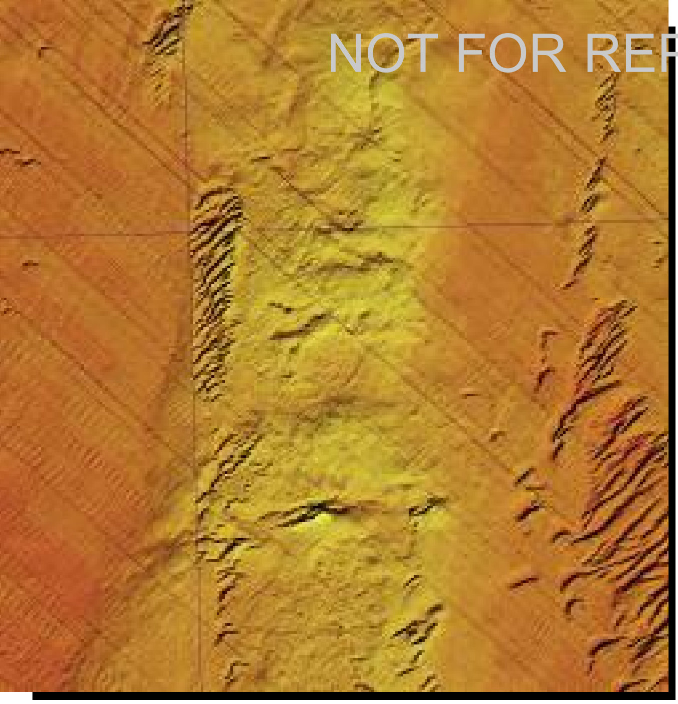

Benthic habitat mapping in Canada – *a perspective*

by Vladimir E. Kostylev, Brian J. Todd and John Shaw

Benthic habitat mapping is essential for stock assessment, fishing success and sustainable ocean management. This is a point that Natural Resources Canada (NRCan) or more precisely Geological Survey of Canada Atlantic (GSCA) located at Bedford Institute of Oceanography in Dartmouth, Nova Scotia, has been proving for the last decade. Now many others are catching onto these ideas.

Seabed habitat mapping has been on the rise since the wide spread implementation of multibeam mapping technologies. The acoustic signal obtained from multibeam sonar yields georeferenced, three dimensional depictions of seabed morphology and allows interpretation of sediment properties (Figure 1). When used in conjunction with other geophysical instruments and augmented by geological sampling (Figure 2), the technology enables the production of detailed maps of seabed morphology and texture. The precisely positioned multibeam imagery has revolutionised hydrography, marine geoscience, benthic ecology, and habitat mapping, enabling scientists to collect valuable contextual information for habitat management and thereby establish the knowledge base for implementing integrated ocean management.

Harvesting or protecting animals is most successfully done where they are the most likely to occur. To find these places one has to understand the relationships between the animals and their habitats. GSCA is working towards this understanding by developing predictive models of geological controls on benthic ecosystems and by creating better tools for surveying and interpreting the nature of the seabed.

Joint projects between GSCA, Fisheries and Oceans Canada (DFO) and the commercial fishing industry have proven the utility of habitat mapping techniques in application to fisheries management. The fishing industry provided the initial funding for surveys of scallop banks off southwest Nova Scotia. Beginning in 1992, scientists from GSCA and Canadian Hydrographic Service at the Bedford Institute of Oceanography developed a unique methodology that employs multibeam sonar data to aid interpretation of sediment texture, map seabed habitats and predict distributions of commercial species. Traditional trawling practices of dragging gear over large swathes of seafloor destroyed not only aquatic habitats but also expensive fishing gear. By discerning different surface textures such as gravel, sand or rocky outcrops, we were able to predict where different species were likely to be found. Maps of the bathymetry, surficial

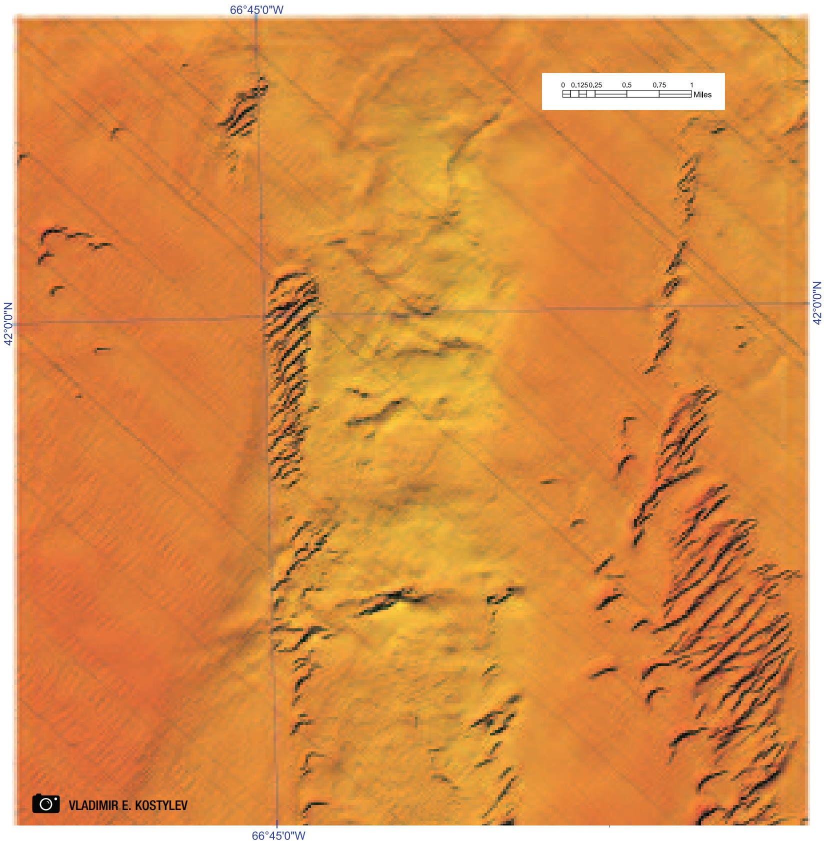

Figure 1: Multibeam bathymetry of a part of Georges Bank. The image shows large sand dunes on seabed atop of gravel lag.

geology, and benthic habitat were exported into electronic charts and have been used to improve fishing efficiency, reduce environmental damage, and introduce new management practices to the fishery. For the successful development, transfer and commercialization of multibeam seafloor imaging applications for the fishing industry, the interdepartmental team from NRCan and DFO received a prestigious Federal Partners in Technology Transfer award (more info available at www.fptt-pftt.gc.ca/eng/success/awards2008/2008awards1.html).

The new maps (Figure 3) enabled a previously inaccessible fishery off Nova Scotia in 2001, adding $29 million to the economy in the first five years. Reducing trawling by as much as 75%, interpreted multibeam imaging is a powerful tool for conservation of seabed habitats and ocean management. More importantly, fishing companies have realized that sustainable fishery profits can only come from sustainably managed (environmentally responsible) fisheries. Sustainable fisheries are only possible when they are managed in an ecosystem context.

Benthic habitat mapping is much broader than just using multibeam sonar for a three-dimensional representation of seabed. Different habitat mapping approaches can be taken depending on the scale of the area being mapped, the amount of available time and the available resources. The application of these various approaches to seabed habitat mapping is the focus of GeoHab (Marine Geological and Biological Habitat mapping; www.geohab.org), the annual conference of an interdisciplinary group of scientists working on seabed mapping. GeoHab was established in 2001 to bring together scientists from around the world working on the development of new types of thematic maps linking acoustic mapping and geological sampling to ecological patterns and processes within a Geographic Information System (GIS). The goals of GeoHab are to maintain awareness of technological advances and standards, to develop new thematic maps useful for fisheries, biodiversity management and assessment of Marine Protected Areas (MPAs), to encourage standardization of maps through creation of a habitat mapping glossary, and to establish links to marine mapping agencies worldwide. GSCA is one of the organizers and promoters of this conference because one of its priorities is to achieve balance between resource exploitation and preservation of unique natural habitats.

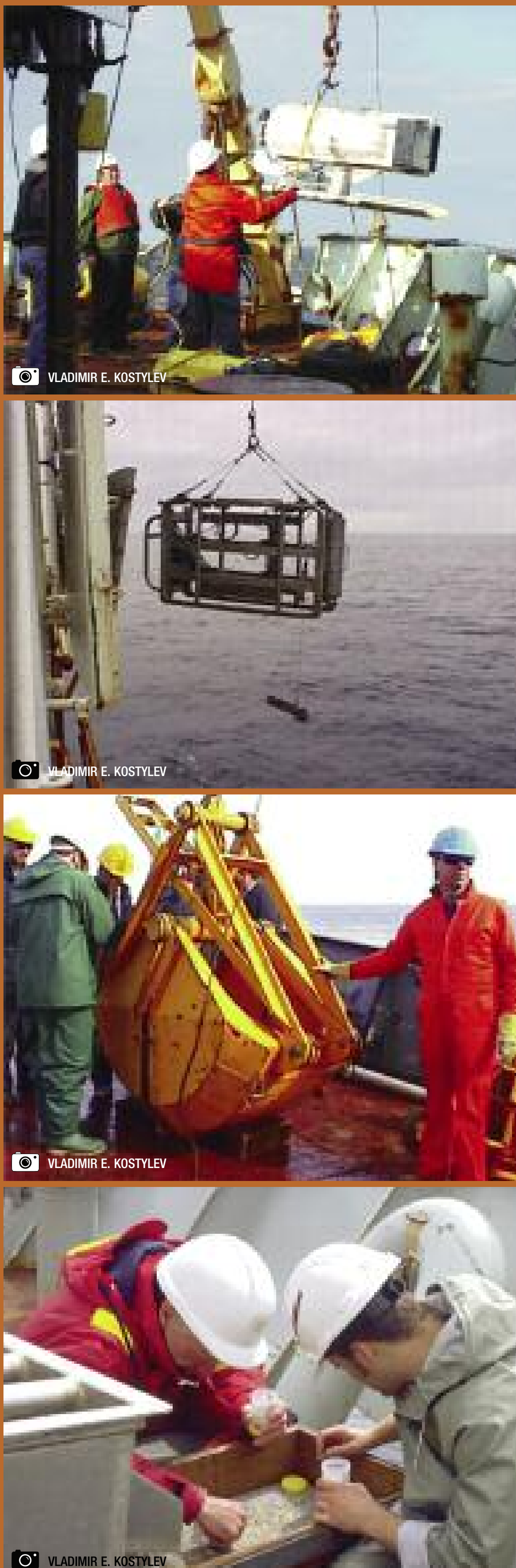

Figure 2: Collecting groundtruthing information for seabed habitat mapping. From top to bottom: Deployment of sidescan sonar; Benthic camera system; Sediment grab sample on board ship; Sorting a benthic sample.

GeoHab recently produced a book of collected papers "Mapping the Seafloor for Habitat Characterization," published by Geological Association of Canada, demonstrating the broad scope of interests and technical approaches to the issue.

Since 2002 the GSCA's Geoscience for Oceans Management Program (GOM) has focused on delivery of the geoscience knowledge base for informed decision making in Canada's offshore lands to ensure that natural resource development does not harm the environment and that appropriate land-use decisions are made while balancing social, economic and environmental considerations. Under this program, mapping of seabed habitats has been a challenging but engaging topic. The area of seabed under Canadian jurisdiction is almost as large as the area of Canada's land. However, our knowledge of this area is much more limited. The application of multibeam sonar technology for seabed mapping is constrained by the large seabed area to be mapped and the required resources to do the mapping. The creation of benthic habitat maps is also challenging because visual observations of the seafloor are unavoidably fragmentary. Remote sensing techniques in the marine realm are mainly limited to structural descriptions of the seabed through acoustic surveying. Even if high-resolution bathymetry was available for all Canadian waters, the biological information is not easily obtained at the same level of detail. In marine remote sensing there is no analogy yet to aerial photography and satellite imagery, which provide detailed spatial information on land.

Several years ago, a number of DFO, GSCA and university scientists discussed the possibility of developing a classification scheme for benthic habitats of the Scotian Shelf using a series of physical variables describing direct and indirect environmental gradients. After carefully considering a number of existing habitat classification schemes we asked ourselves a question — if our goal is to protect slow-growing, long-lived, unique, endangered species, why don't we target that from the very beginning? We settled on using the habitat template approach, which allows prediction of types of habitats

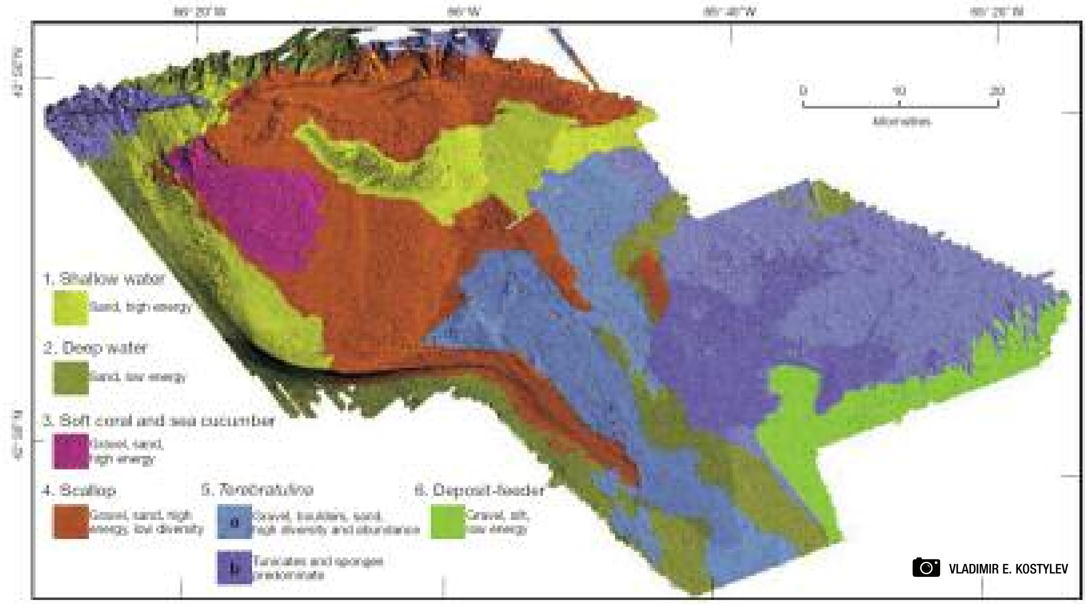

Figure 3: Interpreted habitat map of Browns Bank. Six colour-coded benthic habitats are defined, distinguished on the basis of substrate type, benthic assemblage, habitat complexity, relative current strength and water depth.

where slowly growing and slowly reproducing species (most likely to be adversely impacted by humans) would occur. This ecological classification framework is based on the consideration of the effects of the physical environment on life history traits of benthic species and on the stability of natural habitats. This conceptual model views natural rates of seabed disturbance and scope for growth (energy available for growth and reproduction) of the environment as the main explanatory variables for the types of animals and communities expected on the seabed. As a result, we could more clearly address the following key questions: Which areas of the seafloor are the most sensitive to human impacts, and where would the effects of fishery be more harmful?

These questions were answered through detailed mapping and characterization of the seafloor environment based on the current understanding of biological, geological and oceanographic patterns and processes on the Scotian Shelf. The maps of natural disturbance are used to predict the risk of adverse human disturbance following a simple logic — habitats and communities adapted to natural disturbance, such as shallow sandy banks, will be at a lower risk of adverse impacts than stable (e.g. deep water) habitats. A scope for growth map was used to show which areas may have populations with fast recovery rates from fishing impacts and areas in which populations may not recover at all. In particular, populations in less productive environments, having less energy for growth and reproduction, are at higher risk of extinction than the populations dwelling in highly productive environments.

With these maps we can identify habitats of concern where the risk of overfishing or habitat destruction following high-energy anthropogenic impacts, such as bottom dredging, is high. We can also use these maps to inform managers about habitats that are critical for a particular marine resource, and habitats that will experience largest changes in functionality as the natural environment changes.

In 2006, a new GOM project was initiated by GSCA called "National Morpho-Dynamic Framework for Seabed Management on Continental Shelves." This project will provide a national scale perspective to identify vulnerable regions of Canadian seabed and set national seabed management priorities. The emphasis of the project is on

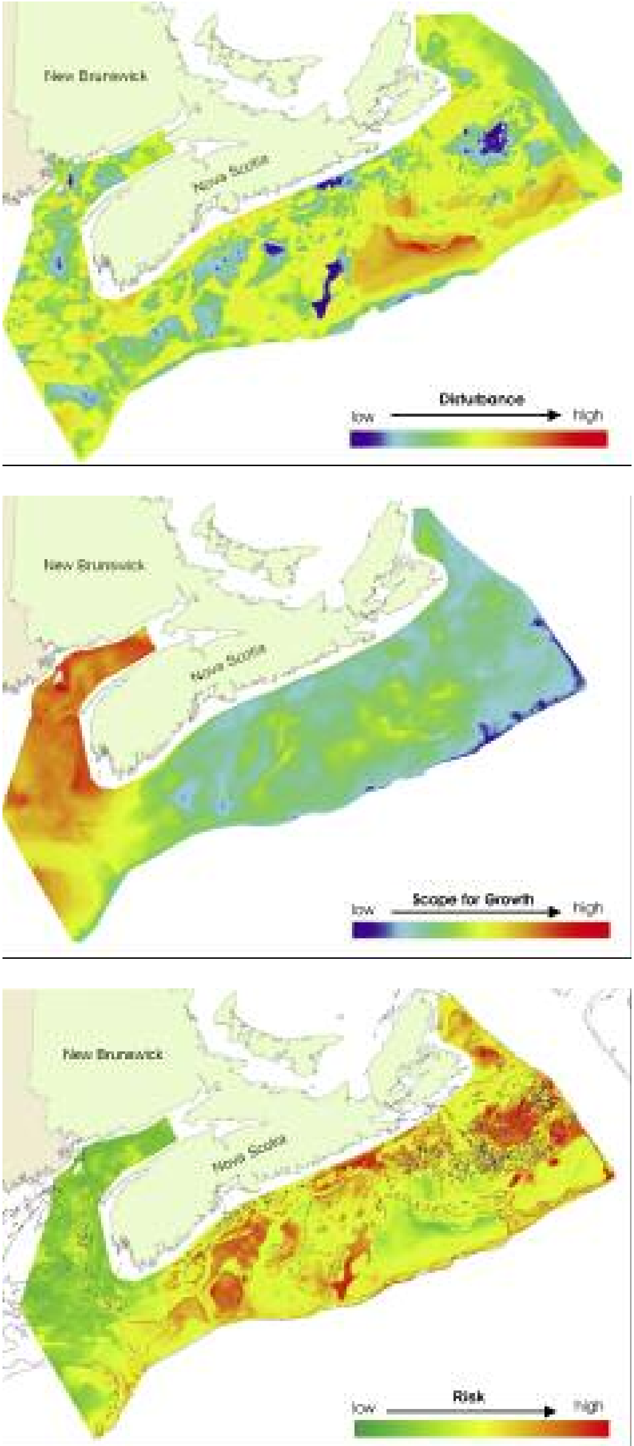

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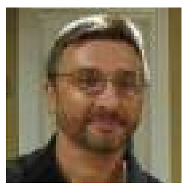
Figure 4: Natural disturbance, scope for growth and risk maps for the Scotian Shelf. The risk of habitat destruction and overfishing is the highest where habitats are naturally stable and provide less energy for growth and reproduction of benthic fauna.

establishing a countrywide perspective of the geo-environment and seabed habitats on continental shelves and assessment of the relative importance of physical factors at different spatial scales. The unifying idea of the project is to interpret and map emergent properties of Canadian seabed habitats based on the integration of knowledge of geologic, oceanographic and ecological patterns and processes. Creating a "big picture" for Canada is as challenging as creating high-resolution maps. The work includes compilation of existing data in GIS databases, physical and ecological modeling of seabed processes, and groundtruthing of the models. The scope of work is interdisciplinary, involving other government departments (DFO) and drawing together geological data (e.g. sediment grain size, geomorphology, sediment dynamics), oceanographic variables (e.g. bathymetry, bottom temperature, salinity, oxygen saturation, nutrients, currents) and ecological data (e.g. benthic community patterns, species diversity, fishery information). The information on sediment type and geomorphology is being produced from a patchwork of maps published since the 1960s. In order to construct a single map using this patchwork it has been necessary to delineate six surficial geology units common across the study area: bedrock, till, glaciomarine sediments, postglacial mud, postglacial sand, and postglacial gravel. Sediment dynamics models, based on current stresses and wave climatology, will be used to predict near bed disturbances and sediment mobility for all shelf regions. Maps of seabed disturbances (including ice scouring) are used to understand the relationship between the geological environment and ecological processes on Canadian continental shelves. Biological data layers in the GIS project will include information on existing benthic communities, distribution of commercially important benthic species, ground fish catches, data on sampling and surveying effort, etc. The project is compiling a Canada-wide dataset on the seabed environment. In the next year the physical and biological data will be summarized following the habitat template approach already successfully implemented on the Scotian Shelf. The resulting maps will act as a guide for defining areas of concern by predicting risks of human disturbance to seabed habitats, and in assessing the likelihood of recovery of benthic habitats and populations following a destructive event.

These maps will be essential for aiding Canada's commitment to establish a network of comprehensive, representative and effectively managed MPAs by 2012. The importance of national-scale perspectives is highlighted in the recent report by the Canadian Parks and Wilderness Society in which Canada is ranked number 70 amongst 228 countries. Australia, ranked at number 1, has adopted a systematic approach to mapping 'seascapes' of the Australian margin, an approach not greatly different from the GOM mapping framework.

The approaches to creating habitat maps and the types of maps produced depend on the management objectives. Managers of living marine resources, government bodies responsible for fisheries, non-governmental organizations (NGOs) and fishery consortia, as well as marine researchers focusing on resource management and habitat conservation, have various, and not necessarily overlapping, needs in seabed habitat maps. In Canada we need habitat maps first and foremost to assist with the fishery and to determine its impacts on the environment. At other levels of marine spatial planning we need habitat maps to implement an ecosystem approach to ocean management, to assist in environmental monitoring and to resolve potential seabed use conflicts. In several recent decades, habitat mapping has grown into a separate scientific discipline. To achieve the fishery and conservation objectives, habitat mapping should be better coordinated nationally and internationally. We need better distribution of seabed habitat maps and increased support for habitat research to enable us to more efficiently address marine management challenges.

Currently seabed habitat mapping is mostly reactive. Concentrating efforts in areas which have important fishery species or unique habitats seems logical, but it would be beneficial to expand habitat research into new seabed regions. We need to undertake proactive mapping targeting ocean management problems such as biodiversity conservation, design of MPA network, protection of fish habitat, environmental impact assessment in seabed engineering projects, defining sensitive habitats and predicting effects of global warming on the functionality of marine ecosystems. Such work requires interdisciplinary effort bringing together the understanding of geological, oceanographic and ecological processes in the benthic boundary layer. GSCA and its partners are well positioned to carry out this task because of the extensive experience in seabed mapping, proven success record and strong horizontal linkages with other government departments.



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Brian J. Todd is a marine geoscientist with the Geological Survey of Canada at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. His research interests include applying marine geophysics and geology to benthic habitat mapping, and the glacial and deglacial history of the eastern Canadian continental shelf.

Dr. John Shaw is a research scientist with the Geological Survey of Canada, part of Natural Resources Canada. His research was initially focused on sea-level change and its impacts on coasts, but in recent years he has been using multibeam sonar data to decipher the glacial history of the continental shelves of Atlantic Canada.