Near-seafloor optical imagery surveys conducted in 2023 and 2024 across the St. Anns Bank Marine Protected Area, Nova Scotia, Canada: Mission report and preliminary findings

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by

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ABSTRACT

Teed, L.L., Lawton, P., and Murillo, F.J. 2025. Near-seafloor optical imagery surveys conducted in 2023 and 2024 across the St. Anns Bank Marine Protected Area, Nova Scotia, Canada: Mission report and preliminary findings. Can. Tech. Rep. Fish. Aquat. Sci. 3739: viii + 46 p.
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A near-seafloor optical imagery survey was conducted in 2023 and 2024 at 41 locations (depths ranging from 17 to 144 m) across the St. Anns Bank Marine Protected Area (MPA), Nova Scotia. Objectives were to characterize unique bathymetric features (e.g., Curdo and Scatarie Banks), validate previously published benthoscape predictions (i.e., classifications of the landscape of the seafloor encompassing biophysical characteristics), and to update information on benthic species assemblages for the first time since MPA designation in 2017. Target locations were selected using high-resolution multibeam data, benthoscape classifications, and prior benthic biological survey locations. Over 44.5 km of the seafloor was surveyed (estimated area coverage 60430 m2) resulting in over 36 hours of digital video, and over 3300 digital still images. Full video sequences were used to describe and characterize each transect and all images were analyzed to ground-truth benthoscapes. Summary observations for Curdo and Scatarie Banks are presented. A sub-set of 639 images was selected for preliminary analysis of species occurrences. Several benthic species recognized as Vulnerable Marine Ecosystem indicators, and/or contributory to defining Ecologically and Biologically Significant Areas, were common throughout the MPA across varying depths, including soft corals (Malacalcyonacea) and stalked tunicate fields. Crinoids (Heliometra glacialis) were found at high densities in gravel and bedrock habitats in the southeast corner of the MPA near plateau features ~100-m deep. Previously noted to occur within the MPA, the 2023 and 2024 surveys provided significant new areal coverage for defining the overall extent of crinoid beds.

RÉSUMÉ

Teed, L.L., Lawton, P., and Murillo, F.J. 2025. Near-seafloor optical imagery surveys conducted in 2023 and 2024 across the St. Anns Bank Marine Protected Area, Nova Scotia, Canada: Mission report and preliminary findings. Can. Tech. Rep. Fish. Aquat. Sci. 3739: viii + 46 p. https://doi.org/10.60825/cqrn-3f33

Des relevés par imagerie optique près du plancher océanique ont été effectués en 2023 et 2024 à 41 emplacements (profondeurs allant de 17 à 144 m) dans la zone de protection marine (ZPM) du banc de Sainte-Anne, en Nouvelle-Écosse. Les objectifs étaient de caractériser des entités bathymétriques uniques (p. ex. bancs Curdo et Scatarie), de valider des prévisions publiées précédemment sur le paysage benthique (c.-à-d. des classifications du paysage du plancher océanique englobant ses caractéristiques biophysiques) et d'actualiser l'information sur les assemblages d'espèces benthiques pour la première fois depuis la désignation de la ZPM en 2017. Les emplacements cibles ont été sélectionnés d'après des données multifaisceaux à haute résolution, des classifications du paysage benthique et des emplacements de relevés biologiques des communautés benthiques effectués antérieurement. Plus de 44,5 km du plancher océanique ont fait l'objet d'un relevé (superficie estimée de 60 430 m^2), ce qui a donné lieu à plus de 36 heures de vidéo numérique et à plus de 3300 images numériques fixes. Des séquences vidéo entières ont servi à décrire et à caractériser chaque transect, et toutes les images ont été analysées pour confirmer les paysages benthiques sur le terrain. Des observations sommaires pour les bancs Curdo et Scatarie sont présentées. Un sous-ensemble de 639 images a été sélectionné à des fins d'analyse préliminaire de la présence d'espèces. Plusieurs espèces benthiques reconnues comme des indicateurs d'un écosystème marin vulnérable et/ou contribuant à définir les zones d'importance écologique et biologique étaient communes dans l'ensemble de la ZPM à différentes profondeurs, y compris des champs de mains de mer (Malacalcyonacea) et de tuniciers lobés. Des crinoïdes (*Heliometra glacialis)* étaient présents en forte densité dans les habitats de gravier et de substratum rocheux du coin sud-est de la ZPM, près du plateaux situés à environ 100 m de profondeur. Les relevés de 2023 et 2024 ont fourni une nouvelle couverture spatiale importante permettant de définir l'étendue globale des lits de crinoïdes dont la présence avait déjà été signalée dans la ZPM.

1 INTRODUCTION

1.1 BACKGROUND

The St. Anns Bank Marine Protected Area (MPA) is situated in the Scotian Shelf Bioregion off the coast of Cape Breton, Nova Scotia (DFO 2023), and contains numerous ecologically and biologically significant features including areas of high biodiversity that include species vulnerable to disturbance (Ford and Serdynska 2013). St. Anns Bank was designated a MPA under Canada's *Oceans Act* in 2017 with conservation objectives structured around three thematic elements: "1) Habitat – conserve and protect all benthic, demersal, and pelagic habitats in the MPA and distinctive physical features and their associated ecological characteristics; 2) Biodiversity – conserve and protect areas of high biodiversity at the community, species, population and genetic levels including priority species and areas of high fish diversity within the site; and 3) Productivity – conserve and protect biological productivity across all trophic levels so that they can fill their ecological role in the ecosystems of the MPA" (DFO 2012, 2023, 2024).

The St. Anns Bank MPA has depths ranging from 17 to 412 m, and is characterized by outflow currents from the Gulf of the St. Lawrence and variable seafloor topography such as shallow banks and deeper plateau features comprised of mixed sediments (DFO 2012; T.J. Kenchington 2014). Numerous habitat types exist here, associated with a high biodiversity of organisms and communities including dense kelp and red algae beds, stalked tunicate fields, crinoid beds, sponge communities, and soft coral gardens (DFO 2012; Ford and Serdynska 2013). An area previously documented to support high benthic diversity is Scatarie Bank, which includes some portions among the shallowest parts of the MPA. Scatarie Bank contains extensive rocky outcrops encapsulating a young volcanic ridge eroded by glaciers and thus contains glacial sediments (Ford and Serdynska 2013; T.J. Kenchington 2014; King 2014). Similar bank features within the MPA include Curdo Bank in the southwest corner; however, this bank has not previously been documented in terms of substrate features and the benthic assemblages associated with it. Shallow bank features within the MPA contain dense sponge populations and extensive coralline algae and red algae cover along with kelp cover (Ford and Serdynska 2013; DFO 2023). Soft corals and sea pens can also be found in the MPA (Cogswell *et al.* 2009), the latter of which occur beyond the shelf (>200 m). Significant concentrations of soft-bottom coral gardens are listed as Ecologically and Biologically Significant Areas (EBSAs; Cogswell *et al.* 2009; E. Kenchington 2014; DFO 2018; NAFO 2024), and thus a conservation priority. High densities of the unstalked (Deja *et al.* 2023) crinoid (feather star) species, *Heliometra glacialis* (Owen, 1833 ex Leach MS), are known to occur towards the eastern portion of the MPA at depths shallower than 200 m (Lacharité *et al.* 2018). Stalked tunicate fields commonly occur across the MPA (Guijarro *et al.* 2016; Beazley et al. 2017; Murillo *et al.* 2024), increasing habitat complexity and when highly aggregated, contribute to the designation of EBSAs domestically and Vulnerable Marine Ecosystems (VMEs) internationally (Murillo *et al.* 2011; DFO 2018; Kenchington *et al.* 2019; NAFO 2024). Numerous fish species are found in St. Anns Bank, including American plaice, Atlantic cod, Witch flounder, Atlantic redfish and the Thorny skate (DFO 2012; Ford and Serdynska 2013; Mancion and Jeffery 2025). Cetaceans also use the MPA, displaying year-round occurrence, suggesting that St. Anns Bank is an important migration route for baleen whales (Ford and Serdynska 2013; DFO 2023).

The MPA is divided into four management zones and covers an area of 4364 km^2 of the inner Eastern Scotian Shelf adjacent to the Laurentian Channel (Figure 1). Zone 1 (3308 km^2) provides a complete refuge from human disruption from fisheries and other bottom contact activities, while Zone 2 (720 km^2), 3 (113 km^2) and 4 (221 km^2) allow for commercial or recreational fishing as adaptive management zones (Minister of Justice 2017). Fisheries and Oceans Canada (DFO) Science and external partners can conduct research in the MPA to support objectives related to monitoring biological communities and evaluating the MPA's design, management, and effectiveness (DFO 2023). Particularly, this includes conducting non-invasive research to monitor the health of ecosystems as a baseline to fill knowledge gaps, or to report trends for long-term monitoring (Choi *et al.* 2018).

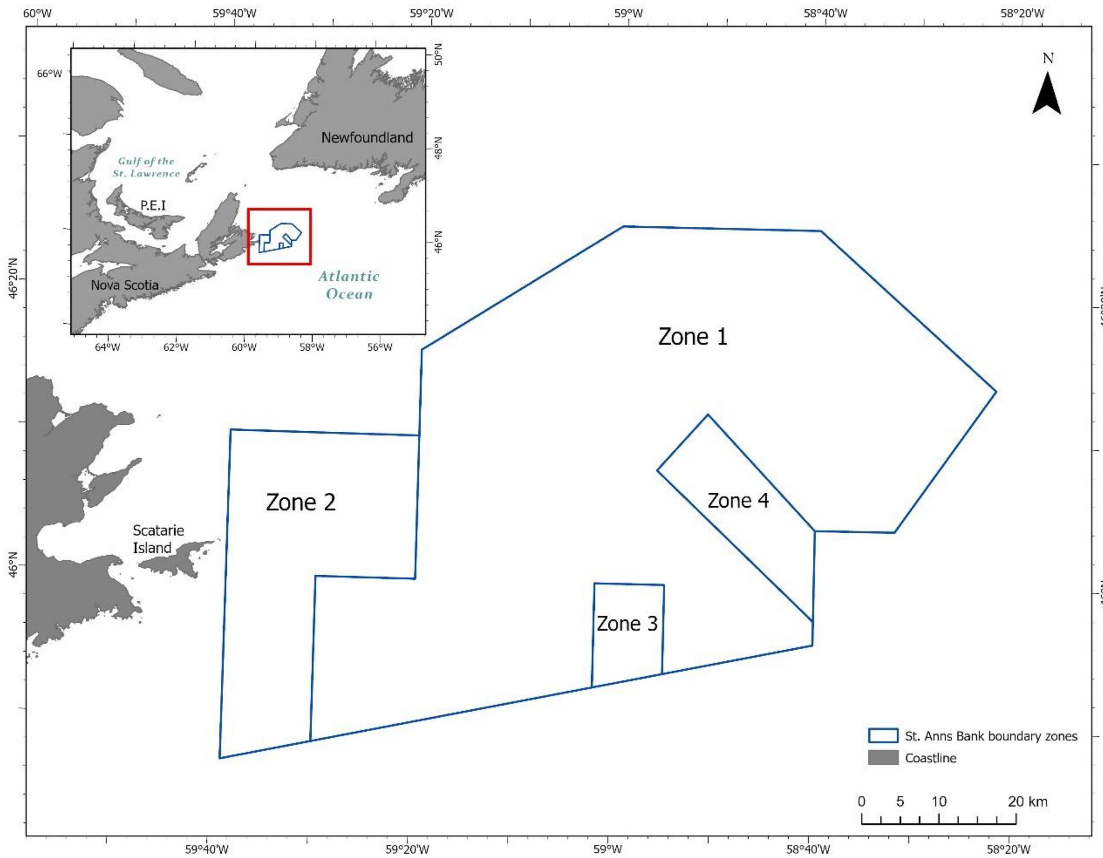

Figure 1 – Management zone boundaries of the St. Anns Bank Marine Protected Area off the Atlantic coast of Nova Scotia. Permitted activities within each Zone are noted in the text.

1.2 PRIOR SURVEYS

Numerous scientific surveys have previously been conducted in the St. Anns Bank MPA, including benthic imaging surveys, trawl surveys, and environmental DNA (eDNA) sampling. Benthic imagery surveys have used drop-camera systems operating off large research vessels to collect imagery along transects at various stations throughout the MPA, conducted prior to the 2017 MPA designation (2009-2010, and 2013-2015; Lacharité *et al.* 2018; Lacharité and Brown 2019; Kenchington and Lirette 2023 – Figure 2). This includes the use of imagery to define unique descriptive categories of the seafloor, referred to as benthoscapes, and to develop predictive benthic habitat maps based on biophysical characteristics and the occurrence of biological structures (Lacharité *et al.* 2018 - Figure 3, see section 2.1 for details). While research conducted prior to MPA designation provided context for developing conservation objectives, there remains the need to conduct follow-up surveys to observe changes in community assemblages over time, especially since MPA designation, provide characterization of previously unsampled areas, and further ground-truth benthoscape predictions. One study found high densities of unstalked crinoids in the southeast portion of the MPA, forming one of seven unique benthoscapes (Lacharité *et al.* 2018 - Figure 3). As dense aggregations of stalked crinoids can form biogenic habitats constituting EBSAs domestically (E. Kenchington 2014; Guijarro *et al.* 2016; DFO 2018) or Vulnerable Marine Ecosystems (VMEs) internationally (Murillo *et al.* 2011; Kenchington *et al.* 2019; NAFO 2024), further research on unstalked species aggregations is warranted.

Historical data and recent ecological monitoring for this MPA also include the use of trawl sets and eDNA metabarcoding surveys. DFO Maritimes Summer Ecosystem Research Vessel Surveys (RV Survey, details in Emberley and Clark, 2012) have included 17 trawl sets within the MPA across 2017, 2019, 2023 and 2024 (Figure 2), with preliminary results documenting over 160 species of fish and invertebrates (Murillo *et al.* 2018, 2024; Mancion and Jeffery 2025). Similarly, the annual Maritimes Snow Crab Survey (using a Bigouden Nephrops net for five-minute deployments) analyzed trawl data from 2015-2023 and found that fish and invertebrate species richness remained stable over time (DFO 2024). Nonetheless, there is a general recognition to prioritize the use of complimentary non-invasive surveys to monitor diversity and abundance more effectively and accurately at fine scales (DFO 2024). As such, non-invasive passive eDNA metabarcoding surveys have been conducted in recent years (since 2021) throughout the MPA to sample biodiversity, revealing nearly 100 invertebrate species and 14 fish species from the 2022 samples (Mancion and Jeffery 2025). This predominantly includes fish and invertebrates known to commonly occur in the area, as well as numerous newly detected zooplankton and phytoplankton species, which cannot be sampled in trawl surveys. While eDNA surveys can passively detect species, this technique does not capture species abundance, distribution or diversity at local scales and requires validation from ground-truthing methods such as benthic imaging surveys.

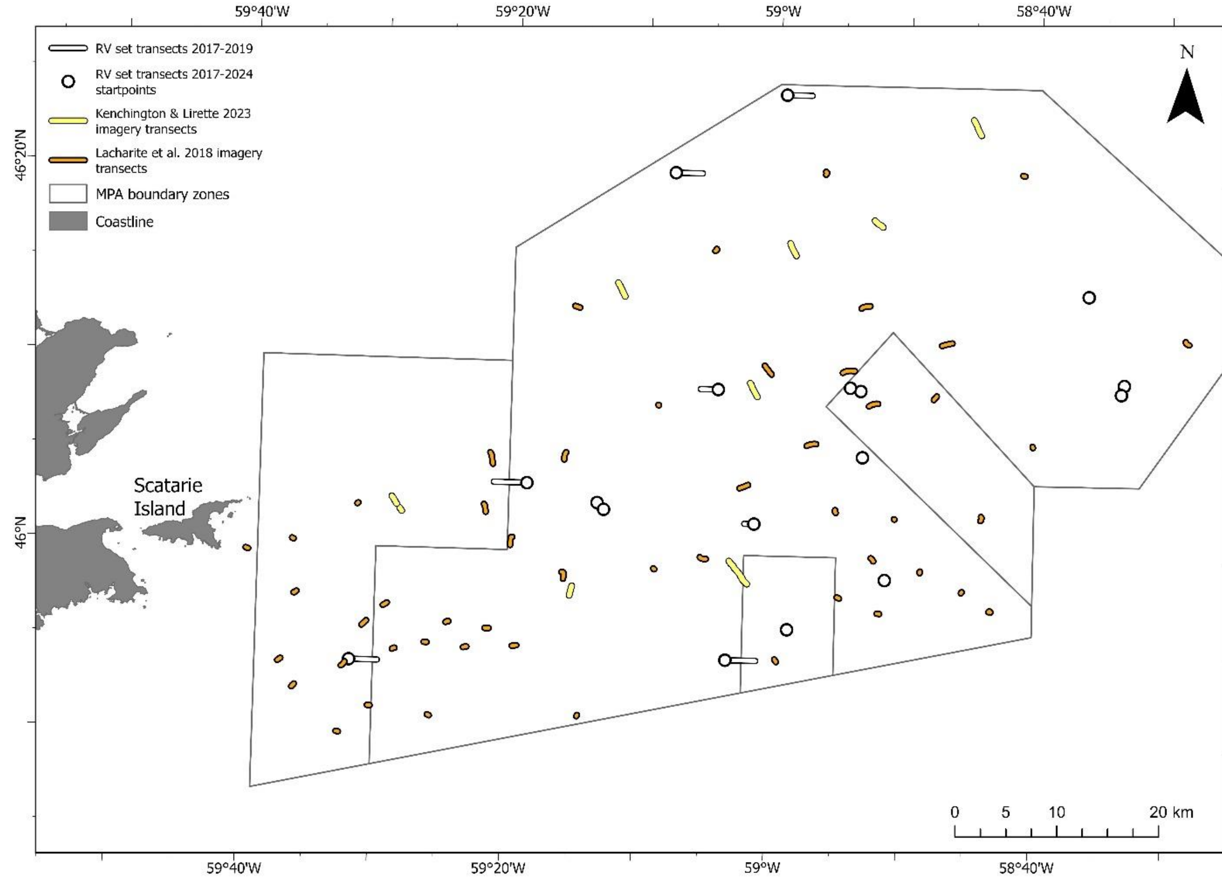

Figure 2 - Prior survey locations for DFO ecosystem trawl surveys (RV set transects, n =17) and benthic imagery surveys (n =71 transects) conducted in the St. Anns Bank MPA.

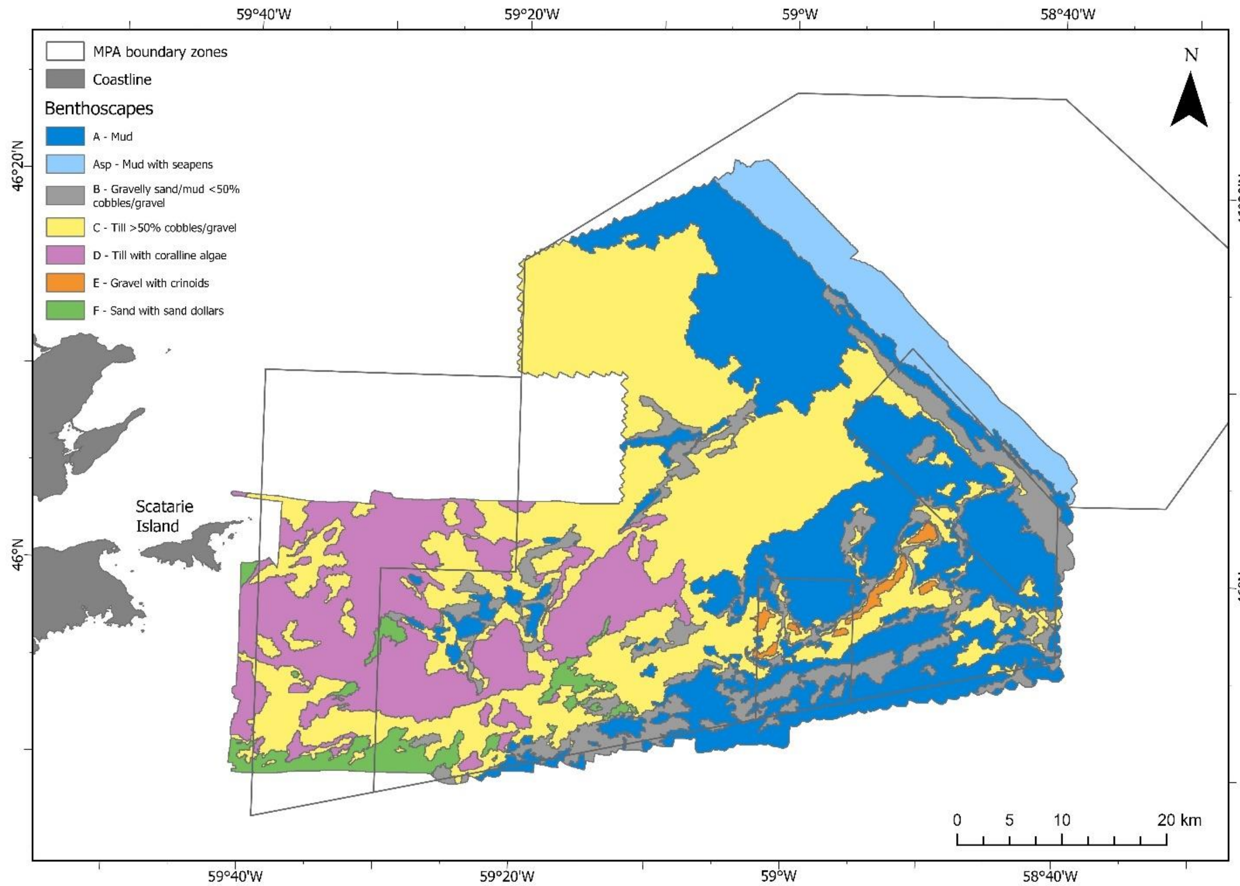

Figure 3 - Benthoscape classification prediction map of the St. Anns Bank MPA derived by Lacharité et al. (2018). Shape files were provided by the authors and used to create this map representation (shape files not available as an open source product)

1.3 PROJECT OBJECTIVES

A DFO Maritimes Region science project "Coastal seabed habitat inventory and biodiversity assessment in support of bioregional conservation network planning and development of MPA monitoring programs", funded under the DFO Science Marine Conservation Targets program from 2021 to 2025, has generated a renewed focus on using both near-seafloor imaging tools and SCUBA diving approaches to survey coastal and inner-shelf benthic habitats in support of the development of MPA ecological monitoring programs. In particular, this project supported the introduction in 2022 of a new regional near-seafloor optical imaging system capable in its initial configuration of surveying to depths of 200 m. The camera system (hereafter referred to as the FOBIS system, for Fibre Optic-Based Imaging System; further details in Section 2.2) was co-developed by ocean technologists within DFO's Ocean Engineering and Technology Section at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, and lead project scientist, Peter Lawton, at DFO's Biological Station, Saint Andrews, New Brunswick. As part of the design criteria for the FOBIS system, the underwater components (cameras, lighting, frame, etc.), as well as the fibre optical cable-based deck winch system, and surface operations consoles were designed to be easily transportable for installation on different regional coastal and inner-shelf survey vessels. A Fall 2022 survey (and subsequent missions in southwest New Brunswick coastal waters in 2023 and 2024) have used the FOBIS system on the Canadian Coast Guard Ship (CCGS) *Viola M.*

Davidson, an 18 m-length research vessel (Teed *et al.* 2024; Lawton and Teed 2025a). The FOBIS system inherits a number of design criteria from the DFO Maritimes Region CAMPOD system, a much larger benthic imaging system, which requires a large ocean research vessel platform, often 90 m-length or more (see for example de Mendonça and Metaxas 2021). Many of the FOBIS system components (cameras, lights, lasers, digital recording systems) are interchangeable with those used on the CAMPOD system, providing for two complementary benthic imaging survey tools for use in DFO's Maritimes Region science programs.

This report outlines the first major benthic survey efforts in 2023 and 2024 with the FOBIS system at regional inner-shelf locations, specifically within the St. Anns Bank MPA, using the 22 m-length CCGS *M. Perley*. Here, we summarize the spatial coverage of near-seafloor imaging transects, as well as preliminary observations on key species encountered, and benthic habitats investigated in relation to previous surveys. We also provide further ground-truthing of prior benthoscape predictions (Lacharité *et al.* 2018). More precisely, three research objectives were developed for this report as the first steps in biodiversity assessments and habitat characterization to support future ecological monitoring efforts in the St Anns Bank MPA:

1) Ground-truth prior benthoscape predictions, making data comparisons in this study's report with previous quantitative work.
2) Provide initial qualitative habitat information on unique bathymetric bank features and other areas of interest associated with high biodiversity not yet described in the St. Anns Bank MPA.
3) Consider future research applications of this benthic survey approach, primarily regarding the use of the regional FOBIS benthic imaging system in developing long-term ecological monitoring programs.**2 MATERIALS AND METHODS**

2.1 SITE SELECTION AND SURVEY PLANNING

In the St. Anns Bank MPA, benthic imagery was obtained at 41 locations (Figure 4A) during five day trips in August 2023 (11 day overall survey window) and a further five day trips in August 2024 (12 day overall survey window), using the FOBIS near-seafloor optical imaging system (described in section 2.2) operating off the CCGS *M. Perley*. Survey target locations in 2023 were chosen using high-resolution (5-35-m spatial resolution) multibeam echosounder bathymetry data acquired from the Canadian Hydrographic Service (CHS), visualized in ArcGIS Pro v.2.8 (ESRI 2021). More specifically, high-resolution multibeam data was used to identify unique bathymetric features including Scatarie and Curdo Banks (Figure 4B and C, respectively) and subsequently choose target survey locations. There are only a few locations within the MPA where shallow bathymetry (e.g. less than 30 m) can potentially be effectively surveyed using SCUBA diving approaches. Preliminary acquisition of benthic imagery using surface-deployed cameras in these areas was additionally intended to provide planning context for developing future dive survey efforts. Other target locations were selected to overlap with prior scientific benthic survey effort within the MPA to provide for potential assessment of changes in community assemblages. These prior surveys included benthic trawl set locations from the RV Survey from 2017-2019 (2023 and 2024 locations were not yet available when planning the survey; Murillo *et al.* 2024), and benthic imagery surveys from 2009-2010 and 2015 (Kenchington and Lirette 2023) and 2013-2014 (Lacharité and Brown 2019) (Figure 2).

Specific locations were also chosen to further ground-truth unique benthoscape classifications previously defined by Lacharité *et al*. (2018). Benthoscape classifications aim to identify discrete regions of the seafloor based on biophysical characteristics including the combination of substrate type, biological structures and general topography estimated by acoustic techniques (Brown *et al.* 2011). In Lacharité *et al.* (2018), seven unique benthoscapes were identified using the ground-truthing images collected at 61 stations throughout the MPA and object-based image analysis (see Lacharité *et al.* 2018 for details) was used to build a benthoscape map using eCognition at a 50-m spatial resolution. Imagery for the 61 stations were collated from surveys occurring in 2009, 2010, and 2013-2015 using various benthic imaging systems operating from different large research vessels. Benthoscape classes defined by Lacharité *et al.* (2018) include: 'Mud', 'Mud with seapens', 'Gravelly sand/mud with <50% cobbles/gravel', 'Glacial till with >50% cobbles/gravel', 'Glacial till with coralline algae', 'Gravel with crinoids', and 'Sand with sand dollars' (Figure 3). This object-based image approach was applied to bathymetry and backscatter layers (along with derivatives such as slope and Bathymetric Position Index – BPI) at a 50-m resolution, and merged image-objects to identify areas of high homogeneity and heterogeneity. Final classification was performed using a nearest neighbor supervised scheme (Lacharité et al. 2018). Based on the comprehensive design and outcomes in our 2023 survey, the 2024 survey design was adapted to aim for better balance in the range of benthoscapes surveyed, as well as to further investigate attributes of specific habitats, including shallow banks and crinoid beds.

During the survey design phase, once target locations were selected, a 500-m buffer was created around each location using the buffer tool in ArcGIS Pro v.2.8 (ESRI 2021). During at-sea operations, a field laptop computer running ArcGIS and tracking the survey vessel GPS position, was used to evaluate the likely vessel drift direction prior to deployment, selecting a start location along the exterior of the buffer line to drift towards the survey target location. Preferred drift directions were pre-identified at some target locations to guide alignment of the drift survey direction over or adjacent to prior survey track lines, unique bathymetric features, or to sample specific predicted benthoscape areas.

In this report, recorded depths (in m Below Chart Datum – BCD) correspond to the depth below the sea surface of the FOBIS system equipped with a SBE39plus temperature and depth sensor (Sea-Bird Scientific; Bellevue, Washington, USA) referenced against tidal data from the Louisbourg station in Cape Breton, Nova Scotia (00600; https://tides.gc.ca/en/stations/00600/). Reported depths refer to the total depth; i.e., the summation of the depth sensor reading and the altitude of the camera package off-bottom

at every survey location, adjusted according to tide. Depth sensor data was used because very high-resolution bathymetry data (1-m resolution) is not yet available for St. Anns Bank. When depth sensor data was not recorded (due to issues in the field), depths were extracted from the highest-resolution bathymetry available (5-35 m resolution).

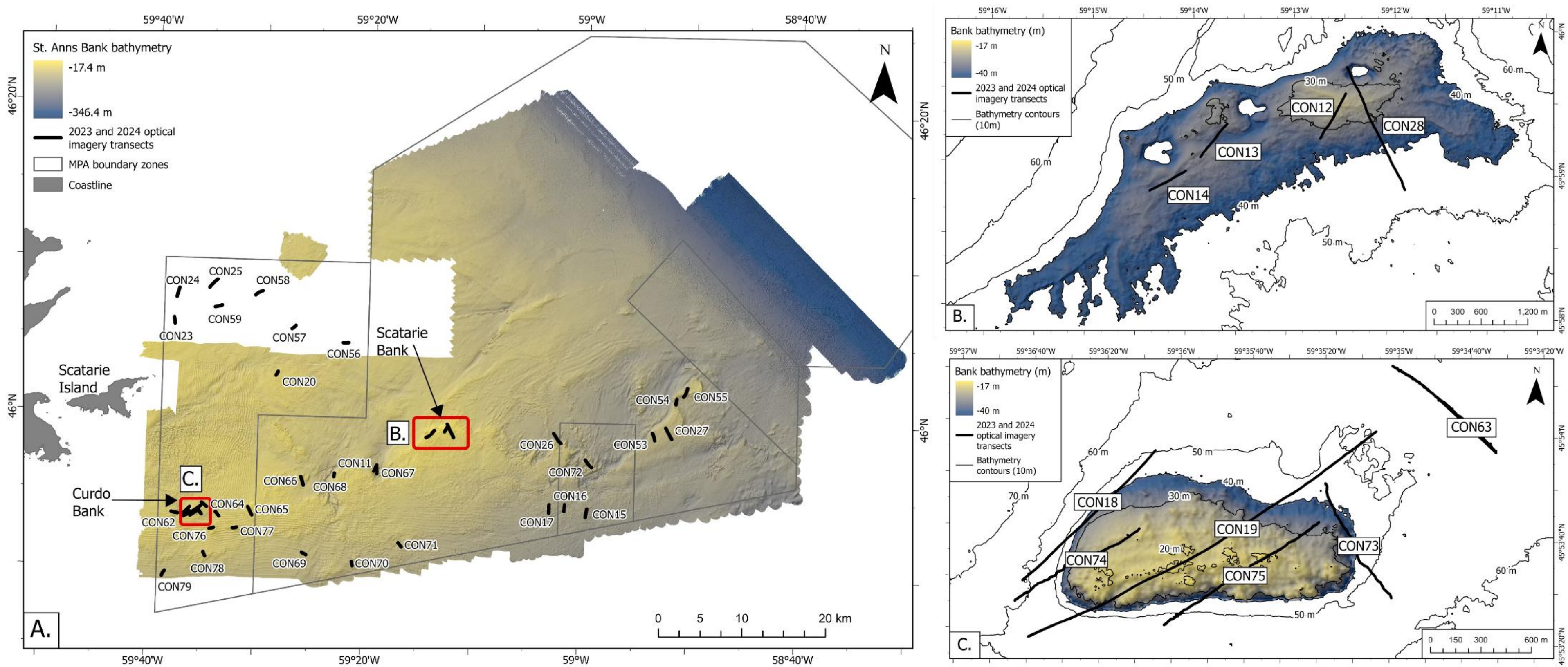

Figure 4 - Near seafloor optical imagery transect locations (A) in the St. Anns Bank MPA with underlying high-resolution bathymetry (5-35 m resolution) and associated hillshade.[1] Complex topography of Scatarie Bank (B) and Curdo Bank (C) highlighted with 10-m contours, near-seafloor transect tracks, and select bathymetry shallower than 40-m depths.

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[1] All figures and associated tables containing bathymetric data includes data provided by the CHS of the Department of Fisheries and Oceans (DFO). The incorporation of CHS data does not constitute an endorsement of this product by CHS or DFO. This product does not meet the requirements of the *Navigation Safety Regulations, 2020* under the *Canada Shipping Act, 2001* and must not be used for navigation.

2.2 NEAR-SEAFLOOR OPTICAL IMAGERY SURVEY APPROACHES

At each target location surveyed, the FOBIS near-seafloor optical imaging camera system (Figure 5; see also Teed *et al.* 2024) was lowered to within 2 m of the seafloor, with a maximum allowable depth deployment of 200 m. Surveys were conducted using a drift transect protocol, for a target 20 to 40-minute deployment time at each location (similar to survey approaches outlined in Teed *et al.* 2024). During the at-sea survey, a laptop computer running GIS displayed both the target location and 500-m buffers while also tracking both vessel and camera package location. The camera system provided three primary digital imagery sources. A full frame digital camera (D850, Nikon, Mississauga, ON, Canada), oriented downwards, captured individual digital still images (approx. 25 MB each) at periodic intervals (with a target of 30-s intervals, dependent on speed over ground). Digital still images were transmitted over the optical cable to the surface control system for near real-time viewing and file storage. Nikon Camera Control Pro 2 software (Nikon, Mississauga, ON, Canada) allowed for remote control of the D850 camera, enabling camera setting adjustments dependent on general marine conditions at target locations (i.e., deployment depth, type of substrate, water turbidity, altitude off bottom, etc.). Primary image settings (ISO speed, aperture, focusing mode – stored in each image file's metadata) were generally set at the start of survey operations, and not continually adjusted. In the 2023 transects (CON11-20 and CON23-28) after some initial adjustments (from CON11-14), the focal length was set to 24 mm; focus was set to Auto; ISO speed to 800; shutter speed to 1/250 s, and the aperture to f13. Based on assessment of camera performance in the 2023 survey, Nikon camera settings for the 2024 transects (CON53-59 and CON62-79) were changed somewhat to a focal length of 25 mm; Auto focus; 800 ISO speed (except 1000 for CON73); 1/200 s shutter speed; and f14 aperture. A downward-facing high-definition video camera (1Cam Mk6, SubC Imaging, Clarenville, NL, Canada) set to Auto focus, IRIS and white balance, along with a shutter speed of 1/500 s and AE shift of -2.0 EV, and a forward-facing high-definition video camera (HD Multi SeaCam, Deep Sea Power & Light, San Diego, CA, USA) provided continuous video imagery of the seafloor (Figure 5). The forward-facing video imagery, along with telemetry from an altimeter on the camera frame, allowed for the FOBIS system operator on the vessel to make real-time adjustment of the camera height above the sea floor using a joy-stick controlling the deck slip-ring winch. Due to limited video channels on the FOBIS system underwater multiplexer, the forward-facing camera only transmitted composite (standard-definition) video to the surface in the configuration used in 2023 and 2024. Video files were captured in mp4 format, automatically subdivided into 10-min file durations (approx. 3.7 GB for downward video; 2.1 GB for forward video).

Both video and still image files were recorded and automatically named according to transect number (CON###), date and UTC time (e.g., CON011-20230815T144755). Transect CON numbers refer to a consecutive numbering system for documenting survey operations using the FOBIS system (i.e., a single numbering sequence across all system users, and survey areas over time; adopted to facilitate creation of overviews of system operations). A VA500 altimeter (Teledyne Valeport Ltd, Totnes, UK) provided records of the height of the survey package off-bottom (once every second), and a pair of lasers (10-cm spacing) provided a means to evaluate the field of view in both the downward digital video and digital still imagery (estimated using ImageJ2 – Rueden et al. 2017; see Teed et al. 2024 for field of view calculation details). For the downward-facing video, 10-cm lasers were in view when the altitude off-bottom ranged from 0.5

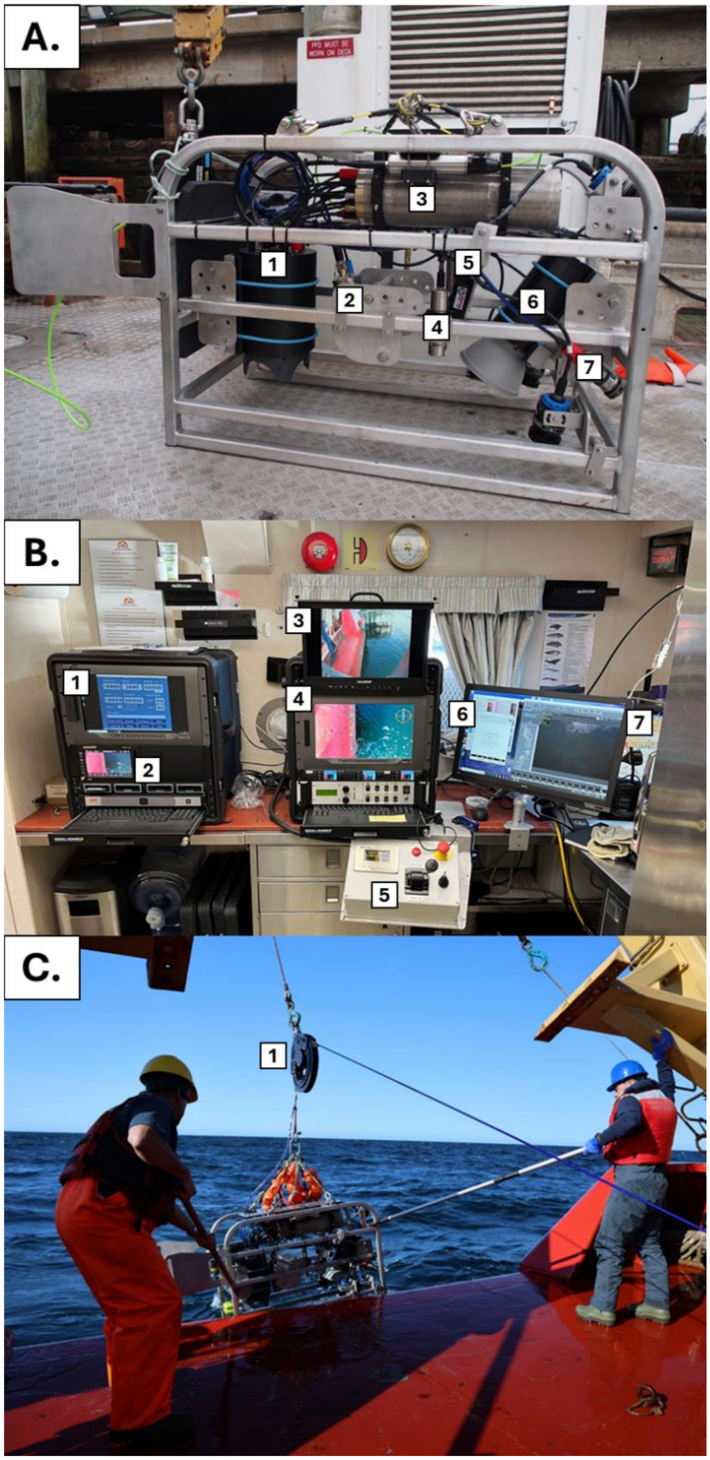

Figure 5 - A: Key underwater imaging components of the FOBIS system as used in the August 2023 survey: (1) Nikon D850 in custom housing; (2) Downward video camera (behind frame bracket); (3) Multiplexer in custom housing; (4) Altimeter; (5) Dual laser unit; (6) Still camera flash in custom housing; (7) Forward video camera. Further details in text. Photo credit: P. Lawton, DFO. B: Surface control station of the FOBIS system as used in the August 2023 survey: (1) Wireless sheave data display; (2) Digital video recording decks; (3) Forward video monitor; (4) Downward video monitor; (5) Winch remote control; (6) Custom engineering telemetry interface; (7) Digital still camera control software and image display. Photo credit: K. Phelan, DFO. C: FOBIS system being deployed off stern of CCGS M. Perley in the August 2023 survey: (1) Metering block through which the cable is deployed has a custom wireless sheave, providing real-time information on cable payout and load. Photo credit: P. Lawton, DFO.

to 2.7 m, while the digital stills were much more restricted with field of view calculations possible when altitudes were 0.7 to 1.7 m. To generate an estimate of area covered (m2) for each transect, the average field of view from the downward-facing video across each transect

was multiplied by the estimated distance travelled. These estimates were then summed across transects to generate overall seafloor area coverage. Optical imagery survey data from both surveys is held in an archive managed by P. Lawton, L.L Teed and the DFO Coastal Ecosystems Science Division data management team at the St. Andrews Biological Station, New Brunswick, Canada (Lawton and Teed 2025b). A formal technical report detailing FOBIS set-up, protocols, and analyses is currently in development. One still image was selected every 50 m along each transect, using buffer tools in ArcGIS Pro v.2.8 (ESRI 2021), to provide a sub-set of still images to annotate the presence of organisms. Organism occurrences in selected still images were analyzed using the image annotation software BIIGLE (Langenkamper *et al.* 2017) with detailed methodology described in a separate imagery annotation report (Teed *et al.* in press). In this report, we provide qualitative observations across transects of substrates and habitat descriptions derived from viewing a combination of video (forward- and downward-facing) and still images (see Appendix Table 1).

Additionally, the benthoscape class of each still image was noted, using criteria established by Lacharité *et al.* (2018) to ground-truth their predictions: A - Mud, B - Gravelly sand/mud with <50% cobbles/gravel, C - Till with >50% cobbles/gravel, D - Till with coralline algae, E - Gravel with crinoids, and F - Sand with sand dollars (Figure 6). Each transect was assigned an overall benthoscape class based on the highest represented benthoscape across all images in a transect (i.e., the primary benthoscape).

For year one (2023) of the survey, an available underwater ultra-short baseline acoustic positioning system was used (Tracklink 1500HA transceiver with Tracklink 1505B transponder; Linkquest Inc., San Diego, USA); however, it proved not to be fully reliable (i.e., intermittent issues in starting up the Tracklink system or the receiver showing camera package positions 'jumping' around to far distances), and so in 2023, survey vessel geographic positions were recorded using a SeaNav 300 Global Navigation Satellite System receiver at the surface (Kongsberg Gruppen ASA, Kirkegårdsveien, Norway). The track line of each transect can be expected to correspond to the actual distance travelled by the camera package over the seafloor, although the offset of the camera system from the vessel was not defined. In year two (2024) of the survey, a new underwater acoustic positioning system was implemented on the survey vessel, based on the uPAP 201-H transceiver/transducer, along with cNODE Micro transponders/beacons from Kongsberg (Kongsberg Gruppen ASA, Kirkegårdsveien, Norway) allowing for transects to be mapped according to the camera system position. Year two also allowed for direct comparison of the camera system position in relation to the vessel's position, where it was found that spatial offsets from the survey vessel ranged up to 50 m astern and 1-10 m port or starboard depending on depth and tidal influences.

Drift camera tracks for all transects were plotted in ArcGIS Pro v.2.8 corresponding to the date and time when the camera package was in a near-seafloor survey mode. The actual distance traveled (m) by the camera package over the seafloor was calculated using the z-field geometry tool in ArcGIS Pro v.2.8 (ESRI 2021), calculated for each transect.

Once transect and affiliated image positions were obtained and imported into ArcGIS Pro v.2.8, a proximity analysis, using the Near (Analysis) tool (ESRI 2021) was performed to determine the shortest distance (in m) that the 2023 and 2024 still images were away from prior survey locations (including imagery surveys and RV transect sets: putative transect lines from 2017-2019 and start points from 2017-2024 - Figure 2). This will allow for assessment of the spatial relationship between different survey data sources towards future comparisons of community assemblages according to various sampled habitats.

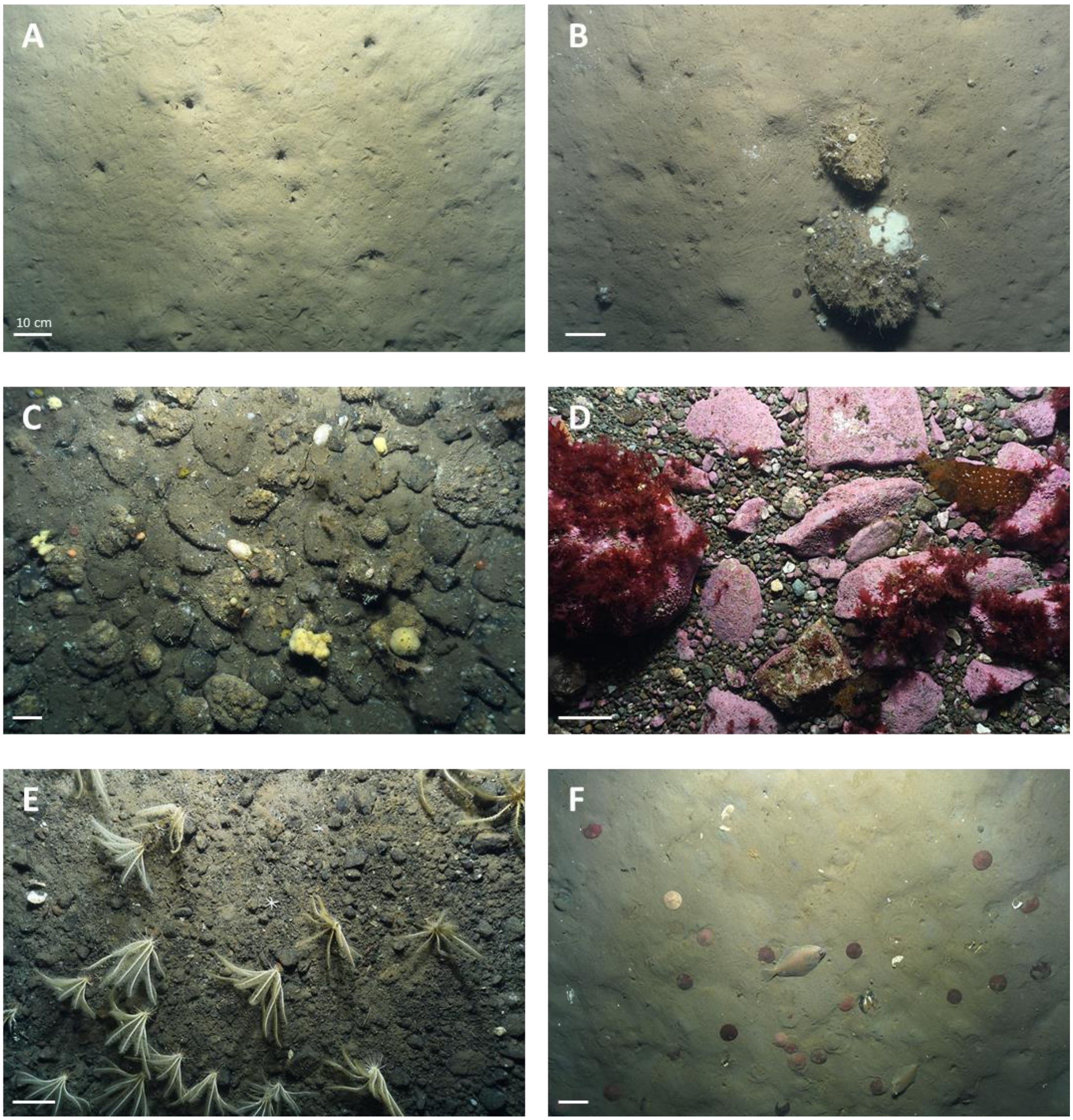

Figure 5 - Representative images from the 2023 survey of the benthoscape classes as defined by Lacharité et al. (2018): A – Mud (CON16-20230816T182745, depth: 134.3 m), B - Gravelly sand/mud with <50% cobbles/gravel (CON15-20230816T165542, depth: 141.1 m), C - Till with >50% cobbles/gravel (CON26-20230823T150118, depth: 96.2 m), D - Till with coralline algae (CON23-20230821T124024, depth: 26.5 m), E - Gravel with crinoids (CON27-20230823T165033, depth: 94.02 m), and F - Sand with sand dollars (CON11-20230815T144755, depth: 105.5 m). White scale bars represent a 10-cm scale.

3 RESULTS

Forty-one drift camera transects (CON11-20, CON23-28, CON53-59, CON62-79) were completed in the St. Anns Bank MPA across five days in August 2023 and five days in 2024, continuously recording seafloor observations over periods of 19 minutes to just over one hour per transect (Table 1, Figure 4). Due to the CCGS *M. Perley* conducting survey operations on a day-trip basis, transiting from and back to the port of Louisbourg each day (up to four hour transit times each way to the eastern portion of the MPA) restricted the time available to conduct near-seafloor survey operations. Also, due to the requirement to operate the camera system in quite low sea states, the number of camera operation days on each mission was low relative to the overall mission length; there were also requirements to conduct a series of eDNA survey locations as part of daily survey operations (five days of 11 mission days in 2023 and five days of 12 mission days in 2024 involved near-seafloor imaging transects). Conversely, the actual operational efficiency of near-seafloor transect deployments was good, with each survey location generally only taking between 30 min to 1 h to complete (depending on the overall depth for camera deployment to the seafloor).

Current speeds were highly variable, causing fluctuating drift speeds with the camera package speed over ground (SOG) ranging from 0.01 to 4.55 knots (average: 1.2 knots – see Lawton and Teed 2025b). Instances of high SOG occurred in several 2023 transects, however these instances did not exceed 10-s increments, while SOG was much more stable in year two of the survey, with speeds rarely exceeding 2 knots. More specifically, instances of high SOG likely resulted from camera cable slack pulling to catch-up to the vessel drift/surface current conditions (common when transiting across topographically complex features). Fluctuating SOG resulted in variable distance travelled with transect lengths ranging from 631 m to 2.9 km, covering a total estimated survey distance of approximately 44.5 km (Table 1). Variable distance covered generated seafloor area coverage estimates of 814 to 2884 m^2 per transect, equating to a total estimated area surveyed of approximately 60430 m^2. In general, SOG up to ~4 knots was deemed to provide usable downward and forward video imagery for general assessment of habitat characteristics (as it was reviewed at 0.25x speed); digital still images resolved good image detail even at high speeds, although it was not always possible to resolve the lasers. The altitude off the seafloor ranged from 0.2 to 8.1 m (average: 1.4 m) while in seafloor transect mode at depths ranging from 17 to 144 m BCD. Very high altitudes off-bottom were associated with having to move the package higher off the seafloor to avoid large seafloor relief features. Due to high water clarity in the MPA, the seafloor is easily distinguishable at altitudes of 2 m.

Table 1 - Near-seafloor imagery transect summary for St. Anns Bank MPA surveys in August 2023 and 2024. Transect numbers are consecutive numbers (CON#) assigned to each FOBIS deployment. Primary benthoscape refers to the dominant benthoscape class in each transect (i.e., occurring across >50% of analyzed images), using criteria defined by Lacharité et al. (2018) (A - Mud, Asp - Mud with seapens, B - Gravelly sand/mud with <50% cobbles/gravel, C - Till with >50% cobbles/gravel, D - Till with coralline algae, E - Gravel with crinoids, and F - Sand with sand dollars). Additional imagery metadata and full transect track lines are available on Canada's open data portal including transect drift direction, speed over ground, and still imagery and video data volume (see Lawton and Teed 2025b).

Transect	Date (DD-MM-YYYY)	Transect duration (H:MM:SS)	Distance travelled (m)	Estimated area covered (m^2)	Start latitude (DD)	Start longitude (DD)	Minimum depth (m)	Maximum depth (m)	Number of still images	Number of still images analyzed	Primary benthoscape
CON11	15-08-2023	26:07	1072.4	1779.9	45.9493	-59.3147	80.9	105.3	62	14	F
CON12	15-08-2023	25:23	959.2	2278.4	45.9922	-59.2078	19.5	31.5	33	7	D
CON13	15-08-2023	20:43	754.5	1642.3	45.9883	-59.2273	27.4	35.5	38	9	D
CON14	15-08-2023	24:59	929	1919.2	45.9828	-59.2340	27.7	35.1	61	10	D
CON15	16-08-2023	25:56	1121.1	1151.6	45.9079	-58.9890	139.0	144.1	113	19	A
CON16	16-08-2023	20:16	889.8	950.4	45.9121	-59.0234	129.3	141.7	89	15	A
CON17	16-08-2023	24:32	1098.2	1261.2	45.9117	-59.0473	120.7	132.5	121	18	C
CON18	17-08-2023	24:34	1227.9	1464.9	45.8987	-59.6017	34.7	60.1	147	20	D
CON19	17-08-2023	1:01:04	2884.7	3491.7	45.9000	-59.5849	17.4	56.5	377	44	D
CON20	17-08-2023	30:27	921.8	1056.9	46.0469	-59.4714	47.5	52.4	118	10	D
CON23	21-08-2023	22:27	833.3	853.0	46.0955	-59.6330	23.4	27.0	87	15	D
CON24	21-08-2023	20:37	1158.7	1225.2	46.1241	-59.6313	30.7	26.9	79	19	D
CON25	21-08-2023	20:22	1413.5	2376.1	46.1352	-59.5811	27.4	34.7	68	16	D
CON26	23-08-2023	36:08	1599.4	1738.1	45.9884	-59.0429	85.5	125.7	157	26	C
CON27	23-08-2023	31:05	1643.1	2145.7	45.9971	-58.8700	90.5	106.8	111	25	E
CON28	23-08-2023	33:44	1816.9	2300.9	45.9952	-59.2077	23.8	44.2	131	29	D
CON53	08-08-2024	25:45	1063.1	1335.2	45.9911	-58.8903	92.6	118.8	55	15	E
CON54	08-08-2024	24:00	781.1	843.6	46.0282	-58.8537	98.7	119.3	64	12	E
CON55	08-08-2024	40:35	1421.5	1956.8	46.0401	-58.8373	77.0	108.3	96	21	E
CON56	09-08-2024	25:47	966.2	1123.4	46.0799	-59.3720	61.6	65.6	64	11	C
CON57	09-08-2024	20:05	781.7	921.1	46.0934	-59.4519	51.4	55.4	48	11	D
CON58	09-08-2024	20:37	1119.6	1317.0	46.1285	-59.5098	45.0	49.0	58	17	D
CON59	09-08-2024	20:22	1000.5	1107.3	46.1144	-59.5718	28.5	40.9	63	15	D
CON62	15-08-2024	24:10	1060.3	1743.4	45.8915	-59.6198	61.0	74.9	47	14	C
CON63	15-08-2024	22:26	971.2	1666.7	45.8991	-59.5756	53.3	55.8	49	14	D
CON64	15-08-2024	19:52	927.7	1132.4	45.8893	-59.5561	63.1	67.2	55	12	C
CON65	15-08-2024	29:37	1319.7	1978.9	45.8916	-59.5054	34.5	55.1	80	19	D
CON66	15-08-2024	30:20	1202.1	1454.8	45.9254	-59.4273	43.0	81.3	84	19	D
CON67	15-08-2024	25:57	843.0	1169.6	45.9401	-59.3144	79.1	114.4	73	14	C
CON68	15-08-2024	22:23	630.8	1093.7	45.9355	-59.3806	58.9	71.2	29	5	C
CON69	16-08-2024	23:16	812.8	1069.2	45.8504	-59.4203	89.9	93.2	56	12	F
CON70	16-08-2024	20:18	696.6	816.4	45.8402	-59.3484	91.4	98.1	45	10	C
CON71	16-08-2024	20:44	739.6	977.9	45.8618	-59.2735	91.1	97.0	48	11	C
CON72	16-08-2024	32:17	1314.4	1666.1	45.9529	-58.9832	87.0	104.5	102	21	C/E
CON73	16-08-2024	27:35	1038.9	1709.4	45.8912	-59.5833	37.4	56.5	83	14	D

Transect	Date (DD-MM-YYYY)	Transect duration (H:MM:SS)	Distance travelled (m)	Estimated area covered (m^2)	Start latitude (DD)	Start longitude (DD)	Minimum depth (m)	Maximum depth (m)	Number of still images	Number of still images analyzed	Primary benthoscape
CON74	17-08-2024	29:47	990.4	1592.3	45.8945	-59.6028	22.3	61.9	79	15	D
CON75	17-08-2024	39:35	1391.2	2058.1	45.8951	-59.5890	18.4	53.2	105	18	D
CON76	17-08-2024	20:49	778.3	1148.9	45.8769	-59.5639	51.9	56.0	43	10	D
CON77	17-08-2024	30:27	730.1	1112.3	45.8781	-59.5283	42.0	49.0	65	9	D
CON78	17-08-2024	20:51	664.0	979.9	45.8460	-59.5758	53.1	61.1	39	11	D
CON79	17-08-2024	20:31	933.9	818.5	45.8236	-59.6418	85.4	90.5	59	13	F

However, ability to identify benthic organisms to lower taxonomic levels decreased with increasing altitude. Images selected for detailed assemblage analysis included altitudes ranging from 0.6 to 2 m (Appendix Table 2 with additional details found in the separate annotation report: Teed *et al.* in press).

CON11 and 15 had no recorded depth sensor data while CON12 had inconsistent recordings, and thus reported depths for these transects are from the 5-35-m resolution multibeam bathymetry data. In CON23, depth sensor data only began recording halfway through the transect, and as no high-resolution bathymetry data was available in the northwest corner of the MPA, reported minimum and maximum depths correspond to when the depth sensor began to record.

When combined, the drift transects produced over eighteen hours of both downward- and forward-facing continuous video in total, and between 29 and 377 still images per transect, with 3381 images in total. Images were collected at intervals ranging from 1 to 124 seconds (average ~ 19 s), representing distances ranging from 0.2 to 106 m (average ~ 11 m) between still images. A set of 639 images were selected for preliminary analysis of organism occurrences, using a 50-m buffer between still images to better limit analysis time and ensure no overlap of the field of view (Teed *et al.* in press). Selected images for annotation ranged from 5 to 44 images per transect with average altitudes off the seafloor and field of view (FOV) ranging from 1.06-1.84 m and 1.17-1.70 m^2, respectively at depths of 17 m (in CON18 and 75) to the deeper southeast portion at 144 m (in CON15) (Appendix Table 2).

3.1 GROUND-TRUTHING BENTHOSCAPE PREDICTIONS

Based on review of all 3381 still images collected, 337 (10.0%) were categorized as consistent with the 'Mud' benthoscape (as defined in Lacharité *et al.* 2018), 180 (6.2%) were in the 'Gravelly sand/mud with <50% coverage of cobbles/gravel' benthoscape, 847 (25.1%) images occurred in 'Glacial till/mixed sediment >50% cobbles/gravel' habitats, 1264 (37.4%) in 'Glacial till with coralline algae and mixed sediments', 216 (6.4%) images in 'Gravel with crinoids', and 70 (2.1%) in the 'Sand with sand dollars' benthoscape. No images were obtained from the 'Mud with seapens' benthoscape, as this habitat occurs off the shelf (>200-m depths). These areas were beyond initial survey limit of 200 m defined for the FOBIS system, taking into account the existing optical cable winch system and other logistics. The cameras and other underwater system components are capable of significantly greater deployment depths. As an additional factor, the 'Mud with seapens' benthoscapes were also located beyond the daily transit/survey operations range of the CCGS *M. Perley*.

Overall, 2914 still images occurred within the predicted benthoscape map, of which the observed benthoscape matched predicted benthoscape at that location in 66% of images (Table 2). The remaining 34% of images did not match predicted benthoscape. More specifically, at the transect level, CON11 was expected to occur within a mud and glacial till/mixed sediment benthoscape (Table 2), but was observed to predominately be 'Sand with sand dollars' (Figure 7). Similarly, CON15, 16 and 17 fell predominately within the predicted 'Mud' benthoscape class, however reported benthoscapes from this survey varied, including 'Mud', 'Gravelly sand/mud with <50% coverage of cobbles/gravel' and 'Glacial till/mixed sediments with >50% cobbles/gravel (Figure 7, Table 2). CON27 was dominated by dense aggregations of crinoids on gravel substrates, however the dominant predicted benthoscape class was ‘Glacial till/mixed sediments with >50% cobbles/gravel’ (Figure 7. Table 2). Comparably, CON54 was also dominated by crinoids, while the dominant predicted benthoscape class was ‘Gravelly sand/mud with <50% cobbles/gravel’ (Table 2). CON23, 24, 25, 56, 57, 58, and 59 all occurred outside of the benthoscape prediction space, however the primary benthoscape reported for all of these transects was ‘Glacial till with coralline algae and mixed sediments’, with the exception of CON56 which was dominated by ‘Glacial till/mixed sediment >50% cobbles/gravel’. CON67 and 71 contained variable benthoscapes, including ‘Mud’, ‘Gravelly sand/mud with <50% cobbles/gravel’, ‘Glacial till/mixed sediments with >50% cobbles/gravel’, and ‘Sand with sand dollars’ (Figure 7). The benthoscape ‘Gravelly sand/mud with <50% coverage of cobbles/gravel’, was expected to occur in CON69 and 72 (Table 2), however these transects were dominated by ‘Sand with sand dollars’ and ‘Gravel with crinoids’ respectively. Finally, CON68 falls within the ‘Glacial till with coralline algae and mixed sediments’ benthoscape (Table 2), however it was dominated by ‘Glacial till/mixed sediment >50% cobbles/gravel’ habitats, while CON78 was the opposite.

Table 2 - Agreement (%) of prior benthoscape predictions (from Lacharité et al. 2018) with the 2023 and 2024 optical imagery in the St. Anns Bank MPA according to individual image locations along a transect of expected versus observed benthoscapes. Benthoscape classes include: A – Mud, B – Gravelly sand/mud with <50% cobbles/gravel, C – Till with >50% cobbles/gravel, D – Till with coralline algae, E – Gravel with crinoids, and F – Sand with sand dollars. Transects located outside of the prediction space are indicated by ‘NA’.

Transect	Benthoscape prediction (Lacharité *et al.* 2018)	Images expected (#) within prediction	Images observed (#) matching prediction	Agreement (%)
CON11	A	30	1	3
	C	32	30	94
CON12	D	33	33	100
CON13	D	38	37	97
CON14	D	61	61	100
CON15	A	83	39	47
	B	30	1	3
CON16	A	89	61	69
CON17	A	67	17	25
	B	54	8	15
CON18	C	120	30	25
	D	27	18	67
CON19	C	85	22	26
	D	292	282	97
CON20	D	118	118	100
CON23	NA	NA	NA	NA
CON24	NA	NA	NA	NA
CON25	NA	NA	NA	NA
CON26	A	47	14	30
	B	8	2	25

Transect	**Benthoscape prediction (Lacharité *et al.* 2018)**	**Images expected (#) within prediction**	**Images observed (#) matching prediction**	**Agreement (%)**
	C	102	93	91
CON27	C	91	0	0
	E	20	18	90
CON28	D	131	130	99
CON53	C	3	1	33
	E	52	46	88
CON54	B	60	0	0
	C	4	0	0
CON55	B	7	0	0
	C	30	3	10
	E	59	29	49
CON56	NA	NA	NA	NA
CON57	NA	NA	NA	NA
CON58	NA	NA	NA	NA
CON59	NA	NA	NA	NA
CON62	C	47	47	100
CON63	D	49	41	84
CON64	C	46	46	100
	F	9	6	67
CON65	C	1	0	0
	D	79	75	95
CON66	C	24	17	71
	D	60	51	85
CON67	A	21	1	5
	C	51	50	98
	D	1	0	0
CON68	C	1	1	100
	D	28	0	0
CON69	B	18	6	33
	C	38	0	100
CON70	C	45	38	84
CON71	C	46	22	48
	F	2	0	0
CON72	C	17	3	18
	E	85	32	38
CON73	C	4	0	0
	D	79	79	100
CON74	C	19	7	37

Transect	**Benthoscape prediction (Lacharité *et al.* 2018)**	**Images expected (#) within prediction**	**Images observed (#) matching prediction**	**Agreement (%)**
	D	60	57	95
CON75	D	105	105	100
CON76	D	43	43	100
CON77	C	5	0	0
	D	60	60	100
CON78	C	36	7	19
	F	3	0	0
CON79	F	59	45	76

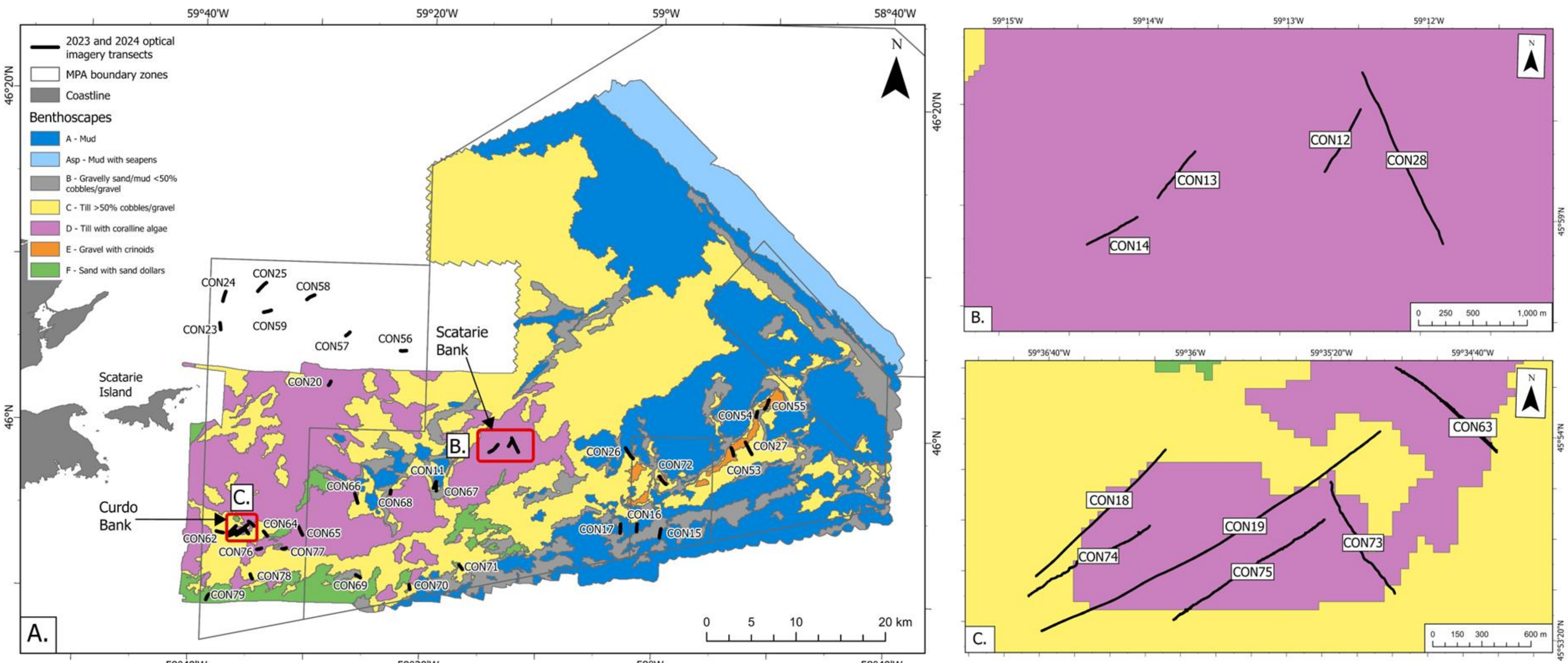

Figure 6 - Transect locations from the 2023 and 2024 imaging survey in the St. Anns Bank MPA (A) with underlying benthoscape predictions provided by Larcharité et al. (2018). Transects in close proximity are highlighted in red boxes on Scatarie (B) and Curdo (C) Bank.

3.2 QUALITATIVE HABITAT DESCRIPTIONS

In general, transects conducted on the shallow banks (Scatarie, Curdo and in the northwest corner of the MPA) observed high *Alaria esculenta* (Linneaus) Greville, 1830 and *Agarum clathratum* Dumortier, 1822 kelp cover on top of the banks in CON12, 13, 28 (Scatarie Bank – Figure 8), CON19, 74 and 75 (Curdo Bank – Figure 9), and CON23 and 59 (northwest corner at depths ranging from 24 to 32 m), as well as high densities of the plumose anemone, *Metridium senile* (Linnaeus, 1761). Several fish species were observed within the video imagery, swimming on the top of the banks or in crevices, including cunners, redfish, Atlantic cod, and the rare Atlantic wolffish. At approximately 40-m depths, the banks transitioned from red algae and kelp dominated to more soft corals, encrusting sponges and coralline algae habitats, specifically as density of cobbles and boulders increased with increasing depth. Soft corals (Malacalcyonacea), various anemones and encrusting sponges such as *Aplysilla sulfurea* Schulze, 1878 and *Hymedesmia* spp. were common across boulders within and surrounding the banks, and stalked tunicates (*Boltenia ovifera* (Linnaeus, 1767)) were commonly seen along bank margins, forming widespread tunicate fields in mixed substrates.

Scatarie Bank was estimated to be approximately 7.9 km^2 in size extending from the shallowest features outwards to the transition zone at ~40-m depths (Figure 4B). Transects conducted on Scatarie Bank (CON12-14, and 28) observed small bedrock outcrops, dominated by coralline algae covered pebbles, cobbles and boulders (Figure 8, Appendix Table 1). Scatarie Bank edges, where surveyed, did not have high slope sections, rather declining ~12-15 m over a 500-m distance (Appendix Figure 1), as they were characterized by more widespread boulder fields, with bathymetry levelling out at approximately 50 to 60-m depths (Figure 4B), extending the overall bank area by ~15 km^2.

Curdo Bank was notably smaller than Scatarie Bank, with an estimated area of 1.1 km^2 from the shallow bedrock features, down a steep slope on the southern side of the bank to ~40-m depths. Curdo Bank transects (CON18-19, 73-75) observed extensive rocky outcrops encrusted with coralline algae and dense red algae cover, interspersed with cobbles and boulders (Figure 9, Appendix Table 1). CON18 and 73 largely skirted along the 40-m depth contour, steered by tide, while CON19, 74 and 75 went directly over the bank. Some areas of Curdo Bank contained deep crevices and overhangs; for example, in CON75 the depth sensor profile was noted to change from 23 to 30 m depths in less than 1-m distance at a SOG of 1.3 knots (Appendix Figure 2). Steep rock walls and large, stacked boulders were observed primarily on the southwest and southern margins of Curdo Bank, with local bathymetry dropping from 25 to 50-m depths over a 100-m distance (as observed in CON19 with similar observations made in CON74 – Appendix Figure 2) leading down to sandy gravel and cobble substrates where bathymetry evened out at approximately 50-m depths (Figure 4C), extending the Curdo Bank area by ~0.6 km2.

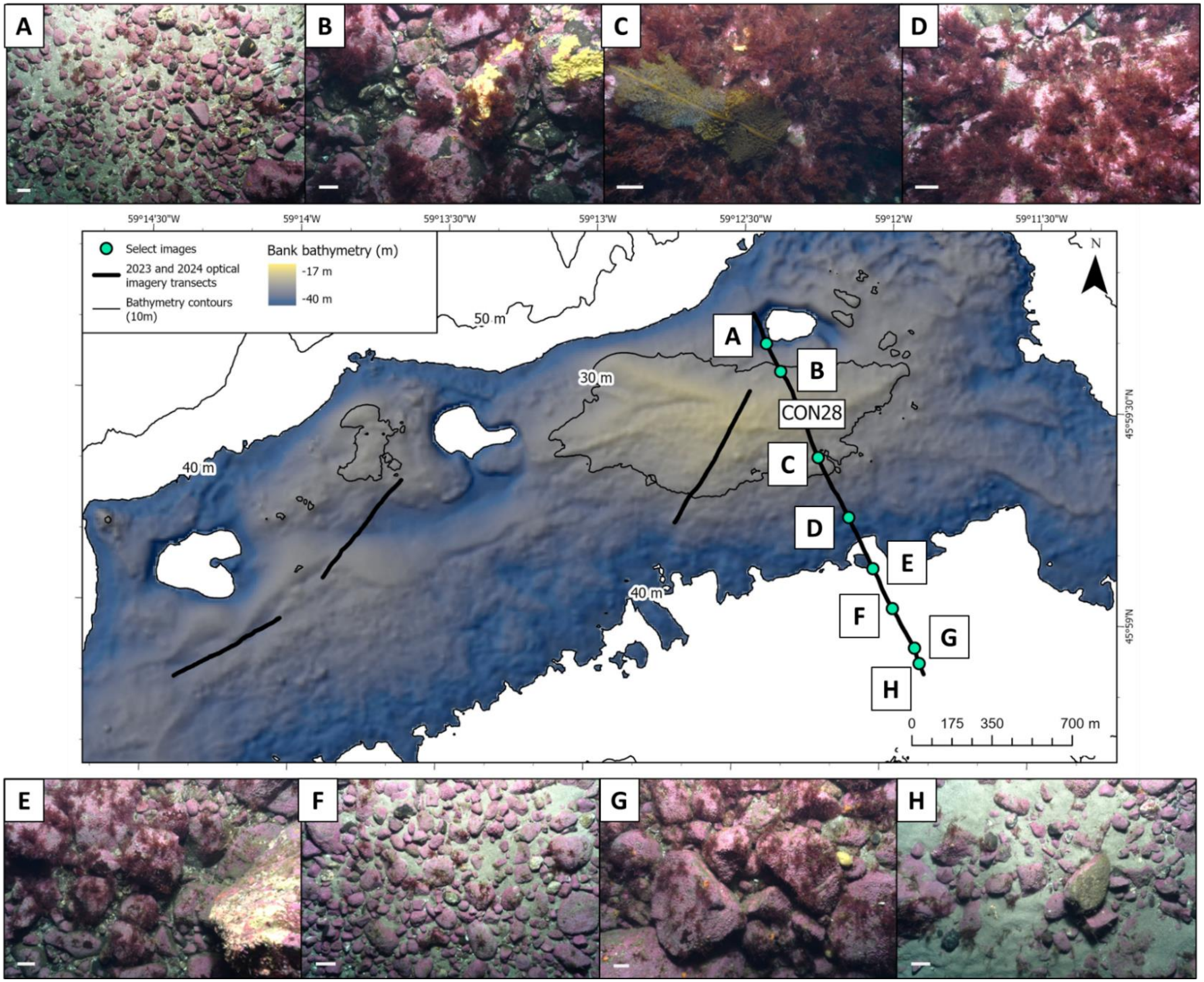

Figure 7 - Select images demonstrating some general variation and gradation in seafloor substrates across Scatarie Bank in transect CON28 with underlying bathymetry less than 40 m, and 10-m bathymetric contours also derived from multibeam survey data. Representative images are searchable in the open data portal (see Lawton and Teed 2025b) under the following image file names: A – CON028-20230823T195849, B – CON028-20230823T200128, C – CON028-20230823T200948, D – CON028-20230823T201528, E – CON028-20230823T202023, F – CON028-20230823T202401, G – CON028-20230823T202742, H – CON028-20230823T202848. White scale bars represent a 10-cm scale.

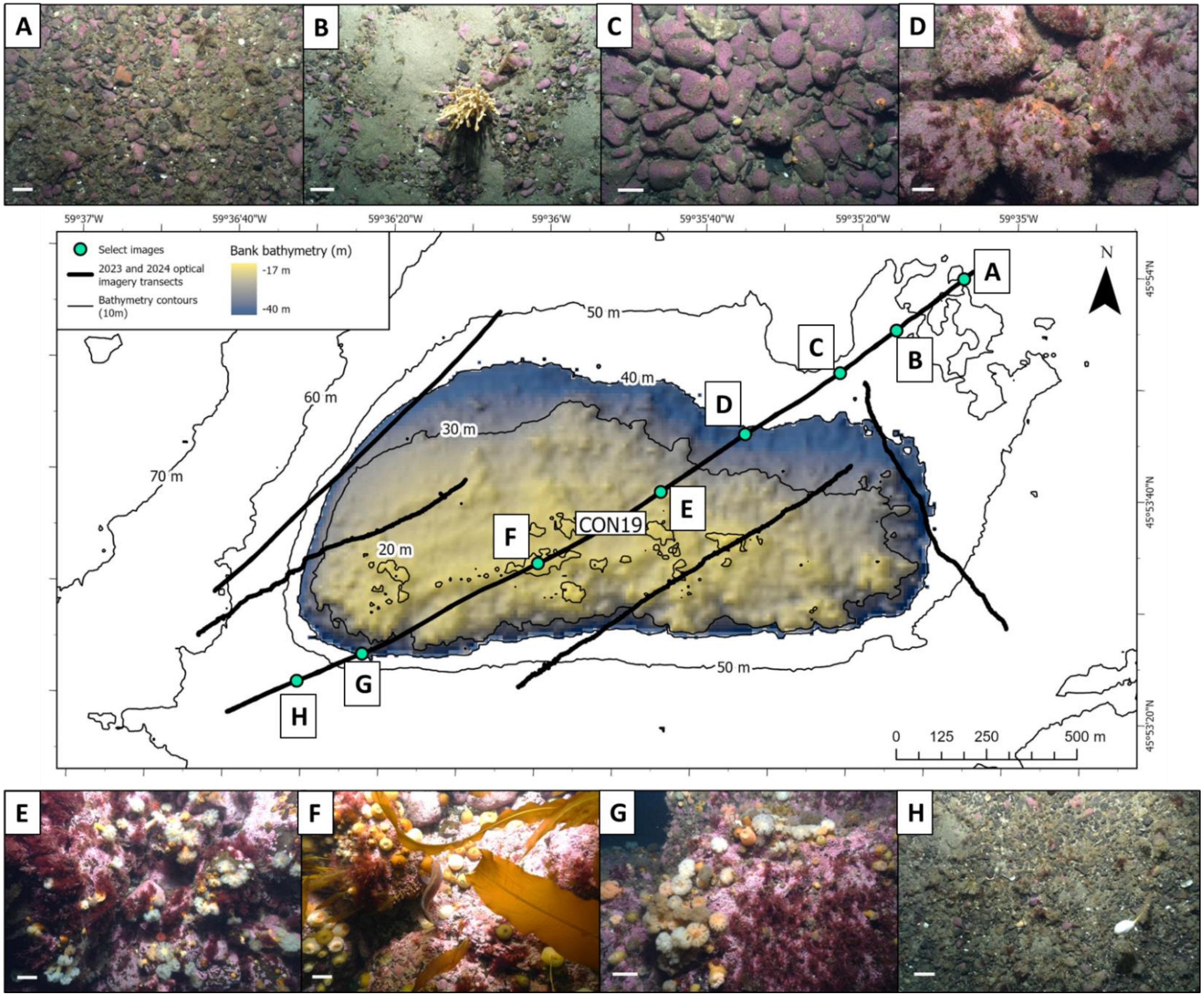

Figure 8 - Select images demonstrating heterogenous substrates along Curdo Bank in transect CON19 with underlying bathymetry less than 40 m, and 10-m contours. Representative images are searchable in the open data portal (see Lawton and Teed 2025b) under the following image file names: A – CON019-20230817T125919, B – CON019-20230817T130450, C – CON019-20230817T130950, D – CON019-20230817T131806, E – CON019-20230817T132515, F – CON019-20230817T133503, G – CON019-20230817T134844, H – CON019-20230817T135427. White scale bars represent a 10-cm scale.

Substrates in the shallow areas surveyed in the northwest, unmapped (i.e., lacking high-resolution multibeam bathymetry and backscatter data) corner of the MPA in CON23-25 and 58-59, were comprised of extensive, linear bedrock outcrops surrounded by mixed sediments covered in coralline algae. Steep bedrock formed few vertical walls throughout (Appendix Figure 3); for example in CON25 which contained a 4-m vertical face over a reported 10-m distance (Appendix Figure 3C). Stacks of large boulders along a gentle slope were observed in CON59, where depth increased ~6 m over a 75-m distance (Appendix Figure 3D).

Large basket stars (*Gorgonocephalus arcticus* Leach, 1819) were observed in the MPA, with a few individuals present in nine transects (CON11, 53, 56, 62, 63, 64, 67, 70, and 79) at depths ranging from 54 to 102 m. Basket stars were sparsely distributed where encountered, with most observations made in CON67 and 11. Adult basket stars were often situated atop large boulders within cobble and boulder fields, often associated with high local densities of soft corals; they were only rarely seen on finer sediments (e.g., CON79), while a few juvenile basket stars were observed entangled with soft corals (e.g., CON53).

Soft corals, likely a mixture of *Gersemia rubiformes* (Ehrenberg, 1834), *Gersemia fruticosa* (Sars, 1860), *Duva florida* (Rathke, 1806) and *Drifa glomerata* (Verrill, 1869), were common across the St. Anns Bank MPA, observed in 28 transects (CON11, 15, 16, 17, 19, 20, 26, 27, 28, 53, 54, 55, 56, 57, 58, 62, 65, 66, 67, 68, 70, 71, 72, 73, 75, 76, 77, and 78) at depths ranging from 17 to 144 m. Benthoscapes within which soft corals were frequently documented included 'Gravelly sand/mud with <50% coverage of cobbles/gravel', 'Glacial till/mixed sediment >50% cobbles/gravel' and, 'Glacial till with coralline algae and mixed sediments'. They were observed attached to bedrock and boulders and also cobbles embedded in mud. High densities were noted surrounding basket stars in CON11 and 67 (Appendix Table 1). In shallower habitats where soft corals were present (CON19, 20, 28 and 75), they were often found within expansive areas of crustose coralline algae and encrusting sponges.

Stalked tunicates commonly occurred across survey locations, observed in 28 of 41 transects (CON11, 15, 16, 17, 18, 19, 20, 26, 28, 55, 56, 58, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 75, 76, 77, and 78). They were found in the 'Gravelly sand/mud with <50% coverage of cobbles/gravel', 'Glacial till/mixed sediment >50% cobbles/gravel', 'Glacial till with coralline algae and mixed sediments', and 'Gravel with crinoids' benthoscapes. Tunicate fields were most frequent (among the currently analyzed imagery) along bank edges at moderate survey depths (40 to 60 m), attached to mixed sediments, primarily boulders and cobbles, but also interspersed within finer sediments, presumably anchored to some local hard attachment within the sediment matrix. The full depth distribution of stalked tunicates was ~38 to 142 m (in CON19 and 15, respectively). Large individuals were scattered, in aggregate forming broad tunicate fields along bank margins, commonly associated with encrusting sponges and hydroids, and becoming sparser as depth increased.

In near-seafloor imagery transects conducted in the southern portion of the MPA, (CON15-17) brachiopods, mostly *Terebratulina septentrionalis* (Couthouy, 1838), and encrusting sponges were common along mud with mixed sediment bottoms at depths ranging from 120 to 144 m. Similarly, in CON26, encrusting sponges were abundant and found with anemones and numerous bryozoans in sandy/cobble habitats from depths of 85 to 125 m.

Unstalked crinoids (*Heliometra glacialis* – Figure 6E) were observed in CON27, 53, 54, 55, and 72, which were the transects furthest offshore to the eastern side of the MPA boundary and at depths ranging from 77 to 119 m. High densities of crinoids were observed in CON53 and 54, along the edges of a prior-defined crinoid benthoscape patch (Figure 7) (Lacharité *et al.* 2018). Transects CON27, 53, 55 and 72, all occurred mostly within the 'Gravel with crinoids' benthoscape prediction space (Figure 7). CON54 predominately occurred in the 'Gravelly sand/mud with <50% coverage of cobbles/gravel' and 'Glacial till with >50% cobbles/gravel' benthoscapes, only transitioning to a predicted crinoid patch at the end of the transect. Crinoids were not only present on gravel substrates but also found at high densities on boulders and bedrock patches, specifically in CON55, where crinoids were observed scattered on cobbles, boulders and bedrock also covered in high densities of the native tunicate *Ascidia callosa* Stimpson, 1852. When crinoids were present on gravel substrates, they were often spread across the field of view, with higher densities occurring on the few cobble patches or boulders encountered (as seen in CON53, 54 and 72). While *H. glacialis* is an unstalked species capable of movement (Deja *et al.* 2023), no individuals were observed unattached to a substrate, and as each transect collected continuous seafloor video in drift-survey mode (and analyzed images were ~50-m apart), individual crinoid presence was distinct (i.e., observations were not duplicated).

3.3 PROXIMITY ANALYSIS

To assist with consideration for future analysis options to compare the currently analyzed still images with prior surveys, a proximity analysis of the 639 selected still images in the 2023 and 2024 surveys was conducted. While approximately one third of the selected images were within 1-km of prior survey locations, only 40 images were within 100-m of prior survey locations (Figure 10). This included images directly overlapping putative RV Survey set transects (CON16, 17 and 65) and proximity to prior benthic imagery survey tracks (CON15 and 26 - Figure 10). Overall, proximity of the 2023 and 2024 analyzed stills to prior survey data ranged from 3 m to 13.3 km. One of the challenges encountered in conducting the 2023 and 2024 surveys using drift survey approaches was that pre-defined "preferred drift directions" to align with prior surveys were typically not able to be selected, due to a small range of primary near-seafloor current directions, as well as some entrainment along bathymetric contours.

The current survey sampled across all predicted benthoscape polygons except for the 'Mud with seapens' habitat. As previously noted, this benthoscape occurred at depths, and distance from Louisbourg that could not be surveyed using the camera system as configured in 2023 and 2024, and survey vessel logistics. Even the use of larger off-shore vessels in previous surveys scarcely sampled the 'Mud with seapens' benthoscape, with only three imagery transects completed (by Lacharité *et al.* 2018) and one RV Survey set (Appendix Table 3). Overall, considering prior survey locations (including the most recent RV Survey set starting points) and the transects conducted in the current imaging survey, the 'Glacial till with >50% cobbles/gravel' benthoscape has been most extensively sampled with 40 transects, followed by the 'Glacial till with coralline algae' and 'Mud' benthoscapes with 29 and 26 transects, respectively (Figure 10, Appendix Table 3). A total of 11 transects have been conducted in the 'Gravelly sand/mud with <50% cobbles/gravel' benthoscape, and seven transects in both the 'Gravel with crinoids' and 'Sand with sand dollars' benthoscapes (Appendix Table 3).

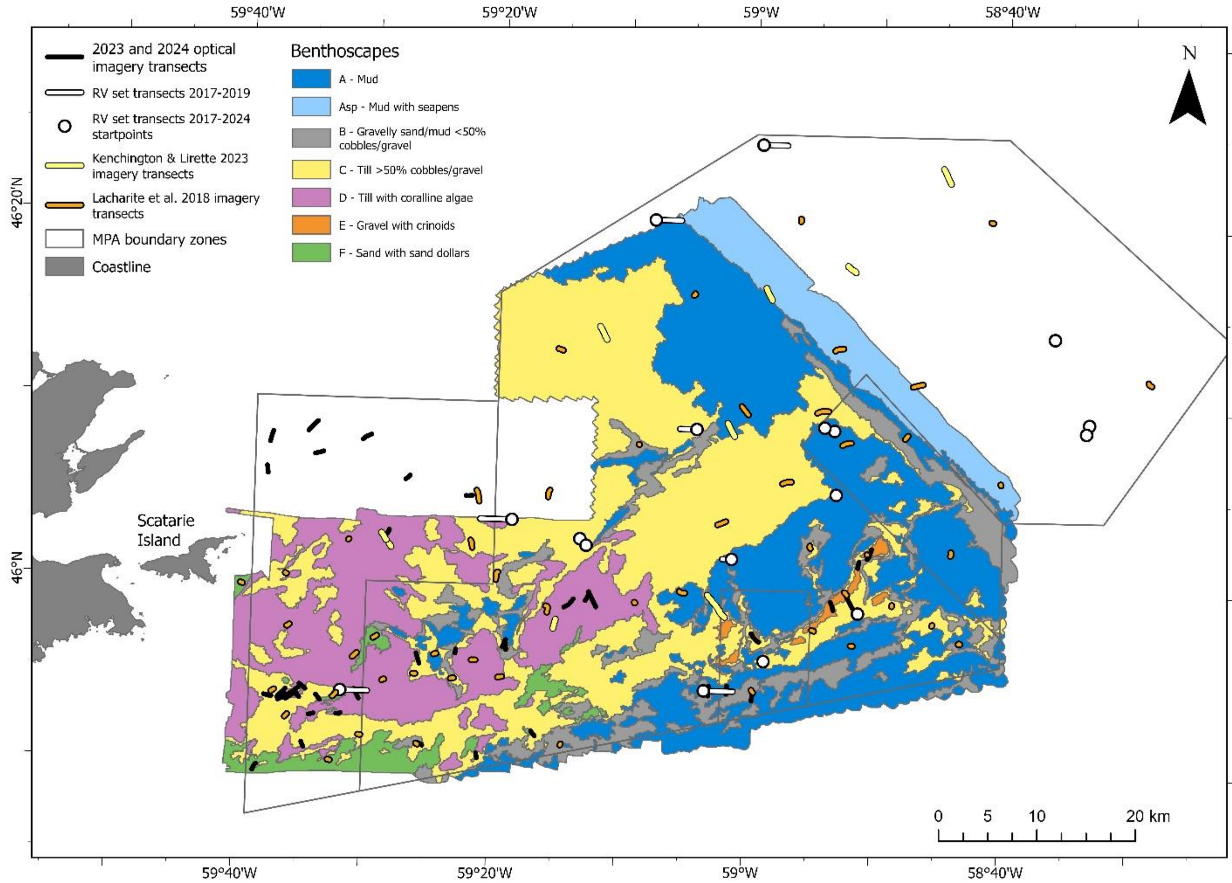

Figure 9 - Near-seafloor 2023 and 2024 optical imagery transect locations along with prior survey locations (from Lacharité et al. 2018; Kenchington and Lirette 2023; Murillo et al. 2024) in the St. Anns Bank MPA according to benthoscape class (A - Mud, Asp - Mud with sea pens, B - Gravelly sand/mud with <50% cobbles/gravel, C - Till with >50% cobbles/gravel, D - Till with coralline algae, E - Gravel with crinoids, and F – Sand with sand dollars).

4 DISCUSSION

Our two-year survey successfully sampled three key areas of potential high biodiversity and conservation priority identified during the development stages of the St. Anns Bank MPA as requiring more research: including the 'Big Shoal' (i.e., the northwestern corner of the MPA), Scatarie Bank, and other high relief areas (i.e., the southern, deeper portion of the MPA) (DFO, 2012). We provide an initial characterization of several significant benthic habitat features within the St Anns Bank MPA that have not previously been well documented, specifically the northwestern corner, and Scatarie and Curdo Banks. We also provide additional characterization of high relief areas/ridge features in the southern portion of the MPA. Moreover, we summarize near-seafloor imagery survey coverage across prior-defined benthoscapes within the MPA. The 2023 and 2024 surveys provide new and detailed high-resolution descriptions of the variety of habitats present in the St. Anns Bank MPA from shallow banks at depths of 17 m down to deeper crinoid beds and fine substrates at 144-m depths.

4.1 GROUND-TRUTHING BENTHOSCAPE PREDICTIONS

Benthoscape categories we assigned to images on several transects did not match the predicted habitat maps produced by Lacharité *et al.* (2018), with 34% disagreement across all still images (Table 2). This exemplifies the context of the benthoscape approach, which seeks to identify a set of defined habitat types along with putative boundaries for use in both management planning and scientific surveys (Brown *et al.* 2011; Lacharité and Brown 2019; Misiuk *et al.* 2021). Primarily, such an approach provides an overall set of habitat types which can be used to stratify survey designs and pinpoint key areas where VMEs are expected to occur. However, benthoscapes may fail to capture transitions across boundaries, and may benefit from the input of other physical characteristics into statistical modelling to better delineate boundaries and transition zones. Specifically, the spatial density of ground-truthed locations and the degree to which specific geomorphometry is included in the original analysis does not appear to have adequately captured ridge features or local-scale patchiness in varying sediments. Such features may be influential in determining habitat distributions, such as suitable areas for established crinoid beds. In fact, Lacharité *et al.* (2018) stated that their ground-truthing data within benthoscape patches was often limited as most survey stations only displayed one benthoscape. Additionally, regarding putative boundaries, they explained that confusion between benthoscapes was mostly observed between those most similar to each other (e.g., gravelly sand/mud being mistaken for mud). This could explain the disagreement of observed image benthoscapes in our survey, where most images that did not agree, were observed to be a benthoscape closely adjacent to the prediction. In general, Lacharité *et al.* (2018) and Misiuk *et al.* (2021) emphasized the need for higher-resolution multibeam bathymetry and backscatter (and associated derivatives) to better characterize micro-scale seafloor features and highlight boundary zones, as acoustic signatures may be too inconspicuous to be representative at a 50-m scale.

Overall, the current study provides clearer context on the range of local-scale habitat variability by assigning a benthoscape to each still image within predicted benthoscape patches, with a few limitations. While we were able to spatially locate our digital still images with a certain precision (<50 m in 2023 and ≤5 m in 2024), the benthoscape predictions themselves were based on a 50-m horizontal resolution, along with patch sizes ranging from 100 m^2 to over 600 km^2 (Lacharité *et* *al.* 2018). Instead, complete classification analysis of the 36-hours of continuous video tracks crossing putative benthoscape boundaries could offer better insight, but has not been undertaken to date due to resource constraints.

4.2 HABITATS OF ST. ANNS BANK

Benthic habitat surveys conducted prior to the designation of the St. Anns Bank MPA noted Scatarie Bank as an area of high biodiversity, given its complex topography. Imagery surveys using SCUBA have been completed on Scatarie Bank in recent years with the development of a permanent mooring and Autonomous Reef Monitoring Structure (ARMS) deployed in December 2023, however this data is still being analyzed (Mancion and Jeffery 2025; Dr. Bruce Hatcher, Cape Breton University, Sydney, Nova Scotia, *pers. comm.*). Early results describe a diversity of macroalgae and abundant sessile invertebrates, particularly sponges and bryozoans (Mancion and Jeffery 2025). Prior to MPA designation, Ford and Serdynska (2013) conducted benthic imagery transects on and surrounding Scatarie Bank in 2009-2010, describing it as an area dominated by red algae featuring encrusting sponges and a high diversity of invertebrates. Here, we collected just under two hours of high-definition video over a compiled distance of approximately 4.5 km, covering an estimated area greater than 8000 m^2 on and at the margins of Scatarie Bank, resulting in analogous findings of dense coralline and red algal cover, some kelp cover, and gentle slopes on small bedrock outcrops surrounded by boulder fields with common stalked tunicates. Surficial geology maps describe Scatarie Bank as predominately bedrock with gravel veneer, containing gravel up to boulder size appearing over bedrock (T.J. Kenchington 2014; King 2014; Philibert *et al.* 2022). This locally includes small glacial deposits and finer sediments on bedrock, with small rocky outcrops commonly occurring (King 2014). Our results support geological interpretations, as Scatarie Bank was observed to be dominated by cobbles and boulders with only small bedrock outcrops rather than one continuous feature (as was observed in the northwest corner of the MPA).

Similar bank features exist elsewhere in the MPA, and we are the first to recognize, sample, and characterize these features including Curdo Bank, and a predominantly shallow, extensive bank area in the unmapped (in terms of contemporary high-resolution multibeam survey technology) northwestern corner of the MPA. On Curdo Bank we collected just under 3.3 hours of video over a collated distance of approximately 7.5 km, covering an estimated area of over 10000 m^2. Curdo Bank contains dense kelp and red algal cover with numerous sponges (massive and encrusting), and steep rock walls along the bank edges with stalked tunicate fields and a high diversity of invertebrates. Our observations of the presence of bedrock outcrops seemingly confirm geological interpretations describing bedrock areas within the MPA as bare rock (sometimes with tabular morphology) and scattered gravel up to boulder size with some local sand patches (King 2014; Philibert *et al.* 2022).

In the northwestern corner of the MPA, we collected approximately 1.5 hours of video over a compiled distance of 4.4 km and an estimated area of approximately 5500 m^2. Similar diverse assemblages to the other banks were observed here, but the bathymetric features in the northwest corner were generally composed of more open, shallower regions with many elevation features represented by quite low vertical relief, often occurring at discrete points along the length of the transect. Dense kelp beds were encountered along the top of these extensive features.

Soft corals were common throughout the near-seafloor transects, occurring at both the shallowest and deepest areas surveyed (17-144 m), and across varying benthoscapes, aligning with prior studies that frequently observed them throughout the MPA (Ford and Serdynska 2013; Lacharité and Brown 2019). High densities of soft corals coincided with basket star occurrence particularly in CON67 and CON11 from depths of ~79 to 115 m. Studies suggest that juvenile basket stars are strongly linked to cold-water soft corals, in which basket stars use soft corals for habitat provision, primarily as a platform for recruitment (Buhl-Mortensen *et al.* 2017; Neves *et al.* 2020). However, basket stars do not necessarily rely on the presence of soft corals, instead showing a high degree of co-occurrence (Neves *et al.* 2020). Thus, it is expected that basket stars are more common in the St. Anns Bank MPA than reported here, as juveniles were likely entangled on or within soft corals and therefore too small to document from underwater imagery alone.

Tunicate fields commonly occurred across the study area in multiple benthoscapes. This was expected as stalked tunicates are known to be widely distributed in the Maritimes Region at depths ranging from 10 to 300 m, with dense concentrations described in the Bay of Fundy, off the coast of Cape Breton, and in shallow waters off Halifax, Nova Scotia (Francis *et al.* 2014; Beazley *et al.* 2017; Mireault *et al.* 2023, 2025). Widespread tunicate fields increase habitat complexity in subtidal communities and can form biogenic habitat, known to increase local species abundances or diversity and are thus considered VMEs internationally (Francis *et al.* 2014; DFO 2018; Kenchington *et al*. 2019; NAFO 2024). Specifically, previous studies show that these tunicates have been associated with higher occurrences of sponges, anemones, soft corals and hydroids (Francis *et al.* 2014; Mireault *et al.* 2025), similar to findings in this survey. As such, knowledge on the distribution and density of these tunicate fields is crucial to informing conservation and management strategies at local scales.

Crinoids have previously been documented in the St. Anns Bank MPA, with brief mention of their occurrence at high densities in the southeast portion of the MPA (Ford and Serdynska 2013). We observed dense crinoid beds in several transects located on or near ridge features from 77 to 119-m depths, similar to previous reports in the MPA (~100 m – Lacharité *et al.* 2018). Lacharité *et al.* (2018) found crinoids in just two transects in the southeast portion of the MPA, likely under-sampling this featured benthoscape and leading to only seven sporadically predicted patches of ‘Gravel with crinoids’ in the MPA (~1% of the area they surveyed), with patch sizes ranging from 0.7 to 6.2 km^2 (Lacharité and Brown 2019). As a result, crinoids could be expected to occur on other substrates (i.e., not exclusive to gravel) including bedrock, which was observed in CON55, only 220 m away from a transect conducted by Lacharité *et al.* (2018), which would likely not be captured using the current predicted benthoscape map. Both Lacharité and Brown (2019) and Ford and Serdynska (2013) suggest that crinoid beds are therefore more likely to be a fine-scale habitat feature not represented in broad-scale habitat generalizations. Indeed, as two of our crinoid transects occur near prior imagery surveys (within ~100-250 m of prior survey transects) along the edges of predicted benthoscape patches, crinoid beds are likely a localized feature. Crinoid beds may also be mis-represented in habitat generalizations because of the capacity of this species to move; while individual *H. glacialis* are expected to be primarily sedentary, crinoid aggregations may shift over time if environmental conditions become unfavourable (Deja *et al.* 2023). Even so, crinoids in this study were observed exclusively attached to a substrate, suggesting environmental conditions in the southeast portion of the MPA are likely stable and within a preferred range, resulting in little to no crinoid movement over our two-year survey.

4.3 FUTURE RESEARCH PRIORITIES

The 2023-2024 near-seafloor optical imagery survey provided new descriptions of several areas in the St. Anns Bank MPA that have not previously been well-documented, including the northwest corner, Curdo Bank, and crinoid beds located in the southeast portion of the MPA. Benthic habitat characteristics of Curdo Bank have not been previously described, with the benthic assemblages there forming a direct analog to those of Scatarie Bank, based on our preliminary analyses. Curdo Bank is situated closer to the Cape Breton shore, approximately 30 km closer to the port of Louisbourg, providing easier access for a range of survey vessels. Future research efforts could set-up monitoring stations there to better document temporal changes in community assemblages. Curdo Bank may also be better suited for follow-up dive surveys, in comparison to Scatarie Bank, to collect specimen samples and higher-resolution imagery as it is a smaller, shallower bank characterized by steep slopes that are often indicative of high species diversity. Even though Scatarie Bank is 8-13 times larger in size, depending on the bathymetry contour used as the margin (40 or 50 m), Curdo Bank contains expansive bedrock outcrops that were rarely observed on Scatarie Bank. Additionally, similar extensive outcrops to Curdo Bank were also observed in the northwest corner of the MPA, although with a lower overall range in height above the surrounding seafloor. To support potential future benthic surveys in the northwestern corner of the MPA, focus should first be given to acquire high-resolution multibeam bathymetry and backscatter data to better delineate the extent of such features to discover if it is in fact several fine-scale bank features, or one large bank. Current broad-scale geological interpretations describe the northwest corner as predominately postglacial sand and gravel (Philibert *et al.* 2022), yet our transects revealed extensive linear bedrock features. Moreover, higher-resolution multibeam surveys throughout the MPA could be used to enhance benthoscape predictions, capturing micro-scale features that may be indicative of habitats such as crinoid beds (Lacharité *et al.* 2018; Misiuk *et al.* 2021).

Crinoid beds are recognized as forming biogenic habitats where dense aggregations of stalked species constitute EBSAs domestically (E. Kenchington 2014; Guijarro *et al.* 2016; DFO 2018) and VMEs internationally (Murillo *et al.* 2011; Kenchington *et al.* 2019; NAFO 2024). Our current survey effort and preliminary analysis have identified additional locations within the MPA where there are significant densities of unstalked crinoids. Follow-on analysis will supplement the initial observations with detailed density estimates of crinoid beds using all available digital still imagery and high-definition video from our two-year survey. The extent and distribution of crinoids could then be evaluated in relation to specific bathymetric features, such as elongated ridge and surrounding plateau features, identified within the multibeam bathymetry data available for the MPA. Furthermore, transects with crinoids as well as other transects with mis-matched expected versus observed primary benthoscapes could be used to refine benthoscape boundaries, improving statistical modelling. This could also include the review of prior imagery surveys (Kenchington and Lirette 2023) for further ground-truthing data. Similarly, closer inspection can be given to the benthoscapes assigned to each image to precisely define percent cover of varying substrate types (i.e., using the Wentworth scale). Such detailed substrate data could be used in species distribution modelling and to better describe transition zones between habitats.

4.3.1 LONG-TERM MONITORING POTENTIAL

Prior surveys and predicted benthoscape patches helped delineate methodology to target areas that could be used in long-term monitoring efforts to document possible changes in community assemblages over time. However, all prior surveys have been independent studies lacking temporal objectives and repeatability, and therefore would be considered baseline or characterization surveys (Lacharité and Brown 2019). While baseline surveys are paramount to be able to incorporate ecosystem variability into monitoring survey design (ensuring accountability to stakeholders by supporting evidence-based management – T.J. Kenchington 2014), previous imaging studies within the MPA do not allow for efficient repeatability required for the implementation of long-term monitoring. Particularly, as they did not sample areas described as possible high biodiversity priority areas including the northwest corner (also described as the 'Big Shoal') and Scatarie Bank. Currently, images undergoing analysis from our two-year survey generate a 'snapshot' of organism occurrences rather than a measure of temporal change in assemblages, and principally generate additional baseline data, particularly in the northwest corner as well as Scatarie and Curdo Banks. While some target transect locations were chosen to overlap prior surveys, direct overlap was often not possible due to the drift protocol of the camera system operating off the surface vessel and local current regimes. The FOBIS system itself could be deployed in either a drift transect mode, with the existing frame design, or an alternate frame could be developed that would permit towed operations. Design of the underwater frame is one element that could require redesign, but the surface winch system, cable type, and deployment scenarios would also requirement amendment for implementation of a near-seafloor towed package. Such a system could potentially provide for repeated surveys at specific locations; however, near-seafloor towed systems may not be able to be used in as wide a range of seafloor topography as has been possible with the current drift system design. With an increase in capacity building to improve Autonomous Underwater Vehicles (AUVs) for benthic surveys, future monitoring protocols could additionally employ AUVs to specifically resample FOBIS transects at a much higher spatial resolution.

Though we cannot yet quantitatively assess change over time in benthic community assemblages using our survey, we can qualitatively describe assemblages in relation to prior studies based on similar habitat types such as bank and ridge features. Future analyses are planned to undertake comparison of taxa from prior imagery and RV Surveys (dating back to 2009) against the newly-acquired benthic imagery considering relative proximity, identified by our proximity analysis. A few transects do directly overlap with prior RV Survey sets, where identifications from physical samples could help confirm identifications of species in selected analyzed imagery and in turn help evaluate the relationship between compositional diversity (derived from trawls) against structural and functional diversity (as observed in imaging surveys). Additionally, some transects in the current survey do directly overlap with previous imaging surveys and would be directly comparable, as prior use of the regional DFO CAMPOD system included downward- and forward-facing continuous video, as well as downward, laser-scaled photographic imagery (Lacharité *et al.* 2018; de Mendonça and Metaxas 2021; Kenchington and Lirette 2023).

Overall, the 2023-2024 study should be considered a new baseline characterization survey with the ability in the future to repeat surveys using the same imaging system (owned and operated by DFO Science, Maritimes Region) operating off the same small local Coast Guard vessels (the

CCGS *M. Perley* and *Viola M. Davidson*). Our imaging system is available for regional use across coastal conservation areas (can sample to 200-m depths) with established standardized operating protocols and analysis procedures (a detailed technical report on FOBIS set-up, procedures, and applications is currently in development). This imaging system is cost-effective in that it does not require large vessel use or numerous personnel to operate, and can be deployed alongside other monitoring efforts, including eDNA and water quality sampling, to maximize vessel use in conditions where the camera system cannot be safely deployed. Although some previous imaging surveys within the St. Anns Bank MPA were able to better control the camera position (enhancing repeatability) as they exclusively operated off large research vessels, resource constraints (i.e., funding, ship time, and personnel) do not support the frequent use of large research vessels for standardized follow-on surveys needed for long-term monitoring.

Previous work has been done to describe and develop a general monitoring framework for the St. Anns Bank MPA (T.J. Kenchington 2014), however, imaging surveys are not currently included in the monitoring program (DFO 2024). Monitoring currently in place in the MPA is comprised of acoustic telemetry of fishes, passive acoustic monitoring of cetaceans, the Atlantic Zone Monitoring Program (collecting oceanographic data), and the annual Maritimes Snow Crab Survey (Choi *et al.* 2018; DFO 2024). Despite the usefulness of these monitoring efforts for some ecosystem components, non-invasive imaging and diver surveys have been suggested to increase ability to observe benthic ecosystem structure and species assemblages (DFO 2024). More specifically, T.J. Kenchington (2014) presented 76 monitoring indicators for the St. Anns Bank MPA, 28 of which were labelled as 'background' and 'effectiveness' indicators in which monitoring would be led by federal science programs with support from external partners. Imaging tools were identified as a priority sampling method to measure several indicators as they are a non-invasive tool that can detect change temporally and across scales relevant to management. Such indicators that could be measured from imaging surveys include indicators of diversity, community structure, ecosystem function, species abundance and size composition, invasive species, surficial geology characterization, spatial extent of unique seafloor features, presence of anthropogenic debris, and evidence of trawling impacts (T.J. Kenchington 2014). Our survey approach provides crucial information applicable to many of these indicators within the St. Anns Bank MPA, and could be repeated in the future to monitor specific benthic indicators over time.

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6 COMPETING INTERESTS STATEMENT

The authors declare there are no competing interests.

7 AUTHOR CONTRIBUTION STATEMENT

Conceptualization: PL, LLT, FJP; Data curation: LLT, PL; Formal analysis: LLT, FJP; Funding acquisition: PL, FJP; Investigation: PL, LLT; Methodology: LLT, PL, FJP; Project administration: LLT, PL; Software: PL, LLT; Resources: PL, FJP; Supervision: PL, FJP; Validation: LLT, FJP; Visualization: LLT; Writing – original draft: LLT, PL ; Writing – review and editing: LLT, PL, FJP.

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9 DATA AVAILABILITY STATEMENT

Transect and imagery metadata generated and analyzed during this study are available in the Lawton and Teed 2025b repository, https://open.canada.ca/data/en/dataset/2a55e2b4-cbb6-4fea-b17e-a16f5e99e68f. Still imagery and video files for this study are available from Lawton and Teed upon reasonable request. Current open data formats only permit the publication of files 2 GB in size; imagery files may be uploaded in batches to the open data link provided (Lawton and Teed 2025b) at a later date.

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APPENDIX I: TABLES

Appendix Table 1 - Detailed description of seafloor substrates and habitats observed in each near-seafloor imagery transect from observations made while viewing the downward- and forward-facing underwater video.

Transect	Seafloor substrate and habitat description
CON11	Fine sediments (likely sand) with sparse pebbles, cobbles and boulders. Numerous sand dollars on sandy patches and some snow crab. Eventually switches to mixed sediments with soft corals, massive sponges, basket stars and stalked tunicates attached to cobbles and boulders.
CON12	Poor lighting throughout this transect, but mixed sediments seen covered in coralline and red algae with some dense patches of Agarum clathratum on small bedrock outcrops.
CON13	Mixed sediments covered in coralline and red algae with some Agarum clathratum. Eventually some small bedrock patches (gently sloping) with encrusting sponges and algae cover, then back to mixed sediments (gravel, cobbles and boulders).
CON14	Mixed sediments (pebbles, cobbles and boulders) covered in coralline and red algae with some Agarum clathratum. Some gravel patches with few boulders and cobbles, eventually returning to mixed sediments with dense red algae cover.
CON15	Fine sediments with sparse cobbles. Soft corals, encrusting sponges and stalked tunicates are common throughout this transect. Some larger mixed sediment patches with numerous brachiopods, then back to fine sediments with sparse cobbles and boulders.
CON16	Fine sediments with cobbles and pebbles. Brachiopods common, with some soft corals and stalked tunicates throughout. Transect ends with only fine sediments (likely mud).
CON17	Sand with sparse mixed sediments and soft corals. Some boulder and cobbles patches with few stalked tunicates, then later with sponges and brachiopods. Eventually turning to fine sediments with sparse cobbles and pebbles.
CON18	Mixed sediments covered in coralline algae interspersed with shell hash. Stalked tunicates and sea cucumbers are present throughout the transect. Eventually switches to sand with mixed coarse sediments and few soft corals. Then some bedrock and boulder patches on the top of the bank with dense Metridium senile and encrusting sponges. Transect ends with fine sediments and shell hash.
CON19	Sandy gravel covered in coralline algae with coarser mixed sediments and some stalked tunicates and sea cucumbers throughout. Some bedrock outcrops (some quite steep) with numerous sponges interspersed with boulders and cobbles with dense red algae and Agarum clathratum along with Metridium senile as the transect moves up some steep bedrock walls a few meters high to shallower depths. Cunners and cod are commonly observed swimming along the top of the bank. Missing about 10 minutes of downward-facing video and 20 minutes of forward-facing video, which would show transition back to deeper depths with mixed sediments, shell hash and some soft corals (observed in still images).

Transect	Seafloor substrate and habitat description
CON20	Mixed sediments covered in coralline algae, interspersed with shell hash. Soft corals, sea cucumbers and stalked tunicates throughout. Some sandy bedrock patches near the end of the transect.
CON23	Large boulders and bedrock outcrops covered in coralline and red algae with dense, large Agarum clathratum interspersed with sandy shell hash. Eventually switches to mixed sediments.
CON24	Mixed sediments covered in coralline algae, then some bedrock outcrops with dense red algae and Agarum clathratum. Then back to finer mixed sediments with sparse boulders throughout.
CON25	Bedrock covered in coralline and red algae with Agarum clathratum. Switches to mixed sediments with coralline algae cover, few bedrock patches with some sand, and then up a high-slope bedrock wall a few meters high before ending with mixed sediment patches.
CON26	Fine sediments with sparse coarser sediment patches with numerous brachiopods, soft corals and few stalked tunicates throughout. Eventually reaches a boulder patch with extensive encrusting sponges before returning to mixed sediments. Gravel cover with high densities of the native tunicate Ascidia callosa at the end of the transect with scattered boulders.
CON27	Gravel and pebbles with high densities of crinoids. Some scattered boulders with few soft corals and encrusting sponges throughout.
CON28	Mixed sediments covered in coralline and red algae with Agarum clathratum interspersed with few bedrock patches covered in encrusting sponges on top of the bank. Eventually switches to sandy pebbles and cobbles with some red algae and stalked tunicates.
CON53	Mixed sediments with crinoids and extensive encrusting sponges. Some small bedrock patches with shell hash mixed with boulders and crinoids that become sparse as the transect continues.
CON54	Mixed sediments interspersed with shell hash and crinoids that continue throughout the transect. Few soft corals and massive sponges throughout. Numerous anemones on larger boulders.
CON55	Bedrock with numerous crinoids, soft corals, stalked tunicates and high densities of Ascidia callosa. Eventually switches to mixed sediments with shell hash and crinoids, with some bedrock patches covered in coralline algae.
CON56	Mixed sediments with soft corals and stalked tunicates, sea cucumbers, and a few basket stars throughout.
CON57	Mixed sediments with coralline algae and numerous soft corals. Some sandy bedrock patches throughout the transect.
CON58	Sandy bedrock covered in coralline algae with soft corals and sea cucumbers, then switching to mixed sediments with stalked tunicates scattered throughout. This transect finishes in a bedrock outcrop.
CON59	Mixed sediments with coralline algae, eventually turning to bedrock with dense red algae and Agarum clathratum cover. Eventually switching back to mixed sediments with few bedrock patches.
CON62	Sandy gravel with shell hash. Stalked tunicates, snow crabs, sea cucumbers, and soft corals throughout. Few basket stars.

Transect	Seafloor substrate and habitat description
CON63	Sandy gravel with some coralline algae cover, then mixed sediments with stalked tunicates, sea cucumbers, small snow crabs and basket stars scattered throughout the transect.
CON64	Sand with sand dollars and lots of snow crabs and then switching to mixed sediments with one basket star and some stalked tunicates throughout.
CON65	Mixed sediments covered in coralline algae with some soft corals, sea cucumbers and stalked tunicates throughout. Eventually as the transect transitioned to shallower depths, we encountered bedrock with dense red algae, Agarum clathratum and Metridium senile. Transect ends with boulders and cobbles densely covered in red algae with few bedrock patches.
CON66	Sand with sand dollars and lots of snow crabs, shell hash, and some sea urchins, sea cucumbers and stalked tunicates throughout. Then mixed sediments covered in coralline algae with soft corals and numerous sponges.
CON67	Boulders and cobbles with lots of soft corals and sponges. Few basket stars throughout. Then mixed sediments with stalked tunicates, few snow crabs, ending with sand and sand dollars.
CON68	Sandy gravel with shell hash and scattered snow crabs and soft corals. Few stalked tunicates throughout.
CON69	Sand with sand dollars and snow crabs, few stalked tunicates throughout. Later some mixed sediments.
CON70	Mixed sediments with stalked tunicates, soft corals and basket stars throughout.
CON71	Mixed sediments with stalked tunicates and soft corals. Then switches to sand with sand dollars as well as scarce cobble and boulder patches with encrusting sponges.
CON72	Mixed sediments with extensive Ascidia callosa and numerous soft corals and stalked tunicates throughout. Few dense patches of gravel with crinoids.
CON73	Gravel with coralline algae and numerous large stalked tunicates before switching to large boulders and bedrock patches covered in coralline algae, sponges, anemones and soft corals. Then switches to mixed sediments with encrusting sponges.
CON74	Bedrock and boulders with dense red algae, Agarum clathratum and Alaria esculenta cover with numerous Metridium senile along the top of the bank. Several cunners and cod observed swimming along the bank with few wolffish observed. Transect ends with mixed sediments.
CON75	Large boulders and cobbles covered in coralline and red algae with Agarum clathratum, stalked tunicates and sea cucumbers throughout. Later encounter steep bedrock walls a few meters high, and then back to mixed sediments with lots of Metridium senile and Alaria esculenta cover and soft corals. Cunners, rockfish and cod observed throughout this transect.
CON76	Mixed sediments covered in coralline algae interspersed with shell hash. Sea cucumbers and stalked tunicates throughout with soft corals. Large boulders near the end of the transect.
CON77	Cobbles and boulders covered in coralline and red algae with soft corals, encrusting sponges. Sea cucumbers and stalked tunicates throughout. Some bedrock outcrops with steep rock walls a few meters high. High densities of anemones on bedrock.

Transect	Seafloor substrate and habitat description
CON78	Mixed sediments with some coralline algae cover. Bedrock patches with soft corals, sea cucumbers and stalked tunicates throughout.
CON79	Sand with sand dollars and few snow crabs and basket stars.

Appendix Table 2 – Details on the selected still images for annotation analysis per transect including average altitude, field of view (FOV), depth of image and the distance between annotated stills.

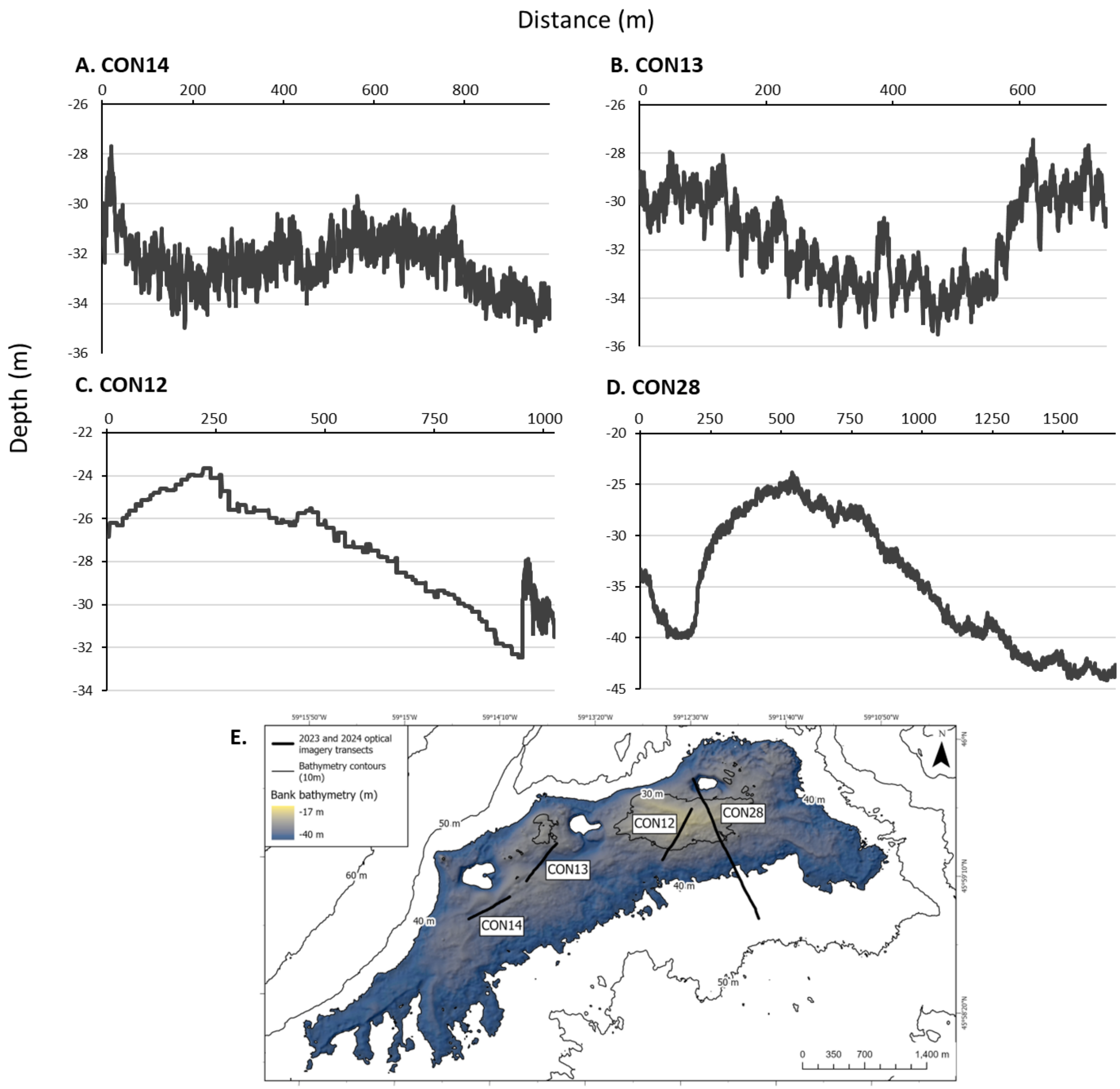
Transect	Number of images analyzed	% of images analyzed	Average altitude (m ±SD)	Average FOV (m2 ±SD)	Average depth (m ±SD)	Average distance to next image (m ±SD)
CON11	14	22.6	1.06 (±0.19)	1.17 (±0.21)	98 (±8.6)	62 (±10.7)
CON12	7	21.2	1.43 (±0.35)	1.53 (±0.29)	28 (±2.6)	67 (±9.0)
CON13	9	23.7	1.23 (±0.39)	1.34 (±0.37)	33 (±2.1)	61 (±7.1)
CON14	10	16.4	1.32 (±0.27)	1.41 (±0.24)	34 (±0.9)	55 (±4.5)
CON15	19	16.8	1.25 (±0.40)	1.33 (±0.36)	142 (±1.6)	55 (±5.8)
CON16	15	16.9	1.36 (±0.35)	1.44 (±0.31)	137 (±3.3)	55 (±6.0)
CON17	18	14.9	1.33 (±0.30)	1.39 (±0.28)	128 (±3.6)	56 (±7.0)
CON18	20	13.6	1.44 (±0.30)	1.51 (±0.26)	46 (±9.1)	56 (±4.9)
CON19	44	11.7	1.36 (±0.35)	1.49 (±0.30)	37 (±13.0)	55 (±5.3)
CON20	10	8.5	1.27 (±0.32)	1.36 (±0.30)	52 (±0.6)	54 (±3.9)
CON23	15	17.2	1.27 (±0.31)	1.36 (±0.27)	27 (±1.1)	53 (±6.6)
CON24	19	24.1	1.22 (±0.21)	1.33 (±0.20)	35 (±1.0)	59 (±7.2)
CON25	16	23.5	1.66 (±0.22)	1.70 (±0.30)	34 (±1.4)	83 (±25.2)
CON26	26	16.6	1.33 (±0.30)	1.41 (±0.27)	107 (±14.4)	58 (±8.3)
CON27	25	22.5	1.35 (±0.21)	1.44 (±0.19)	100 (±5.1)	60 (±7.0)
CON28	29	22.1	1.33 (±0.32)	1.42 (±0.29)	36 (±6.8)	61 (±10.7)
CON53	15	27.3	1.31 (±0.15)	1.41 (±0.13)	100 (±6.2)	65 (±10.0)
CON54	12	18.5	1.23 (±0.26)	1.34 (±0.25)	113 (±5.8)	56 (±3.9)
CON55	21	21.9	1.66 (±0.36)	1.55 (±0.24)	84 (±8.8)	55 (±4.6)
CON56	11	17.8	1.33 (±0.36)	1.34 (±0.31)	64 (±1.0)	60 (±4.6)
CON57	11	22.9	1.49 (±0.23)	1.53 (±0.12)	53 (±1.2)	58 (±11.0)
CON58	17	29.3	1.49 (±0.33)	1.49 (±0.22)	48 (±0.7)	62 (±11.7)
CON59	15	23.8	1.32 (±0.39)	1.34 (±0.29)	35 (±4.2)	62 (±11.5)
CON62	14	29.8	1.37 (±0.27)	1.41 (±0.21)	66 (±4.3)	58 (±11.0)
CON63	14	28.6	1.39 (±0.14)	1.50 (±0.09)	54 (±0.5)	61 (±7.8)
CON64	12	21.8	1.20 (±0.20)	1.32 (±0.21)	65 (±1.0)	58 (±5.1)
CON65	19	23.8	1.29 (±0.25)	1.34 (±0.18)	48 (±6.9)	61 (±10.2)
CON66	19	22.6	1.26 (±0.24)	1.35 (±0.24)	60 (±13.1)	59 (±8.0)
CON67	14	19.2	1.34 (±0.31)	1.38 (±0.19)	97 (±12.4)	56 (±6.4)
CON68	5	17.2	1.84 (±0.25)	1.67 (±0.06)	67 (±2.4)	60 (±10.6)
CON69	12	21.4	1.59 (±0.31)	1.49 (±0.23)	92 (±0.9)	55 (±4.8)
CON70	10	22.2	1.52 (±0.20)	1.56 (±0.12)	96 (±1.7)	57 (±5.7)
CON71	11	22.9	1.77 (±0.43)	1.47 (±0.29)	94 (±1.6)	62 (±9.6)
CON72	21	20.6	1.49 (±0.40)	1.39 (±0.25)	99 (±5.3)	57 (±5.1)
CON73	14	16.9	1.66 (±0.29)	1.58 (±0.12)	44 (±6.3)	60 (±5.6)
CON74	15	19.0	1.66 (±0.29)	1.58 (±0.13)	38 (±16.1)	60 (±5.4)
CON75	18	17.1	1.43 (±0.37)	1.42 (±0.28)	31 (±10.3)	62 (±13.5)

Transect	Number of images analyzed	% of images analyzed	Average altitude (m ±SD)	Average FOV (m2 ±SD)	Average depth (m ±SD)	Average distance to next image (m ±SD)
CON76	10	23.3	1.75 (±0.36)	1.46 (±0.26)	53 (±0.7)	59 (±4.4)
CON77	9	13.8	1.41 (±0.55)	1.30 (±0.48)	46 (±1.9)	59 (±7.7)
CON78	11	28.2	1.70 (±0.26)	1.60 (±0.08)	57 (±2.2)	56 (±5.0)
CON79	13	22.0	1.12 (±0.18)	1.24 (±0.21)	88 (±1.6)	57 (±4.6)

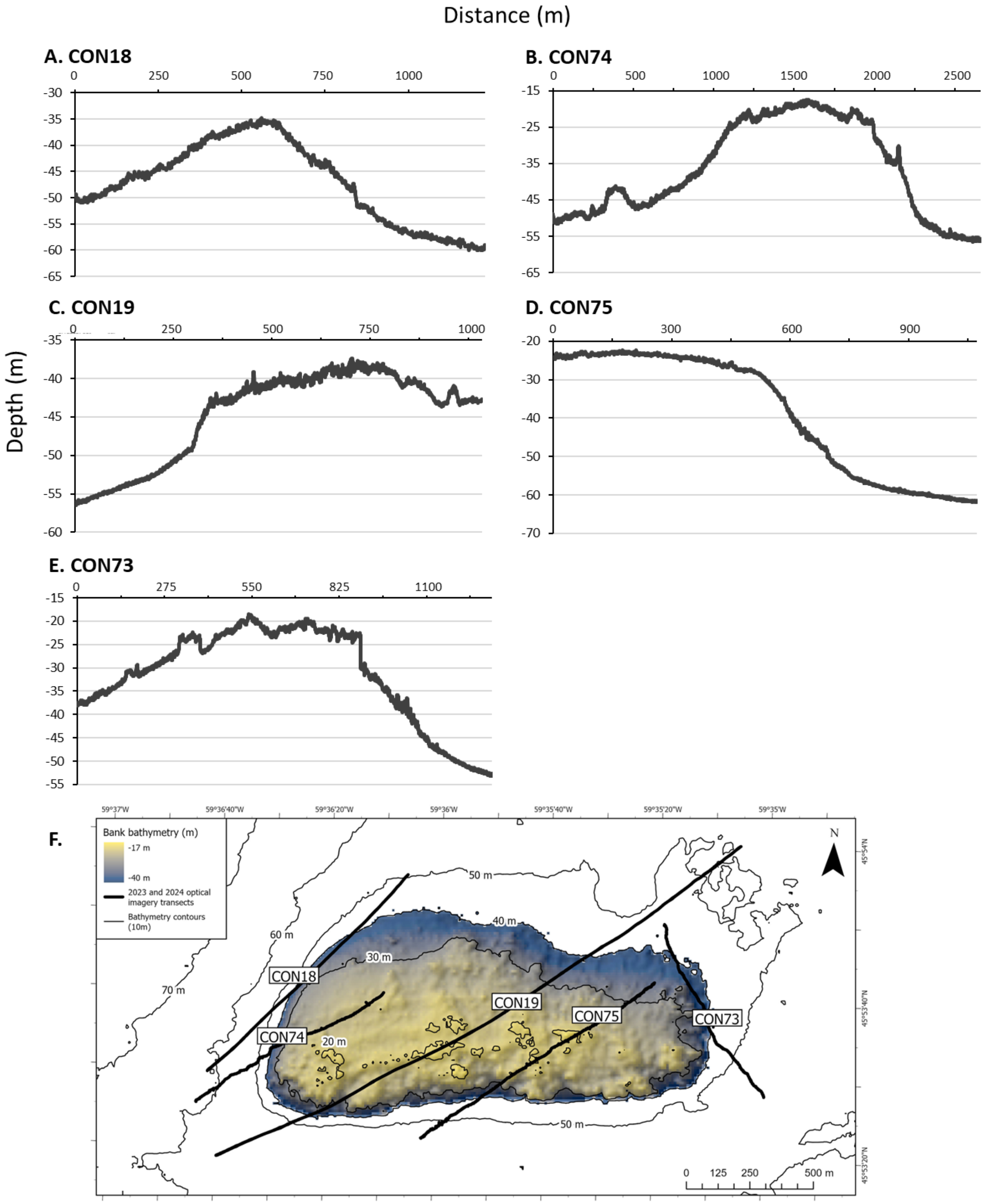
Appendix Table 3 - Summary of prior and current benthic habitat survey locations within predicted benthoscapes including near-seafloor imagery surveys and RV Survey sets. Numerous transects crossed benthoscape boundaries, and therefore may be listed under two benthoscapes.

Benthoscape	Number of survey locations	Survey locations by study
A – Mud	26 transects	6 RV Survey sets 3 Kenchington and Lirette 2023 11 Lacharité *et al.* 2018 6 Lawton and Teed 2025b
Asp – Mud with seapens	4 transects	1 Kenchington and Lirette 2023 3 Lacharité *et al.* 2018
B - Gravelly sand/mud with <50% cobbles/gravel	11 transects	1 RV Survey sets 6 Lacharité *et al.* 2018 4 Lawton and Teed 2025b
C - Till with >50% cobbles/gravel	40 transects	5 RV Survey sets 3 Kenchington and Lirette 2023 15 Lacharité *et al.* 2018 17 Lawton and Teed 2025b
D – Till with coralline algae	29 transects	2 RV Survey sets 3 Kenchington and Lirette 2023 8 Lacharité *et al.* 2018 16 Lawton and Teed 2025b
E – Gravel with crinoids	7 transects	2 Lacharité *et al.* 2018 5 Lawton and Teed 2025b
F – Sand with sand dollars	7 transects	1 RV Survey set 4 Lacharité *et al.* 2018 2 Lawton and Teed 2025b

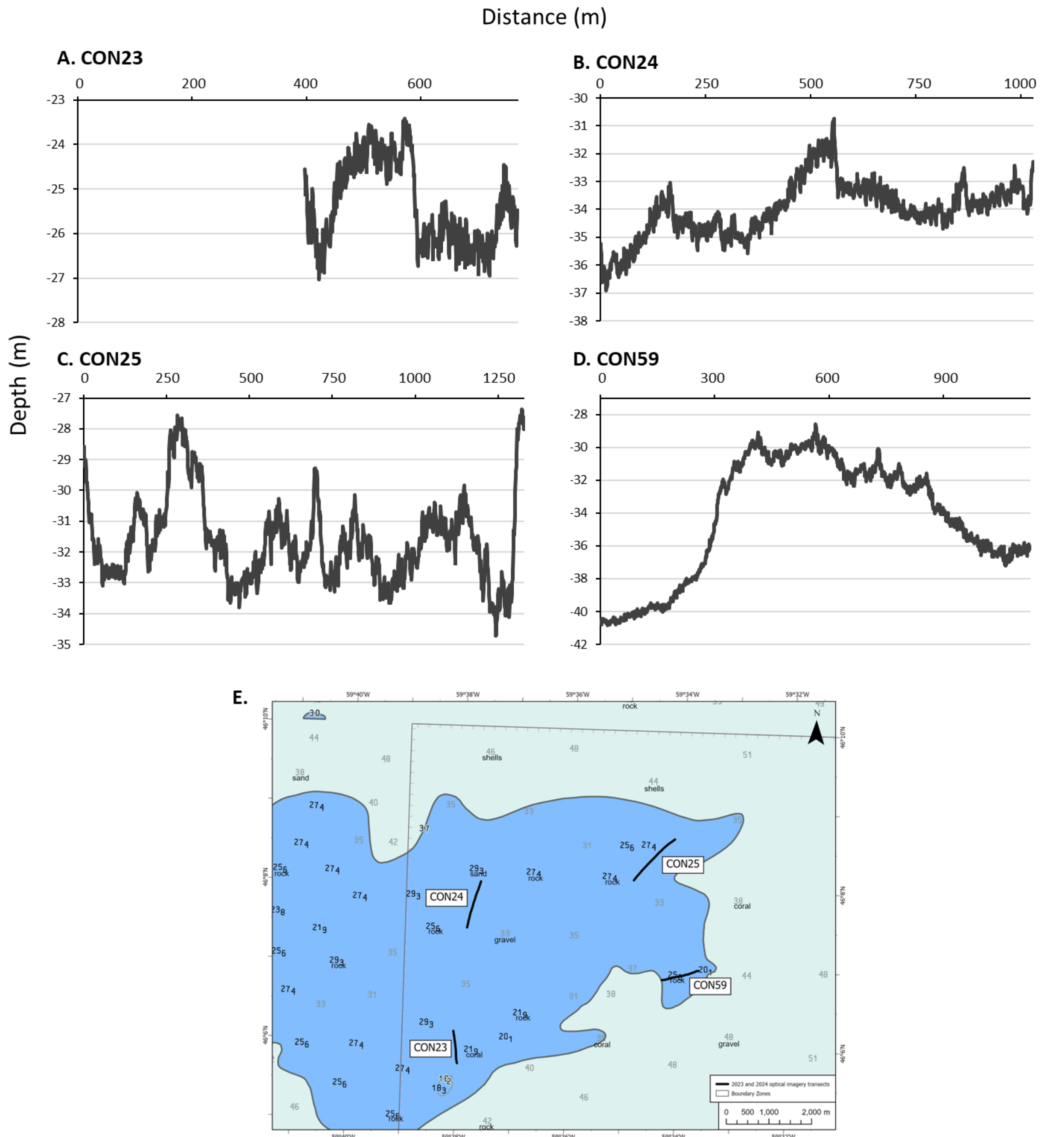
APPENDIX II: FIGURES



Appendix Figure 1 – Depth profiles (in m) of the transects conducted on Scatarie Bank in the St. Anns Bank MPA, demonstrating complex seafloor topography. Transects include: A – CON14, B – CON13, C – CON12, and D – CON28 from west to east over Scatarie Bank (E).



Appendix Figure 2 – Depth profiles (in m) of the transects conducted on and surrounding Curdo Bank in the St. Anns Bank MPA, demonstrating complex seafloor topography. Transects include: A – CON18, B – CON19, C – CON73, D – CON74, and E – CON75 from west to east over Curdo Bank (E).



Appendix Figure 3 – Depth profiles (in m) of the transects conducted on shallow banks in the northwestern corner of the St. Anns Bank MPA, demonstrating complex seafloor topography. Transects include: A – CON23, B – CON24, C – CON25, and D – CON59 from west to east across the northwestern corner (E).