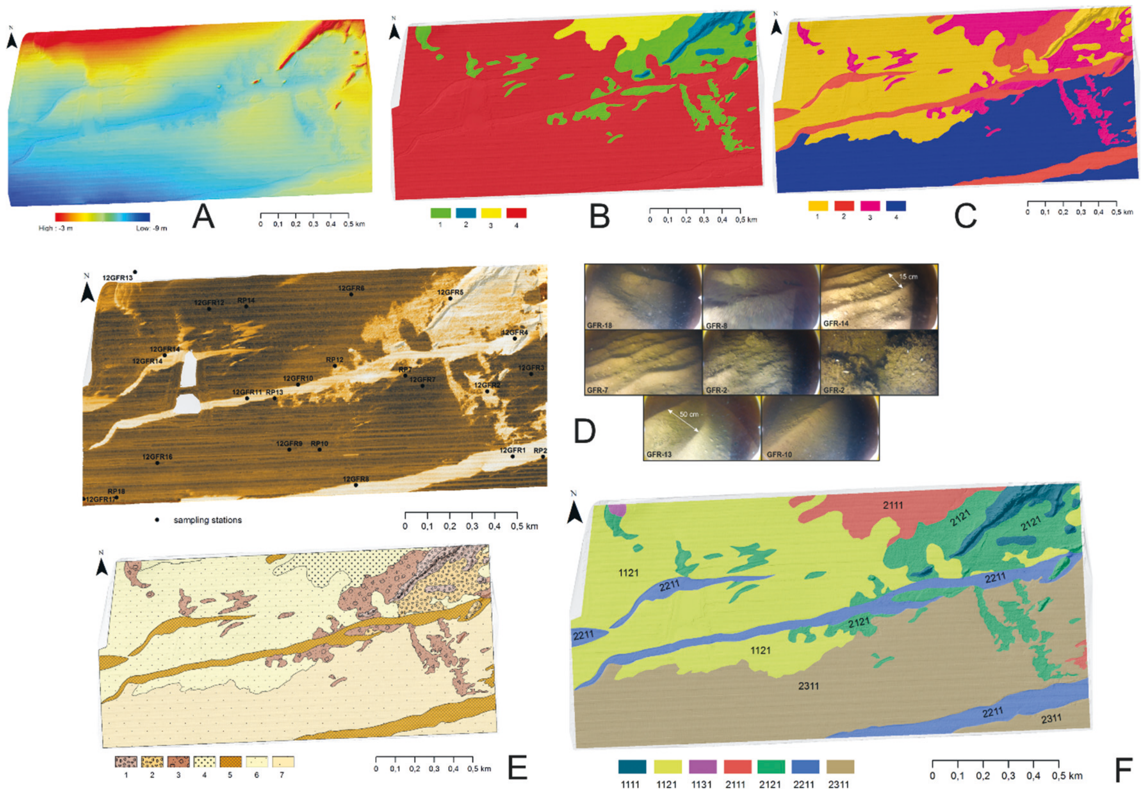

Figure. Maps of Kurortny key area.
A) Digital bathymetric model (DBM) (multibeam bathymetry); B) generalized seabed substrate type map (1 — mixed substrata; 2 — nonmobile substrata; 3 — temporally mobile substrata; 4 — mobile substrata); C) map of nearbottom hydrodynamics (1 — wave impact high energy; 2 — current impact temporally high energy; 3 — current impact medium energy; 4 — current impact low energy); D) backscatter mosaic with location of geological sampling sites and submarine photos; E) seabed map (1 — boulders; 2 — boulders partly covered by sands; 3 — pebbles, gravel, sand; 4 — gravel, course-grained sands; 5 — coarse grained sands with megaripples; 6 — fine-grained sands with ripples; 7 — very fine grained and silty sands). F — map of submarine benthic landscapes (1111 — high energy infralittoral stony bottom; 1121 — high energy infralittoral sandy bottom; 1131 — high energy infralittoral mixed-sediment bottom; 2111 — medium energy circalittoral sandy bottom; 2121 — medium energy circalittoral mixed-sediment bottom; 2211 — temporary high energy circalittoral gravel bottom; 2311 — low energy circalittoral silty-sand bottom)

so far an assemblage there from) is contributed by non-periodic natural events and human activity (e. g. dredging, dumping). However, periphyton is relatively resilient and able to recover after destructive practices are discontinued. The macrozoobenthos is highly dominated by eurybiotic invasive species spatially distributed along the area according to their environmental requirements and sensitivity to sporadic natural and human impacts.

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* Submitted to Second Edition of GeoHab Atlas

S1PO12. Defining river estuaries in low salinity brackish water environment

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River estuaries are one of the most important habitats for birds, fish and underwater vascular plants and charales. Birds and fish use the river estuaries to feed and breed, and fish also migrate through the area to breed in the rivers. In mappings that were carried out in the SEAmBOTH-project (Seamless Mapping and Management of the Bothnian Bay) in 2017 and 2018, it was discovered that river estuaries have a remarkable range of vascular plants, and several endangered species populate these areas.

There is a need to define the borders of river estuaries because legally binding protection measures are often tied to clearly defined parts of the environment. Based of EU directives, protection measures can be placed on an area when they have been defined. However, drawing a border on river estuaries is very difficult in the brackish water environment, especially in the Bothnian Bay area as it is difficult to define river estuaries and to draw an actual border on a map due to the extremely low salinity, which prevents us from using salinity as a straightforward indicator. In our work in the SEAmBOTH-project we aimed to find suitable methods to define estuarine areas without relying on the differences of salinity.

Pre-field methods consisted of modelling and analyzing aerial images. Data collected in the field were from dive transects, underwater drop video sites, wading points, and salinity samples. Post-field-

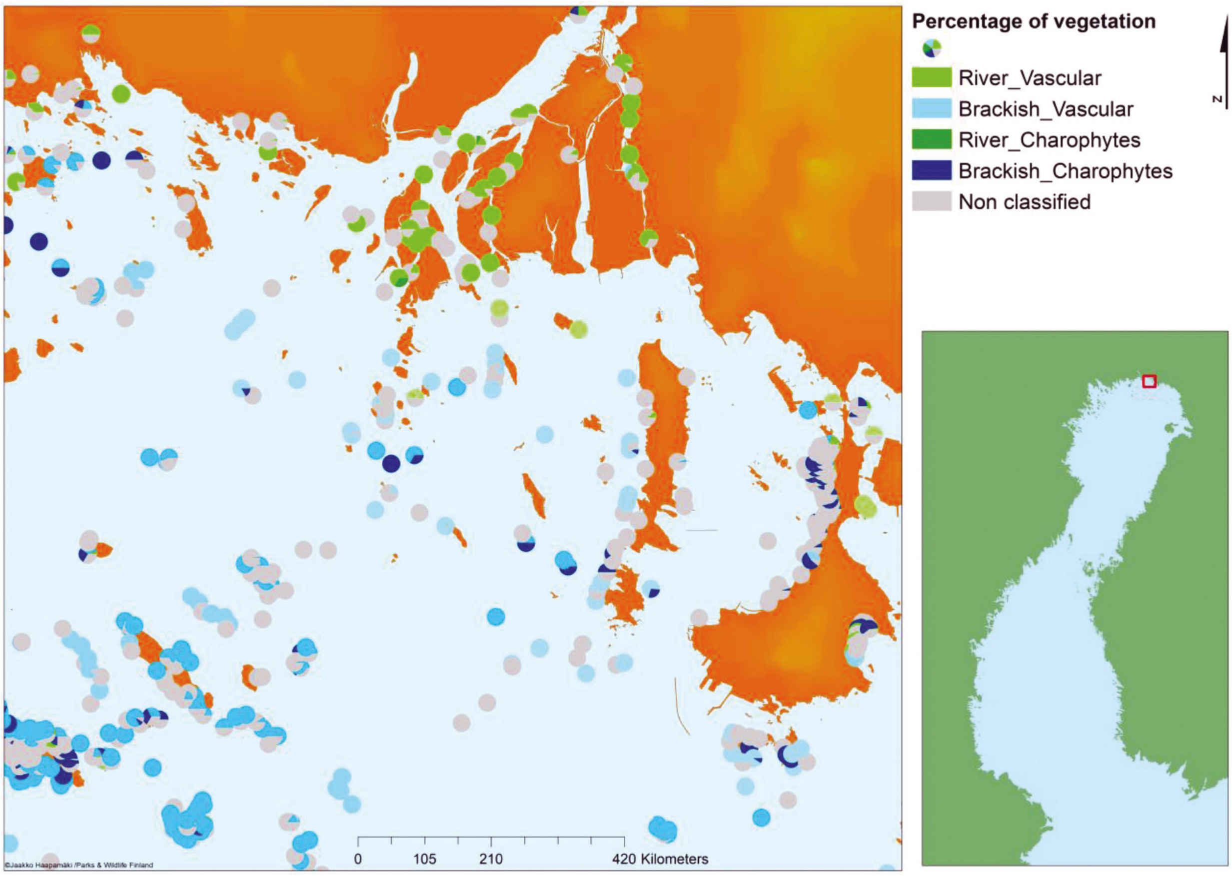


Figure 1. River and brackish water species in the Kemijoki-river in the Northern Bothnian Bay (Jaakko Haapamäki, Metsähallitus)

work, collected biological samples were categorized into “river species” and “brackish water species” based on literature and expert analysis, and all the inventory points were plotted on a map.

The results of the species categorization were presented on a map to compare the results to a model based on physical factors and expert analysis. Our results from field work completed in 2017 indicate that species categorization can be used for defining river estuaries. Figure 1 is showing the results from Kemijoki-river with data collected up to 2017. A numerous amount of wading points was done in 2018 in the Kemijoki-river area, but the data is still being processed. This work on defining river estuaries in the Northern Bothnian Bay will continue until Spring 2019 when data from 2018 will be added to the analysis, just before the GeoHab-conference in May 2019, and thus we will be able to share detailed results at that meeting.

S3O16. EMODnet Bathymetry a compilation of bathymetric data in the European waters

Thierry SCHMITT (on behalf of the EMODnet High Resolution Seabed Mapping Consortium)

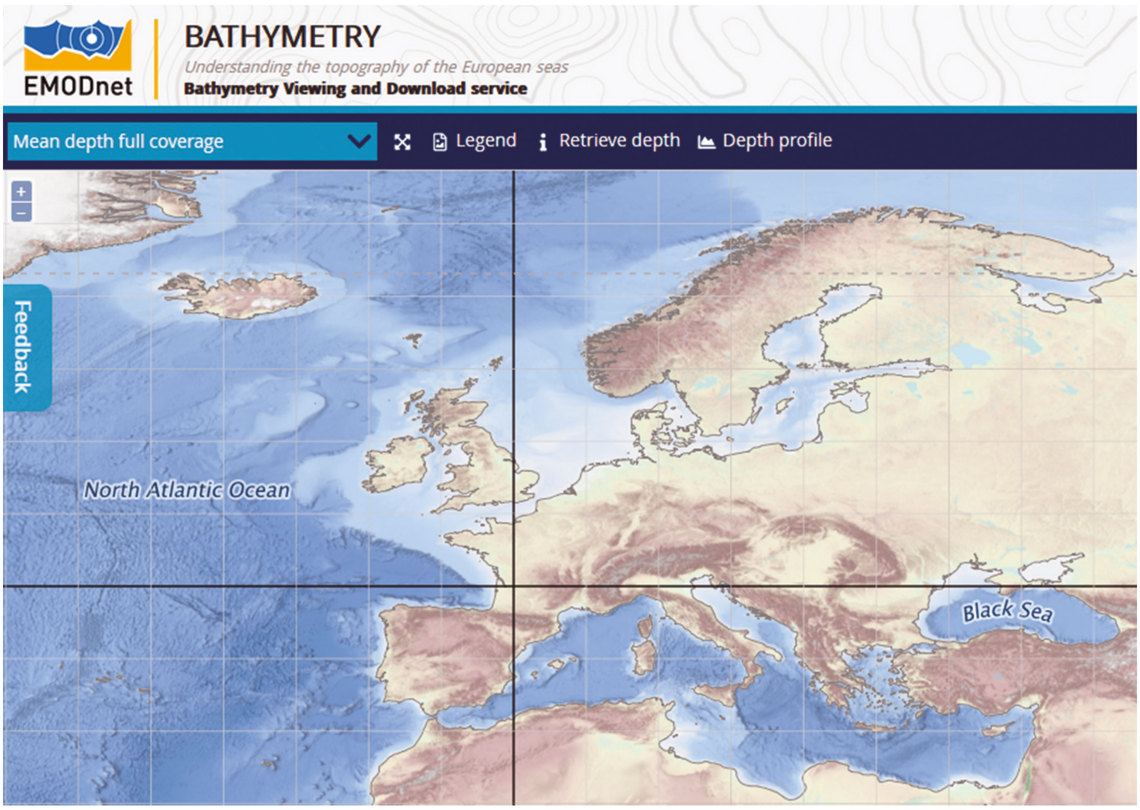
Access to marine data is a key issue for the EU Marine Strategy Framework Directive and the EU Marine Knowledge 2020 agenda. The European Marine Observation and Data Network (EMODnet) initiative is a concrete answer to this issue. EMODnet aims at assembling European marine data, data products, and metadata from diverse sources in a uniform way.

The EMODnet Bathymetry project has developed a Digital Terrain Model (DTM) for the European seas. These have been produced from survey and aggregated data sets that are indexed with metadata adopting the SeaDataNet Catalogue services. SeaDataNet is a network of major oceanographic data centres around the European seas that manage, operate and further develop a pan-European infrastructure for marine and ocean data management. The latest EMODnet Bathymetry DTM release has a grid resolution of 1/16 ar cminute (circa 100 * 100 meters) and covers all European sea regions. Use has been made of circa 9400 gathered survey datasets and composite DTMs from 48 data providers mainly from hydrographic offices, industries, research, and Academia sector.

With such a grid resolution of nearly 100 m extra focus has been brought on the coverage of coastal waters. For that, optical satellite derived bathymetry (mainly from Sentinel 2 and Landsat 8 sensors) have been included in the DTM to complement the coverage of conventional, but logistically constrained methods such as shallow bathymetry from multibeam sounders or LIDAR. Prior to this, the quality of the satellite derived bathymetry datasets has been assessed by comparisons, where possible, with common acoustic remote sensing technologies. A distinct improvement compared to previous release (EMODnet 2016) of the representation of the shallow water areas has been noticed.

Where bathymetric coverage is unavailable, mostly in deep areas, a fruitful collaboration with the General Bathymetric Chart of the Ocean (GEBCO) allows the EMODnet bathymetric DTM to benefit from estimated bathymetry generated from an altimetry-derived solution. Reciprocally, EMODNet Bathymetry is integrated into the GEBCO worldwide compilation.

Catalogues of bathymetric sources and the EMODnet DTM product are published at the ded-



icated EMODnet Bathymetry portal (www.emodnet-bathymetry.eu) including versatile DTM viewing and downloading services. Amongst these services a browser embedded multi-resolution 3D viewer is implemented, allowing the visitor to view the bathymetric surface product directly in the portal without the need of any dedicated software. This viewer is based on an open source adapted implementation of the Cesium viewer. Moreover, in order to generate smooth 3D views with affordable performances on an average computer, simplification of the DTM has been investigated as a function of level of detail (LoD) and local complexity. Using a Triangular Irregular Network (TIN) instead of a regular grid enables faster representation of the complexity of the map (i. e. the number and size of triangles).

Finally, along with each of the sources of bathymetric information metadata have been generated to qualify each of the sources with respect to four qualitative indicators, which are the age of the information (date at which the information was acquired), the expected horizontal accuracy, the expected vertical accuracy, and the intended objective of the survey. Also, as part of the generation of the DTM, the source reference of each grid cell is carefully managed. In this way, a direct relationship between the generated grid cell and the above mentioned indicators is possible, enabling the users to assess at a glance which areas of the DTM are of confidence with respect to the intended usage.

The present paper will detail all the processes of inventory and fusion of bathymetric data into the EMODnet bathymetry 2018 release. A discussion will also be included on the design and the limitations of the confidence indicator, as part of potential uses in habitat mapping studies. Facilities available to discover and use this bathymetric product will also be the topic of this presentation and may be the subject of live demonstrations during the conference.

S1O28. Towards a multifrequency detection of mussel beds in the Baltic Sea

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The sedimentology of the Oderbank surrounding (Baltic Sea/German EEZ) is characterized by vast areas of fine sand [1]. On the Oderbank, elongated patches of mussel beds occur, which were the target of multifrequency acoustic surveys in summer 2018 and winter 2019. Most of the approx. 10 km long working transect shows a rather homogeneous backscatter pattern in a multifrequency dataset, recorded with a calibrated NORBIT iWBMS STX system. The mussel beds are expressed as elongated patches of variably increased backscatter strength in different frequencies (200 kHz, 400 kHz, 550 kHz, 700 kHz). Video images from a towed camera sledge show a strong overlap of high-backscatter patches with the occurrence of unattached mussel clusters on top of fine sand ripples. First results show that it is possible to detect these unattached mussel clusters and indicate a minimum abundance of mussel coverage required for detection in backscatter data. Using angular range analysis (ARA), suggestions concerning the most appropriate surveying frequency targeting blue mussels (*Mytilus edulis*) can be made. The secure identification of mussel beds in backscatter data allows to monitor their yearly dynamics. Future analysis will lead to an optimized detection strategy of mussels in the Baltic Sea, and results contribute to a remote sensing catalogue within the multidisciplinary EU-funded project BONUS ECOMAP.

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S1O29. Habitat Mapping in Coastal Waters of the Baltic Sea — a 12-Years Experience from Schleswig-Holstein (Germany)

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Habitats are defined as "areas of the seabed that are (geo)-statistically significantly different from their surroundings in terms of physical, chemical and biological characteristics, when observed at particular spatial and temporal scales" [1]. In the marine domain, they are ranked as high graded ecological environments. Along with the awareness of human impact on the marine ecosphere, the weight of sound habitats for a sustainable environment is recognized [2], which requires research activities on the inventory, capacity, integrity and dynamics of the marine realm. Full coverage maps of sediment distribution patterns and the geomorphological built up are an essential requirement for marine nature conservation and marine spatial planning [3]. Those maps are the groundwork for high confidence assessments of the environmental conditions and subsequent monitoring activities, which are demanded by national and international regulations, like the European Water Framework Directive (WFD). Increasing pressure on the natural development of habitats due to human impact (dredging, dumping, pipelines, windfarms, fisheries and other uses) is observed creating disturbance and decline of their natural development. In many countries, plans for mapping programs have been developed to meet the requirements for detailed habitat maps, but the progress in inventory and managing habitats differs strongly, often caused by differing nomenclatures, poor infrastructure and a lack of guidance and standardized schemes.

Hard bottom substrates are an important habitat for zoo- and phytobenthic species in the southern and south-western Baltic Sea. These deposits are remnants of the last glaciation. Hydrodynamic processes have shaped them during the Holocene, when the Baltic Sea evolved through a set of different lacustrine and brackish water stages. As a result, abrasion platforms were formed building geomorphological heights, which are partly covered by stones, gravel and thin veneers of sandy material up to 30 cm in thickness. These veneers are not stationary but dynamic according to prevailing hydrodynamic conditions. Either the geomorphological heights are connected to the land and in this case, they are bordered by active cliffs, or they form morphological elevations in the open sea. In any case, they are exposed to wave conditions at least during storms. In both cases, a belt of sandy sediments resulting from abrasion processes, which started when the postglacial sea level has reached a height allowing wind induced waves to shape the seafloor, surrounds these areas. The EU Habitat Directive 92/43/EEC addresses those abrasion platforms as "reef".

As like in many countries a comprehensive knowledge of the seafloor conditions, which is required to identify precisely different habitats, did not exist. We started our habitat inventory with the development of a 3-step approach from identifying "probable habitat areas" to "precisely defined habitats" where "probable" areas are always larger in space than the precisely defined areas [4].

Step 1 : Collection of all available information for a selected area from scientific and public institutions. This included in our case bathymetrical charts (1), internal and official reports (9), MSc- and Diploma-thesis (22), PhD thesis (6), Habilitation (1) and publications (9). All data have been compiled in a GIS system, resulting in a map showing areas with the potential to be regarded as habitat according to the EU-Directive.

Step 2: Geoscientific ground-trouthing by fieldwork using high resolution and full-coverage hydro-acoustic remote sensing techniques, which allowed to map and to explore geo-acoustic properties of the seabed. Full coverage backscatter information was collected using side scan sonars with different frequencies (TTV-298, Teledyne Benthos, 200 kHz, Benthos 1624, 100 and 400 kHz). An Acoustic Ground Discrimination System (AGDS) ECHO*plus* (Seatronics Ltd., 200 kHz) was used to measure "roughness" and "hardness" of the seabed. Visual observations were performed using a ROV system (VideoRay) and a dropped video camera. ROV position were obtained by USBL (ultra short baseline), while drop-camera flights were referenced to the actual ship location. Sub-bottom architecture reflection seismic data was collected using a sub-bottom profiler and a parametric sediment echo-sounder. Sediment samples were collected with a Van-Veen grab sampler. Depending on the material, sieving or laser granulometry was used to obtain grain size distributions. All processed data were classified and transferred into seabed types [5].

Step 3: Biological validation needs to be carried out by direct sampling (grab sampler, diving observations) and visual remote sensing techniques. Until now, there is a delay in collection of the remaining data to finalize step 3.

The area which was full coverage mapped with high resolution during the last 12 years comprises about 1.540 km². The water depth range from 5 m to 25 m. Typical abrasion platform habitats were identified. The most prominent one is a hard bottom substrate composed of morainic material. This type matches the definition of a reef [6], which is of geogenic origin in the Baltic Sea. Veneers of sandy material on these hard bottom platforms are mobile and show variable thickness, seldom exceeding 30–40 cm. For this reason, they are not regarded as sandbanks according to the Interpretation Manual of the EU. Thicker sandy deposits exist, filling up former channels. These deposits are on the same morphological level than the surrounding seafloor. As the definition for a sandbank requires some elevation in relation to the surrounding seafloor [6], these deposits are as well not defined as sandbank even if biota depending on sand was observed.

The apparent zonation of seabed types and organism following morphological gradients in the research area indicate a strong link to the geological subsurface and the recent sediment dynamics. The exposure of platforms and ongoing abrasion processes with rates in the range of cm/year will support an increase of the availability of hard-bottom substrate in the future.

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S3P9. Features of the Structure of the Geological Section in the Areas of Hydrocarbons Occurrence on Lake Baikal

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The central ecological area of Lake Baikal natural territory is related to a large oil-and-gas bearing structure. This fact is indicated with numerous naphthide exposures such as combustible gas, bitumen, and gas crystalline hydrates. One of important issues is how hydrocarbon travel process takes part in forming of extensive circular structures on ice surface at different areas of the Baikal. The answer can be given after studies of geologic profile peculiarities at these areas. For that purpose we have carried out complex geophysical work which are include continuous seismoacoustic profiling (CSP) and multibeam echolocation. In addition, we have carried out hydrochemical studies of near-bottom water layers and analyzed peculiarities of temperature field at the "bottom — water" border. The experiments have been done at Goloustnoe, Posolskaya Bank, gas hydrates exposures "Bolshoy", "Malenky", "Mamay", "Kedr", "Talanka", "Turka", and exposures of oil and gas crystalline hydrates "Gorevoy Utes", Kultuk bay and others.

Multibeam echolocation data have shown that the exposures of gas crystalline hydrates are related to complex shoreface configuration with pronounced canyons (see Fig. 1). Analysis of seismoacoustic profiles have identified that the wave field has skip zones at the areas of gas hydrate and gas spring exposures. The skip zones are characterized with either complete absence of signal reflection or their partial appearance that is apparently caused by high gas saturation in sedimentary layers. The areas of gas saturation and discovered gas exposures are connected with tectonic deformations which are located on intercanyon elevations and have secant orientation to the canyons.

Another type of gas crystalline hydrate exposures is observed within a sub-horizontal and weakly inclined abyssal plane and associated with tectonic deformations of north-east course. In the bottom profile it looks like local conical elevations covered with unsorted brecciated sediments. Analysis of seismoacoustic profiles indicates high level of gas saturation within these structures. Besides that, there is a significant local disturbance of the reflecting horizons that can be caused by mud-volcanic nature of the examined structures.

Comparison of the results of temperature measurements and locations of natural hydrocarbon travel has shown that the temperature field anomalies at the "bottom — water" border are associated with areas of intensive gas emission (gas springs) and the observing gas hydrate exposures. Some of them are followed with complex geochemical anomalies [1]. This fact may point at local heating of the bottom with subaqueous ejection of thermal

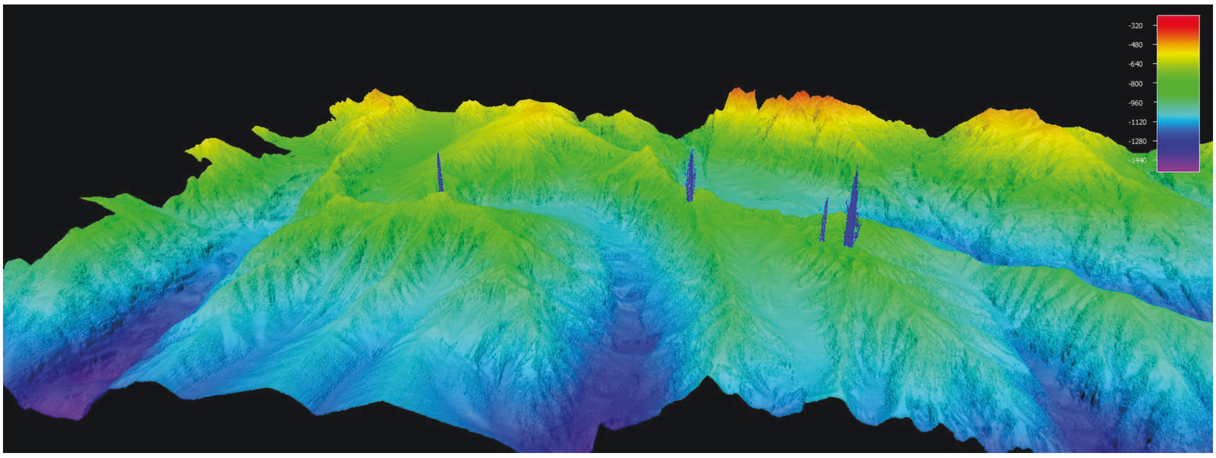

Fig. 1 Surface of the seabed in the area "Talanka", "Turka"

water that causes destruction of gas hydrates and lead to intensive emission of methane.

For several years circular structures on ice surface appear at Kultuk bay. They are related to shoreface periphery that is connected with tectonic disturbance of north-west course. Seismoacoustic measurements has shown presence of a permeable gas saturated channel within the sediment profile at the area of tectonic disturbance. Signs of intensive gas emissions into water column as well as exposures of gas crystalline hydrates at this research are have not been observed [2]. At the same time near-bottom temperature field anomaly is registered. Thus, one of the reasons of the circular structures forming can be centers of deep ejection (seepage) of gas-saturated low-intensive solutions through permeable channels that leads to generating of vortex flows.

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S1P24. SGUs Marine survey for SEAmBOTH in northern Bothnian Bay

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As partner in SEAmBOTH (SEAmless Maps and Management of the northern BOTHnian Bay) SGU has surveyed the Swedish part of the project area using two vessels equipped with state of the art hydroacoustic sonars. Ground truthing was performed using video and drop cameras as well as geological and biological sampling. Survey lines were run with an average line spacing of 90 m resulting in a complete coverage of the surveyed area. Also, 400 sediment samples were taken from the seafloor. The full coverage data set collected by SGU will be used in combination with equal datasets on the Finnish side for cross-border habitat and substrate modelling.

The main goal of the SEAmBOTH-project is to help ensure the conservation of the biological diversity, habitats, ecosystems, and the ecosystem services existing within the Bothnian Bay. To do this it is vital to have data on the bathymetry, geomorphology, substrates, biota, etc. of the area. The main work within the project is to collect data and make information and maps available for stakeholders, planners, and decisionmakers in a seamless and accessible way. The project is partly founded by Interreg Nord and is a three-year project. The main participants are GTK, Metsähallitus, SGU, Länsstyrelsen Norrbotten, Lapin Liitto, Lapin ELY, Pohjois pohjanmaan ELY, SYKE Merikeskus, SWAM.

The poster shows the hydroacoustic surveys SGU has done to date, sample positions, the equipment used, preliminary results and some examples of the expected end products.

S5O8. Spatial Distribution and Morphology of Cold-Water Coral Mounds on the Namibian Shelf

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More than 2000 fossil cold-water coral mounds have been detected by high-resolution hydroacoustic surveys on the northern Namibian shelf. The Namibian coral mounds (NCM) occur between 160–230 m water depth, on a shelf-edge clinoform system characterized by a prominent NNW-SSE-oriented escarpment and other topographic features derived from erosional processes, originated before mound initiation. Coral mound distribution, development and morphology is primarily controlled by different environmental parameters (current regime, sediment input, etc.). However, morphometric analyses and facies mapping of the NCM reveal that their distribution and morphological variability reflect the different underlying topographic features, composed by erosional furrows. The latter resulted from the action of cascading density currents that carved the isobaths at the clinoform foresets sub-perpendicularly. In addition, the erosion of the shelf-edge clinoform system is likely affected by the action of the Poleward Undercurrent (PUC), a strong contour current flowing southward along the shelf break. Mounds in the northern area (Squid Mounds) are widespread over an almost plain topography, rooted on top of very smooth furrows. These mounds are greater in size (up to 20 m high, with diameters >500 m) and exhibit a more complex morphology (merged mounds) compared to the Coral Belt Mounds further south. These are relatively small (up to 12 m high, with diameters of ca. 200 m) and conical mounds occurring in a narrow belt of furrows. Multichannel seismic profiles show a reduced thickness, a low-angle clinoforms and slope for the uppermost unit of the clinoform system in the area of the northern Squid Mounds On the rather flat, low-angle slope, the furrows might have provided a better exposure of the corals to the PUC, justifying their relatively large size, high complexity and wide E-W-oriented cluster distribution. In the Coral Belt, the uppermost unit of the shelf-edge clinoform has been largely preserved as erosion by the PUC was hampered due to the occurrence of a “protecting” lobe composed of older clinothems north of the Coral Belt. Therefore, the coral mounds of the Coral Belt occur within well-preserved furrows with a narrow distribution. A reduced sediment input in the Coral Belt, due to the lower exposure towards the prevailing current regime, might have led to the development of smaller mounds compared to the Squid Mounds. The spatial and morphological investigation of coral mounds, combined with multichannel seismic surveys, suggested that the geological configuration of the shelf-break in concert with hydrodynamic processes before mound initiation shaped the Namibian shelf-break as a geomorphological setting with topographic features that likely controlled mound distribution and potentially influenced mound development.

S3O17. Deep-ocean mapping in the Norwegian Sea — Strategy and Plans

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The Norwegian Sea is located between Greenland in the west and Norway in the east. The Norwegian part of these occupies c. 1 200 000 km^2, and constitutes one of three ocean management regions in the Norwegian waters (see Fig. 1 below). The area covers the deep sea, the continental slopes of Norway and Greenland, the shallow areas around Jan Mayen, and the Molloy Deep, situated close to 80° N and forming the deepest part of the Norwegian sea area (c. 5 700 metres). Potential mineral resources associated with Mid-Atlantic Ridge (Mohn's Ridge and the Knipovich Ridge) have led to increased interest in the deep ocean. Scientific research by university groups has been supplemented with resource potential mapping performed by the Norwegian Petroleum Directorate, who has the main legal responsibility for future exploration and exploitation. The Norwegian government has requested more knowledge on the environmental conditions and ecosystems (government white paper on the ocean management plan for the Norwegian Sea, last revised in 2016). This is the background for a large seabed mapping campaign in the Norwegian Sea under the government-funded MAREANO programme (www.mareano.no).

The remit for MAREANO under this initiative is to provide a broad characterisation of biodiversity and geodiversity and give the basis for eco-

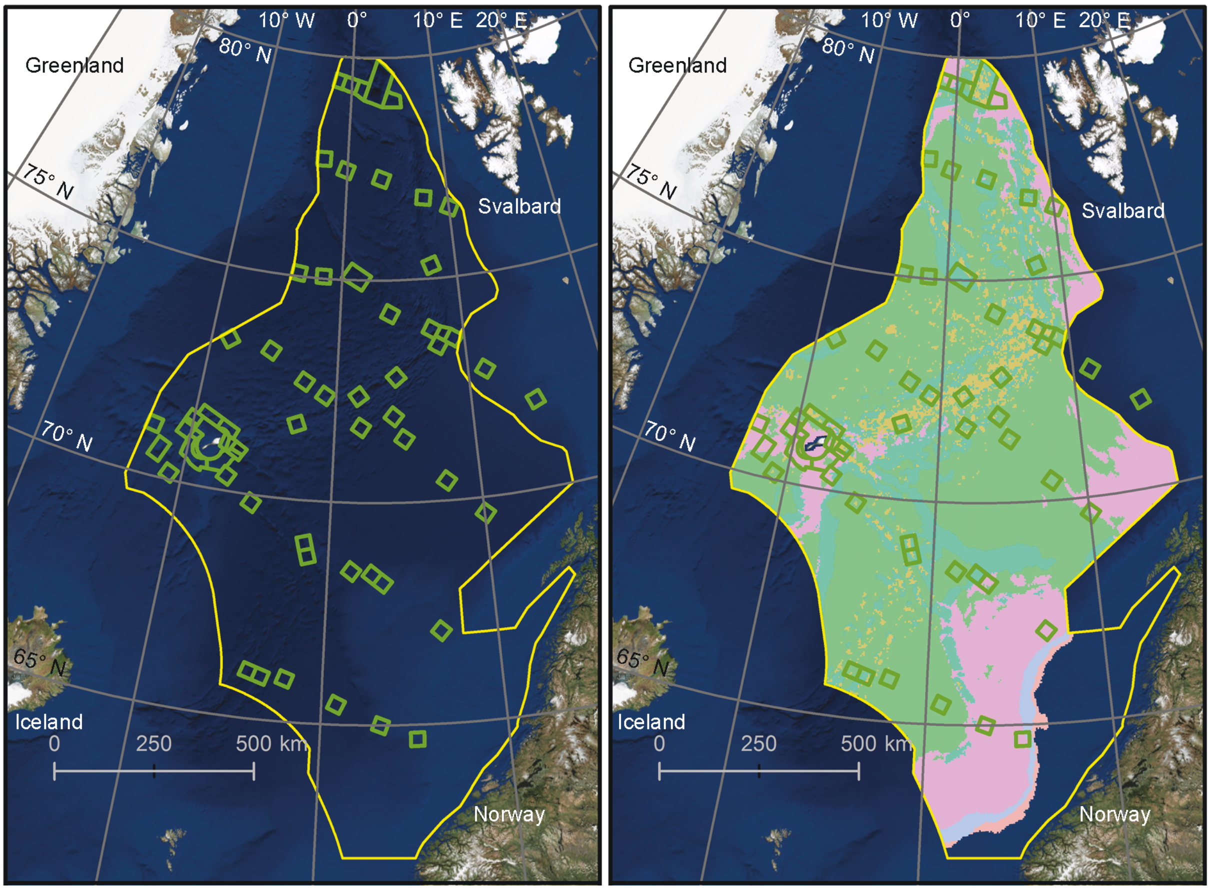

Figure 1. Left: The Norwegian Sea management plan area, and planned survey areas (green). Right: k-means unsupervised classification

system-based management. This includes suggesting areas that can be defined by the management authorities as particularly valuable areas. The survey area includes a depth range from a few hundred metres to about 5 700 metres; latitudes between 64° 30' to 80° N; different biogeographic regions; landscapes from continental shelf to continental slopes to abyssal plains and, not least, an active mid-ocean ridge where black smokers and vivid chemotrophic communities have been documented. It has been important to try to cover the entire environmental space, using available data in designing the mapping strategy. Existing multibeam bathymetry data together with regional bathymetry data (EMODnet) have been combined with regional oceanographic data to provide a k-means unsupervised classification. This unsupervised classification was combined with categorical data like biogeographic regions and geology and used as a basis for planning the mapping strategy. Valuable input was also received from the scientists responsible for university studies, particularly the University of Bergen.

The plan is for MAREANO to collect surface-based multibeam echosounder data from about 75 000 km^2 in 2019. Mapping the geology, biology and chemistry will start in 2020. The first year will include testing several platforms and sensors, in order to identify the best suite of methods for working in these deep offshore environments. Traditionally, MAREANO has used tools like a towed video platform, grabs, multicorer (for chemistry), trawls and epibenthic sledge. For the deep-ocean work, new platforms like Video Assisted Multi Sampler (VAMS), autonomous underwater vehicles (AUV), towed systems, and remotely operated vehicles (ROV) will be tested. Acoustic sensors on the AUV will likely include subbottom profiler, multibeam echosounder and synthetic aperture sonar (SAS), with the latter providing very-high-resolution imagery and interferometric bathymetry. A still-image system together with standard environmental sensors will also be fitted on the AUV. High-resolution video systems will likely be mounted on the ROV, together with equipment for physical sampling of geology, biology and chemistry. Traditional MAREANO tools like towed video platform, multi-corer, trawls and epibenthic sledge, will also be tested. Other sensors may also be considered.

This deep-ocean mapping campaign will start in 2019 with surface-based multibeam surveys, to be followed up in 2020 with near-bottom and bottom data acquisition. In addition to the aforementioned field-testing, the 2020 work must also include adapting MAREANO standards, procedures and products to this deep offshore environment, and according to the knowledge needs identified in the Norwegian Sea ocean management plan.

S1P25. Filling in the "white strip": onshore–offshore geomorphological mapping on the Scotian Shelf

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The littoral zone of marine habitats, or the so-called "white strip" often appearing on bathymetric and habitat maps, is a recurring technical challenge for seafloor mapping. The white strip is frequently, depending on the tidal cycle, too shallow and dangerous for surface survey vessel operations and too energetic for the deployment of valuable and delicate autonomous underwater vehicles. Concurrently, the littoral zone is often the locus of the most challenging aspects of marine spatial management with competing interests which include recreation, fishing, renewable energy installations, pipelines, seafloor cables, and Marine Protected Areas (MPAs). The littoral zone off Nova Scotia, on the Scotian Shelf, is host to lucrative fishing grounds and is presently being considered by the Canadian government for MPA designation. Habitat maps are required to underpin informed decision-making so that all sectors can abide by the marine spatial planning decision in this region.

Subaerial geomorphological mapping is based on the revision of published surficial geology field mapping, with further insight gained using the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Shuttle Radar Topography Mission (SRTM) 1-arc second (30 m) global digital elevation models, and commercially collected terrestrial CHS (Canadian Hydrographic Service) LiDAR. The region is dominated by drumlin fields interpreted as originating from southward flowing ice during the Last Glacial Period (LGP).

Seafloor geomorphological mapping is based on a 100 m bathymetric grid released in 2018 by the CHS, single beam sonar soundings provided by Olex AS, and marine LiDAR collected commercially for the CHS. Although glacial landforms in the littoral zone were modified by erosion during sea level rise since the end of the LGP, the orientation of drumlinoid features and recessional moraines are interpreted as marking the northward retreat of the Laurentide Ice Sheet margin across the Scotian Shelf.

The resulting onshore–offshore geomorphological map will inform subsequent sediment sampling, seabed imagery collection, and sediment transport modelling which, in turn, will strengthen the marine spatial planning decision for the white strip off Nova Scotia.

S1O30. Bridging between seafloor geology, geochemistry and biology using the trait-based approach

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Seafloor heterogeneity is primarily caused by biology. The presence of

marine organisms create voids and frameworks within and on the sediment, and their behaviour often layers or sorts the uppermost 25 cm of the sediment. To improve understanding of this biologically active part of the sediment, a common language and approach is required across disciplines such as geology, geochemistry and biology. Here I present and propose the trait-based approach as a way forward. Because there are simply too many species to describe and include in one model, reducing this complexity is essential and can be done by considering a few key characteristics, or traits of organisms. Relevant biological traits span morphology, behaviour and life-history and can be applied on single individuals and scaled up to whole communities, incorporating the density of organisms. By exemplifying the progress in benthic ecology, I outline where we currently stand, possible key traits of value especially for acoustical approaches, and ideas on how to progress.

S1PO13. Correction of the effect of seabed slope on the signal recorded by multibeam echosounder

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The variable slope dip of the seabed has a significant effect on the bottom backscatter strength (BBS) [2]. This can cause errors in the interpretation of the acoustic signal and the classification of the bottom habitats. In addition, the backscatter strength measured by a multibeam echosounder needs to be calibrated. This is necessary to remove any dependence of hydroacoustic measurement results on the technical parameters of measuring devices. The impact on signal recorded by a multibeam echosounder is even more pronounced in very shallow environments and in those with significant depth differences.

The main goal of this study is an angular correction of signals scattered back from a rough seabed in order to improve signal quality. Authors used Norbit software to correct any dependence of the recorded signal on the characteristics of a multibeam echosounder. Then they prepared a BBS correction algorithm depending on the slope of the seabed in relation to the hydroacoustic transducer. This makes it possible to measure the absolute values of BBS of different types of bottom habitats occurring in the studied area and to assess the natural variability of the characteristic features of the habitats.

Our algorithms were tested in the area located approximately 1.5 km off shore the southern edge of the Baltic Sea near Rowy harbour, within the Polish Exclusive Economic Zone. The seafloor there has a general trend of slope tilting to the north-west, but in the central part a large elevation built of glacial till covered with boulders is present. Numerous pebbles and boulders are covered with Mytilus Trossulus. The whole research area is shallow, the depth range from 4 to 20 m, and morphologically diversified [1].

This research was funded by EU BONUS-185 ECOMAP project (Baltic Sea environmental assessments by opto-acoustic remote sensing, mapping, and monitoring) and co-financed by the National Centre for Research and Development no. BONUS-BB/ECOMAP/07/2017.

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S1O31. Challenges and opportunities in a combined hydrographic and marine science survey of the Kaikoura coastline, New Zealand, following an earthquake

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A combined hydrographic and marine science survey of radically modified, shallow, coastal habitats following an earthquake, provided a range of valuable outputs for different organisations in New Zealand, as well as several lessons learned while overcoming challenges encountered during the survey. A 7.8 magnitude earthquake in November 2016 caused significant changes to the structure of the coastline and the seabed off of Kaikoura, New Zealand. Sections of the coastline were uplifted by up to 6 m resulting in the loss of substantial portions of nearshore sub-tidal rocky reef habitat, significant losses of marine life, and uncertainties regarding the impacts on the future productivity of species that support valuable fisheries. The Ministry for Primary Industries (MPI) needed to understand to what extent the habitats that support these species had changed so to enable effective management interventions. At the same time, Land Information New Zealand (LINZ) needed to conduct a hydrographic survey to provide updated charts for the region. A partnership between LINZ and MPI commissioned a combined hydrographic and marine science survey of the Kaikoura to Cape Campbell coastline to fulfil both mandates.

A combination of a high resolution multi-beam technology, detailed acoustic backscatter analysis, and seabed imagery was used to produce nautical charts and detailed habitat maps for eight sites. In addition the survey provided a baseline for the distribution of rocky reefs following the earthquake and new insights regarding the extent and abundance of freshwater seeps in the region.

Ensuring that the needs of both MPI and LINZ were met presented a series of challenges for the multidisciplinary team in the field as well as the organisations commissioning the work. The outputs expected from the survey differed for LINZ and MPI and required different technical specifications, such as resolution, and survey design considerations, such as minimum survey depth. This presentation will outline the challenges encountered, the approaches taken, lessons learned, and the final outputs of this combined survey.

P4. Discover Europe's seabed geology — The EMODNET-Geology project

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There is a worldwide need of proper knowledge of the seafloor. Maritime spatial planning, management of marine resources, environmental assessments and forecasting all require good seabed maps. There is also a need to support the objectives to achieve Good Environmental Status in Europe's seas by 2020, as set up by the European Commission's Marine Strategy Framework Directive. Already in 2008 the European Commission established the European Marine Observation and Data Network (EMODnet), which is now in its third phase (2017–2019). The EMODnet concept is to assemble existing but often fragmented and partly inaccessible marine data into harmonized, interoperable and publicly freely available information layers which encompass whole marine basins. As the data and data products are free of restrictions on use the program is supporting any European maritime activities in promotion of sustainable use and management of the European seas.

The whole package of independent EMODNET-projects ("lots" or groups) covers the marine disciplines geology, chemistry, biology, bathymetry, seabed habitats, physics, human activities, sea-basin check-points as well as a data ingestion project.

In the third phase the EMODnet-Geology project has delivered integrated geological map products that include seabed substrates, sediment accumulation rates, seafloor geology including lithology and stratigraphy, geomorphology, Quaternary geology, coastal behaviour, geological events such as submarine slides and earthquakes as well as marine mineral resources and as a new feature map products on submerged landscapes of the European continental shelf at various time-frames. All new map products are presented at a scale of 1 : 100,000 all over but finer where the underlying data permit. A multi-scale approach has been adopted whenever possible.

The EMODnet Geology project has been executed by a consortium of 39 partners which core is made up by 24 members of European geological surveys (Eurogeosurveys) backed up by 15 other partner organizations with valuable expertise and data.

S4O3. From seabed mapping to geo-environmental knowledge base, a pathway towards a more sustainable resource management

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Global developments in seafloor mapping demand significant areal expansion and coordination of seabed mapping efforts. However, to address today's challenges and tomorrow's opportunities key is also to strive towards in-depth integration of various sources of information that can be queried and analysed using most flexible and easy-to-use tools.

For the surface and subsurface of the Belgian and southern part of the North Sea a voxel-based (volume pixels with information) geological knowledge base is now available of which the backbone is a 3D geological model of the Quaternary, together with 4D numerical tools allowing scenario analyses of resource use on the long term [1]. As such, resource quality and quantity can be balanced amongst various applications whilst minimizing environmental impact.

In this presentation we will demonstrate how this geological knowledge base supports decision making related to Marine Spatial Planning (e. g., subsurface planning of offshore wind versus sand and gravel exploitation); Marine Policy, i. e. its environmental pillars European Marine Strategy Framework Directive, Habitat and Water Framework Directive (e. g., habitat change; hydromorphology), as well as industry applications.

In the framework of the Belgian Federal State's responsibility to manage and monitor its seabed resources, we envisage expanding the knowledge base modularly, e. g., with various ecosystem components, as well as socio-economic models. Overall aim is to build on the concept of natural capital and to safeguard its integrity for future generations.

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S1O32. The Geological Mapping of the Inner Shelf off Cape Town's Atlantic Seaboard

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The Atlantic Seaboard is an 18 km stretch of coastline located on the Cape Peninsula, South Africa, roughly between the Cape Town suburbs of Sea Point in the north and Hout Bay in the south. It contains a mix of urban and natural environments including up-market seaside neighbourhoods, the Table Mountain National Park and Marine Protected Area. The predominantly rocky coastline has a northeast–southwest orientation with interspersed sandy pocket beaches. A narrow, low-lying coastal plain (marine terrace) in the north merges with coastal cliffs further south. The geomorphology and sedimentology of the coast are closely linked to the underlying geology, influencing the shape of coastal embayments and promontories, as well as the composition and distribution of sediment. Hydrographic, geophysical and sedimentological techniques were used to collect high-resolution bathymetry, seafloor geology and sediment distribution data to better understand modern coastal processes and serve as a baseline for benthic habitat mapping. The results indicate a low-relief seafloor consisting of Malmesbury Group rocks in the north. To the south the seafloor consists of high-relief Cape Granite reefs interspersed with fine to medium grain sand and bioclastic (shelly) gravel. Sediment transport is generally northward by longshore drift. In the south, the high-relief granite reef and headlands form sediment traps resulting in several large pocket beaches and offshore sediment deposits. In the north, the low-relief Malmesbury bedrock is largely free of sediment, except within narrow erosional gullies. Most sediment rapidly passes through to the north resulting in a sediment-starved rocky seafloor. The three principal sources of beach sand are aeolian fine-sand transported by the Karbonkelberg headlands bypass dune entering the sea at Sandy Bay, biogenic carbonate production along the coast, and weathering of Table Mountain Group sandstone and granite bedrock. A fourth potential source is sediment entering the system via longshore drift from the south of Duiker Point. The water depth around the Duiker Point headland is presently too deep for sediment to be transported easily through longshore drift, other than during large storm events, but during past sea-level low stands this would have played an important part in supplying sediment to the coast. The study has therefore highlighted a highly variable seabed and coastal environment shape and formed by the marine geology and the coastal processes effecting it.

S1P26. Formation of thermodenudation relief in the coastal zone, Yugorsky peninsula, Kara Sea

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Tabular underground ice of undetermined origin is wide-spread phenomenon in Yugor Peninsula (South coast of Kara Sea). Now the thawing of ice bodies greatly controls the evolution of coastal processes and formation of thermocircs. Detailed geodesic studies of the key area, known as Shpindler site (located to the east of Amderma and stretched to the right coast of Khubt'yakha river), reveal the relic thermocircs formation within the adjacent areas of sea bottom.

All over the coastal part of the study area the cliff is formed by quaternary dispersed frozen deposits enclosing tabular ice, which is unleashed on the different heights. The tabular ice bodies are of various thickness and shape from large thermocircs (to 500 m in diameter) to small exposures (to tens of meters) on the cliff surface. The positive correlation is observed between the detected tabular ice exposures and positive landforms as well as with zones of high concentration of the linear topographic forms.

On the submerged coastal slope near the key area the oval-shaped depression was encountered at sea depth 6,5–7,5 m. The depression is limited by gentle slope of North-West outstretch (315–320^{o}) which has size and contour similar to Western thermocirc inland and probably represent a bottom of the relic thermocirc. It is corresponding to the results of bottom sampling with gravity corer which revealed firm and dry Pleustocene clays with temperature –1,2 ^{0}C.

The data obtained shows that the system of hills on the modern coast containing ice bodies broken by thermocircs was earlier of great extension in Northern direction.

According to some data the sea level in the study area took place at 6,5–7,5 m depth 3–3,5 thousands years ago, while the coastline was located at 650 m distance from the modern position. Thus, the average speed of the shore retreat within the corresponding time scale was about 20 cm y^{-1} excluding the thermocirc headwall displacement. displacement. As far as the thermocirc headwalls are embedded in the coast at 300–500 m, the speed of the shore retreat in such sites appears to be 1,5 times higher reaching 35 cm $y^{–1}$.

The increasing icy coast retreat, especially including the tabular ice bodies, is of cyclical fluctuation related to climate oscillations. The modern speed of the shore retreat measured at intensively degraded headwalls varies fron 1 to 5 mm $y^{–1}$. Thus the thermocirc headwall retreat for 950–1100 m could happen during 200–1000 years. Consequently the period of intensive degradation at each segment of the coastline within the latest 3,5 thousands years comprises 6–10 % of the whole time of the coastal thermodenudation. The remaining time is probably reflect the duration of the conservation stage.

S7O4. The submerged cultural landscape off Phlegraean Fields, Bay of Naples, Southern Italy

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The study area belongs to the Campi Flegrei volcanic field, an active volcanic area characterized by frequent earthquakes and repeated episodes of bradyseism (slow vertical ground movement). Volcanic activity dates back to ca. 60.000 yeas BP, with the last eruptive event occurred in 1538, when a new volcanic structure (the Mont Nuovo) was formed. A 200 m seaward shift of the coastline was recorded at that time.

Aerial photography and diving surveys testify the presence of archaeological remains at Pozzuoli (the ancient "Puteoli" — Bay of Naples) including the ports of Misenum and Baiae, and Portus Julius and Nisida (the ancient Pozzuoli, Baia, Bacoli, Miseno and Nisida) that are presently drowned up to 15 m below mean sea level. This is one of the most extensive submerged archaeological area in Italy. Besides harbour infrastructures, it includes urban sites, residential buildings, thermal baths, and fisheries.

The ground movements of this area are well known thanks to the borings produced by marine molluscs on the columns of Serapeo, the ruins of a roman market in the city of Pozzuoli. In the third century AD, the Serapeo and its neighbours started to be submerged by the sea. The subsidence continued until the tenth century, reaching about 7 m below sea level. Then the pattern changed and an uplift started, culminating in 1538 with the Mount Nuovo eruption. After 1538 the site subsided again until 1968, since than the Campi Flegrei have been characterized by rapid and significant uplifts and subsequent slow and slight subsidence. The two major events of 1969–1972 and 1982–1984 resulted in a total uplift of ca. 3.5 m. After that, only minor (a few centimeters) and short-lasting uplift episodes have been recorded in 1989, 1994, and 2000.

Baiae was a natural embayment probably used as a harbour by the 'Cumani' settlement. In Roman time, the inner part of the bay was occupied by a lake (Baianus Lacus) surrounded by several structures whose remains are now submerged at depths ranging from 4 to 10 m. They are the Claudius' Nympheo (1st Century BC), a thermal complex near the Nympheo and a great villa attributed to the Pisoni family (Pisoni's Villa). A paved dam, ca. 1300 m long, was used as trail (the Via Herculanea) to connect Portus Iulius to Baianus Lacus. Sedimentary evidence shows that the town of Baiae was active until the end of the fourth century after Christ, when a decline started following the insurgence of the bradyseism and the resultant inundation of entire areas of the town.

For this study, the submerged archaeological sites were investigated using a Reson Seabat 8101 multibeam. Processed data were interpolated and merged to produce a digital elevation model (DEM) with a bin size of 1 m. The resulting bathymetric maps provided detailed images of the submerged cultural landscape off Pozzuoli Bay, testifying the rapid and dramatic changes that completely reshaped the coastal area during the last 2000 years.

S1O33. Benthic habitats and anthropic disturbance in a Marine Protected Area. The Punta Campanella MPA, southern Italy

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The study area is located at the western end of the Sorrento Peninsula in the Bay of Naples, southern Italy. It is a rocky coast consisting of vertical or near vertical limestone cliffs of structural control, with marine areas characterized by sub-outcropping rocky substrate. Seabed sediments are mainly coarse and biogenic in origin with skeletal grains and coralligenous bioconstructions occurring widely [1].

The main goal of this study is to investigate the anthropic influence on benthic habitats in the Punta Campanella Marine Protected Area (MPA). For this aim, several environmental components including benthic habitat characters and distribution, foraminifera assemblages, water column features and inorganic pollutants (heavy metals) have been analysed in two sampling areas within the MPA. In addition, other environmental components such as terrestrial biota, fresh water supply and quality, land use and natural hazard have been taken into account.

At present, marine geophysical and sedimentological data together with results from benthic communities allowed us to characterize and map benthic habitats of the study area. At the same time, the presence of specific heavy metals (Ni, Hg) in seabed sediments resulting from geochemical analyses suggest a human-made disturbance of the benthic environments. Anthropic influence is also confirmed by the structure and composition of the benthic foraminiferal assemblages and by morphological deformities that characterize some species.

As a next step of this study, we aim to analyse the Punta Campanella MPA with a holistic-based approach that includes territorial data and selected socio-economic components of the coastal zone (i. e. human pressure, land use, etc.) [2]. For this purpose, we propose a methodology based on the Environmental Functional Analysis (EFA), a technique originally developed by Cendrero and Fischer (1997) as a procedure for assessing the quality of coastal areas [3]. This method has been successful employed as management tool and monitoring technique for coastal areas [4] and terrestrial protected areas [5] and may be used to evaluate the anthropic disturbance in the Punta Campanella MPA. In addition, the proposed methodology may be employed to compare the potential for conservation and the potential for use of the study area.

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S6O7. Pockmarks Caused by Submarine Groundwater Discharge at Hanko, South Finland

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Multibeam bathymetric and sidescan sonar images show many pockmarks on the seafloor at the Lappohja area on the south-eastern side of the Hanko Peninsula in south Finland (Fig. 1). The location is characterized by an arc-shaped sandy beach, a sandy shore platform that extends 100–250 m seaward sloping gently to ca. 4 m water depth, and a steep slope to ca. 17 m water depth within ca. 50 m distance. The pockmarks are up to 25 m wide and 2 m deep, and occur on the sandy shore platform slope and at the base of the slope down to ca. 17 m water depth [1].

Elevated radon concentrations in seawater above the larger pockmarks B and D strongly indicate groundwater discharge, and permit calculating a rough estimate of the discharge rate of 1 cm/day. Porewater profiles of elements of marine affinity such as Cl show strong vertical gradients in sandy sediments below the pockmarks. End-member modeling using δ^2H and δ^{18}O shows that the share of groundwater is ca. 83 % in the pockmark porewaters, while it is ca. 9 % in the overlying water column. In contrast, the pockmark E was covered with a thin layer of soft organic-rich mud, and radon concentration in the overlying water was at background level, which strongly indicate that the pockmark E had been inactive for several years, at least.

The local stratigraphy was investigated using marine seismic profiles, and onshore ground-penetrating radar and refraction seismic profiles. The profiles of different types were correlated based on major unconformities recognized in the profiles, following the allostratigraphic approach. The groundwater discharge site is situated in the sandy distal part of a subaqueous fan, which is a part of the late Pleistocene First Salpausselkä ice-marginal formation that runs along the Hanko Peninsula. The First Salpausselkä deposits are known to have originally deposited in a 100-m-deep lake in the front of the Fennoscandian continental ice-sheet, but been uplifted above sea level as a result of postglacial rebound. Coarse sand interbeds and lenses in the fine sand-dominated distal fan deposits provide conduits for localized groundwater flow to the pockmarks on the seafloor [1].

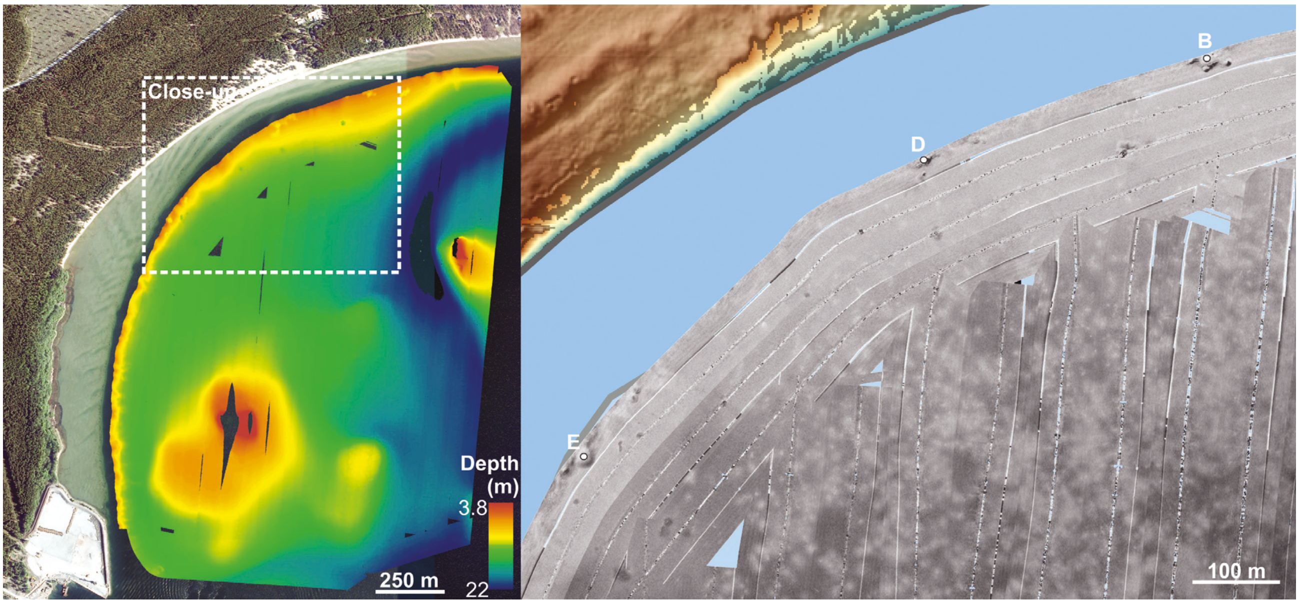

Figure 1. Multibeam bathymetric image (left) and a sidescan sonar close-up image (right) of pockmarks at the Hanko submarine groundwater discharge site

This work resulted from the BONUS SEAMOUNT project supported by BONUS (Art 185), funded jointly by the EU, the Academy of Finland (Grant No. 311983), and the Federal Ministry of Education and Research, Germany (Grant No. 03F0771B). The SEAMOUNT project develops innovative autonomous sea survey technologies, which are applied in studies of submarine groundwater discharge. The project aims to improve the understanding of submarine groundwater discharge and associated fluxes of nutrients and harmful substances to the Baltic Sea, which are largely missing in the current ecosystem models.

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S1O34. Limitations of stone detection in shallow water using high-resolution Side scan sonar images

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The southwestern Baltic Sea is mainly built up by glacial till deposits, forming the seafloor of the shallow water areas, where grain sizes range from clay to boulders. These shallow water environments (0–10 m water depth) are highly dynamic with waves and currents as the main hydrodynamic forces shaping the seafloor. As a result, abrasion of submarine platforms develops where fine fractions are eroded and transported offshore leaving coarser material behind. Therefore, gravel, stones and boulders occur frequently in shallow waters along the Baltic Sea coastline. Thus, the sedimentological composition of the shallow water seafloor has a high degree of heterogeneity and is locally subjected to high temporal dynamics (e. g. storm activity). Stones and boulders in shallow waters form complex geo-habitats in which many species coexist and therefore they are important contributors to coastal biodiversity and high benthic primary production. In addition, they provide valuable feeding areas and spawning and nursery grounds for fish.

Commonly high-resolution seafloor mapping techniques with side-scan sonars (SSS) are used to map and investigate the seafloor in coastal waters of the Baltic Sea, but most of these surveys are limited to areas with water depth of >10 m. Only limited data is available describing the seafloor between 1 and 10 m water depth, where highly variable compositions of gravel, stones and boulders are found in a confined space reaching up to the coastlines. Due to this heterogeneity of these geo-habitats and the limited available data, a detailed characterization of the seafloor, especially precise detection and identification of submarine stones and stone assemblages is of increasing importance. There are some approaches to localize ecological important marine habitats using hydroacoustic surveys [1]–[3], however important methodological constraints are often ignored which may lead to erroneous analyses. The motivation of this study is to assess limitations of methods to identify and locate stone compositions in shallow waters for habitat characterization and classification.

High-resolution observations of a small area (25 × 25 m) of the seafloor in shallow coastal waters of the Baltic Sea were carried out by side scan sonars with frequencies from 450 kHz up to 990 kHz. Different frequencies were used to identify possible discrepancies in stone detection within different levels of resolution. In addition, measurements were executed from different positions with various headings (Fig. 1). For all surveys stones were counted manually, and heights were calculated using the approach of geometric relationships [4].

All SSS images allow a distinction between single stones and the surrounding sediment (e. g. gravel, sand) and various stone assemblages are identified. However, the comparison of images of different resolution reveals considerable discrepancies in stone detection and distribution patterns. Even at a comparatively high resolution (0.1m/pix) a reduction of 83 % is observed in stone numbers compared to the image of highest resolution (“true state”) of 0.01 m/pix (Fig.1).

Additional analyses reveal the dependence of detected stone properties on the approach angle. When taking into account the whole swath width, numbers of detected stones range from 340 to 541 for the same area, a difference 37 %.

When methodological constraints are known and taken into account, detected stones and calculated stone heights can provide detailed information about potential settlement space for marine organisms. Stone heights within the study area show a clear distribution. About 90 % of the stones range from 10 to 30 cm, 7 % are range from 30 to 40 cm sized stones and only 3 % have a height 40–110 cm.

Repeated surveys on the study site demonstrate the practical application for the use of SSS in geo-habitats like shallow water stone assemblages. The abundance of stones with various sizes indicates a complex habitat structure. Using SSS images the assessment of shallow water stone assemblages

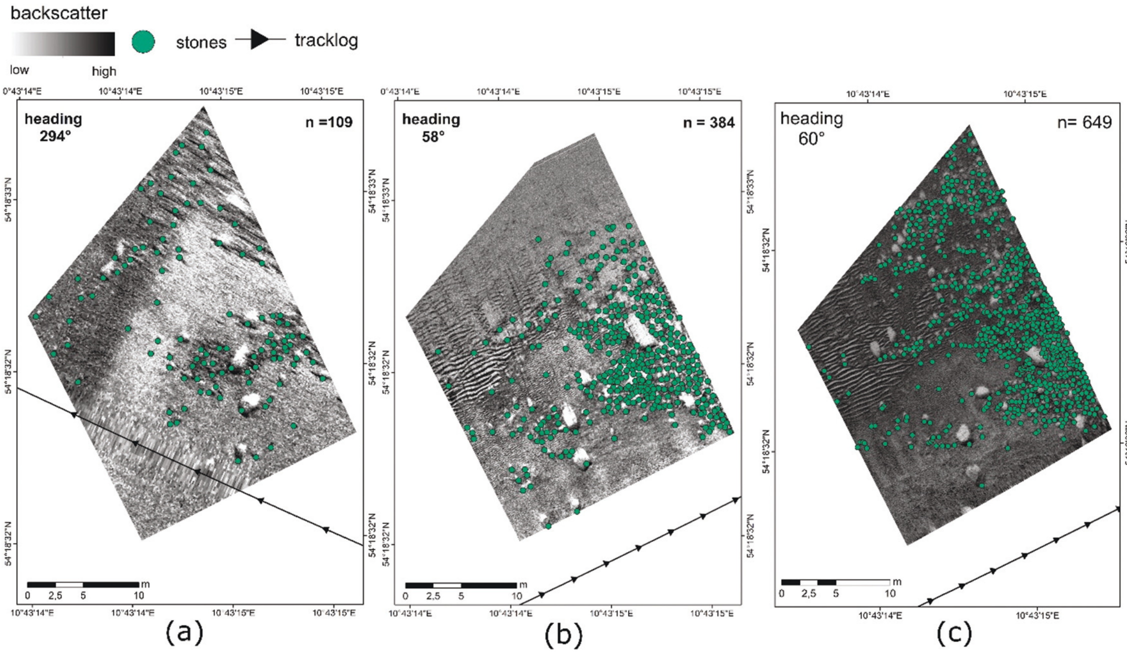

Figure 1. Sonographies of the study area displayed in three different levels of resolution. Green dots symbolize detected stones. (a) resolution: 0.1m/pixel, (b) resolution: 0.05m/pixel, (c) resolution: 0.01m/pixel

as a habitat changes dramatically with the level of resolution. A precise identification of stones is necessary to indicate the amount of potential settling space for marine organisms. The data acquisition, processing and evaluation of efficient high-resolution SSS data is time consuming but crucial in order to properly assess submarine stone assemblages as a habitat.

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S1O35. Using an Autonomous Surface Vehicle (ASV) to assess coral condition

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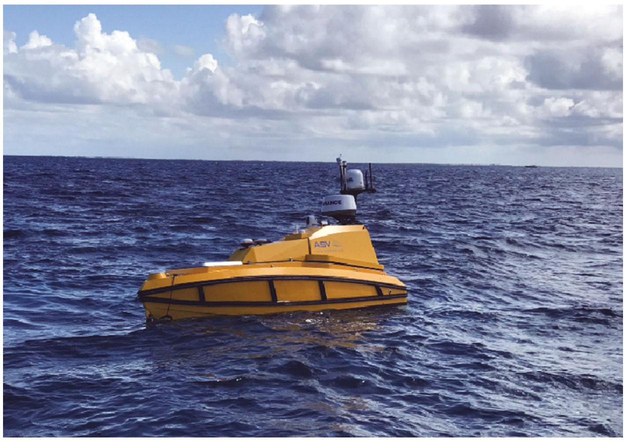
Barrier reefs are of significant ecological and economic value. However, the structure of these reefs, and the biogenic organisms that compose them, are prone to many environmental and anthropogenic pressures including ocean acidification, hurricane damage, excess heating causing bleaching events and pollution. We present a project off the coast of Belize (the Commonwealth Marine Economies Programme) that will assist the Belizean Government and local science community to survey, monitor and understand the functioning of the Meso-American Barrier Reef that mostly lies within their waters.

To assess in how far the coral reefs offshore Belize are affected by the changing water quality of the Belize river outflow, scientists from the National Oceanography Centre (UK) used an Autonomous Surface Vehicle (ASV) to map the condition of coral in very shallow water. The ASV is part of the CAMEL (Containerised Autonomous Marine Environmental Laboratory) facility, which consists of two 20 foot containers, one containing a control centre for the ASV, and one containing the ASV itself and a workshop. Other equipment available are a Deep Trekker mini Remotely Operated Vehicle (ROV) and a small support RIB. The ASV is about 4 metres long and weighs about 750 kg. It has three interchangeable payloads: a hydrographic payload (a multibeam bathymetry system), a geophysical payload (an interferometric side scan sonar system), and an oceanographic payload (a range of sensors including pH, ADCP, temperature, fluorescence and conductivity).



ASV C-worker 4

Using an ASV brings its own issues in operations. Currently a support boat is required to ensure that the ASV is navigating safely and responsibly, according to maritime regulations. However, while keeping a watching brief on the ASV, the support boat can carry out other operations such as ROV video, seabed sampling and water sampling. The CAMEL facility was deployed in Belize City and a support boat was hired to monitor the ASV along the outer edge of the Belize barrier reef. Water depths, between 1 and 10 metres, were successfully navigated and surveyed. We will present very high resolution bathymetry from the multibeam (gridded at 5 cm) and interferometric system (gridded at 25 cm), together with sidescan and backscatter mosaics and their combination with ROV video footage. The high resolution bathymetry and backscatter will allow modelling of coral cover, morphology and condition, while the combination of ROV video will examine other indicators of turbidity related damage (e. g. ratio of hard and soft corals, presence of nuisance algae etc.).

S3PO8. Estimating Potential Hard Rock Habitats within Atlantic Fracture Zones

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The world's oceans still contain plenty of uncharted seafloor, especially in the deep sea. Despite the absence of large-scale high-resolution bathymetric maps, the perception that abyssal regions stand for more than just sedimented homogenous plains, is increasingly gaining momentum. It is assumed that diverse marine environments with high biodiversity exist in the deep ocean, many of which have not yet been mapped. Fracture zones that cross-cut abyssal regions belong to these environments, with their distinct relief and alteration of the substrate. The aim of this study was to estimate the amount of sediment-free seafloor, which occur within Atlantic fracture zones and could promote benthic biodiversity. The GIS approach used was based on a high-resolution multibeam dataset from the trans-Atlantic Vema Fracture Zone, covering oceanic crust ages up to 100 million years. Seafloor types were defined and the amounts of hard substrate quantified, using a combination of seafloor variables, i. e., acoustic backscatter and topographic roughness. The findings from the Vema Fracture Zone were extrapolated to the whole Atlantic Ocean, showing that large quantities of rock habitats potentially occur along the identified fracture zone regions. This significantly increases our understanding about abyssal habitat heterogeneity and may help explain the high, yet largely unexplained biodiversity in the abyss.

S1O36. Habitat Geological Mapping Supports Artificial Fish Reef Construction at Zhejiang Offshore, China: from Research to Management

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Human activities including the marine fishery activities dramatically changed the Chinese coastal and offshore ecosystem in the past half century, trawlers used in the offshore benthonic fishery changed the seabed surface and the benthonic ecosystem recovery are under challenge. It is estimated the offshore sea-grass coverage have been decreased over 1/2, the dominant benthonic species changed and biomass decreased even though the biodiversity stayed relatively stable. China had set up state marine natural reserves and marine special reserves for the ecosystem protection and recovery. Artificial fish reefs were deployed to help the rehabilitation of benthonic biomass near the coast and islands, the practices need further assessment for better implement in the future.

China Geological Survey is conducting a coastal and offshore mapping program intend to support the coastal and offshore resources development and environment protection, including the ecosystem assessment and recovery. A pilot habitat mapping project was conducted in the offshore of Nanji Island, Zhejiang, China, to collect integrated information on the seabed for assessment of artificial fish reefs construction. Multi-beam bathymetry mapping data reveal the artificial fish reefs on the seafloor which were deployed in the last 10years. Apparent erosion of the sea floor can be detected around the artificial fish reefs, and some reefs were sunk or covered by sediment and undetected from bathymetry data or sonar data. Sediment sampling and seismic data show fine and fluid muddy sediments on the sea floor top layer which had been underestimated during the artificial fish reefs planning and construction. New design soil parameters are suggested to the local fishery authorities for the better design of artificial fish reefs construction.

S6O8. Mapping the Carbon Storage Potential of Coastal Blue Carbon Ecosystems Across Australia

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Propelled by the urgent need to identify effective approaches to address climate change, research into carbon storage by natural ecosystems is growing. In particular, the carbon storage potential of coastal "blue carbon" ecosystems — which include seagrass meadows, tidal marshes, and mangrove forests — is being pursued globally to help inform national carbon inventories and guide potential carbon offset initiatives. In fact, many nations have declared plans to utilize blue carbon ecosystems as a climate mitigation strategy through the protection, restoration, and creation of these ecosystems. These ecosystems not only store carbon in their living biomass, they also have the ability to sequester large amounts of carbon in soils for long-term storage. However, there is a lot of variability in the amount of carbon stored in the soils both within and across these ecosystems. The purpose of this project is to determine the anthropogenic and environmental drivers that can be used to explain this variability and allow for the broad scale mapping of carbon stocks on a national scale across Australia where data is limited. To do this, we used boosted regression trees (BRT) to associate soil carbon stock from soil cores taken throughout Australia with a combination of spatial variables including ecosystem type, land use, topography, population, climatic conditions, geology, and geomorphology to determine which variables best explain the distribution of soil carbon across Australia. We found that a BRT containing distance to coast, ecosystem type, average annual rainfall, deviation from natural state (catchment scale), deviation from natural state (local scale), annual average temperature, total population, sea level pressure, solar exposure, soil type, terrain slope, and elevation produced the best model and explained 70 % of the variation in soil carbon. When we

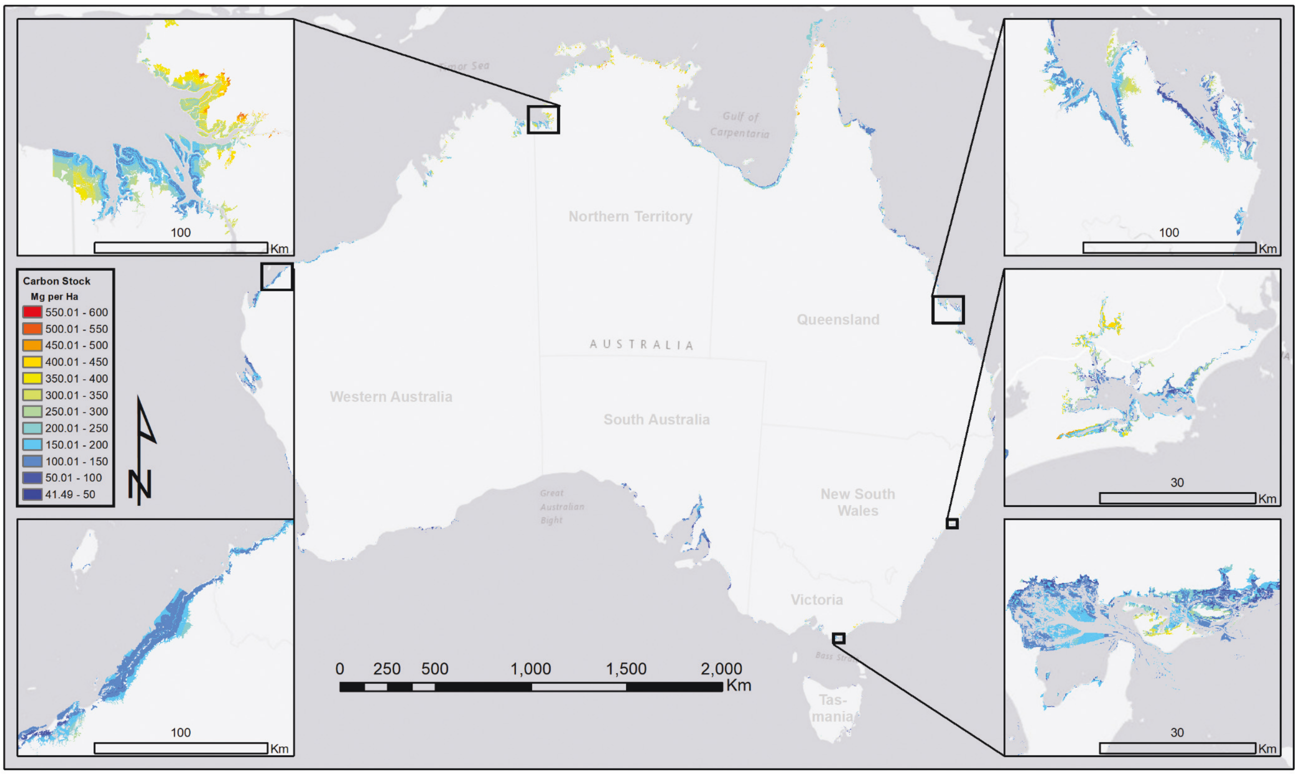

Figure 1. Predictive map of carbon stock values across Australia in blue carbon ecosystems (seagrass, tidal marsh, mangrove)

tested the predictive ability of this model on a reserved set of data (25 %), we found that the model predicts with an accuracy of 75 %. We then used the BRT to extrapolate soil carbon values across the coastal ecosystems of Australia to quantify the total amount of carbon stored by these ecosystems (see Figure 1). Also, because many of the variables significant in the model are likely to change with climate change, we used IPCC scenario projections of future (2050 and 2090) sea level pressure, temperature, rainfall, sea level rise, and solar radiation (RCP 2.6, 4.5, 6.0, and 8.5) to determine how carbon storage is likely to vary into the future. The maps resulting from these projections were compared to those for current conditions to determine which coastal areas throughout Australia are expected to experience gains or losses in carbon storage under climate change. This project helps to understand where carbon storage hot spots and cold spots exist throughout Australia and how those are likely to change with a changing climate. This information is important for determining the contribution of blue carbon ecosystems to the total national carbon budget and helping to designate those areas most important for protection or prioritizing sites for restoration. This project demonstrates how habitat maps can be used to inform coastal values in a changing climate.

S3O18. GEBCO-NF Alumni Team Multibeam and HISAS Bathymetric Data Processing and Delivery Workflow developed for Shell Ocean Discovery XPRIZE competition

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This study provides an overview of the GEBCO-NF (General Bathymetric Chart of the Oceans — Nippon Foundation) Alumni Team's solution for rapid and semi-automated seabed data processing, geospatial integration, and web mapping during the First and Final Rounds of the Shell Ocean Discovery XPRIZE (https://oceandiscovery.xprize.org/prizes/ocean-discovery). The team, comprised of alumni and affiliates of the Nippon Foundation — GEBCO Postgraduate program at the Center for Coastal and Ocean Mapping (UNH) assembled a robust, workflow and hybrid-cloud computing architecture designed to meet the competition deadline of 48 hours for data processing and submittal.

Once the team's innovative, customized Unmanned Surface Vessel (SEA-KIT) and Autonomous Underwater Vehicle (Hugin) completed a survey and returned to the port of Kalamata (Greece), data recovery, processing, cloud GIS integration and secure web publishing tasks were completed within a 43-hour period.

Datasets presented to the Shell Ocean Discovery XPRIZE representatives both as physical data deliverables and web services via the team's secure SmartOcean ArcGIS Enterprise environment and ArcGIS Online include: 1 to 5 m resolution bathymetry (multibeam and HISAS), 0.02 to 1 m synthetic aperture imagery, 1 m backscatter imagery and 3D images.

S6PO1. Landforms and geomorphological processes in the Southern Part of the Barents Sea Shelf

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Barents Sea Shelf is the most studied area of Russian Arctic in terms of geomorphology, geology and geophysics. However, multibeam coverage in Russian sector is still quite sparse. Most of the studies are focused in the areas with confirmed gas fields. The study of landforms and geomorphological processes in the southern part of the Barents Sea shelf is basic for a region of promising resource development. Sea floor features of the study area include Pleistocene glacial landforms as well as modern features in the areas of focused fluids rise and degassing. Based on the complex of geophysical data (multibeam bathymetry, side-scan sonar mazaic, high-frequency and continuous seismic profiling data) received during the cruises of R/V "Akademik Nikolaj Strakhov", a morphogenetic analysis of the seafloor landscape of the southern part of the Barents Sea is carried out. The detailed mapping of the fields of pockmarks and the complex analysis of their morphology and distribution and thermophysical properties of the sedimentary cover allows to assess the contribution of degassing processes to the development of the seabed.

Multibeam bathymetry acquired during 25–28 cruises of R/V "Akademik Nikolaj Strakhov" shows the distribution of glacial landforms in the wast depth range (50–400 m). Although the direction of movement of glacial masses is well studied for the outer regions of the Barents Sea [1], it shows more complex structure in Central and Southern regions.

The pockmarks are distributed in the Southern part of the Barents Sea. These features have been mapped and described for the Norwegian part of the Barents Shelf [2]. Fields of pockmarks that were mapped during the R/V "Akademik Nikolaj Strakhov" cruises show the variety of features with different diameter and depth. The high frequency seismic profiling allows to map gas seeps in the water column.

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