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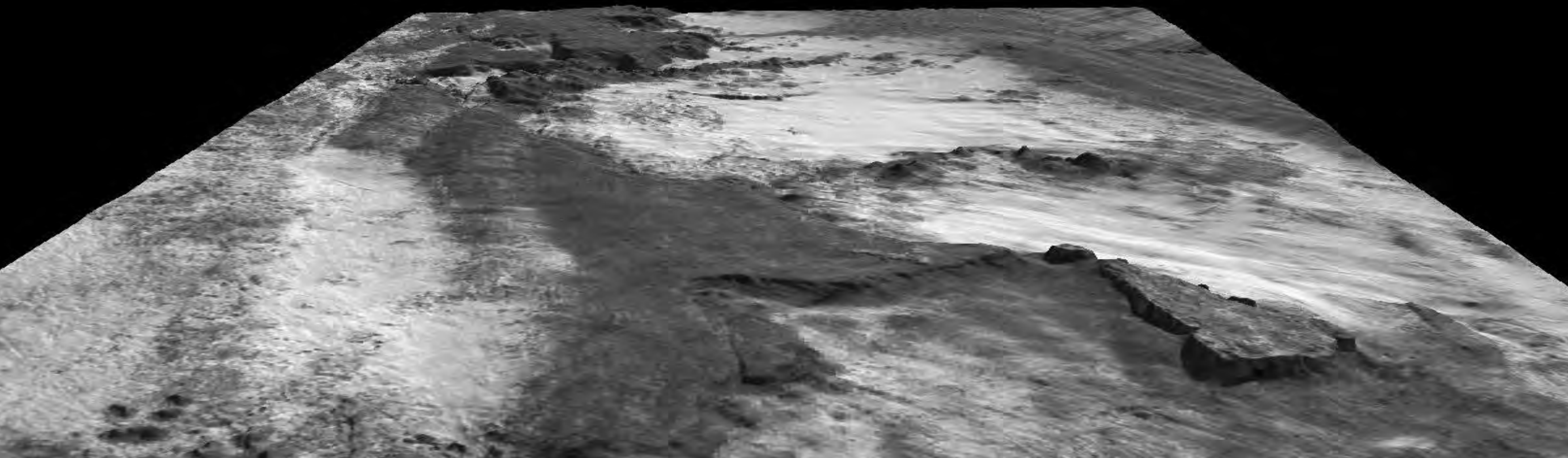
SEAM
Seascape Ecology & Mapping Lab

Advanced processing and applications using multibeam sonar backscatter

Craig J. Brown PhD

Department of Oceanography, Dalhousie University, Halifax, Nova Scotia
craig.brown@dal.ca

28th October 2021



Presentation overview

- o Introduction: Adding spatial context to ecological study of the ocean floor…the importance of backscatter?
- o Multibeam backscatter basics – a technology walk-through
- o Evolution of backscatter processing and classification methods
- o Dealing with legacy, multisource backscatter for seafloor geological and benthic habitat mapping mapping
- o Multispectral backscatter
- o Future research

What is seafloor habitat mapping?


Estuarine, Coastal and Shelf Science 92 (2011) 502–520

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

ELSEVIER

Benthic habitat mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques

Craig J. Brown[a,b,*], Stephen J. Smith[a], Peter Lawton[c], John T. Anderson[d]

[a] Fisheries and Oceans Canada, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS B2Y 4A2, Canada
[b] Canadian Hydrographic Service, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS B2Y 4A2, Canada
[c] Fisheries and Oceans Canada, St. Andrews Biological Station, 531 Brandy Cove, St. Andrews, NB E5B 2L9, Canada
[d] Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, PO Box 5667, St. John's, NF A1C 5X1, Canada

ARTICLE INFO

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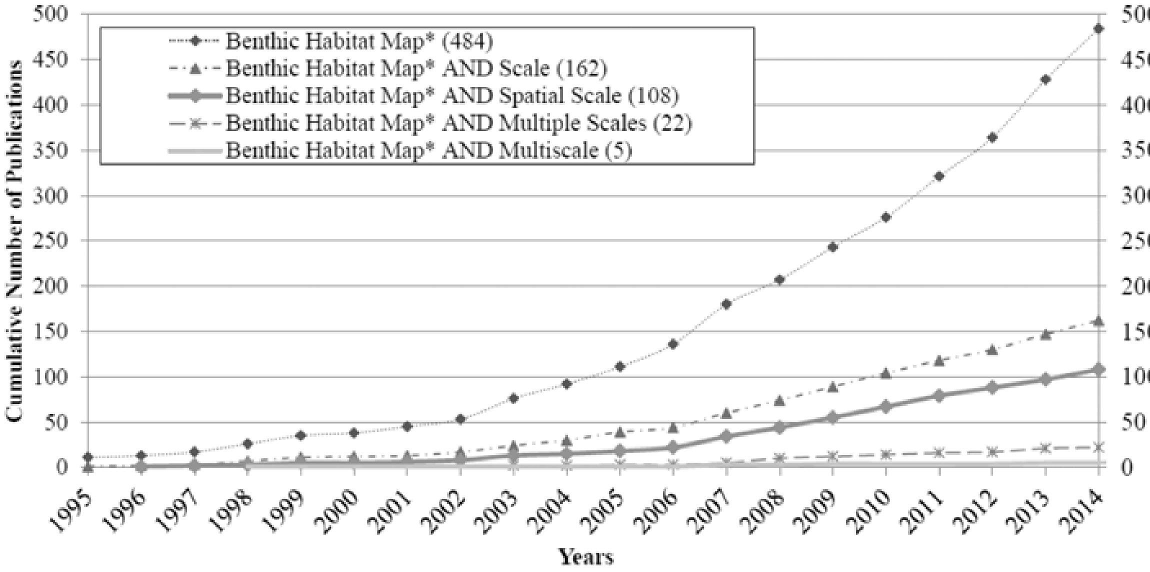
ABSTRACT

This review examines the various strategies and methods used to produce benthic habitat maps using acoustic remote sensing techniques, coupled with *in situ* sampling. The applications of three acoustic survey techniques are examined in detail: single-beam acoustic ground discrimination systems, sidescan sonar systems, and multi-beam echo sounders. Over the past decade we have witnessed the nascence of the field



"The use of spatially continuous environmental data sets to represent and predict biological patterns on the seafloor (in a continuous or discontinuous manner)".

Brown et al. (2011) *Estuarine Coastal and Shelf Science* 92 (3): 502-520

Lucieer et al. (2018) *Mar Geophys Res.* 39: 23-40

Seafloor “Landscapes” = “Benthoscapes”


Journal of Sea Research 72 (2012) 1–13

Contents lists available at SciVerse ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

Multiple methods, maps, and management applications: Purpose made seafloor maps in support of ocean management

Craig J. Brown [a,b,*], Jessica A. Sameoto [a], Stephen J. Smith [a]

[a] Fisheries and Oceans Canada, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2
[b] Canadian Hydrographic Service, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2

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ABSTRACT

The establishment of multibeam echosounders (MBES) as a mainstream tool in ocean mapping has facilitated integrative approaches toward nautical charting, benthic habitat mapping, and seafloor geotechnical surveys. The inherent bathymetric and backscatter information generated by MBES enables marine scientists to present highly accurate bathymetric data with a spatial resolution closely matching that of terrestrial mapping. Furthermore, developments in data collection and processing of MBES backscatter, combined with

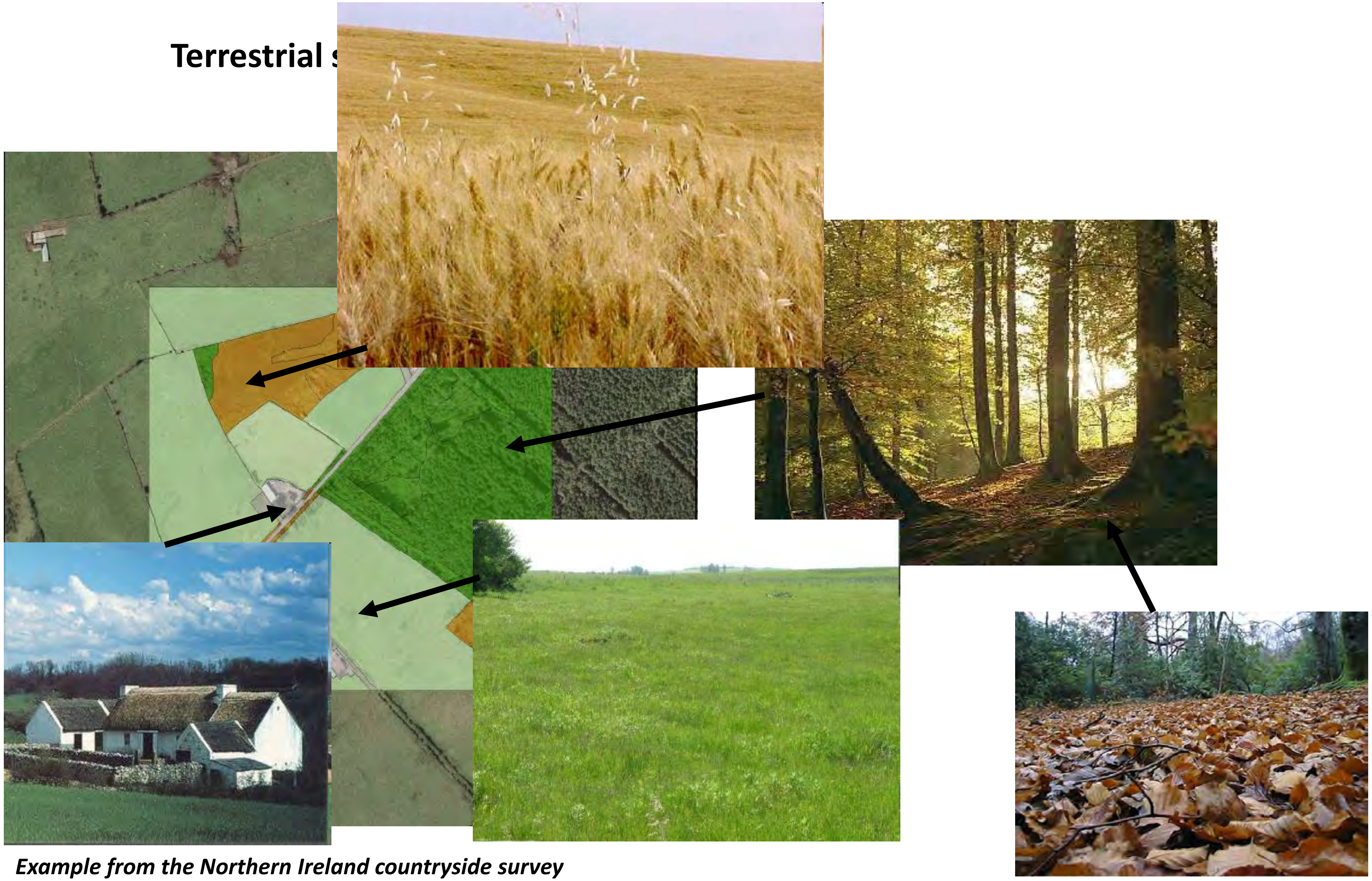
Working definition of the term *“Benthoscape”* : *“The minimum mapping unit (grain) at which distinctive bio-physical characteristics can be identified and objectively delineated based on continuous, remotely sensed environmental data sets from a study area”.*

Brown et al. (2012) Multiple methods, maps, and management applications: Purpose made seafloor maps in support of ocean management. *Journal of Sea Resaerch* (72): 1-13. doi:10.1016/j.seares.2012.04.009

The “Benthoscape” approach

(spatial ecology – a landscape-scale approach)

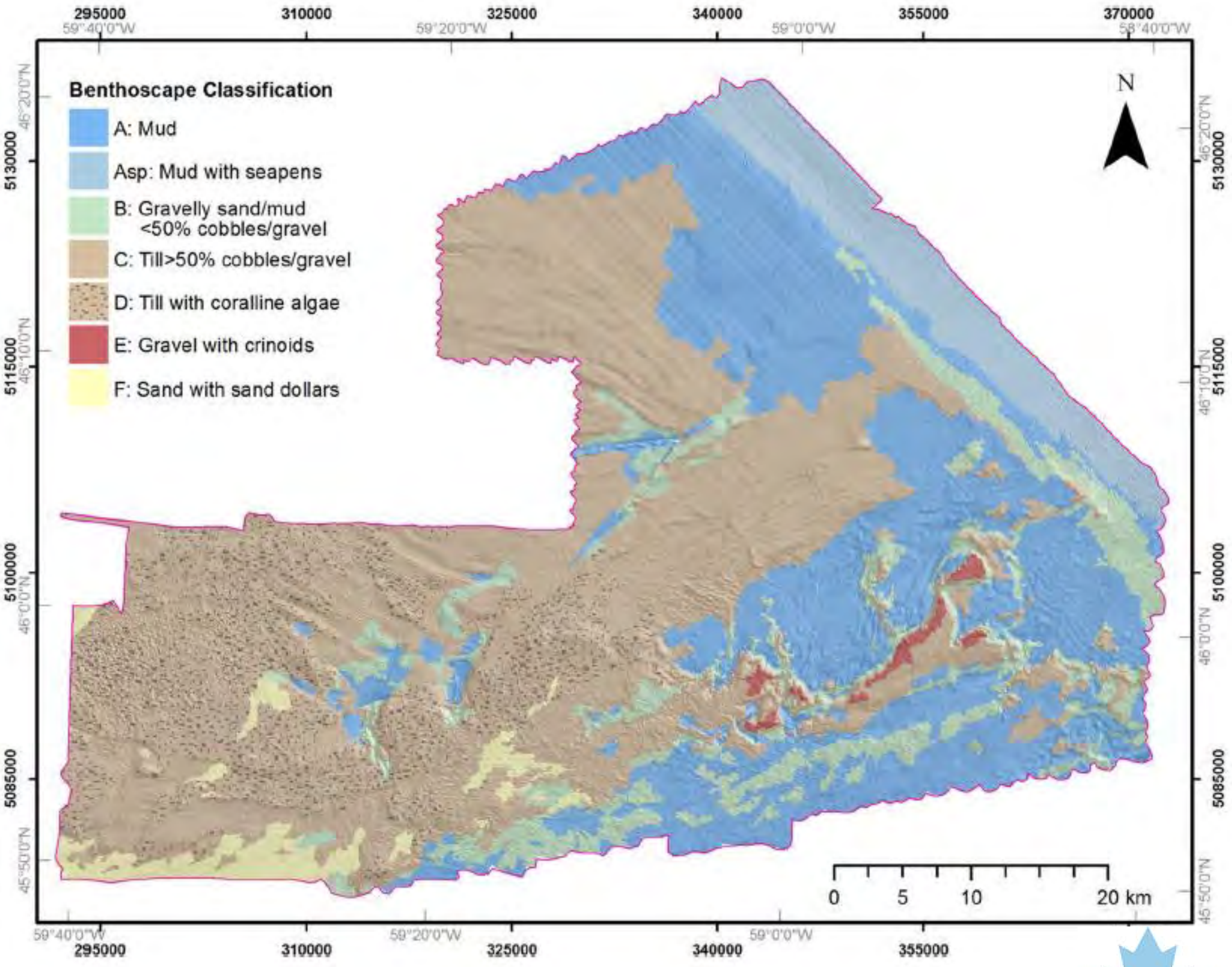
Terrestrial s



Example from the Northern Ireland countryside survey

Ecology…spatial context is everything

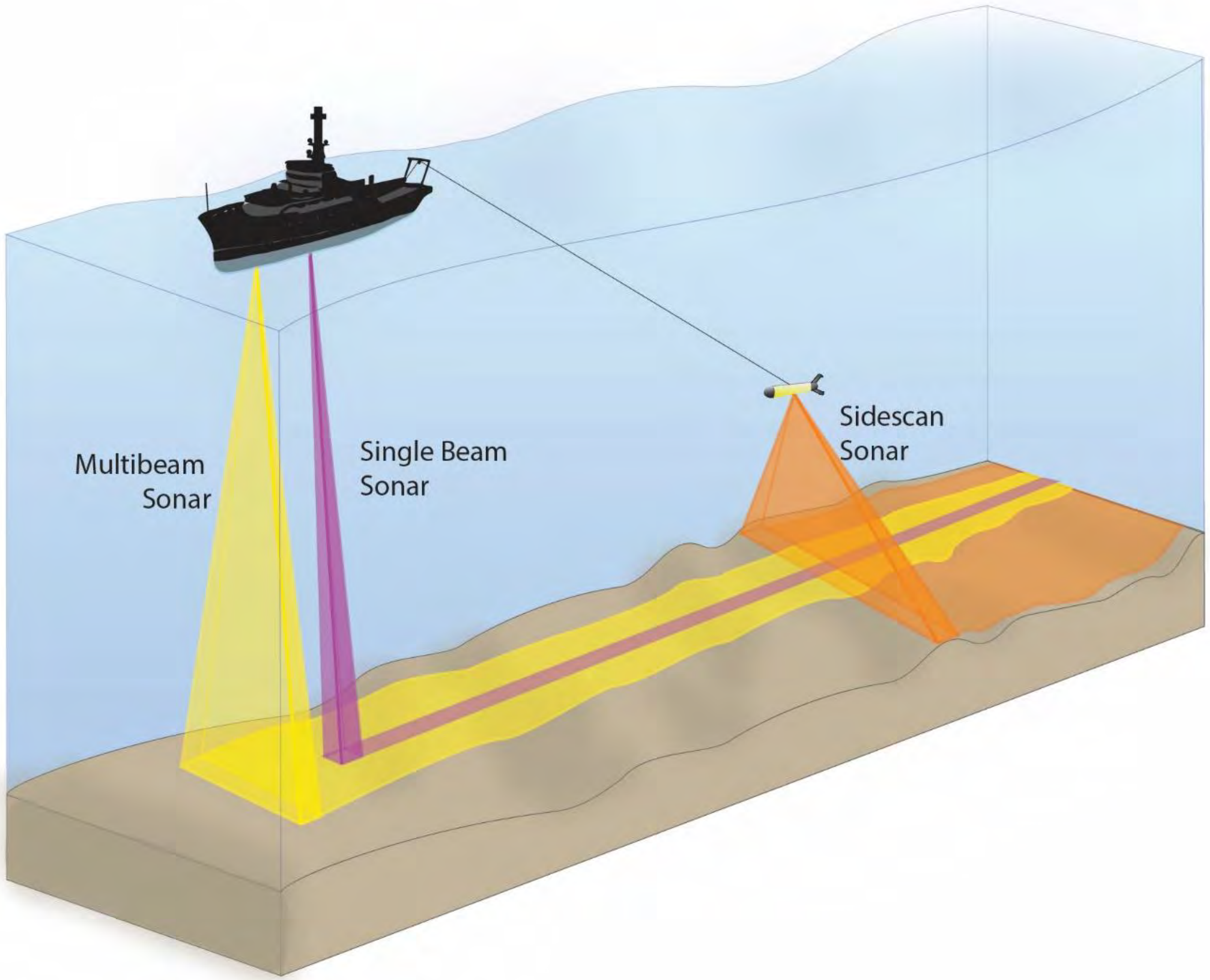
Example: Seafloor habitat map – St Anns Bank MPA



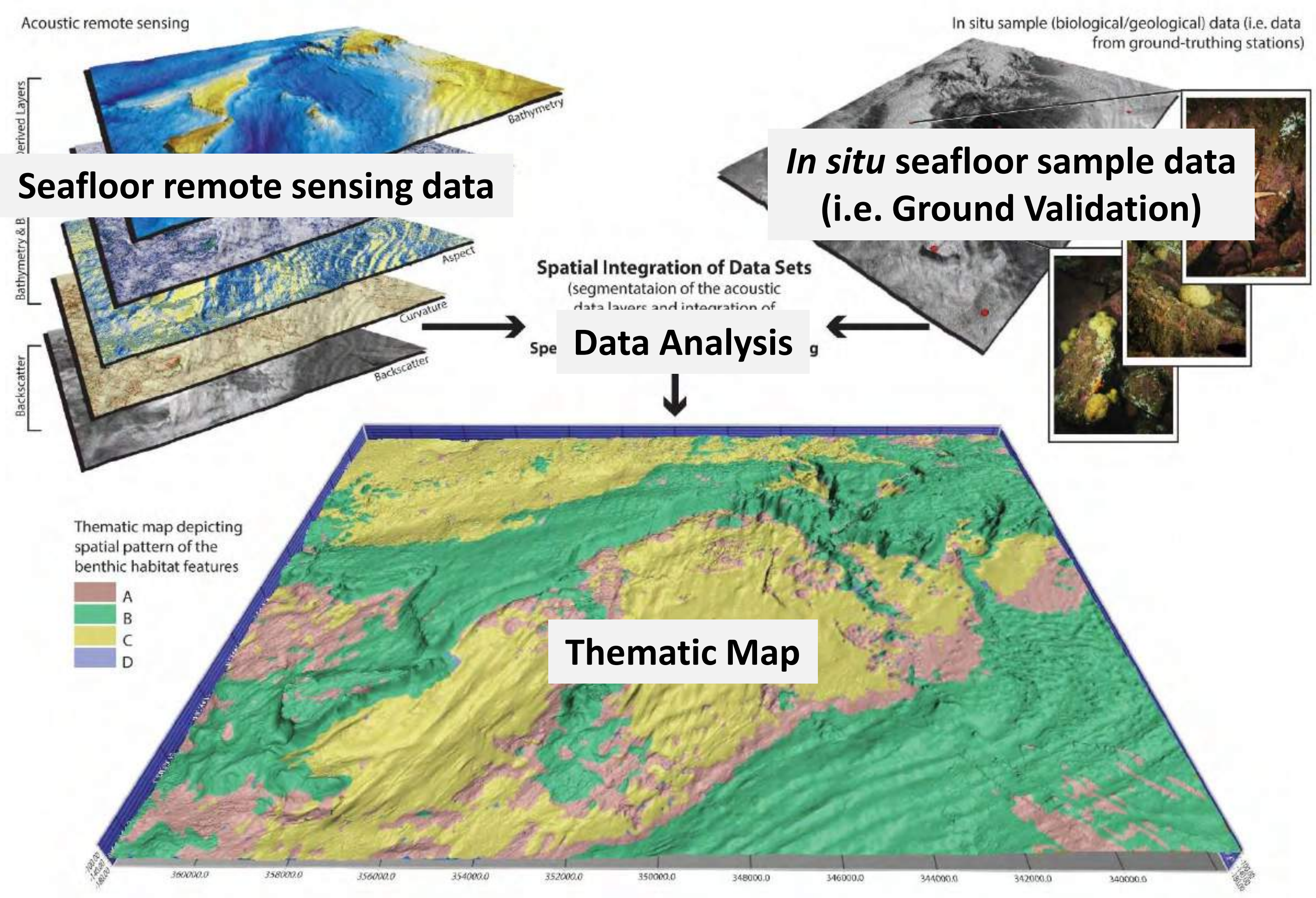
Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

CHONe
CANADIAN HEALTHY OCEANS NETWORK

Acoustic Survey Techniques



Seafloor Habitat Mapping: Generalized approach…

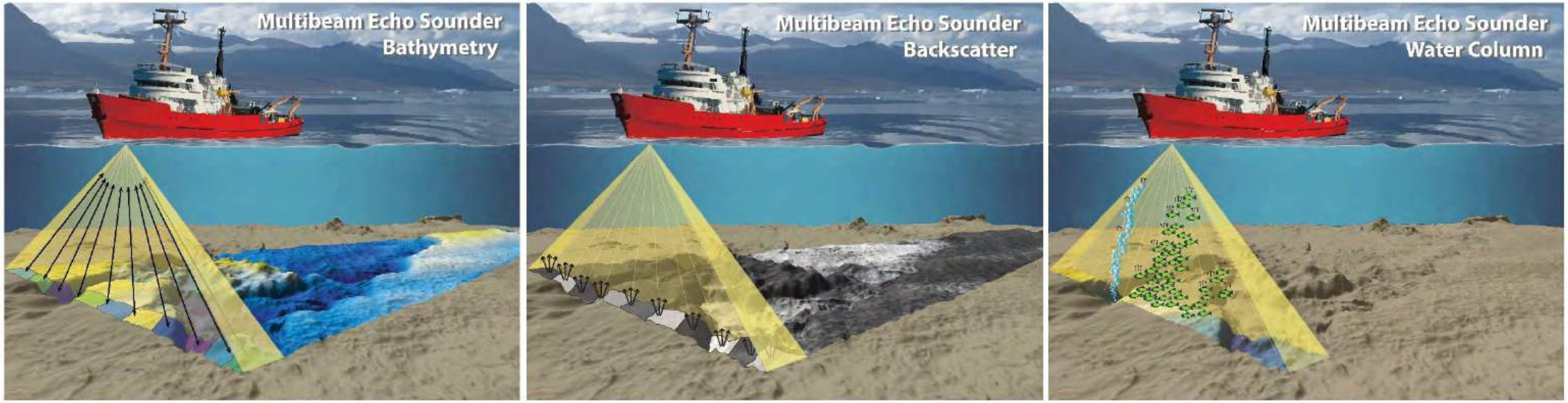


APPLICATIONS:
Marine Spatial Planning

- Nautical Charting
- Geology & Geomorphology
- Marine Protected Area
- Fisheries Management
- Oil and Gas
- Aquaculture
- Etc….

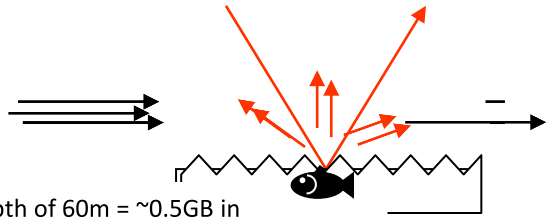
Brown et al. (2011) Benthic Habitat Mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques. *Estuarine Coastal and Shelf Science* 92 (3): 502-520

Multibeam Echosounders

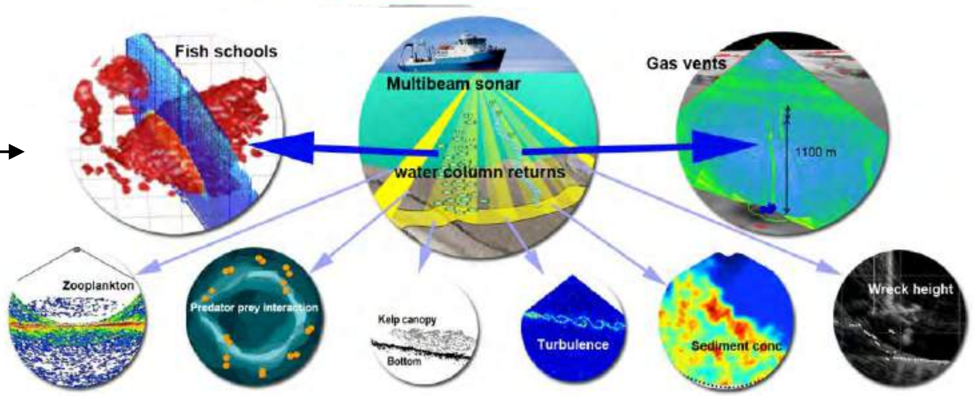


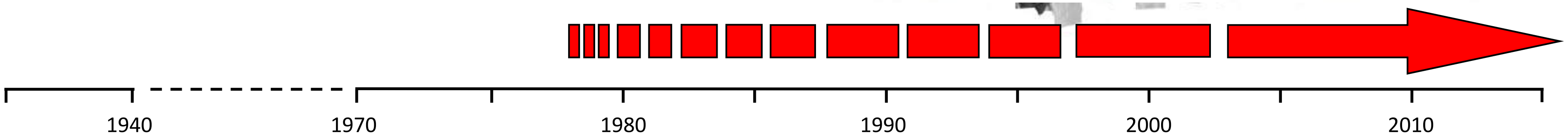
Multibeam Sonar Surveys

Watercolumn



2 square kilometers at a depth of 60m = ~0.5GB in bathymetry data. With watercolumn = ~3GB or more
6x increases data volume





Multibeam Echosounders - Backscatter

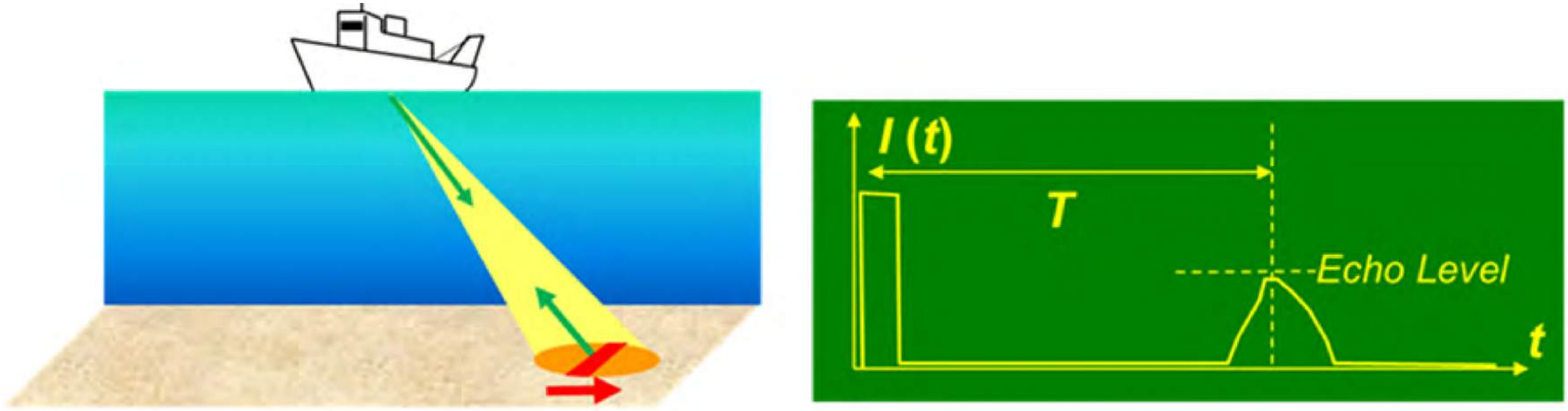
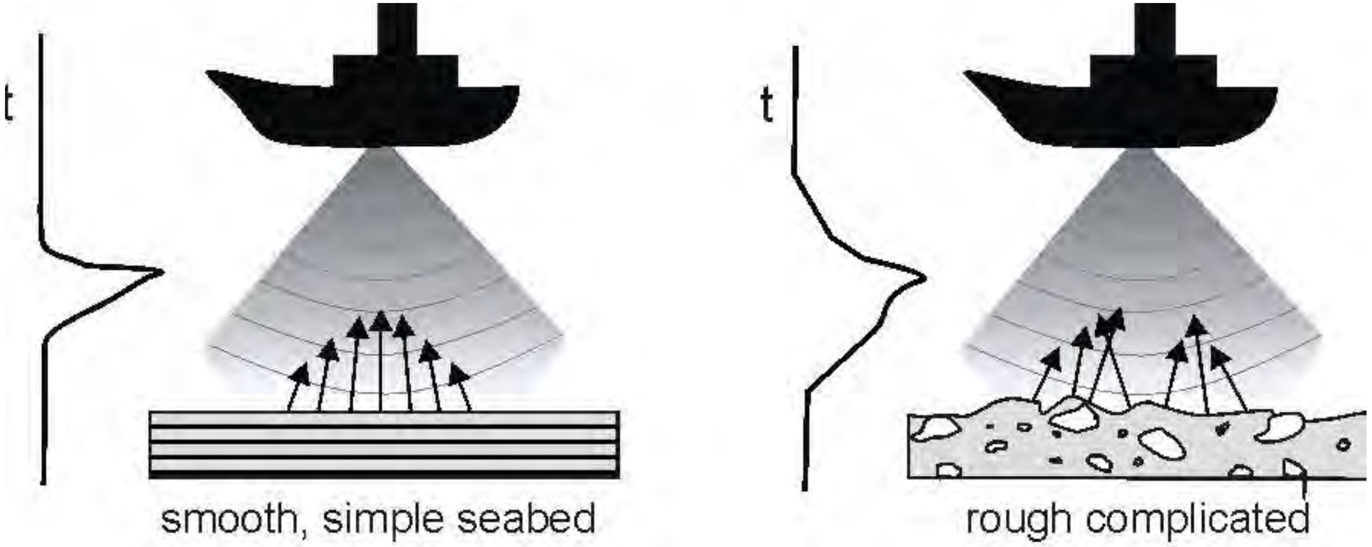
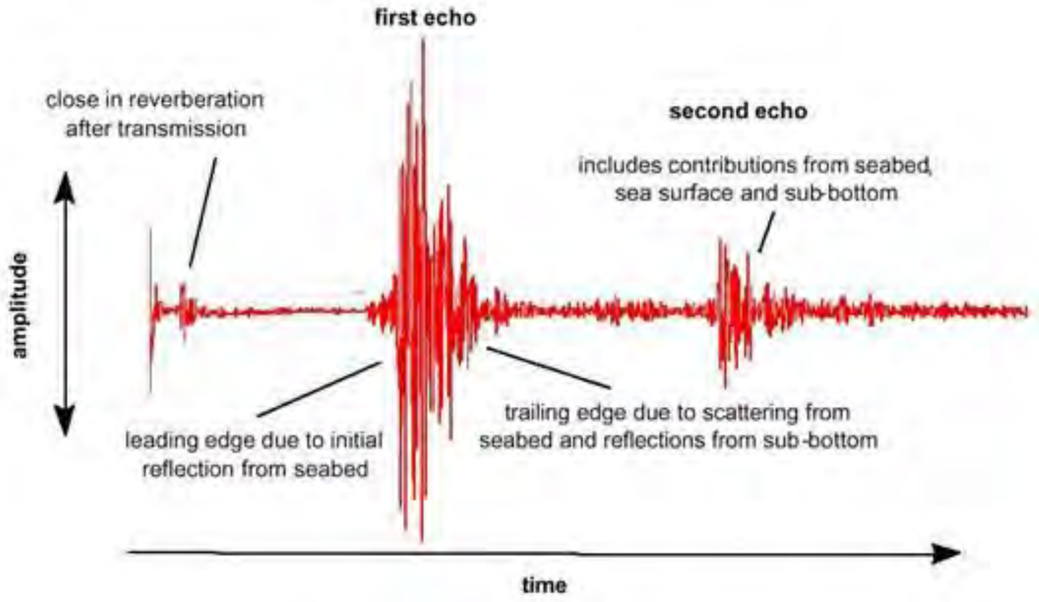


Figure 2-1 The echo recorded by a seafloor-mapping echosounder. The sonar beam delimitates a footprint (orange) on the seafloor, which is swept outwards by the (short) signal (red), generating a backscattered signal varying with time. The echo intensity I(t) is recorded by the receiver: the shape of its time envelope is determined by the footprint geometry, and its intensity level by the seafloor reflectivity. The delay T of the echo relatively to the transmission instant is used to compute the range (at a fixed angle) from the sonar to the sounding point.

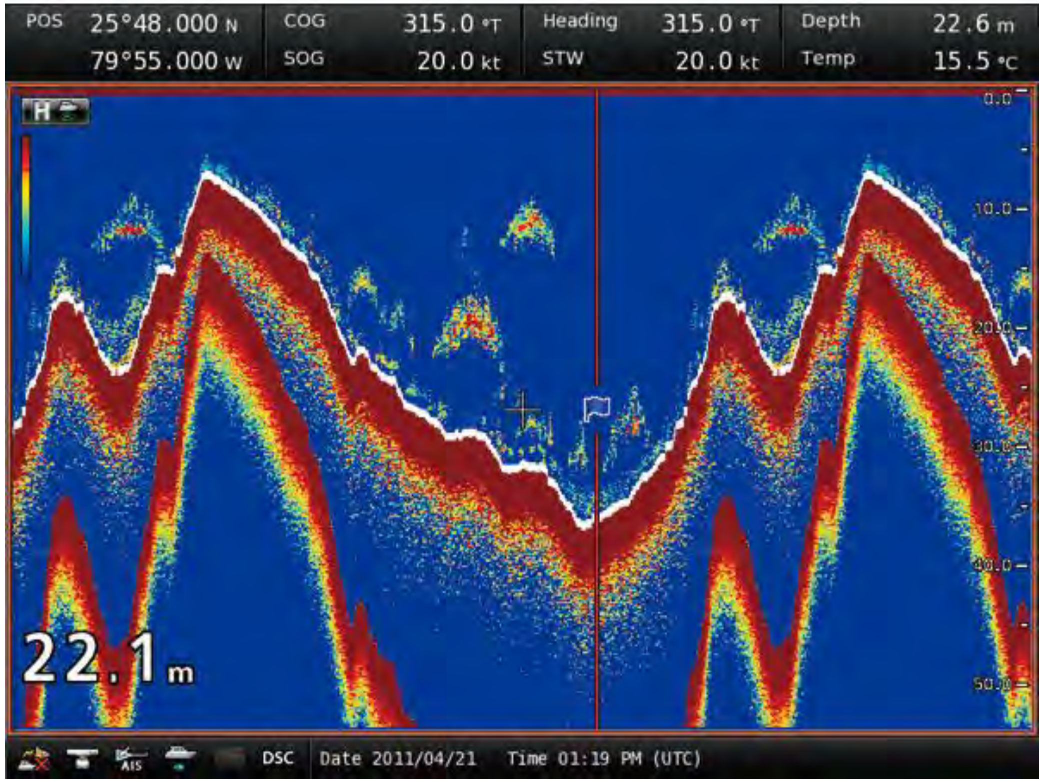
Backscatter – The basics….

MBES: Bottom Backscatter Strength



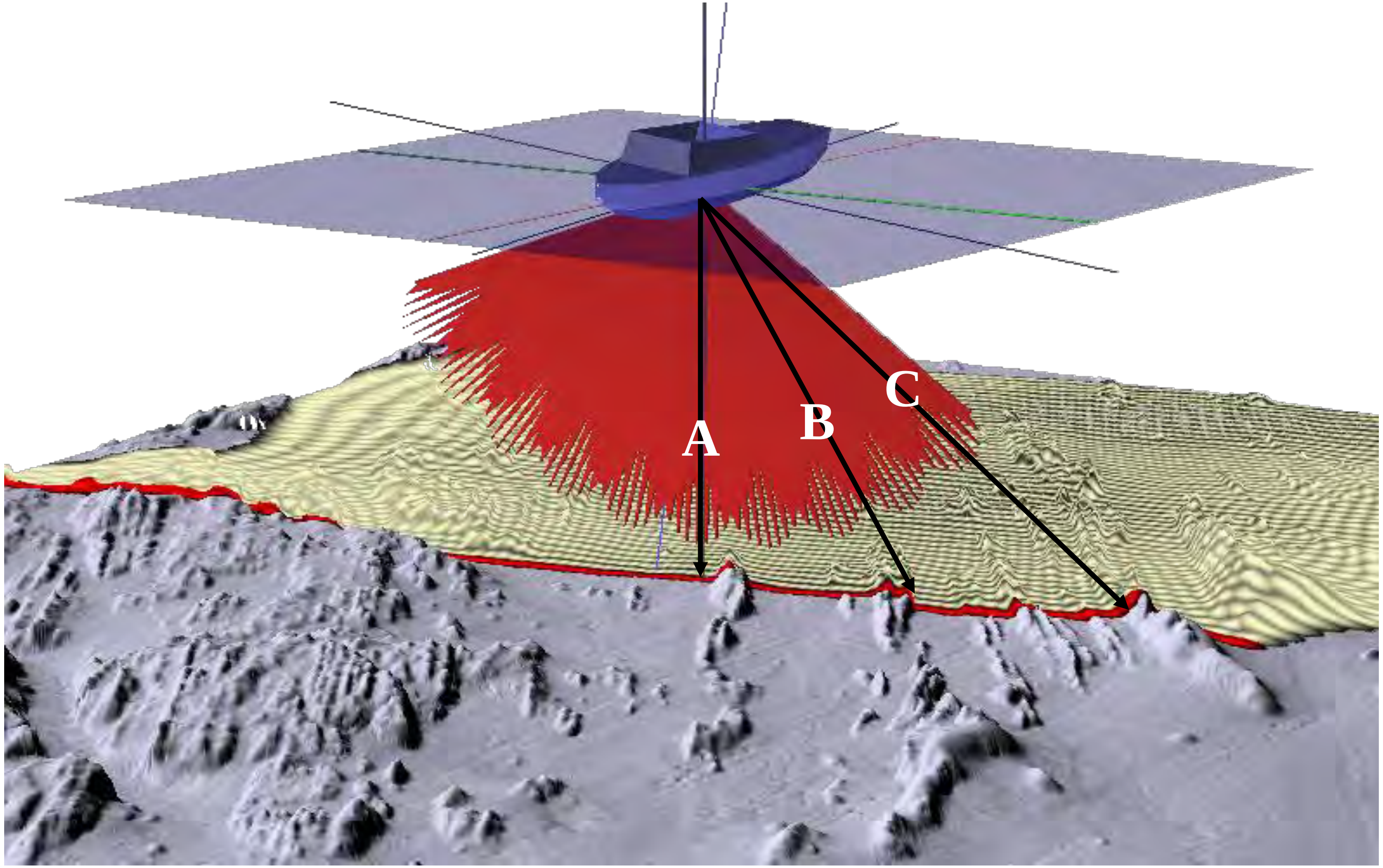


Sounder screen



Backscatter – The basics….

MBES: Bottom Backscatter Strength and Angular Dependence



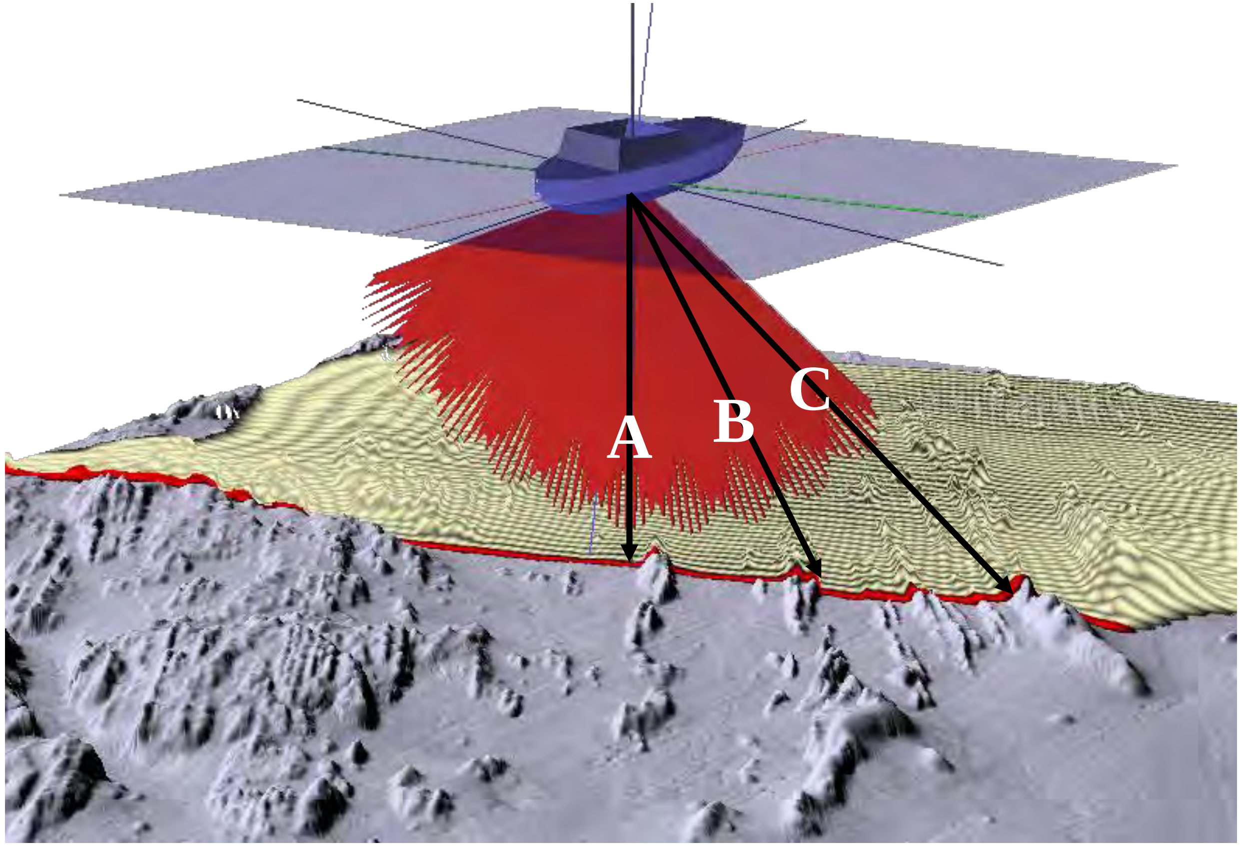
Multibeam Echosounders - Backscatter

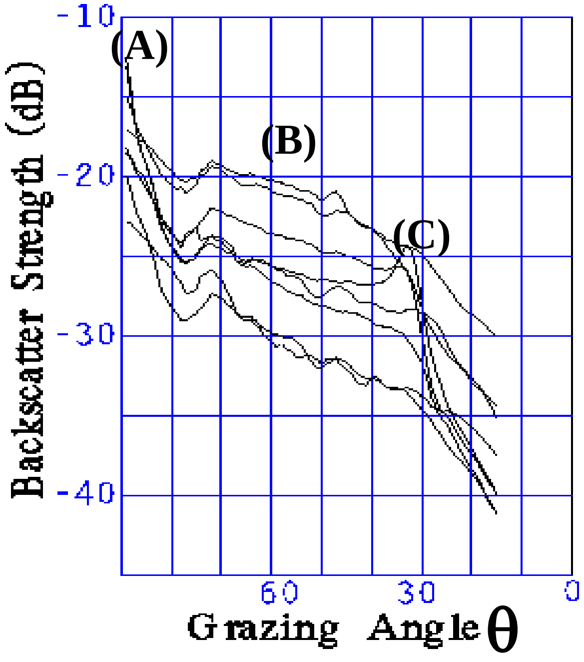
In contrast to the bathymetric measurement, characterizing the physical make-up of the seafloor from a sonar echo is more complex and requires more parameters to be known or estimated. The physical quantity of interest is now the echo amplitude which depends on many factors:

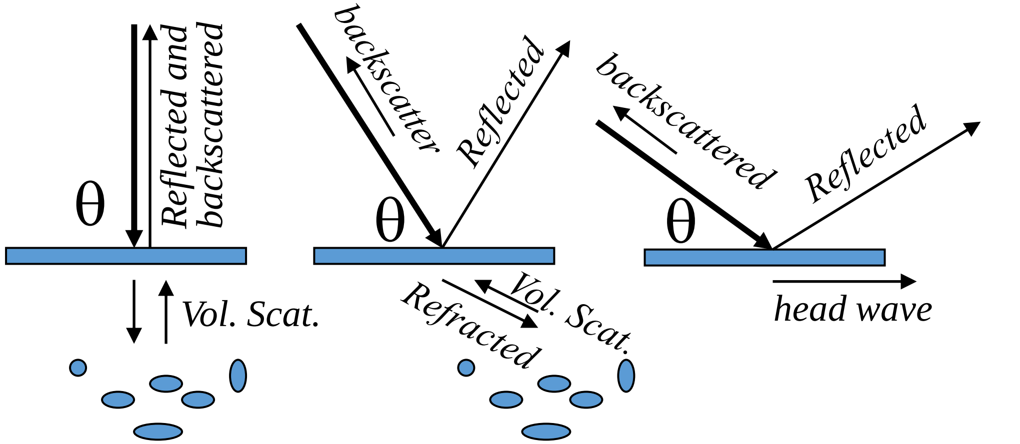
- The **amplitude of the acoustic signal projected** into the water, depending on the transmission power setting and the projector angular directivity pattern;
- The **loss and redistribution of acoustic energy** as the signal travels through the water to the seafloor and back again, depending on the signal-target range, on the physical properties of seawater (temperature and salinity *vs* depth) and on the signal frequency;
- The **sensitivity of the sonar receiver** to acoustic signals, which depends on the hydrophone sensitivity at the observation angle, the receiving electronics response, and the sonar settings;
- The contribution of **unwanted signal fluctuations** caused either by additive noise generated by other sound sources and receiver’s electronics, or by the intrinsic variability of the echo itself
- The physical phenomena of **interaction of the pulse arriving at the seafloor** that generate the echo itself.

Backscatter – The basics….

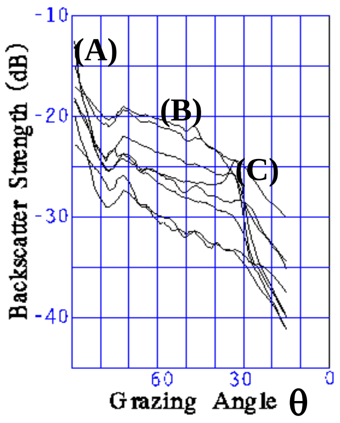
MBES: Bottom Backscatter Strength and Angular Dependence

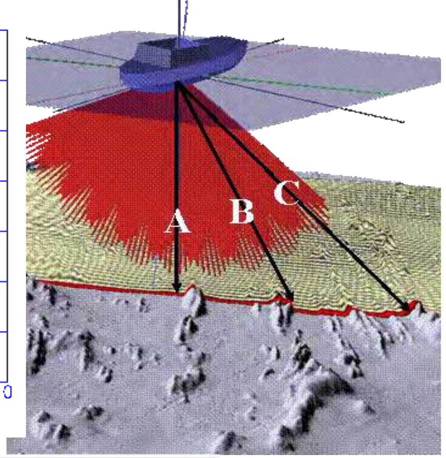


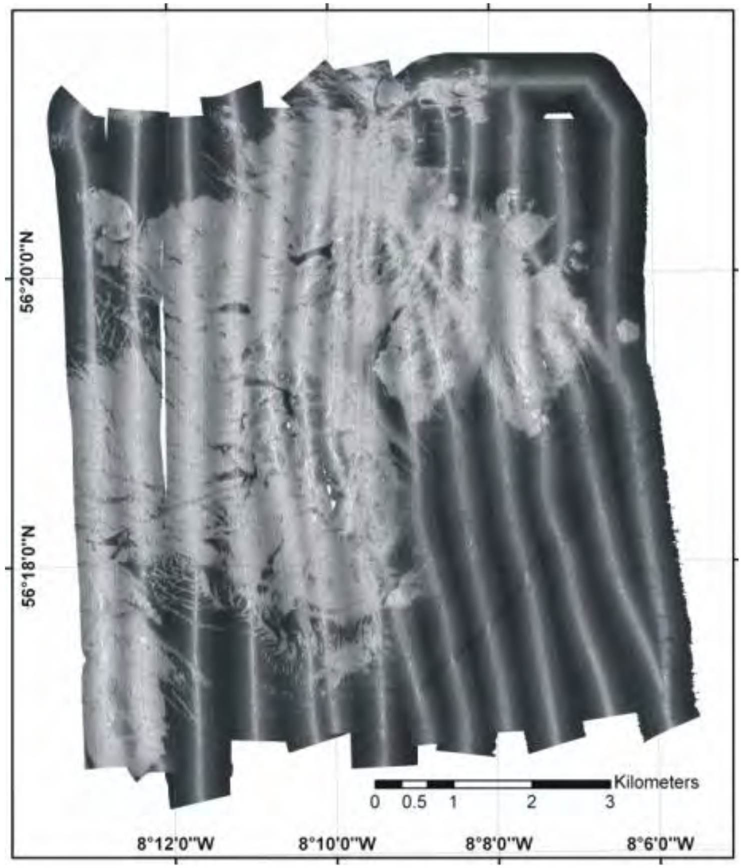


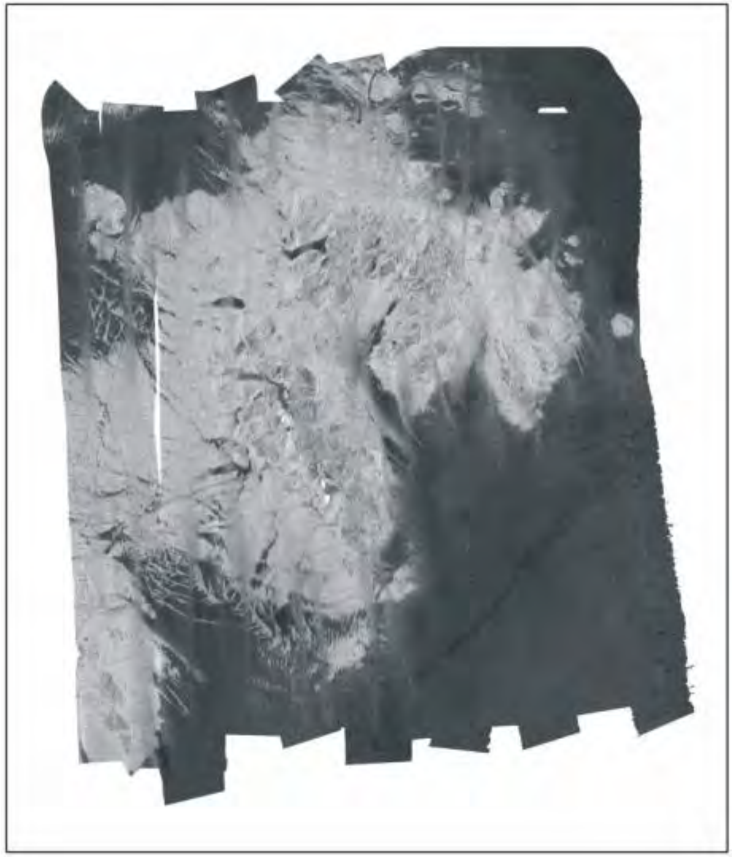


Backscatter data processing









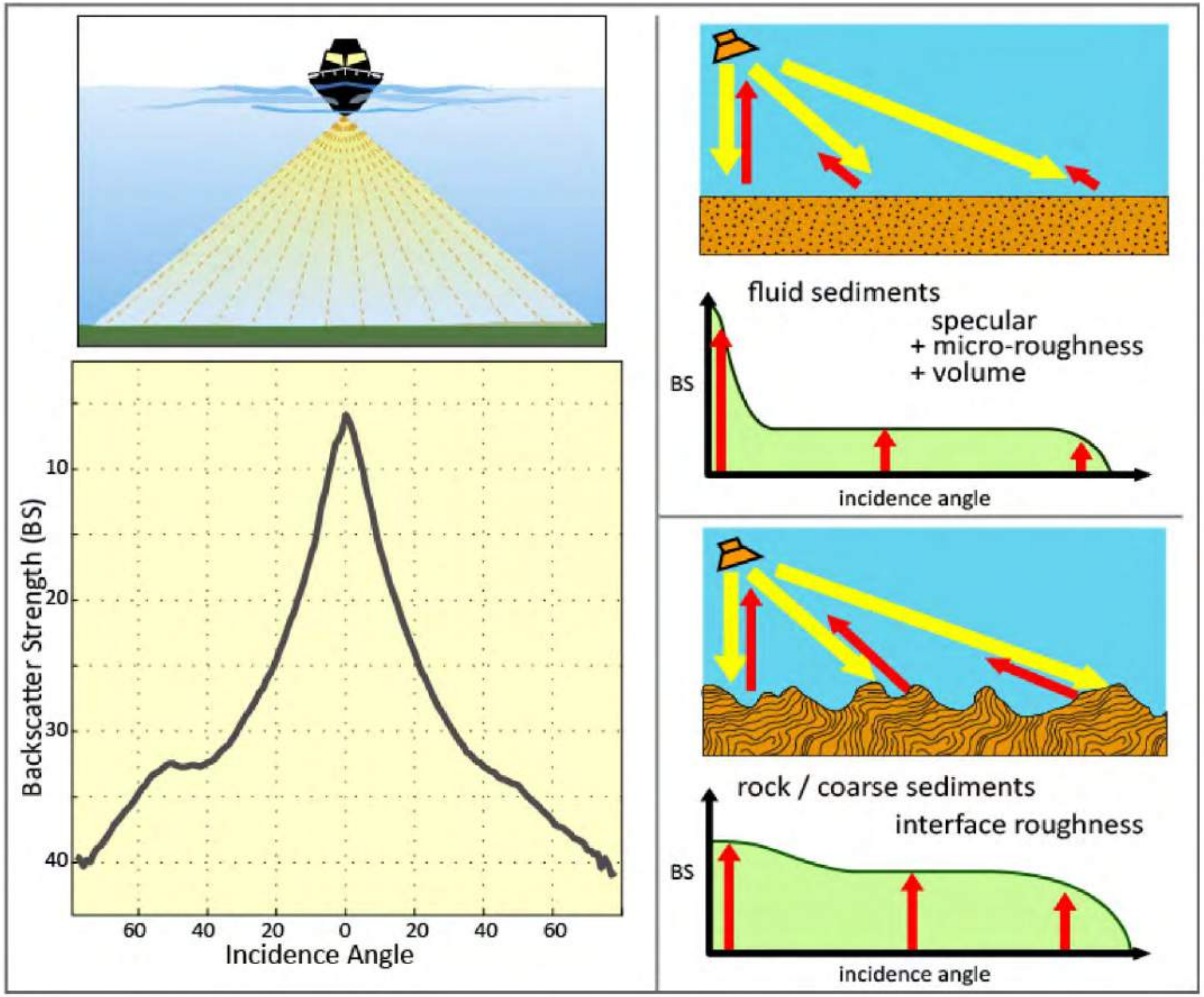


Figure 1-4 The angular dependence of Backscatter Strength (BS). The rapid decrease in the BS intensity with incidence angles shows well in the BS angular profile (bottom left): high BS values at the nadir (0° incidence) decrease rapidly with gazing angle. The shape of the angular profile is directly influenced by the interface roughness (right); it is not necessarily symmetrical in practice (example shown here), depending on local features

Multibeam Echosounders – Backscatter Angular Response Curves

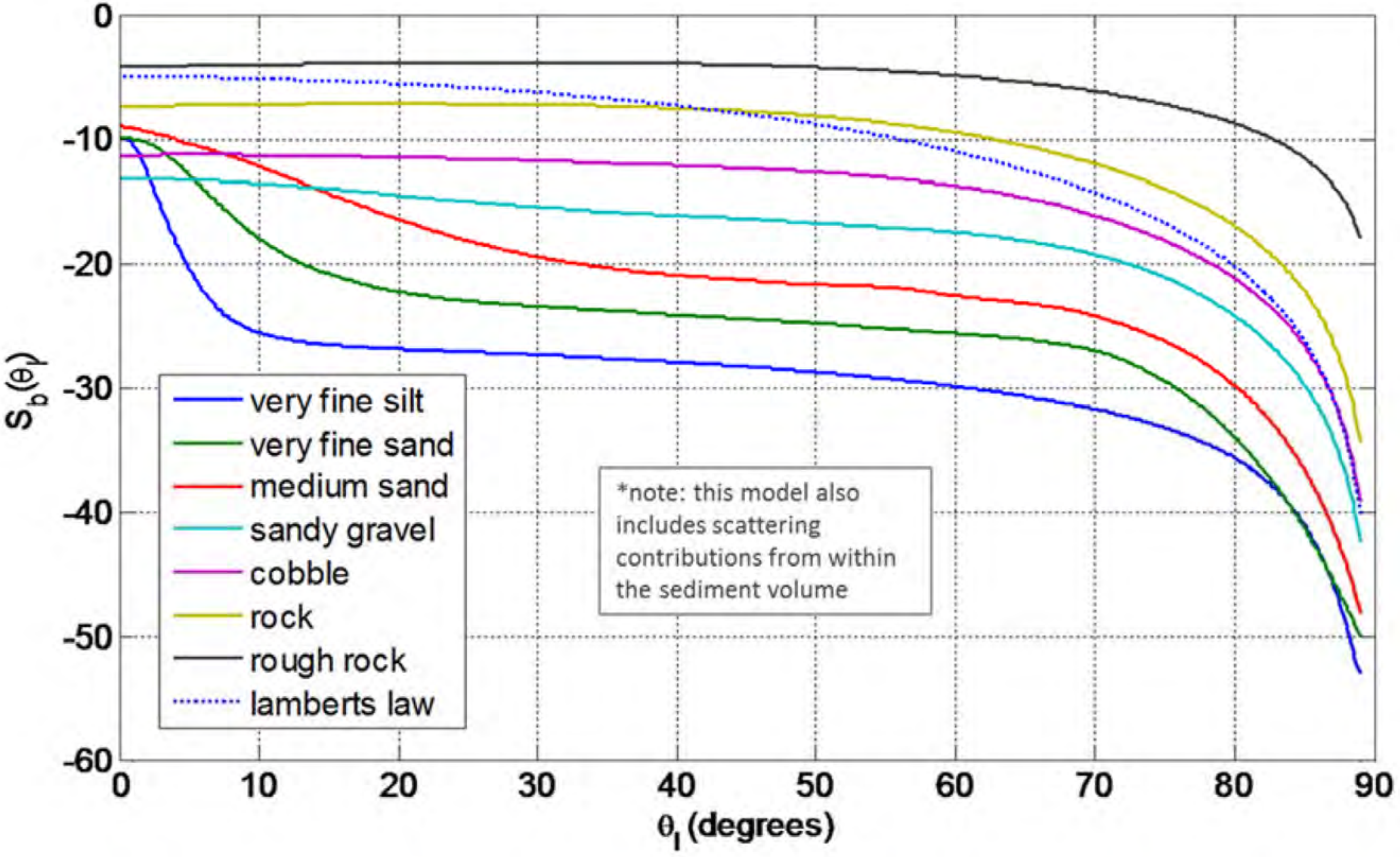


Figure 2-11 Example of angle-dependent backscatter for different substrate types at 100 kHz, based on model results using the APL-UW High-frequency Ocean Environmental Acoustic Models Handbook, APL-UW TR9407 (1994).

Multibeam Echosounders – Backscatter Frequency Response

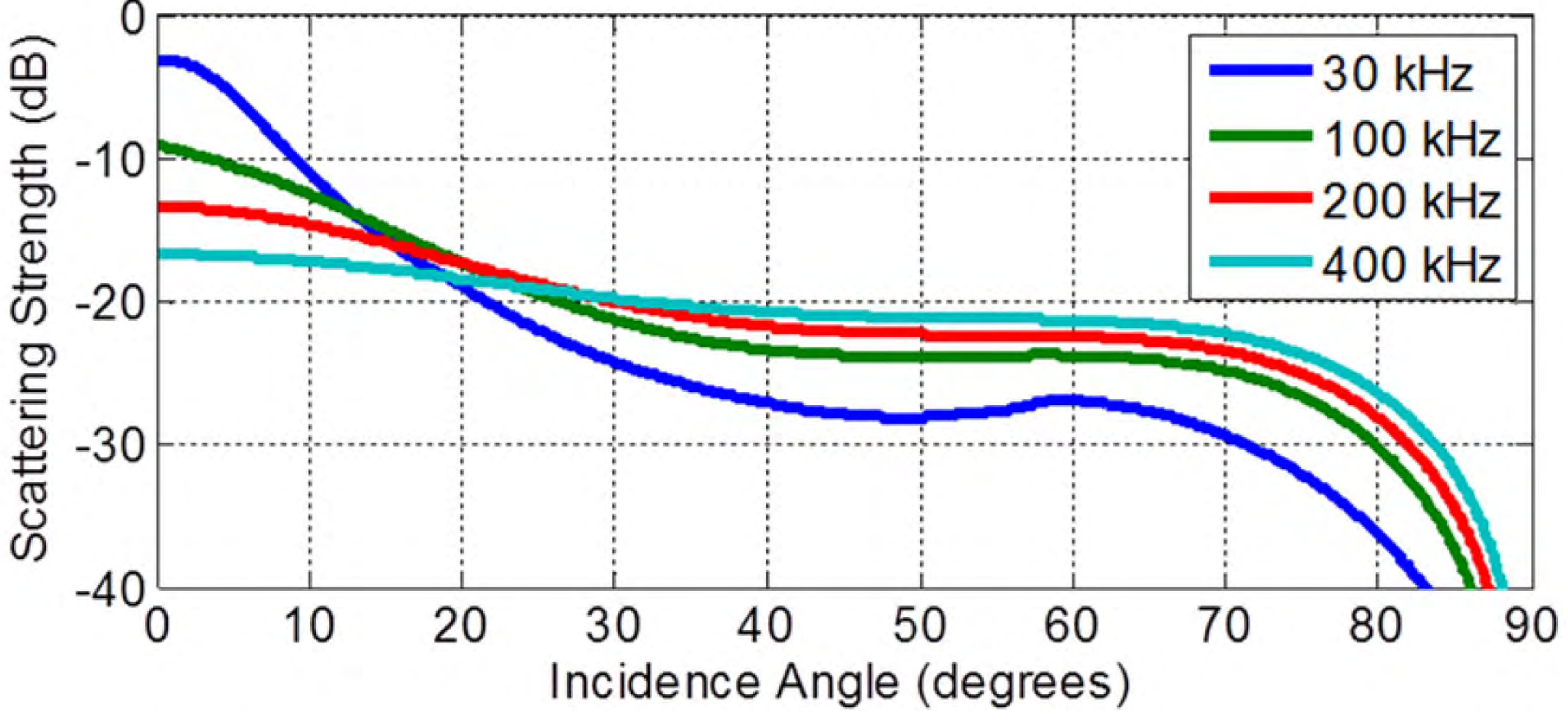


Figure 2-12 Example of angle-dependent backscatter for medium sand at different frequencies, based on model results using the APL-UW High-frequency Ocean Environmental Acoustic Models Handbook, APL-UW TR9407 (1994).

Multibeam Echosounders – Backscatter Frequency Response and Bottom Roughness

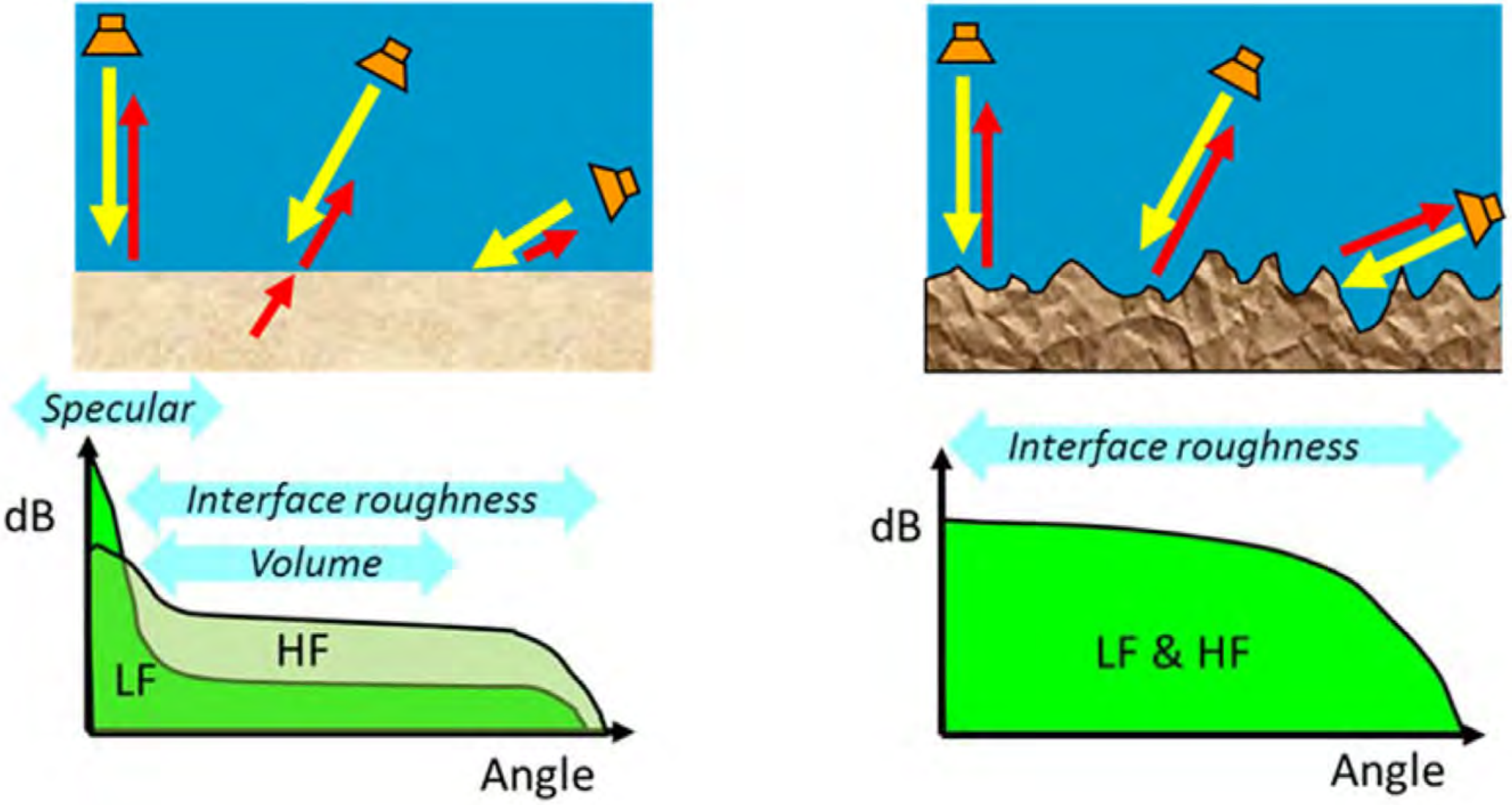
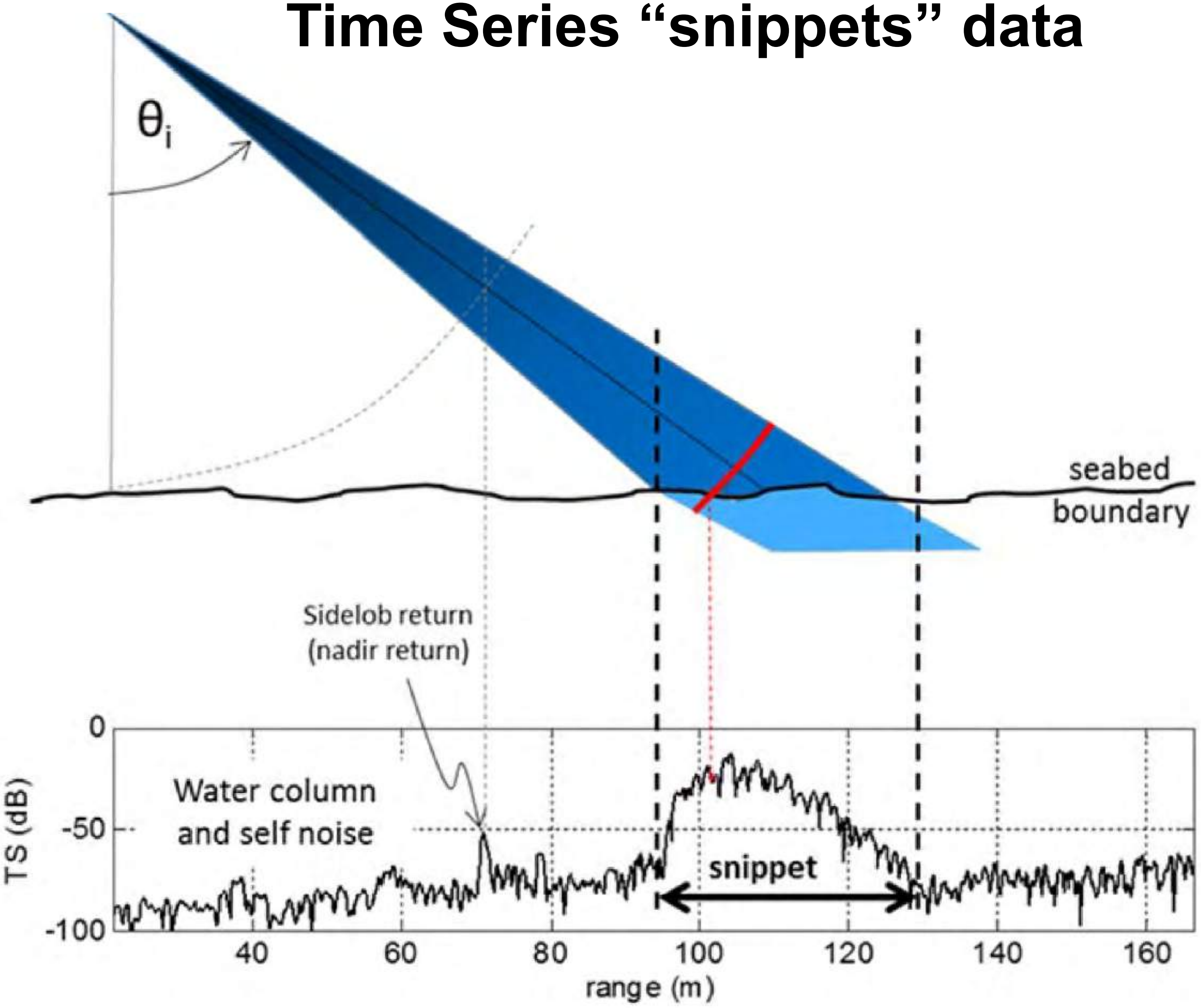
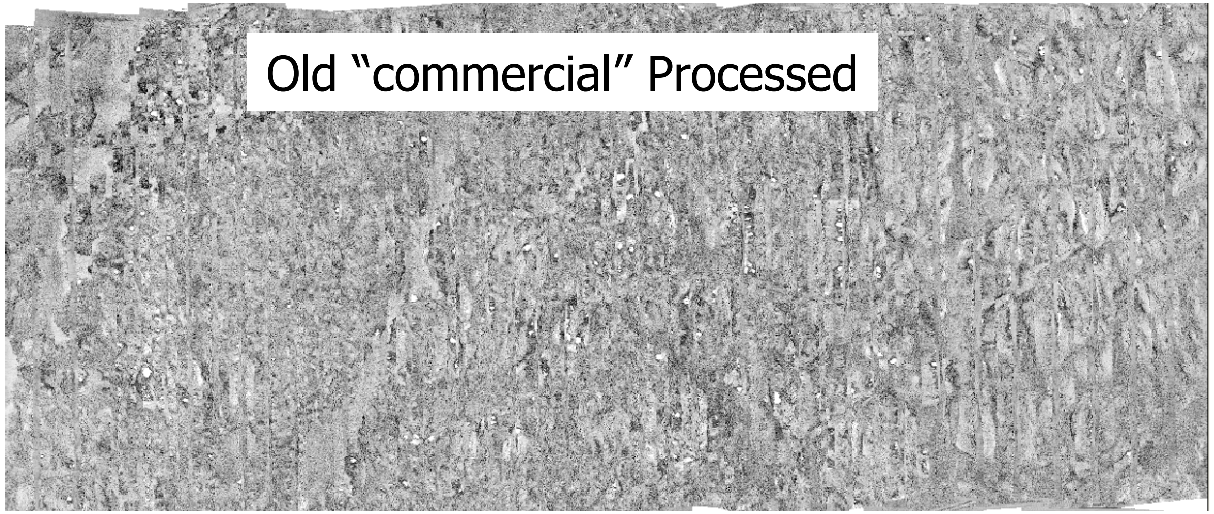


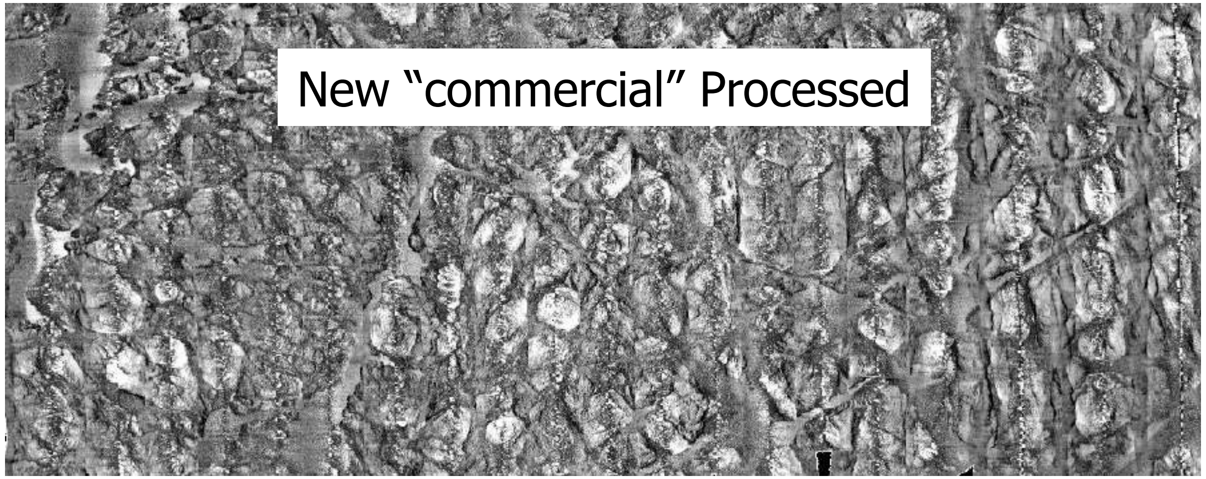
Figure 2-7 Angle dependence of the backscatter level in two typical cases. (Left) On a soft, fluid-like, sediment, a strong and narrow specular component, and a low contribution at oblique angles; this behavior is best marked at low frequencies (LF) compared to high frequencies (HF). (Right) On a rough/hard seafloor, the roughness effect is similar whatever the angle, excepted at low-grazing angle, and the frequency dependence is small.

Multibeam Echosounders – Backscatter Time Series "snippets" data



Improvements in MBES backscatter processing





Technical issues and considerations (the “backscatter bible”)

GEOHAB Marine Geological and Biological Habitat Mapping

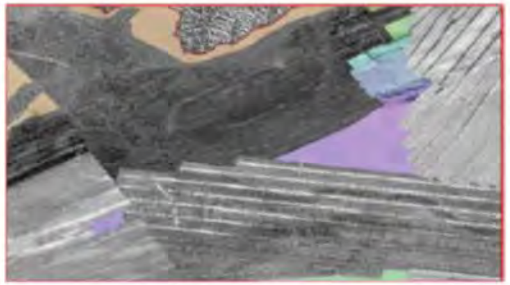
Ifremer

NIWA Taihoro Nukurangi

Backscatter measurements by seafloor-mapping sonars

Guidelines and Recommendations

A collective report by members of the GeoHab Backscatter Working Group



Editors

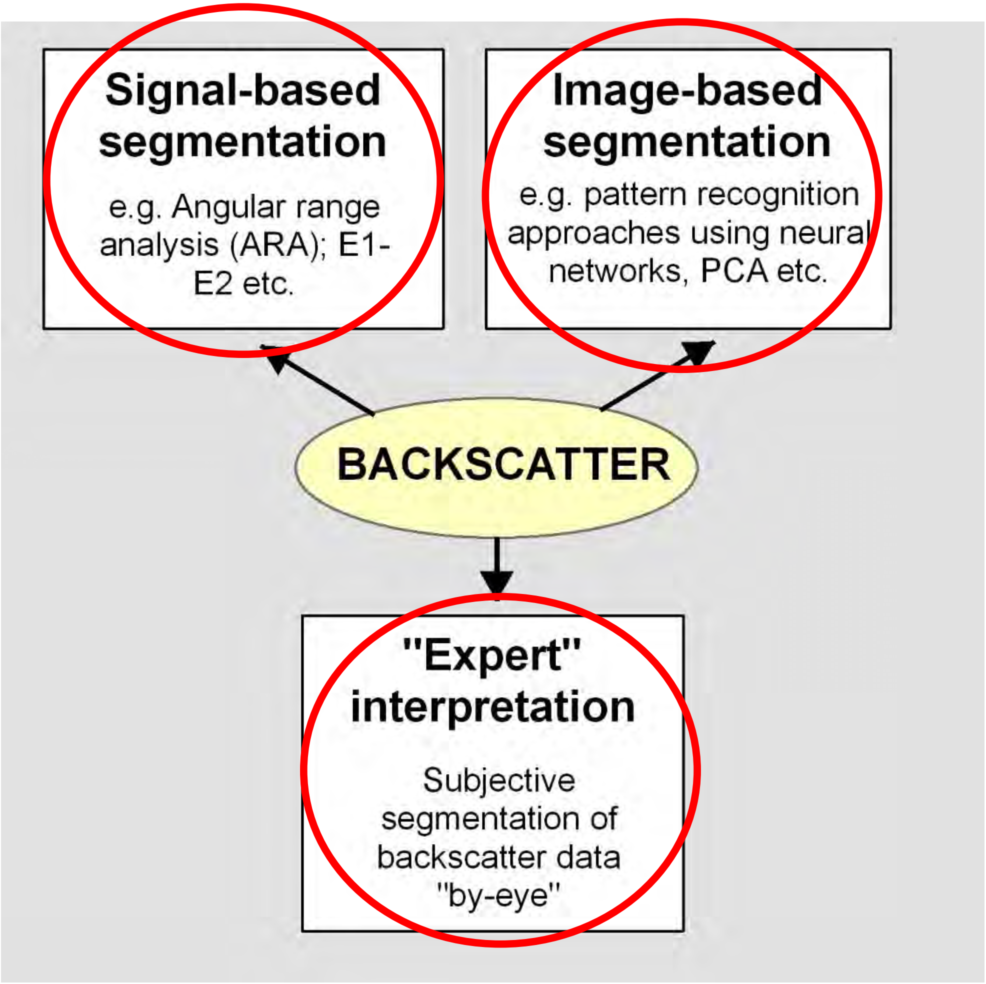
Xavier Lurton and Geoffroy Lamarche

May 2015

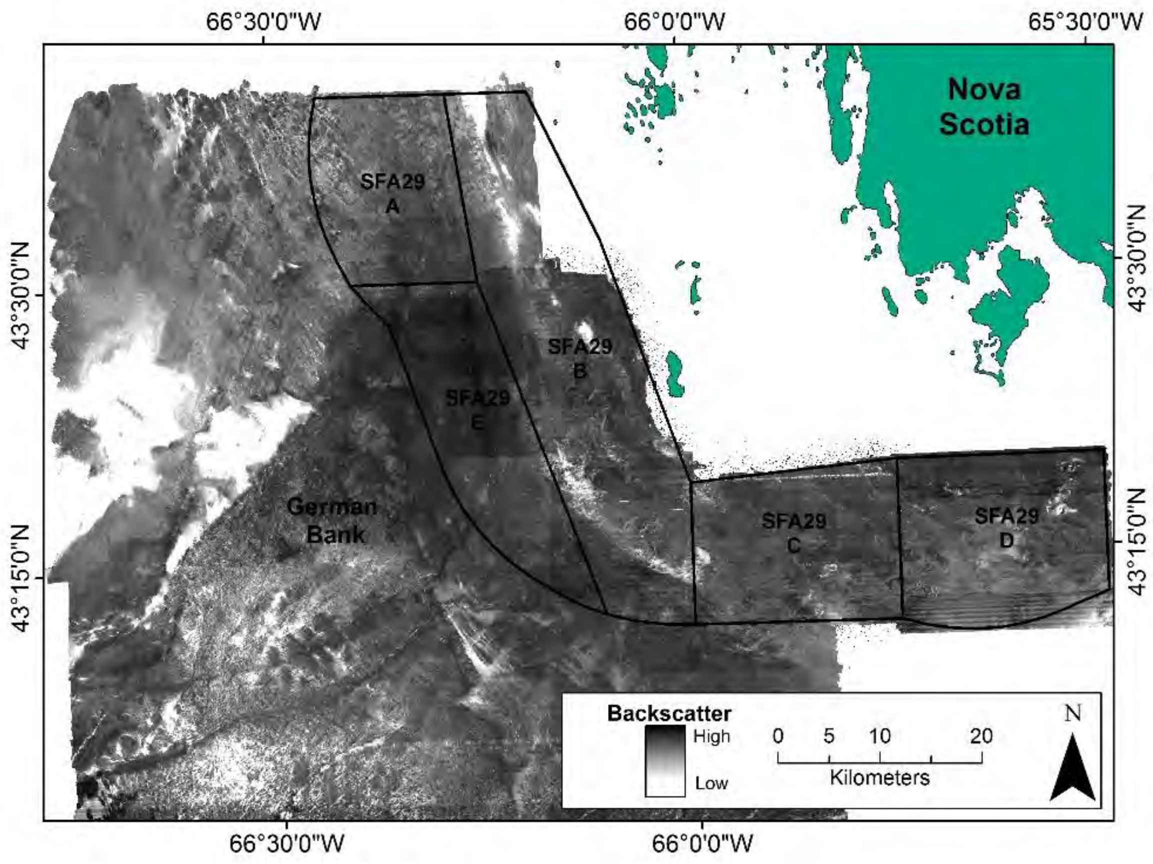
nscc UNIVERSITY of TASMANIA AUSTRALIA QPS

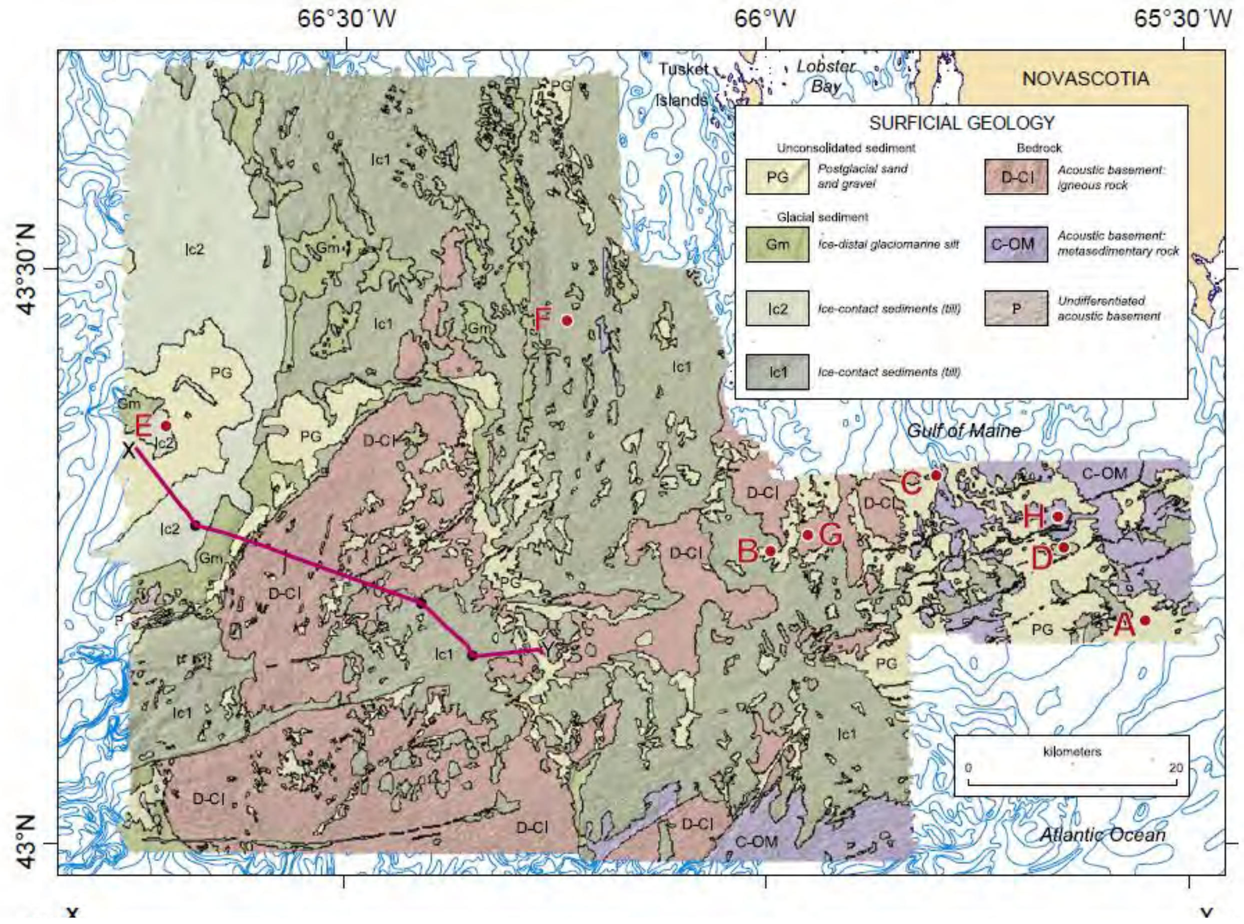
http://geohab.org/publications/

Backscatter Classification/Segmentation



“Expert” interpretation (i.e. segmentation) of backscatter



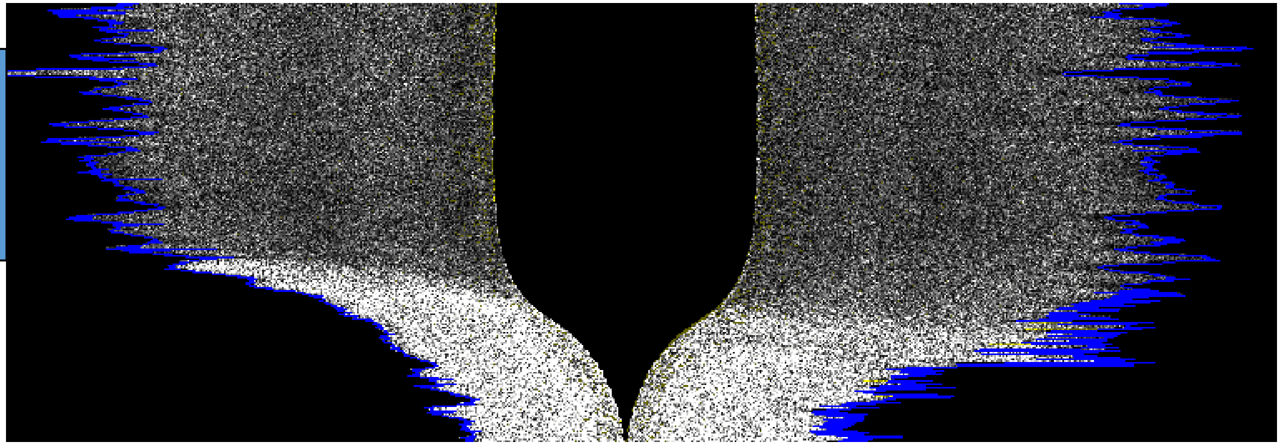


LOAD RAW DATA
(raw.all files)

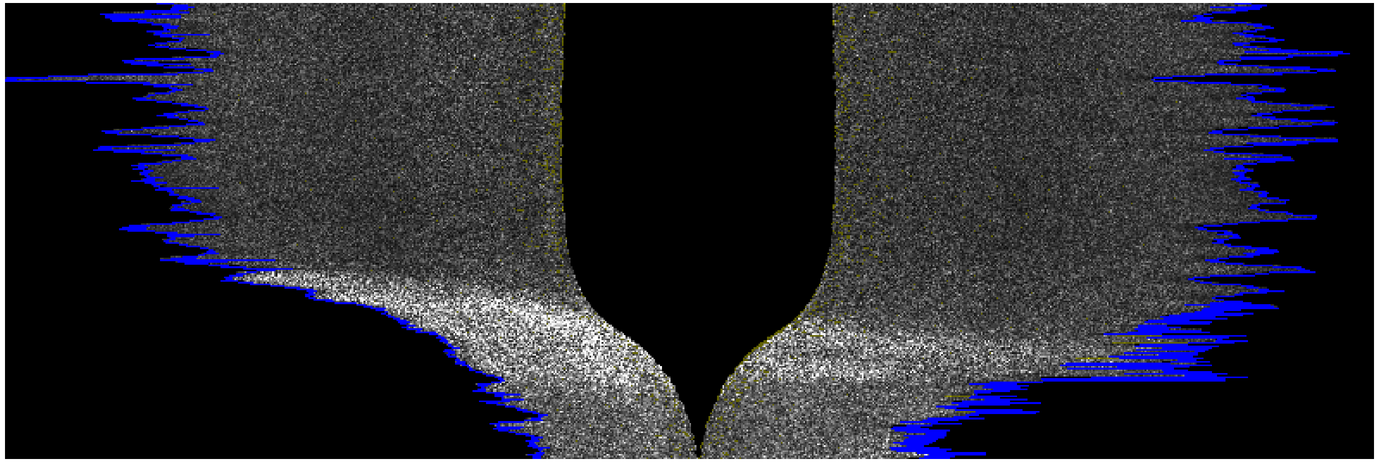
IMAGE COMPENSATION

Image-based segmentation

QTC MULTIVIEW™ (IMAGE-BASED CLASSIFICATION)



Before compensation



After compensation

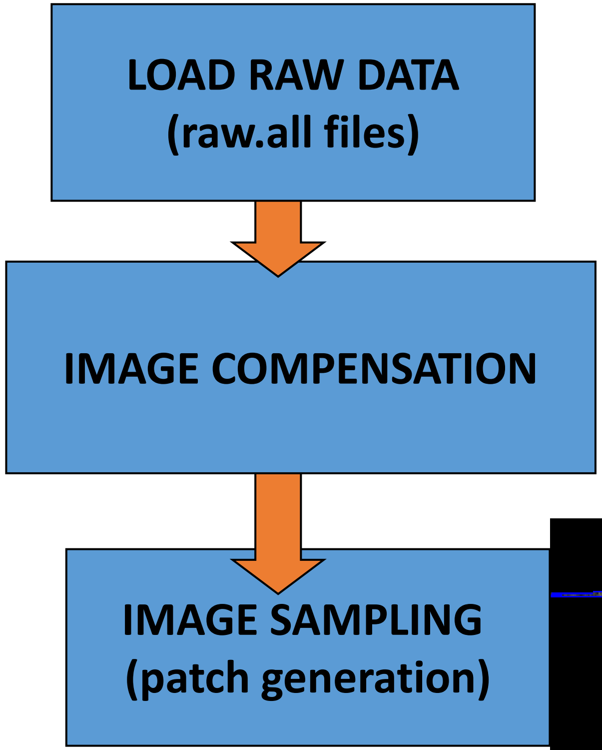
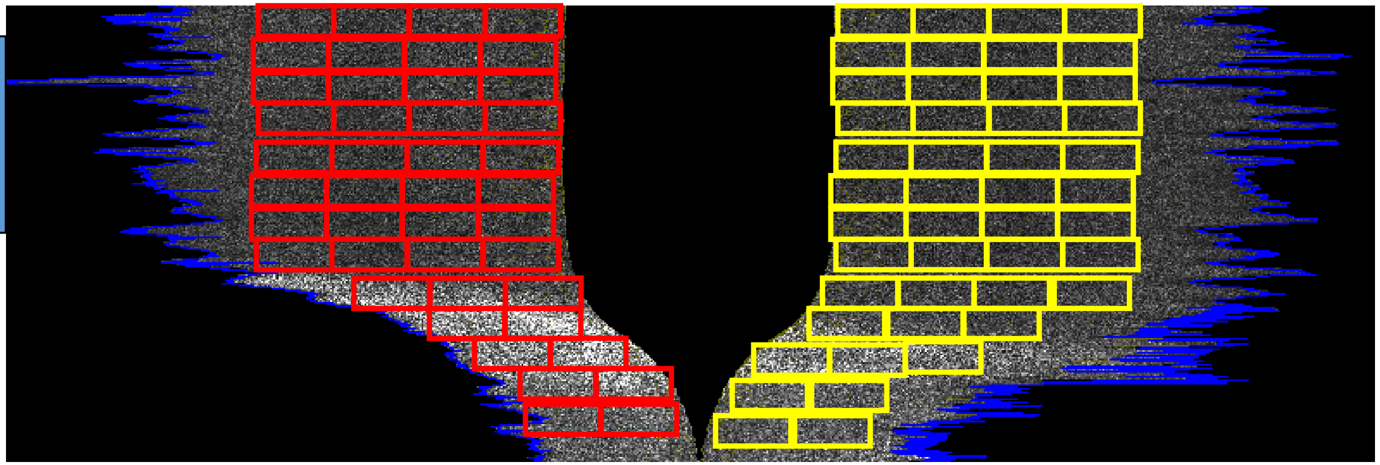


Image-based segmentation

QTC MULTIVIEW™ (IMAGE-BASED CLASSIFICATION)



Rectangle generation

Brown, C.J. et al. (2011). Continental Shelf Research. 31: S110-S119.

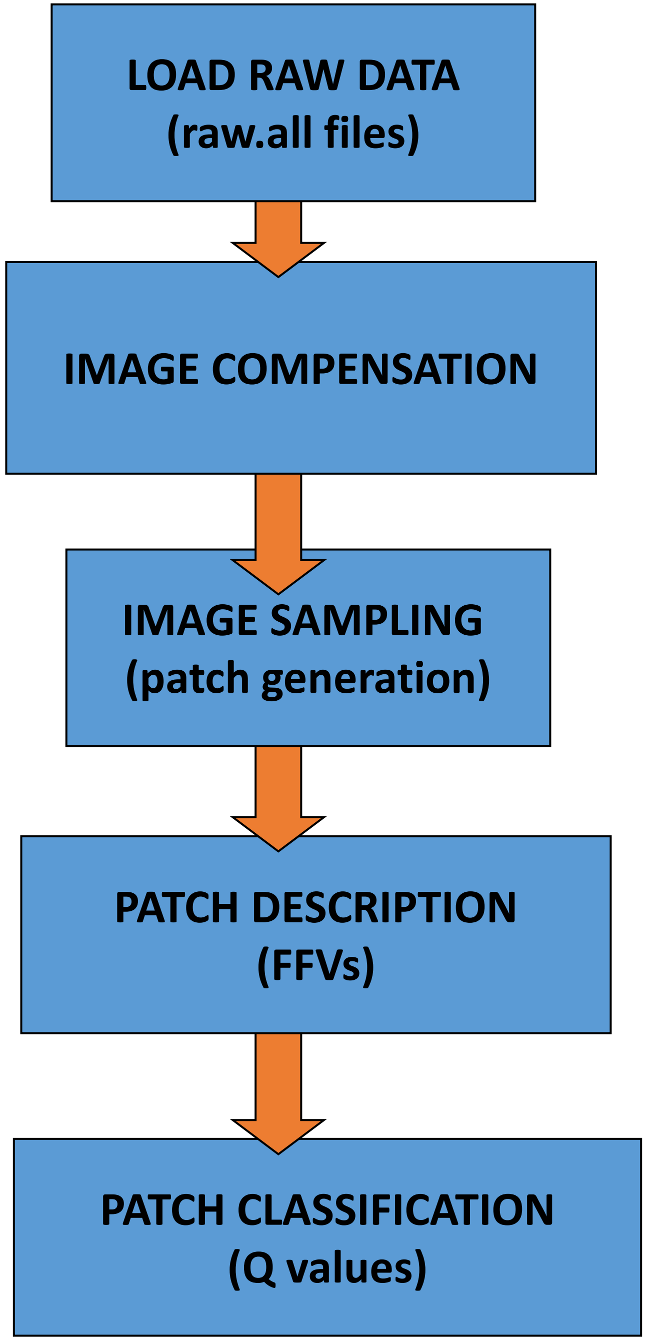
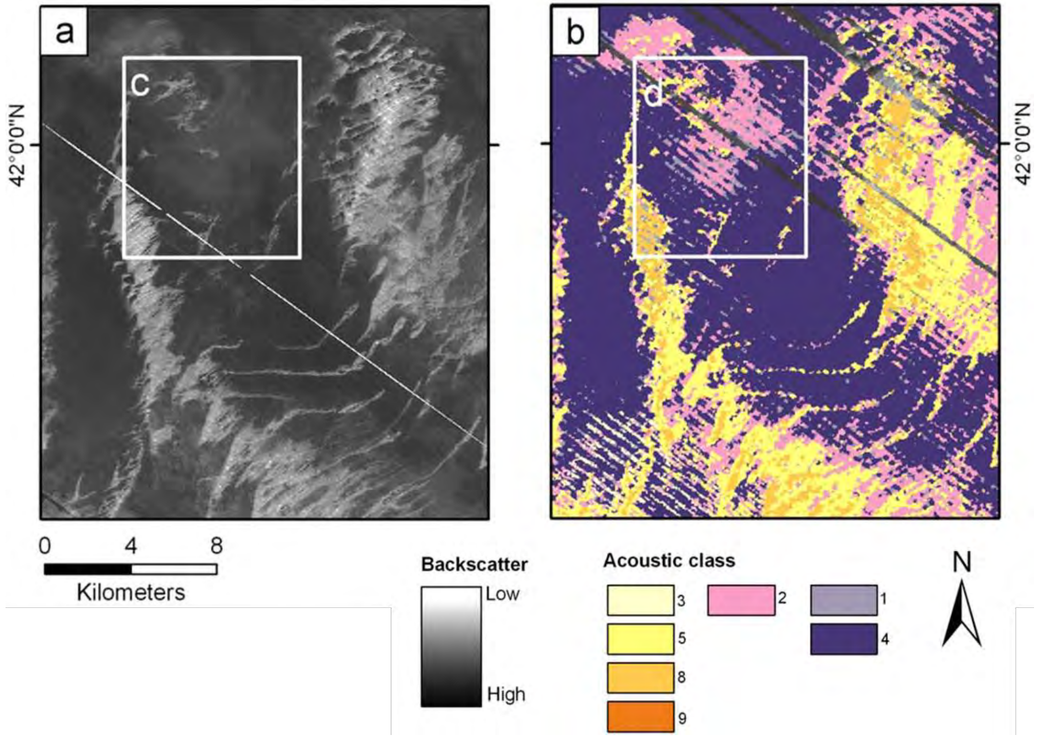


Image-based segmentation

- Full Feature Vectors (FFVs) (29) - string of features that characterize the backscatter of a rectangular patch of sediment
- Reduced to three values using PCA (Q1, Q2, Q3)
- Automated Clustering Engine used to group patches based on acoustic similarity



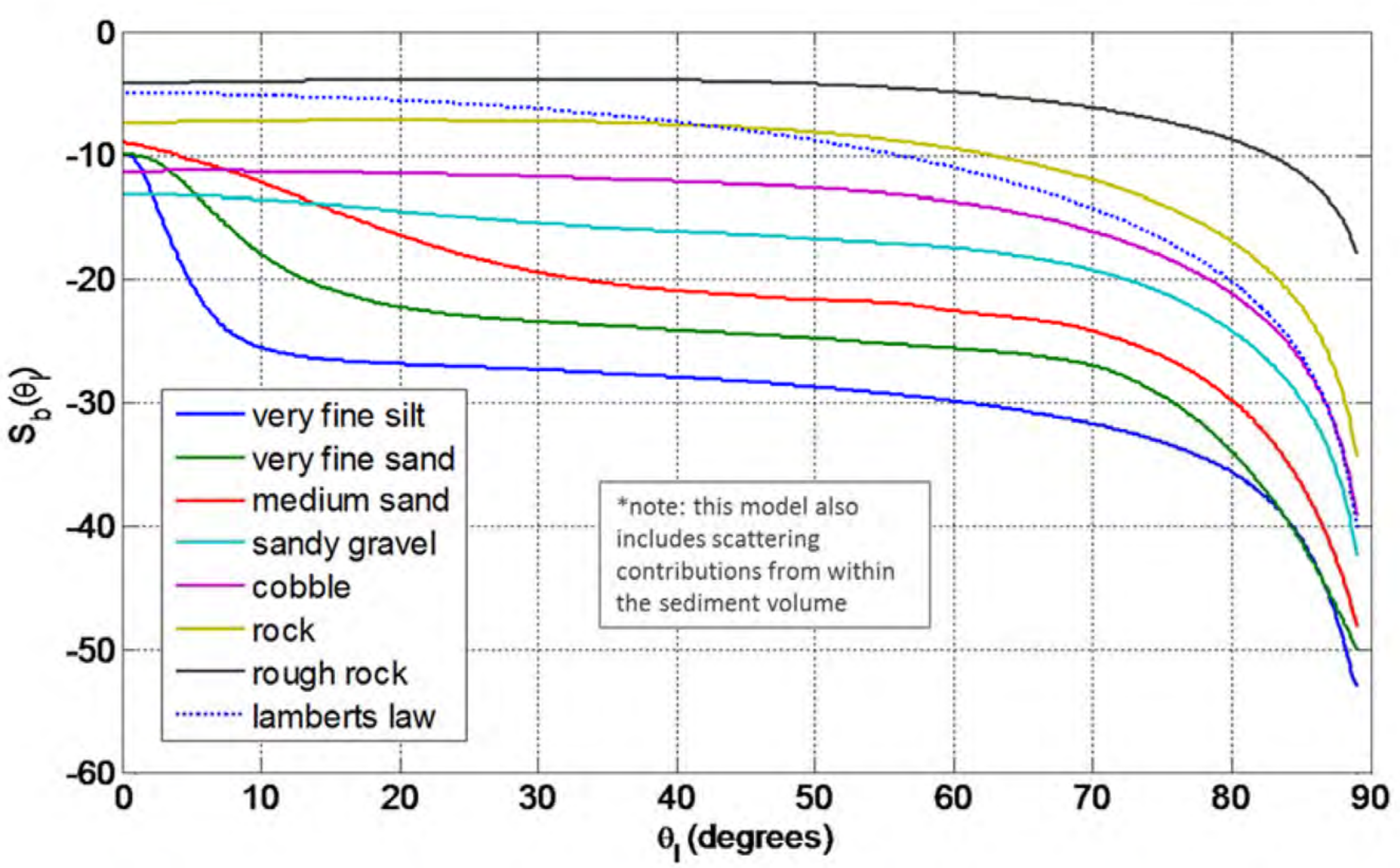


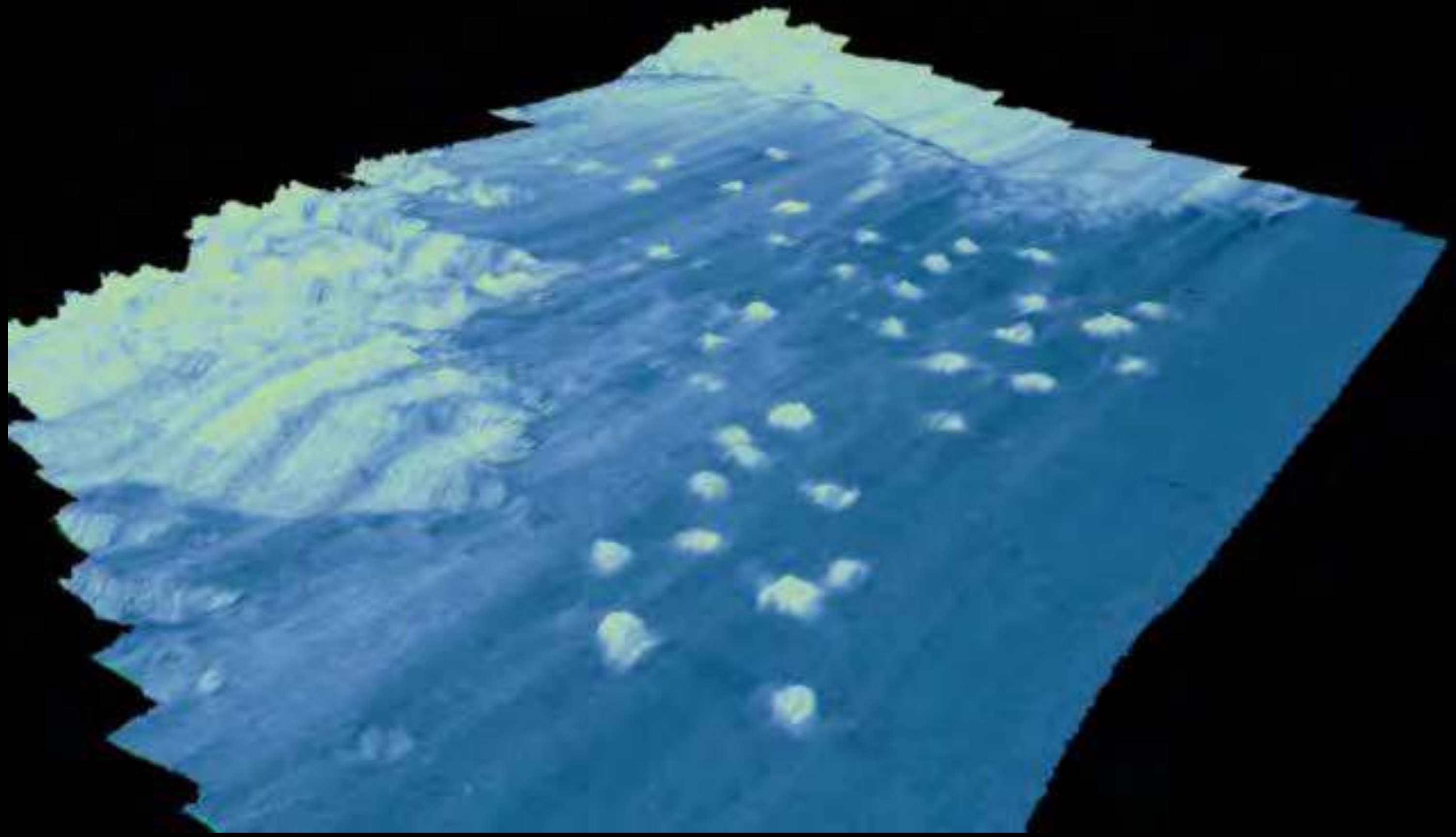
Figure 2-11 Example of angle-dependent backscatter for different substrate types at 100 kHz, based on model results using the APL-UW High-frequency Ocean Environmental Acoustic Models Handbook, APL-UW TR9407 (1994).

2) Seafloor Characterization -ARA Analysis

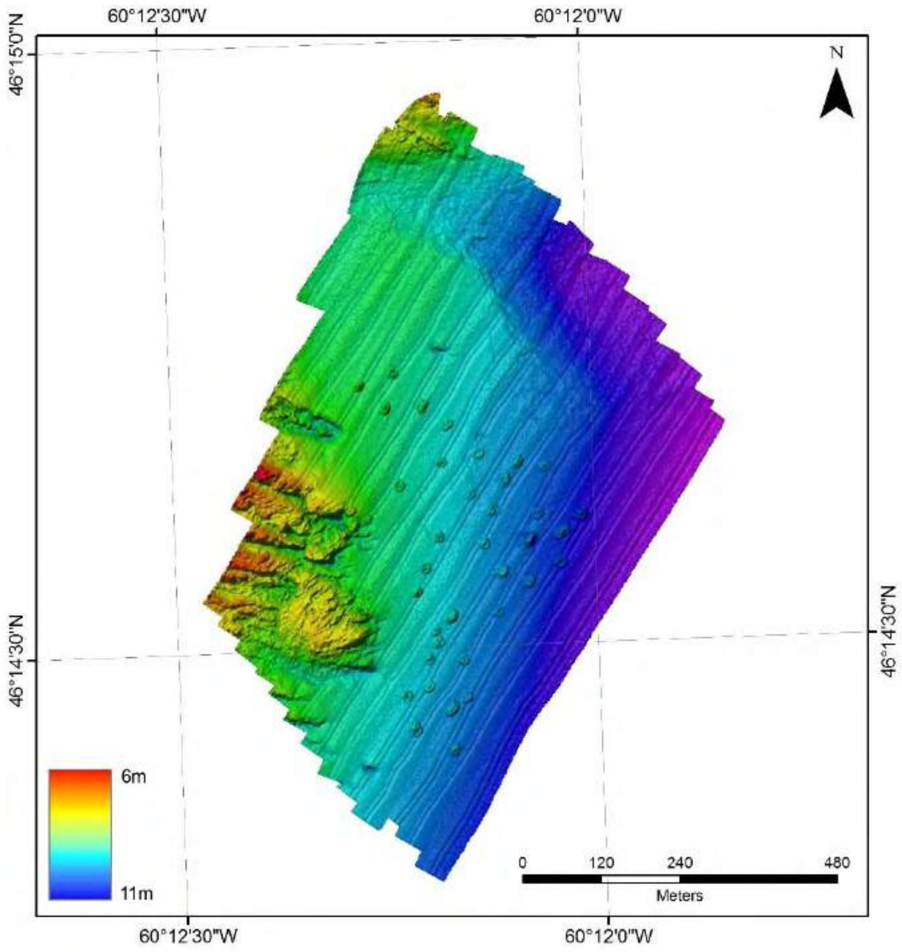
Fonseca, Brown, Calder, Mayer and Rzhanov (2009) *Applied Acoustics, 70, 1298-1304*

Comparison of segmentation/classification methods

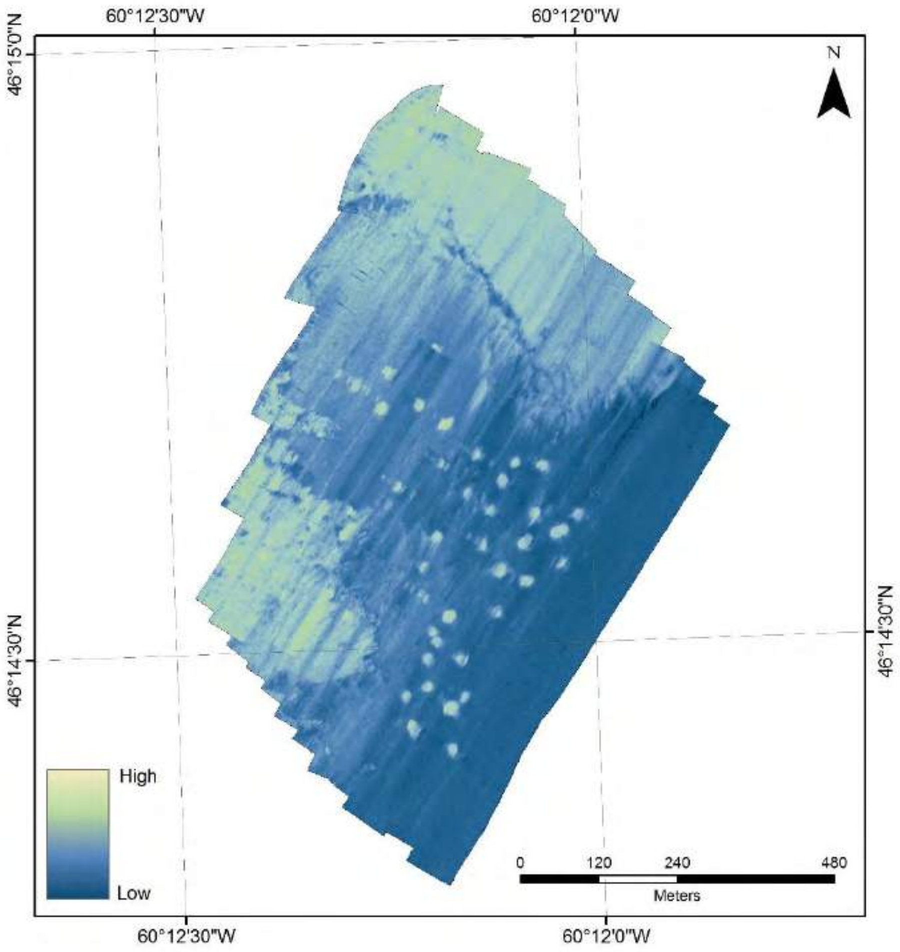
Reson 8101 survey: Fish habitat compensation – habitat mapping



Comparison of segmentation/classification methods



Bathymetry



Backscatter

Comparison of segmentation/classification methods

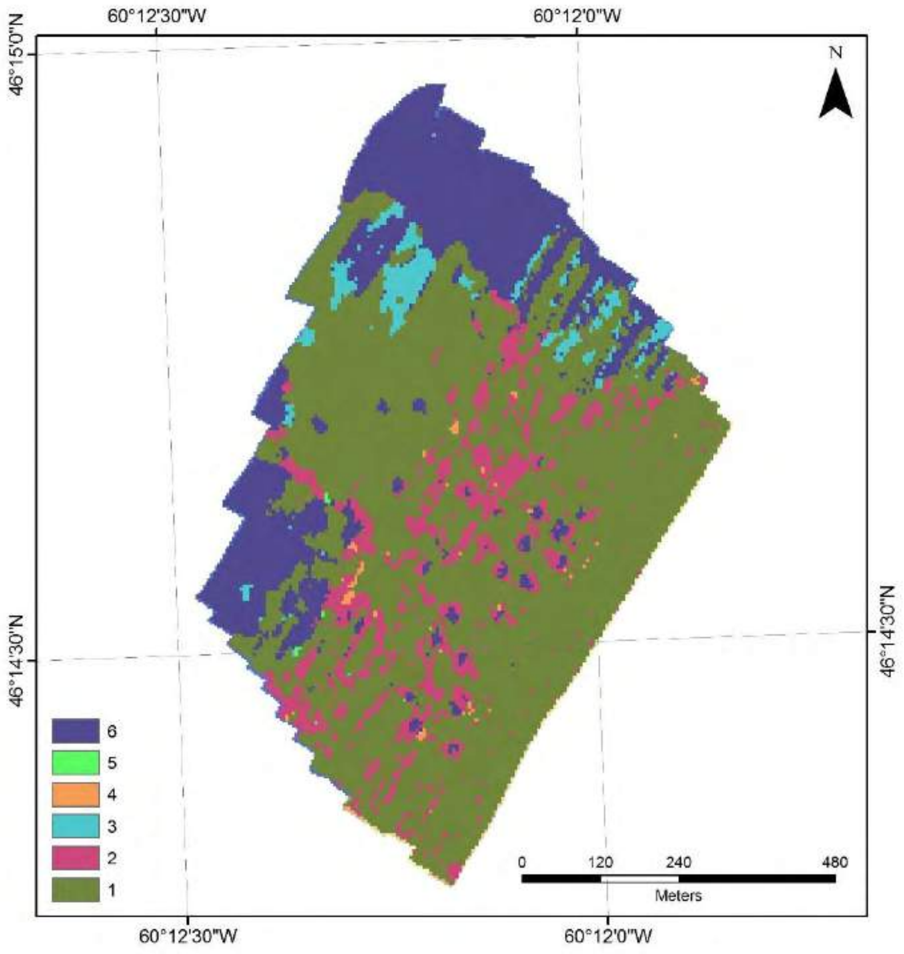
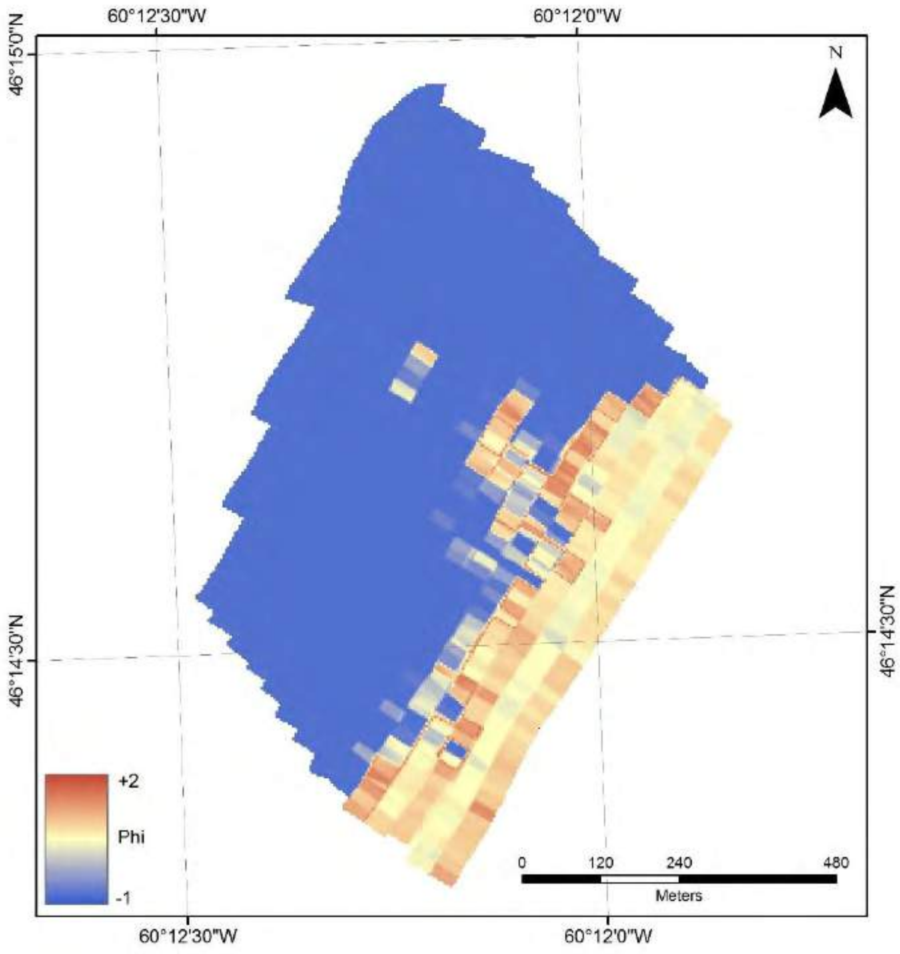
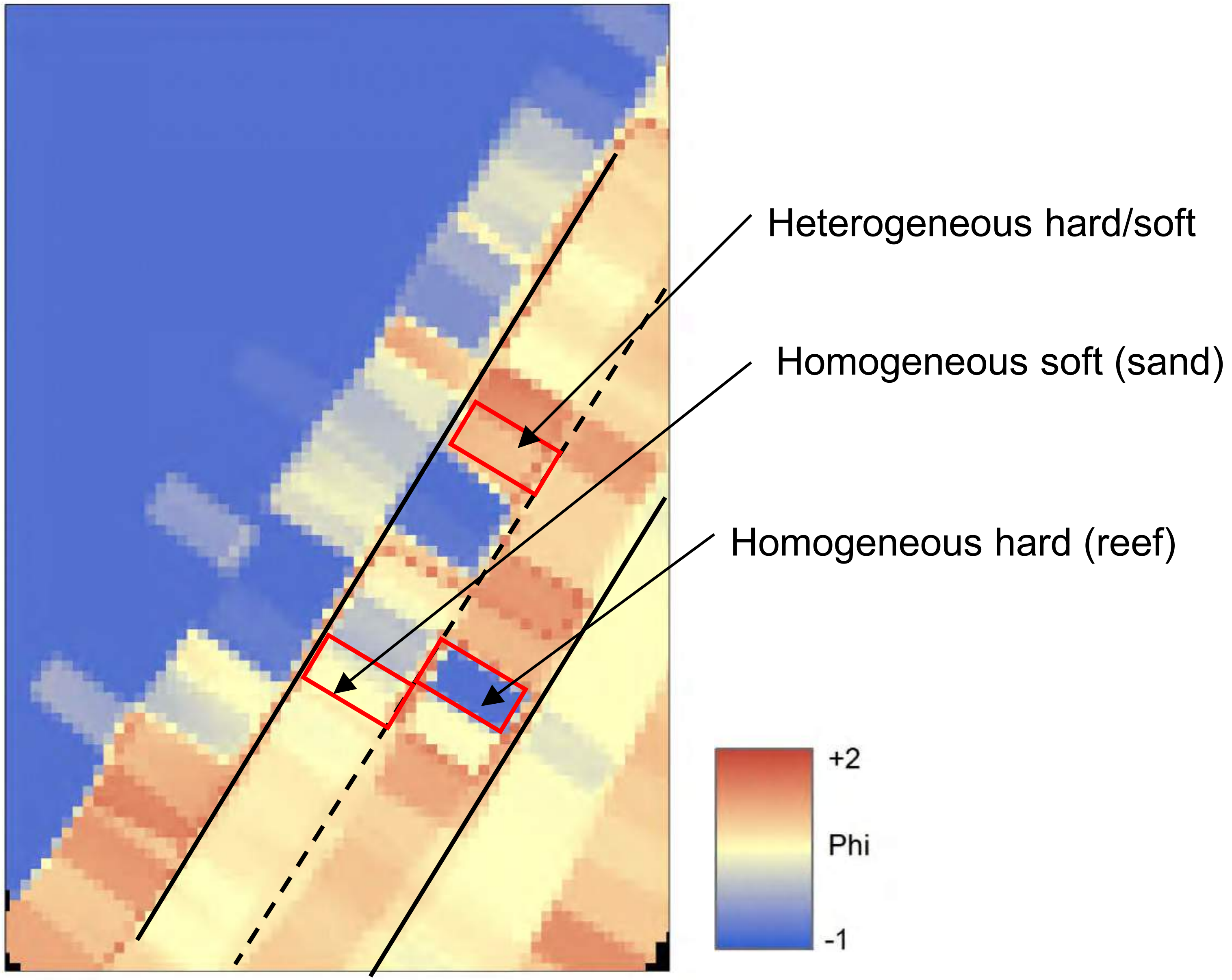


Image-based – QTC-Swathview

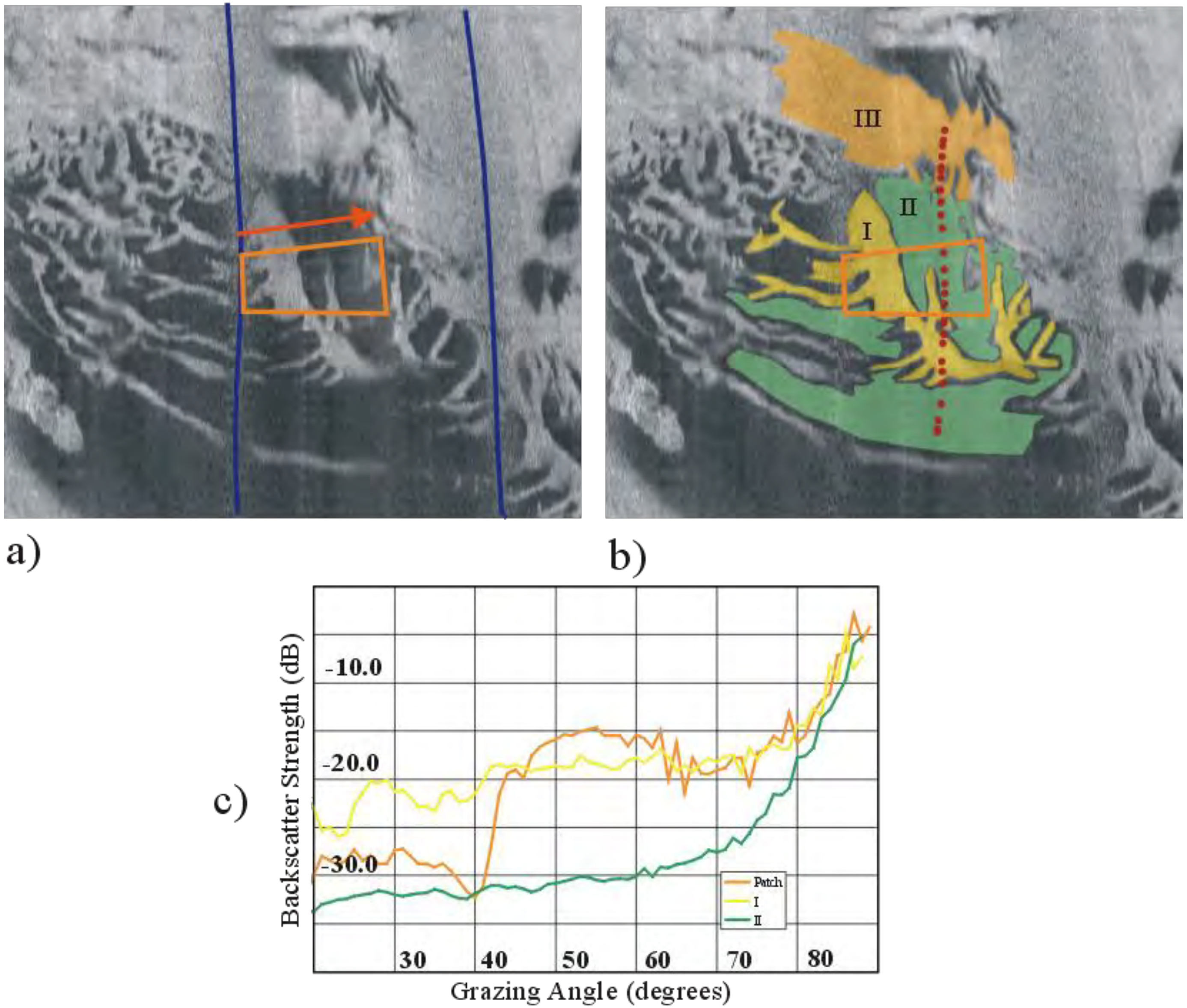


Signal-based - Geocoder

Scale and heterogeneity: Signal-based classification

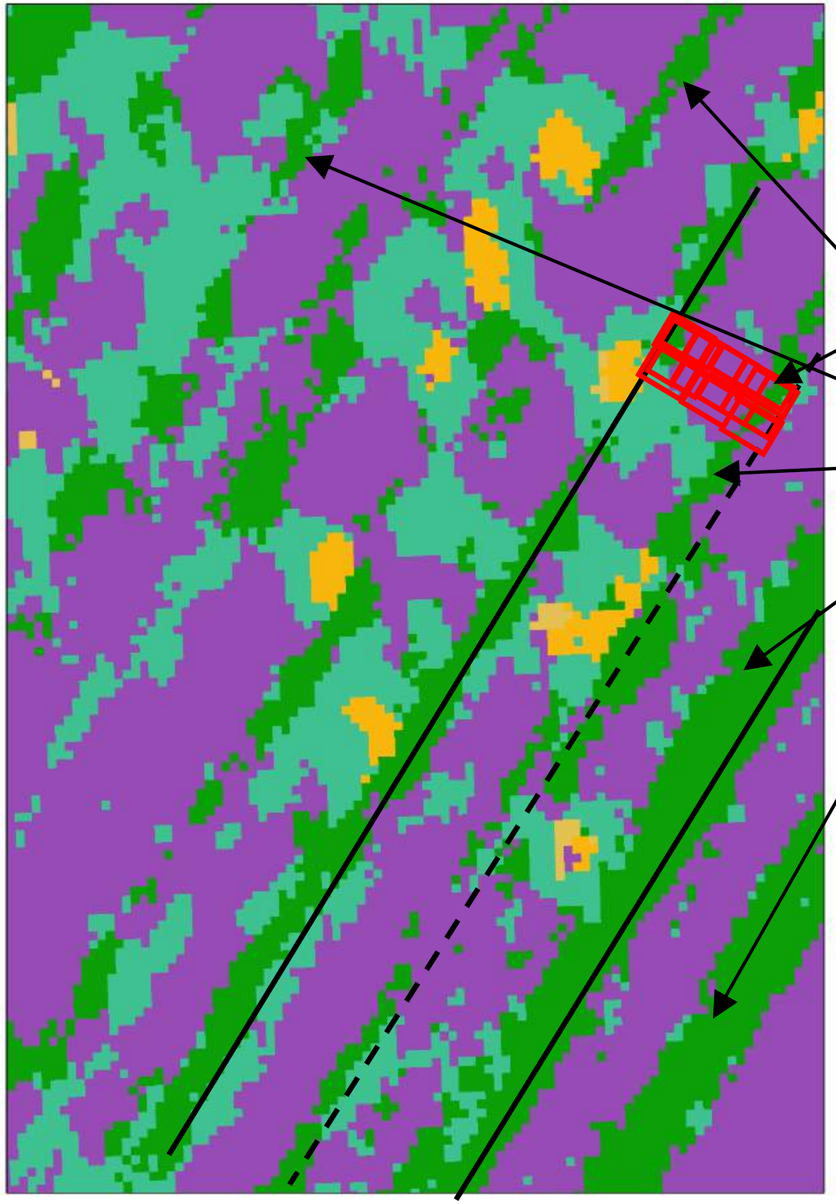


Scale and heterogeneity: Signal-based classification



Fonseca, Brown, Calder, Mayer and Rzhanov (2009) *Applied Acoustics, 70, 1298-1304*

Scale and heterogeneity: Signal-based classification



Choice of rectangular patch size important in determining scale of features/artefacts segmented

Along track angular range artefacts caused by an non-perfect image compensation

Comparison of segmentation/classification methods

Technical issues and considerations

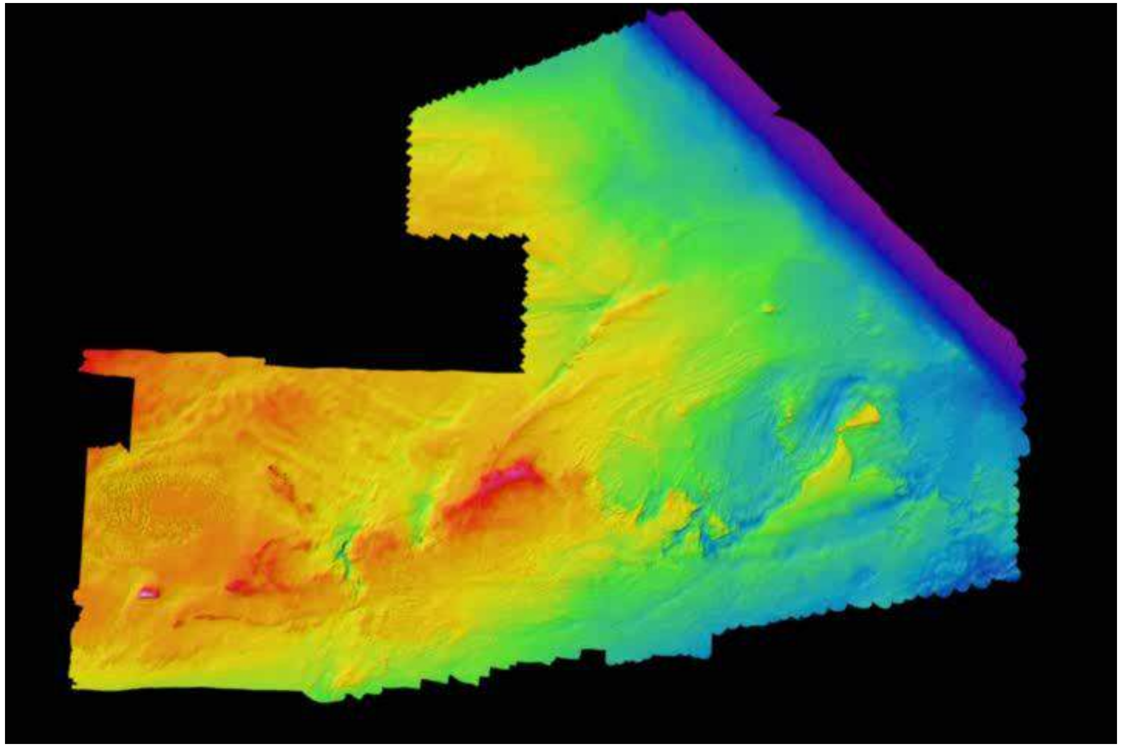
- Scale and sediment heterogeneity very important in both signal- and image-based classification methods

- Need to consider processing parameters on a site-by-site basis, and select processing settings based on known information about the site

- Ground-truthing is crucial!

- Software and processing for backscatter still evolving rapidly – staying abreast of developments can be challenging…

St Anns Bank MPA – OBIA Case Study

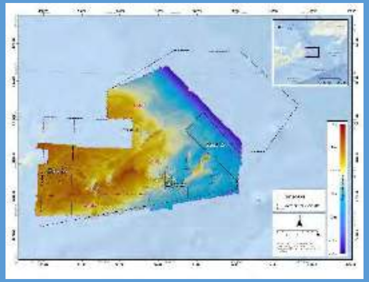


- Selected from shortlist of candidate areas following a 7 month public consultation period 2009-2010
- Chosen because of its natural features and high diversity of fish species
- Important habitat for species at risk (e.g., Atlantic wolffish), depleted species (e.g., Atlantic cod), and several commercial species that are at low biomass levels (American plaice, white hake, redfish, witch flounder)
- 2,800 km^2 of marine habitat
- Water depth: 20 – 280m.



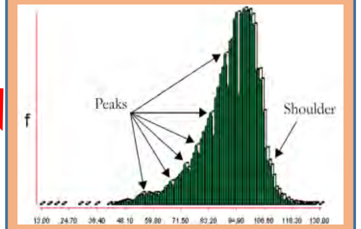
“Developing Methods for Benthic Habitat Mapping of MPAs in Atlantic Canada”

Bathymetry and bathymetry-derived data sets

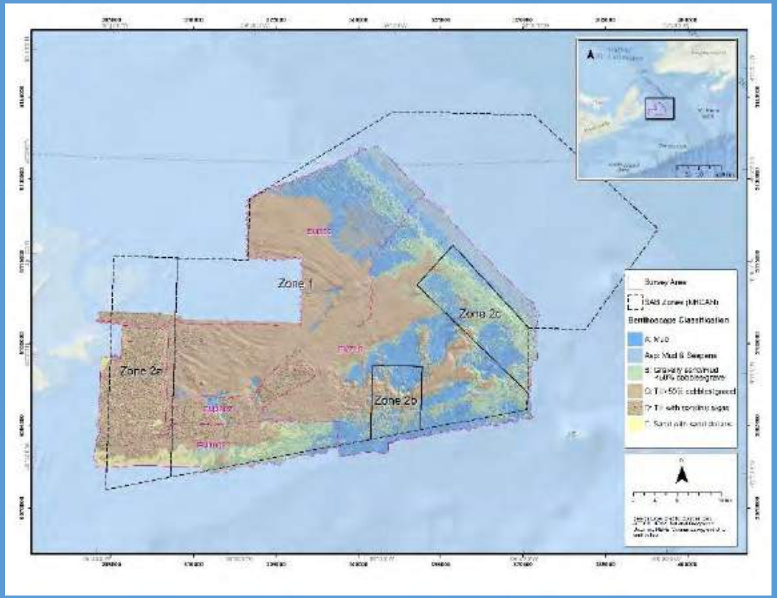


Backscatter

Acoustic segmentation method



Classified Map

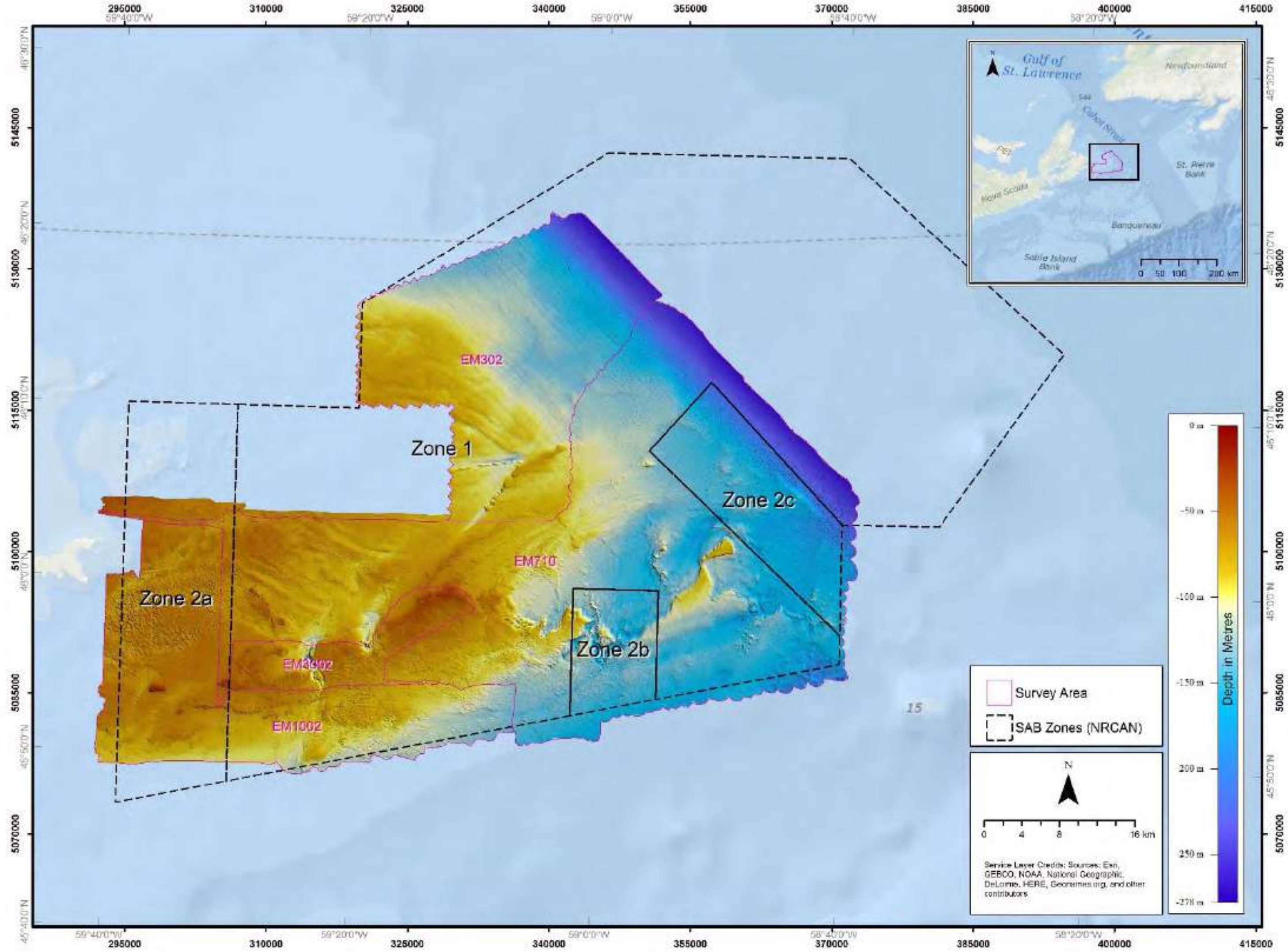


Ground-truthing (benthic photographs)

Ground-truthing Analysis
i.e. Photos classified into biophysical “benthoscape” classes

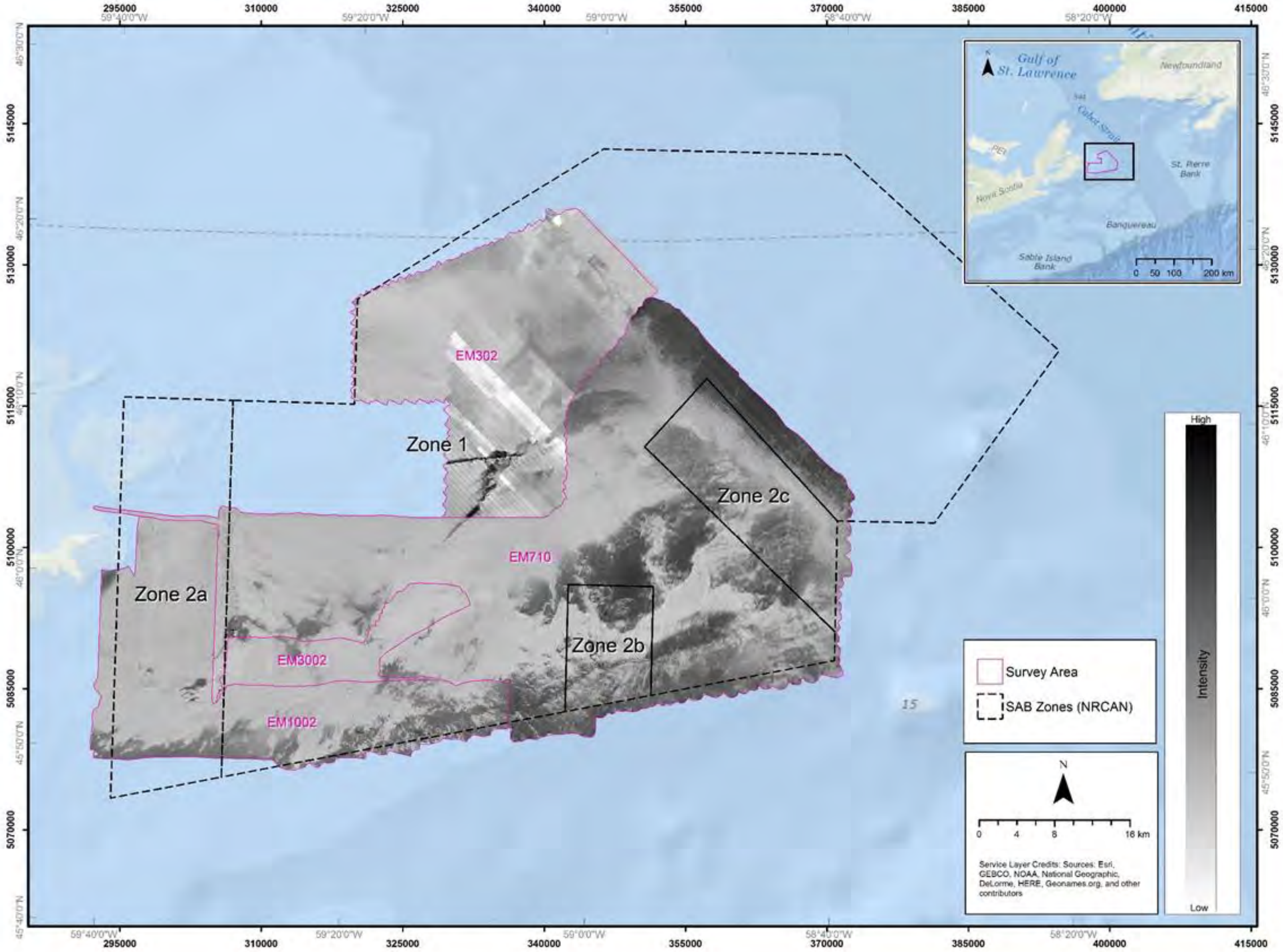
Brown et al. (2012) Multiple methods, maps, and management applications: Purpose made seafloor maps in support of ocean management. *Journal of Sea Research* (72): 1-13. doi:10.1016/j.seares.2012.04.009

St Anns Bank MPA – Case Study



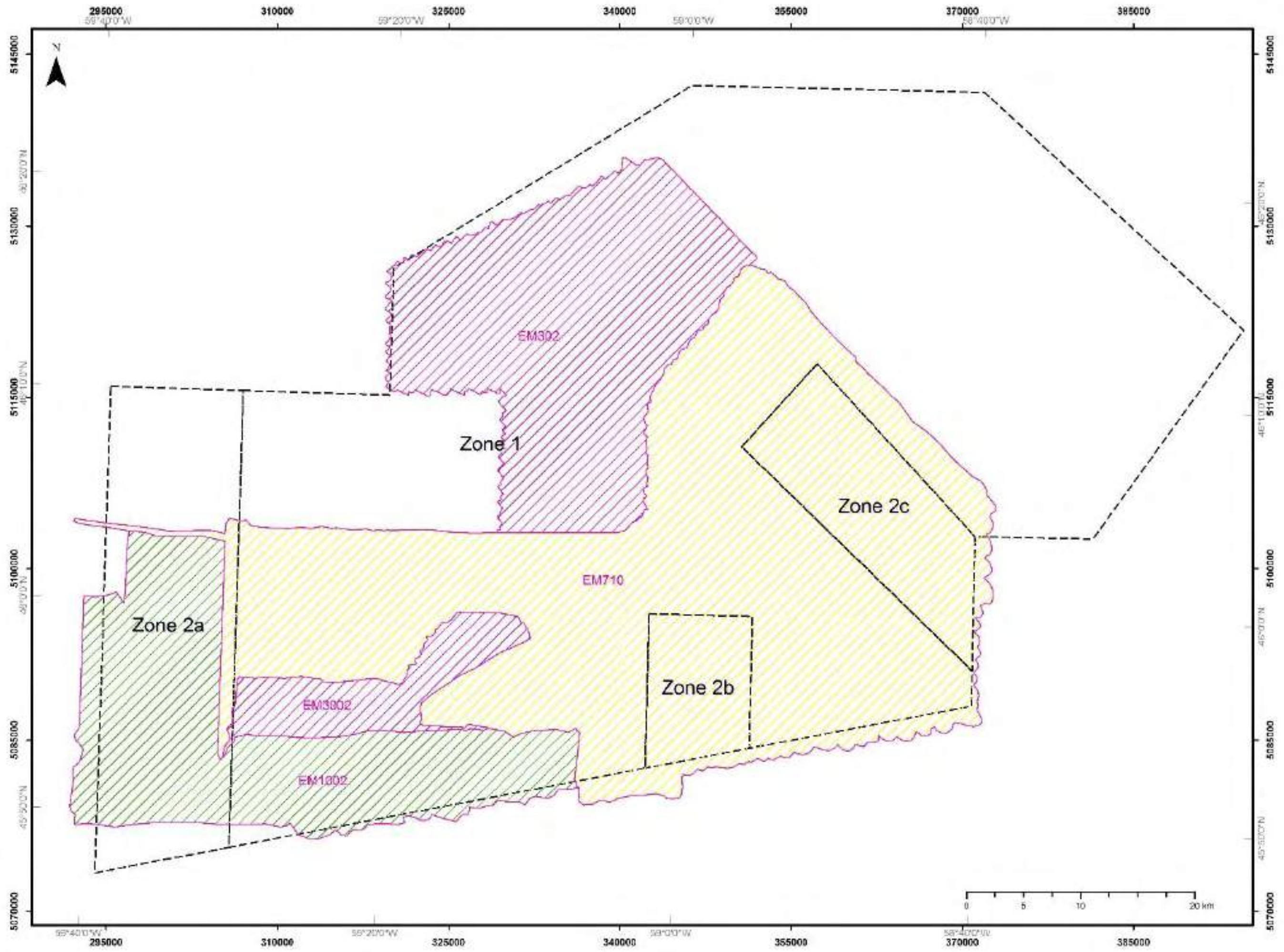
Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

St Anns Bank MPA – Case Study



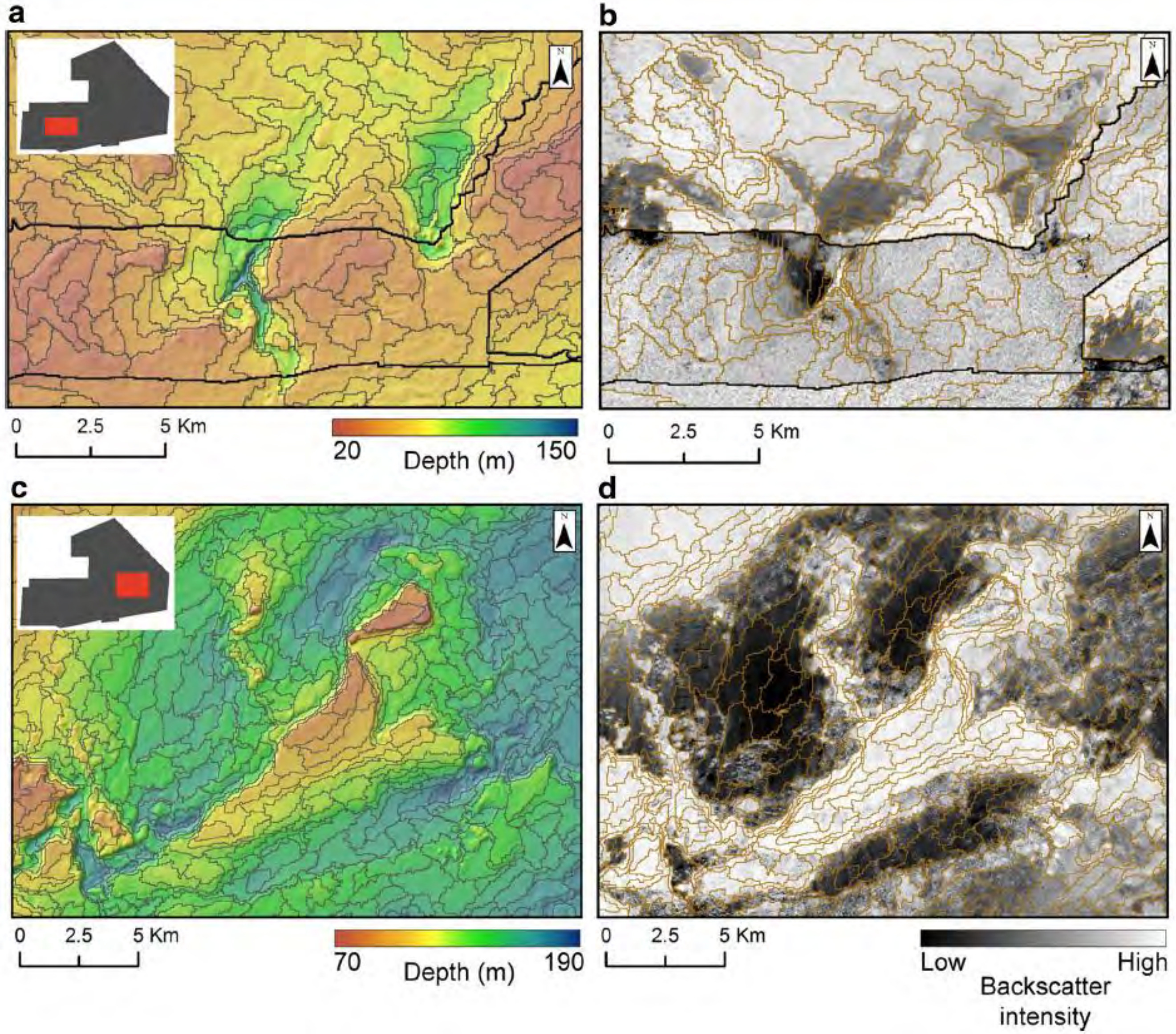
Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

St Anns Bank MPA – Case Study



Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

Object Based Image Analysis (OBIA)

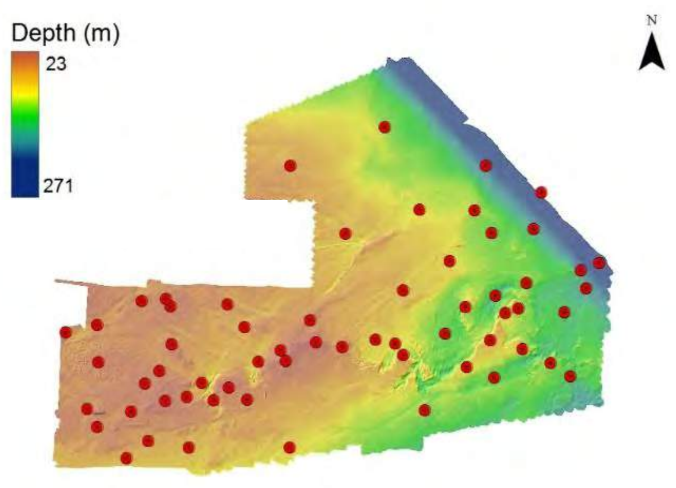


Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

St Anns Bank MPA – Case Study

● **Ground-truthing stations**

4214 images

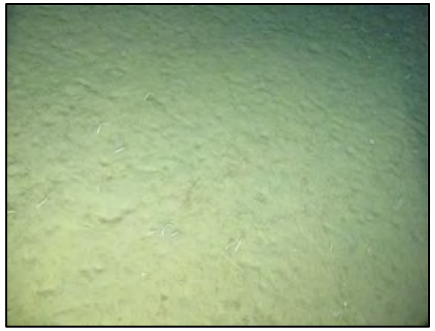


The benthoscape approach to guide supervised classification

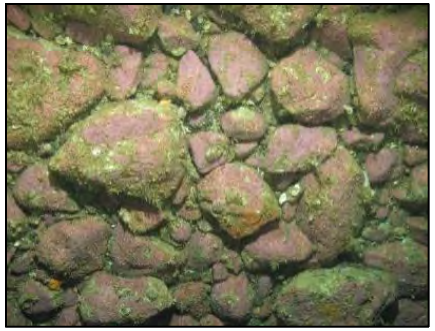
Till
(> 50% cover pebbles/gravel)

Gravelly sand/mud
(< 50% cover pebbles/gravel)

Mud

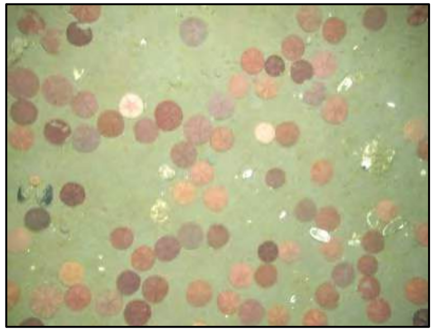


Till (with coralline algae)



Gravel with crinoids

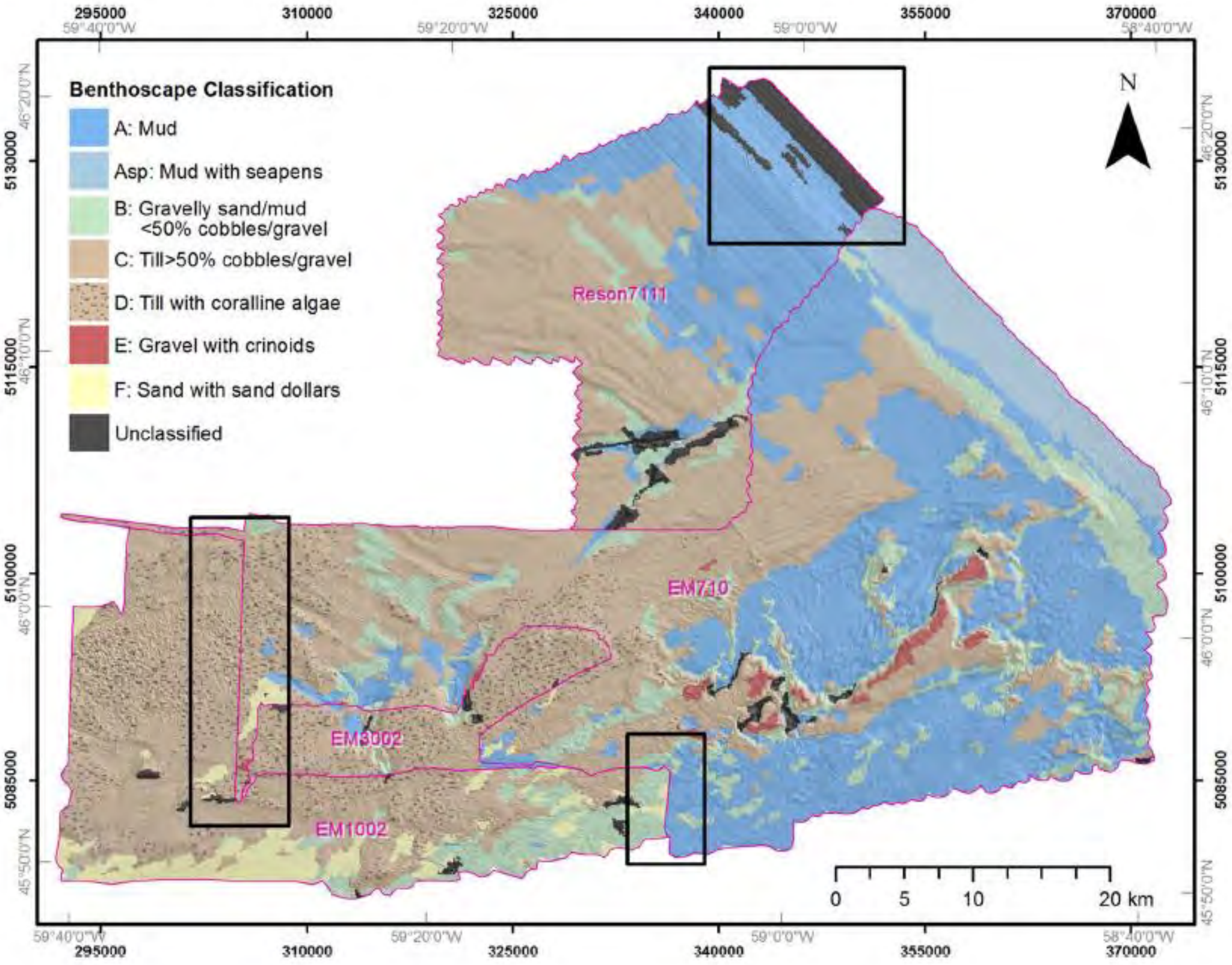
Sand with sand dollars



Mud with seapens

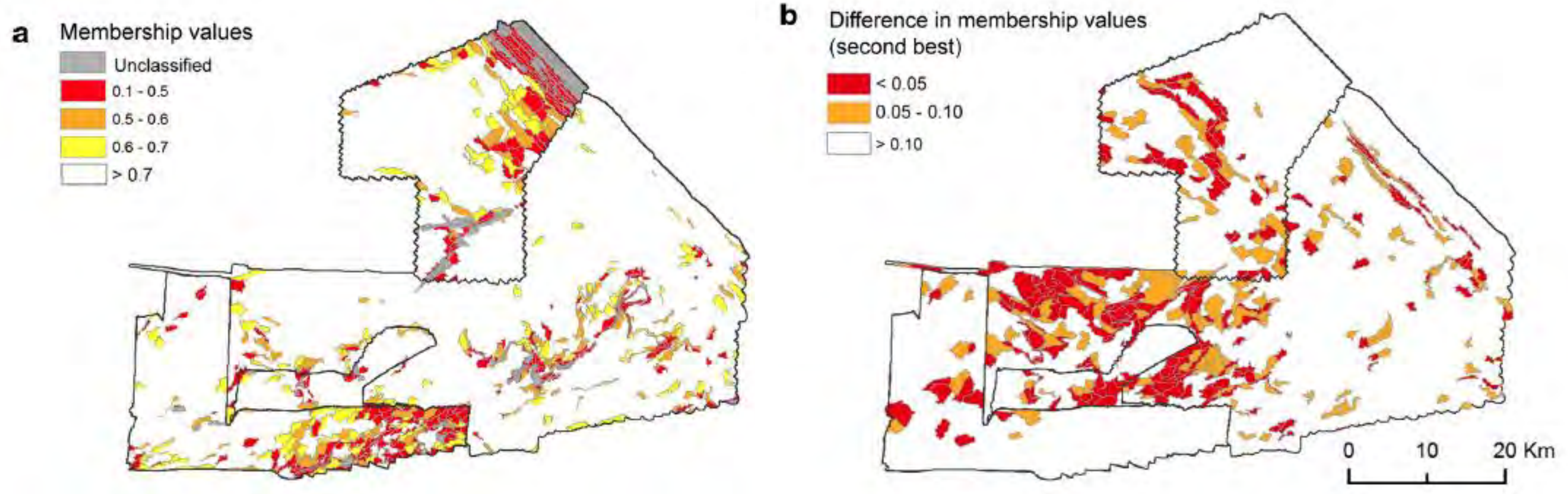
Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

Object Based Image Analysis (OBIA)
Initial benthoscape maps combined from the 4 non-overlapping MBES surveys



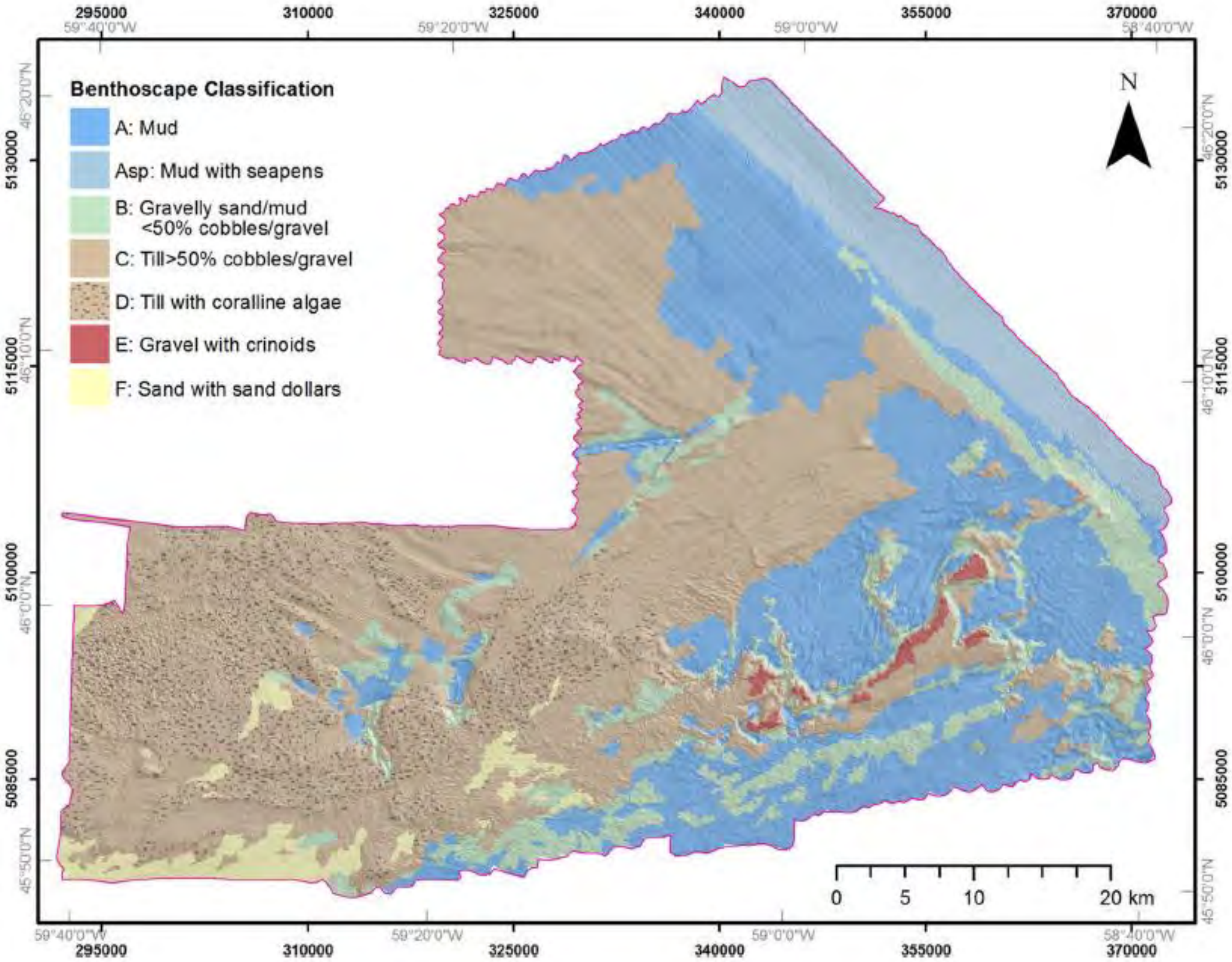
Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

Object Based Image Analysis (OBIA)
Summary of confusion based on membership values in the initial benthoscape map.



Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

Object Based Image Analysis (OBIA)
Final Benthoscape Map



Lacharité, M., Brown, C.J., Gazzola, V. (2017) Multisource multibeam backscatter data: developing a strategy for the production of benthic habitat maps using semi-automated seafloor classification methods. *Marine Geophysical Researches* 1-16. https://doi.org/10.1007/s11001-017-9331-6

Science of Remote Sensing 3 (2021) 100015

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journal homepage: www.journals.elsevier.com/science-of-remote-sensing

Full Length Article

Assessing the use of harmonized multisource backscatter data for thematic benthic habitat mapping

Benjamin Misiuk [a,*], Myriam Lacharité [b], Craig J. Brown [a]

[a] Department of Oceanography, Dalhousie University, 6299 South St., Halifax, NS, B3H 4R2, Canada
[b] Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, TAS, 7001, Australia

ARTICLE INFO

Keywords:
Benthic habitat mapping
Multibeam echosounder
Backscatter
Seabed mapping
Benthoscape
Object-based image analysis

ABSTRACT

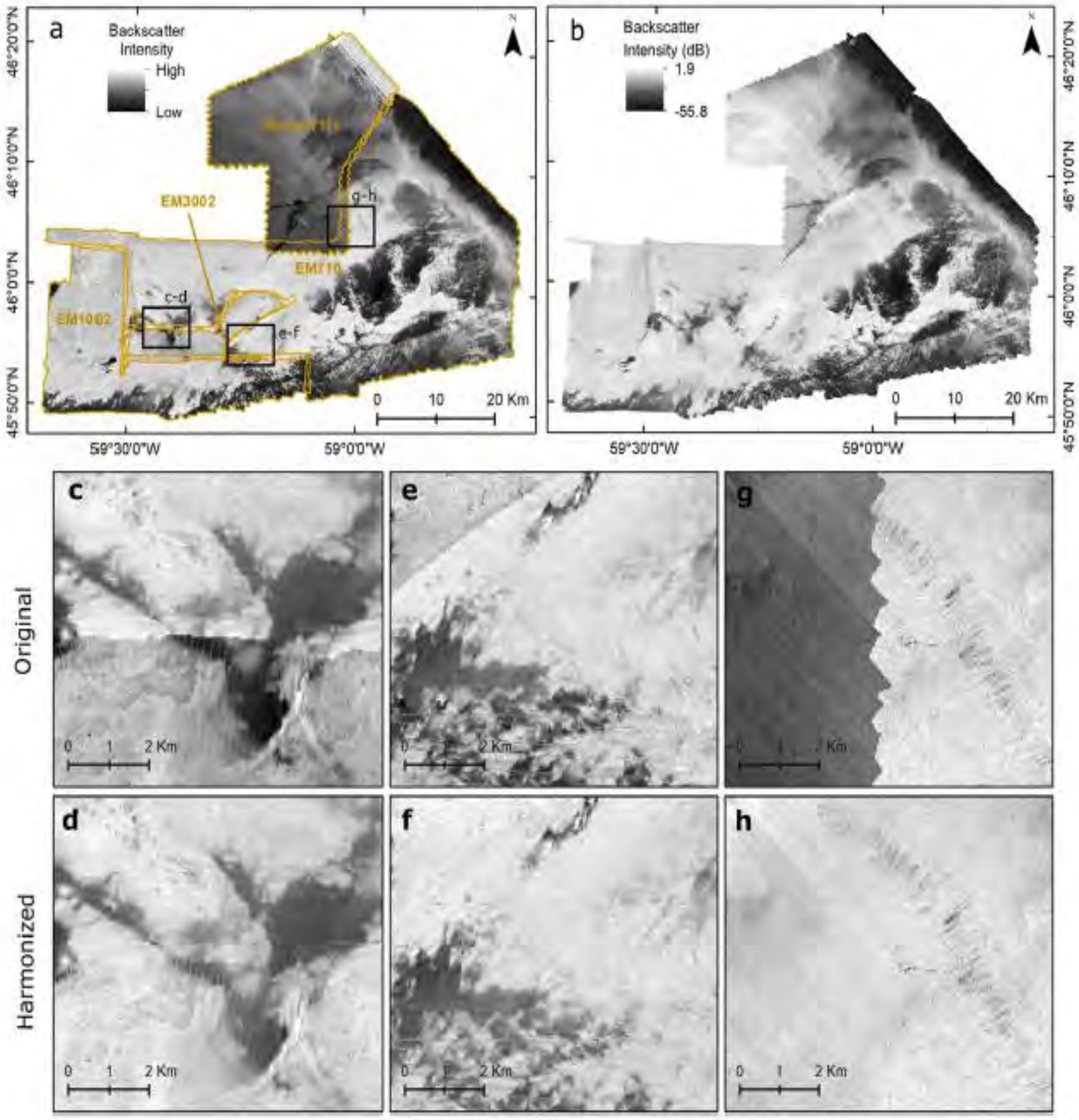
Legacy seabed mapping datasets are increasingly common as the need for detailed seabed information is recognized. Acoustic backscatter data from multibeam echosounders can be a useful surrogate for seabed properties and are commonly used for benthic habitat mapping. Legacy backscatter data, however, are often uncalibrated, rendering measurements relative to a given survey and complicating the use of multisource acoustic datasets for habitat mapping. Recently, 'bulk shift' methods have been proposed to harmonize multisource backscatter layers that overlap spatially, but their application to benthic habitat mapping has not been evaluated. Here, four relative backscatter datasets at the St. Anns Bank Marine Protected Area were harmonized to produce a single continuous surface spanning the extent of available bathymetric data. The harmonized surface was used as a predictor in a benthic habitat ('benthoscape') classification, which was compared to previous results using individual backscatter coverages. Results were similar to those obtained previously, but the harmonized surface provided increased class discrimination, fewer unclassified areas, and predictions that cross dataset boundaries – eliminating the need for manual reclassification by the user. While this generally increases the efficiency and repeatability of the analysis and the useability of the data, we caution that an inappropriate harmonization model is a potential source of error for the classification.

1. Introduction

Acoustic remote sensing of the seafloor has been increasingly adopted over the past three decades for a wide variety of applications, including geological mapping (e.g., Ferrini and Flood, 2006; Hughes Clarke et al., 1996; Misiuk et al., 2018; Plets et al., 2012; Stephens and Diesing, 2014; Todd et al., 1999), marine archaeology (e.g., Passaro et al., 2013; Plets et al., 2011), seafloor environmental change monitoring (e.g., Montereale-Gavazzi et al., 2018; Montereale-Gavazzi et al., 2019; Snellen et al., 2019; van Rein et al., 2011) and benthic habitat studies (e.g., Boswarva

seafloor, and seafloor composition, which can be inferred from the signal of the returning echo – a property referred to as acoustic backscatter intensity (De Falco et al., 2010; Lamarche and Lurton, 2018; Lamarche et al., 2011; Lurton, 2010).

Acoustic backscatter is influenced by seafloor geophysical properties, including sediment grain size, hardness, roughness, and biotic elements (Brown and Blondel, 2009; Lamarche and Lurton, 2018). Sediment-acoustic relationships from MBES are complex due to the influence of angular dependency of the signal intensity caused by ensonification geometry across the MBES swath (Fonseca et al., 2009; Lamarche

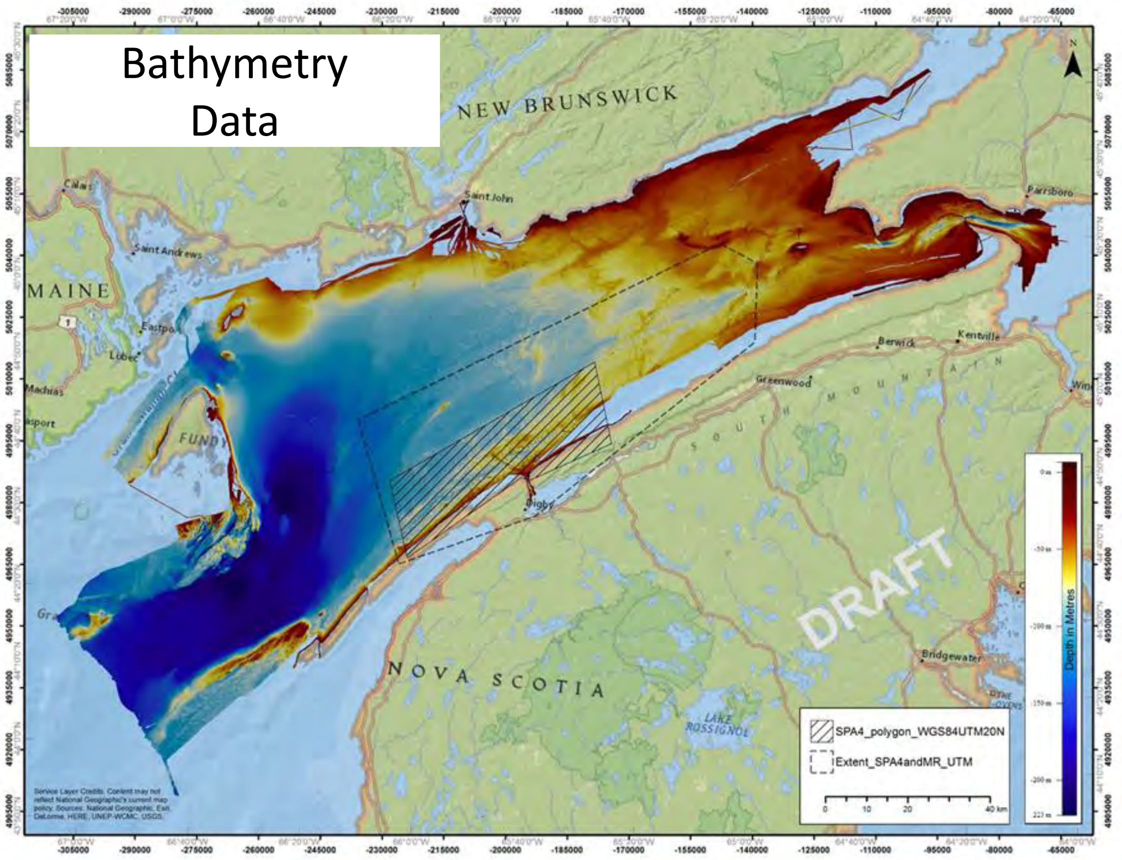


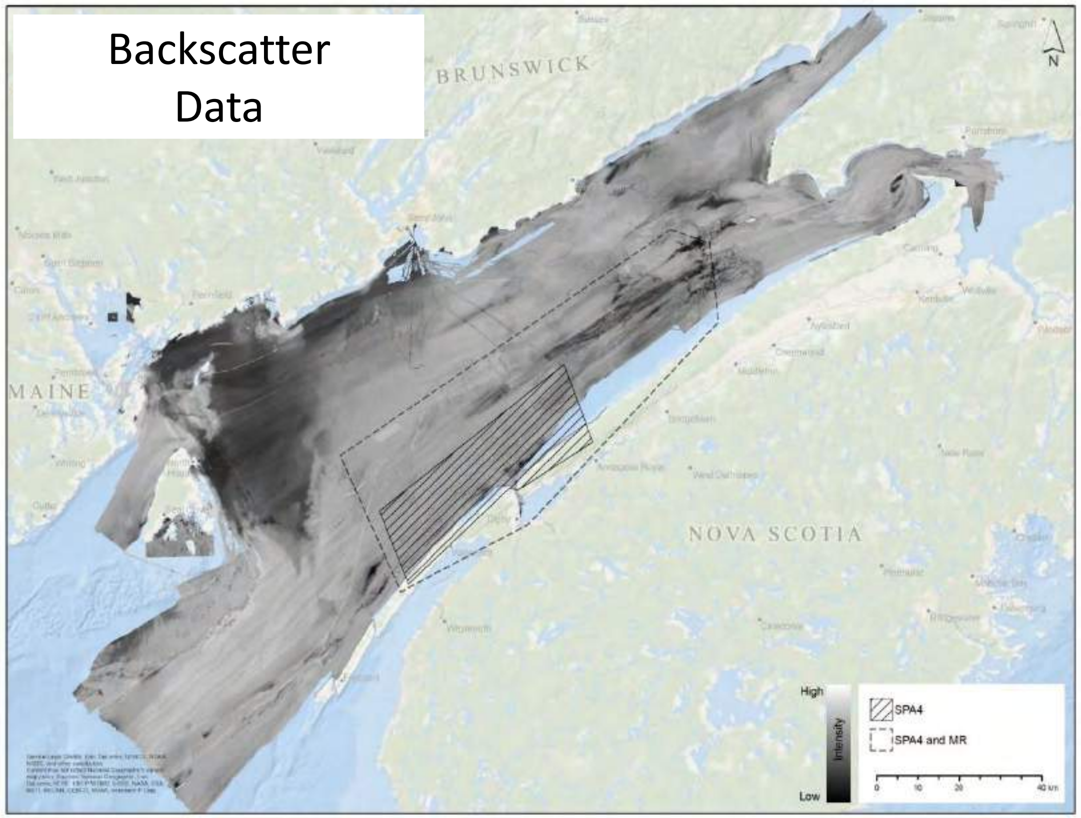
Misiuk et al. 2021 *Science of. Remote Sensing*, 3

NSCC AORG Projects: Data integration and map production

Fisheries mapping

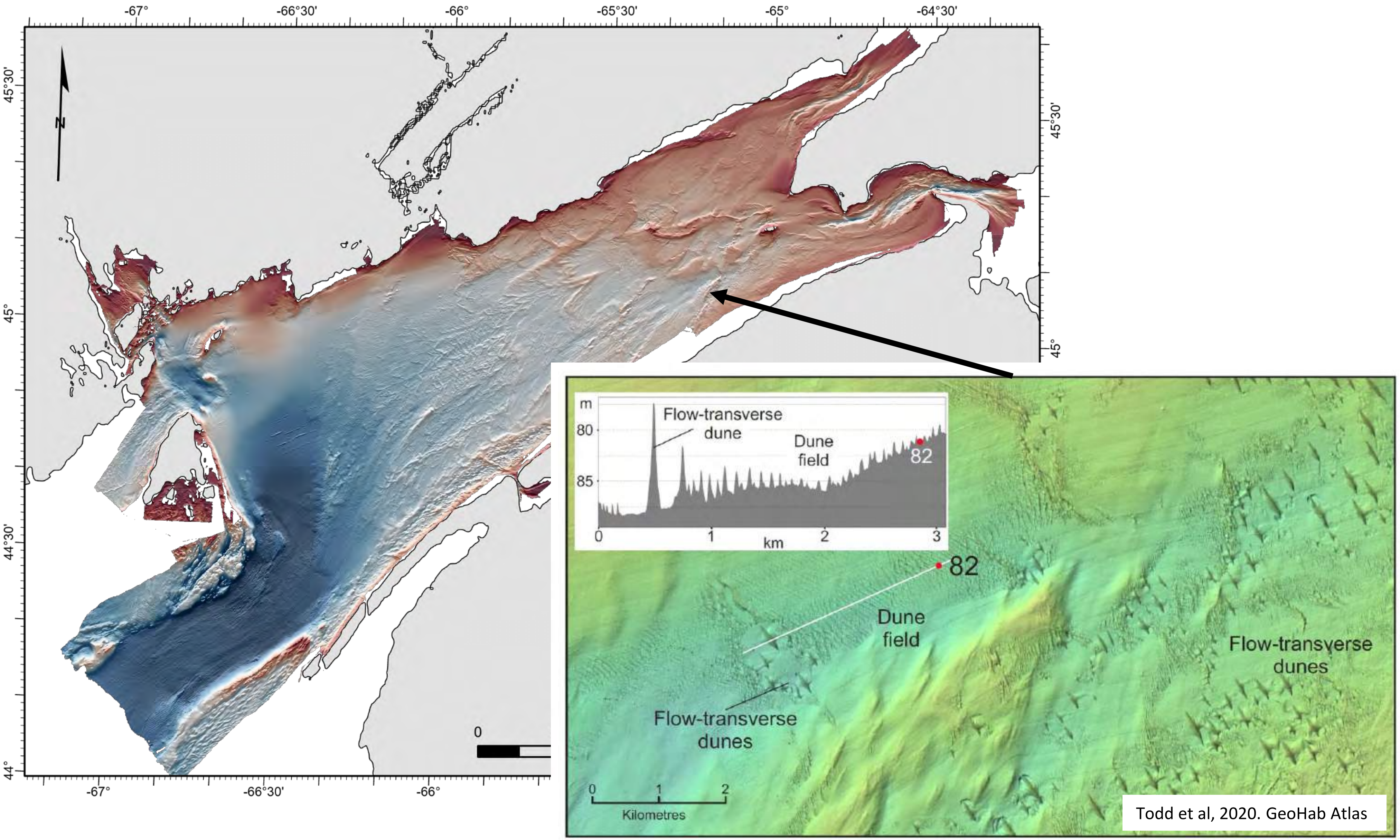
"Hydrography to biology: Developing integrated approaches for benthic habitat mapping"





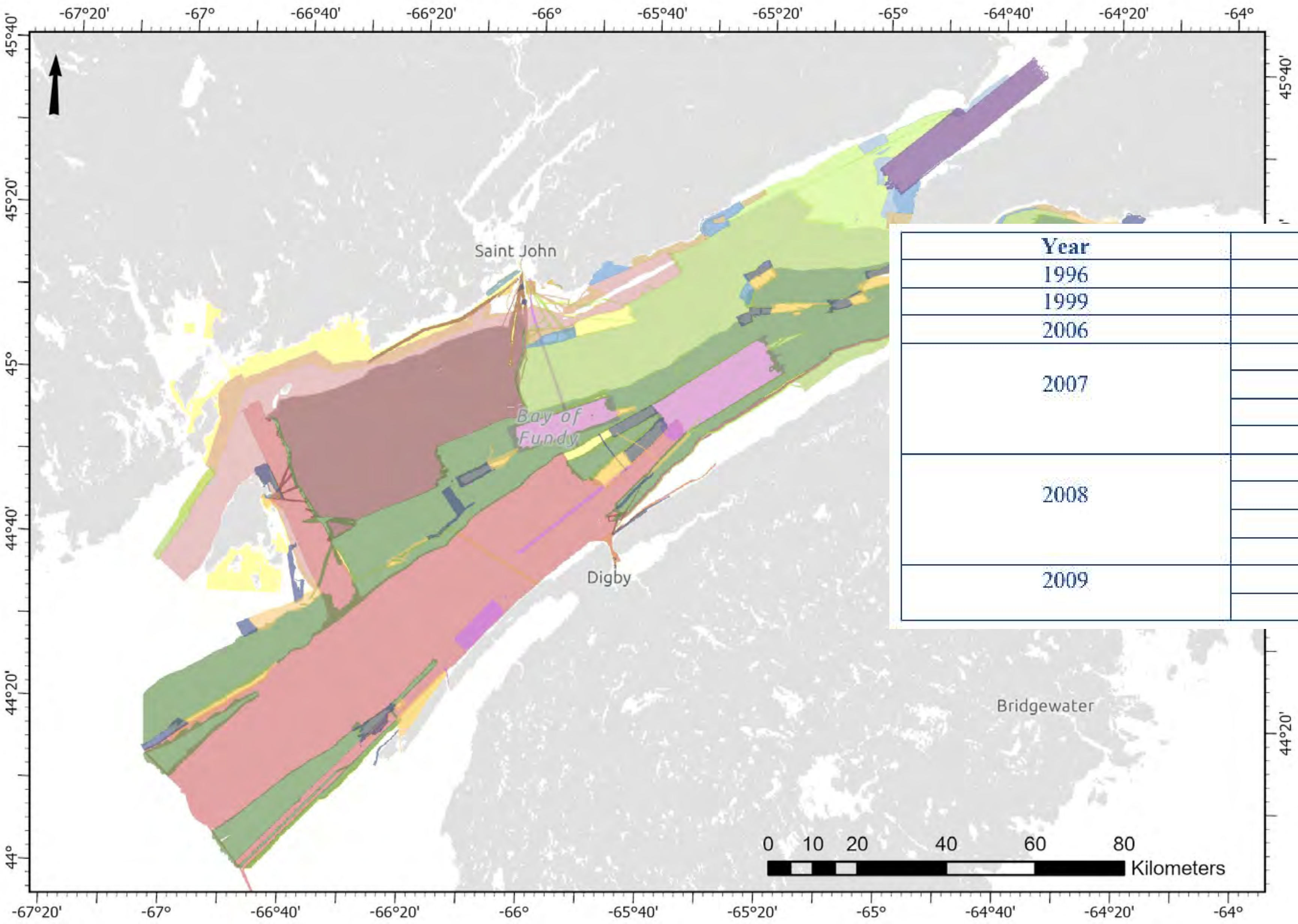
nscc | UNB EST. 1785 UNIVERSITY OF NEW BRUNSWICK | Fisheries and Oceans Canada | COMREN Canadian Ocean Mapping Research & Education Network / RéCREH Réseau Canadien de Recherche et d'Enseignement en Hydrographie

Multibeam bathymetry – legacy, multisource data sets



Todd et al, 2020. GeoHab Atlas

Multibeam bathymetry – legacy, multisource data sets

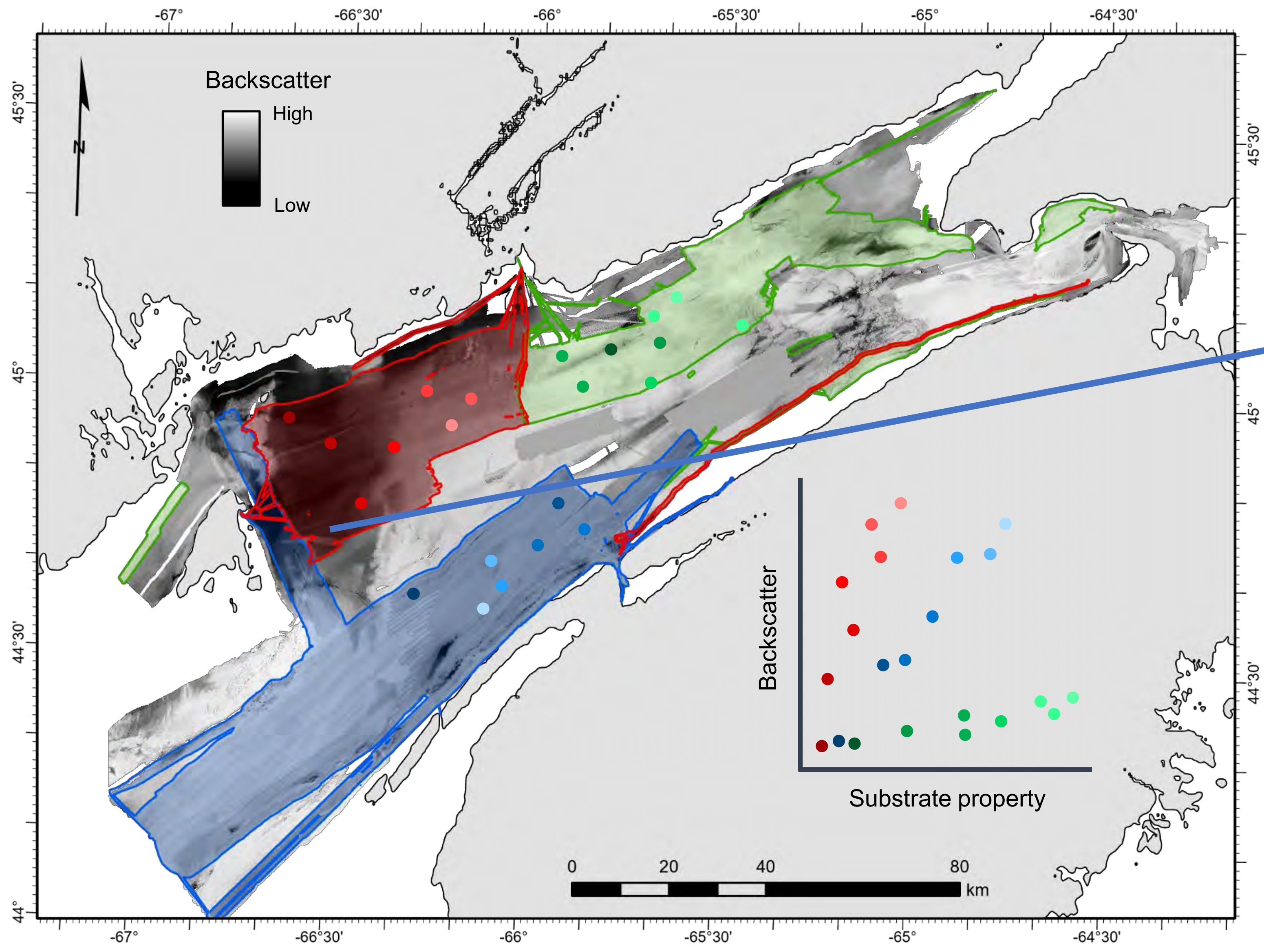


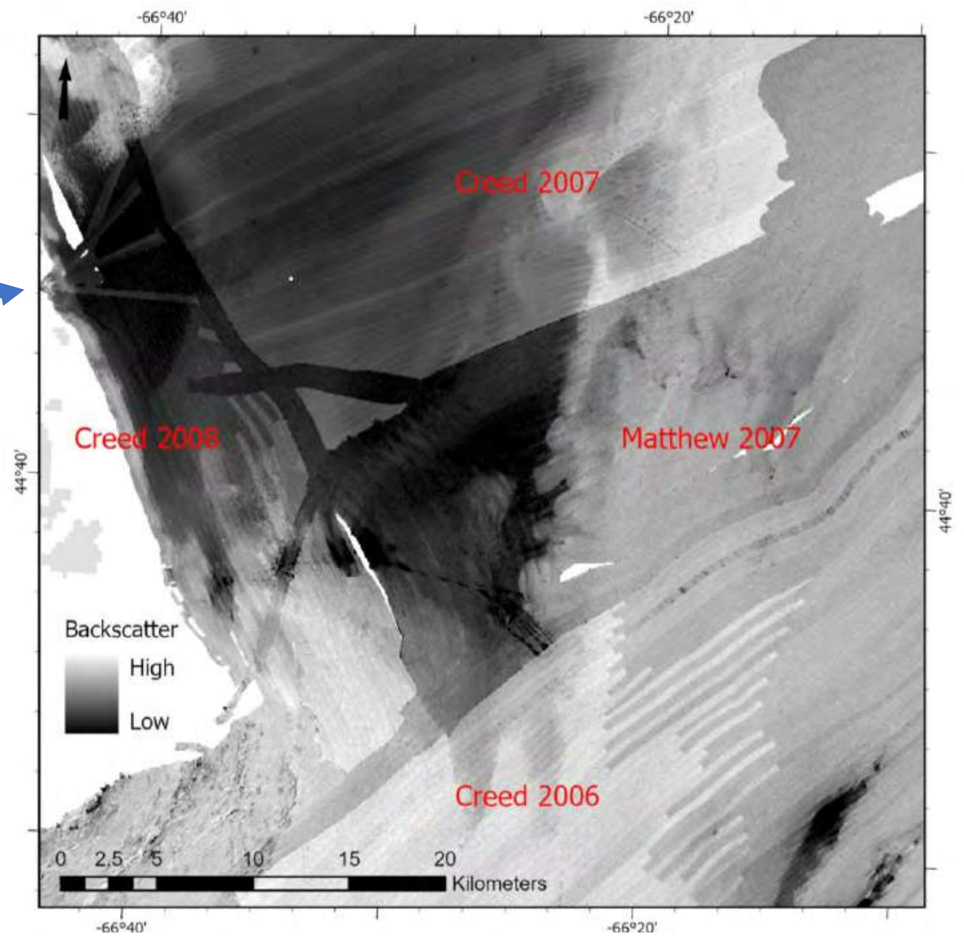
- 13 individual data layers
- 4 operating systems
- 13-year period

Year	Vessel	Sensor
1996	Creed	EM1000
1999	Creed	EM1000
2006	Creed	EM1002
2007	Creed	EM1002
	Matthew	EM710
	Pipit	EM3002
	Plover	EM3002
2008	Creed	EM1002
	Matthew	EM710
	Pipit	EM3002
	Plover	EM3002
2009	Matthew	EM710
	Plover	EM3002

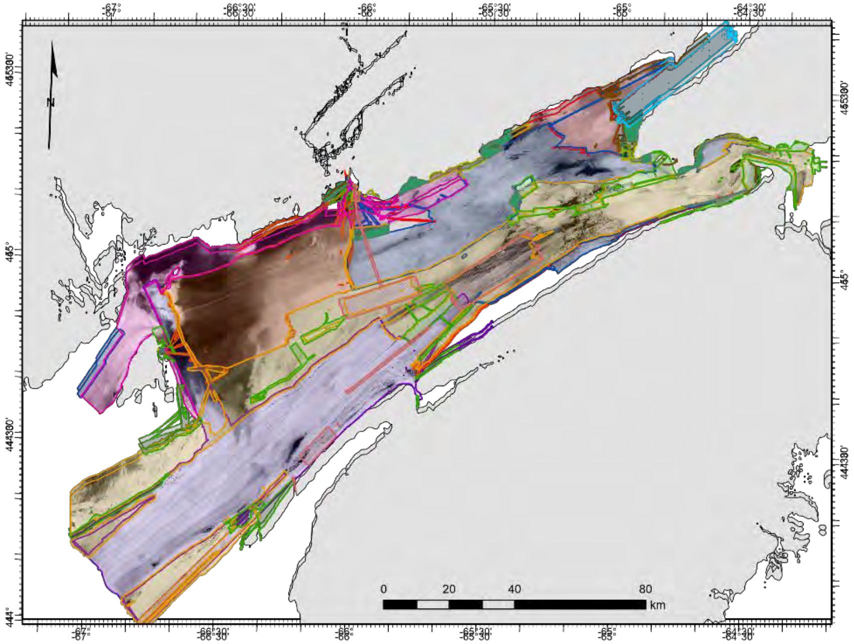
Sensor	Freq.
EM3002	300 kHz
EM1000	95 kHz
EM1002	93 & 98 kHz
EM710	71-97 kHz

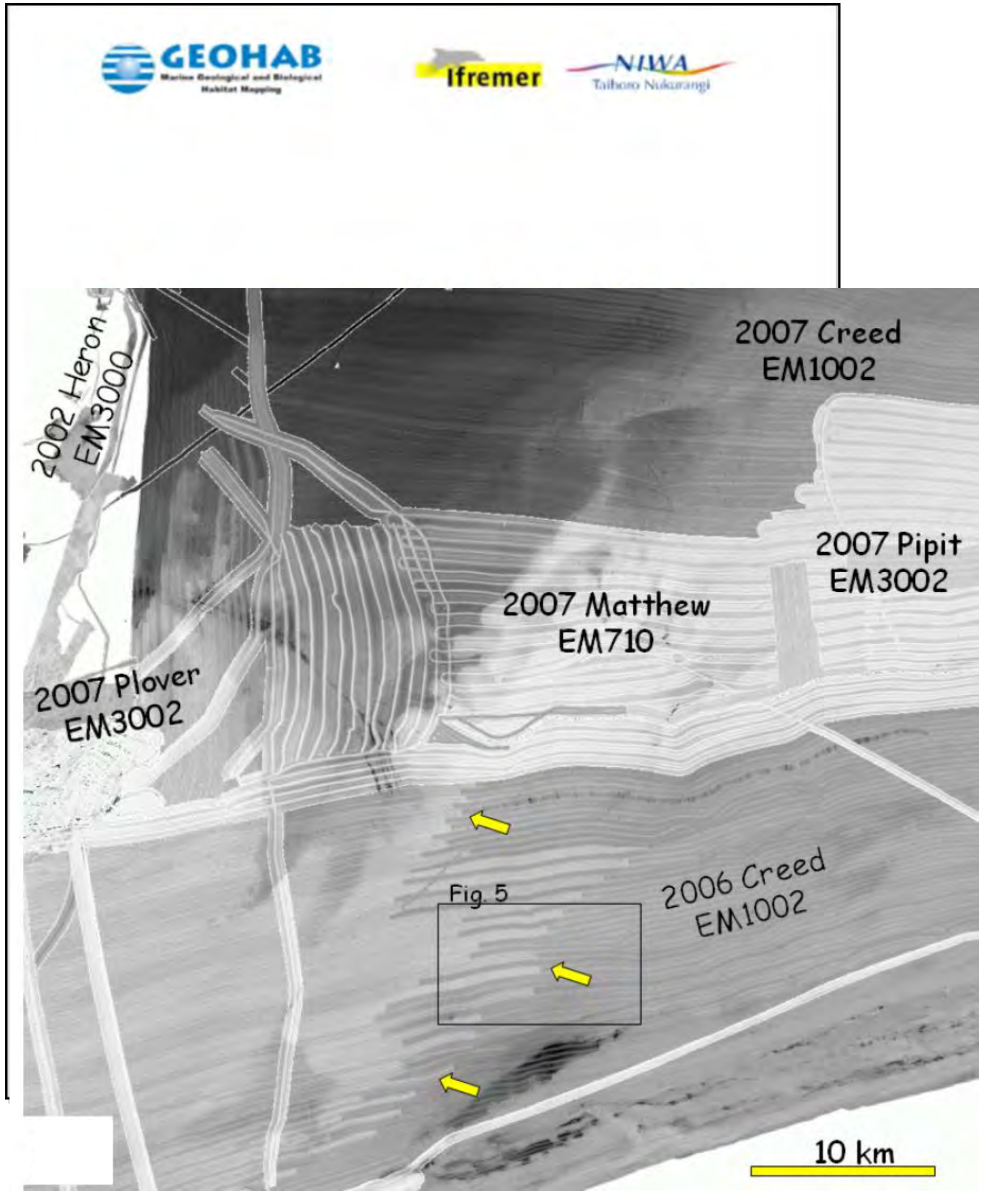
Multibeam bathymetry – legacy, multisource data sets

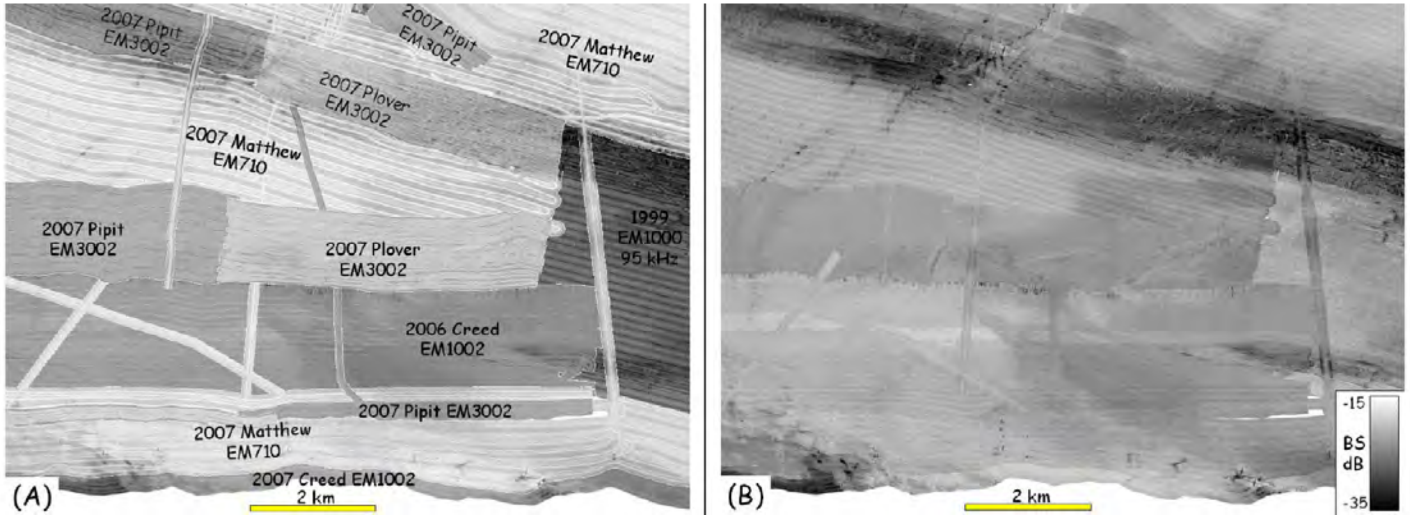




Legacy, multisource multibeam backscatter







Hughes Clarke (2008). Proceedings of the Canadian Hydrographic Conference and National Surveyors Conference

Legacy, multisource multibeam backscatter

remote sensing

MDPI

Article

Harmonizing Multi-Source Sonar Backscatter Datasets for Seabed Mapping Using Bulk Shift Approaches

Benjamin Misiuk [1,*], Craig J. Brown [2], Katleen Robert [1] and Myriam Lacharité [3]

1 School of Ocean Technology, Fisheries and Marine Institute of Memorial University of Newfoundland, St. John's, NL A1C 5R3, Canada; katleen.robert@mi.mun.ca
2 Department of Oceanography, Dalhousie University, Halifax, NS B5H 4R2, Canada; craig.brown@dal.ca
3 Institute for Marine and Antarctic Studies, University of Tasmania, Hobart 7053, Australia; myriam.lacharite@utas.edu.au
* Correspondence: bmisiuk@mun.ca; Tel.: +1-709-778-0584

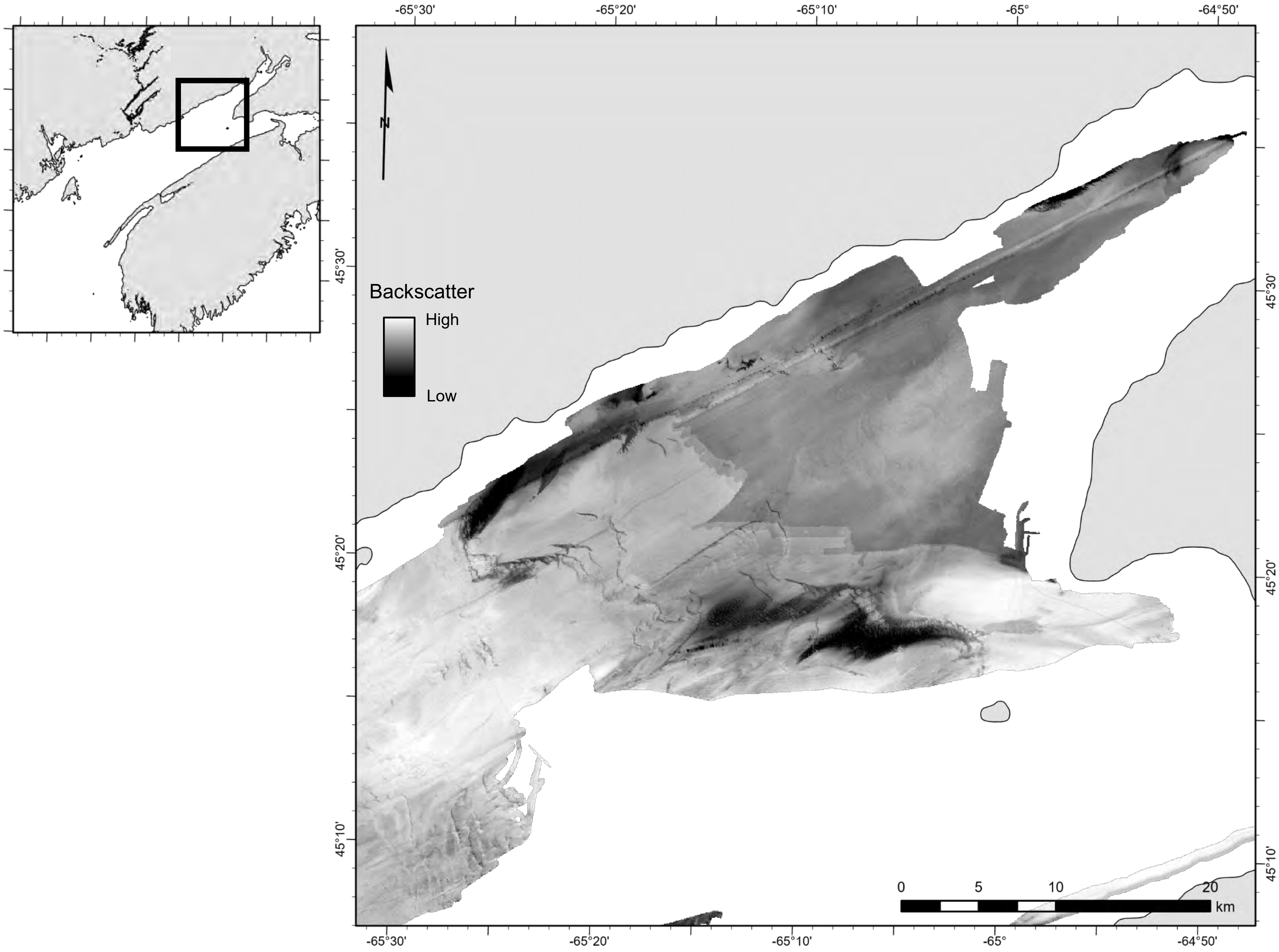
Received: 20 January 2020; Accepted: 8 February 2020; Published: 11 February 2020

check for updates

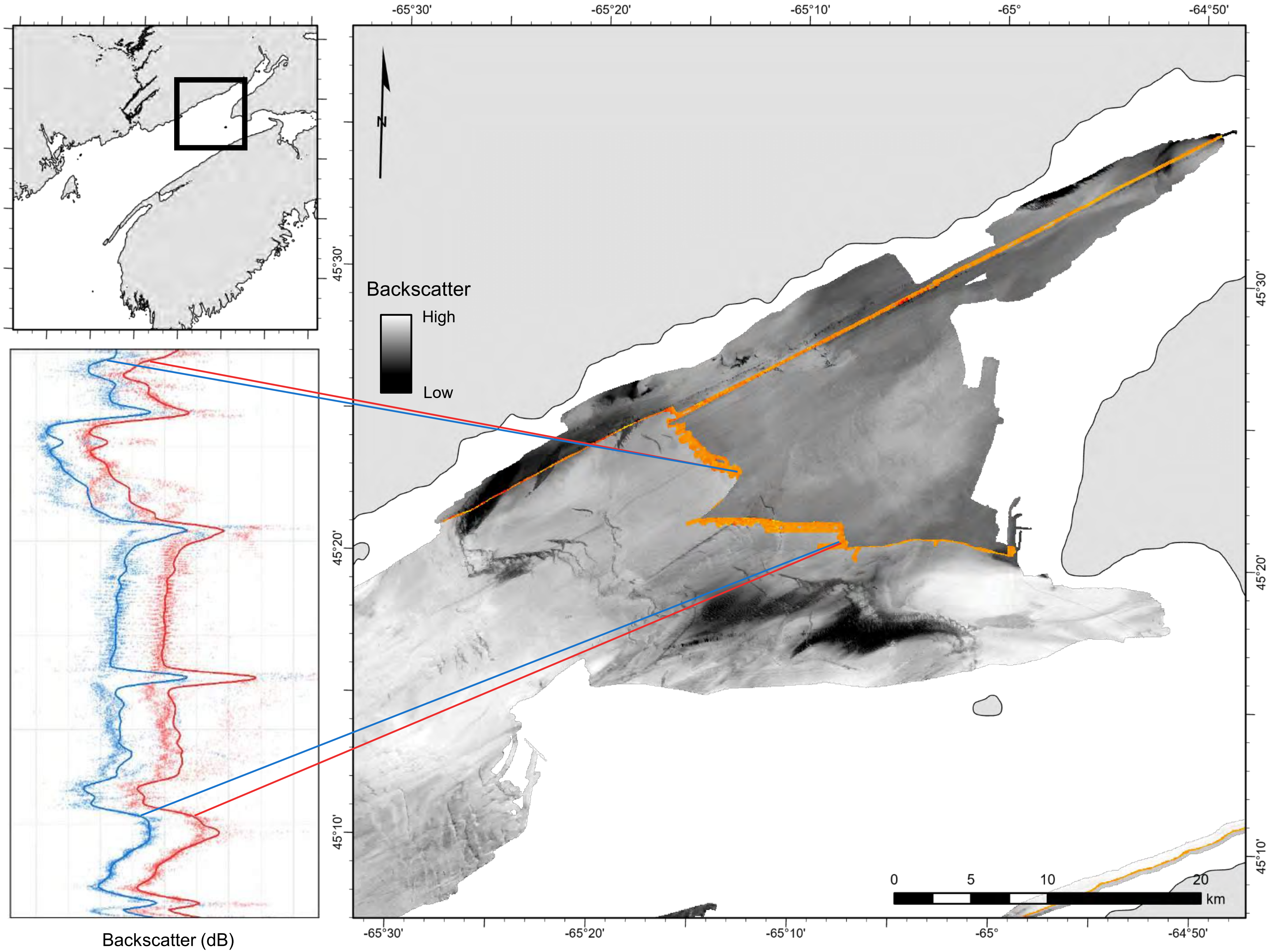
Abstract: The development of multibeam echosounders (MBES) as a seabed mapping tool has resulted in the widespread uptake of backscatter intensity as an indicator of seabed substrate properties. Though increasingly common, the lack of standard calibration and the characteristics of individual sonars generally produce backscatter measurements that are relative to a given survey, presenting major challenges for seabed mapping in areas that comprise multiple MBES surveys. Here, we explore methods for backscatter dataset harmonization that leverage areas of mutual overlap between surveys for relative statistical calibration—referred to as "bulk shift" approaches. We use three multispectral MBES datasets to simulate the harmonization of backscatter collected over multiple years, and using multiple operating frequencies. Results suggest that relatively simple statistical models are adequate for bulk shift harmonization procedures, and that more flexible approaches may produce inconsistent results that risk statistical overfitting. While harmonizing datasets collected using the same operating frequency from separate surveys is generally feasible given reasonable temporal limitations, results suggest that the success at harmonizing datasets of different operating frequencies partly depends on the extent to which the frequencies differ. We recommend approaches and diagnostics for ensuring the quality of harmonized backscatter mosaics, and provide an R function for implementing the methods presented here.

Keywords: backscatter; multispectral; multibeam; echosounder; seabed mapping; benthic; habitat mapping

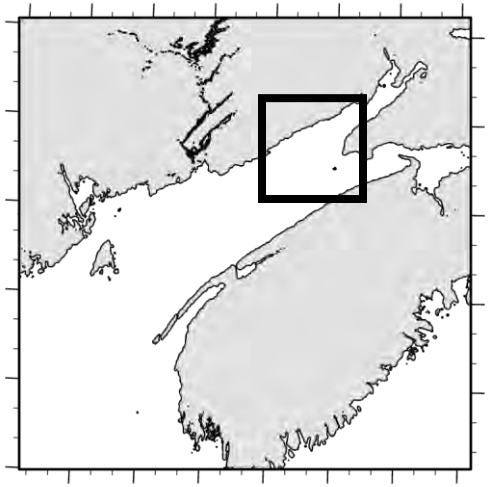
Misiuk et al. 2020. Remote Sensing, 12, 601.

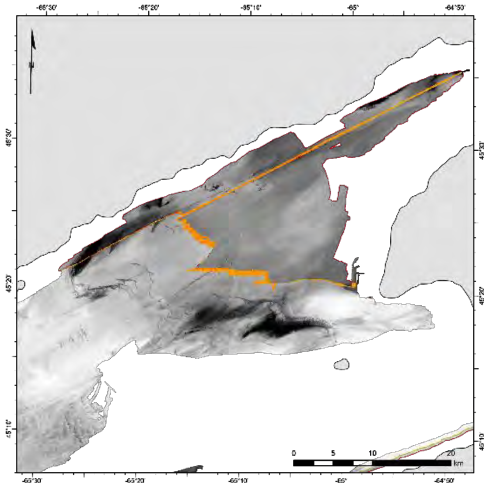


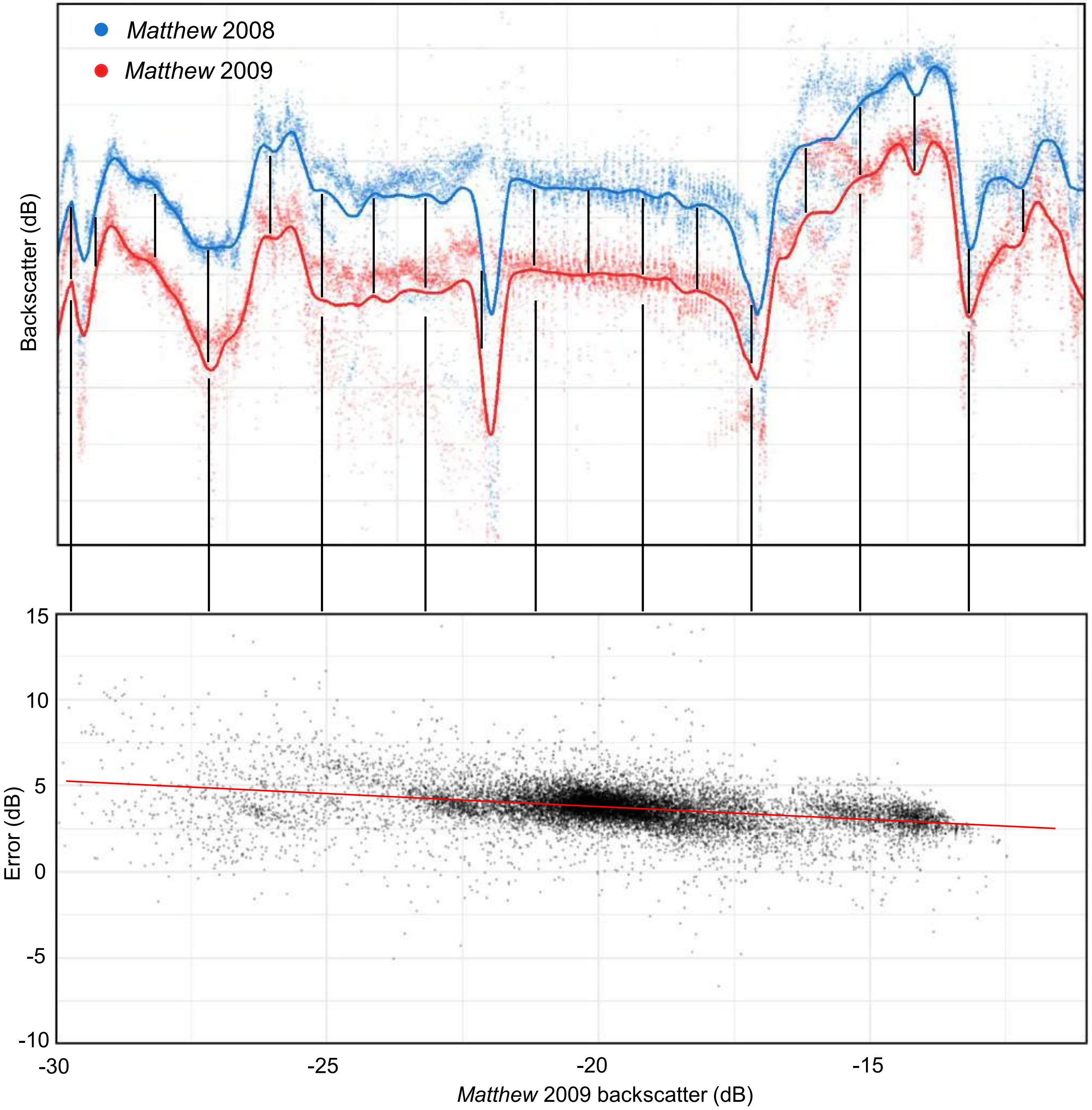
-65°30'
-65°20'
-65°10'
-65°
-64°50'
45°30'
45°20'
45°10'
N
Backscatter
High
Low
0
5
10
20
km



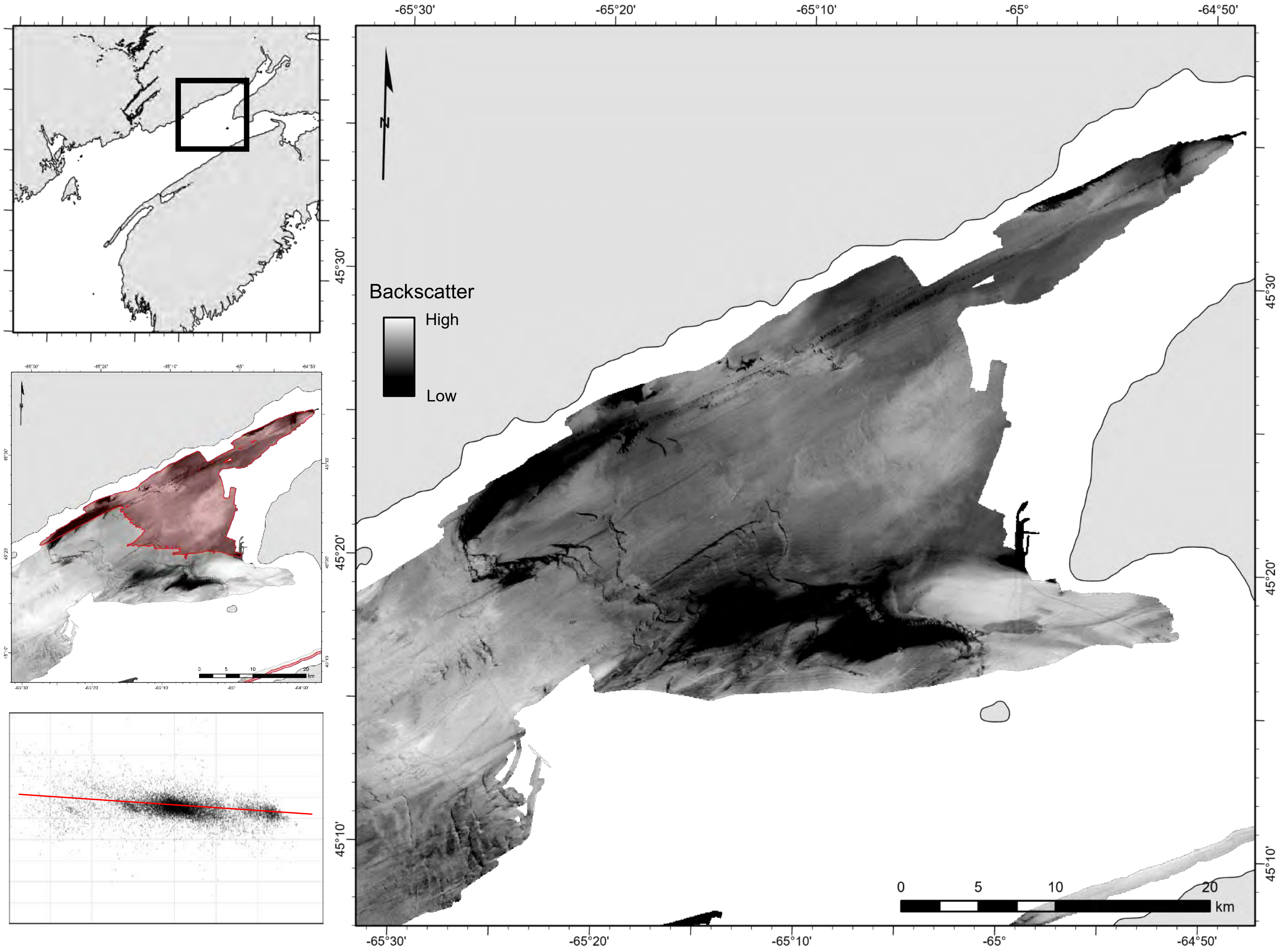
-65°30'
-65°20'
-65°10'
-65°
-64°50'
45°30'
45°20'
45°10'
N
Backscatter
High
Low
0
5
10
20
km
Backscatter (dB)



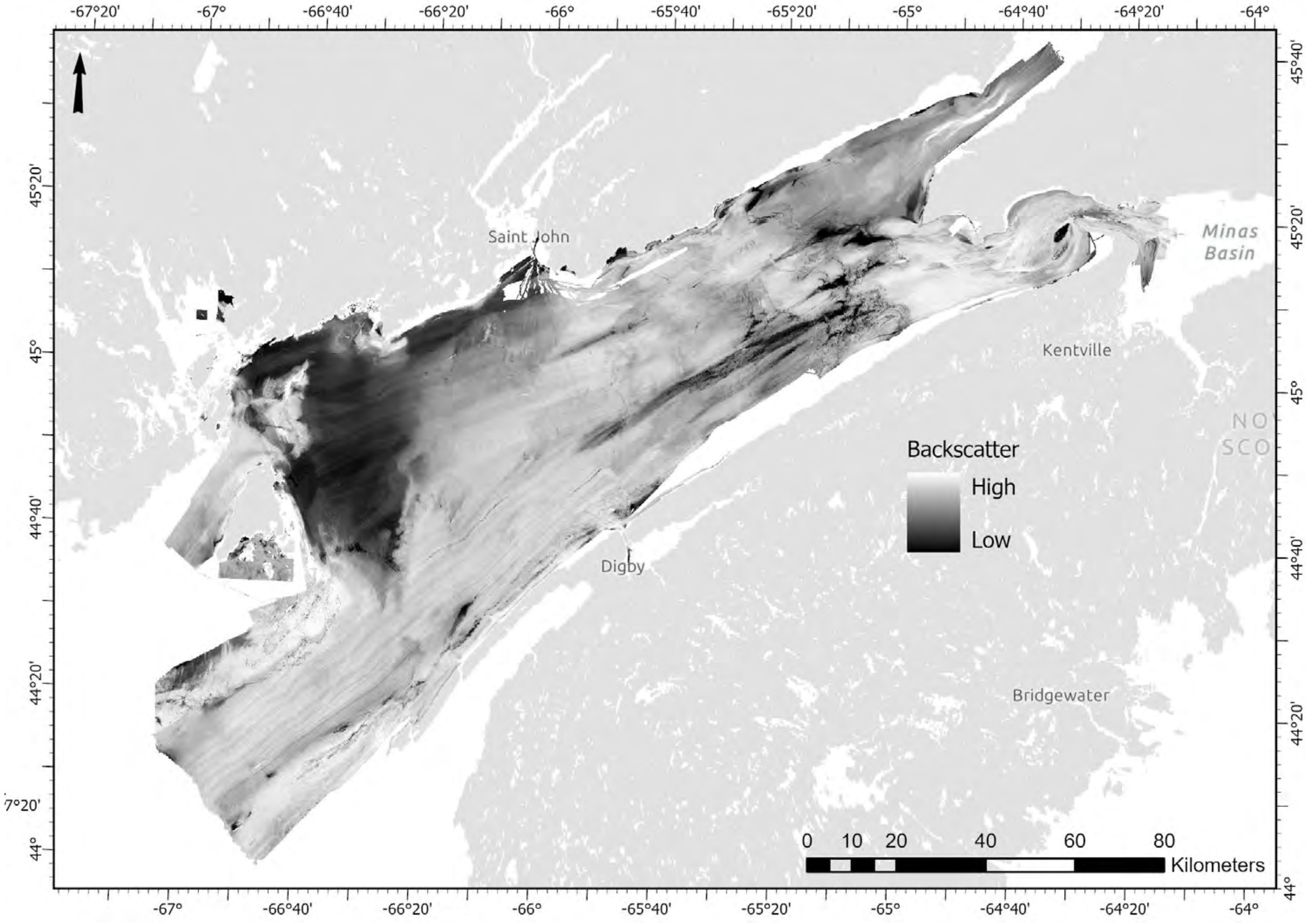




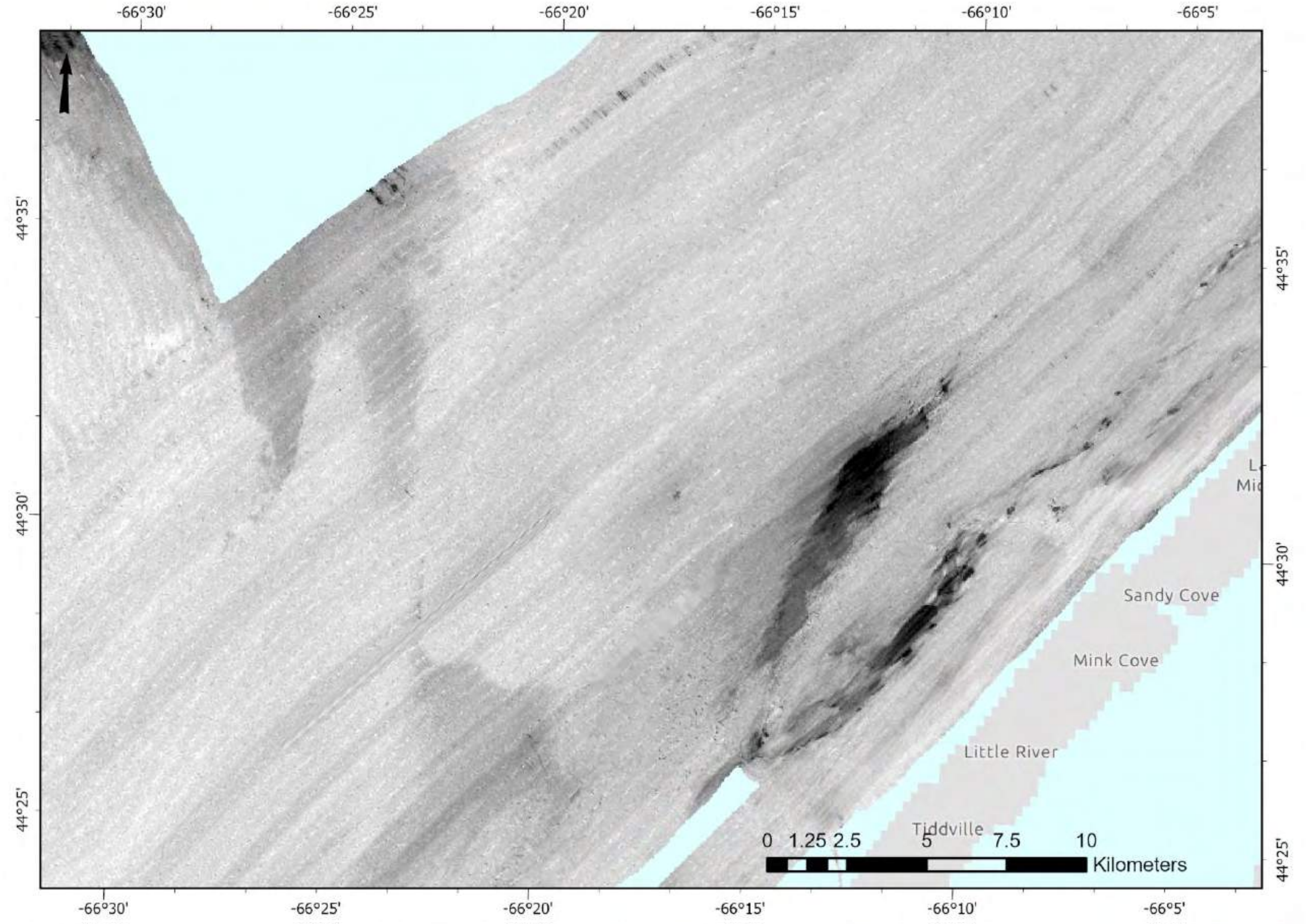
Matthew 2008
Matthew 2009
Backscatter (dB)
Error (dB)
15
10
5
0
-5
-10
-30
-25
-20
-15
Matthew 2009 backscatter (dB)



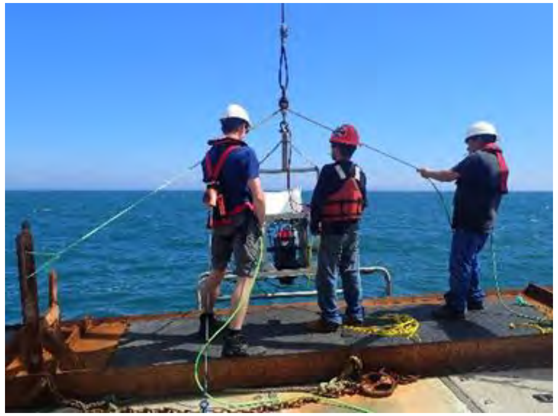
-65°30'
-65°20'
-65°10'
-65°
-64°50'
45°30'
45°20'
45°10'
N
Backscatter
High
Low
0
5
10
20
km



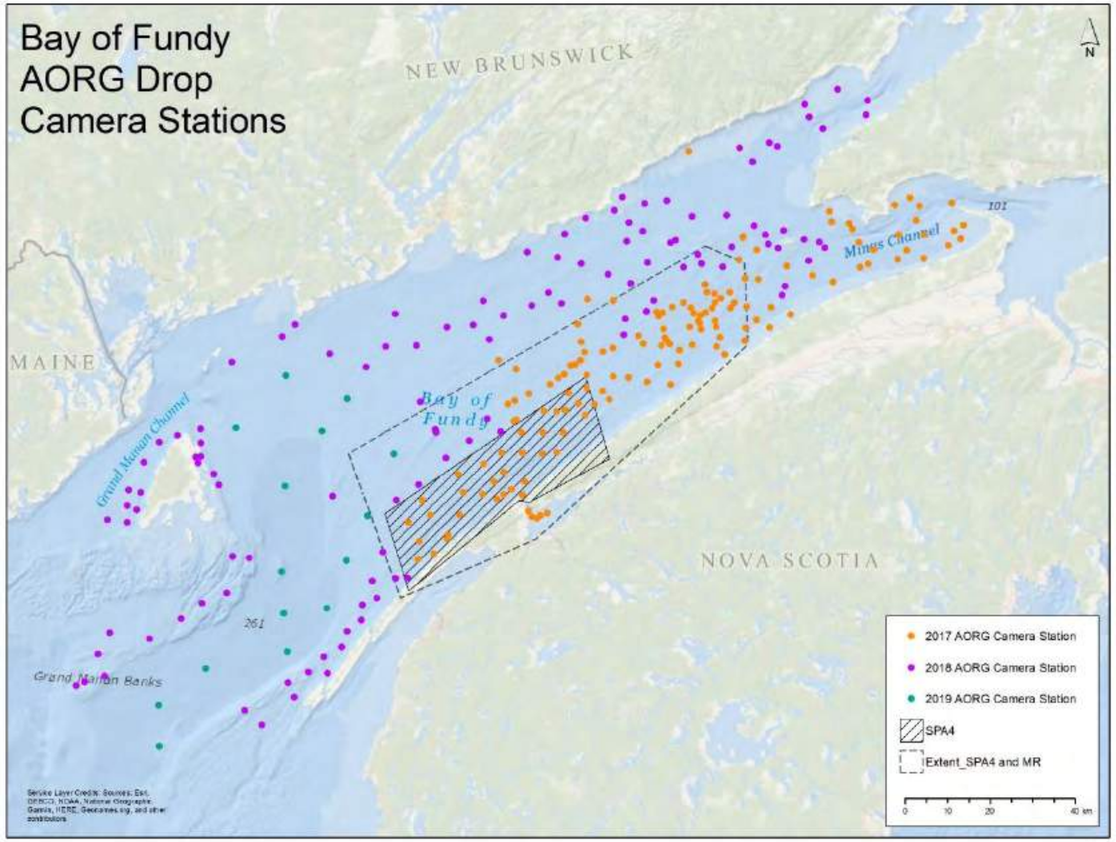
Haar et al. In prep.

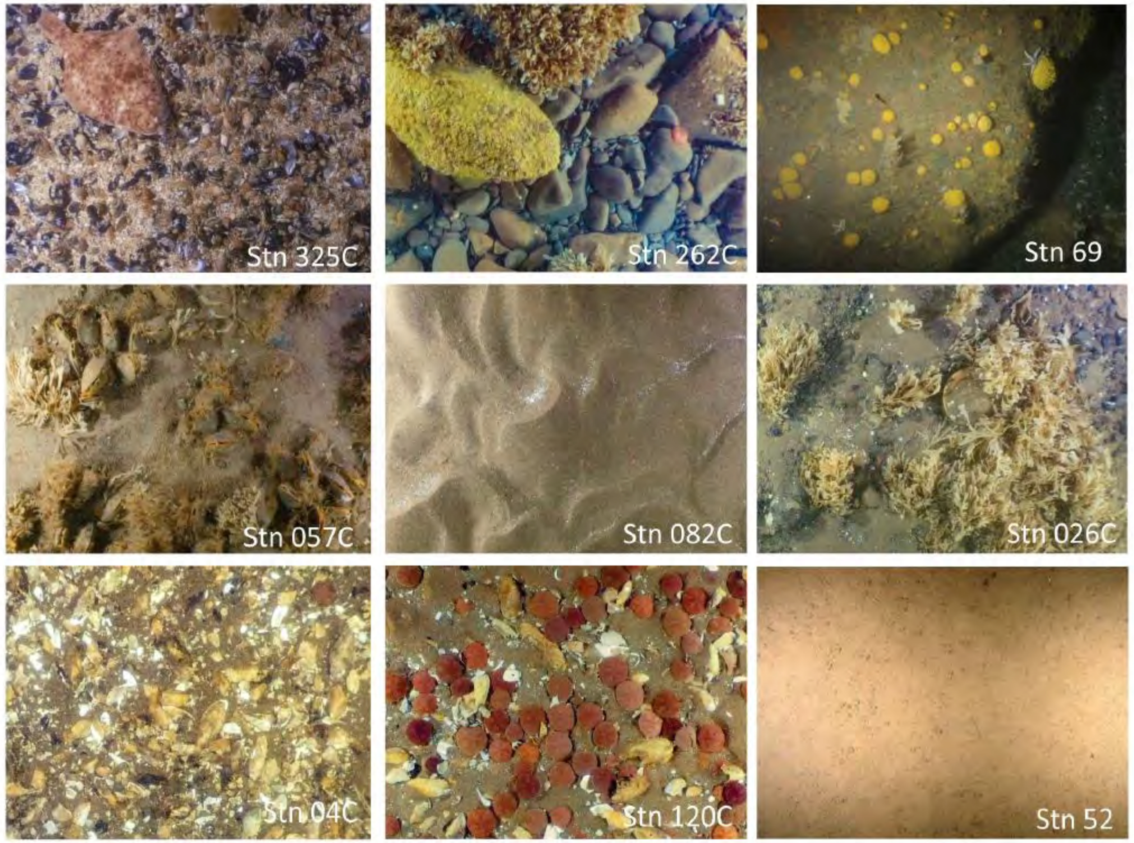

-66°30'
-66°25'
-66°20'
-66°15'
-66°10'
-66°5'
44°35'
44°30'
44°25'
Sandy Cove
Mink Cove
Little River
Tiddville
0 1.25 2.5 5 7.5 10
Kilometers

Hydrography to biology 2017-2020: Camera surveys

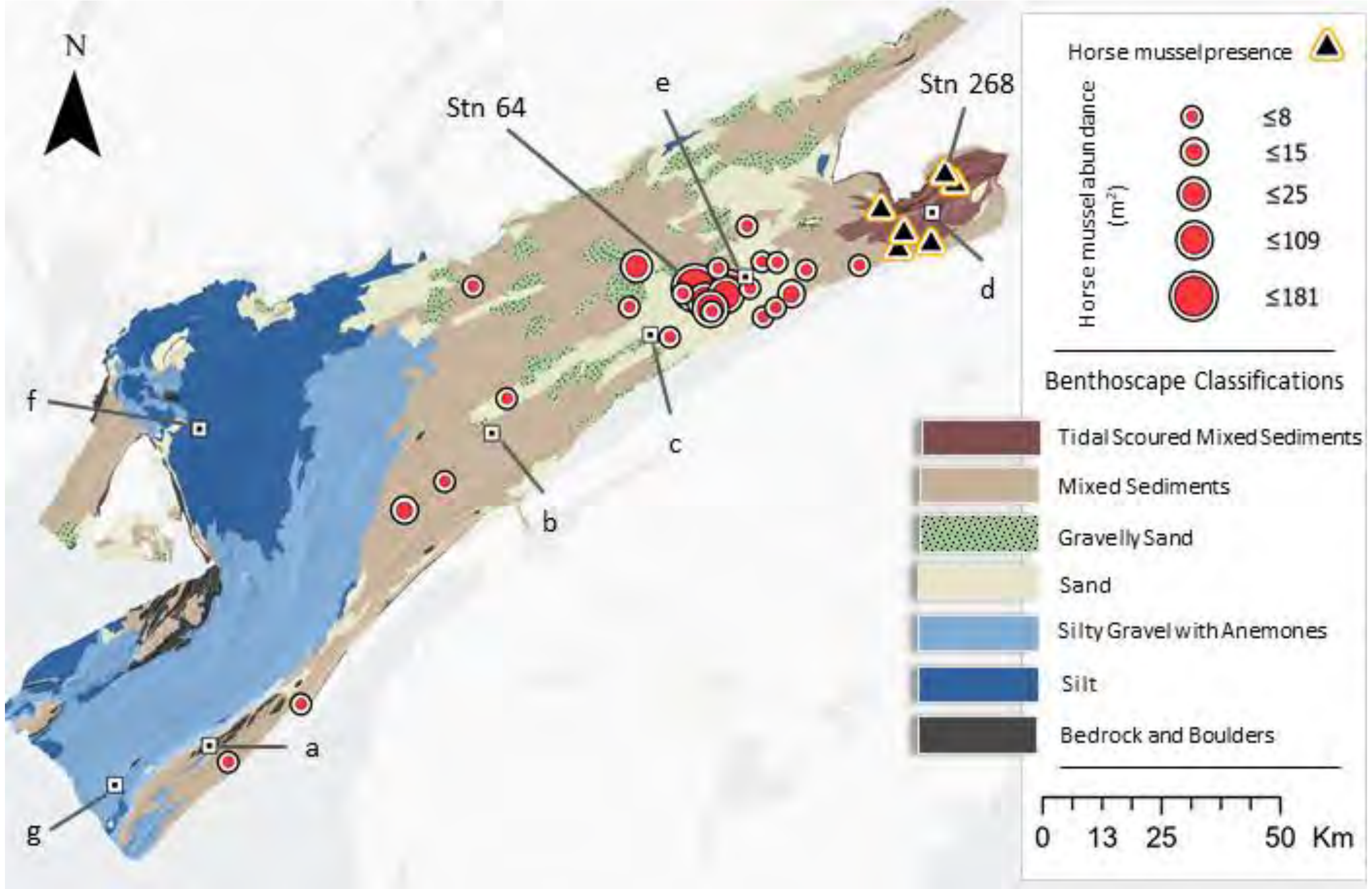


Year	Data Volume (4k)	Total video (~hrs)	Total # stations	# CTD casts	Scallop/Lobster/HM analysis	Benthoscape analysis
2017	2.7 TB	17	146	18	Complete	Complete
2018	1.6 TB	13	120	96	Complete	Complete
2019	0.1 TB	2	15	14	Complete	Complete
TOTAL	**4.4 TB**	**32**	**281**	**128**		

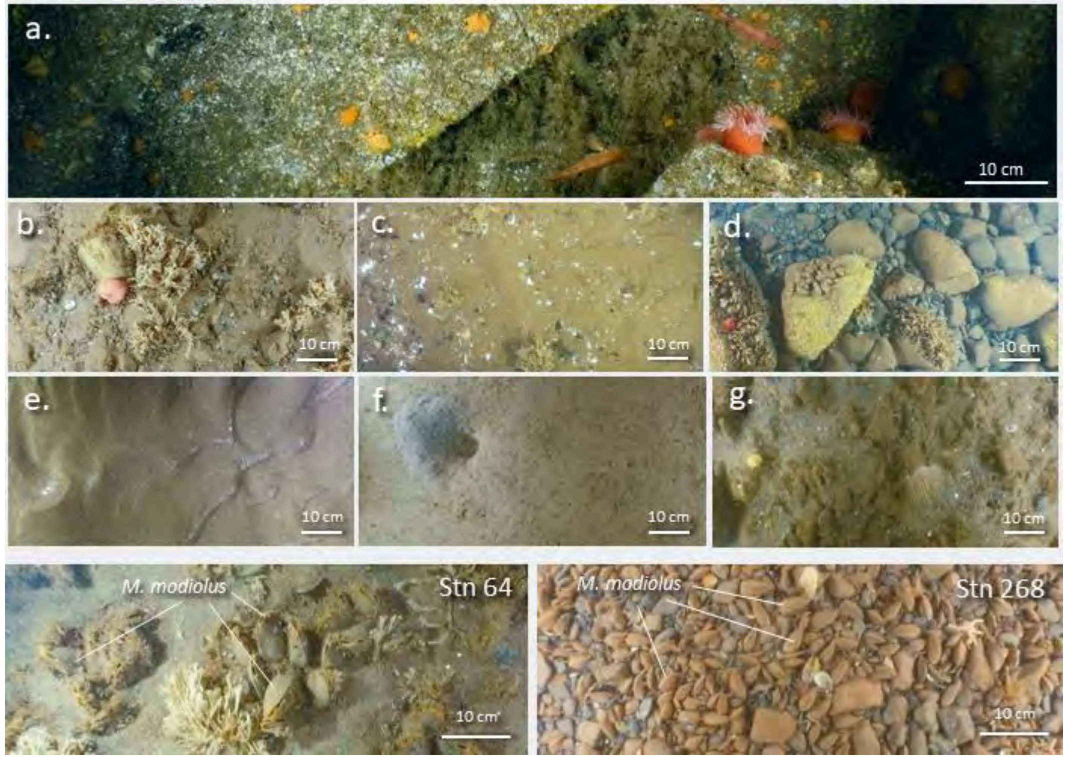


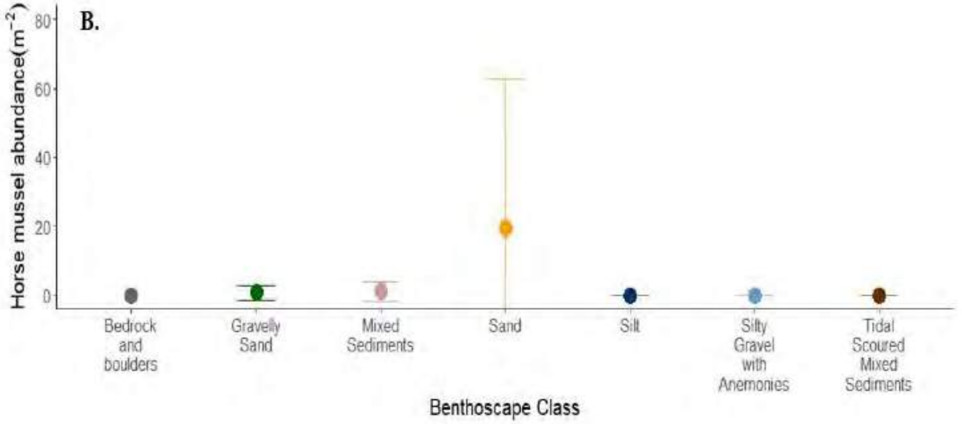


Benthoscape map and Horse mussel habitat



Wilson, B.R. (2020) MSc Thesis; Wilson et al. (In Prep).





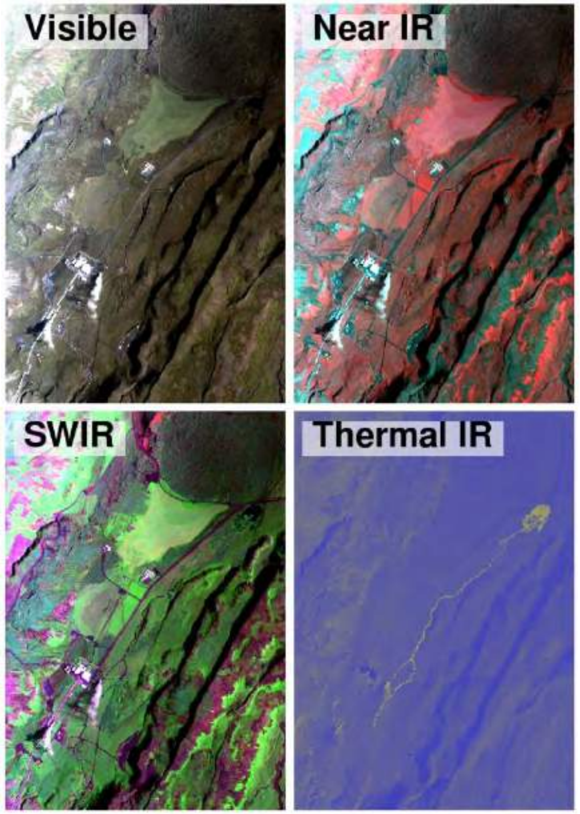
Multispectral backscatter

Analogy with multispectral satellite remote sensing

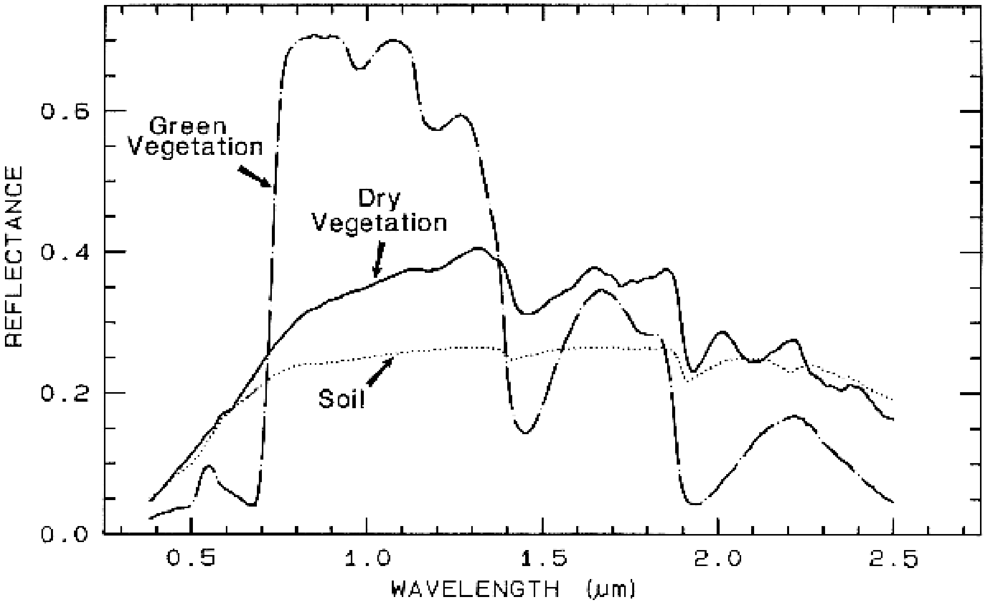
Why is multi-spectral remote sensing important?

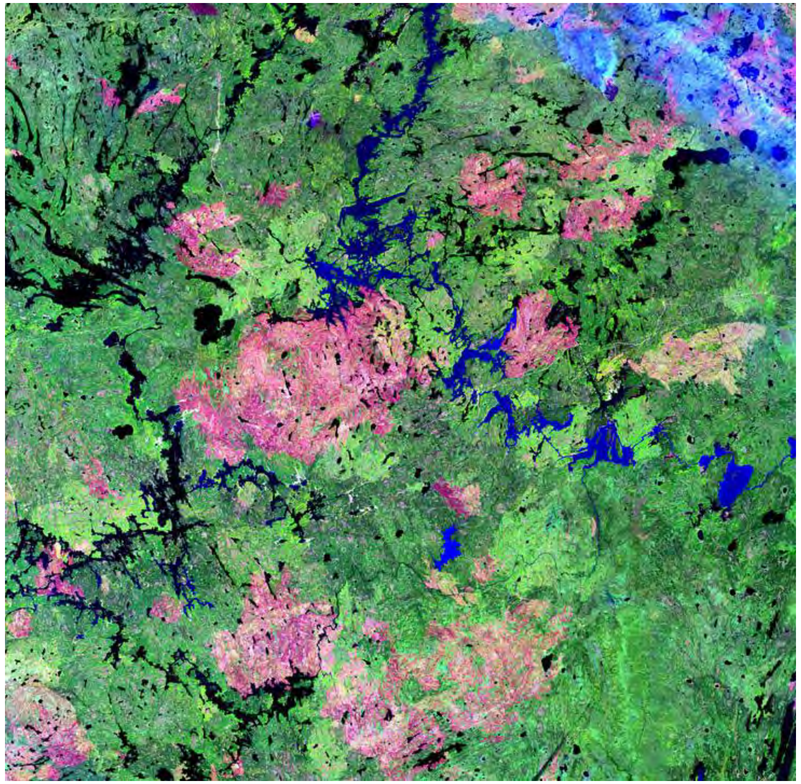
It allows for increased discriminatory power in characterization and classification efforts for remotely sensed data.

Terrestrial multispectral remote sensing
LANDSCAPE



Electro-Magnetic





Multispectral backscatter

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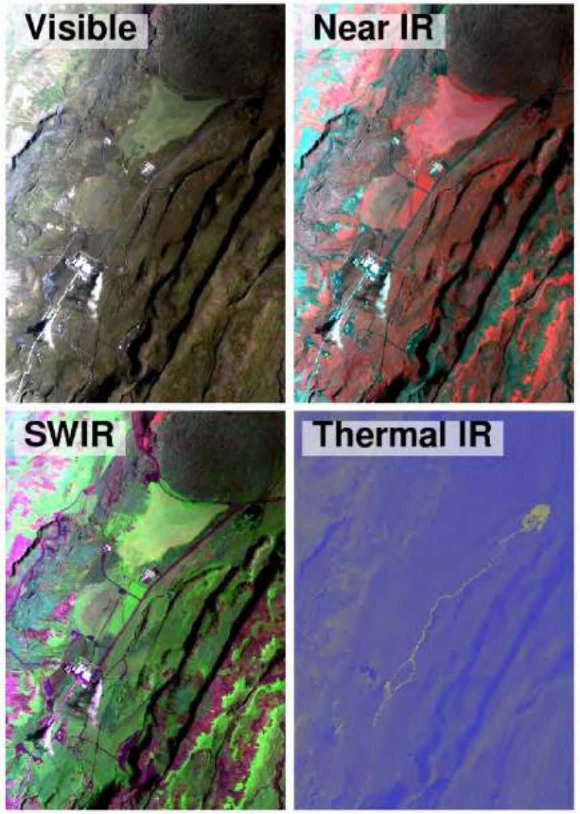
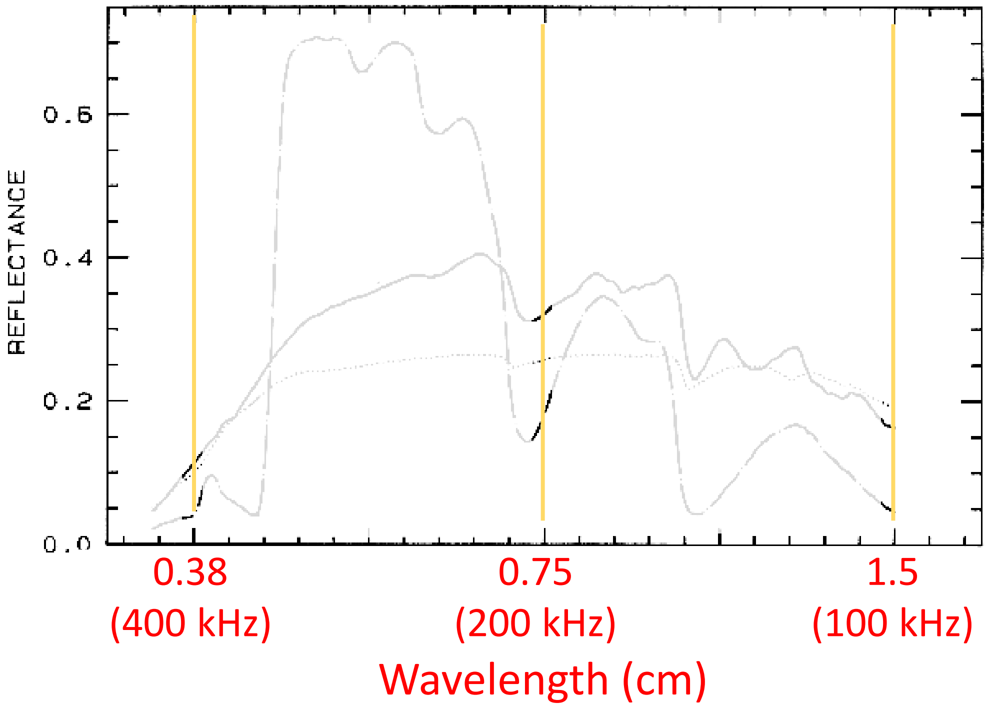
Why is multi-spectral remote sensing important?

It allows for increased discriminatory power in characterization and classification efforts for remotely sensed data.

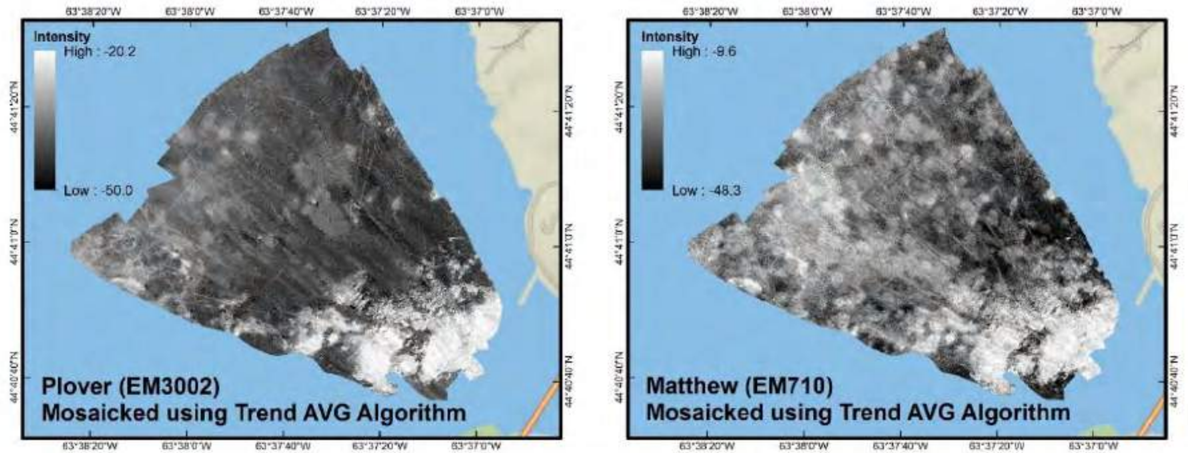


Marine remote sensing
BENTHOSCAPE

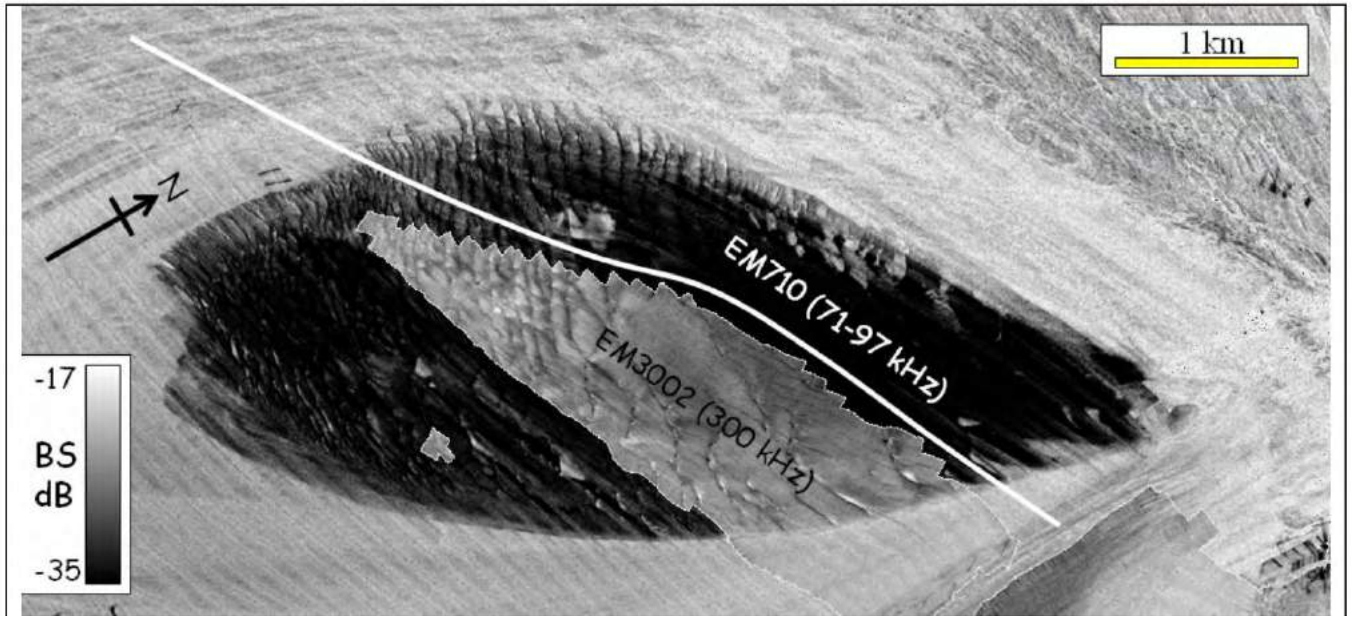
Acoustics



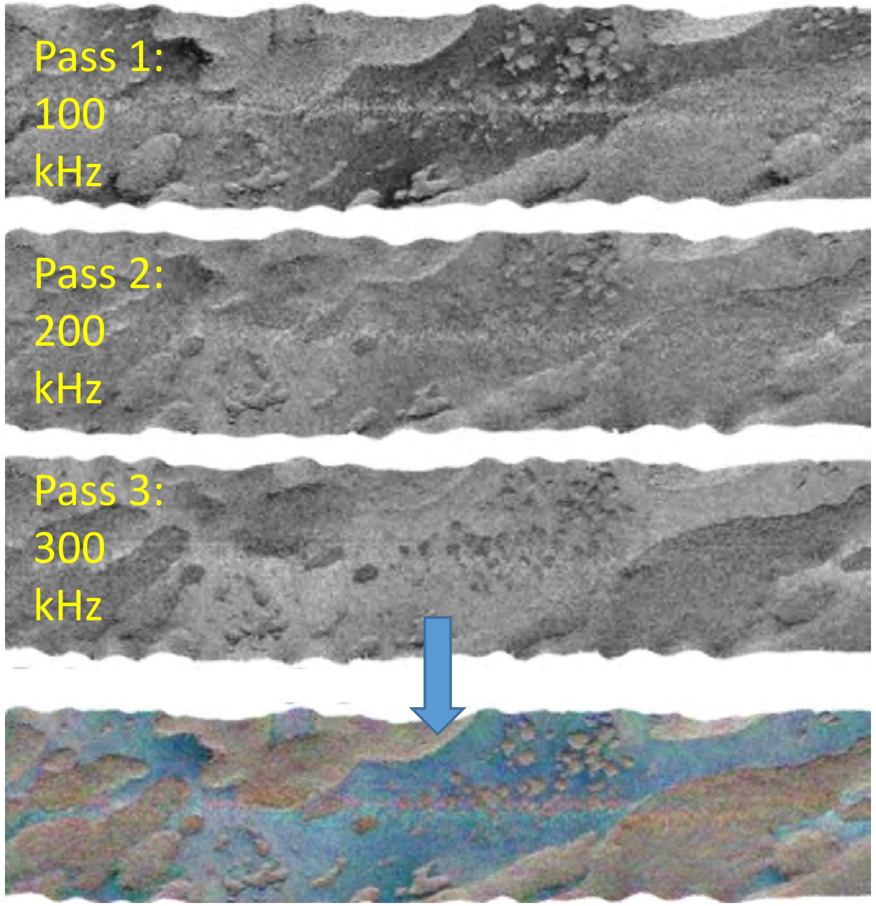
Early Research…



Brown et.al. (2010). Hydro 2010 Conference



Hughes Clarke (2015). US Hydro 2015

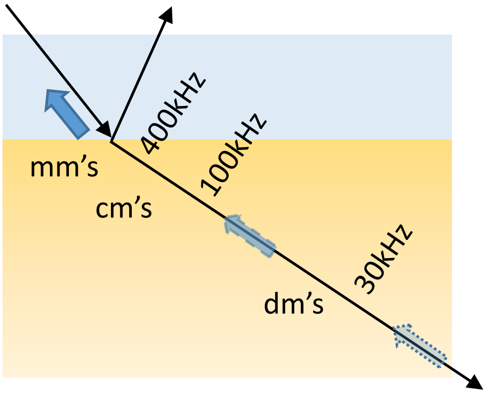


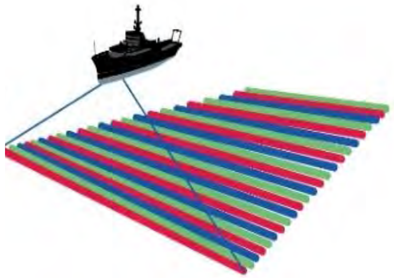
False colour composite: R (100 kHz), G (200 kHz), B (300 kHz)

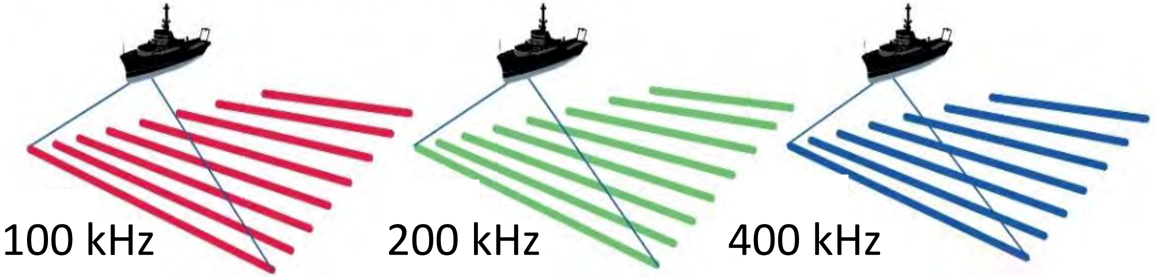
These maps created with data from either **multiple vessels**, or the same vessel equipped with **multiple sensors**

Multispectral backscatter

Bedford Basin Case Study

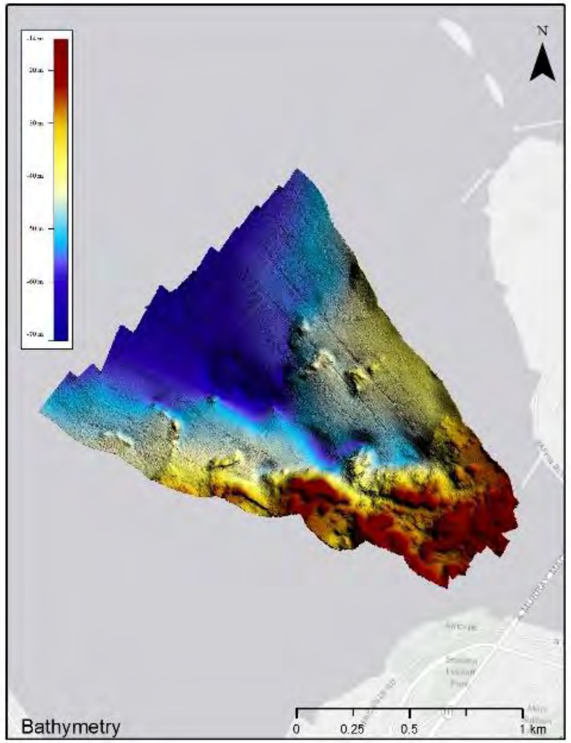




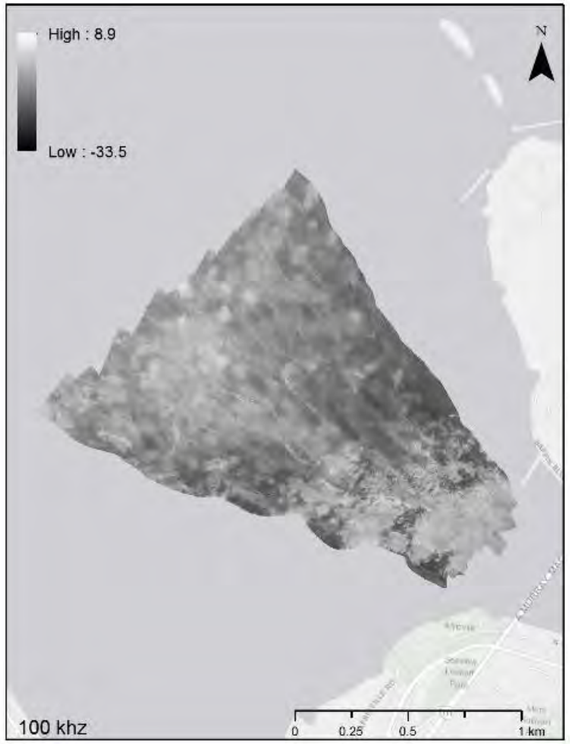


Brown, C.J., Beaudoin, J., Brissette, M. & Gazzola, V. (2019) Multispectral multibeam echo sounder backscatter as a tool for improved seafloor characterization. *Geosciences.* 9(3), 126; https://doi.org/10.3390/geosciences9030126

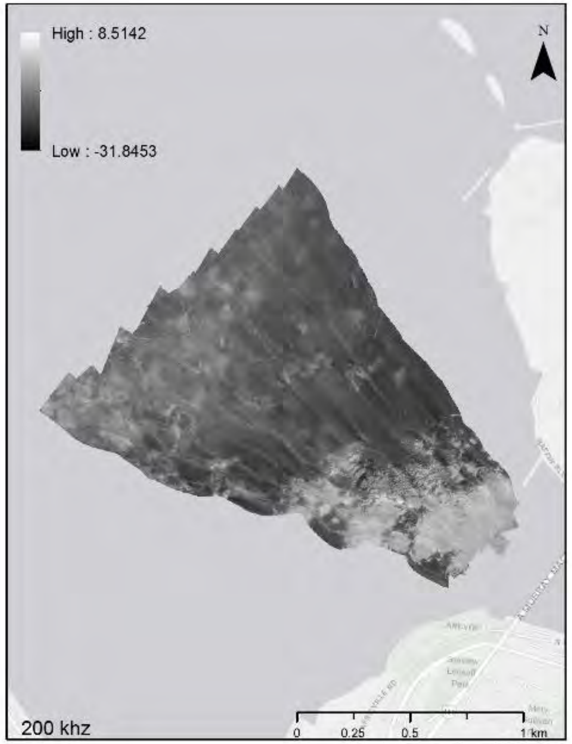
Multispectral backscatter
Bedford Basin Case Study



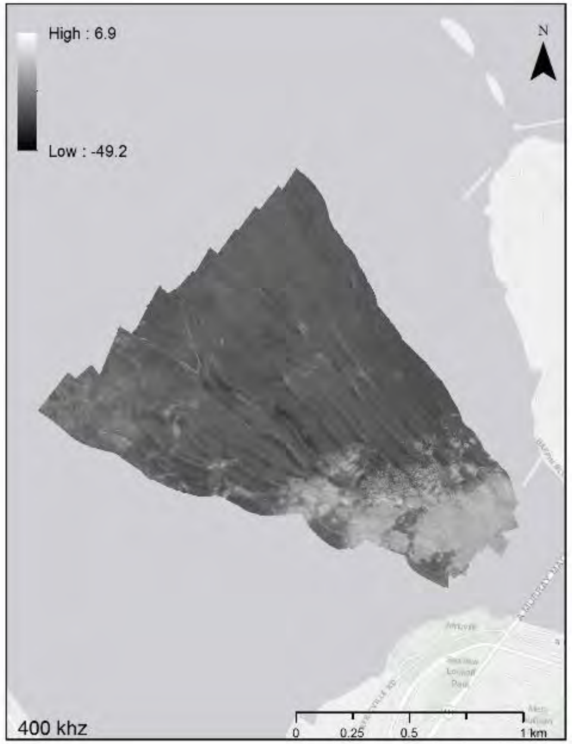
Bathymetry



100 kHz



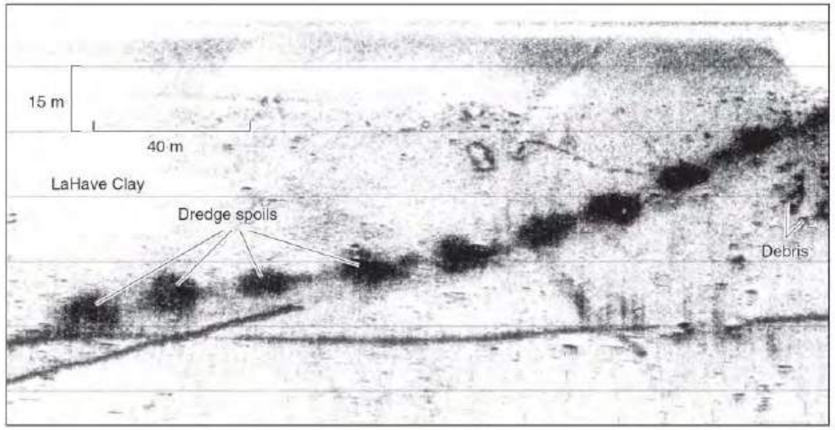
200 kHz



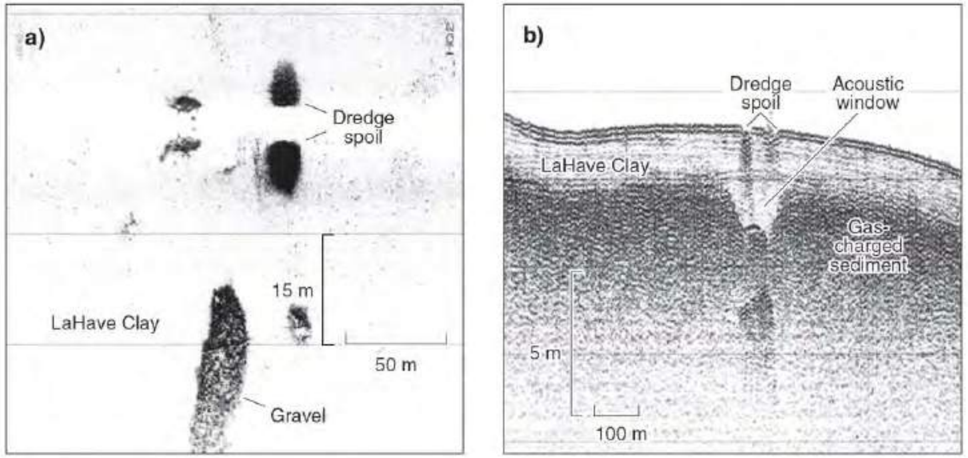
400 kHz

Brown, C.J., Beaudoin, J., Brissette, M. & Gazzola, V. (2019) Multispectral multibeam echo sounder backscatter as a tool for improved seafloor characterization. *Geosciences.* 9(3), 126; https://doi.org/10.3390/geosciences9030126

Multispectral backscatter
Bedford Basin Case Study

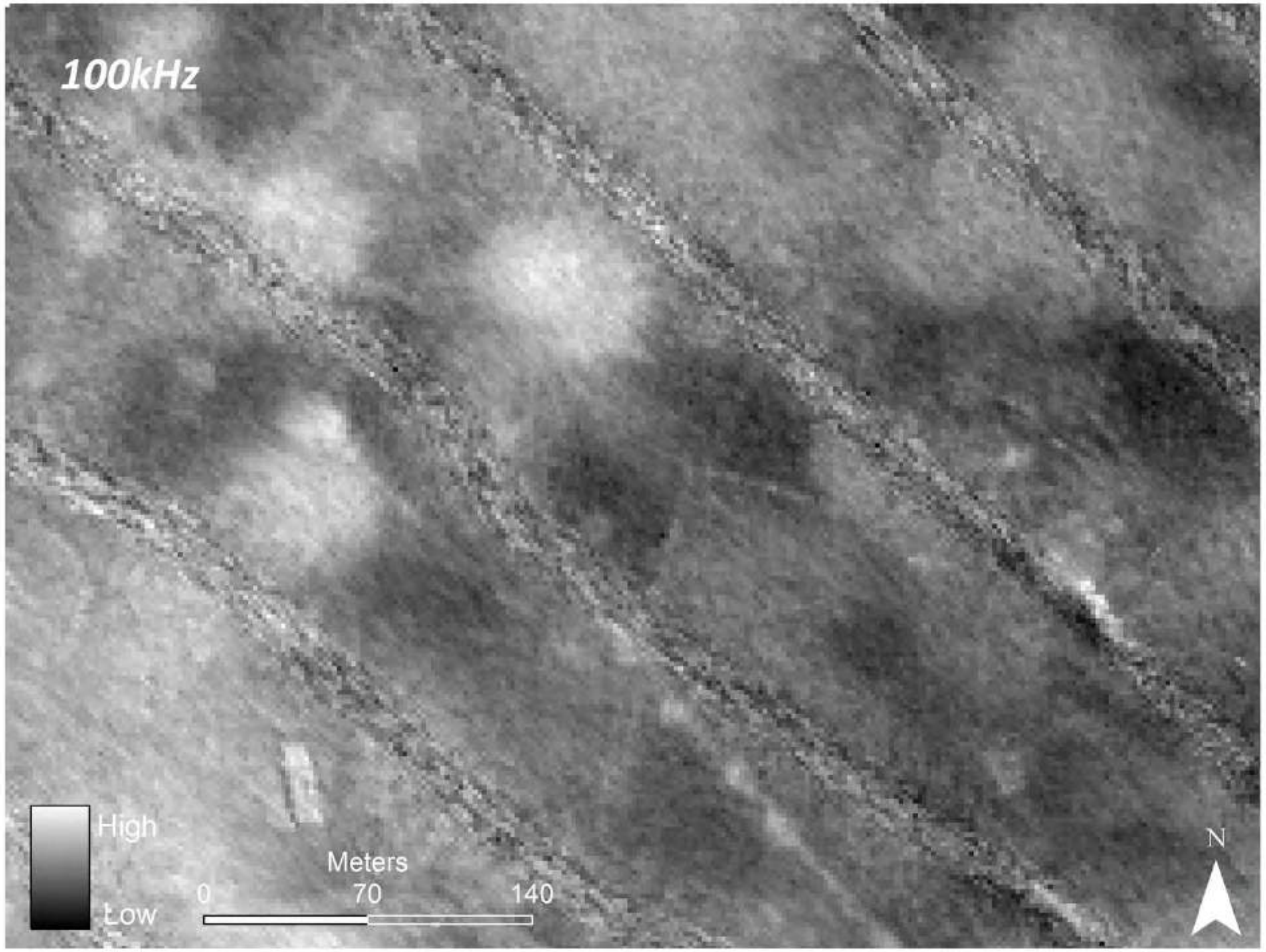


Sidescan sonar gram – Halifax Harbour showing dredge spoil



a) Sidescan sonar gram and b) seismic-reflection profile

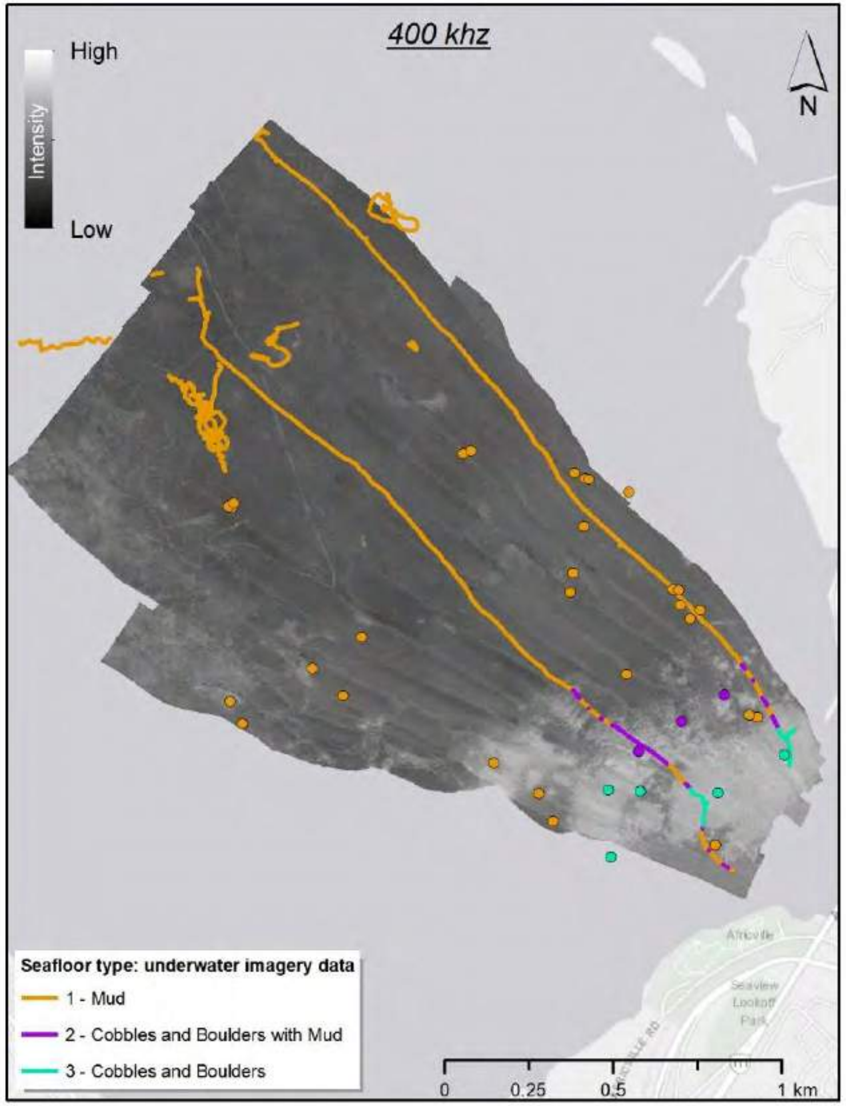
Fader and Miller (2008) Surficial geology, Halifax Harbour, Nova Scotia; Geological Survey of Canada, Bulletin 590, 163p.



Brown, et al. (2019) *Geosciences.* 9(3), 126; https://doi.org/10.3390/geosciences9030126

Multispectral backscatter

Bedford Basin Case Study

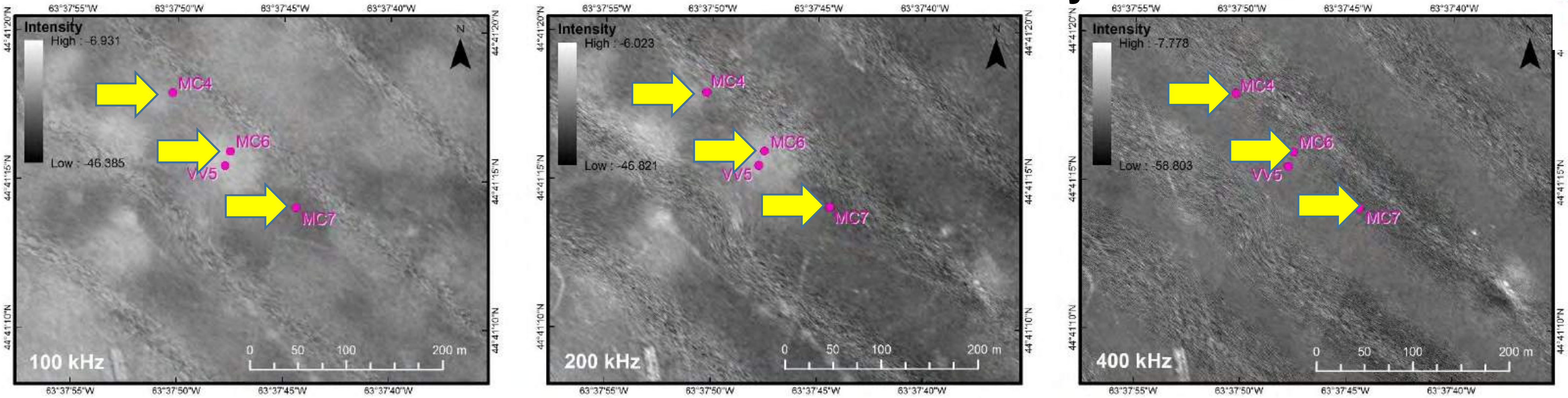


Seafloor Class	Representative Seafloor Image	Description
Mud		Mud with signs of bioturbation. Burrowing anemones, tube worms and other invertebrates.
Cobbles and boulders with mud		Cobbles and boulders with extensive epifauna of barnacles, hydroids and coralline algae. Patches of mud, with signs of bioturbation, visible between coarser substrate.
Gravel, cobbles and boulders		Coarse, mixed substrate ranging from gravel through to large boulders/outcropping bedrock. Epifauna comprising barnacles, bryozoan, hydroids and other invertebrates. Scallops frequently observed. No visible fine sediments.

Brown, C.J., Beaudoin, J., Brissette, M. & Gazzola, V. (2019) Multispectral multibeam echo sounder backscatter as a tool for improved seafloor characterization. *Geosciences.* 9(3), 126; https://doi.org/10.3390/geosciences9030126

Multispectral backscatter

Bedford Basin Case Study

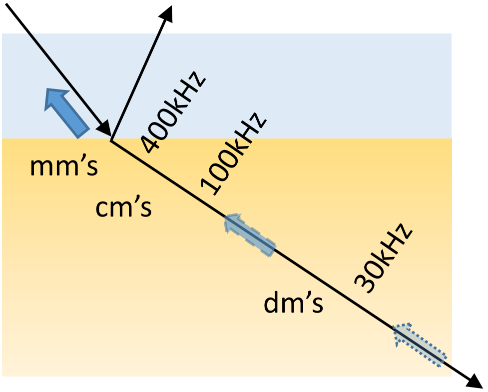


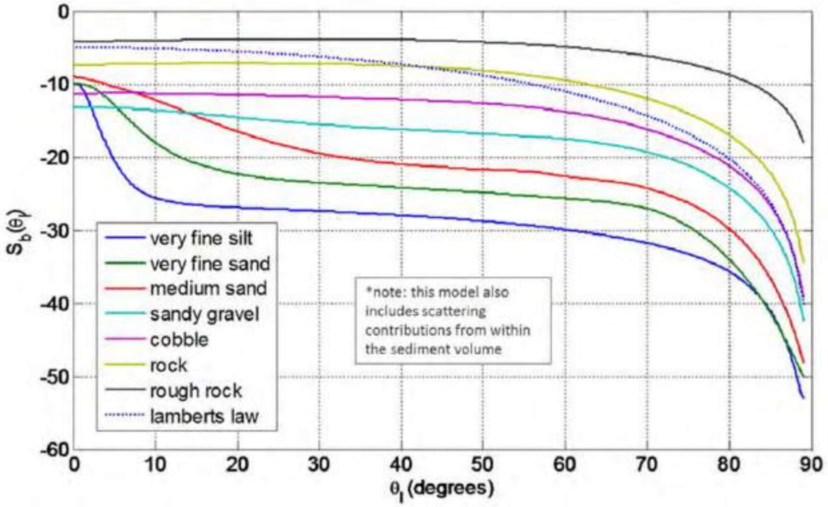
MC4 MC6 MC7

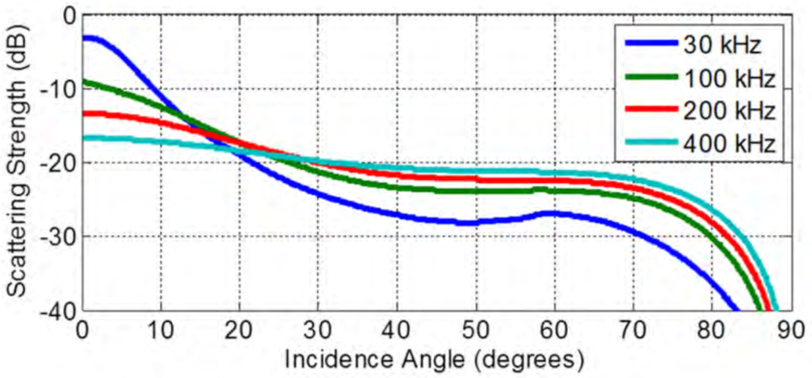
Brown, C.J., Beaudoin, J., Brissette, M. & Gazzola, V. (2019) Multispectral multibeam echo sounder backscatter as a tool for improved seafloor characterization. *Geosciences*. 9(3), 126; https://doi.org/10.3390/geosciences9030126

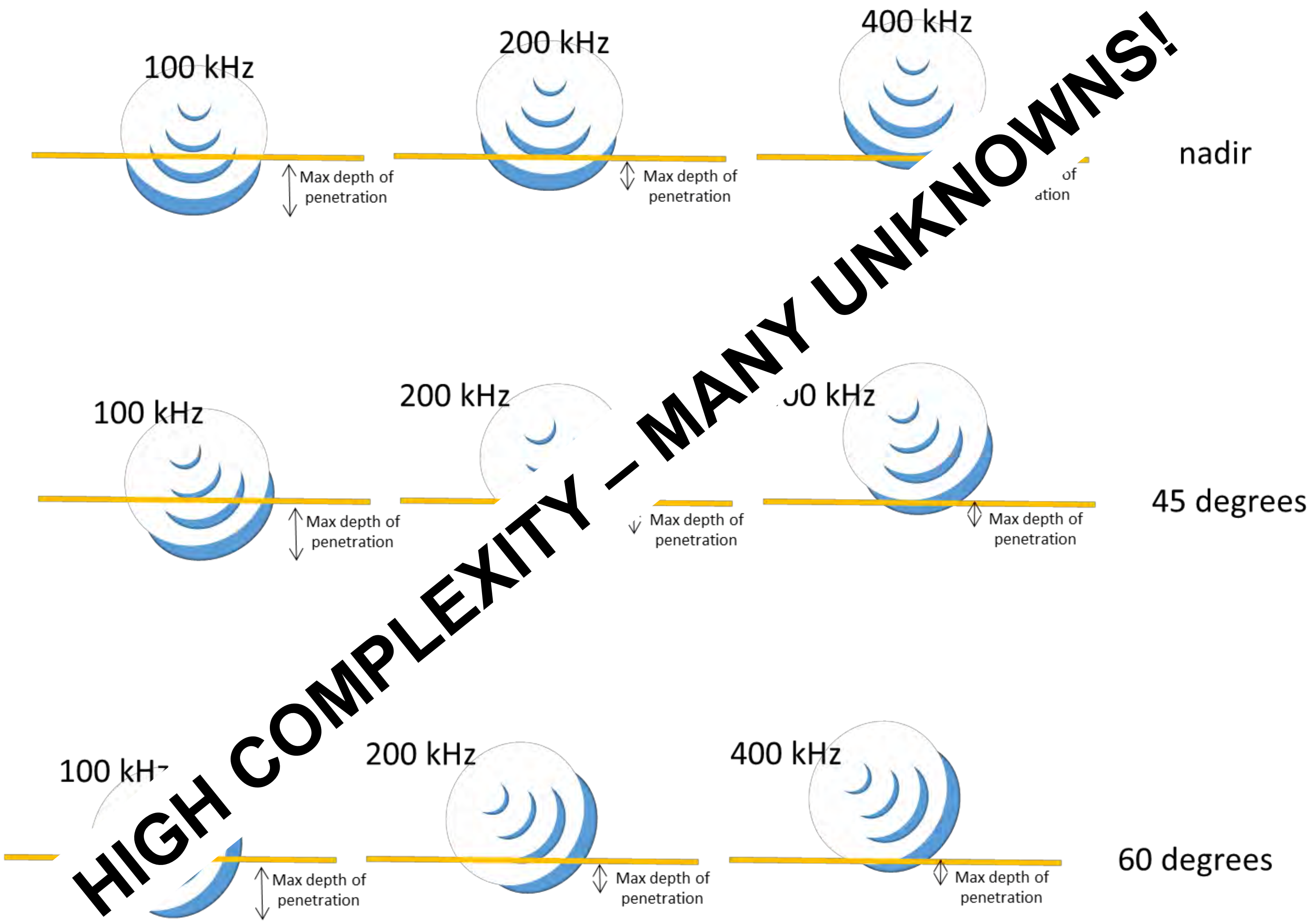
Multispectral backscatter

Bedford Basin Case Study



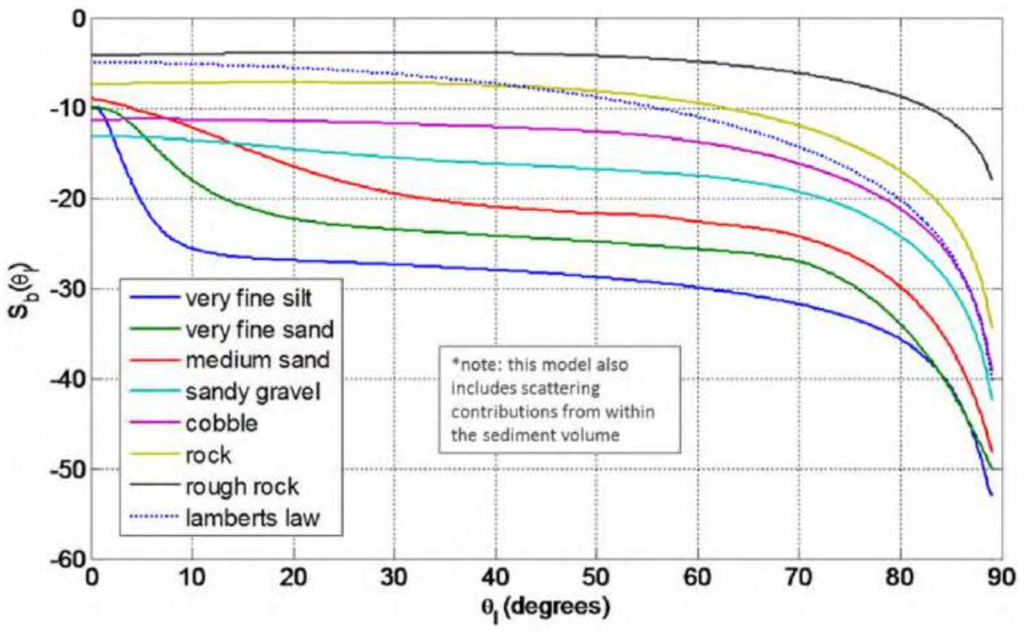


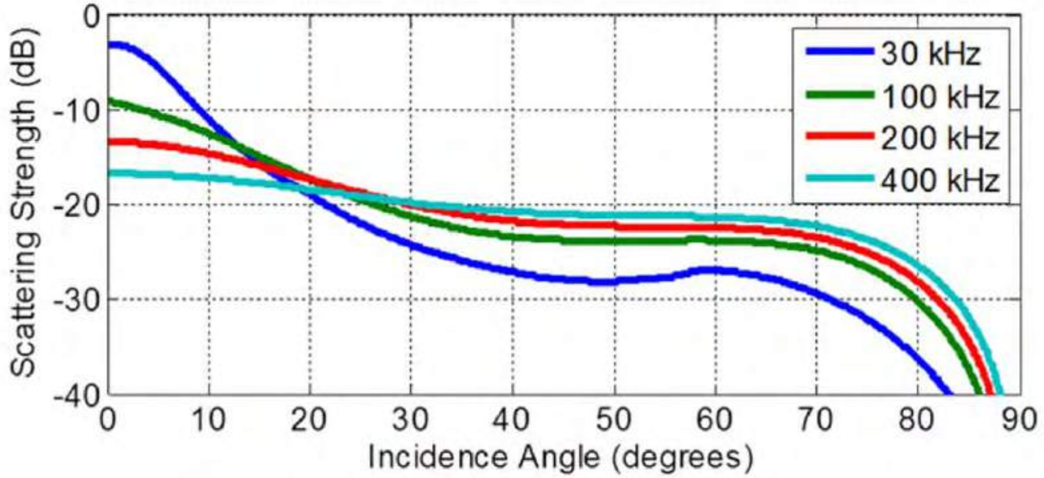


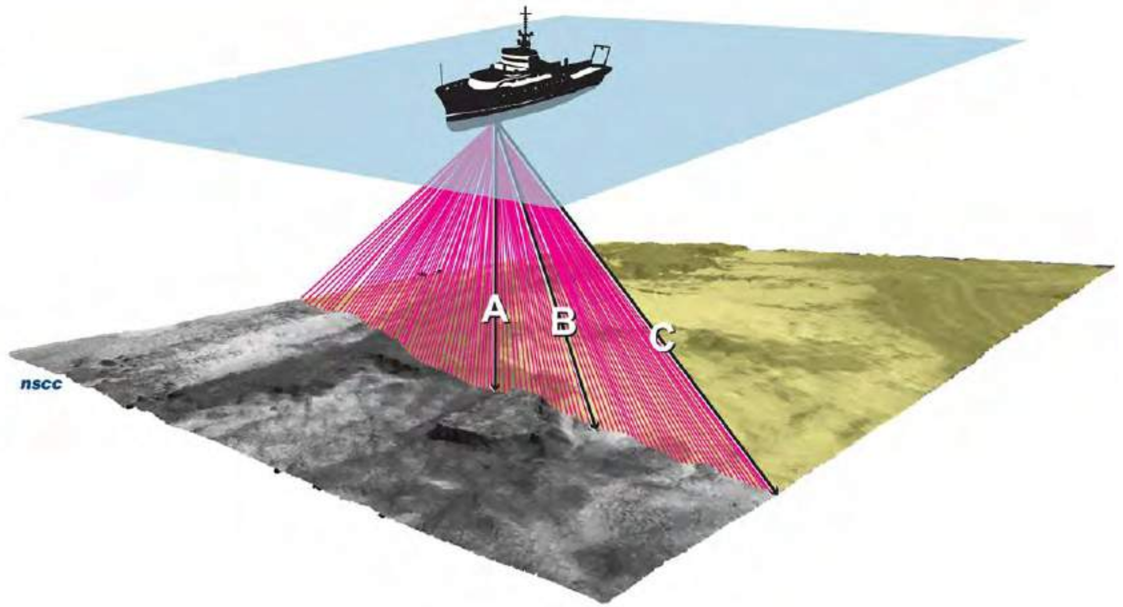


HIGH COMPLEXITY – MANY UNKNOWNS!

Future Research







Need for empirical research

- Field trials under controlled conditions
  - Homogenous/non-stratified substrata
  - Different sediment types
- Multispectral data collection
  - Consistent ensonification geometry
- Extensive ground truthing
  - Sediment grain size
  - Geotechnical
  - Bottom roughness (Intermediate Scale Roughness)
- Further modelling

Benthic ecosystem mapping for sustainable ocean stewardship in a shifting ocean climate

Principal Investigators: Craig J. Brown[1] and Katleen Robert[2]

1) Dalhousie University, Department of Oceanography
2) Marine Institute, Memorial University

DALHOUSIE UNIVERSITY

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OCEAN FRONTIER INSTITUTE

BEcoME

Benthic Ecosystem Mapping & Engagement

Benthic ecosystem mapping for sustainable ocean stewardship in a shifting ocean climate

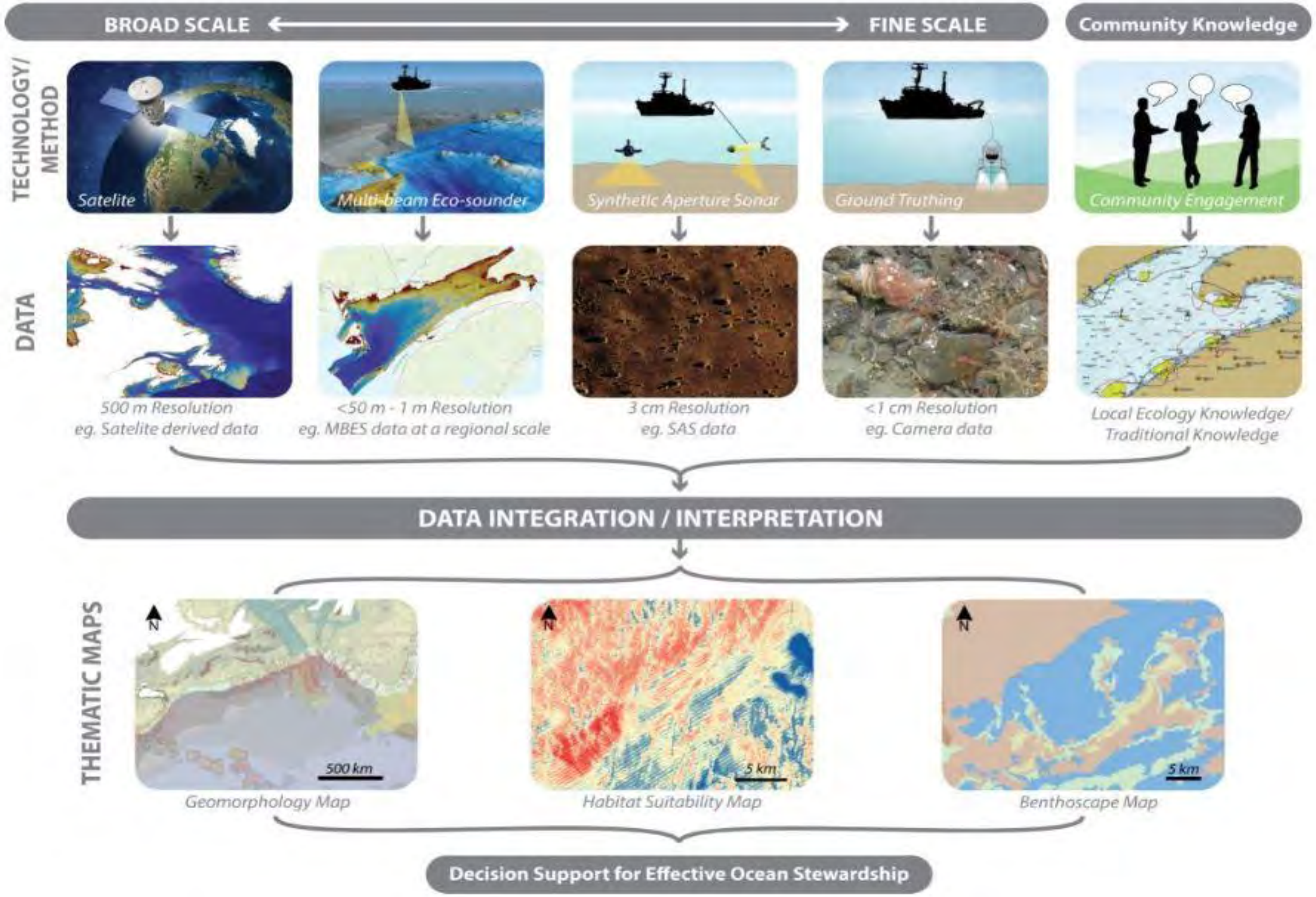
- Benthic Ecosystem Mapping and Engagement – BEcoME Project – www.ofibecome.org

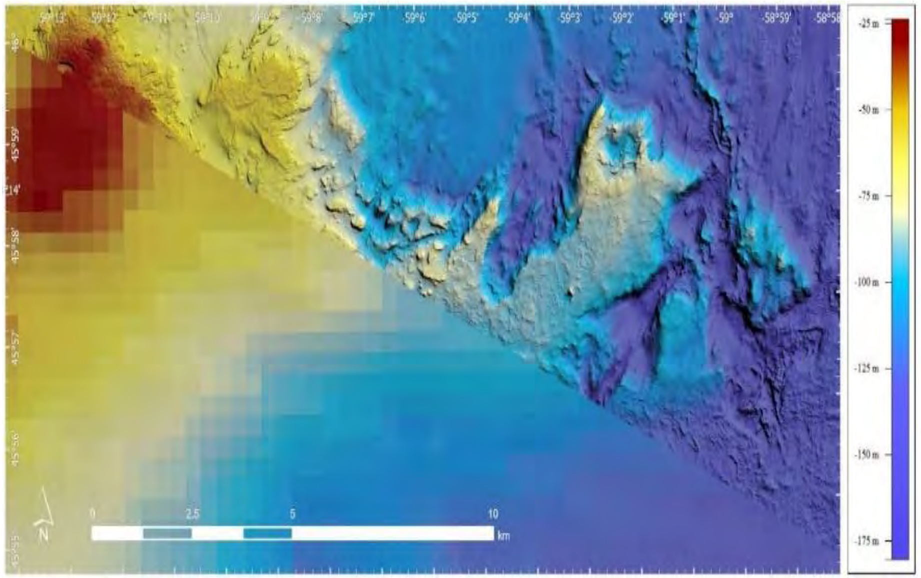
- Through a series of inter-connected, cross-disciplinary work-packages, this OFI project (**BEcoME – Benthic Ecosystem Mapping and Engagement**) will address **what role benthic habitat plays in controlling shifting patterns in species and biodiversity caused by a changing ocean climate**.

- https://www.youtube.com/watch?v=Dw_zUhaKlzc&feature=youtu.be

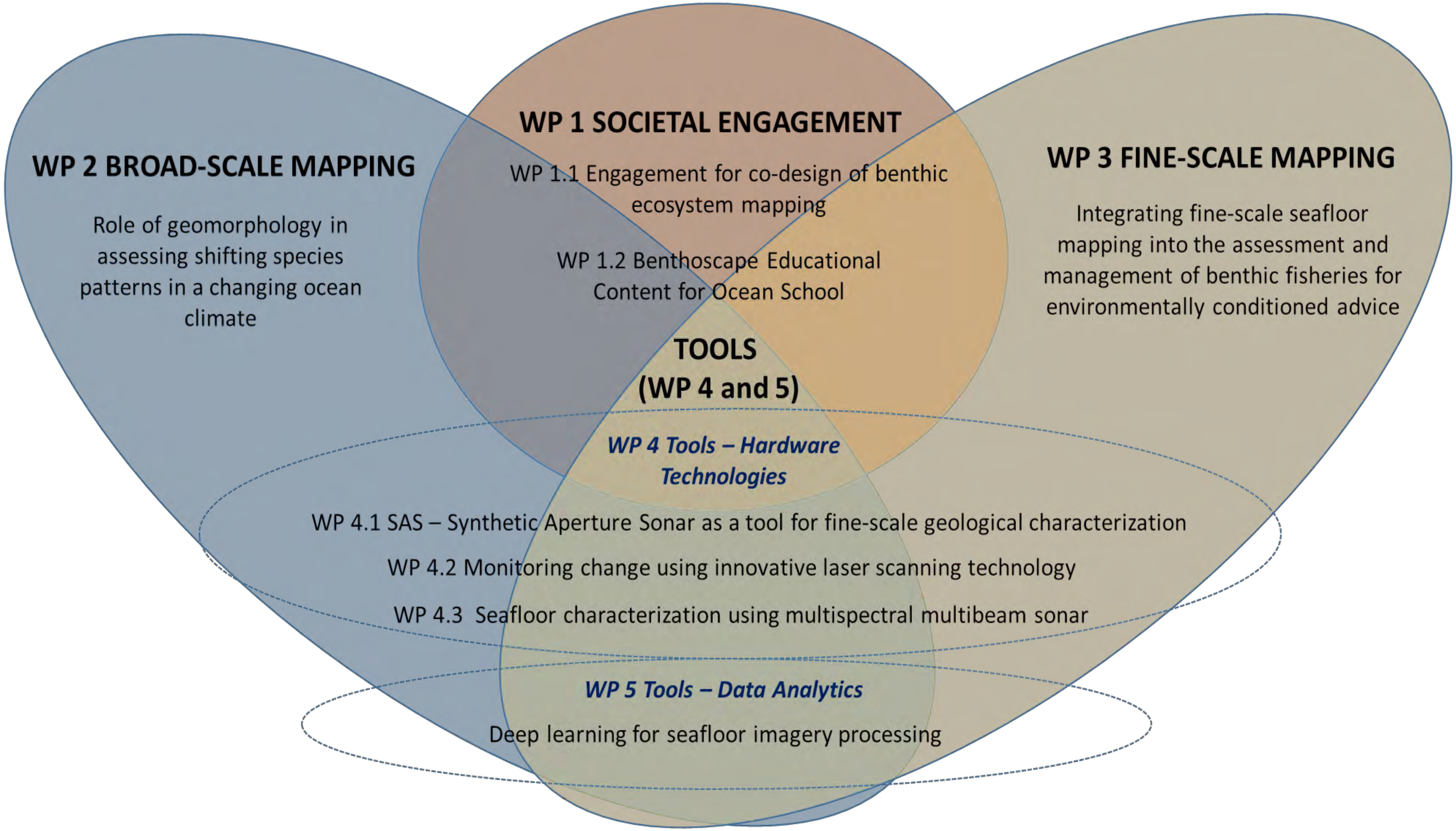
DALHOUSIE UNIVERSITY *Inspiring Minds*   OCEAN FRONTIER INSTITUTE   BEcoME Benthic Ecosystem Mapping & Engagement   MEMORIAL UNIVERSITY

Benthic Ecosystem Mapping and Engagement: BEcoME Project





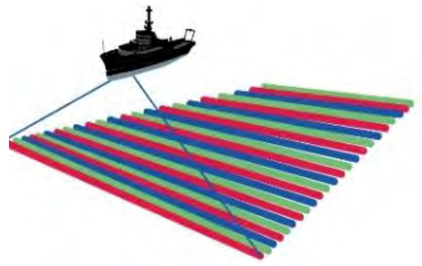
Benthic Ecosystem Mapping and Engagement: BEcoME Project

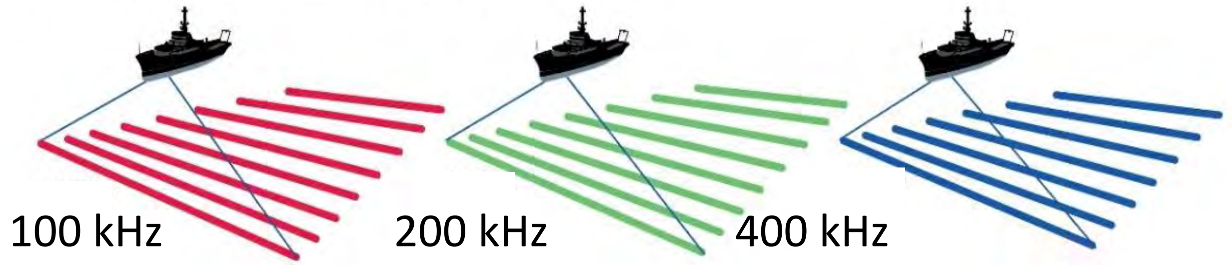


www.ofibecome.org

WP 4.3: Seafloor characterization using multispectral multibeam sonar

1) Collect multispectral backscatter data sets under controlled experimental conditions at suitable field sites
2) Conduct extensive, spatially georeferenced ground truthing (e.g. grain size, intermediate scale roughness, geotechnical measurements, etc.)
3) Compare seafloor measurements to MBES acoustic backscatter at the full range of ensonification angles
4) Compare how measurements vary over different substrate types and in different environmental settings/locations
5) Evaluate to what extent Angular Range Analysis of the backscatter signal over different operating frequencies can be used to predict seafloor sediment characteristics





QPS. R2SONIC OUR VISION IS SOUND™


Thank you!
Questions?