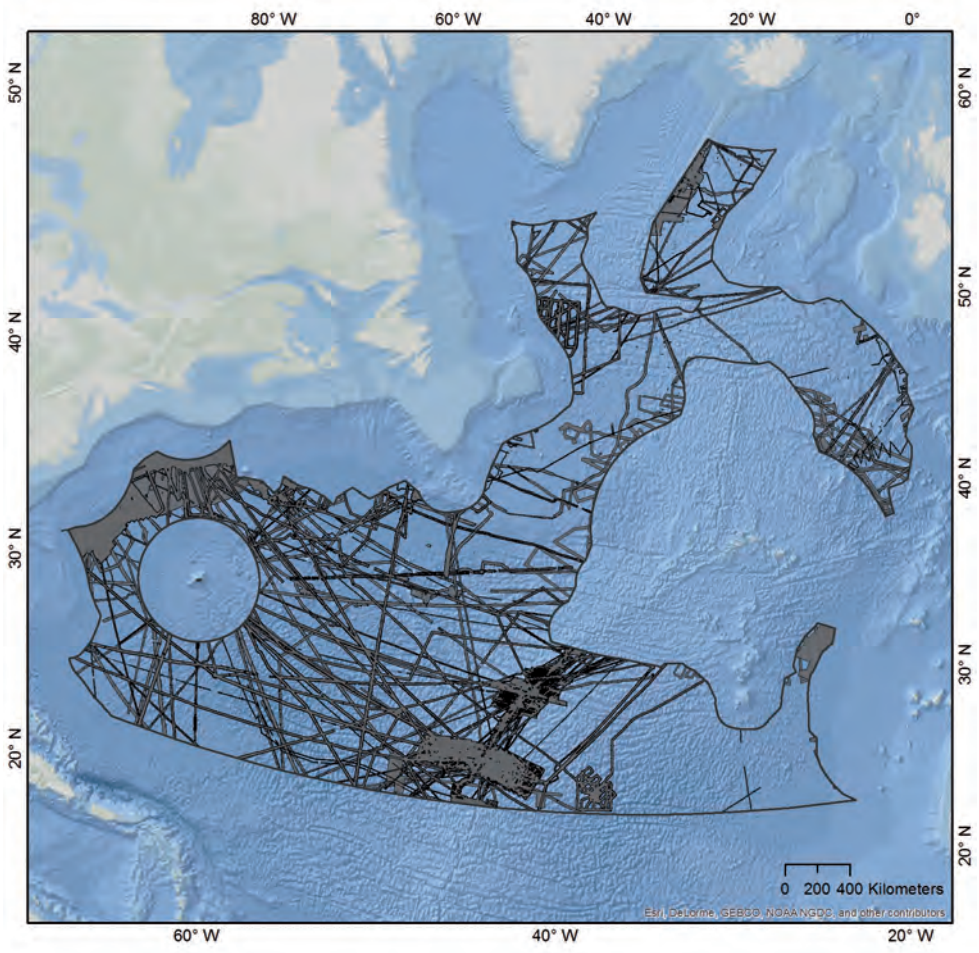
A GIS Case Study from the Atlantic

Where Do We Map Next?

Mapping the world's oceans is a tremendous task that would benefit from a prioritisation strategy. In this article, an in-depth presentation of one such approach is given: a GIS-based analysis that identified potential target areas for future mapping efforts in the North Atlantic Ocean. The authors state that more knowledge about the seafloor could be significantly accelerated if all bathymetric data were publically available.

A Worldwide Data Gap

Bathymetry underpins the safe, sustainable and cost effective execution of almost every human activity that takes place at sea, yet most of the seafloor remains virtually unmapped, unobserved and unexplored. In fact, less than 15% of the depth of the world's ocean waters have been measured directly and only about 50% of the world's coastal waters (waters < 200m deep) have ever been surveyed. Knowledge of the seafloor is a crucial factor in using the oceans, seas and marine resources for sustainable development and hence attaining the UN Sustainable Development Goal 14. With so much ocean floor out there that needs to be surveyed, how do we choose where to begin?



▲ *Figure 1: Map showing multibeam data in the study area from the Global Multi-resolution Topography Synthesis (GMRT), National Centers for Environmental Information (NCEI), EMODnet and from the Spanish and Portuguese National Archives (modified after Wölfl et al. (2017)).*

A Strategy is Needed

Even today, any mapping of the seafloor is likely to cover 'terra incognita'. So it may not seem particularly important to choose where to go - any mapping will yield new results. However, as global and regional campaign mapping initiatives (e.g.: Seabed 2030) gain momentum, more strategic approaches will be needed to avoid costly duplicative efforts and also to keep potential mapping-related environmental impacts (e.g. ocean noise) to a minimum.

Furthermore, there are regions within the ocean that are of potential special interest to a variety of stakeholder groups: prioritising mapping in these regions may have advantages in terms of the blue economy or developing sustainable ocean management plans.

An Idea is Born

The idea to analyse and identify seafloor mapping areas for future bathymetric surveys in the North Atlantic was initiated by the Atlantic Seabed Mapping International Working Group (ASMIWG), whose aim is to develop and implement a cohesive mapping strategy in the Atlantic Ocean. This working group was established in association with the 2013 Galway Statement on Atlantic Ocean Cooperation that was signed by Canada, the European Union and the United States to enhance cooperation and increase knowledge of the Atlantic through better coordination and collaboration in ocean observation efforts.

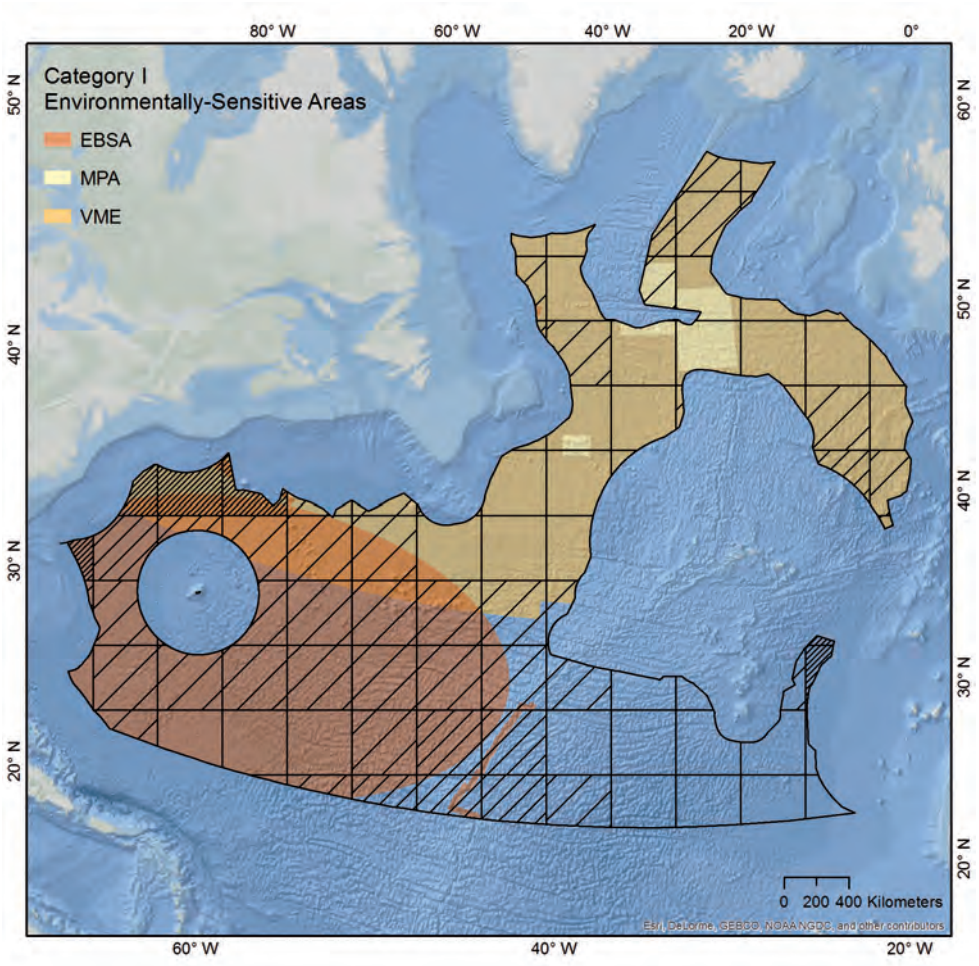
The working group set out to determine the priority of survey need, based on pre-defined

stakeholder parameters, of every 400 x 400km area within the North Atlantic High Seas area and to identify the three areas with both the highest suitability and least amount of previous bathymetric data coverage. The basic assumption was that the greater the number of stakeholder interests present at a certain site, the higher its suitability. The area size of 400 x 400km was chosen as being mappable within approximately 100 days using modern techniques, equivalent to a single cruise campaign involving three ships, one from each of the major Galway partners. The North Atlantic study area was defined as lying between 23°N (Tropic of Cancer) and 66°N (Arctic Circle), and excluding both national EEZ and their granted or pending extended continental shelf claims.

The Selection of Parameters

A key step in the analysis was to first determine where bathymetric data already existed. Perhaps surprisingly, this was not a trivial task as only a small percentage of existing multibeam data and associated geographic information is easily accessible through online portals such as the International Hydrographic Organization Data Centre for Digital Bathymetry, Global Multi-Resolution Topography Synthesis (GMRT) and EMODnet Bathymetry. To determine the current data coverage in an area, multibeam swaths accessed from these databases were combined and displayed. Where only ship tracks were available and the swath coverage was unknown, a buffer of 2.5km around the track was used (Figure 1). A single-beam density grid from NOAA, showing the number of soundings per 0.02° cell, was also analysed but not included in the data coverage calculations, due to the lack of significant spatial coverage of single-beam data in areas where multibeam coverage did not already exist.

The working group then identified a set of parameters based on the interests of various stakeholder groups (such as scientists, industry and environmental organisations) that factor in areas of public interest, sensitive marine areas and areas with marine resource potential. The following parameters were then included in the analysis:



▲ *Figure 2: Map of the study area showing the GIS parameter layers of category I -Environmentally-sensitive Areas (modified after Wölfl et al. (2017)).*

- Ecologically or Biologically Significant Marine Areas (EBSA)
- Marine Protected Areas Network (MPA)
- Vulnerable Marine Ecosystems (VME)
- Flight Lines (FL)
- Shipping Lanes (SL)
- Important Areas for Cobalt-rich Ferromanganese Crust Formation (FMC)
- Important Areas for Manganese Nodule Formation (MN)
- Important Areas for Massive Sulphide Formation (MS)

The parameters were grouped into three categories, i) Environmentally-sensitive Areas (EBSA, MPA, VME) displayed in Figure 2, ii) Areas of Public Interest (FL, SL) and iii) Areas with Marine Resource Potential (FMC, MN, MS), to ensure a balance between user-group interests. These parameters reflect the attributes a potential target area could possess in order to increase its priority for future planned bathymetric surveys. Which particular parameter within a category is of interest to any particular stakeholder depends on the individual stakeholder interest.

Identify three areas with both the highest suitability and least amount of previous bathymetric data coverage

The GIS Analysis

The target areas were defined using GIS techniques and included parameters of the marine environment as well as available information regarding data coverage. The GIS analysis was performed with ArcGIS 10.4, but can also be performed with other common GIS software. First, the three categories were integrated into the GIS as individual geospatial vector layers (shapefiles) and transformed into raster layers of 1 x 1km cells. These layers were then combined using an overlay technique and

an expression executed to add up the cell values. The desired outcome of the analysis was to obtain information about the suitability of every cell as a target area by assigning it a suitability value. Therefore, a value of one or zero was assigned to each cell for every raster layer, depending on the presence or absence of the respective category in the cell. The result is a map showing the spatial overlap of the three categories. A very low suitability would result from the absence of all categories in a cell, a low suitability for the occurrence of one category, a medium suitability for the occurrence of two categories and a high suitability for the occurrence of all three categories.

Results and Discussions

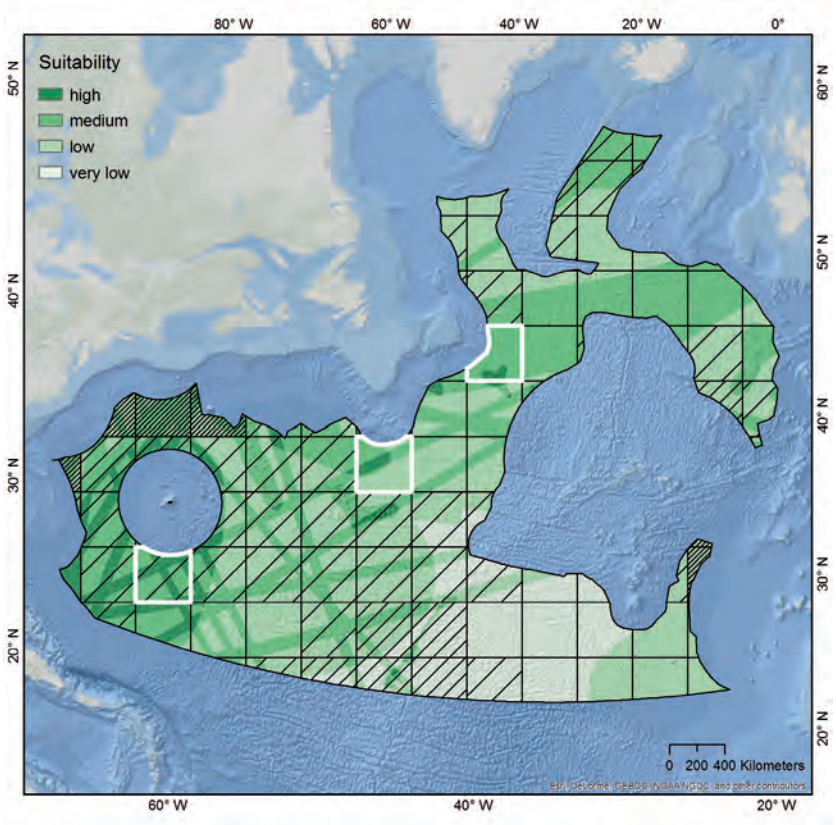
Figure 3 shows the results of the suitability analysis based on select stakeholder interests. For visualisation purposes, the multibeam data coverage was classified into four bands (0-25%, 25-50%, 50-75% and 75-100% of the area mapped with multibeam data) for each polygon. A high occurrence of desired attributes at a specific location results in a high suitability as a potential target site. The three regions of highest priority singled out by this analysis have not only a high occurrence of desired attributes, reflected in a high suitability class, but also a relatively low multibeam data coverage.

The first target area, in the north of the study region, includes the Milne Seamount located close to the continental slope and reaching abyssal depths of 6000m. Milne Seamount is part of the Milne Seamount Complex, a Marine Protected Area. 13% of this area was classified as highly suitable, the rest, of medium suitability, with all three categories represented. Only 13% of this area has been mapped in detail.

Southwest of the Milne Seamount Complex is the Sohm Plain Area. With 24% of the area mapped, the seafloor has been characterised as being made up of abyssal plains and hills. 14% of the area is classified as highly suitable with all three categories occurring. The remaining area shows medium and low suitability classifications.

Directly east of the US coastline and north of the Caribbean is the Sargasso Sea Area. Almost half of this target area is highly suitable (45%), the

A GIS analysis can be easily adjusted and repeated to include new criteria depending on interest or new data



▲ *Figure 3: Result map showing the suitability of the study area and the three selected target areas (modified after Wölfl et al. (2017)).*

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Colin Devey is Professor of Oceanic Volcanism at GEOMAR in Kiel, Germany. His research centres on the fluxes of heat and materials from the Earth´s interior to the seafloor, trying to understand how the oceanic crust and ocean water interact over geological time. His present focus is on finding ways to map large areas of the seafloor to make useful geological maps relevant for global mass balances, mineral prospection, marine protection and spatial planning.

For the past nine years, **Jennifer Jencks** has been working at the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) in Boulder, Colorado. She is the director of the IHO Data Center for Digital Bathymetry, leads the NCEI Ocean and Coastal Mapping Team, manages global marine geophysical data archives, and is actively involved with many national and international seafloor mapping projects. Before joining NCEI, Jennifer worked offshore for the Integrated Ocean Drilling Program and for a geophysical consulting firm in California. She earned her BSc in Geological Engineering from the University of Mississippi and her MSc in Ocean Engineering from the University of Rhode Island.