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Research

Local ecological knowledge and multidisciplinary approach lead to discovery of hidden biodiversity in the deep ocean of Labrador, Canada

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ABSTRACT. International commitments to preserve global biodiversity target the protection of 30% of marine habitats by 2030. The lack of even basic knowledge of many marine areas (e.g., deep oceans) combined with short timelines require integrative knowledge and multidisciplinary techniques to be used to efficiently identify areas worthy of protection. Here we outline a case study of the discovery of the Makkovik Hanging Gardens found in a deep-water trough in coastal Labrador, Canada. The area is of ecological significance because it supports high densities of vulnerable marine ecosystem indicator taxa, including the gorgonian coral *Primnoa resedaeformis* on portions of its vertical submarine walls. This study illustrates the exploratory process initiated by Nunatsiavut, which integrated local knowledge, scientific models, and a variety of technologies (such as remotely operated vehicles and multibeam sonar) to discover deep-water hidden biodiversity toward the advancement of both local Indigenous and global conservation goals.

Key Words: *deep-water corals; Indigenous knowledge; local ecological knowledge; Nunatsiavut; ROV/benthic survey/video survey; VME*

INTRODUCTION

Marine biodiversity faces increasing pressure from expanding resource extraction and anthropogenic stressors such as climate change (Martin et al. 2020). In response, calls for measures that protect biodiversity and marine habitats have intensified, culminating in international agreements to protect 30% of the world's ocean habitats by 2030 (United Nations Environment Program 2022). Unfortunately, in much of the world's oceans, particularly deep ocean areas, information is lacking for identifying priority areas for protection.

To maximize the benefits of protection, area-based conservation measures (e.g., marine protected areas [MPAs] and other effective conservation measures [OECMs]) are ideally applied to habitats that support some combination of high biodiversity, productivity, and vulnerable taxa. In some cases, vulnerable taxa can support elevated biodiversity (Cerrano et al. 2010). For example, deep-water corals and sponges are habitat-forming species, modifying environmental conditions with their presence (Zedel and Fowler 2009) and creating foraging (Buhl-Mortensen and Mortensen 2004, Gale et al. 2013), nursery (Aldrich and Lu 1968, Baillon et al. 2012, Neves et al. 2020), and refuge (Wulff 2006) areas for other taxa. At the same time, their sessile nature, fragile structures, and slow growth make them extremely vulnerable to disturbance from human activities, such as bottom-contact trawling, from which they can take decades or more to recover (Neves et al. 2014). The United Nations General Assembly has recognized the importance of such vulnerable marine ecosystems (VMEs) and has called for their identification and protection (UNGA 2006).

The Northwest Atlantic Ocean is home to a high diversity of suitable habitats for deep-water corals and sponges (Knudby et al. 2013, Gullage et al. 2017), but our knowledge of their distribution in this region of the world is primarily based on catches from research trawl surveys (Wareham and Edinger 2007, Murillo et al. 2011, Guijarro et al. 2016, Kenchington et al. 2016, Gullage et al. 2017) and bycatch documented by fisheries observers (Wareham and Edinger 2007, Kenchington et al. 2010). Although these surveys have impressive spatial coverage and have allowed the identification of areas hosting significant concentrations of corals and sponges (e.g., Guijarro et al. 2016, Kenchington et al. 2016) and ecologically and biologically significant areas (Kenchington et al. 2011), they often avoid rough bottom areas and generally do not include shallow coastal or deep-water environments > 1500 m (Walsh et al. 2009, Rideout and Ings 2018). Surveys using remotely operated vehicles (ROVs), on the other hand, have provided an opportunity to explore these environments (e.g., Edinger et al. 2011, Baker et al. 2012, Buhl-Mortensen et al. 2017, Dinn et al. 2020, Lecours et al. 2020), but they occur less frequently than trawl surveys and cover much smaller areas. Therefore, there remains vast areas of benthic habitat with very limited information.

There are significant hurdles to filling these knowledge gaps, including the limited area that targeted ROV and other camera surveys can cover because of cost, the small number of capable research vessels, the small scales that they can survey with technologically advanced equipment, and the short research seasons in remote and often challenging environments (e.g., the presence of seasonal sea ice; Fisheries and Oceans Canada [DFO] 2021). These challenges are exacerbated by the short timelines required to meet protection targets. To mitigate these limitations and make the most efficient use of resources, researchers need to prioritize their exploration plans with the best available knowledge. In addition to combining multidisciplinary approaches with new technologies, integration of local knowledge can leverage lifetimes of informal surveys (Gass and Willison 2005, Breeze and Fenton 2007, Colpron 2016, Wilder et al. 2016) that include areas relatively untouched by western science. Contributions from such "experts of place" are critical for addressing the current biodiversity crisis (Wilder et al. 2016, Ogar

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et al. 2020) and can be instrumental to identifying ecologically and culturally important areas worthy of protection (e.g., Sheil et al. 2003, Wilder et al. 2016, Ogar et al. 2020, Rangeley et al. 2022, Parks Canada 2022). At the same time, such knowledge is proprietary and must be used in a way that is respectful of the culture and needs of knowledge holders (Nadasdy 1999). It also must be utilized in a way that follows the consent given for that knowledge and provides positive outcomes to knowledge holders and their community.

Much of the ocean off the coast of Labrador, eastern Canada, lies adjacent to Nunatsiavut, the homeland of the Labrador Inuit. Nunatsiavut's land claim extends seaward 12 nautical miles (19.3 km) from the coast, an area for which they have rich traditional and local knowledge. This zone also includes deep and often inaccessible habitats that remain largely unmapped and unexplored by both Nunatsiavummiut (people of Nunatsiavut) and western scientists (DFO 2021). Consequently, the Nunatsiavut Government has implemented the Imappivut (Our Waters) Marine Planning Initiative, which is intended to compile Indigenous knowledge and generate additional scientific information to support self-determined marine spatial planning, including potential Indigenous area-based protection measures (Nunatsiavut Government 2020).

Here we present a case-study that highlights the integrated and multidisciplinary process initiated by Nunatsiavut, which led to the discovery of hidden deep-water biodiversity near the community of Makkovik. It demonstrates the benefits of integrating local knowledge and multiple disciplines of science to locate, explore, and understand biodiversity.

METHODS AND RESULTS

Study area

Labrador Inuit have relied on the coastal ecosystem of Nunatsiavut for generations and maintain strong cultural and economic connections to this environment, including activities such as subsistence hunting; communal, commercial, and subsistence fishing; and travel (DFO 2021). Through the Imappivut Marine Planning Initiative, the Nunatsiavut Government encourages multidisciplinary and collaborative research, including Indigenous knowledge and western science, along coastal Labrador in pursuit of as much knowledge as possible to sustain their ecosystems and way of life. A biophysical overview of the area was conducted, which includes information on coral and sponge diversity and distribution, seafloor features, oceanographic information, and local knowledge (DFO 2021). This work triggered an interest by the Nunatsiavut Government and collaborators to search for VMEs in an area of the Makkovik Trough. This geological feature is one of the largest glacially excavated shelf-crossing troughs of the Labrador Shelf (Fig. 1) and permits relatively warm Atlantic-origin water to penetrate underneath the cold, low salinity, Arctic-origin waters of the Labrador Coastal Current at depths of approximately 300 m (Petrie et al. 1988, DFO 2021). The Makkovik Trough also sustains intensive Indigenous and non-Indigenous commercial fishing that comprises mostly fixed-gear fisheries for crab and groundfish, such as Greenland halibut (Koen-Alonso et al. 2018, DFO 2021).

Existing knowledge

Bycatch information

Most of the bycatch information on corals and sponges in the Newfoundland and Labrador region is available from Fisheries and Oceans Canada (DFO) trawl surveys (Fig. 1). Unfortunately, these observations are limited to the extent of existing fisheries, which leaves notable gaps in deeper waters and in Nunatsiavut waters along the coast (DFO 2021). Fisheries observer data are another important source that have helped to shape our understanding of coral and sponge distribution in the region (Wareham and Edinger 2007, Edinger et al. 2007). These observers have provided scientists with samples or photographs that confirm the presence of these organisms in many inaccessible areas (V. Hayes, *personal communication*). Coral observations off Labrador span the shelf to the continental shelf break, but habitat-forming large gorgonians and large sponges are primarily found at the shelf break (MacIsaac et al. 2001, Gass and Willison 2005, Edinger et al. 2007, Wareham and Edinger 2007; Fig. 1).

Predictive distribution models of coral and sponge species

Predictive distribution models are also available for some coral functional groups in the region, such as large and small gorgonians, sea pens (Gullage et al. 2017), and sponges (Knudby et al. 2013). These models were created by linking bycatch data from DFO trawl surveys with various environmental conditions (depth, temperature, salinity, slope, aspect, current, and shear) and extrapolating to surrounding areas beyond the catch data, and remain largely unvalidated. Whereas these models suggest only sparse highly suitable habitats for corals like large gorgonians outside the continental shelf break, potentially suitable habitat was indeed identified within the deep waters of the Makkovik Trough (Fig. 1). Although an interesting target, the Makkovik Trough is vast (~10,000 km²) and is far beyond what can reasonably be surveyed during a single scientific mission.

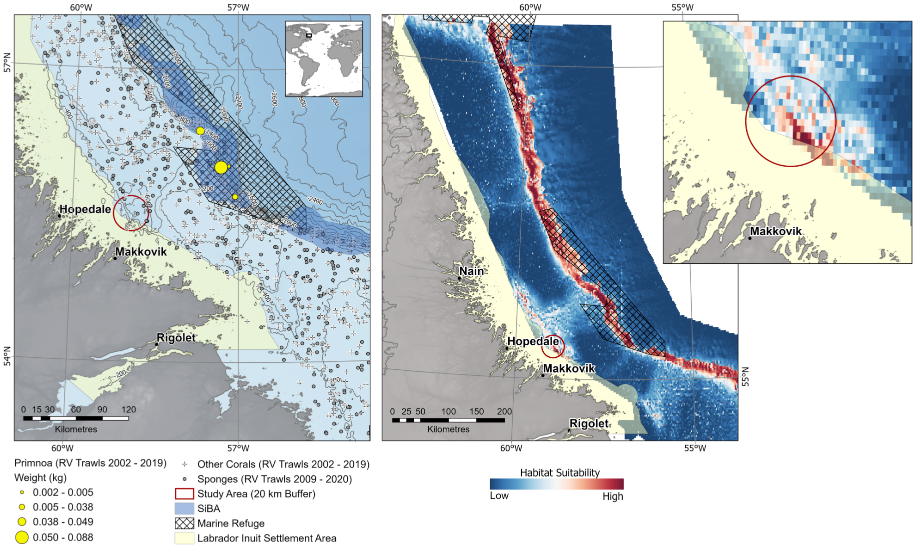
Local ecological knowledge

Although the coral data obtained from the trawl surveys were limited to trawlable bottoms, it indicated the overall presence and high biomass of corals in the Labrador Shelf region. In addition, the model produced by Gullage et al. (2017) predicted the Makkovik Trough would include highly suitable habitat for large gorgonian corals (Fig. 1). Yet, these scientific sources lacked the spatial precision with which to guide ship-based exploration efforts. Many of the region's corals are deep-water species and were not highlighted in the most recent compendium of Nunatsiavut knowledge (DFO 2021). Fortunately, we were able to refine our area of interest based on two sources of local ecological knowledge (LEK; Neis and Felt 2000). We use the term LEK because the following information is derived from direct experiences of the knowledge holders (Anadón et al. 2009) as opposed to traditional ecological knowledge (TEK), which implies knowledge that is passed down through generations (Berkes et al. 2000).

Captain Bartlett information

Captain Bartlett, a retired fish harvester who fished off Makkovik for eight years prior to the cod moratorium of 1992, first shared his bycatch collection of deep-water corals and bryozoans and their general area of collection with researchers in 2005 while advocating for their protection. Among the specimens in his collection were large gorgonian corals (*Primnoa resedaeformis*

Fig. 1. Left panel: Distribution and biomass of large gorgonian coral and sponge bycatch documented as part of DFO's multispecies research trawl program. The Makkovik Trough study area is shown by the red circle. Noteworthy coral and sponge areas such as the Hatton Basin Marine Refuge, other established Significant Benthic Areas (SiBAs - significant areas of coral-water coral and sponge dominated communities), and General Bathymetric Chart of the Oceans–derived bathymetry are also depicted. Right panel: Model outputs of large gorgonian habitat suitability across the Labrador shelf (based on data from Gullage et al. 2017). The inset provides a more detailed view of the Makkovik Trough study area.

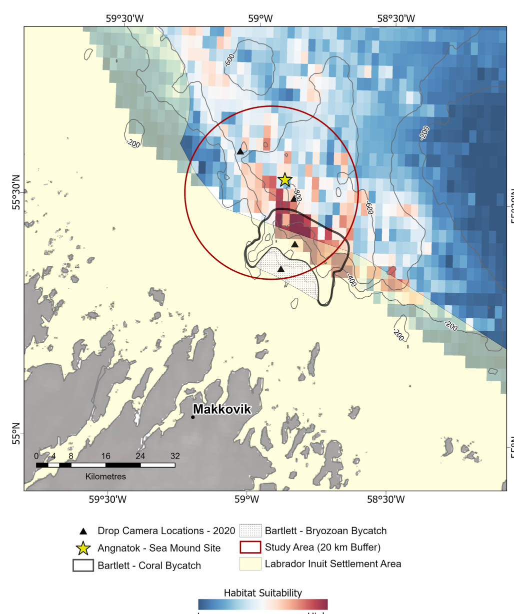


and *Paragorgia arborea*) collected at the landward extent of the Makkovik Trough. This information was particularly important because these large gorgonian species can be long-lived (Sherwood et al. 2005, Sherwood and Edinger 2009), and their occurrence might indicate the presence of a VME (Buhl-Mortensen et al. 2019) close to the coast of Labrador. Although more precise than existing scientific knowledge, the identified area was still ~1400 km². The boundaries of his area of collection were later delineated and included as part of the biophysical overview in 2019 (DFO 2021).

Captain Angnatok information

A key element of the Imappivut collaboration is the inclusion of LEK and guidance in research efforts in accordance with the National Inuit Strategy on Research (Inuit Tapirit Kanatami 2018). Direction on research priorities, including advice on high-potential areas to survey was provided by Nunatsiavut collaborators. Captain Joey Angnatok, a Nunatsiavut beneficiary, Indigenous researcher, and fish harvester with a lifetime of experience in Nunatsiavut waters, shared his story of fishing on his vessel, the FV *What's Happening*, in the Makkovik Trough. He recalled setting his nets and buoy lines in what he expected to be approximately 700 m of water based on existing bathymetric charts (notoriously inaccurate in Nunatsiavut waters). When most of his buoy line at one end of the net was not submerged, he realized that the seafloor rose dramatically at least 300 m on what he interpreted as an uncharted "sea mound." Furthermore, based on the degree of entanglement of his gill nets, the area appeared to have structurally complex substrates consistent with the presence of coral habitats. He marked the position on his vessel's plotter to avoid this area for fishing in the future. The marked position was within 8.5 km of Wilfrid Bartlett's coral area (Fig. 2).

Fig. 2. Drop camera stations surveyed in 2020 relative to existing knowledge sources of deepwater corals in the Makkovik Trough region. Knowledge sources include the reported location of the "sea mound" by Captain Angnatok, the coral and bryozoan regions provided by Captain Bartlett, and modeled areas of high large gorgonian suitability (Gullage et al. 2017). Bathymetric contours displayed are based on General Bathymetric Chart of the Oceans data.



Survey target development

Preliminary bathymetric analysis (General Bathymetric Chart of the Oceans)
With multiple streams of corroborating information, we planned to visit the identified area with a multidisciplinary team aboard the Canadian research icebreaker CCGS *Amundsen* in 2020 (Nunatsiavut research permit 72639630). In addition to targeting the sea mound site identified by Captain Angnatok, we used the corals and bryozoans polygons delimited by Captain Bartlett and General Bathymetric Chart of the Oceans (GEBCO) bathymetry data to identify other nearby areas of high potential based on bathymetric relief. In total, four stations were identified, which spanned depths of 224 to 882 m (Fig. 2).

Year 1: initial surveys

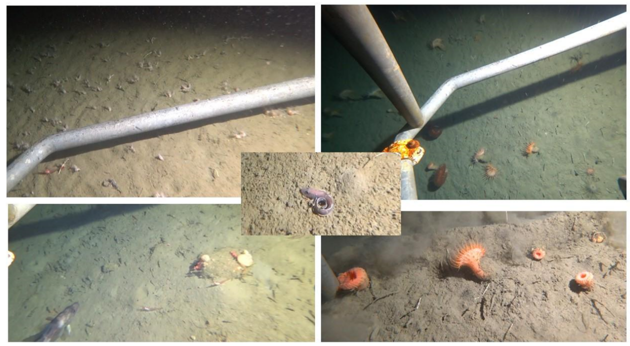
Site selection was primarily based on the potential to identify sites of significant benthic diversity. Our plan was to conduct ROV and drop camera deployments to visually survey the seafloor, in addition to using other benthic and pelagic tools. The first survey was planned to take place in 2020, but pandemic-related supply chain issues delayed the delivery of the new *ASTRID* ROV that was expected on board the CCGS *Amundsen*, and therefore we planned to visually survey our target sites using a drop camera system during Year 1.

Drop camera surveys
These surveys were planned to take place at the sites identified through GEBCO bathymetry with little additional pre-survey investigation. The drop camera consisted of a downward-facing camera (Mark VI AlphaCam; 4K, SubC Limited, Clarenville, NL, Canada), a forward-facing camera (Sony 4K Cam), and two lights (Aquarea Mk3, SubC Limited, 15,000 lumens; Nautilux, 2000 lumens) attached to a modified box corer frame. The system was repeatedly lowered to the seafloor in a yo-yo motion for 30 min while the vessel conducted a controlled drift at ~1knt.

Drop camera deployments took place at three sites in the general area: two inside the coral-bryozoan polygon and one 4 km NW from the location indicated by Captain Angnatok (Fig. 2). A distinct sea mound was not identified at the position provided by local knowledge holders, where newly collected multibeam data indicated a flat seafloor. At all of these high-potential targets, observed habitats consisted of mud and supported no large gorgonian corals or large sponges (Fig. 3). These surveys did identify other VME taxa, such as sea pens and cerianthids (tube dwelling anemones) that are more suited to mud habitats, in addition to a variety of fish (Atlantic cod, Greenland halibut, rocklings, grenadier) and other benthic fauna (anemones, shrimp, starfish, worms, soft corals, urchins, and sea cucumbers; Fig. 3).

Multibeam mapping
Understanding that the coordinates of fishing gear are subject to error because of the hundreds of meters of buoy line that can move about an anchor and that our survey methods can only cover a small area, we used the remaining time we had in 2020 to conduct more precise multibeam surveys of the area, aiming to pinpoint the sea mound (Fig. 4). The CCGS *Amundsen* was equipped with an EM302 multibeam sonar (Kongsberg) operated with the Seafloor Information System (SIS). Position accuracies were approximately < 0.8 m in planimetry and < 1 m in altimetry.

Fig. 3. Characteristic habitats and biodiversity observed during drop camera surveys in Year 1 (2020). Top left: sea cucumber fields; bottom left: Atlantic cod and a shrimp; bottom right: flytrap anemones; top right: sea pens (e.g., *Anthoptilum* sp.) and flytrap anemones; center: pout.



Despite surveying over 275 km² of habitat in the study area, we were unable to locate a sea mound and left the study area to pursue other mission priorities.

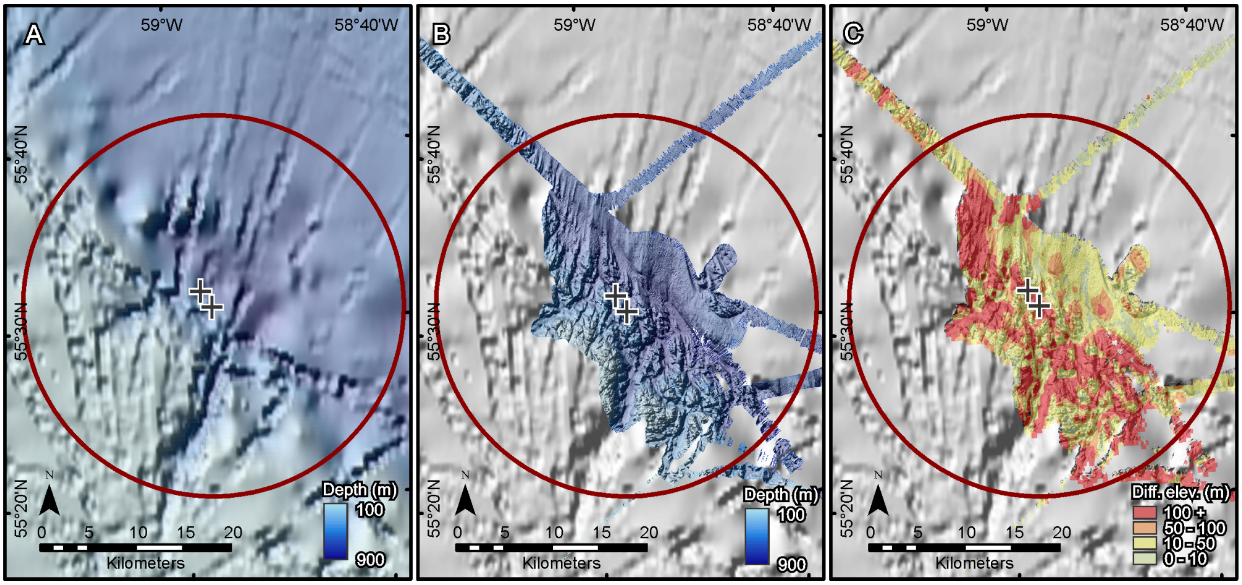
Year 2: secondary target development and surveys

Refined bathymetric mapping
Resolute in our belief of local knowledge holders, we used the 2020 multibeam data to create an enhanced resolution bathymetric map to identify additional targets. The processed data illustrated the inaccuracy of GEBCO data in this region, with over 33% of the surveyed area differing in depth by over 100 m (Fig. 4). The more accurate, higher resolution data also showed a highly dissected glacially carved seascape of steeply sloping bedrock edifices gradually deepening from south to north. We identified two of these submarine cliffs that plunged from 460 m to ~700 m depth and with slopes sometimes exceeding 70° (Fig. 5).

Remotely operated vehicle dive plans
Knowing that the ASTRID ROV was going to be available in 2021, we proceeded with plans for ROV surveys that year. Bathymetry and slope maps were generated from the multibeam raster by using ArcMap 10.6.1 and were the main tool used to refine specific ROV dive locations and survey plans. We were particularly interested in areas of high slope because of known association of corals with these habitats (e.g., Edinger et al. 2011). The slope map showed several such areas, including the potential presence of steep or vertical walls. The area showing the most interesting seafloor features was located at ~4.3 km SW from the original location proposed by Captain Angnatok and ~4 km NW from the coral area polygon estimated by Captain Bartlett. Because of the potential for coral presence in these types of environments, we planned our ROV video transects to cross sites with the highest slope (in some cases > 70°), which could indicate the presence of vertical walls.

Remotely operated vehicle surveys
The return mission in 2021 was supported by more precise bathymetric maps and enhanced by the addition of *ASTRID*, the CCGS *Amundsen*'s Comanche 38 Small Work Class ROV (Sub-

Fig. 4. Study area (red circle) bathymetry derived from (A) General Bathymetric Chart of the Oceans and (B) multibeam surveys. (C) Elevation differences between the two methods. Crosses denote areas targeted for remotely operated vehicle transect surveys in 2021.



Atlantic). *ASTRID* was essential in the survey of the submarine cliffs, which were not within the operational capabilities of the drop camera equipment. We returned to the study area from 19 to 21 July 2021 and conducted three dives across two target areas (Fig. 5).

Dive 1 (ASTRID - C13)
The first dive was planned to start at the base of a submarine cliff and reach slopes > 50° on the basis of the 2020 multibeam sonar. At the beginning of the dive, the seafloor was soft and flat to gently inclined, hosting abundant sea anemones, sea pens, and cerianthids. As the ROV transect continued, the steeply inclined (albeit not vertical) rock wall was reached. Cliff faces with more moderate slopes were covered in a thin coating of sediment and were dominated by sponges (mostly *Plicatellopsis bowerbanki*), but contained a few *Primnoa resedaeformis* and rarer *Paragorgia arborea* large gorgonians. The observation of these corals was encouraging, indicating the suitability of that environment to their presence. However, technical issues with *ASTRID* precluded us from continuing the dive to the second planned rock face, which had slopes exceeding 70°. With the first dive prematurely ended, the team met to discuss the second dive planned for the next day, and opted for keeping the original plan and surveying the second location, rather than completing the transect line for the first dive.

Dive 2 (ASTRID - C14)
The second dive was planned to video survey another steep rock wall, with multibeam data indicating a slope exceeding 70°. This site was located only 2 km from the first dive site. Sediment veneer was observed on the rock, and the fauna was dominated by a variety of sponges. Where the slope became more nearly vertical, the surface was virtually free of sediment, and we observed abundant *Primnoa resedaeformis* corals hanging from their holdfast attachment points (Fig. 6).

Although we had originally planned to conduct only two ROV dives at the Makkovik location, finding the coral walls motivated us to remain on site for one extra day to continue investigating the area.

Dive 3 (ASTRID - C15)
For this dive, the team planned to revisit the coral walls location, with the ROV surveying a parallel line to that surveyed the previous day. The first half of the dive documented additional *P. resedaeformis* corals whereas the remainder of the dive was spent collecting samples. Sampling focused on sponges for species identification and *Primnoa* corals for genetics, carbonate production estimates, sclerochronology, and paleoceanography. The last *Primnoa* coral collected had a number of shrimp and one fish on it, which did not swim away when the coral was collected. The fish was identified as a rockling, *Gaidropsarus ensis*, and the shrimp were identified as *Atlantopandalus propinqvus*.

DISCUSSION

The discovery of the Makkovik Hanging Gardens illustrates the benefits of integrated, multidisciplinary approaches, because the discovery, survey, and understanding of this natural feature was not possible with any single method. The considerable water depths, small footprint, and vertical nature of the submarine cliffs required technologically-sophisticated equipment to pinpoint and survey this natural feature. However, these methods are infeasible to conduct across larger scales and are not cost-effective to employ without additional knowledge to focus their use. Admittedly, the application of local knowledge in our study represents a narrow application of the vast quantities of knowledge that are accumulated by those who have close contact with the ocean over extended time periods and spatial scales (Neis and Felt 2000, Drew 2005, Bohensky and Maru 2011). Such knowledge holders are often better positioned to provide

Fig. 5. Remotely operated vehicle dive locations relative to local ecological knowledge of coral areas, the prospective sea mound, and bathymetric features obtained from the multibeam surveys of 2020 and 2021.

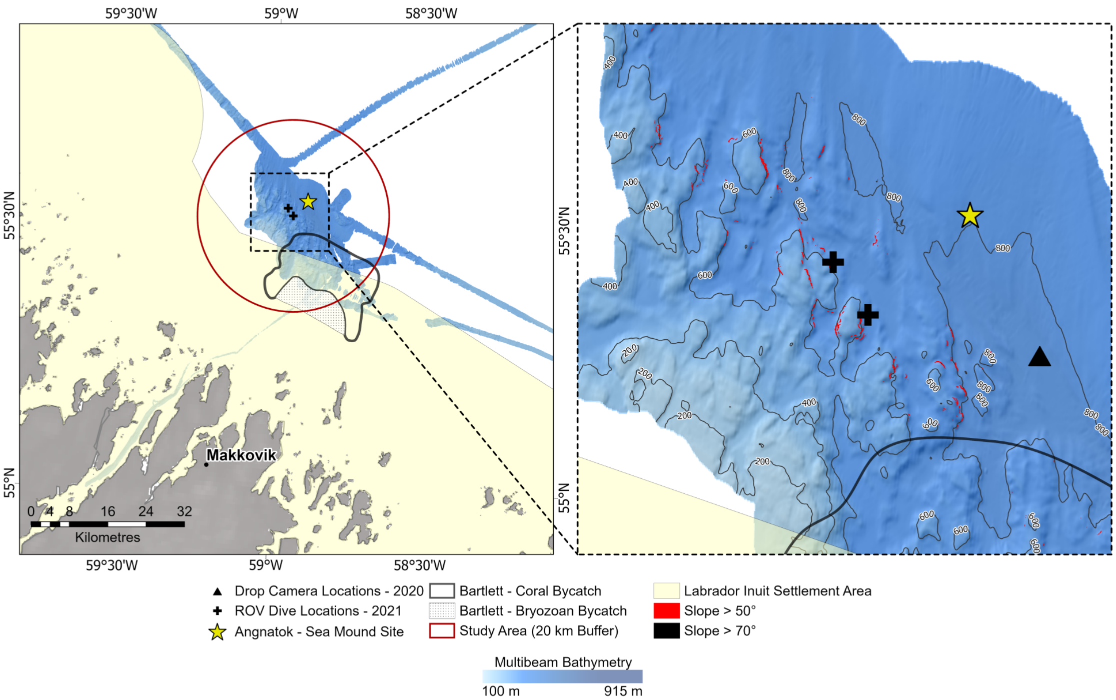
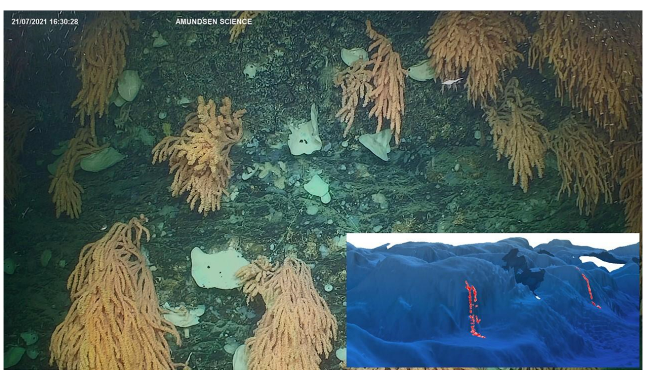


Fig. 6. Hanging morphology of *Primnoa resedaeformis* corals and *Plicatellopsis bowerbanki* sponges observed during remotely operated vehicle (ROV) dives off Makkovik in 2021. Inset: ROV dive tracks (red dots) superimposed on multibeam sonar along submarine cliffs.



guidance on important and/or unusual ecological habitats (Sheil et al. 2003, Wilder et al. 2016) but their knowledge is useful and valued independently from western science (Bohensky and Maru 2011). Our application of LEK was limited by the infrequent encounters of local knowledge holders with our target species in this deep-water environment. Even so, LEK was critical to this discovery, and has been for other discoveries beyond ecological systems. For example, LEK played a key role in the rediscovery of the culturally significant wrecks of the lost Franklin expedition, where a combination of Indigenous knowledge (both LEK and TEK) and archaeological evidence narrowed the search area from a vast region of the Arctic Ocean (Barr 2015, Parks Canada 2022).

Repeated satellite mapping of the Earth surface has increased our ability to assess and monitor ecosystem health through time (Araujo Barbosa et al. 2015). Knowledge of biological hotspot distribution in the ocean realm is decades behind that of on land, mainly because of the limited mapping of the ocean floor. As of writing, only about 15% of the seafloor has been mapped by using multibeam echosounders (Mayer and Roach 2021), and 23% is mapped at a resolution of 100 m or less by using a combination of single-beam and multibeam echosounders (GEBCO 2021). These numbers highlight our lack of knowledge of the ocean floor. However, we have shown here that high-resolution seabed maps were critical to discovering near-vertical walls capable of hosting biological hotspots. Increasing the resolution of maps in coastal Nunatsiavut will be an important component of discovering new hotspots of biodiversity like the Hanging Gardens. Moreover, these data provide local users with information that can be used to better place their fishing gear and avoid hazards.

Ecologically, the Hanging Gardens are a noteworthy discovery in that they represent to our knowledge the most coastal (within 34 km of shore) known occurrence of large *Primnoa* corals in the northwest Atlantic. These colonies of *P. resedaeformis* have an atypical hanging morphology compared to other areas on shelf break, where they grow up into the water column, often attached to boulders. *P. resedaeformis* colonies, growing on vertical walls, appear similar to shallower-water populations seen in Norway (Mortensen and Buhl-Mortensen 2005) and in deep water along the upper continental shelf from the Flemish Cap (Miles 2018) to the Gulf of Maine (Auster et al. 2013).

Beyond the Hanging Gardens, the study area also appears to feature relatively high beta (habitat) and gamma (regional) diversity. The vertical walls of corals and sponges rise above deep, muddy, and relatively warm trough habitats that are characterized by species assemblages that resemble those on the shelf break. In these areas, among the other fish and invertebrate taxa observed with video surveys were VME indicator taxa, such as sea pens and cerianthids, and commercially important species, such as Atlantic cod, Greenland halibut, and shrimp. The plateaus on top of the walls have more depauperate communities, representative of shallower, cold-water shelf habitats.

Much work remains to characterize the biodiversity and spatial extent of the Hanging Gardens, including understanding the processes that shape the biological communities. Seabed mapping conducted closer to shore in 2021 revealed similar large, deep troughs that incise the shelf and that consist of near-vertical walls. Those troughs have the potential to host warmer bottom waters originating from the higher-density waters of the continental slope region that are favorable to large gorgonians, such as *Primnoa* (Gullage et al. 2017). More surveys are needed to fully delineate the link between these geological and oceanographic conditions on the distribution of *Primnoa* corals in this area. The study by Gullage et al. (2017) showed that depth was the most important variable contributing to the habitat suitability of large gorgonians in the Newfoundland and Labrador region, and also identified a maximum preferred slope of 13° for this functional group. However, that model's underlying trawl data would not include habitats such as the vertical walls identified in this study.

The vertical walls that support the corals and sponges of the Hanging Gardens can entangle and damage both fixed and towed fishing gear of unwary harvesters and are natural deterrents to fishing. The finding of a VME indicator species in such high concentrations suggests the presence of a VME (e.g., Kenchington et al. 2014). Nevertheless, despite the significance of the area, the process of establishing formal protections in Canadian waters requires socioeconomic considerations, consultation with stakeholders, and inclusion of Indigenous rightsholders. Given that the Hanging Gardens lie within the Imappivut Marine Plan region and are in close proximity to Nunatsiavut's marine zone, any discussions around the potential establishment of protective measures (area-based or gear-restriction) will need the support of the Nunatsiavut Government. If such an initiative proceeds, the knowledge of the Hanging Gardens will be an important consideration in the final delineation of protected area boundaries.

The inclusion of Indigenous people in directing science, generating knowledge, and interpreting data is an ethical imperative after decades of colonial-based science (Inuit Tapirit Kanatami 2018). The benefits of Indigenous and local knowledge for understanding and managing ecosystems are increasingly recognized (Bohensky and Maru 2011, Wilder et al. 2016, Ogar et al. 2020) particularly because much of the world's remaining biodiversity falls within Indigenous lands (Sobrevila 2008). Although the establishment of protected areas has not always served to benefit Indigenous people (Dressler et al. 2010), the 2022 Kunming-Montreal Global Diversity Framework has reiterated the important role Indigenous people must play in the establishment of protected areas and maintenance of biodiversity (United Nations Environment Program 2022). In our study area the Nunatsiavut Government is the driving force behind conservation initiatives, which started in terrestrial environments, such as the Torngat Mountains National Park, and now are extending into their marine zone. A primary objective of these existing and potential protected areas is to sustain the ecosystems and way of life of Nunatsiavummiut. Whereas the integration of local knowledge with western science has been criticized for concentrating power in external administrative centers (Nadasdy 1999), Nunatsiavut advances self-determination through the equitable use of both Indigenous knowledge and knowledge derived from their own research programs.

With many areas left to explore in Nunatsiavut waters, we continue to work in an integrative and multidisciplinary manner. In the short time since the 2021 expedition we have witnessed the continued emergence of Nunatsiavut representatives to leadership roles in the development and implementation of local knowledge and science in their marine zone (e.g., Rangeley et al. 2022). In this role, Nunatsiavut is well positioned to incorporate all forms of knowledge to the long-term benefits of Nunatsiavummiut while simultaneously contributing to global conservation objectives.

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Data Availability:

Data/code sharing is not applicable to this article because no data/code were analyzed in this study.

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