Proceedings of the Bay of Fundy Seafloor Mapping Forum: Dartmouth, Nova Scotia, March 13, 2020

Jessica A. Sameoto, Freya Keyser, David Keith, Craig J. Brown, Ian Church

Fisheries and Oceans Canada
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

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2020

PROCEEDINGS OF THE BAY OF FUNDY SEAFLOOR MAPPING FORUM: DARTMOUTH, NOVA SCOTIA, MARCH 13, 2020

by

Jessica A. Sameoto[1], Freya Keyser[1], David Keith[1], Craig J. Brown[2], Ian Church[3]

[1]Bedford Institute of Oceanography
1 Challenger Drive
PO Box 1006
Dartmouth, NS
B2Y 4A2

[2]Dalhousie University
Department of Oceanography
Life Sciences Centre, 1355 Oxford Street
PO Box 15000, Halifax, NS
B3H 4R2

[3]University of New Brunswick
Department of Geodesy and Geomatics Engineering
15 Dineen Drive, PO Box 4400
Fredericton, NB
E3B 5A3

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ABSTRACT

Sameoto, J.A., Keyser, F., Keith, D., Brown, C.J., Church, I. 2020. Proceedings of the Bay of Fundy Seafloor Mapping Forum: Dartmouth, Nova Scotia, March 13, 2020. Can. Tech. Rep. Fish. Aquat. Sci. 3395: v + 24 p.

Through the Department of Fisheries and Oceans (DFO) Ocean and Freshwater Science Contribution Program (Partnerships and Priorities Fund), funding was provided to the Nova Scotia Community College (NSCC) and University of New Brunswick (UNB) between 2017-2020 to undertake multi-year research focused on developing seafloor mapping and ocean modelling approaches to improve understanding of benthic ecosystems in the Bay of Fundy. This *“Hydrography to biology: Developing integrated approaches for benthic habitat mapping”* project aimed to refine existing and test new approaches to habitat mapping by integrating existing multibeam echosounder datasets from the Bay of Fundy with newly conducted *in situ* sampling of the seafloor and hydrodynamic modelling. A one-day forum was held on March 13, 2020, at the Bedford Institute of Oceanography, in Dartmouth, Nova Scotia, with participation from academic researchers, students, government scientists, hydrographers, resource managers, and science managers. The objectives of this forum were to communicate the main results from this 3-year project, present an update on upcoming major research initiatives that are leveraging the results of this project (e.g. Ocean Frontier Institute Phase 2 Project – Benthic Ecosystem Mapping and Engagement (BEcoME)), and to discuss how this research could be operationalized by DFO. These proceedings provide an overall summary of the forum presentations and discussion sessions.

RÉSUMÉ

Sameoto, J.A., Keyser, F., Keith, D., Brown, C.J., Church, I. 2020. Proceedings of the Bay of Fundy Seafloor Mapping Forum: Dartmouth, Nova Scotia, March 13, 2020. Can. Tech. Rep. Fish. Aquat. Sci. 3395: v + 24 p.

Dans le cadre du Programme de contribution à la recherche scientifique sur les océans et les eaux douces (Fonds des partenariats) du ministère des Pêches et des Océans (MPO), du financement a été accordé au Nova Scotia Community College (NSCC) et à l'Université du Nouveau Brunswick (UNB) de 2017 à 2020, pour entreprendre une recherche pluriannuelle axée sur l'élaboration d'approches pour la cartographie des fonds marins et la modélisation des océans, pour améliorer la compréhension des écosystèmes benthiques dans la baie de Fundy. Le projet intitulé « De l'hydrographie à la biologie : Élaborer des approches intégrées pour la cartographie de l'habitat benthique » visait à mettre au point les approches actuelles et à mettre à l'essai de nouvelles approches pour la cartographie de l'habitat, en intégrant des ensembles de données d'échosondeur multifaisceaux de la baie de Fundy à un nouvel échantillonnage in situ récent des fonds marins et une modélisation hydrodynamique. Un forum d'un jour a eu lieu le 13 mars 2020, à l'Institut océanographique de Bedford, à Dartmouth, en Nouvelle Écosse, auquel ont participé des chercheurs universitaires, des étudiants, des scientifiques du gouvernement, des hydrographes, des gestionnaires de ressources et des gestionnaires scientifiques. Ce forum avait pour objectifs de communiquer les principaux résultats de ce projet de trois ans, de présenter une mise à jour sur les grandes initiatives de recherche à venir misant sur les résultats du projet (ex. phase 2 du projet de l'Ocean Frontier Institute – Benthic Ecosystem Mapping and Engagement [BEcoME]) et de discuter de la façon dont cette recherche pourrait être mise en œuvre par le MPO. Ce compte rendu fournit un résumé global des présentations et des séances de discussion du forum.

INTRODUCTION

Sustainable management of marine resources requires spatial information, often in the form of maps. From delineating sensitive benthic areas and marine protected area (MPA) planning, to species distribution mapping, to defining critical habitat for Species-At-Risk, to fishery management – benthic habitat mapping is an essential first step towards supporting these and other ecosystem based management initiatives. Developments in the field of acoustic remote sensing such as multibeam echo-sounders (MBES) combined with *in situ* sampling (e.g. video, stills, grab samples) have allowed for the development of high resolution seafloor maps that can dramatically improve our understanding of the spatial patterns and complexities of the benthic environment.

A variety of map products (e.g. habitat maps, species distribution models) can be developed from the same underlying data sets using a suite of analytical tools. Therefore, a single investment can produce a diverse set of products that address multiple management objectives. Hydrographic data sets (MBES bathymetry and backscatter) form the foundation of these maps. Through the Department of Fisheries and Oceans (DFO) Ocean and Freshwater Science Contribution Program (Partnerships and Priorities Fund), funding was provided to the Nova Scotia Community College Applied Oceans Research Group (NSCC-AORG) and University of New Brunswick (UNB) between 2017-2020 to undertake multi-year research focused on developing seafloor mapping and ocean modelling approaches to improve the understanding of benthic ecosystems in the Bay of Fundy. This *“Hydrography to biology: Developing integrated approaches for benthic habitat mapping”* project aimed to refine existing and test new approaches to habitat mapping by integrating existing MBES datasets from the Bay of Fundy with newly conducted *in situ* sampling of the seafloor and hydrodynamic modelling.

A one-day forum was held on March 13, 2020, at the Bedford Institute of Oceanography, in Dartmouth, Nova Scotia, with participation from academic researchers, students, government scientists, hydrographers, resource managers, and science managers (Appendix 1). This forum aimed to achieve the following objectives:

i. To communicate the main results from the 3-year *“Hydrography to biology”* habitat mapping partnership project,
ii. To present an update on upcoming major research initiatives that are leveraging the results of this project (e.g. Ocean Frontier Institute (OFI) Phase 2 project – Benthic Ecosystem Mapping and Engagement (BEcoME)), and
iii. To discuss how this research can be operationalized by DFO.

Forum Format

The first session of the forum consisted of 9 presentations related to results produced from the *"Hydrography to biology"* project. The second session of the forum consisted of an update on the OFI Phase 2 – BEcoME project, led by Craig Brown of Dalhousie University and Katleen Robert of Memorial University. BEcoME is a 4-year (2020-2023) international research initiative that will address the role of benthic habitat in controlling shifting patterns in species and biodiversity caused by a changing ocean climate across multiple scales. This OFI research initiative will leverage data and data products produced by the partnership project from the Bay of Fundy as part of the planned research.

The final session of the forum was a facilitated discussion on how the research produced from the *"Hydrography to Biology"* project could be operationalized within DFO. Discussions to identify opportunities to operationalize, further develop and/or build upon the data products and research results from the project were discussed and documented. DFO Science's mandate in the Maritimes covers five main themes: Marine Spatial Planning (MSP), assessment and mitigation of ecosystem stressors, adaptation to a changing environment, population and ecosystem assessment, and safe navigation and emergency response. Discussions as part of this session were guided based on these themes.

I. PRESENTATIONS

The need for seafloor habitat maps: fisheries assessment and management

Jessica A. Sameoto[1], David Keith[1], Craig J. Brown[2]

[1]Fisheries and Oceans Canada, Dartmouth, NS
[2]Dalhousie University, Halifax, NS

In June 2019, amendments to the Fisheries Act (Bill C-68), including new fish stock provisions, received Royal Assent. There is now a requirement to maintain prescribed major fish stocks at or above levels that promote sustainability, and to implement rebuilding plans for stocks that have declined below their limit reference point; all while taking into account the biology of the fish and environmental conditions affecting the stock. To address these requirements, fisheries assessments need reliable metrics of stock status, reference points, and an ability to account for environmental conditions affecting the stock, such as habitat considerations. From 2008-2012, a multi-year habitat and species-mapping project was conducted on German Bank off South-West Nova Scotia in the Scallop Fishing Area (SFA) 29 West. From this project, bio-physical benthoscape habitat maps, and scallop species distribution maps were developed.

Combined with survey and geospatial fishery information, these maps have subsequently been used to: evaluate overlap between the fishery and benthic communities, improve the understanding of scallop population dynamics, develop a habitat based population model, develop biological reference points for fisheries management that incorporates habitat productivity, and operationalize environmentally conditioned science advice (Figure 1; Brown et al. 2012; Smith et al. 2015; Smith and Sameoto 2016; Smith et al. 2017). Accounting for spatial structure of biological processes, population productivity, and fishing patterns has been shown to improve the performance of stock indicators, models, and advice. The success of this project demonstrates the tremendous potential that habitat and species distribution mapping and modelling have to support new science commitments under Bill C-68.

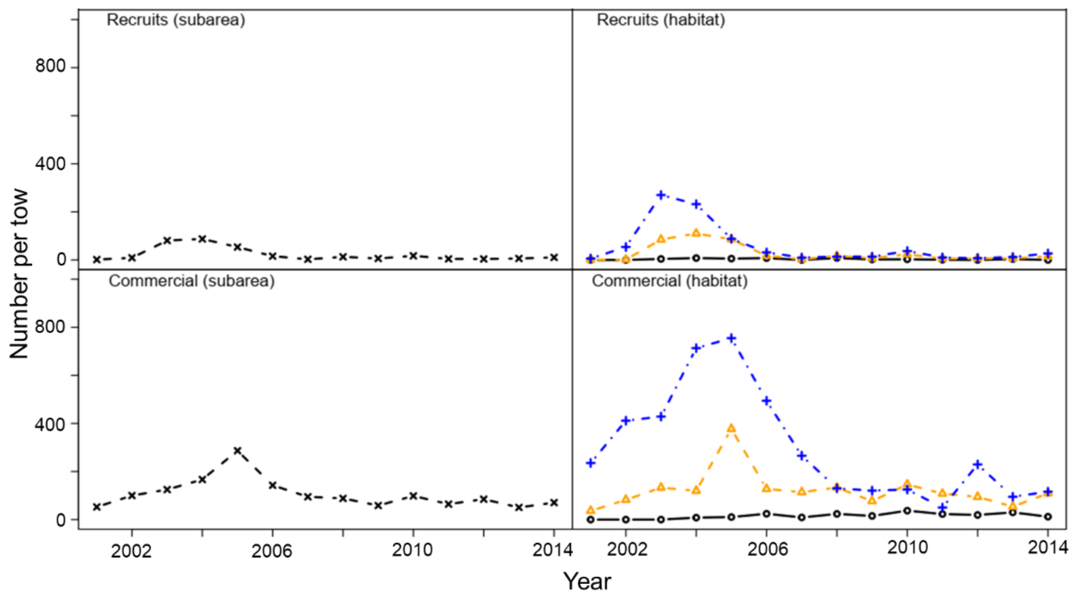

Figure 1. Survey mean number per tow for recruit size scallop (90-99 mm) and commercial size scallops (≥ 100 mm) for SFA 29W Subarea D. Left: Standard survey stratified mean for all of Subarea D. Right: Survey mean number for Low, Medium, and High areas of habitat suitability as defined by the habitat suitability probabilities (Smith et al. 2017).

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Hydrography to biology – Developing integrated approaches for benthic habitat mapping: Introduction and overview of the project

Craig J. Brown[1], Brittany Wilson[2], Myriam Lacharité[3], Ian Church[4], Ahmadreza Alleosfour[4], Vicki Gazzola[2]

[1]Dalhousie University, Halifax, NS
[2]Nova Scotia Community College, Dartmouth, NS
[3]University of Tasmania, Hobart, Australia
[4]University of New Brunswick, Fredericton, NB

The Bay of Fundy, adjacent to the Gulf of Maine, is a highly dynamic marine ecosystem known for its large tidal range and is of significant socio-economic importance to Atlantic Canada (Figure 2). Through a major multi-year research project (2017-2020), funded through Fisheries and Oceans Canada (DFO), and with support from the Full Bay Scallop Association, we have developed a spatially-explicit approach of combining geological seafloor mapping and high-resolution oceanographic variables, to characterize and map benthic ecosystems. A variety of thematic maps of the seafloor have been built using acoustic data from high-resolution multibeam (MBES) bathymetry and backscatter validated with extensive seafloor imagery and sediment samples. The thematic maps include broadscale benthoscape maps (i.e. benthic landscape maps displaying broad biophysical patterns of the seabed), and species-specific habitat maps for scallop, lobster, and horse mussels derived from species distribution modelling (SDM) approaches. The study adopted a multi-scale approach and has considered how down-scaled, modelled oceanographic variables can be utilized to improve our understanding of distribution patterns and habitat preferences of benthic fauna. The project objectives were to:

1) Ground-truth existing acoustic remotely sensed data by conducting a benthic imagery and sediment grab sampling survey of the entire Bay of Fundy (within the existing MBES coverage) using the NSCC-AORG survey infrastructure.
2) Develop methods to integrate down-scaled baroclinic ocean circulation and tidal current model simulations with MBES data into the habitat mapping methodology at fine spatial scale.
3) Develop a robust approach for habitat mapping over large geographical areas utilizing multi-source MBES data sets combined with ground truthed and modelled oceanographic data.
4) Within the context of the benthic mapping methodology (objective 3), evaluate seafloor classification systems that are currently in use around the world (e.g.

HMECS, EUNIS, etc.), and provide recommendation on the feasibility of adopting a standard classification scheme.

5) Develop customized map products (e.g. species habitat suitability maps, benthoscape maps, etc) for use by stakeholders and regulators to facilitate marine spatial planning, management and monitoring activities.

This presentation provided an overview and introduction to subsequent presentations in the forum.

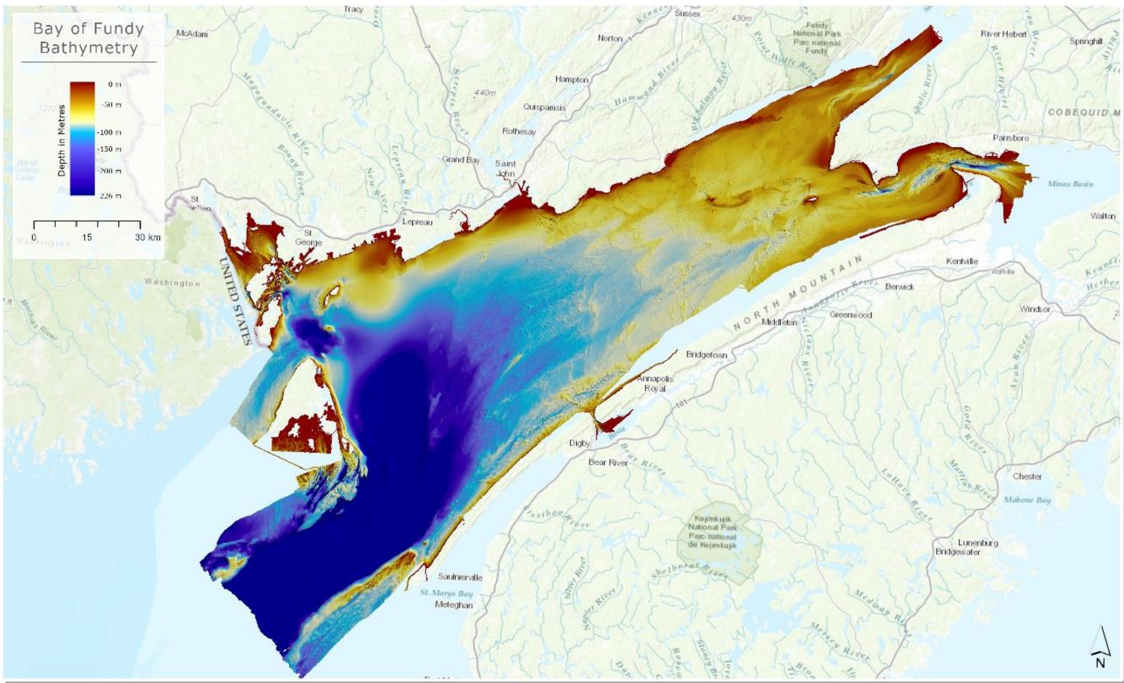

Figure 2. Bay of Fundy multibeam sonar data set used for the Hydrography to Biology project.

Multibeam Sonar data processing – dealing with multi-source backscatter data sets

Benjamin Misiuk[1], Craig J. Brown[2]

[1]Memorial University of Newfoundland, St. John’s, NL
[2]Dalhousie University, Halifax, NS

Sonar backscatter has become an essential tool for mapping benthic habitats. Because backscatter intensity depends on the composition of the seabed, it is one of the few indicators that can directly describe substrate characteristics – a fundamental component to benthic habitat. Despite its importance, a lack of standard calibration generally renders backscatter measurements relative to a given survey. The Bay of Fundy mapping dataset comprises data collected over a 15-year period by multiple survey platforms and sonar types (Hughes Clarke et al. 2008), and the non-comparability of these data limit their usefulness for predicting benthic habitats.

Recent advances in sonar data processing facilitate the development of novel approaches for handling disparate backscatter data. Here we present results from piloting a method for multi-source backscatter harmonization presented in Misiuk et al. (2020) that uses areas of mutual survey coverage to derive relative calibrations for different datasets. Preliminary results suggest that harmonizing backscatter data collected in the Bay of Fundy using a single sonar system over multiple surveys is entirely feasible (Figure 3). While harmonizing datasets collected using different systems is also feasible, care must be taken to consider the magnitude of difference between sonar operating frequencies. These results demonstrate the possibility of producing an updated harmonized backscatter mosaic for the entire Bay of Fundy, which will be undertaken as part of an upcoming habitat mapping project.

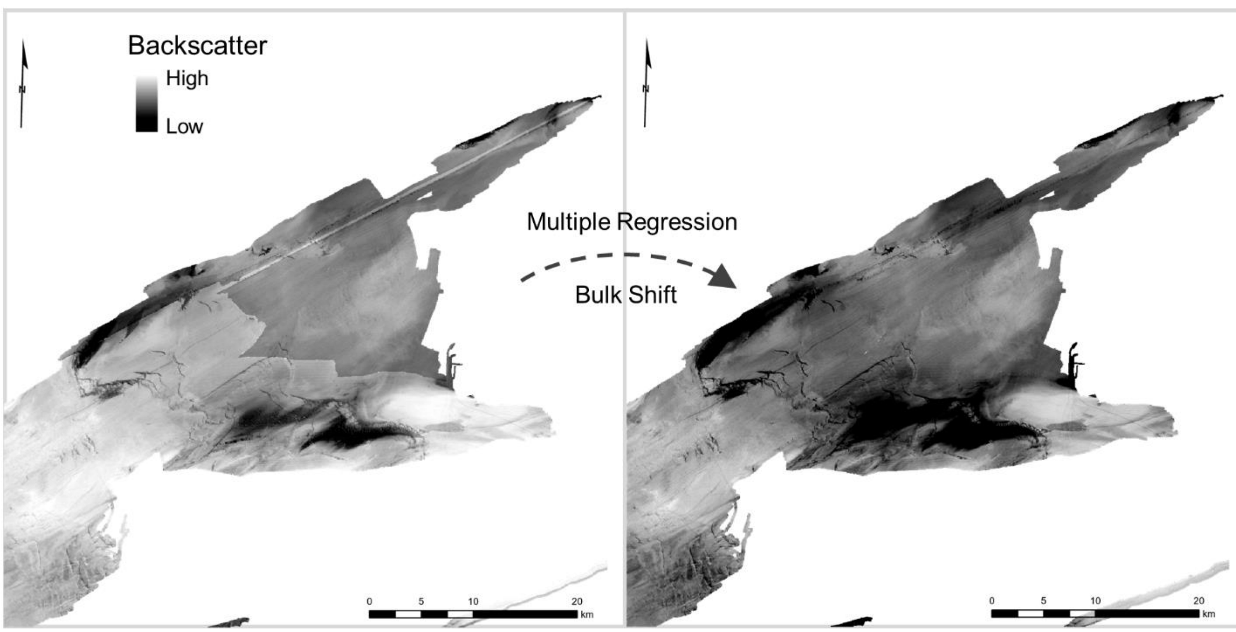

Figure 3. Results of a multiple regression bulk shift applied to CCGS Matthew backscatter data collected in 2008 and 2009.

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Hughes Clarke, J.E., Iwanowska, K.K., Parrott, R., Duffy, G., Lamplugh, M., and Griffin, J. 2008. Inter-calibrating multi-source, multi-platform backscatter data sets to assist in compiling regional sediment type maps: Bay of Fundy. Proceedings of the Canadian Hydrographic Conference and National Surveyors Conference 2008. 8-2, 22.

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Benthic marine debris in the Bay of Fundy: Spatial distribution and categorization using seafloor video footage

Alexa J. Goodman[1], Tony. R. Walker[1], **Craig J. Brown[1]**, Brittany R. Wilson[2], Vicki Gazzola[2], Jessica A. Sameoto[3]

[1]Dalhousie University, Halifax, Nova Scotia, NS
[2]Nova Scotia Community College, Dartmouth, NS
[3]Fisheries and Oceans Canada, Dartmouth, NS

Marine debris, particularly plastic and abandoned, lost and discarded fishing gear, is ubiquitous in marine environments. This study provides the first quantitative and qualitative assessment of benthic debris using seafloor video collected from a drop camera system in the Bay of Fundy, Eastern Canada. An estimated 137 debris items km^{-2} of seafloor were counted, comprising of plastic (51%), fishing gear (including plastic categories; 28%) and other (cable, metal, tires; 21%). Debris was widespread, but mainly located nearshore (within 9 km) and on the periphery of areas with high fishing intensity. This baseline benthic marine debris characterization and estimate of abundance (Figure 4) provides valuable information for government (municipal, provincial and federal) and for other stakeholders to implement management strategies to reduce plastic and other categories of benthic marine pollution at source. Strategies may include limiting plastic use and reducing illegal dumping through improved education among fishers.

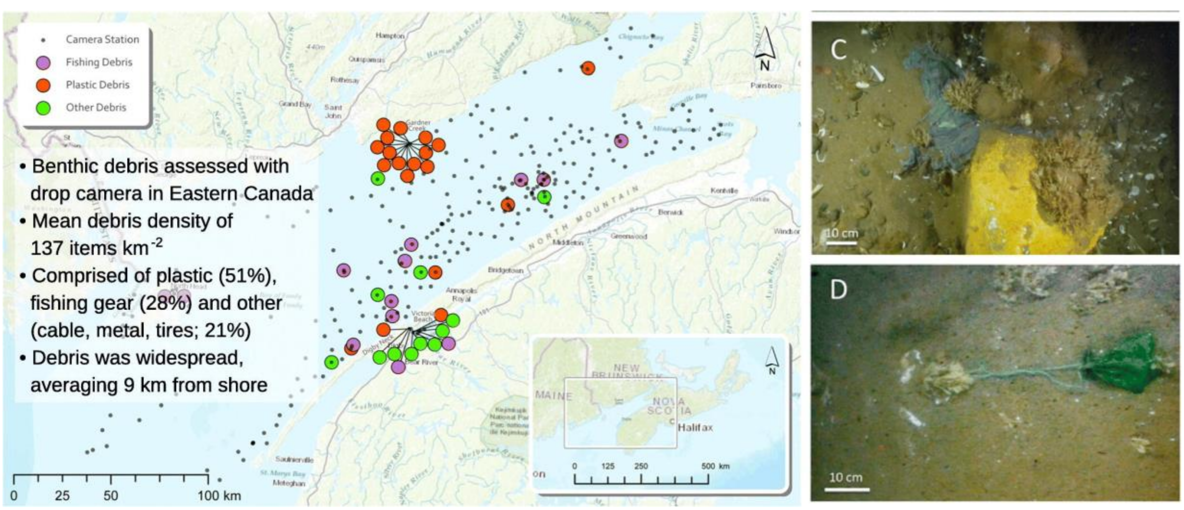

Figure 4. Baseline benthic marine debris characterization and abundance map (left); example images of benthic marine debris (right).

References

Goodman, A.J., Walker, T.R., Brown, C.J., Wilson, B.R., Gazzola, V., and Sameoto, J.A. 2020. Benthic marine debris in the Bay of Fundy, eastern Canada: Spatial distribution and categorization using seafloor video footage. Mar. Pollut. Bull. 150: 1-6.

Down-scaled oceanographic modelling in the Bay of Fundy

Ahmadreza Alleosfour[1], Ian Church[1]

[1]University of New Brunswick, Fredericton, NB

A high-resolution ocean model was run for the Bay of Fundy using the Finite-Volume Community Ocean Model (FVCOM), to provide physical oceanographic layers, such as temperature, salinity, and currents, for integration with habitat suitability models. Downscaling existing operational models to resolve oceanographic features at a similar resolution to the multibeam sonar bathymetry was the primary focus of the modelling effort. FVCOM was an appropriate choice for the Bay of Fundy simulation as a wetting and drying module is embedded in FVCOM that is beneficial for environments with extensive tidal range. It also uses an unstructured grid to resolve the geometry and constraints of a complex coastline. The model was run in barotropic and baroclinic mode for two months in 2018 (July and August) to be consistent with the timing of project fieldwork. The horizontal resolution ranges from 6 km to 9.5 m in open boundary and two high-resolution spots in the middle of the Bay, respectively, and 40 sigma layers in the vertical coordinate. The open boundary forcing is river water level and temperature for the upper part of Saint John River, and tidal elevation, temperature, and salinity for the open boundary adjacent to the Gulf of Maine. Temperature and salinity from a regional operational model were used for the model initialization. The model results were analyzed against observed and archive CTD measurements and published tidal constituents to evaluate regional open boundary forcing and internal model parameters, such as bottom drag coefficients. The model is able to reproduce the oceanography of the Bay, including tidal amplitude and phase, gyre locations, and the freshwater discharge plume of the Saint John River. The model is also able to simulate the downscaled high-resolution bathymetric features to observe the effects on the currents speed and direction (Figure 5).

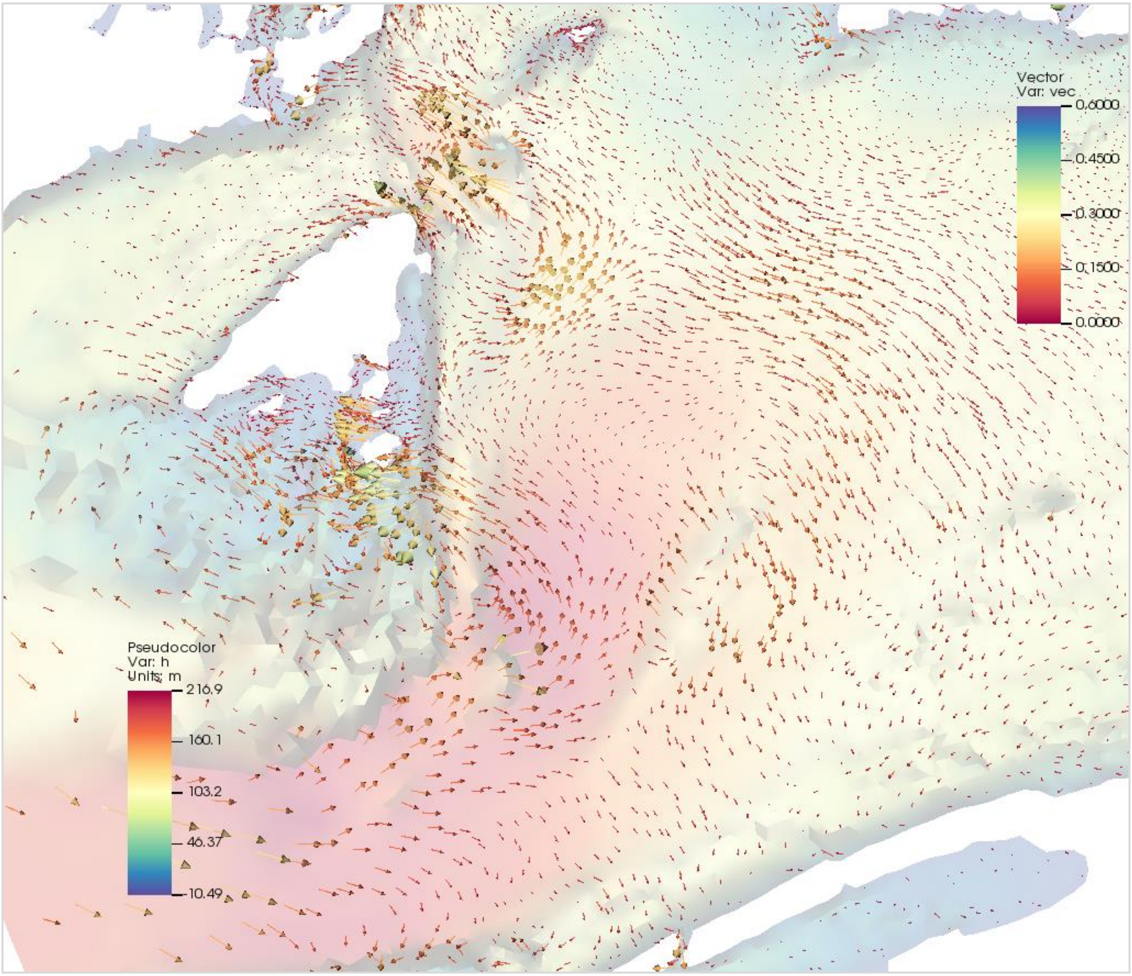

Figure 5. Tidally averaged residual seafloor currents at the entrance to the Bay of Fundy.

Benthoscape mapping in the Bay of Fundy

Craig J. Brown[1], Brittany Wilson[2], Myriam Lacharité[3], Vicki Gazzola[2]

[1]Dalhousie University, Halifax, NS
[2]Nova Scotia Community College, Dartmouth, NS
[3]University of Tasmania, Hobart, Australia

The Bay of Fundy, adjacent to the Gulf of Maine, is a highly dynamic marine ecosystem known for its large tidal range and is of significant socio-economic importance to Atlantic Canada. We have applied a spatially-explicit approach of combining seafloor acoustic remote sensing data sets, *in situ* ground validation data, and high-resolution trends in modelled oceanographic variables, to characterize and map benthoscapes in the Bay of Fundy. A benthoscape can be defined as “the minimum mapping unit (grain) at which distinctive bio-physical characteristics can be identified and objectively delineated based on continuous, remotely sensed environmental data sets from a study area" (Brown et al. 2012). Multibeam echosounder (MBES) bathymetry, derived geomorphology (e.g. seabed slope, curvature and benthic position index), MBES backscatter, and modelled wave current shear velocity (all gridded at 50 m horizontal resolution) were compiled to form the underlying continuous, remotely sensed environmental data layers. An object-based image analysis (OBIA) segmentation was produced using the 50-m gridded bathymetry and backscatter, which was used for all subsequent classification/map production stages.

Seafloor biophysical characteristics were determined from georeferenced still images extracted from 281 camera stations collected in the Bay of Fundy between 2017-2019. Each image was analysed for abundance or percent cover of benthic fauna and substrate characteristics. Images were also classified into seven benthoscape classes describing the broad substrate/biotic characteristics: Bedrock and boulders; Mixed sediments; Tidal scoured mixed sediments; Silty gravel with anemones; Gravelly sand; Sand; and Silt. A fuzzy c-means unsupervised classification process was used to classify the suite of continuous environmental data layers based on the OBIA segmentation, resulting in 14 classes. The fuzzy c-means classifications was spatially compared, grouped and condensed based on best match with the seven benthoscape class, with an overall accuracy of 71% and a kappa statistic of 0.60 (preliminary benthoscape map, Figure 6). Faunal patterns were compared using multivariate statistical methods to assess how benthic community patterns related to benthoscape classes. Ongoing analysis is evaluating the utility of four other international classification schemes. Once finalized, the output maps will be of value for marine spatial planning, fisheries management, and conservation planning in the Bay of Fundy.

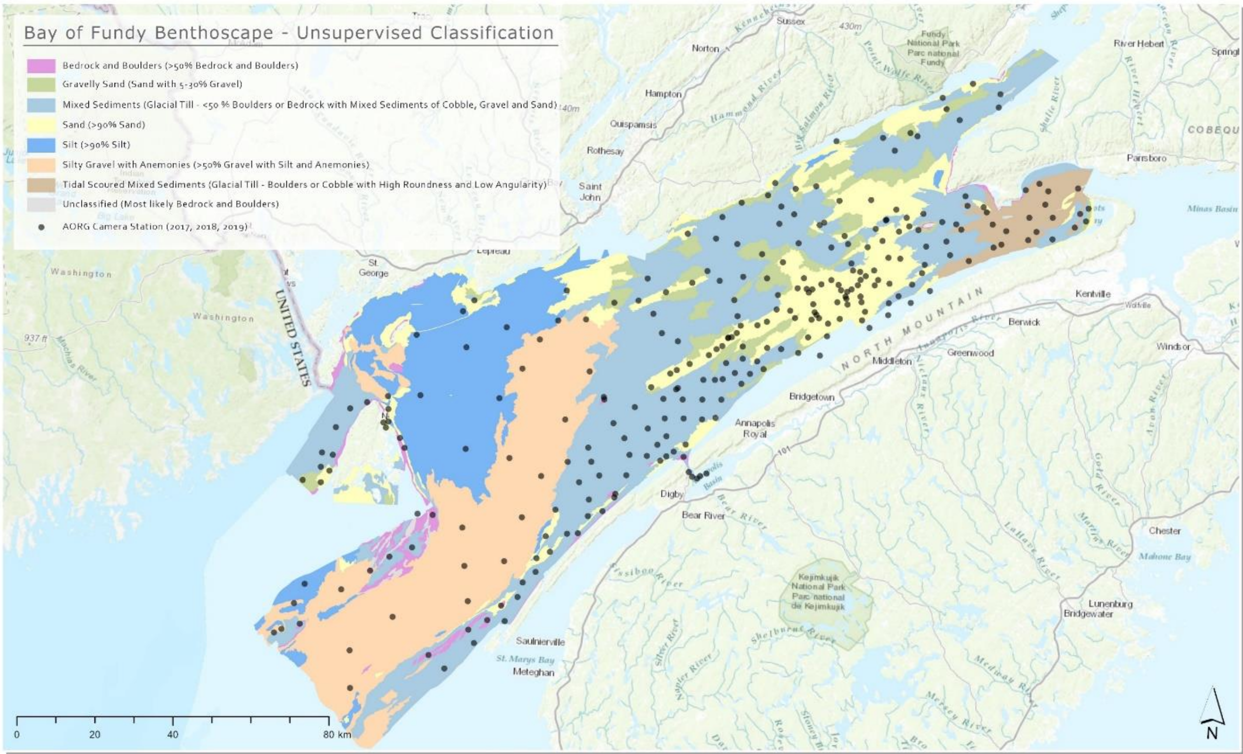

Figure 6. Preliminary Benthoscape Map, Bay of Fundy.

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Bay of Fundy Horse Mussel EBSA: Demographic changes over 20 years

Jessica A. Sameoto[1], Kelly Hall[1,2], Susan Gass[2], David Keith[1], Stephane Kirchhoff[3], Craig J. Brown[2]

[1]Fisheries and Oceans Canada, Dartmouth, NS
[2]Dalhousie University, Halifax, NS
[3]Nova Scotia Community College, Dartmouth, NS

Although the horse mussel *Modiolus modiolus* is present throughout coastal areas of the Bay of Fundy region, dense aggregations of horse mussels are more limited. Significant aggregations have been identified within the inner Bay of Fundy and this area has been identified as an Ecologically and Biologically Significant Area (EBSA; Buzeta 2014). However, basic demographic information on this population is limited. For effective conservation and management strategies to be developed, an understanding of basic population processes and life-history traits is first required. The objective of this study was to characterize the population structure of horse mussels in the Bay of Fundy and to assess change in key demographic characteristics since the last sampling effort in this area in 1997 and 1998 (Wildish et al. 1998). Results show that the current population (2017) is comprised of much larger, older, mature individuals, with significantly more females than in 1997/1998 (Figure 7). In 1997/1998, the median valve length of horse mussels was 62 mm, corresponding to 7.5 years of age, whereas in 2017 the median length was 113 mm, corresponding to 15 years. Length at 50% maturity was 39.8 mm and the first documented evidence of a hermaphrodite in this population was observed. Patterns of shell damage and subsequent repair consistent with incidental damage from heavy fishing gear was observed in 1.7% of the population. Consistent with other *M. modiolus* populations worldwide, this population demonstrates life history traits that would make recovery from incidental fishing impacts difficult, with low recruitment to the mature population and slow growth.

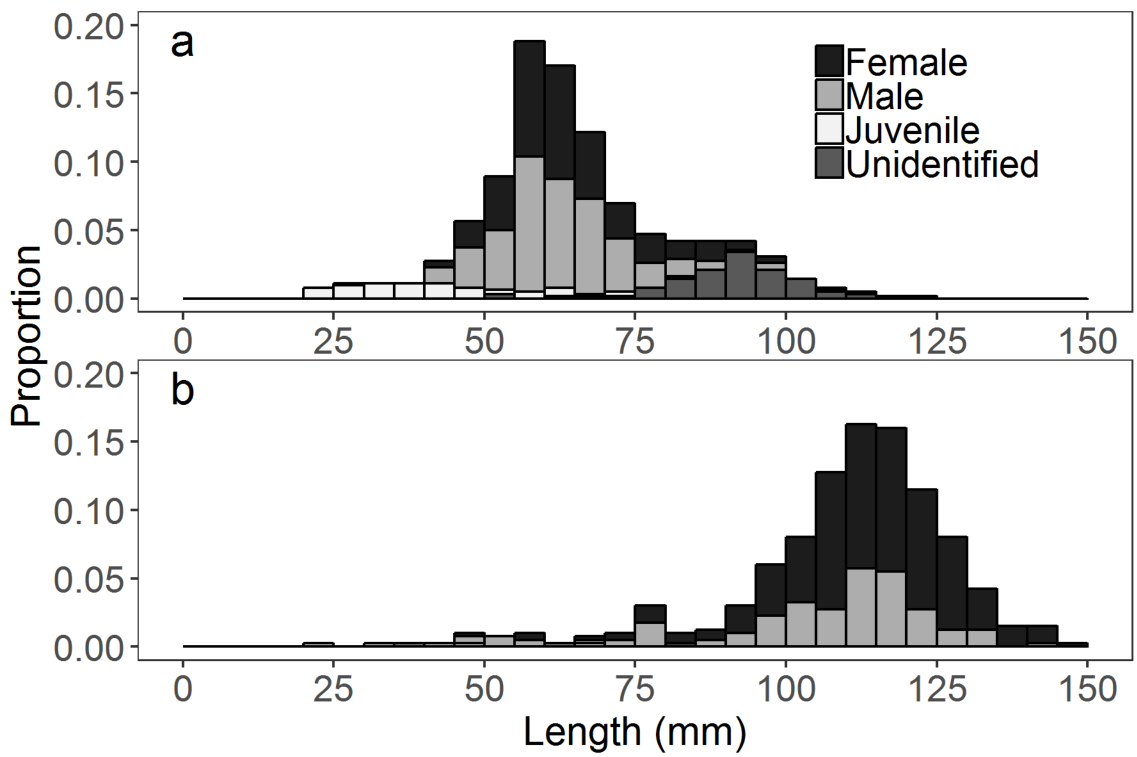

Figure 7. Length frequency of valves, proportional to the population, of live horse mussels from the Bay of Fundy in 1998 (a) and 2017 (b) as a function of sex. Bin width = 5 mm.

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Mapping horse mussel biogenic habitat in the Bay of Fundy

Brittany Wilson[1], Craig J. Brown[2], Anna M. Redden[3], Myriam Lacharité[4], Jessica A. Sameoto[5]

[1]Nova Scotia Community College, Dartmouth, NS
[2]Dalhousie University, Halifax, NS
[3]Acadia University, Wolfville, NS
[4]University of Tasmania, Hobart, Australia
[5]Fisheries and Oceans Canada, Dartmouth, NS

Dense aggregations of horse mussels exist in the Bay of Fundy and are thought to be associated with high biodiversity compared to surrounding habitats. Previous research show correlations between these aggregations and long narrow flow-parallel bedforms. In this study, MaxEnt was used to map habitat suitability at multiple scales in the area surrounding the bedforms. Habitat suitability was best measured at a 10-m spatial scale and not all flow-parallel bedforms were found to be suitable habitat (Figure 8). These findings suggest, in contrast to previous studies, that not all bedforms contain horse mussel aggregations. Seafloor images were compared to multibeam echosounder layers to further investigate community patterns and biodiversity. Community patterns shifted gradually across the bedforms and surrounding areas, the abundance of horse mussel was significantly greater on the bedforms and no significant differences in biodiversity were found. These findings will ultimately facilitate decisions around marine spatial planning and protection of these habitats.

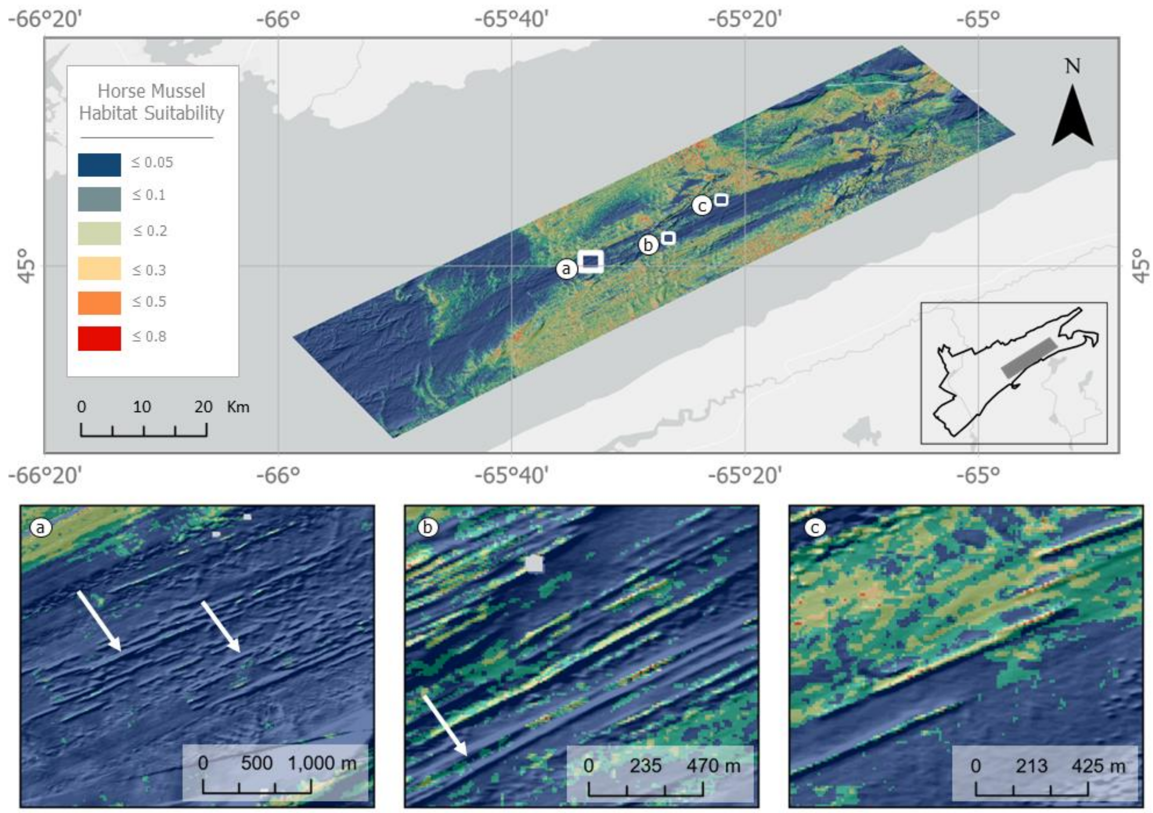

Figure 8. Horse mussel habitat suitability model at 10-m spatial scale. Some flow parallel bedforms within areas of low suitability are predicting high suitability (e.g. B), and a number of flow-parallel bedforms are predicting low suitability (e.g. A, C) (white arrows are indicating flow-parallel bedforms predicting low suitability).

Species distribution modelling for scallop and lobster in the Bay of Fundy

Brittany Wilson[1], Craig J. Brown[2], Vicki Gazzola[1], Myriam Lacharité[3], Jessica A. Sameoto[4]

[1]Nova Scotia Community College, Dartmouth, NS
[2]Dalhousie University, Halifax, NS
[3]University of Tasmania, Hobart, Australia
[4]Fisheries and Oceans Canada, Dartmouth, NS

Utilization of multibeam echosounder (MBES) data and *in situ* video data can produce various thematic maps. Species-specific maps were developed in the Bay of Fundy using species distribution modelling techniques. By incorporating presence locations and underlying environmental variables derived from MBES data, these maps effectively represent a species realized niche (one that incorporates abiotic conditions (e.g. substrate type, temperature, salinity) and biotic factors (e.g. predation, recruitment, competition)). MaxEnt was used to develop preliminary distribution maps of Sea Scallop (*Placopecten magellanicus*) and American Lobster (*Homarus americanus*) in the Bay of Fundy using MBES data, oceanographic variables, and presence locations acquired from video data (Figures 9 and 10). The scallop data produced a fair model (AUC > 0.7) with depth and wave shear stress contributing most to the prediction. The lobster data produced a good model (AUC > 0.8) with depth, slope, and sediment mobility frequency contributing the most to the model. Both preliminary models can be considered useful in predicting the distribution of scallop and lobster in the Bay of Fundy. These preliminary models demonstrate the applicability of species-specific maps in facilitating marine spatial planning and fisheries management decisions.

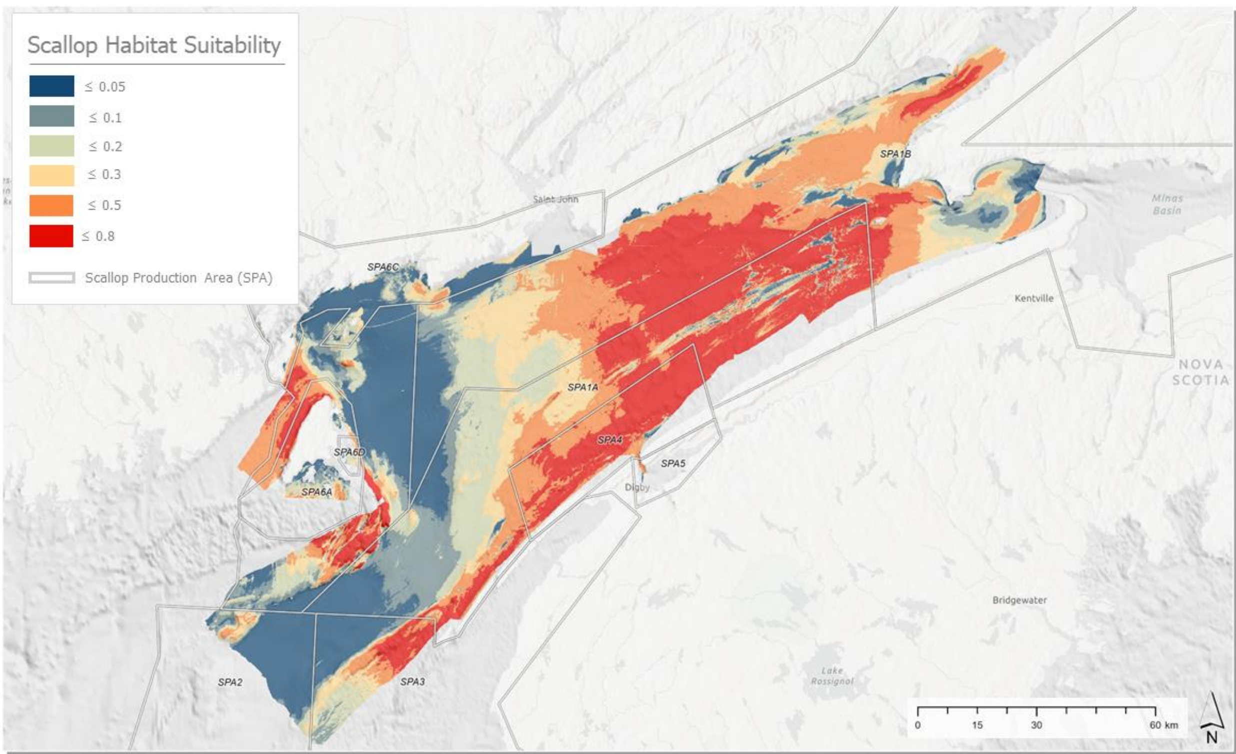

Figure 9. Species distribution model (indicating habitat suitability) for Sea Scallop in the Bay of Fundy. Models were produced with Maximum Entropy (MaxEnt) using MBES data, oceanographic parameters and presence data acquired through in-situ video data.

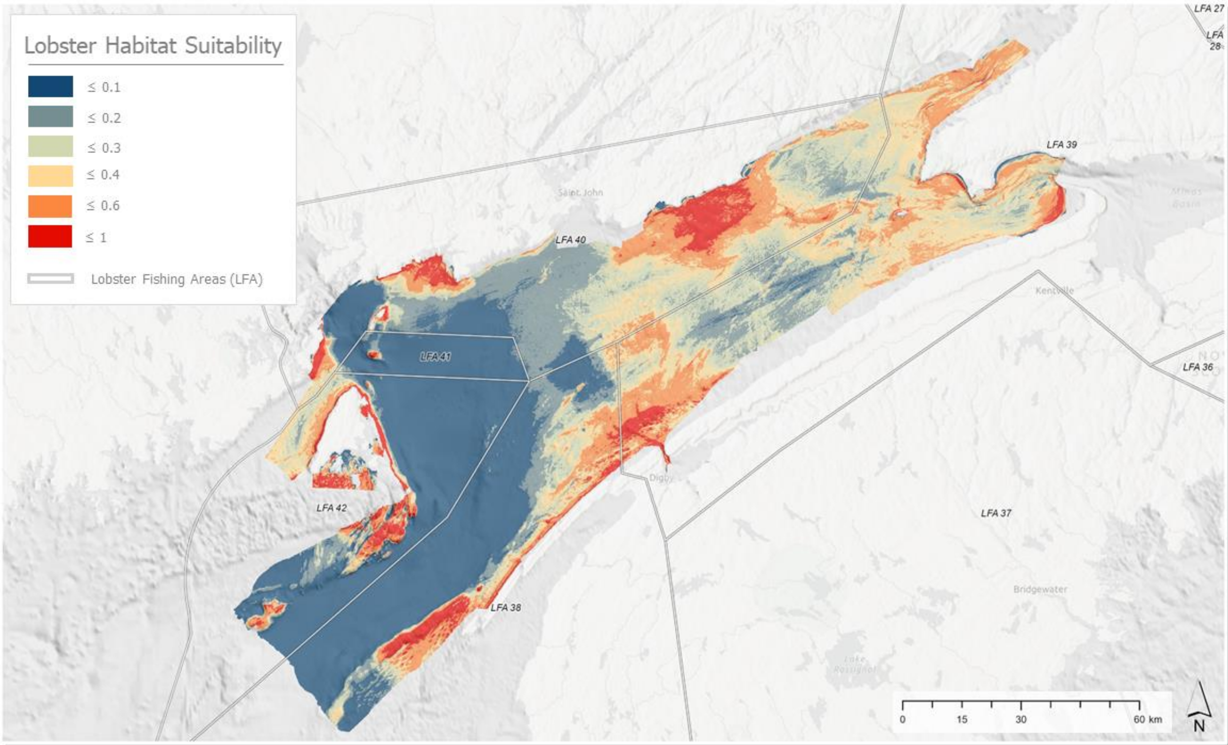

Figure 10. Species distribution model (indicating habitat suitability) for American Lobster in the Bay of Fundy. Models were produced with Maximum Entropy (MaxEnt) using MBES data, oceanographic parameters and presence data acquired through in-situ video data.

II. OCEAN FRONTIER INSTITUTE (OFI) PHASE 2 PROJECT – Benthic Ecosystem Mapping and Engagement (BEcoME)

Next steps: OFI BEcoME project overview

Craig J. Brown[1], Katleen Robert[2]

[1]Dalhousie University, Halifax, NS
[2]Memorial University of Newfoundland, St. John's, NL

In the Northwest Atlantic (NWA), marine ecosystems have been identified as particularly vulnerable to pressure from rapid changes in ocean parameters driven by climate shifts due to the region's important effect on the Atlantic Meridional Overturning Circulation (AMOC) and to its significant role in ocean uptake of anthropogenic CO_2. Climate-induced change on the range and distribution patterns of benthic fauna are expected, but precise prediction on how these changes will occur, or the underlying abiotic and biotic drivers of change, are mostly unknown. When faced with warming temperatures, studies have shown that many species are likely to exhibit poleward range shifts. However, the role that availability of suitable benthic habitat plays in this process is largely unknown due to a scarcity of available seafloor mapping data. This is a critical gap in almost every study to date examining climate impacts on benthic faunal distributions.

To address this knowledge gap, a major, multi-year research program will commence in 2020, funded through the Ocean Frontier Institute (OFI): The BEcoME project – Benthic Ecosystem Mapping and Engagement. Through a series of inter-connected, cross-disciplinary work-packages, the BEcoME project will address what role benthic habitat plays in controlling shifting patterns in species and biodiversity caused by a changing ocean climate. This will be examined across spatial scales, from: 1) broad-scale geomorphology mapping over the entire NWA (Figure 11), to; 2) fine-scale surficial geology and benthic habitat mapping using innovative technologies over local case study areas. Strong cross-institutional collaborations will be fostered with industry, government, non-profit and academic project partners. The project will align with a major industry-led seafloor mapping initiative in the region (OceanVision – led by Kraken Robotics). In the next 3 years, OceanVision aims to map 5,000 km^2 of ocean floor using innovative technologies at targeted locations in the NWA. Compiling these geospatial data sets will amass extremely large volumes of data, and the BEcoME project will therefore explore innovative big data analytical approaches for seafloor habitat mapping. The project will also work with indigenous and community groups to examine the role that Local Ecological Knowledge, Traditional Knowledge, and Citizen Science can play in generating seafloor habitat information and maps against which climate-induced shifting patterns of species distribution can be determined. Results from all these research activities will be operationalized through continued engagement with industry, government and community end-users to determine when, how and where seafloor maps can facilitate sustainable ocean stewardship. This presentation provided an overview of this new project.

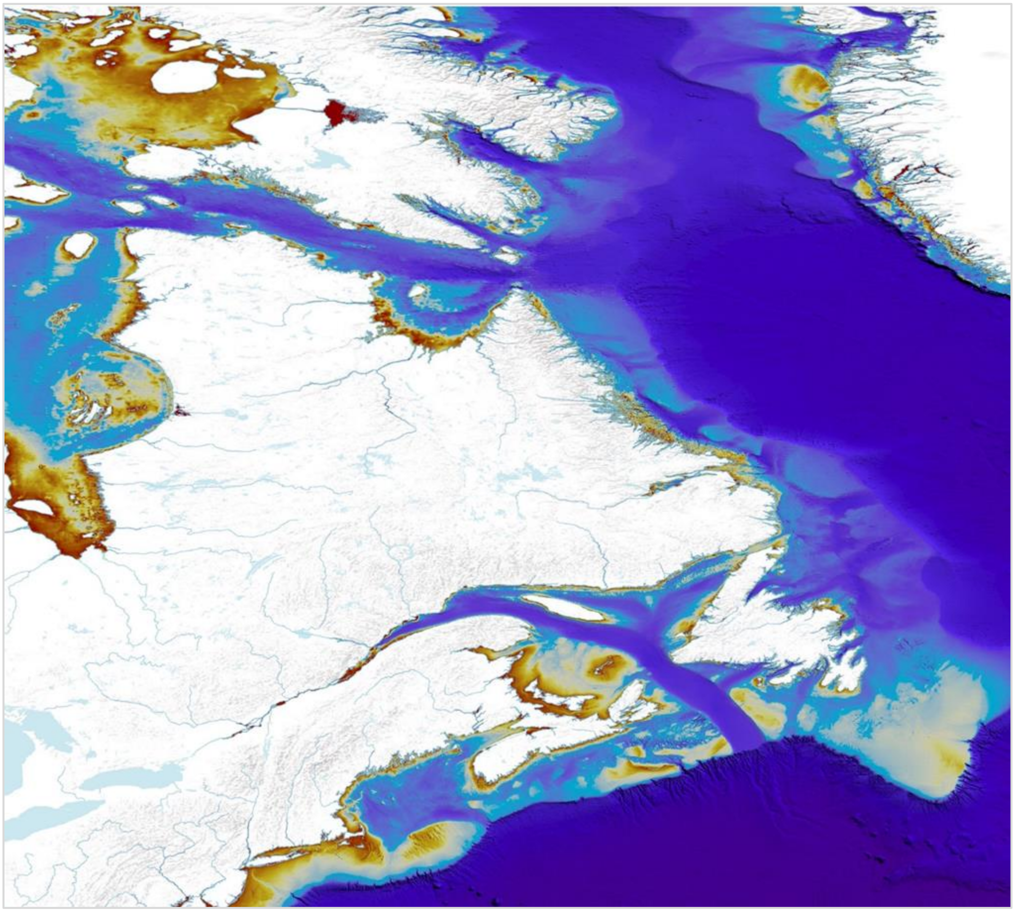

Figure 11. Bathymetric data in the Northwest Atlantic, which will be the geographical study area for the BEcoME project.

III. DISCUSSION

Facilitated by **David Keith**[1]

[1]Fisheries and Oceans Canada, Dartmouth, NS

The goal of this discussion session was to identify potential opportunities to operationalize, further develop, and/or build upon the data products and results from the *"Hydrography to Biology"* project. DFO Science's mandate in the Maritimes Region covers five main themes: Marine Spatial Planning (MSP), assessment and mitigation of ecosystem stressors, adaptation to a changing environment, population and ecosystem assessment, and safe navigation and emergency response. Discussions were guided based on these themes.

Mapping products are integral to MSP to support a data-driven and systematic approach to ocean planning. The MSP process being led at DFO brings together relevant authorities and stakeholders to better coordinate how we use and manage marine spaces to achieve ecological, economic, and social objectives. Identifying reliable data products, data sources and gaps, such as the ones identified in this forum, is an important step in MSP. Eventually, the Marine Spatial Data Infrastructure (MSDI) will host an online Atlantic Canada-wide atlas of data and information to support MSP. Coastal data are a major gap and therefore a priority under MSP. There is interest in collating data for the Minas Basin area, as well as other "Areas of Interest" such as the Fundian Channel. Data products, demonstrated at this forum are valuable to MSP processes and are directly relevant for informing Oceans Management decision making. In particular, benthoscape maps are very helpful to guide planning at the regional scale. These products can help inform on representative habitats in relation to MPA planning and inform finer scale planning (e.g. EBSA or MPA delineation). It was acknowledged that maps are very useful for stakeholder consultations.

From a population and ecosystem assessment perspective, spatial data products are needed to identify core habitat. Historically, methods have averaged across productivity domains, but identifying core habitat areas and areas of differing habitat productivity has significant potential to improve assessment advice. However, a challenge is how to operationalize and incorporate these spatial products and processes into stock assessment models and stock assessment processes. With the implementation of Bill C-68, there will be a renewed focus on developing stock assessments that support an Ecosystem Approach to Fisheries Management (EAFM). Incorporating spatial dynamics into the science advice process would help fulfil requirements for Bill C-68 as these data products will directly facilitate the incorporation of environmental and climate variables into science advice.

Suggestions were made to strategically scope out priorities and objectives to build on, and leverage, the data products and research produced by this project. It was suggested that the approach used in SFA 29W could be adapted for other stock assessments. The same process could be followed for scallop and potentially for lobster assessments in the Bay of Fundy, with the next step being the incorporation of oceanographic variables to address fishery dynamics and biological change over time. It was noted that scallop are particularly convenient for these research questions since they are sedentary; however, similar research on Halibut (*Hippoglossus hippoglosus*) to identify core habitat areas has also been successful. There is also a precedent for using vessel monitoring system data as a proxy for habitat, but currently, this tends to only work well for sedentary species and in fisheries with management approaches that do not lead to biased fishing dynamics (e.g. Nasmith et al. 2016, DFO 2018).

It was suggested that, with the data products now available, the Bay of Fundy may be a good location to conduct an ecosystem assessment. A spatial ecosystem model could be developed that mechanistically links with global ocean models so that management questions could be explored. Questions of connectivity in the Grand Manan region relative to larval lobster dispersal may be an interesting next step; it will be crucial to start linking the oceanographic patterns to biological patterns. In order to capitalize on the momentum of the Bay of Fundy project, there is also a need for good data stewardship and management, and this would require resources and coordination with existing data management committees. There are also anticipated benefits to the fishing industry as these spatial mapping products could benefit the industry by improving their efficiency and lowering their impact on the seafloor (e.g. reduce bycatch, benthic impacts). Seafloor mapping can also improve safety-at-sea by reducing the probability fishing will occur in unsuitable bottom, thus minimizing gear hook ups, and damaged and/or lost gear.

Within DFO Maritimes Region, the Cumulative Effects research group is addressing questions around the assessment and mitigation of ecosystem stressors and cumulative impacts. The spatial data products produced by this project would be of use as data inputs into future analyses related to better understanding stressors and their effects, and pathways of effects. Further, it was noted that characterizing and quantifying marine debris in the Bay of Fundy is of importance to benthic community health since these plastics are known to break down and can be ingested by organisms. Research on the impacts of microplastics is ongoing. There was discussion about the possibility of using oceanographic models (such as those presented by A. Alleosfour and I. Church) to predict the distribution and movement of marine debris within the Bay of Fundy, as well as whether there may be opportunities to explore the movement of debris between the marine and terrestrial environment.

On the theme of adaptation to a changing environment, various projects have identified, and are attempting to identify, current habitat associations, and potential future change. Discussion included the potential opportunity to predict future refugia based on current habitat conditions and climate change models, including having data products from this project inform potential changes in Right Whale distribution in the Bay of Fundy by linking the physical oceanography to prey fields (e.g. *Calanus* distribution). In many other areas, the challenge in conducting research to inform adaptation to a changing climate is a lack of fit-for-purpose data; there is hope that the OFI project will help fill these gaps.

There was discussion about this work supporting improved delineation of the horse mussel Ecologically and Biologically Significant Area and continued monitoring of the horse mussel biogenic habitat in order to detect potential habitat change. This developed into a discussion on identifying sentinel sites for monitoring that could be representative of a wide range of habitats, which could then inform Marine Spatial Planning and Oceans Management planning. Habitat mapping products, like those presented at this forum, could help inform the selection of appropriate sentinel sites for future monitoring and how to monitor different types of habitats; taking into consideration which factors are likely to change and how they are expected to change. It was noted that biology is often a good indicator of shifts.

Finally, with regard to the theme of navigational safety and emergency response planning, the products and outcomes from this project related to St. John Harbour are particularly relevant. There are potential linkages with the Oceans Protection Plan that could be considered further.

References

DFO. 2018. Stock Status Update for Arctic Surfclam (*Mactropmeris polynyma*) on Banquereau and Grand Bank. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/046

Nasmith, L., Sameoto, J., and Glass, A. 2016. Scallop Production Areas in the Bay of Fundy: Stock Status for 2015 and Forecast for 2016. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/021. vi + 140 p.

SUMMARY

The "Bay of Fundy Seafloor Mapping Forum" enabled results from the *"Hydrography to biology: Developing integrated approaches for benthic habitat mapping"* project to be disseminated to government and academic stakeholders in an open and effective manner. Participation included academic researchers, students, government scientists, hydrographers, resource managers, and science managers. Presentations related to the project covered applications of habitat maps and species distribution models and how they can improve fisheries assessment and management, multibeam backscatter processing, down-scaled oceanographic modelling, horse mussel demographics, mapping biogenic habitat of horse mussels, benthoscape mapping, species distribution modelling for scallop and lobster, and quantification and mapping of benthic debris.

Although the development of a pollution baseline from this project was not initially intended as one of the aims, reducing plastic waste, marine litter and plastic pollution recently emerged as a priority for the Government of Canada; and in particular, combating ghost fishing gear[1]. The *"Hydrography to biology*" habitat mapping project was able to be leveraged in response to this emerging priority and provided the first quantitative and qualitative assessment of benthic debris using seafloor video collected from a drop camera system in the Bay of Fundy, Eastern Canada. This baseline of benthic marine debris and estimate of debris abundance provides valuable information for multiple levels of government and for other stakeholders to implement management strategies to reduce plastic and other categories of benthic marine pollution at source, and further demonstrates the wide ranging benefit that benthic habitat mapping studies can provide.

Although the Bay of Fundy habitat mapping project has finished, its results will be further leveraged in future benthic habitat research by the newly funded OFI Phase 2 – BEcoME project, led by Craig Brown of Dalhousie University and Katleen Robert of Memorial University. This 4-year international research initiative (2020-2023) will address what role benthic habitat plays in controlling shifting patterns in species and biodiversity caused by a changing ocean climate across multiple scales and includes a number of DFO researchers as part of the project team.

The facilitated discussion on how the research produced from the Bay of Fundy project could be operationalized within DFO identified clear linkages to DFO Science's Maritime Regions main themes. Numerous linkages and potential opportunities to further leverage and operationalize the data products and research results from this project were identified. To conclude, this interdisciplinary research project has resulted in numerous research results and data products that are relevant to DFO and the broader science community.

[1] https://dfo-mpo.gc.ca/campaign-campagne/oceans/index-eng.html

Appendix 1. Attendee List

Table A1. List of participants who attended the Bay of Fundy Seafloor Mapping Forum on March 13, 2020.

Participant	***Affiliation***
Craig Brown*	DAL Department of Oceanography
Brittany Wilson*	NSCC Applied Ocean Mapping Research Group
Vicki Gazzola*	NSCC Applied Ocean Mapping Research Group
Ben Misiuk*	MUN Fisheries and Marine Institute
Ian Church*	UNB Ocean Mapping Group
Ahmadreza Alleosfour*	UNB Ocean Mapping Group
Jessica Sameoto*	DFO Science
David Keith*	DFO Science
Ross McKinnon*	DFO Science
Raphael McDonald	DAL Canadian Statistical Science Institute
Javier Guijarro-Sabaniel	DFO Science
Michel Therrien	DFO Canadian Hydrographic Service
Anna Serdynska	DFO Oceans Management Program
Elise Will	DFO Oceans Management Program
Marty King	DFO Oceans Management Program
Tanya Koropatnick	DFO Oceans Management Program
Alida Bundy	DFO Science
Jamie Tam	DFO Science
Alan Reeves	DFO Policy and Economics
Adam Cook	DFO Science
Victoria Howse	DFO Science
Lei Harris	DFO Science
Nancy Shackell	DFO Science
Sheila Prall-Dillman	DFO Policy and Economics
Freya Keyser	DFO Science
Tricia PearoDrew	DFO Science
Kelly Hall	DFO Science
Darlene Smith	DFO Science
Kent Smedbol	DFO Science
Leslie Nasmith	DFO Science
Alex Normandeau	NRCAN
Brian Todd	NRCAN

*Denotes project team member.

Appendix 2. Forum Agenda

Hydrography to biology: Developing integrated approaches for benthic habitat mapping

DFO Partnership Project: Bay of Fundy Seafloor Mapping Forum

Date: Friday, 13th March 2020
Location: King Boardroom, Bedford Institute of Oceanography
Link to agenda on Google Drive

8:45 – 9:00 am: Arrive and coffee

9:00 – 9:10 am: Convene workshop – Introductions

9:10 – 9:20 am: The need for seafloor habitat maps: fisheries assessment and management (Jessica Sameoto)

9:20 – 9:40 am: Hydrography to biology - Developing integrated approaches for benthic habitat mapping: Introduction and overview of the project (Craig Brown)

9:40 – 10:00 am: Multibeam Sonar data processing – dealing with multi-source backscatter data sets (Ben Misiuk)

10:00 – 10:20 am: Benthic marine debris in the Bay of Fundy: Spatial distribution and categorization using seafloor video footage (Tony Walker)

10:20 – 10:40 am: Down-scaled oceanographic modelling in the Bay of Fundy (Ian Church/Ahmadreza Alleosfour)

10:40 – 11:00 am: Coffee (to be provided)

11:00 – 11:20 am: Benthoscape mapping in the Bay of Fundy (Craig Brown)

11:20 – 11:40 am: Bay of Fundy Horse Mussel EBSA: Demographic changes over 20 years (Jessica Sameoto)

11:40 am – 12:00 pm: Flow parallel bedforms and horse mussel modelling/biodiversity (Brittany Wilson)

12:00 am – 1:00 pm: Lunch (to be provided)

1:00 pm – 1:20 pm: Species distribution modelling for scallop and lobster in the Bay of Fundy (Brittany Wilson)

1:20 pm – 1:50 pm: Next steps: OFI BEcoME project overview (Craig Brown)

1:50 pm – 3:00 pm: Facilitated Group Discussion: How does DFO leverage the BoF project results? Next steps? (David Keith)

3:00 pm: Close of meeting