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Scotian Shelf geoscience information within Network Candidate Sites (NCS) of Fisheries and Oceans Canada

G. Philibert and B.J. Todd

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Publications in this series have not been edited; they are released as submitted by the author.

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1. CONTEXT AND OBJECTIVES

This study is part of the Marine Geoscience for Marine Spatial Planning (MGMSP) Program which is a Government of Canada initiative focused on improving Impact Assessments and Regulatory Processes (IARP). Natural Resources Canada (NRCan) is one of five departments supporting Environment and Climate Change Canada (ECCC) and Fisheries and Oceans Canada (DFO) in this initiative. Within NRCan, the Geological Survey of Canada (GSC) provides federal expertise and capacity for the characterization and mapping of seabed conditions. Seafloor mapping and analyses provide a regional framework and baseline information in order to inform regulatory decisions and provide advice on management.

This report addresses the Scotian Shelf Bioregion (SSB), with its extent delimited by DFO (DFO, 2009). Within the SSB, DFO has identified 48 Network Candidate Sites (NCS) which include existing and proposed sites of different size and regulatory intent. This report focuses on geoscience information that can contribute to the broader scientific assessment necessary to evaluate future implementation of the NCS.

The Network Candidate Sites include two Areas of Interest (AOI) (Oceans Act), one National Wildlife Area (NWA) (ECCC), one National Park (Parks Canada Agency), one marine refuge announced in 2018, as well as five existing Oceans Act Marine Protected Areas (MPAs), seven Other Effective Conservation Measures sites (OEM) and 31 additional proposed conservation network sites. NCS may include various protection types (e.g., Oceans Act, Fisheries Act, Canada Wildlife Act, other legislation), which will be determined through further analysis and continued discussion with federal partners, provinces, First Nations, Indigenous groups, stakeholders and coastal communities.

High resolution geoscience data are needed to underpin spatial management analyses and support on-going conservation efforts in the Scotian Shelf Bioregion. The objective of this study is to compile geoscience data from previous studies, identify knowledge gaps, define priorities, and consider strategic surveys for the upcoming years of the Program.

Specifically, the objectives of this study are to:

- Compile existing surficial geology and geomorphology of the seabed within each of the 48 NCS identified by DFO. Information sources include surficial geology maps, single beam and multibeam sonar bathymetry and backscatter strength, sub-bottom profiles, cores and other seabed samples, seabed photographs and videography and grainsize analyses.
- Determine which NCS have sufficient information to undertake a detailed study of seabed conditions.
- Identify key knowledge gaps in areas where new data would be required to undertake an analysis of the surficial geology and seafloor conditions.
- Define priority areas for future marine geoscience expeditions for the remaining years of the MGMSP.

2. STUDY AREA

The Scotian Shelf Bioregion extends from the Gulf of Maine in the southwest to the Laurentian Channel in the northeast and includes the continental shelf and part of the slope and covers over 470,000 km^2 (Figure 1). To the south, the SSB extends to the lower continental slope approximately 400 to 500 km off Nova Scotia where the seafloor reaches depths of 4000 to 5000 m.

Within the SSB, 48 NCS were defined by DFO (Figure 1). Table 1 lists the NCS along with their status, type and area.

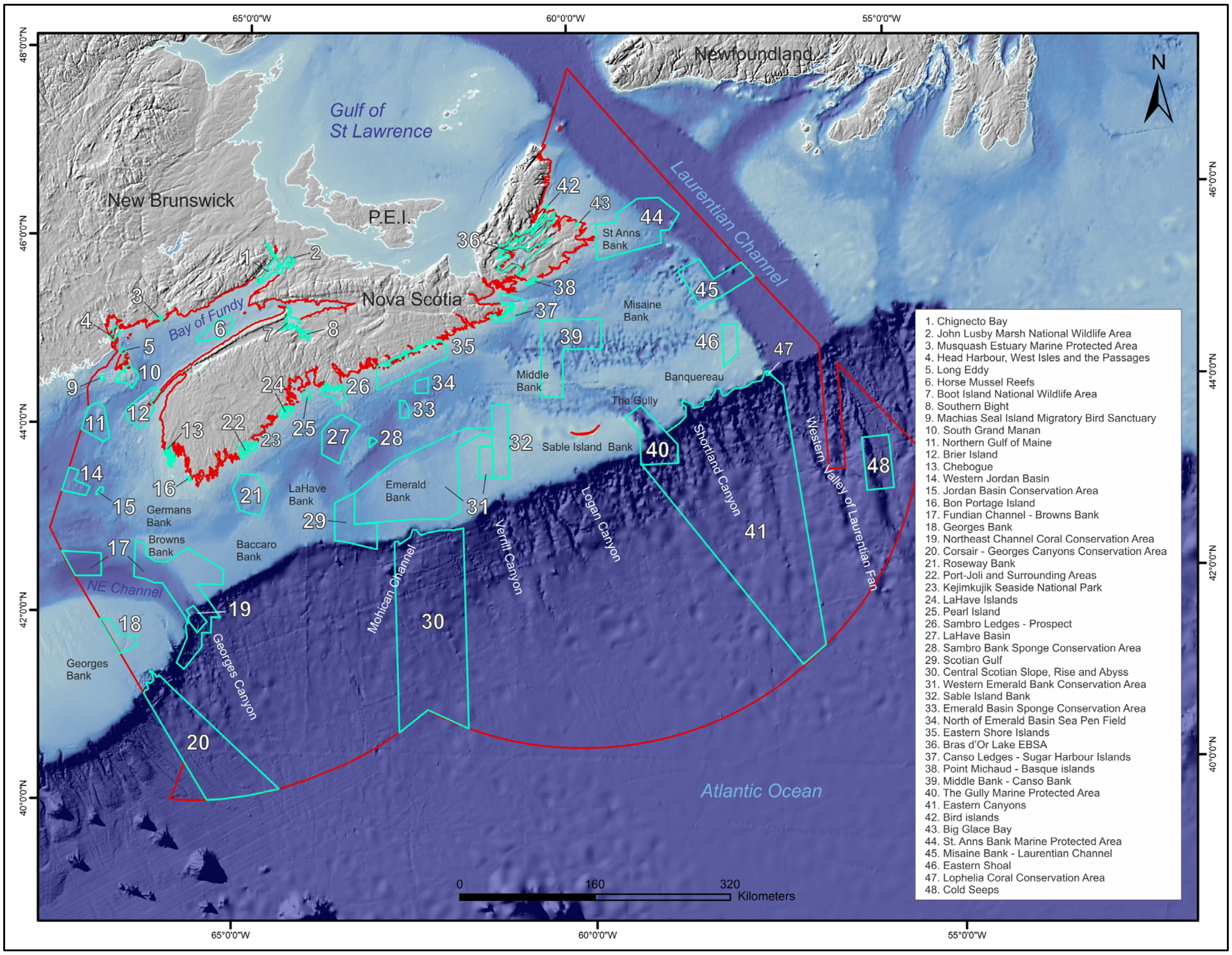

Figure 1: Location map of the study area. The red polygon delimits the Scotian Shelf Bioregion. Blue polygons correspond to NCS of DFO.

Table 1. List of DFO NCS and their characteristics.

NO.	NAME	STATUS	TYPE	AREA (km^2)
1	Chignecto Bay	Proposed	TBD	408.02
2	John Lusby Marsh National Wildlife Area	Existing	MPA	5.38
3	Musquash Estuary Marine Protected Area	Existing	MPA	7.43
4	Head Harbour, West Isles and The Passages	Proposed	TBD	103.89
5	Long Eddy	Proposed	TBD	34.59
6	Horse Mussel Reefs	Proposed	TBD	625.92
7	Boot Island National Wildlife Area	Existing	NWA	0.89
8	Southern Bight	Proposed	TBD	217.44
9	Machias Seal Island Migratory Bird Sanctuary	Existing	MPA	25.32
10	South Grand Manan	Proposed	TBD	414.41
11	Northern Gulf of Maine	Proposed	TBD	977.77
12	Brier Island	Proposed	TBD	1000.27
13	Chebogue	Proposed	TBD	111.37
14	Western Jordan Basin	Proposed	TBD	559.77
15	Jordan Basin Conservation Area	Existing	OEM	48.92
16	Bon Portage Island	Proposed	TBD	14.01
17	Fundian Channel–Browns Bank	Proposed AOI	AOI	7258.15
18	Georges Bank	Proposed	TBD	718.47
19	Northeast Channel Coral Conservation Area	Existing	OEM	391.00
20	Corsair–Georges Canyons Conservation Area	Existing	OEM	8827.38
21	Roseway Bank	Proposed	TBD	1495.77
22	Port Joli and Surrounding Areas	Proposed	TBD	145.25
23	Kejimkujik Seaside National Park and Historic Site	Existing	NP	1.30
24	LaHave Islands	Proposed	TBD	142.54
25	Pearl Island	Proposed	TBD	82.29
26	Sambro Ledges–Prospect	Proposed	TBD	369.45
27	LaHave Basin	Proposed	TBD	1563.31
28	Sambro Bank Sponge Conservation Area	Existing	OEM	62.49
29	Scotian Gulf	Proposed	TBD	1950.95
30	Central Scotian Slope, Rise and Abyss	Proposed	TBD	18186.22

NO.	NAME	STATUS	TYPE	AREA (km^2)
31	Western Emerald Bank Conservation Area	Existing	OEM	10224.48
32	Sable Island Bank	Proposed	TBD	1647.51
33	Emerald Basin Sponge Conservation Area	Existing	OEM	196.91
34	North of Emerald Basin Sea Pen Field	Proposed	TBD	260.27
35	Eastern Shore Islands	Proposed AOI	AOI	2133.80
36	Bras d'Or Lakes EBSA	Proposed	TBD	1456.61
37	Canso Ledges–Sugar Harbour Islands	Proposed	TBD	654.96
38	Point Michaud and Basque Islands	Proposed	TBD	54.28
39	Middle Bank–Canso Bank	Proposed	TBD	3939.46
40	The Gully Marine Protected Area	Existing	MPA	2368.25
41	Eastern Canyons	Proposed	SBA	36499.90
42	Bird Islands	Proposed	TBD	11.16
43	Big Glace Bay	Proposed	TBD	5.31
44	St. Anns Bank Marine Protected Area	Existing	MPA	4380.55
45	Misaine Bank and Laurentian Channel	Proposed	TBD	2460.02
46	Eastern Shoal	Proposed	TBD	734.34
47	Lophelia Coral Conservation Area	Existing	OEM	14.80
48	Cold Seeps	Proposed	TBD	2005.16

*MPA is Marine Protected Area; OEM is Other Effective Area-Based Conservation Measures; TBD is to be determined, NWA is National Wildlife Area; NP is National Park, SBA is Sensitive Benthic Area.

3. DATA AND METHODS

3.1 Available surficial geology maps

Information on the geological conditions of the seafloor within the 48 NCS is taken from a literature review. Even though the surficial geology of the seafloor has already been interpreted within the entire SSB as part of previous studies, most of this information was produced at a smaller scale (i.e. a larger area) than what is required for NCS. Indeed, two existing surficial geology maps produced at small scales cover the seafloor of the SSB. A first map extends over the continental shelf (Fader *et al*., 2004) and a second map covers the continental slope (Piper, 1991). These two maps were combined and updated by Philibert *et al*. (2022) for a bioregional study as part of the MGMSP Program. However, whereas the surficial geological compilation of the bioregion aims to provide an overall picture of the conditions on the seabed, the assessments aim to provide more detailed information in order to answer questions specific to each NCS. Therefore, the maps of Piper (1991), Fader *et al*. (2004) as well as Philibert *et al*. (2022) have not been included in the compilation of available data for the purpose of the present study since they do not provide the horizontal resolution required for NCS. Only large scale (i.e. small area) surficial geology maps that provide higher horizontal resolution than the bioregional compilation of Philibert *et al*. (2022) have been considered here.

3.2 Available bathymetry, backscatter strength and sidescan sonar information

GSC databases, as well as the Canadian Hydrographic Service (CHS) and DFO, provided multibeam sonar bathymetry, backscatter strength information and bathymetric LiDAR from past expeditions. Also included is publicly accessible information such as National Oceanic and Atmospheric Administration expeditions (NOAA, 2021) and Canadian Hydrographic Service Non-Navigational Bathymetric data (NONNA 10 and NONNA 100) (CHS, 2018) as well as LiDAR data available from the Halifax Regional Municipality (HRM, 2018) in the Province of Nova Scotia. Although, most of HRM LiDAR data is focussed on land, some of the points on the coast allowed visualization of the shallow coastal waters usually not accessible using multibeam sonar at sea. Moreover, 3D seismic data acquired by the petroleum industry were included (CNSOPB, 2003 and 2013).

All the available hydroacoustic and LiDAR data were displayed in ArcGIS to map the extent of data coverage and to determine overlap with NCS polygons. High-resolution bathymetric data underpin the interpretation of the surficial geology and seabed conditions. Therefore, mapping the coverage of these data identifies knowledge gaps and guides future survey effort. Multibeam sonar backscatter strength data aids in the characterization of surficial sediments. The intensity of the backscatter is a function of the texture, particle size and porosity of the sediments.

3.3 Sub-bottom profiles

All the seismic reflection and sub-bottom profiles within the SSB were retrieved from the publically available GSCA Expedition Database (ED) (https://ed.gdr.nrcan.gc.ca/index_e.php) and mapped in ArcGIS to determine the geophysical information available within each NCS. The data were acquired using a variety of seismic sources and receivers from the 1960s until the present. Seismic reflection and sub-bottom profiles provide information on the internal structure of seabed sediments as well as provide evidence of events that affected sedimentation. Seismic profiles are often used as a complement to multibeam sonar data; the combination of data types enhances the mapping of the distribution of sedimentary units and structures.

3.4 Seabed samples

The inventory of seabed samples are from the Expedition Database. Sample types include piston and gravity cores, grabs, grainsize analyses and seabed photographs. The results are mapped in ArcGIS to determine the sample information available within each NCS.

Grain size analyses are used to classify seabed sediment type (gravel, sand or mud) following the Wentworth size class scheme for clastic sediments (Wentworth, 1922), modified by Folk (1954). Grain size analyses alone are not sufficient to map the surficial geology as samples are widely distributed within the SSB in general and within the NCS in particular. When combined with other high resolution hydroacoustic and geophysical data, they are useful for confirming or validating interpretations. An inventory of seabed samples (i.e. cores and grabs) within the NCS that have not been analyzed was made to assess the possibility of carrying out additional particle size analyzes. Results of this inventory are given in Section 4.3.

Seabed photographs available within the NCS were extracted from the Expedition Database. This imagery, analysed in conjunction with other high resolution hydroacoustic data and/or sub-bottom profiles, can be used to validate geoscientific interpretations.

4. RESULTS

The available geoscience information is compiled in tables and presented on a series of maps showing the location of the data in relation to the extents of the NCS.

4.1 Surficial geology

The surficial geology maps used for the NCS are from previous GSC publications including Open File reports and formal "A Series" maps. A total of 11 existing surficial geology maps fall within the limits of some of the 48 NCS (Table 2). The areal extent of these maps is shown on Figure 2 along with the location of the NCS polygons.

Table 2. List of surficial geology maps in the SSB

Number	Area	Reference
1	Bay of Fundy	Shaw *et al.*, 2012
2	Browns Bank	Todd *et al.*, 2006
3	Georges Bank	Todd and Valentine, 2015
4	Liverpool and South Shore of Nova Scotia	King *et al.*, 2013
5	South Shore of Nova Scotia	Piper *et al.*, 1986
6	Eastern Islands	King, 2018
7	Bras d'Or Lake and Great Bras d'Or	Shaw and Potter, 2008a, b
8	St. Anns Bank	King, 2014
9	The Gully	Cameron *et al.*, 2008
10	Mohican Channel	Campbell *et al.*, 2008
11	Lower Scotian Slope	Campbell, 2013

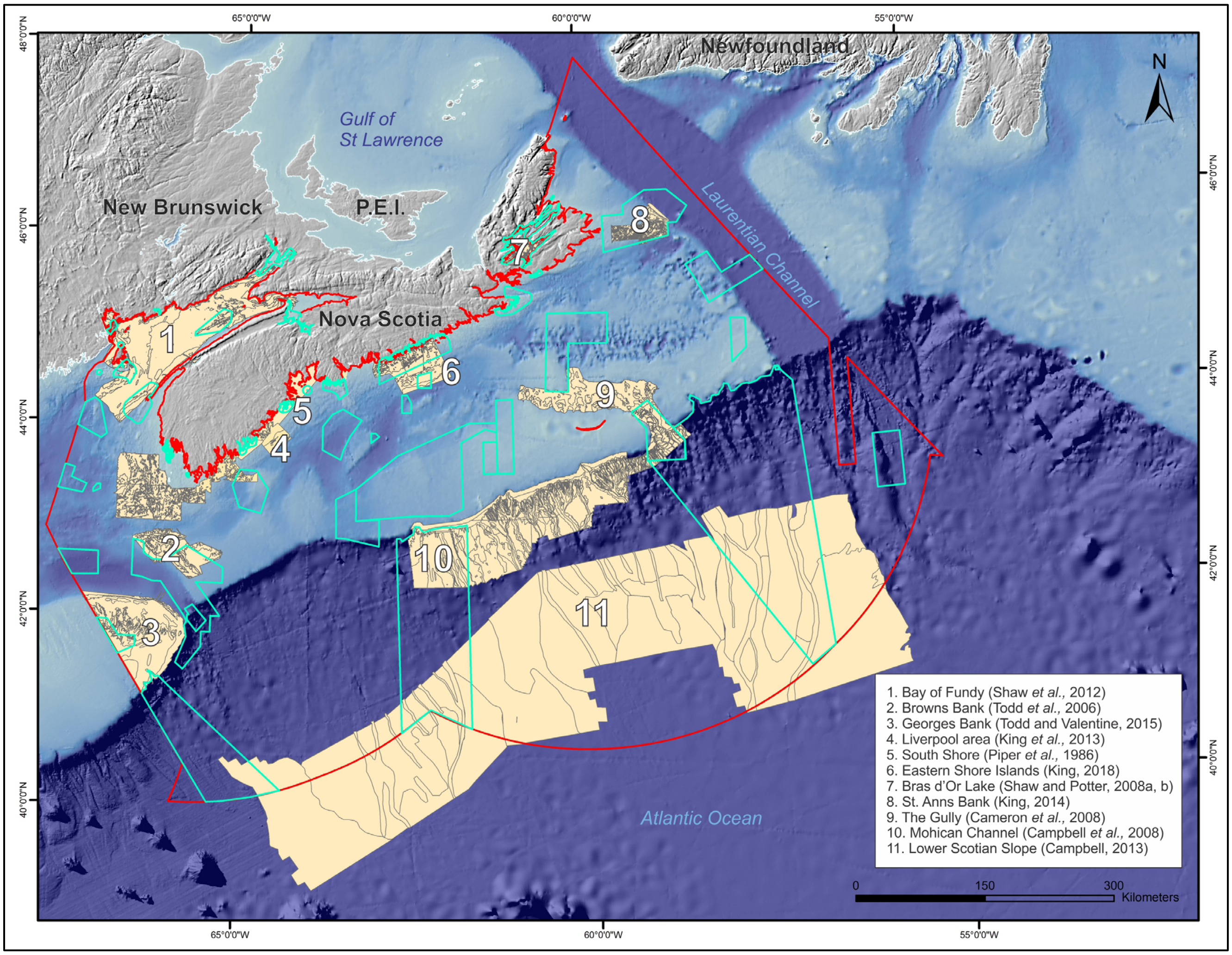

Figure 2: Location map of published surficial geology maps within the SSB, highlighted in light brown. The numbers 1 to 11 on these maps correspond to the maps listed in Table 2. The NCS are indicated by blue polygons.

4.2 Data types

The data used for this study include multibeam sonar, backscatter strength, bathymetric LiDAR, LiDAR and sidescan sonar. These data were acquired by GSC, CHS, academia and industry. Twenty-two datasets of various horizontal resolutions underlie some of the NCS. The datasets are listed in Table 3 and their extent is displayed on Figure 3. LiDAR, hydroacoustic data and surficial geology mapping are shown in Figure 4. These types of information are fundamental to assess the state of geoscientific knowledge within the NCS and establishing knowledge gaps.

Table 3. List of available hydroacoustic and LiDAR datasets within the SSB

No	Area	Institution or Author	Type of data	Resolution
1	Bay of Fundy	Geological Survey of Canada	Gridded Multibeam Bathymetry 1992 - 2009	High
2	Browns Bank	Canadian Hydrographic Service	Gridded Multibeam Bathymetry 1996 - 1997	High
3	Georges Bank	Geological Survey of Canada	Gridded Multibeam Bathymetry 1999 - 2000	High
4	Mahone Bay and St. Margarets Bay	Canadian Hydrographic Service	Multibeam and Bathy-LiDAR 2005 - 2011	High
5	Halifax Approaches–Prospect	Canadian Hydrographic Service	Gridded Multibeam Bathymetry 1990 - 2002	High
6	Halifax Regional Municipality	Halifax Regional Municipality	LiDAR DEM 2018	High
7	Sheet Harbour	Geological Survey of Canada	Gridded Multibeam Bathymetry 2003 - 2004	High
8	Chedabucto Bay	Canadian Hydrographic Service	Gridded Multibeam Bathymetry 1996 - 2000	High
9	Bras d'Or Lake	Canadian Hydrographic Service	Gridded Multibeam Bathymetry 1999, 2000, 2001, 2002, 2003 and 2004	High
10	St. Ann Bank	Canadian Hydrographic Service	Gridded Multibeam Bathymetry	High
11	Western Upper Scotian Slope	United States Geological Survey	Gridded Multibeam Bathymetry 2009	High
12	Western Upper Scotian Slope	NOAA (Okeanos Explorer)	Gridded Multibeam Bathymetry 2019	High
13	Central Scotian Slope	Geological Survey of Canada	Gridded Multibeam Bathymetry 2000	High
14	Central Scotian Slope	CNSOPB Shelburne Project NS24-S006-003E	3D Seismic 2013	High
15	Western Scotian Slope	Hughes Clark *et al.*, 1992	Sidescan Sonar	Medium
16	Central Upper Scotian Slope	Marine Geoscience Data System	Gridded Multibeam Bathymetry 1998	High
17	Lower Scotian Slope	Canadian Hydrographic Service	Gridded Multibeam Bathymetry 2012	High
18	The Gully	Geological Survey of Canada	Gridded Multibeam Bathymetry 1996, 1997, 1998 and 2000	High
19	Eastern Upper Scotian Slope	CNSOPB Stonehouse Project NS24-E043-002E	3D Seismic 2003	High
20	Eastern Upper Scotian Slope	Canadian Hydrographic Service	Gridded Multibeam Bathymetry 2017	High
21	Laurentian Fan	Geological Survey of Canada	Gridded Multibeam Bathymetry 2006	High
22	Inner Scotian Shelf	Canadian Hydrographic Service	Multibeam, Lidar and Non-Navigational Bathymetric Data	Low to High

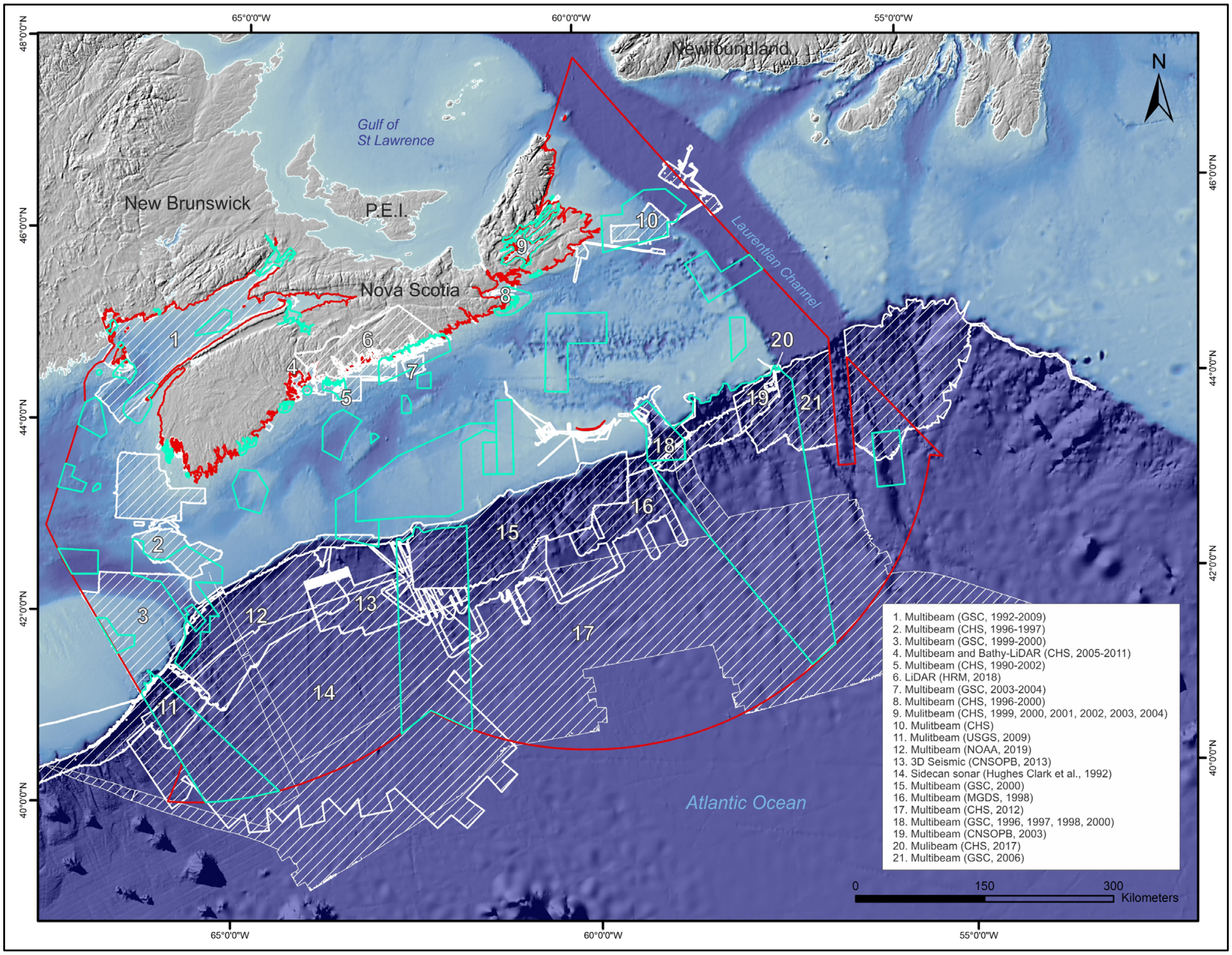

Figure 3: Location of available data within the study area. The numbers 1 to 21 on these datasets correspond to the datasets listed in Table 3. The NCS are indicated by blue polygons. (Non-Navigational Bathymetric data from CHS (NONNA-10 and NONNA-100; Number 22 in Table 3) are not displayed on this map).

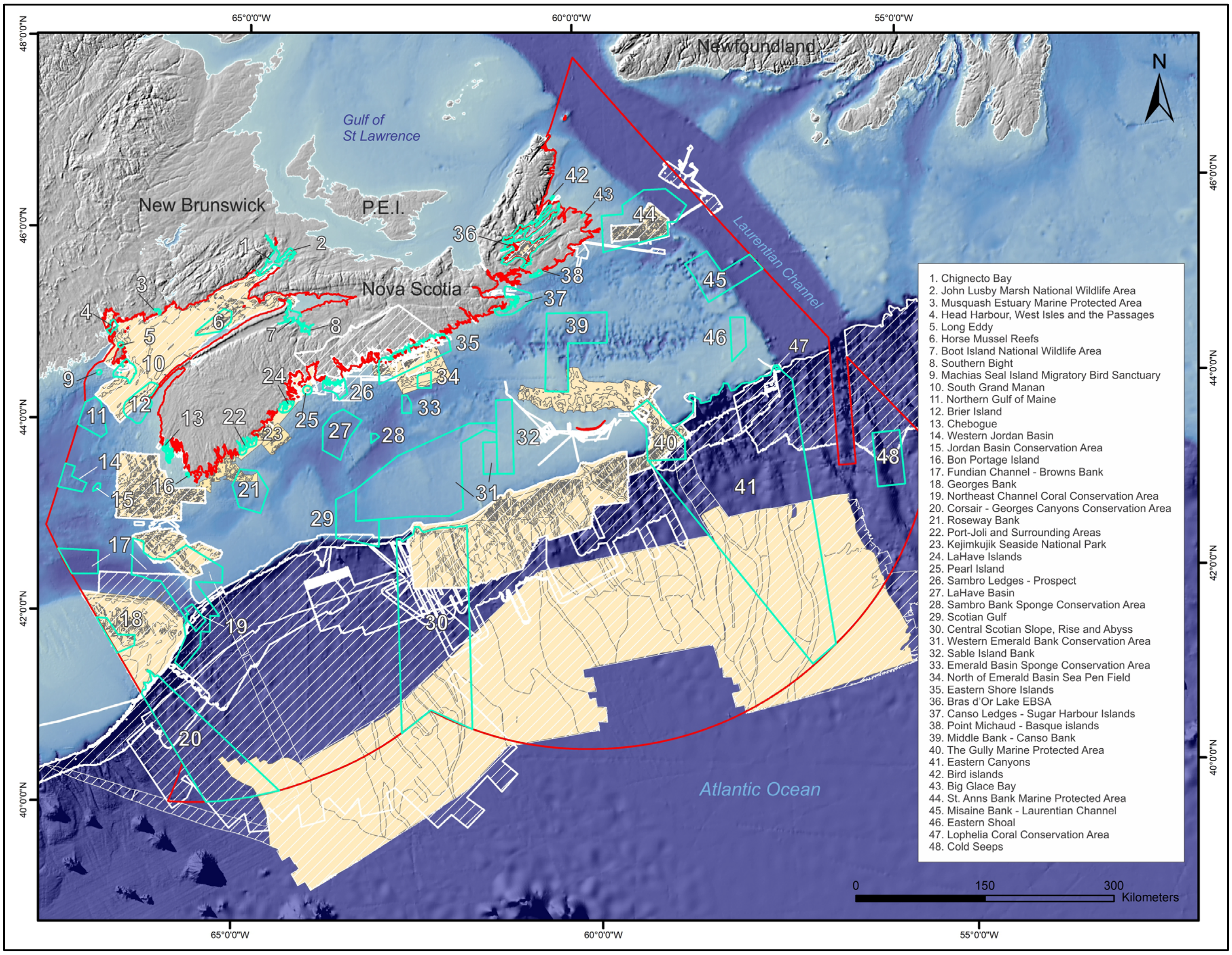

Figure 4: Combined locations of available data and surficial geology maps (brown polygons) within the study area.

4.3 Sub-bottom profiles and grainsize analyses

Figures 5 to 8 show the location of other pertinent data retrieved from the GSC expedition database within the NCS (i.e. sub-bottom profiles, grainsize analyses, seabed photos and videos, sediment cores).

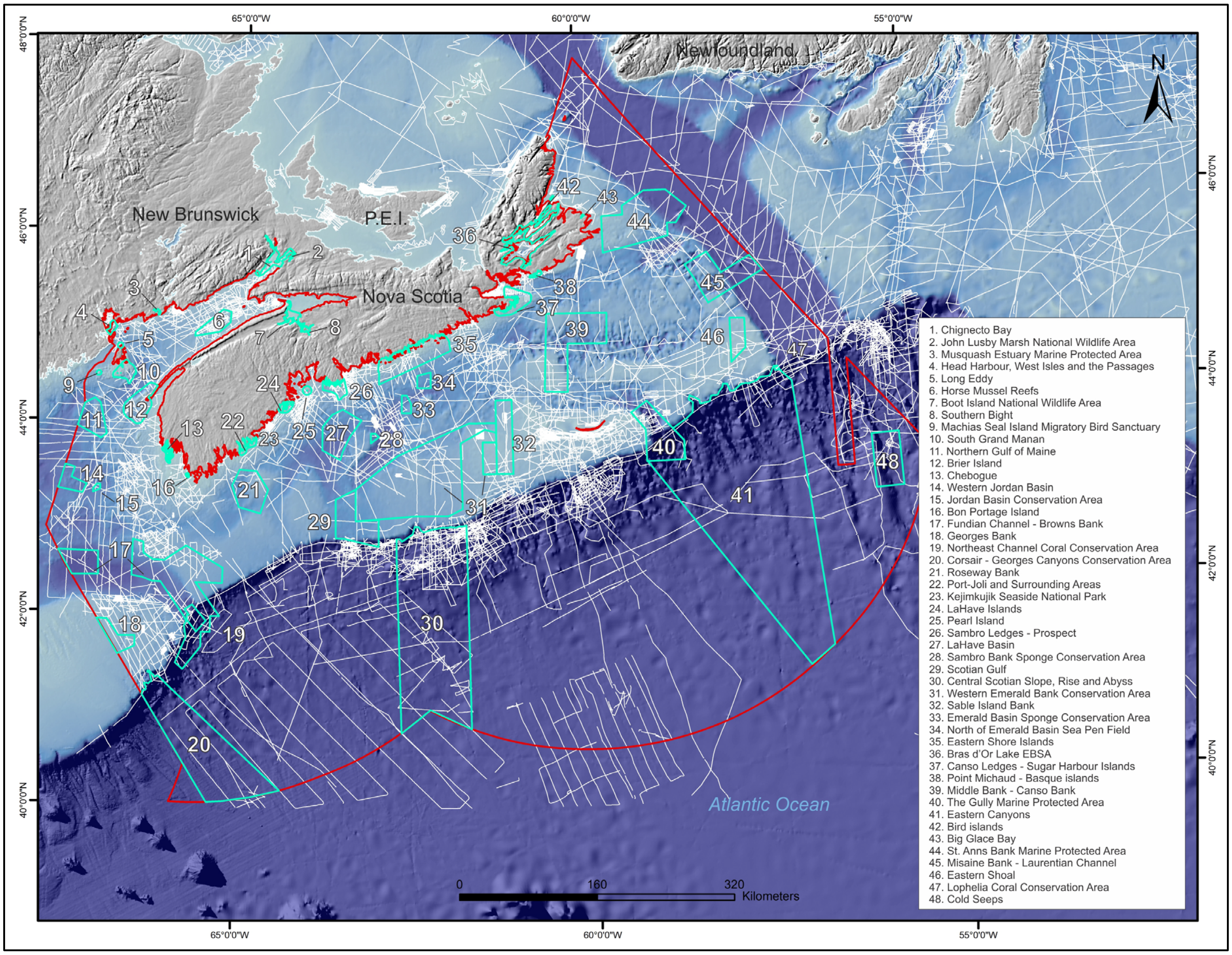

Figure 5: Location of sub-bottom profiles within the study area.

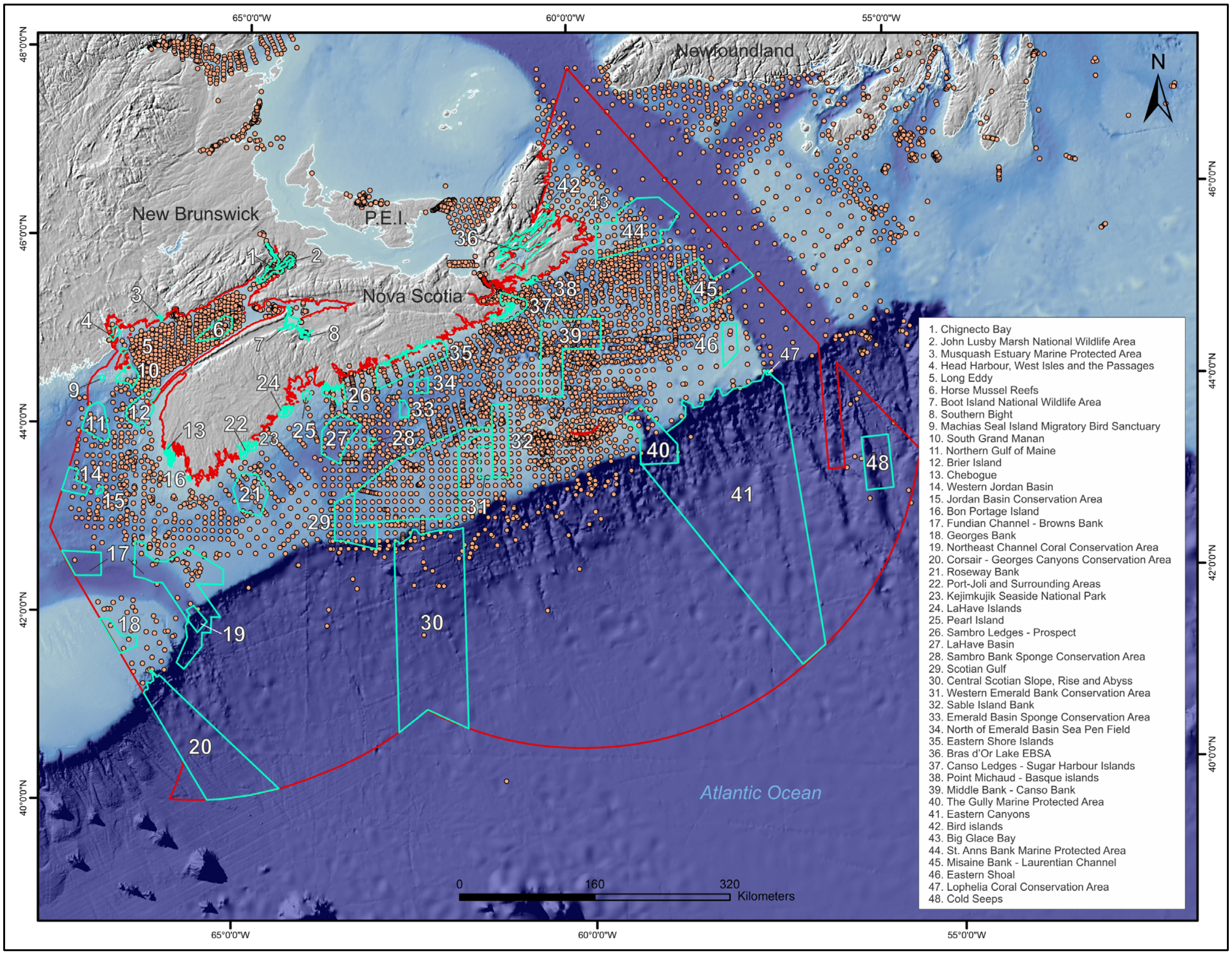

Figure 6: Location of grain size analyses within the study area.

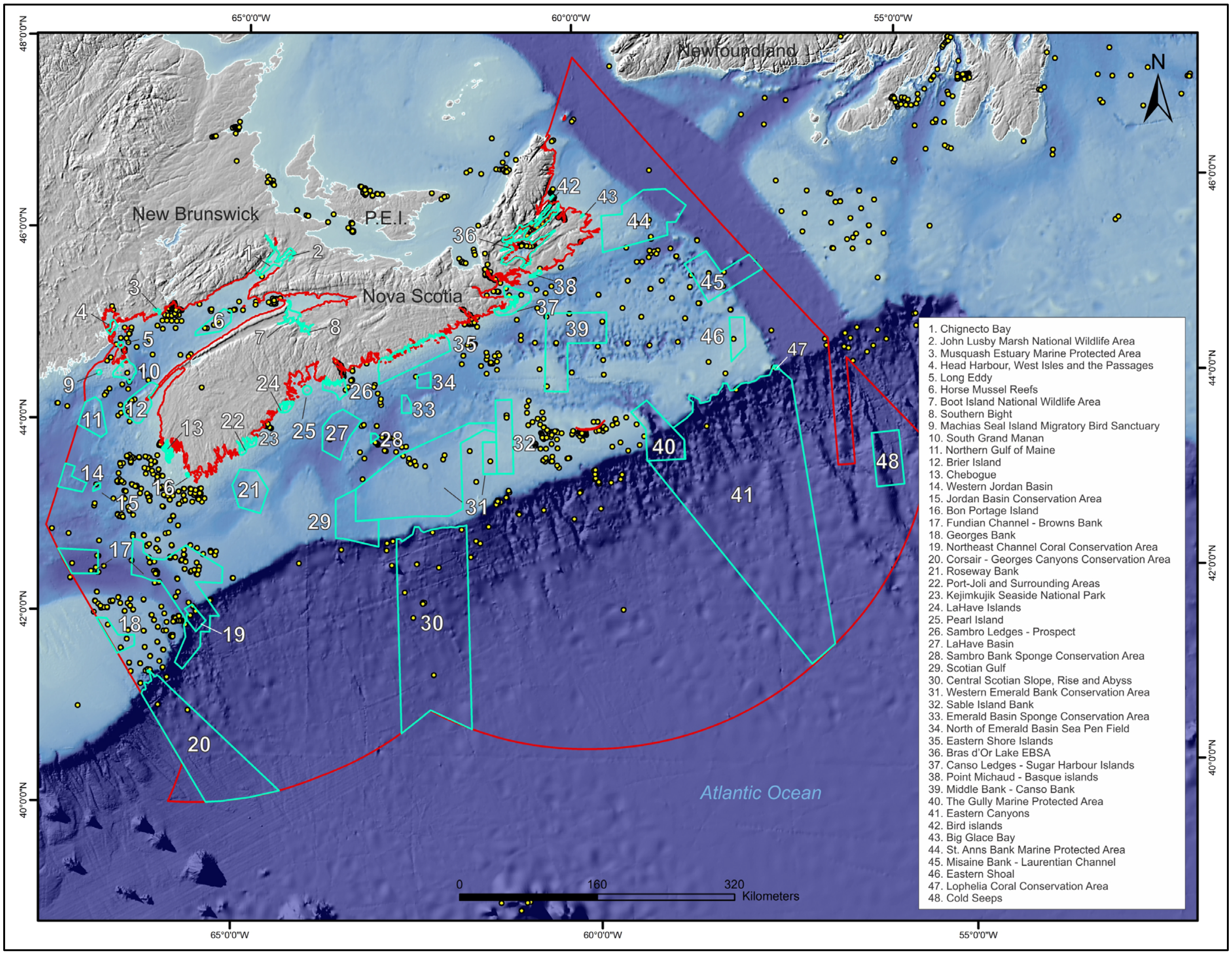

Figure 7: Location of seabed photos and video within the study area.

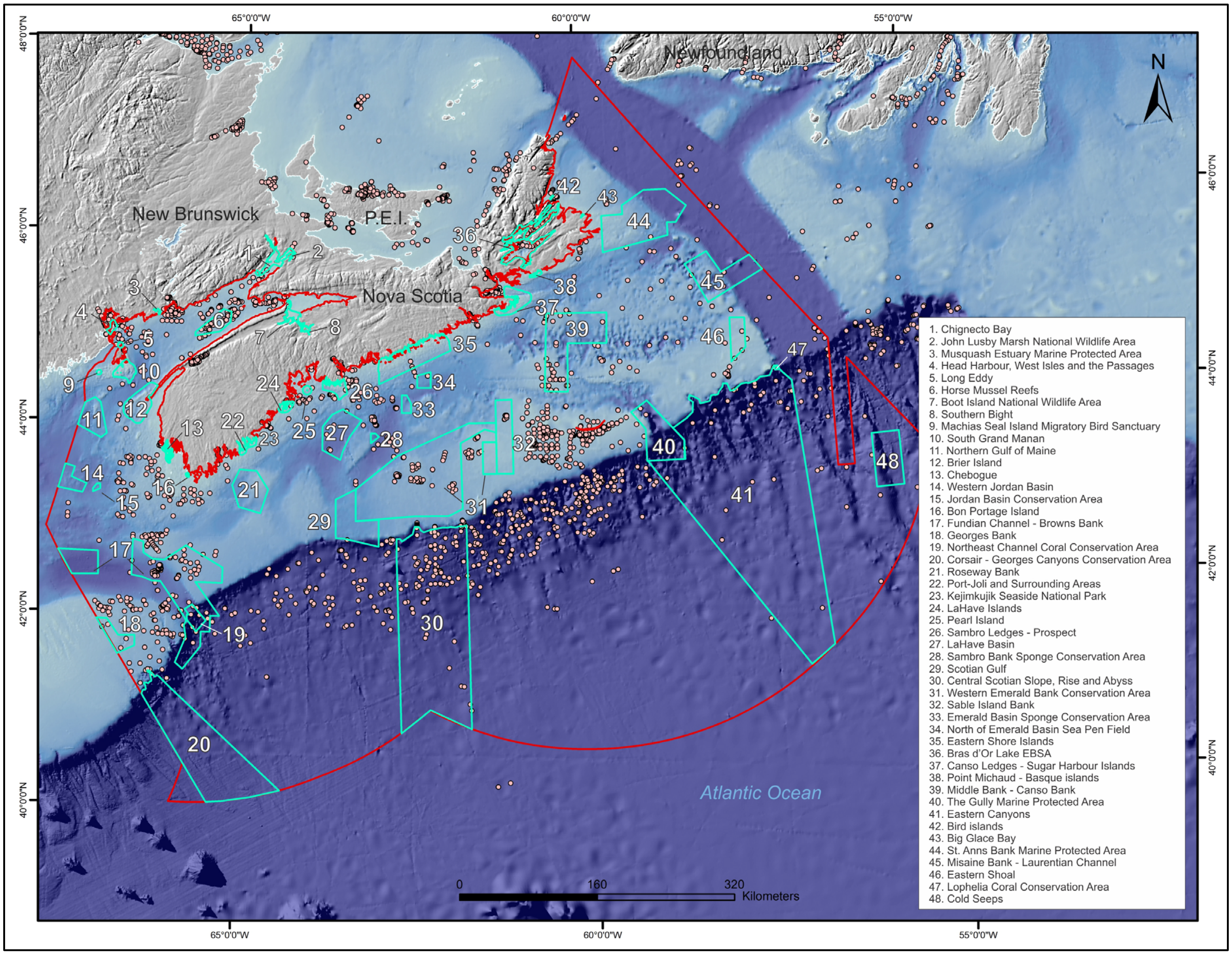

Figure 8: Location of the sediment cores collected within the study area.

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5. DISCUSSION

The compilation of the different types of available geoscience data within each of the NCS highlights considerable knowledge gaps on the Scotian Shelf. Many candidate sites have inadequate available geoscience seabed data to support informed management of the seafloor. Therefore, this compilation will serve as a gap analysis useful in determining priorities for geoscience data acquisition on the Scotian Shelf.

5.1 Relative importance of geoscience data

Geoscience data employed in the creation of seabed surficial geology maps includes 1) single point information, such as grain size samples or seabed photographs; 2) linear information such as a seismic reflection profiles or seabed video transects; and 3) areal coverage information such as multibeam sonar bathymetry and/or backscatter strength, sidescan sonar data and bathymetric LiDAR. Of highest relative importance is multibeam sonar bathymetry and bathymetric LiDAR data which provide a three-dimensional image of seabed morphology; this information underpins surficial geology interpretations. The associated backscatter strength provides insight into the seafloor texture and sediment type. In practice, backscatter strength is often sufficient to create a preliminary surficial geology map. Other geoscience data are then employed to refine the boundaries between seabed geological units. Bathymetry and backscatter strength are the most powerful tools in the geological toolkit. Where multibeam sonar data are not available, it is more challenging to create a seabed surficial geological map because point and linear geoscience data have a limited spatial context. These data types are usually spaced far apart on the seabed forcing the geological mapper to interpolate between observations. In best practice, government, academic and industry seabed geological maps are based on the highest possible resolution multibeam sonar bathymetric and backscatter data. Maps created without this information are considered incomplete.

Sub-bottom profiles provide geoscientific information about the third dimension of a surficial geology map, that is, the sediments below the seabed. When interpreted, seismic profiles are considered in conjunction with the two-dimensional plan view of the seabed revealed through multibeam sonar bathymetry and backscatter strength, interpolation of seabed geological boundaries and sub-seabed geology is enhanced. The grid spacing is dependant on the scale of mapping being undertaken. For a very small area, the grid spacing may be 100 m or less, while regional surveys often have grid lines spaced by kilometres.

Most of the legacy seismic reflection profiles held by the GSC were not collected in a grid pattern because these lines predate the advent and wide adoption of multibeam sonar. Legacy survey lines were most often designed to “chase” specific or suspected geological features of interest on the seabed and in the subsurface, thus after many decades a distinctly disorganized survey line pattern, at least to the modern eye, has emerged. Fortuitously, the present best practice of first surveying a seabed area of interest with multibeam sonar has breathed new life into legacy seismic data. Careful inspection of these legacy lines in conjunction with modern multibeam sonar data allows new and improved geological interpretations. The legacy lines often provide the basis of new, gridded survey lines designed to maximize the gain of subsurface knowledge with a minimum number of survey lines.

Seabed samples (and subsequent analyses of their grain size) combined with seabed photographs and video provide groundtruth geoscience information to support the geological interpretation principally derived from multibeam sonar and seismic data. The groundthruthing via seabed samples and videos helps to identify the precise surficial geology units observed on multibeam sonar and backscatter strength maps.

5.2 Interpretation of the compiled geoscience data

Based on the type and availability of geoscience data within the limits of the NCS, we determined whether the NCS have sufficient publically available data to enable a geologically viable study of the seafloor conditions. This is based primarily on the coverage of high-resolution LiDAR, hydroacoustic data and/or detailed surficial geology maps within each of the NCS as these two types of data provide key information to assess seabed conditions. A four-colour code was established to characterize the feasibility of geologically viable mapping.

- Green: Corresponds to the NCS that are completely covered by high-resolution data and/or detailed surficial geology maps. Some have already been the subject of past studies and are completely interpreted. Some are partially interpreted, but would benefit from high-resolution surveying that would enable the completion of previous studies. Some NCS are entirely covered by high-resolution data but have not been geologically interpreted.

- Yellow: Corresponds to the NCS where high-resolution data and/or detailed surficial geology maps are available for more than 50% of the area. Therefore, geological mapping would remain incomplete until new high-resolution surveys were undertaken.

- Orange: Corresponds to NCS where publically available geoscience data are insufficient, either because they are of a low resolution or they cover less than 50% of the areal extent of the NCS

- Red: Corresponds to the NCS where no publically available data and surficial geology data are currently available within their limits. These areas would require extensive surveys in order to create geological maps.

The compilation of high-resolution data and detailed surficial geology maps within each of the NCS polygons and whether the data meet the minimum requirement for surficial geology mapping is discussed in the following sections 5.3 and 5.4. Figure 9 shows the assigned colour for each polygon.

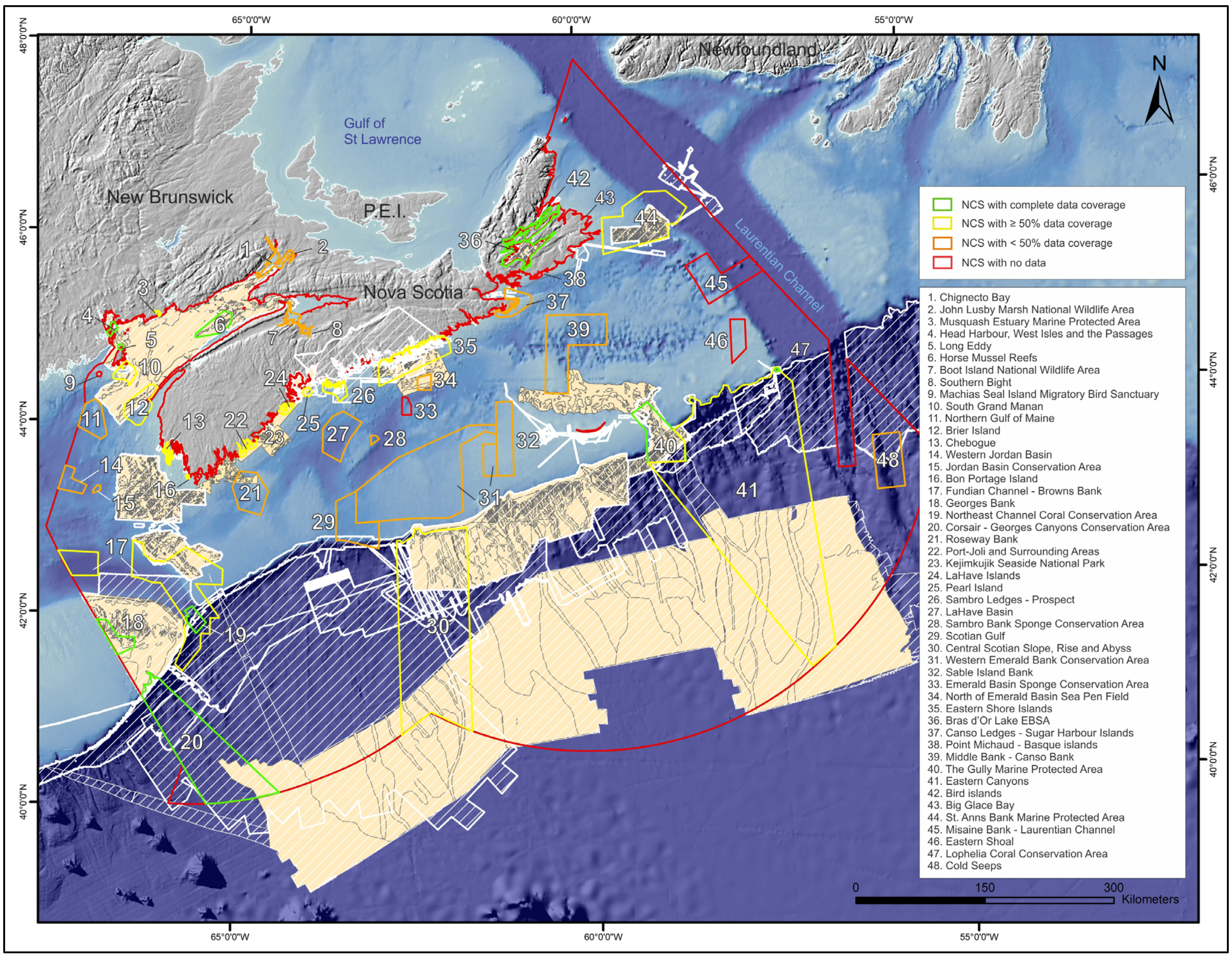

Figure 9: NCS polygons and their assigned colour according to the type, resolution and coverage of geoscience data available within their limits.

5.3 Polygons with minimum requirements

Analysis of the data compilation reveals that of the 48 NCS polygons identified by DFO, 23 appear to have minimum geoscience data requirements to create a geological map either on the entire NCS area or ≥50% of the area. Of those 23 polygons, 9 are entirely covered by high resolution data (green polygons, Figure 9) and 14 have high resolution data or surficial geology available on more than 50% of the area but do not cover the entire area (yellow polygons, Figure 9).

Some of the NCS polygons are located within the boundaries of existing studies and thus have been mapped either partially or entirely at a detailed resolution. In some cases, no further data have been acquired since these studies were conducted. In other cases, new data have been acquired since the publication of these past studies. Therefore, the geological interpretation could be refined or extended. A brief description of these NCS with available surficial geology data and the reference to the associated maps and studies is provided below. These NCS polygons are described below and located on Figure 9.

5.3.1 NCS polygons with complete data coverage (green polygons)

- Three polygons are located in the Bay of Fundy and are fully covered by the interpretation of Shaw *et al*. (2012). These polygons are Head Harbour, West Isles and the Passages (Number 4, Figure 9), Long Eddy (Number 5, Figure 9) and Horse Mussel Reef (Number 6, Figure 9).

- The Georges Bank NCS (Number 18, Figure 9) is entirely located within the limits of the Todd and Valentine (2015) surficial geology and geomorphology map which already provides a good level of detail.

- The Northeast Channel Coral Conservation Area (Number 19, Figure 9) is entirely covered by high resolution multibeam data collected by NOAA onboard the *Okeanos Explorer* (2019) and by the GSC (Georges Bank 1999-2000) (Todd, 2013; Todd and Courtney, 2014). The Corsair–Georges Canyon Conservation Area (Number 20, Figure 9) is also covered by multibeam sonar data acquired by USGS onboard the *Ron Brown* (USGS, 2009), as well as multibeam sonar from CHS (2012) and sidescan from Hughes Clarke *et al*. (1992). In both NCS, a few seismic profiles, cores and grainsize analyses are available to validate the interpretation.

- The Bras d'Or Lake EBSA (Number 36, Figure 9) has been the subject of past studies and is entirely located within the limit of the Shaw and Potter (2008a, b) surficial geology map of Bras d'Or Lake (Shaw and Potter, 2007a, b, c, d).

- The Gully Marine Protected Area (Number 40, Figure 9) has almost entirely (> 79%) been interpreted at a high level of detail by Cameron *et al*. (2008). Their interpretation could be extended to the rest of the polygon using available multibeam sonar data.

- Lophelia Coral Conservation Area (Number 47, Figure 9) is entirely covered by multibeam and backscatter data (CHS, 2017). A few seismic profiles, a core and camera footage are also available to validate the interpretation.

5.3.2 NCS polygons with ≥ 50% data coverage (yellow polygons)

- Three NCS polygons are located in the Bay of Fundy and are partially covered by the interpretation of Shaw *et al*. (2012). These polygons are Musquash Estuary Marine Protected Area (85%) (Number 3, Figure 9), South Grand Manan (66%) (Number 10, Figure 9) and Brier Island (55%) (Number 12, Figure 9). The interpretation potentially could be extended to the rest of the polygon using shaded seafloor relief images (based on OLEX license held by GSCA), seismic profiles and other seabed samples. However, the resolution would be inferior to Shaw *et al*. (2012) unless new multibeam sonar bathymetric data is acquired to complete the data coverage within these NCS polygons.

- Chebogue (Number 13, Figure 9) and Bon Portage Island (Number 16, Figure 9) are both entirely covered by a combination of NONNA 10 and NONNA 100 data from CHS as well as Olex single beam shaded relief. However, these data are of variable resolutions. Therefore, the areas covered by NONNA 10 bathymetric data benefit from a greater resolution then the areas covered by NONNA 100 and Olex. Furthermore, neither of these two polygons have any seismic profiles or seabed samples within their boundaries to enable validation of the interpretation.

- The Fundian Channel–Brown Banks NCS (Number 17, Figure 9) is partially mapped by Todd *et al*. (2006) who interpreted with a high level of detail the surficial geology of Brown Banks. The Todd *et al*. (2006) interpretation could potentially be extended in certain areas of the polygon, notably on the shelf break in the upper slope where new multibeam sonar bathymetric data were collected by NOAA onboard the *Okeanos Explorer* in 2019. However, most of the Fundian Channel is lacking high resolution surveys so any surficial geology interpretation would be of a lower resolution in this area of the polygon unless more data are acquired.

- Two polygons of interest (i.e. Port Joli and Surrounding Areas (Number 22, Figure 9) and LaHave Islands (Number 24, Figure 9) are located within the interpretation of Piper *et al*. (1986) along the South Shore of Nova Scotia. The Port Joli and Surrounding Areas polygon is partly covered by NONNA 10 and NONNA 100 data from DFO and the LaHave Islands polygon is also partially covered by NONNA 100 which could enable the improvement of Piper's (1986) map.

- The surficial geology of Pearl Island (Number 25, Figure 9) and Sambro Ledges–Prospect (Number 26, Figure 9) are covered to 90% and 100% respectively by multibeam sonar and bathy-LiDAR data from CHS which, combined with the seismic profiles and seabed samples, could enable mapping the surficial geology.

- The Central Scotian Slope, Rise and Abyss (Number 30, Figure 9) NCS is located within the limits of different existing maps. The upper section of the polygon close to the shelf break intersects with the Campbell *et al*. (2008) map of the Mohican Channel area and the lower slope has been mapped by Campbell (2013) as part of the United Nations Convention on the Law of the Sea (UNCLOS) program. The interpretation potentially could be extended to the middle section of the polygon using industry 3D Seismic (CNSOPB, 2013) as well as sidescan data from Hughes Clarke *et al*. (1992).

- The Eastern Shore Islands NCS (Number 35, Figure 9) is mapped over most of its area by King (2018). King's interpretation could be extended west and closer to the shoreline using new multibeam sonar and bathy-LiDAR data acquired by CHS as well as NONNA 10 and 100 data.

- The Eastern Canyons NCS (Number 41, Figure 9) intersects with Campbell (2013) map in the mid to lower slope section of the polygon. The surface geology interpretation could be extended to a section in the upper slope below the shelf break using multibeam sonar bathymetric data from GSC (Laurentian Fan 2006). However, 30% of the polygon's area is not covered by any data and therefore, would remain unmapped.

- The polygon of St. Anns Bank Marine Protected Area (Number 44, Figure 9) is covered over 37% of its extent by the King (2014) surficial geology map. King's interpretation could be extended using CHS's NONNA 100 data so that the surficial geology interpretation would cover 50% of the polygon's area. Unless new additional data are collected, the interpretation could not be extended to more then half of the polygon.

5.4 NCS polygons with insufficient data

Analyses of the data compilation revealed that for 25 polygons of interest, the currently available geoscience data either do not exist or are insufficient to enable a high-resolution mapping and study of the seabed conditions. Therefore, unless new data are acquired within these polygons, no further analysis can be conducted. Within these polygons, no surficial geology and/or high-resolution data are available or these data are available only over a small area (less than 50%) and where linear and point data are too sparse to undertake detailed mapping. These polygons are displayed on Figure 9 along with the coverage of existing surficial geology maps and datasets. Figure 9 clearly highlights the knowledge gaps and shows that most of these polygons are located in shallow water close to the coast where surveys are more challenging to perform and on the shelf, notably the eastern portion.

Of these 25 polygons, 15 correspond to areas where currently available data are insufficient, either because they are of a low resolution or they cover less than 50% of their area (orange polygons, Figure 9) and 10 have no data or surficial geology data currently available within their limits (red polygons, Figure 9).

5.4.1 NCS polygons with < 50% data coverage (orange polygons)

- Chignecto Bay (Number 1, Figure 9)
- Southern Bight (Number 8, Figure 9)
- Northern Gulf of Maine (Number 11, Figure 9)
- Jordan Basin Conservation Area (Number 14, Figure 9)
- Western Jordan Basin (Number 15, Figure 9)
- Roseway Bank (Number 21, Figure 9)
- LaHave Basin (Number 27, Figure 9)
- Sambro Bank Sponge Conservation Area (Number 28, Figure 9)
- Scotian Gulf (Number 29, Figure 9)
- Western Emerald Bank Conservation Area (Number 31, Figure 9)
- Sable Island Bank (Number 32, Figure 9)
- North of Emerald Basin Sea Pen Field (Number 34, Figure 9)
- Canso Ledges–Sugar Harbour Islands (Number 37, Figure 9)
- Middle Bank–Canso Bank (Number 39, Figure 9)
- Cold Seeps (Number 48, Figure 9)

5.4.2 NCS polygons with no data (red polygons)

- John Lusby Marsh National Wildlife Area (Number 2, Figure 9)
- Boot Island National Wildlife Area (Number 7, Figure 9)
- Machias Seal Island Migratory Bird Sanctuary (Number 9, Figure 9)
- Kejimkujik Seaside National Park and Historic Site (Number 23, Figure 9)
- Emerald Basin Sponge Conservation Area (Number 33, Figure 9)
- Point Michaud and Basque Islands (Number 38, Figure 9)
- Bird Islands (Number 42, Figure 9)
- Big Glace Bay (Number 43, Figure 9)
- Misaine Bank and Laurentian Channel (Number 45, Figure 9)
- Eastern Shoal (Number 46, Figure 9)

6. CONCLUSION

- A compilation of the different types of available geoscience data within each of the 48 NCS identified by DFO was conducted. The data compiled include surficial geology maps, single beam and multibeam sonar bathymetry and backscatter strength, LiDAR, sub-bottom profiles, cores and other seabed samples, seabed photograph and videography and grainsize analyses.

- This compilation is the preliminary step to the future NCS assessments planned within the MGMSP. The compilation highlights knowledge gaps and therefore provides a tool to determine priorities for future geoscience data acquisition within the Program.

- The results indicate that some NCS have little associated geoscience data and therefore limited seabed knowledge. Characterization of seafloor conditions in these NCS would require the collection of new geoscience information. Despite a significant data gap in the bioregion, some NCS would only require a minimal survey effort to extend the coverage of high resolution data for complete mapping.

- The compilation revealed that of the 48 NCS :

    - 9 have already been the subject of past studies and are entirely covered either by detailed surficial geology maps and/or high resolution data;
    - 14 appear to have the minimum geoscience data requirements to create a geological map on 50% or more of their area;
    - 15 correspond to areas where currently available data are insufficient to create a geological map, either because they are of a low resolution or they cover less than 50% of their area;
    - 10 have no data or surficial geology data currently available within their limits, therefore these areas would require extensive surveys in order to perform a detailed geological study.

- It is important to note that the analyses described in this report correspond to the minimum requirement to study NCS. In addition to the standard analyses described above, new technologies are now allowing for more detailed assessments. In some cases, data acquisition beyond the minimum requirement could be necessary in order to answer specific questions. For example, the use of autonomous underwater vehicles (AUV) (Campbell and Normandeau, 2019) can image features on the seafloor to a higher horizontal and vertical resolution than using conventional hull-mounted multibeam sonar systems. In addition, repeat seafloor mapping in some areas would provide information on seafloor dynamics, which a single multibeam sonar map cannot do.

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