CHARACTERIZING THE COASTAL BENTHIC ECOLOGY OF TWO REGIONS OF INUIT NUNANGAT USING MACHINE LEARNING

by © Myrah Graham

A Thesis submitted to the

School of Graduate Studies in partial fulfillment

of the requirements for the degree of

Master of Science

Department of Environmental Science

Memorial University of Newfoundland and Labrador

February 2025

St. John's Newfoundland and Labrador

Abstract

Understanding the benthic ecology in Canada's Northern coastal areas allows for informed decision-making in their use as the Arctic undergoes rapid changes. Two regions of Inuit Nunangat (Inuit Homelands) were studied: Nunavut and Nunatsiavut. Multibeam sonar provided continuous-coverage geomorphology data, while video ground-truthing enabled us to validate sediment characteristics and benthic community distribution in the estuaries studied. Random Forest Modelling (RF) and a Species Distribution Model (SDM) were employed to better understand and visualize environment-benthos relationships across the study areas. Key findings reveal that positioning within the fjord, terrain curvature, and estuary orientation to oceanographic forces are primary factors influencing benthic distribution across all study sites. The findings support the recent negotiations for the establishment of an Inuit Protected Area in Nunatsiavut and provide valuable ecological data for future marine management plans in the Canadian Arctic.

Acknowledgements

Waves coalescing
Beam of light shines in darkness
Horizons unfold

Eternal gratitude to Dr. Katleen Robert for allowing me to discover the benthic ecology of arctic bays and fjords. Her support, guidance and instruction were invaluable in the process of creating this thesis. Thank you to my committee members Michelle Saunders and David Côté for their contributions to this work every step of the way. Heart-felt thanks to everyone at the 4D Oceans Lab, especially Zachary Macmillan-Kenny and Emmeline Broad for help with coding, logistics and moral support. Work in Nunatsiavut was made tenfold more meaningful through the wonderful collaborations at the Nunatsiavut Government Research Station and the community of Nain. The connections to the Hunters and Trappers Association (HTA) and Hamlet of Pangnirtung allowed us to have avenues to share our findings and hear back from the community. Nakummek to Joey Agnatok and Michelle Saunders for video ground-truthing in Ramah Bay, and Quyanami to Ricky Kilabuk and crew for helping us sample in Pangnirtung Fjord. Big thanks to Adam Templeton for all his invaluable quick thinking in the field and hauling the camera on and off the seafloor for days. Finally, thank you to the schools in Nain and Pangnirtung for their warm welcome and curious students.

Funding for my studies was generously granted through Memorial University's School of Graduate Studies (SGS) graduate stipend, and supplemented through Ocean Frontier Institute (OFI), Flight 302 Legacy Award, Arctic Net Project #69 and funds from the Canadian Chair in Ocean Mapping. Sampling in Nunavut was supported by ArcticNet, a Network of Centres of Excellence Canada for Project # 69: Arctic Seafloor Mapping, data processing and dissemination. Additional funding for scientific outreach in Nunavut was provided by the Northern Scientific Training Program 2023-2024 grant from Polar Knowledge Canada. Work in Nunatsiavut was made possible by funding from OFI, through the Sustainable Nunatsiavut Futures project. Additional funding from the Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) allowed for video sampling in Ramah Bay and outreach in Nunatsiavut.

Arctic Net also funded attendance at the 2022 ArcticNet conference in Toronto, ON. Attendance at the Coastal Zones Canada Conference (CZC) 2023 in Victoria, BC was made possible through the CZC Young Professionals Travel Grant. Travel support to attend the Geohab 2024 Conference in Arendal, Norway was granted through Geohab's Ron McDowell scholarship, with additional support from the OFI Knowledge Mobilization Fund. Creation of benthic imagery and comic was made possible through the Association of Polar Early Career Scientists (APECS) and Association of Canadian Universities for Northern Research (ACUNS) "Science to Art" contest, which allowed me to work with northern artist Misha Donohoe.

I'd be remiss not to mention my incredible parents for their support throughout this journey. Shout-out to Xander Deggan for being my rock, Berson Augustin for being an incredible brother, Mathieu Lamontagne-Cummiford for giving me a home and Matthew Debicki for taking me sailing when I needed a break. The ocean has been a wonderful teacher and friend throughout my life, and I am so lucky I got to dive deeper and understand even a micron more how amazing our planet is. It takes more than a village to make a map, and more than a student to make a thesis. Thank you all. Nakummek, Quanamiik.

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List of Abbreviations

BIIGLE- Bio-Image Indexing and Graphical Labeling Environment

BPI- Bathymetric Position Index

DBM- Digital Bathymetric Model

DFO- Department of Fisheries and Oceans Canada

FAO- Food and Agriculture Organization of the United Nations

FMGT- Fledermaus GeoCoder Toolbox

GIS- Geographic Information System

GSC- Geological Survey of Canada

GRTS- Generalized Random Tessellation Stratified

HTA- Hunters and Trappers Association

IPA- Inuit Protected Area

LILCA- Labrador Inuit Land Claims Agreement

LISA- Labrador Inuit Settlement Area

LOOCV- Leave-one-out cross-validation

MBES- Multibeam Echosounder Sonar

MPA- Marine Protected Area

NG- Nunatsiavut Government

NRCan- Natural Resources Canada

RDMV- Relative Difference to the Mean Value

RF- Random Forest

RMSE- Root Mean Square Error

ROV- Remotely Operated Vehicle

SDM- Species Distribution Model

SMarTaR-ID- Standardised Marine Taxon Reference Image Database

SNF-Sustainable Nunatsiavut Futures

T-AOI: Torngat Area of Interest

UPGMA- Unweighted Pair-Group Method using arithmetic Averages

VME- Vulnerable Marine Ecosystem

VRM- Vector Ruggedness Measure

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Co-authorship Statement

As the primary author, I conducted the majority of the work presented in this thesis. This includes video collection, annotation, community analyses, predictive modeling, interpretation, outreach and writing of the thesis. Data collection and cleaning were performed with assistance from contributors as described below. This collaborative effort has resulted in a comprehensive study of benthic ecology in the eastern Canadian Arctic, combining expertise from multiple disciplines and institutions.

Dr. Katleen Robert of the Marine Institute of Memorial University served as my primary supervisor, providing guidance throughout the research process, assisting with study design, data analysis, and manuscript review. As well as providing review, Rodd Laing and Michelle Saunders from the Nunatsiavut Government facilitated research operations, community engagement and provided a *raison d'être* for this project by synthesizing community interests into research priorities in Nunatsiavut, enhancing the relevance and impact of this research. Michelle Saunders graciously collected the video data, while Rachel Sipler at Memorial University and Ryan Harris from Parks Canada enabled the multibeam sonar data collection in Ramah Bay, and student Jennifer Oteng processed the multibeam data. David Côté from Fisheries and Oceans Canada offered expertise in marine ecology and provided support in interpreting the ecological significance of our findings. David Côté also provided benthic video data in Southwind and outer Pangnirtung Fjord. Student Bianca Barret additional video data for Southwind Fjord, while Adam Templeton assisted me in collecting the video data in the inner portion of Pangnirtung Fjord. Alex Normandeau from Natural Resources Canada provided essential multibeam data for Pangnirtung and Southwind Fjords, which was processed by Benjamin Misiuk.

Chapter 1: Introduction

1.1 Polar Marine Environments

The Arctic marine biome is one of the most underexplored and fastest changing ecosystems in the world (Rogers et al., 2022). As air temperatures in the Arctic are increasing at double the global average rate, sea ice cover is decreasing in thickness, extent and duration (Meredith et al., 2019). This leads to important environmental changes such as warmer seawater, more light and increased primary productivity (Jones et al., 2007). Furthermore, anthropogenic activities such as oil and gas exploration, shipping, and commercial fishing can have negative ecosystem impacts such as habitat destruction and the introduction of contaminants (Al-Habahbeh et al., 2020; Larsen et al., 2016; Thrush et al., 2016). Thus, polar marine ecosystems are facing numerous threats due to human-induced climate change and industrial activity.

Polar marine ecosystems are more vulnerable to disturbance, as each species holds more ecological weight (Buhl-Mortensen et al., 2015). This is mainly due to the lower biodiversity in the circumpolar North, as well as slower growth and reproductive rates of sessile polar benthic organisms, which hinders ecosystem recovery after disturbances (Molis et al., 2019). In the marine environment the seabed topography, sea ice, interaction with currents and water column properties (e.g., temperature, salinity) contribute to species spatial patterns in each area (Buhl-Mortensen et al., 2015; Brown et al., 2011). With changes to these marine conditions, it is projected that arctic marine ecosystems will have lower secondary productivity and food webs will be less efficient at nutrient transfer (Kędra et al., 2015; Renaud et al., 2015; Caroll et al., 2008).

Benthic habitats are regions of the seafloor which support communities of plants and animals that live on the bottom of the ocean (Roff, 2011). The benthos play an important role in the food web via nutrient cycling and habitat building, and can thus be seen as ecosystem health indicators (Griffiths et al., 2017). In the arctic, the benthos account for 98% of the marine biodiversity (Archambault et al., 2016). Alarmingly, changes in the composition of benthos can alter how the entire ecosystem functions (Krumhansl et al., 2014). This has been repeatedly shown in impact assessments of deep-sea fishing, where removal of niche-building benthos such as coral or sponges have led to the loss of macrofaunal diversity and abundance (Clark et al., 2016). Climate change is altering Arctic benthic communities as subarctic species migrate northward (Kortsch et al., 2012; Gotelli, 2008). However, the full extent and impact of these changes remain unclear. Identifying habitat-community associations in these understudied Arctic environments is crucial for understanding and mitigating the effects of various stressors, including rapid climate change (Lecours et al., 2015).

1.2 Characterizing Canada's Polar Marine Environments

With the longest coastline in the world, surveying Canada's coastal waters is a challenge (Roff et al., 2003). This is most true in the Canadian Arctic, where logistical difficulties in access and associated high costs limit our ability to study this area. This knowledge gap not only hinders our understanding of Canadian Arctic coastal ecosystems, but also generates difficulties in marine spatial planning and mitigating the consequences of climate change. Currently, the difficulty in understanding the spatial patterns of benthic habitats in the Canadian Arctic is the lack of ecological and geomorphological data.

One process that allows us to characterize the ecology of the seabed is habitat mapping, whereby ecological data such as megafaunal occurrence and habitat types are collected and represented across a given area through the use of various modeling approaches (Misiuk & Brown, 2024; Harris & Baker, 2020). Habitat mapping allows us to fill in the blanks of our understanding of arctic marine habitats through remote sensing, collecting physical specimens whenever possible, and video ground truthing. Recent advancements in underwater acoustic and visual imaging technology have improved sampling resolution and reduced costs, enabling more comprehensive sampling of environmental and biological data with minimal disturbance (Durden et al., 2016). These developments not only facilitate the creation of detailed habitat maps for specific study areas, but also contribute to a broader understanding of ecological relationships and patterns.

In marine habitat mapping, two key instruments are most often used to map benthic habitats: (1) multibeam echosounder sonar (MBES) and (2) video cameras (Misiuk & Brown, 2024). MBES data allows for extraction of various environmental variables in a marine setting, such as seafloor roughness and slope (derived from bathymetry data), and substrate type (derived from backscatter data, or the intensity of the acoustic signal reflected from the seafloor) (Brown et al., 2011). Additionally, MBES data can be used to map large-scale features such as canyons, ridges, and seamounts, which can influence the distribution and diversity of marine species (Carpenter et al., 2020). However, MBES data are not the appropriate tool for detailing what epibenthic organisms are present, as most biological organisms are acoustically transparent; therefore, video or still imagery is used. Video imagery can be used as a continuous video feed or still images extracted from the video, which are then annotated with information on what species are present (Durden et al., 2016). Observed biological data can then be assigned to clusters of co-occurring species using multivariate analyses to represent species assemblages (Misiuk & Brown, 2024). Although ground truthing sites are interspersed in discrete locations across an area, we are able to make full-coverage predictions of benthos composition based on the interpolation of species-environment relationships using a range of modeling techniques (e.g. supervised classification (Brown et al., 2011) or species distribution models (SDM) (Burgos et al., 2020; Melo-Merino et al., 2020). The insights gained from these models can be extrapolated to inform research and management strategies in other Arctic regions, even those not directly mapped. By identifying key environmental factors influencing benthic communities and species-habitat associations, researchers and managers can make more informed decisions about conservation and resource management across similar polar marine environments.

1.3 Arctic Bays and Fjords

Canada's Arctic represents 70% of its coastline, rutted with bays and inlets. These coastal features play a crucial role in shaping the unique geography of the region. Among these diverse formations, two types stand out for their distinctive characteristics and ecological importance. Estuaries are bays where the tides meet freshwater, and fjords are a particular type of narrow estuary carved by glaciers (Josefson & Hansen, 2004). Arctic fjords are unique ecosystems that support a wide range of benthic species due to their high habitat complexity (Buhl-Mortensen et al., 2015). Carved by glaciers and shaped by erosion and sedimentation, their diverse topography allows for a variety of substrates, depths and exposures which will influence nutrient availability and recruitment potential (Carpenter et al., 2020; Kessler et al. 2008). Fjord hydrodynamics often cause a sill of debris to accumulate, effectively dividing the fjord into inner and outer regions; the inner portion of the fjord being more influenced by proximity to land and freshwater input, the outer portion being more influenced by oceanographic forces (Klootwijk, 2021). Some studies have suggested that the outer regions of fjords tend to have higher species diversity and density compared to inner regions, with increased depth and salinity and lower sedimentation suspected as driving variables (Moon et al., 2015; Brown et al., 2012).

Oceanographic forces play a crucial role in shaping fjord ecology. The orientation of the fjord towards prevailing ocean waters will influence how strongly these oceanographic forces impact the fjord environment (Syvitski 1989). Circulation patterns within fjords are influenced by various factors including tides, winds, freshwater input, and the Coriolis effect (Cottier et al, 2010, Syvitski et al, 1989). These hydrodynamic forces drive the exchange of water masses between the fjord and the open ocean, affecting nutrient distribution, oxygen levels, and sediment transport (Aitken & Fournier, 1992). Sedimentation processes, largely controlled by fluvial input and circulation dynamics, impact benthic habitats and organisms through the modification of seafloor topography, or smothering in negative cases (Dale et al., 1989). Thus, sessile benthos tend to congregate in areas of optimal sedimentation, where burial is not hindering their ability to filter feed yet nutrients are still being supplied through currents. Additionally, the Coriolis effect in Arctic fjords tends to deflect surface currents towards the right-hand shore, leading to asymmetrical sedimentation patterns and potentially affecting benthic community distribution (Gilbert, 1982).

Seasonality strongly impacts the physical and biological processes in Arctic fjords. In the summer months, continental freshwater inputs into estuaries bring nutrients as well as increased sedimentation at the head (Wesławski et al., 2011). In the winter, sea ice formation can have the opposite effect via brine rejection, creating denser, saltier water in the deeper areas of the fjord (McClelland et al., 2012). As a result, salinity gradients develop more strongly in arctic bays than in open shelf areas. The seasonal cycle of stratification and mixing significantly influences nutrient dispersal, primary productivity, and consequently, the distribution and composition of benthic communities throughout the year (Gilbert, 1982). Although arctic bays have seasonal differences, they offer relative shelter within their semi-enclosed area compared to the more exposed coastal shelf (Drewnik et al., 2017).

1.4 Arctic Marine Management Strategies

The Canadian federal government has committed to preserving 30% of its coastline by 2030. As most of the coast is in the North, this will have important implications for northern communities. Inuit Nunangat, or Inuit Homelands, designates the four regions of Arctic Canada which are home to Inuit. With diverse cultures and interests, each region has its own governing body which upholds and manages the rights of their people. With a long history of expertise in the region's coastal land and sea, Inuit communities hold a deep understanding and vested interest in their local marine environments. However, western science can complement local knowledge, especially in the face of climate change (Rangeley et al., 2022). In order to effectively manage the arctic marine coastal environment, we first need to know what is there; both on the seafloor as well as with respect to each communities' interests. Although benthic habitat maps are an important tool for predicting where benthos are distributed on the seafloor, having dialogue and listening to local communities lets us know what to research *for* (Lucieer et al., 2012). We can then prioritize which information to collect in order to understand how to predict where benthic communities are expected to live over a broader geographical area.

Effective marine management ensures marine resources and benefits are sustained (Harrington, 2016). Depending on the region's priorities, there are two main approaches to marine management: 1. Resource extraction (e.g., Fisheries) and 2. Resource protection (e.g., Marine Protected Area (MPA)) (Harris & Baker, 2020). Extractive planning strategies are ideally positioned to know where a particular resource is, and how much of it can be sustainably harvested. Understanding the spatial distribution of a species via a SDM can provide valuable insights into the species' potential range (Reiss et al., 2015). Additionally, predicting the spatial distribution of a commercially important species can have significant implications for Inuit communities' livelihoods and cultural practices. From an ecological perspective, areas of high biodiversity represent a more robust environment, and have been observed to link to important fisheries through the food web (Krawczyk et al., 2021). This is understood to occur due to diverse benthic environments being more apt at providing shelter for juveniles, habitat for nurseries, decomposing of organic matter and nutrient cycling to higher trophic levels (Hansen et al., 2020)

Areas of high biodiversity also serve as great locations for potential MPAs, as it maximizes the number of representative species under protection (Harris & Baker, 2020). Marine conservation is aimed at preserving and/or regulating extraction, and MPAs allow for the spatial and legal implementation of the conditions of use within a designated area (Roff, 2011). Habitat mapping plays a crucial role in this process by providing spatially explicit information on the distribution and characteristics of marine habitats. These maps enable managers to identify areas of high biodiversity, unique ecosystems, and critical habitats that warrant protection. Another way of signaling a region's potential for marine protection is through Vulnerable Marine Ecosystem (VME) indicators. Indicators can range from the uniqueness of a habitat or functional role, to rare or fragile species which are those susceptible to degradation with limited ability to recover (FAO, 2009). Although the Food and Agriculture Organization (FAO) of the United Nations outlines criteria for designating a VME, recent work by Baco et al., (2023) has highlighted the need for a global consensus on what constitutes a VME indicator species through imagery and clearer guidelines to ensure accurate representation within management strategies.

Ultimately, benthic habitat maps can help inform extractive or protective strategies for successful marine management in Inuit Nunangat.

1.5 Thesis Objectives

This master's thesis studies the spatial distribution of benthic habitats in the eastern Canadian Arctic. Another key objective of this research was to build reciprocal relationships in knowledge co-production and sharing with local governments and communities in the North. This collaborative approach included engaging youth and community members in sampling activities and sharing of results in a culturally relevant way, ensuring that local interests and knowledge were integrated into the research process. The scientific outreach materials can be found in Appendix C. As these regions had different interests in their local ecology, the following research questions were posited:

1. What environmental variables influence the spatial distribution of benthic habitats in the Eastern Canadian Arctic?
    a) In Nunavut, what environmental factors influence the distribution of Icelandic Scallops in Pangnirtung Fjord?
    b) In Nunatsiavut, what environmental factors influence the distribution of benthic habitats in Ramah Bay, with a focus on VME indicator species and food sources?

To address these questions, habitat maps and a species distribution map incorporating geomorphological and biological data were built using machine learning algorithms. The project's significance lies in providing insights into the spatial ecology of these Arctic benthic habitats and contributing benthic habitat maps, a species distribution map and a species catalogue to the local governing bodies and communities of Nunavut and Nunatsiavut. Areas of interest, biological representation and/or fisheries stock assessments will be able to be prioritized in future research and decision making. This thesis also provides information for future monitoring of species range shifts and invasive species, identification of VME indicator species, predicting species distribution elsewhere and expanding our understanding of local biodiversity patterns. This work further contributes to the United Nations' Sustainable Development Goal 14, whereby understanding of our oceans will allow us to better manage them in the face of rapid environmental change, especially in the North (Renaud et al., 2015). Through this collaborative approach, this thesis aims to not only advance scientific knowledge, but also empower local communities in the stewardship of their marine resources.

Chapter 2: Materials and Methods

2.1 Study Areas

Three study sites were selected within the eastern Canadian Arctic due to local interest in their potential as conservation or fisheries areas. They are located on either side of the Hudson Strait in Nunavut and Nunatsiavut (Figures 1 and 2).

Nunavut

Baffin Island, named *Qikiqtaaluk* in Inuktitut, is part of the territory of Nunavut in Canada. Executive government is held by the territorial administration, which ensures Inuit rights are upheld in local and federal decisions regarding the Nunavut landmass and adjacent waters (*Nunavut Land Claims Agreement Act,* 1993). It is a tundra environment carved of many fjords along its coastline, fed by local alpine glaciers and ice sheets (Carter, 2022). Ocean waters from the Atlantic and Arctic influence the estuaries of Baffin Island, with the presence of sea ice and calving icebergs most of the year (Münchow et al., 2015; Dale et al., 1989).

Two fjords on the Cumberland Peninsula of *Qikiqtaaluk* were selected for study (Figure 1). Pangnirtung Fjord (*Kangiqturuluk)* is within Cumberland Sound at 66° 9′ 20″ N, -65° 42′ 55″ W (Figure 1C). With a maximum depth of 165 m, an elevation of 1485 m and an area of 93 km^2, Pangnirtung Fjord is considered to be shallow and tall (Carter, 2022). The seafloor is characterized by glacial deposits and bedrock features, as well as thick sediment accumulations which form soft sediment flats in areas of low current disturbance, especially at the head and middle of the fjord (Gilbert, 1978). Two major basins exist in Pangnirtung Fjord, separated by a sill 22 m below the lowest tide level at 98 m from the fjord’s mouth (Gilbert 1978). Nestled within the eastern flank of the fjord, the Hamlet of Pangnirtung is host to a lively fishing community and the site of a Baffin Fisheries enterprise (Galapathi et al., 2019). With a vested interest in fisheries, particularly regarding Iceland scallop populations near the community, discussions with the Hamlet Office and Hunters and Trappers Association (HTA) led to the identification of Iceland scallop as a species of interest. As a local delicacy, Iceland scallops are known to be present at the mouth of Pangnirtung Fjord through a modest subsistence fishery which is shared widely with community members. Furthermore, harvesting and consumption of local country foods is maintained as a way of providing community wellness (Rapinski et al., 2018). Finding and predicting the distribution of Iceland scallop populations within the fjord was therefore an objective which emerged from spending time in the community. This information will be used by the Hamlet Office and HTA to make resource management decisions in Pangnirtung Fjord.

Southwind fjord *(Kangiqtugusiq)* presents a contrasting site with the absence of human settlement and a more exposed morphology to hydrodynamic forces (Figure 1B). Located at 66° 51′ 42″ N, -62° 27′ 24″ W, Southwind Fjord lies on the northern edge of the Cumberland Peninsula and is exposed to the waters of Davis Strait (Figure 1D). Fluvial deposits are mainly supplied from a river at the head of the fjord, with a major sill dividing the fjord’s two main basins 214 m towards the head (Normandeau et al., 2020). With an area of 80 km^2, an elevation of 1389 m and a maximum depth of 433 m, Southwind Fjord is a similar sized albeit deeper counterpart to Pangnirtung Fjord (Carter, 2022). Both fjords have been monitored for the many submarine landslides they experience, marking them as highly dynamic environments (Normandeau et al., 2019).

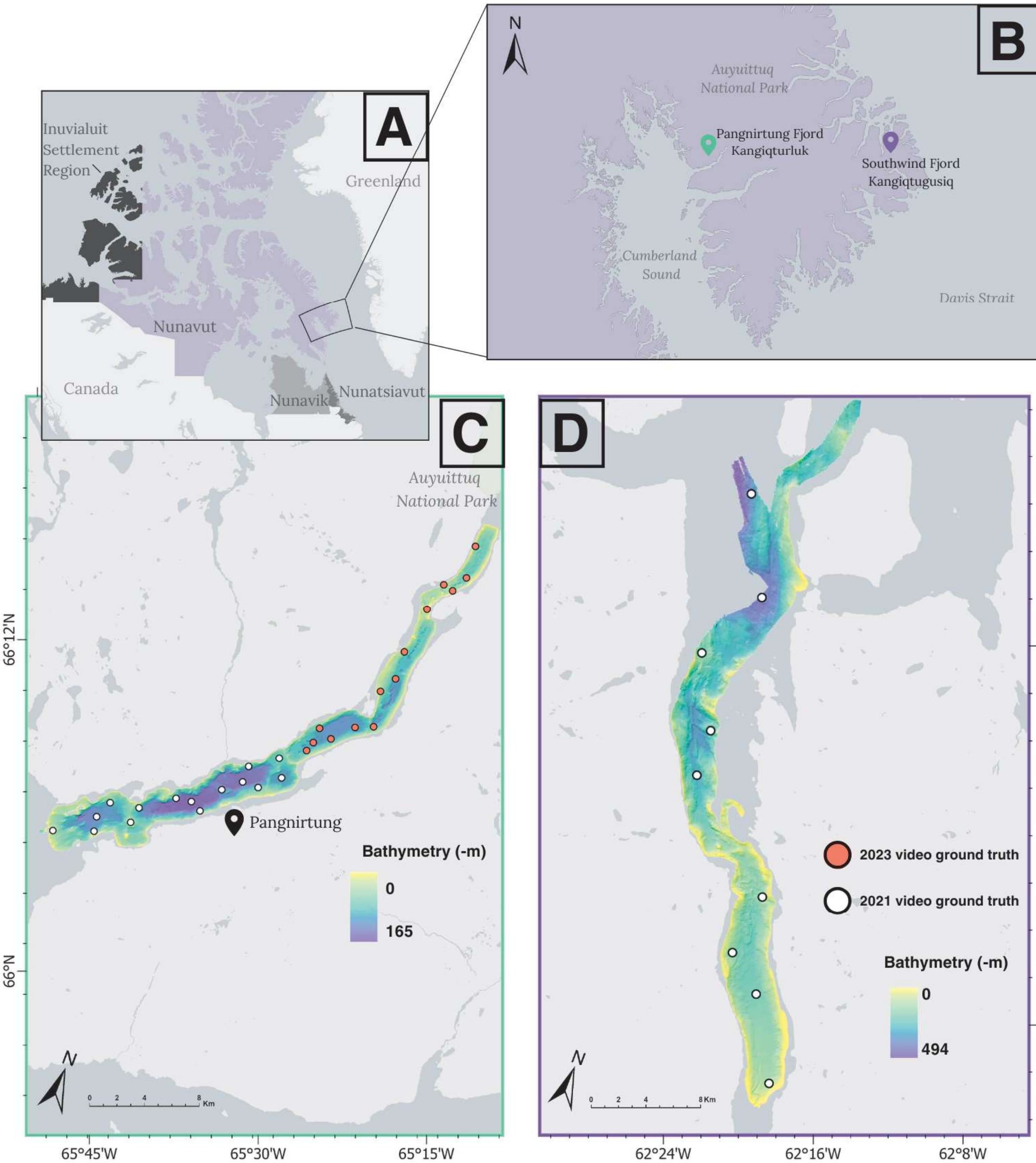


Figure 1: Research sites in Nunavut, Canada. (A) Inuit Nunangat with (B) portions of Baffin Island examined in this study. Research sites sampled in Pangnirtung Fjord *(Kangiqturuluk)* in 2021 and 2023 (n=27), and Southwind Fjord (*Kangiqtugusiq*) in 2021 (n=9). Projection: NSIDC Sea Ice Polar Stereographic North.

Nunatsiavut

Nunatsiavut comprises Inuit-owned lands in the northern-most coastal area of Newfoundland and Labrador, Canada. The Labrador Inuit Settlement Area (LISA) was established as part of the Labrador Inuit Land Claims Agreement (LILCA) in 2005, ensuring Labrador Inuit land-rights are maintained (*Labrador Land Claims Agreement Act*, 2005). Part of the rights outlined in the LILCA refer to the creation and maintenance of parks and protected areas. In partnership with Parks Canada, the Torngat Area of Interest (T-AOI), which borders the Torngat Mountains National Park (*Tongait KakKasuangita SilakKijapvinga*), was delineated to study the establishment of a potential 16791 km^2 Marine Protected Area (MPA) (Laing, 2018).

The Imappivut Nunatsiavut Marine Plan, led by the Nunatsiavut Government, is working towards a co-management plan for their coastal marine area (Laing, 2018). Ramah Bay (Figure 2) was chosen as a study site within the T-AOI because it was highlighted as one of the most culturally significant sites in Nunatsiavut through Nunatsiavut Government-led community consultations (Nunatsiavut Government, 2024). The significance of Ramah Bay is partly due to the adjacent Ramah Chert Quarries (*Kitjigattalik*) dating back 7000 years, as well as current living family histories and cultural use (Parks Canada, 2016).

Ramah Bay is located at 58°51'59" N -63°14'60" W, adjacent to the Labrador Sea (Figure 2B). It is a coastal inlet within the tundra ecoregion, with its waters influenced by both Atlantic and Arctic currents, as well as the Stecker River at the head and a waterfall adjacent to the Ramah Chert Quarries National Historic Site (Brown et al., 2012; Zweng & Münchow, 2006). It encompasses an area of approximately 200 km^2, with two arms known as “Ramah Bay" and “Little Ramah Bay”, the latter being the more southerly arm (Figure 2C).

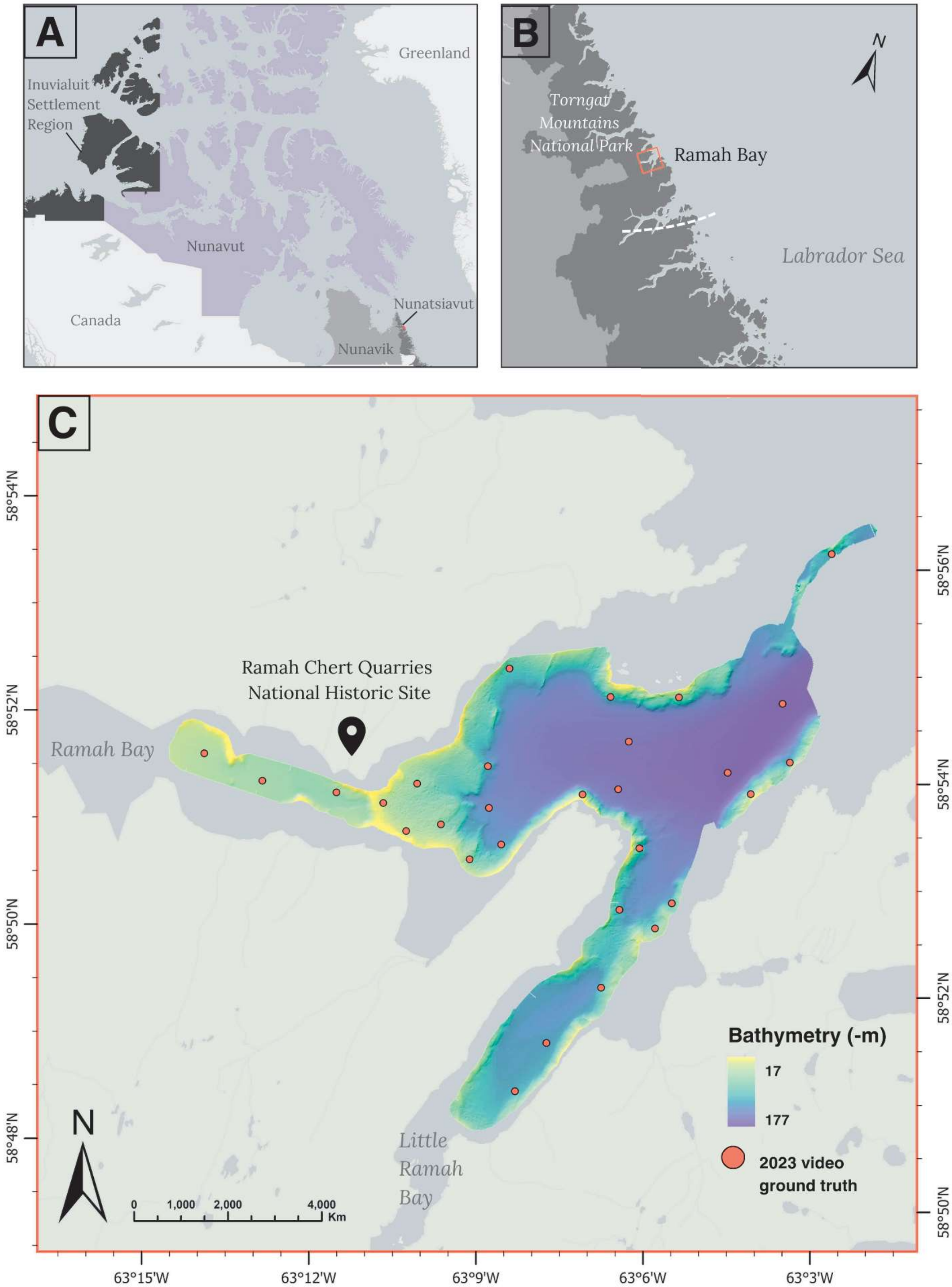


Figure 2: Location of Ramah Bay in Nunatsiavut, Labrador, Canada. Red dots show drop-camera ground truthing locations (n=30). Insets represent the study location within (A) Canada and (B) Nunatsiavut. Projection: NSIDC Sea Ice Polar Stereographic North.

2.2 Acoustic Surveys

In Nunavut, bathymetry and backscatter data were collected by the Geological Survey of Canada on the Government of Nunavut owned research vessel the *N/V Nuliajuk*. The *2019 Nuliajuk* expedition took place in September 2019 and was led by the Geological Survey of Canada (GSC) and Natural Resources Canada (NRCan) (Normandeau et al., 2019). A Kongsberg EM2040 MBES set to 300 kHz with a swath width of 120 degrees was used in both Pangnirtung and Southwind fjords (Normandeau et al., 2019). All the collected bathymetry and backscatter data were processed in CARIS HIPS&SIPS (v.11.1) and exported as 10m raster grids.

In Nunatsiavut, MBES data were collected by Parks Canada in August 2021 using an R2Sonic 2024 MBES system mounted on the hull of the *RV David Thompson*. Ramah Bay was surveyed at 250 and 450 kHZ (Vis et al., unpublished). Vessel navigation and raw multi-beam data were coupled using QPS QINSy software. Sound velocity profiles were processed in QPS Qimera to create Digital Bathymetric Models (DBMs), and backscatter data were further processed using QPS Fledermaus GeoCoder Toolbox (FMGT) software. Both bathymetry and backscatter were exported at a 5m resolution. Thus, the Nunatsiavut rasters were at a finer resolution than the Nunavut rasters.

2.3 Ground Truthing

Site selection for ground-truthing was determined using a generalized random tessellation stratified (GRTS) sampling design based on the bathymetry of the study site (Stevens & Olsen, 2004). This was done to ensure depth representation across the sampling sites. GRTS was performed using R package (version 4.3.2) 'spsurvey' (Dumelle et al., 2023).

Video data in Nunavut were collected in 2021 from July 31- August 10 on the *CCGS Amundsen* (Normandeau et al., 2019). Video data were collected at 13 sites in outer Pangnirtung fjord and nine sites in Southwind fjord. All sites in outer Pangnirtung fjord and three sites in Southwind Fjords were collected with Fisheries and Ocean Canada's Sony 4K camera mounted on a modified box core frame (Desmarais et al., 2021). The camera-mounted frame also held green lasers spaced 10 cm apart, and dual lights at 1000 lumens. As this system did not have live feed onboard the vessel, it was bounced up and down as the vessel drifted from the ground-truth sites. To maximize sampling effort onboard the *Amundsen,* six more sites were sampled concurrently in Southwind fjord from a smaller craft deployed from the vessel with a Deep Trekker DTPod drop camera (1920 x 1080 pixels, 30 fps), with red lasers spaced 2.5 cm apart. Video drifts of the seafloor were recorded for 30 minutes after bringing the boat alongside the planned sample site coordinates.

In 2023, I collected additional video data from the inner portion of Pangnirtung Fjord. In order to have a similar sampling effort to the outer portion of the fjord, 14 sites were recorded off of *Ricky Kilabuk's Boat*, from Kilabuk Services Outfitting in Pangnirtung. A SubC Imaging Coastal Rayfin camera (1920 x1080 pixels, 30 fps), mounted on a metal and plastic custom frame with parallel MantaRay lasers spaced 10 cm apart and lit with two Aquorea mk3 LED lights (15000 lumens) were used to record 30 minute videos.

Video data of Ramah Bay were collected by the Nunatsiavut Government in September 2023 on the *MV What's Happening* with the same Deep Trekker Inc. DTPod drop camera system as for Southwind Fjord. Five-minute drift videos were recorded once the ship was positioned over the start coordinates of the ground-truth site across 30 sites.

2.4 Imagery Annotation

Different cameras were used in Nunavut, which meant we needed to ensure that the area represented in the footage was comparable between datasets (Nakajima, 2014). Therefore, image extractions were performed to standardize the spatial extent captured in the footage. At each site surveyed with the Sony 4K camera, a still frame was extracted every six seconds using "VLC media player "software (VideoLAN, 2006). This rate yielded the most non-overlapping still images, at ~ 45 usable images per ground-truth site. A total of 200 usable frames were selected for the Deep Trekker system to ensure a similar seafloor footprint of ~500 m^2 would be covered.

Video analysis for the Nunatsiavut footage was performed separately from the Nunavut data set, given the differences in footage and independent subsequent analyses. . The five-minute videos were comprehensively annotated frame-by-frame as the video played, rather than subsampled into still images (Durden et al., 2016). This was done due to the shorter video length, and the inconsistent view of the seafloor from the heave and roll of the sampling vessel, leading to the inability to extract frames at regular intervals.

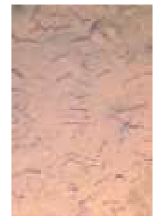
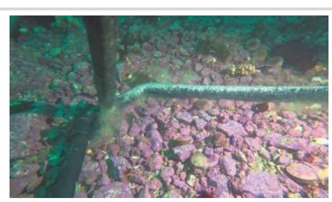
In both video and image annotation workflow, epibenthos >2.5 cm or more were annotated to the lowest morphospecies level using BIIGLE open-source online software (Langenkämper et al., 2017; Gomes-Pereira et al., 2016). Multiple species catalogues ranging from global (SMarTaR-ID, WoRMS), to pan-arctic (Zacharov et al., 2018), to Canadian arctic-wide (Jacobsen et al., unpublished) to localized (Macmillan-Kenny, 2024) were consulted and used to build a reference *East Coast Canadian Arctic* species catalogue for annotation of this dataset (Appendix B). A subsequent "Eastern Canadian Arctic" label tree was developed in BIIGLE as per the SMarTaR-ID taxonomic classification standard (Howell et al., 2019).

Using the reference *East Coast Canadian Arctic* species catalogue, benthos were annotated based on the SMarT-aR ID morphology tree, then refined to lower taxonomic levels using the LARGO tool in BIIGLE and the “Eastern Canadian Arctic" label tree. However, sponges were maintained at morphological level as this has been shown to be a sufficient classification when working with sponge imagery (Schönberg, 2021). Organisms were counted if at least one third of their body was in the frame. The resulting annotations were exported as a csv file of species abundances per ground truth site for statistical analysis. Finally, species accumulation curves were used to assess the sampling effort at each site based on a 95% confidence interval.

Sediment Classes

Since sediment composition throughout a site changed much less frequently than benthic community composition, frames were extracted every 180 seconds, using the “scene video filter” in VLC software (VideoLan, 2006) to quantify sediment type. This approach yielded a smaller sub-sample (~ 10 images per ground-truth transect) for quantitative analysis while remaining representative of the overall substrate composition. Within each frame, 30 random circles were plotted on the image using the “imager” package in the statistical software R. The resulting images were imported into Image J software and annotated into nine categories (Table 1). These classes included biohash, bedrock, boulders, cobbles, gravel, coralline algae-encrusted gravel, seaweed, and soft sediment with and without diatom cover. The presence of diatoms was visually assessed by observing the dark brown color of the algal mats, as opposed to the pale sandy color of the soft sediment. It should be noted that seafloor type #8 (N/A) was removed in the analysis, as it represents portions of the image which could not be annotated, and is thus not a representation of the seafloor of the fjord.

Table 1: Reference images and descriptions for substrate classes identified during image annotation.

Class	#	Description	Reference Image
Biohash	0	Any biological detritus in a large enough amount to be considered a patch	 
Bedrock	1	Earth's crust- solid rock beneath surface materials	
Boulders	2	Large rock	
Cobbles	3	Baseball sized rocks, about the diameter of the camera metal frame (8 cm)	
Gravel	4	Golf ball sized rocks (4 cm)	
Coralline Algae Encrusted Gravel	5	Coralline algae grounds, purple and rugged	

Seaweed	6	Macroalgae, often detached from bottom	
Soft Sediment	7	Mud or sand, hard to distinguish in pictures	
N/A	8	Camera angle or something blocking field of view	
Diatomaceous Sediment	9	Brown algal mat	

2.5 Terrain Analysis

Terrain features for input into the benthic habitat models were extracted from the bathymetry and backscatter rasters in R (v 4.3.2). These features were calculated for both datasets separately. The "Multiscale DTM" library (Ilich et al., 2023) was used to perform multiscale terrain analysis using the Fibonacci sequence to select analysis window sizes ranging from 3x3 to 55x55 cells (Misiuk et al., 2018). This process captures topographic features across various scales, ensuring that significant environmental characteristics are consistently identified (Misiuk et al., 2021). Terrain features examined included: slope, direction of slope (aspect), rate of change of slope (planar and profile terrain curvatures) and the standard deviation of bathymetry, which quantifies the depth variability in an area (Lecours et al., 2017, 2016). Additional terrain features measured were relative difference to the mean value (RDMV) to highlight high and low elevations between cells, bathymetric position index (BPI) which outlines topographic features such as peaks and depressions, and the vector ruggedness measure (VRM) to capture slope and aspect variability (Wilson et al., 2007). Terrain feature values at the start location of the drift were extracted to match the video imagery. These terrain features serve as proxies for various environmental factors that are difficult to measure directly but significantly influence benthic habitats. For instance, terrain curvature is used as a proxy for the direction of main currents, which can affect nutrient distribution and sediment transport (Lecours et al., 2016).

2.6 Benthic Fauna Community Analysis

Community analysis for each region was performed to parse-out which species clustered together. Species assemblages were delineated within each of the study areas using the "vegan" package (Oksanen et al., 2024) of the statistical software R (version 4.3.2). Species with an abundance of less than three were removed from the dataset to reduce the influence of very rare species (Buhl-Mortensen et al., 2020). The resulting dataset was Hellinger transformed to reduce the influence of highly abundant species, with species distributions validated using a Shepard plot and Goodness of Fit plot (Borcard et al., 2018).

Several hierarchical clustering methods were compared: single linkage, complete linkage, Ward clustering and Unweighted Pair-Group Method using arithmetic Averages (UPGMA). UPGMA was selected for clustering as it was the only method with a cophenetic correlation above 0.7 (0.776) (Borcard et al., 2018). Selecting the number of clusters was done using the Silhouette width from the R package "cluster" (Brocard et al., 2018). Indicator species were specified using the "indicspecies" package in R for multilevel pattern analysis. Species with significance values $p<0.05$ were retained for representing a cluster's uniqueness.

2.7 Predictive Modeling

Habitat models (Nunavut and Nunatsiavut)

Supervised machine learning was used to create one predictive habitat map of Ramah Bay and one of Pangnirtung Fjord. With only nine sample sites, Southwind Fjord was not deemed suitable for predictive modelling as it was under sampled (Figure 4). RF was chosen for its ability to handle complex ecological data, resistance to overfitting and capacity to model non-linear relationships between predictor variables and habitat types (Cutler et al., 2007). RF combines the predictions from all trees fit to the dataset being analyzed (i.e: bootstrapping), but decorrelates the trees through feature randomization to increase predictive power (James et al., 2023). The RF algorithm was run through the "caret" package in R (Kuhn, 2008). The dependent variables were the species clusters, with the predictor variables being the terrain features. Only clusters present at more than one site were retained for modelling, as a sample size of one is not sufficient for predictions. All terrain features at their multiple scales were input into the model to gain insight into the initial accuracy of the model.

Following this initial regression, the Boruta backwards feature selection wrapper was applied to determine the importance of terrain features to the model (Nemani et al., 2022; Kursa, 2010). The Boruta wrapper is an algorithm which determines feature importance by comparing the importance of the original terrain features with that of randomly permuted variables (Kursa, 2010). Out of the 70 initial terrain features, 19 important and 6 tentatively important features were retained and re-run through the RF model.

Correlation analysis was then performed to remove any collinear, (thus redundant), terrain features from the model. The "corrplot" package in R was used over several iterations to remove features with correlation coefficients above 0.7 (Wei, 2021). Finally, the remaining terrain features were input into the RF model as predictors for the final model. The model was then trained using leave-one-out cross-validation (LOOCV) on 26 samples, in order to make the most efficient use of the small sample size allowing each site to be used as a test case once, while avoiding overfitting (Kuhn, 2008). Cluster 4 was removed as it was representative of only one site, leading to model failure. Therefore, only 26 samples were used in the final model. The final model's performance was assessed using the LOOCV predictions across all the 26 retained sample sites with the following metrics:

1. Confusion Matrix: To allow us to assess which classifications were done correctly and incorrectly
2. F1 score: to show us the model's precision and recall
3. Balanced Accuracy: to evaluate the model's ability to correctly predict presence and absence of different benthic habitats

Species Distribution Model (Nunavut)

In order to provide a more robust map representing the interests of the community, the spatial distribution of Iceland scallop in Pangnirtung Fjord was explored with a RF SDM. The scallop abundance data was transformed into binary presence/absence data (James et al., 2023), while the terrain features were run through a correlation analysis using the "caret" package (Kuhn, 2008). This was done to reduce the redundancy of the variables input to the model, and therefore improve the model performance. One variable from each highly correlated pair over a correlation threshold of 0.7 was removed to reduce redundancy in the dataset. The remaining variables were further refined through a Recursive Feature Elimination, a technique where the least important features were iteratively removed (Kuhn, 2008).

A RF classification model with 500 trees was built using “tidymodels” in R (Kuhn, 2020). Tidymodels was employed as it offers more flexibility in model tuning options. Two values of mtry (number of variables randomly sampled as candidates at each split) were tested: 2 and 3. Input into the model was the data frame consisting of the scallop presence/absence data and terrain variables. This dataset was subsampled into testing and training datasets at a 70/30 split, as an initial run with LOOCV yielded moderate predictive performance. The final model’s performance was assessed using several metrics as per James et al., 2017:

1. Sensitivity and sensitivity: to assess the model’s ability to predict presence and absence, respectively
2. Kappa statistic: to measure the agreement between predicted and observed classifications, accounting for chance
3. Variable importance: to understand the relative contribution of each predictor to the model
4. Balanced Accuracy: to evaluate the model’s ability to correctly predict the presence and absence of scallops

Chapter 3: Characterization of the Arctic Seafloor

3.1 Sediment Characterization

The seafloor in Southwind Fjord and Ramah Bay were mainly soft sediment while a more heterogeneous environment was identified in Pangnirtung Fjord (Figure 3). Although soft sediment dominated most of the survey sites in Pangnirtung Fjord, sites 1, 4, 6 and 7 were mainly gravel, with coralline algae colonizing the gravel at sites 1 and 6. Of note is the high presence of diatomaceous sediment at sites 23 and 25, a unique habitat likely representing higher primary productivity from within the inner portion of the fjord (Glud et al., 2002). Biohash was present at all sites in the fjord (4% total surveyed area) but covered a quarter of the area surveyed at sites 3, 5 and 7.

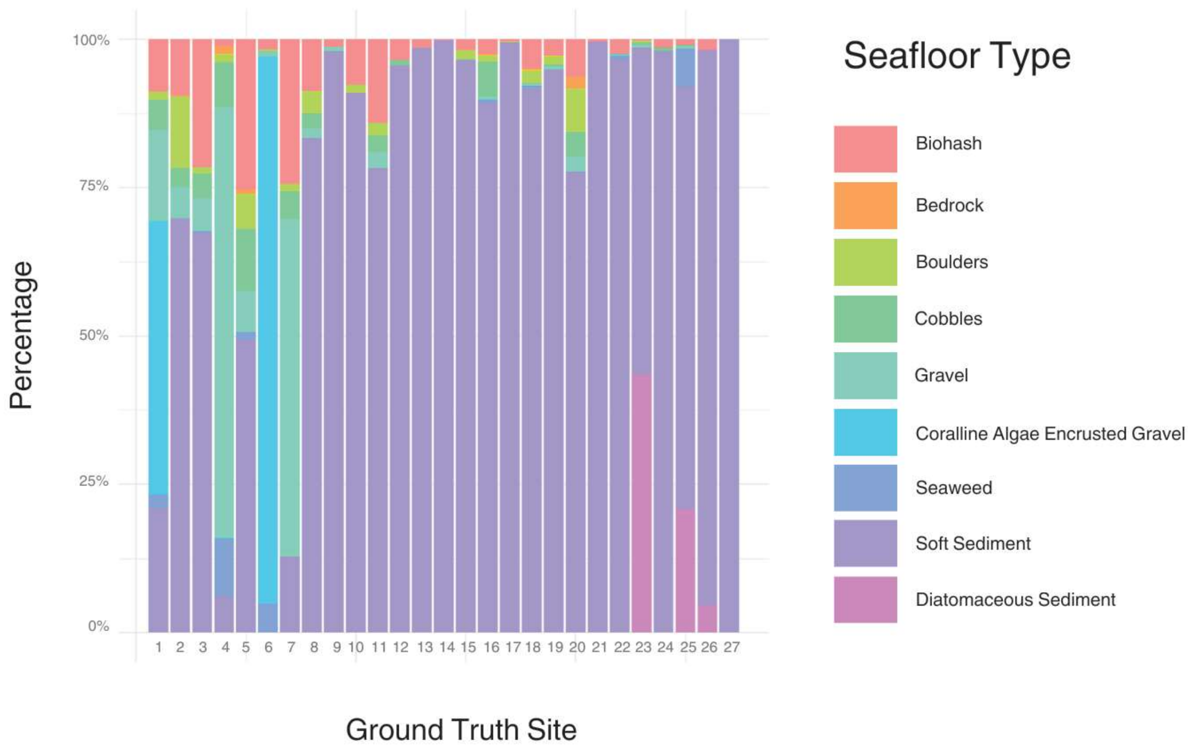


Figure 3: Seafloor types by ground truth site in Pangnirtung Fjord. Location of sites provided in Figure 6.

3.2 Benthic Fauna Communities

Pangnirtung Fjord had the highest species richness, with over 135 morphotypes observed. Both Ramah Bay and Pangnirtung Fjord demonstrate a leveling out on their species accumulation curves, but more sampling would be needed in Southwind Fjord to capture its full diversity .

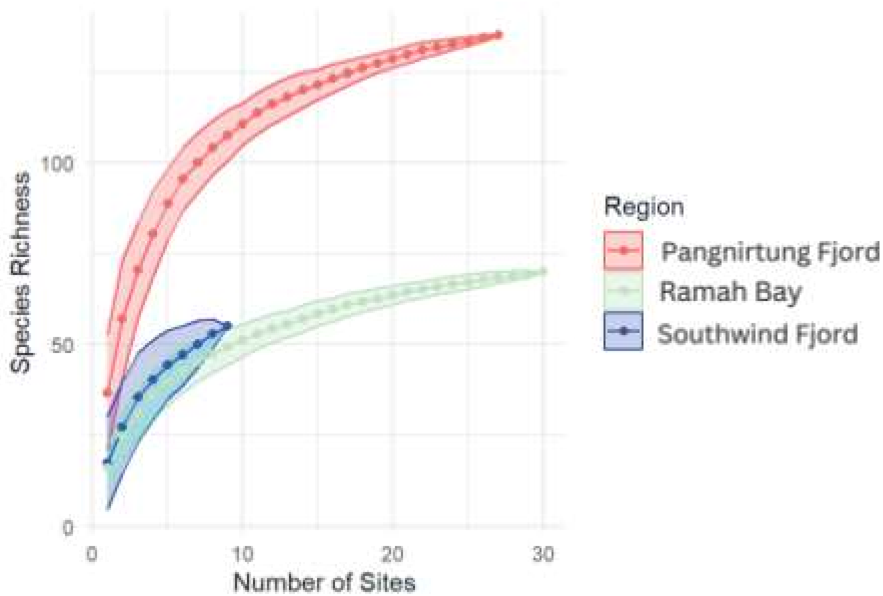


Figure 4: Species accumulation curves for the three study sites in the eastern Arctic with shaded areas representing 95% confidence intervals.

Southwind Fjord

Southwind Fjord was the most sparsely sampled study site, with 7705 organisms annotated to 56 morphotypes. The fjord was mainly composed of brittle star fields, with 87.1% of organisms counted belonging to the Ophiuroids. Two species clusters formed across the nine sample sites (k=2) (Figure 5). Cluster 1 was composed of anemones, shrimp (likely *Eualus gaimardii*), basket stars (Genus *Gorgoncephalus)* and soft corals (*Gersemia sp.)*. Cluster 2 was represented by tube-dwelling anemones (Genus *Cerianthus),* polychaeta, benthic jellyfish (*Ptychogastria* *polaris*) and sea spiders. Sites within Cluster 1 were mainly from the inner portion of the fjord, while Cluster 2 was found in the more exposed outer regions.

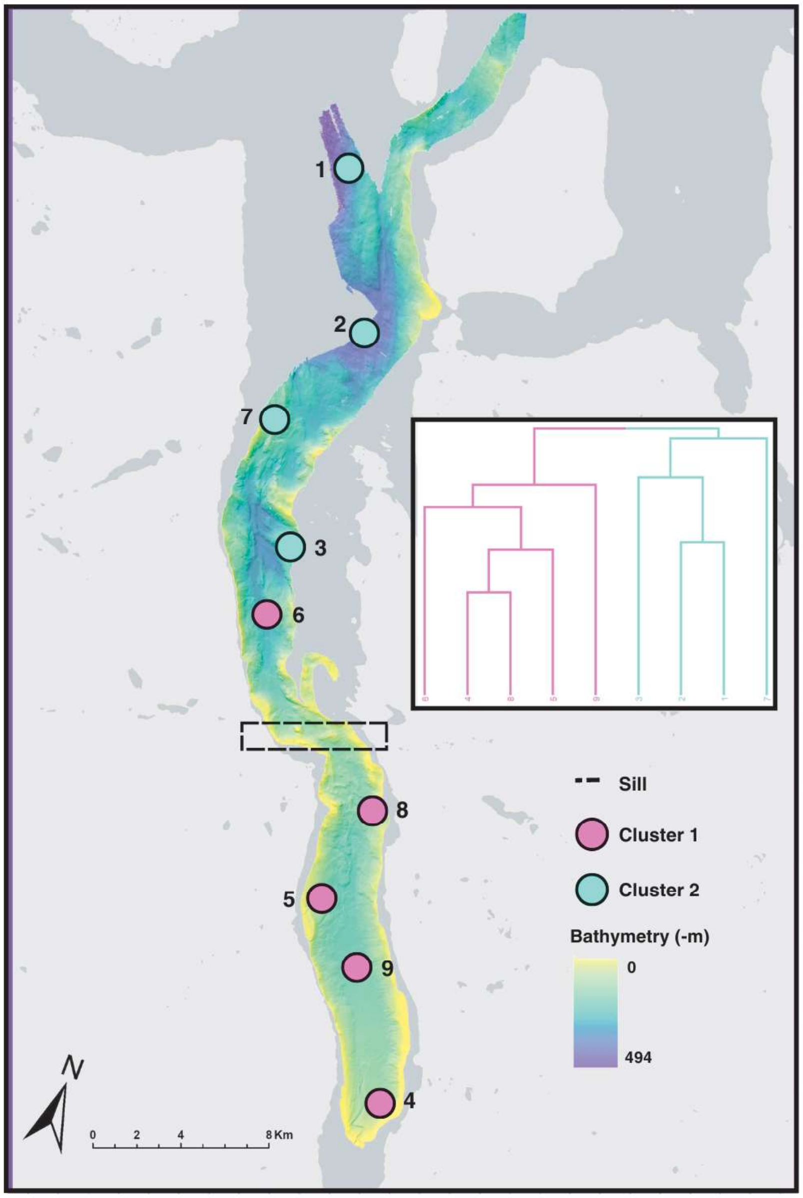


Figure 5: Species cluster plot with dendrogram inset across nine sites within Southwind Fjord. Dashed outline shows the location of the fjord sill.

Pangnirtung Fjord

Footage of Pangnirtung Fjord contained 43802 organisms across 137 morphotypes. Video sampling sites were clustered into four clusters (k=4) of species (Figure 6). Cluster 1 had the largest number of indicator taxa, with massive and globular sponges (three morphotaxa), sea cucumbers (two morphotaxa), a red brittle star, a coral (likely *Anthomastus*) and an anemone. Cluster 2 was composed of bryozoa, whelk and feather star (*Heliometra glacialis).* The most common morphotype across the fjord (72.6%) were brittle stars (*Ophiura, Ophicantha* and *Ophurioidea*), assigned to Cluster 3, along with shrimp. Iceland scallop (*Chlamys islandica*) and an anemone (*Urticina felina*) were the indicator species for Cluster 4. This final cluster was represented by site 6, which had a high presence of coralline algae encrusted gravel. A total of 882 scallops were observed in the fjord, primarily located along the eastern banks, where coralline algae-covered gravel was prevalent (Appendix A).

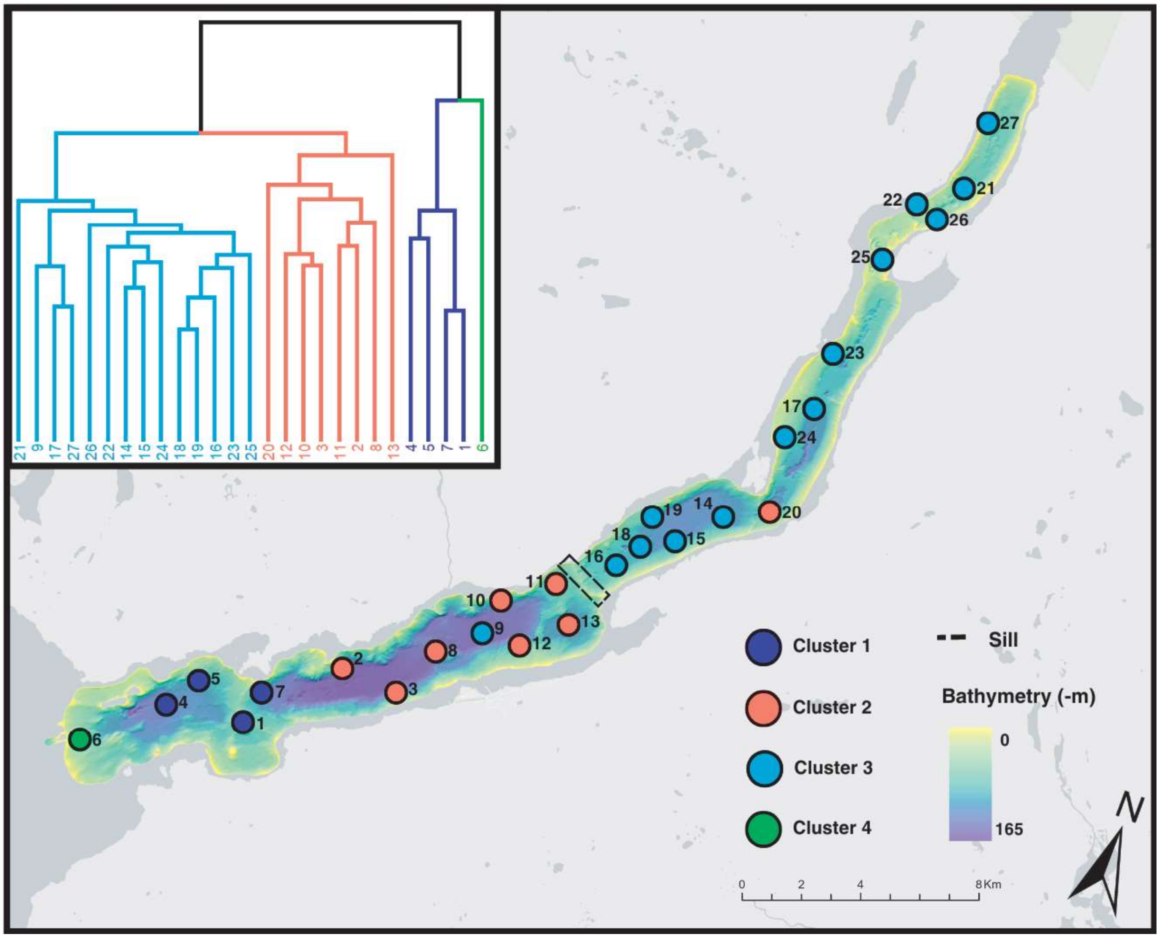


Figure 6: Spatial distribution of species clusters within Pangnirtung Fjord. Dashed outline shows the location of the sill. Inset: species cluster dendrogram illustrating the species community similarity of the 27 sites.

Ramah Bay

A total of 14428 organisms within 74 morphotaxa were identified in Ramah Bay. The final dendrogram revealed three species clusters (k=3) across the 30 sites surveyed (Figure 7). Cluster 1 had the most indicator species, made up of worms (*Sabellidae msp.4*), isopods (*Isopoda msp.2*), an anemone (*Actiniaria msp.3*) and benthic jellyfish (*Hydrozoa msp.2*, likely *Ptychogastria polaris)*. Shrimp (*Pandalus msp.1*) were indicative of Cluster 2, and Cluster 3 was represented by brittle stars (*Ophiura sp.1*) and a hermit crab (*Pagurus msp.1*). Cluster 1 was mostly found in Little Ramah Bay, while Cluster 2 was mainly found in the wider and deeper sites. Cluster 3 was found in sites along the edges of the deeper areas of the bay. The most abundant species were brittle stars (52.17%) and shrimp (26.46%).

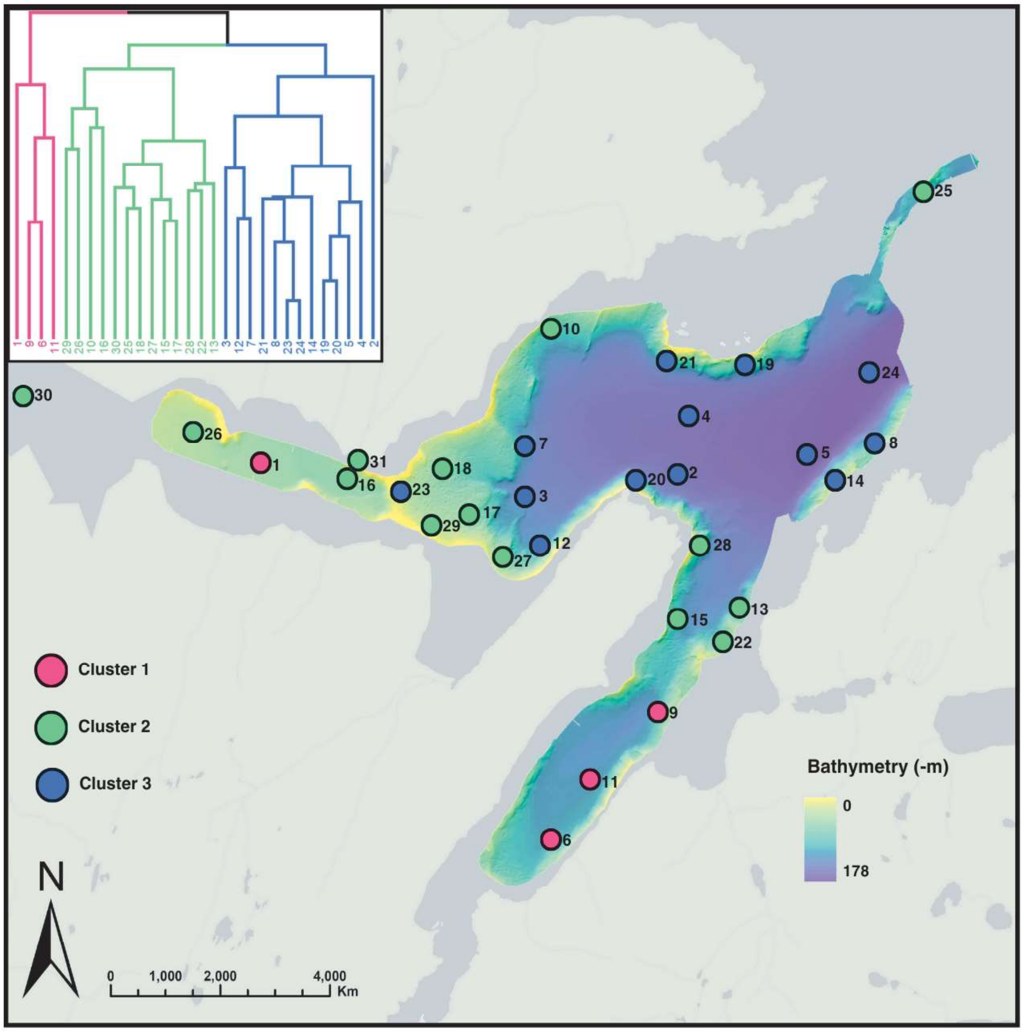


Figure 7: Plot of species clusters across 30 sites within Ramah Bay with dendrogram inset.

3.3 Nunavut Models

3.3.1 Iceland Scallops Species Distribution Model

The five terrain features selected via the Recursive Feature Elimination process were longitude, latitude, profile curvature (21x21 cell window) and Bathymetric Position Index (BPI) at a 21x21 cell window (Figure 8). The model with mtry = 3 performed slightly better, with a lower Root Mean Square Error (RMSE) (1.82) compared to mtry = 2 (1.86).

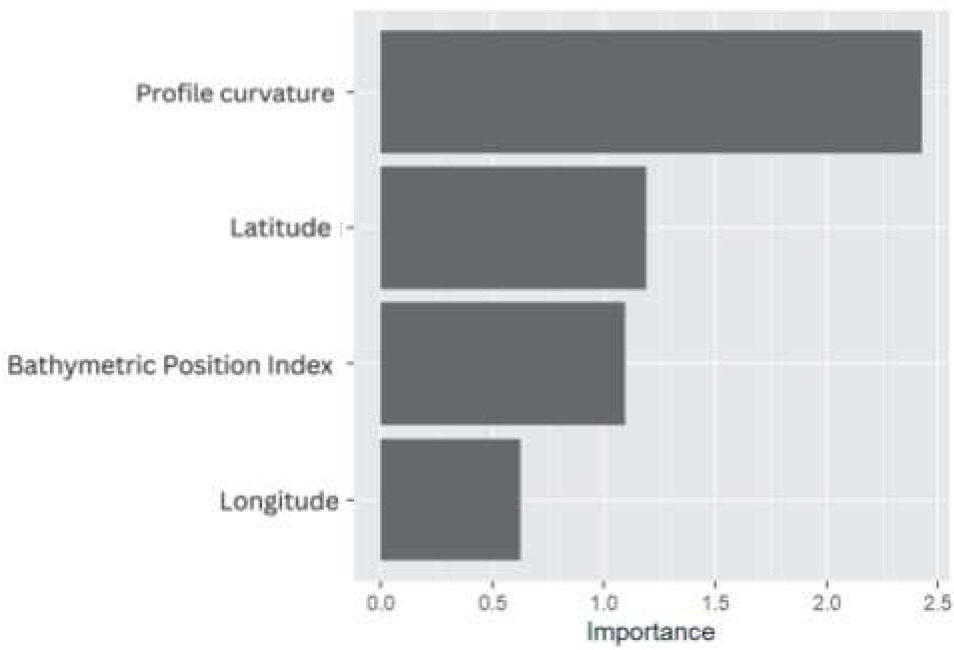


Figure 8: Variable Importance for the final species distribution model

The final RF model showed good predictive performance with a balanced accuracy of 83.3%. The model was able to predict both presence (sensitivity 1.0) and absence (specificity 0.67) of scallops in the fjord. Additionally, the Kappa value (0.57) showed there was moderate agreement between predicted and observed scallop classification. Large scale (21x21 cell window) curvature and relative elevations (BPI) within the fjord were indicative of scallop presence. Longitude and latitude were also key predictor variables, likely representative of the inner vs outer portions of the fjord. The scallop distribution map clearly shows a higher probability of scallops near the mouth of the fjord and the hamlet of Pangnirtung, which is congruent with our observations in the field.

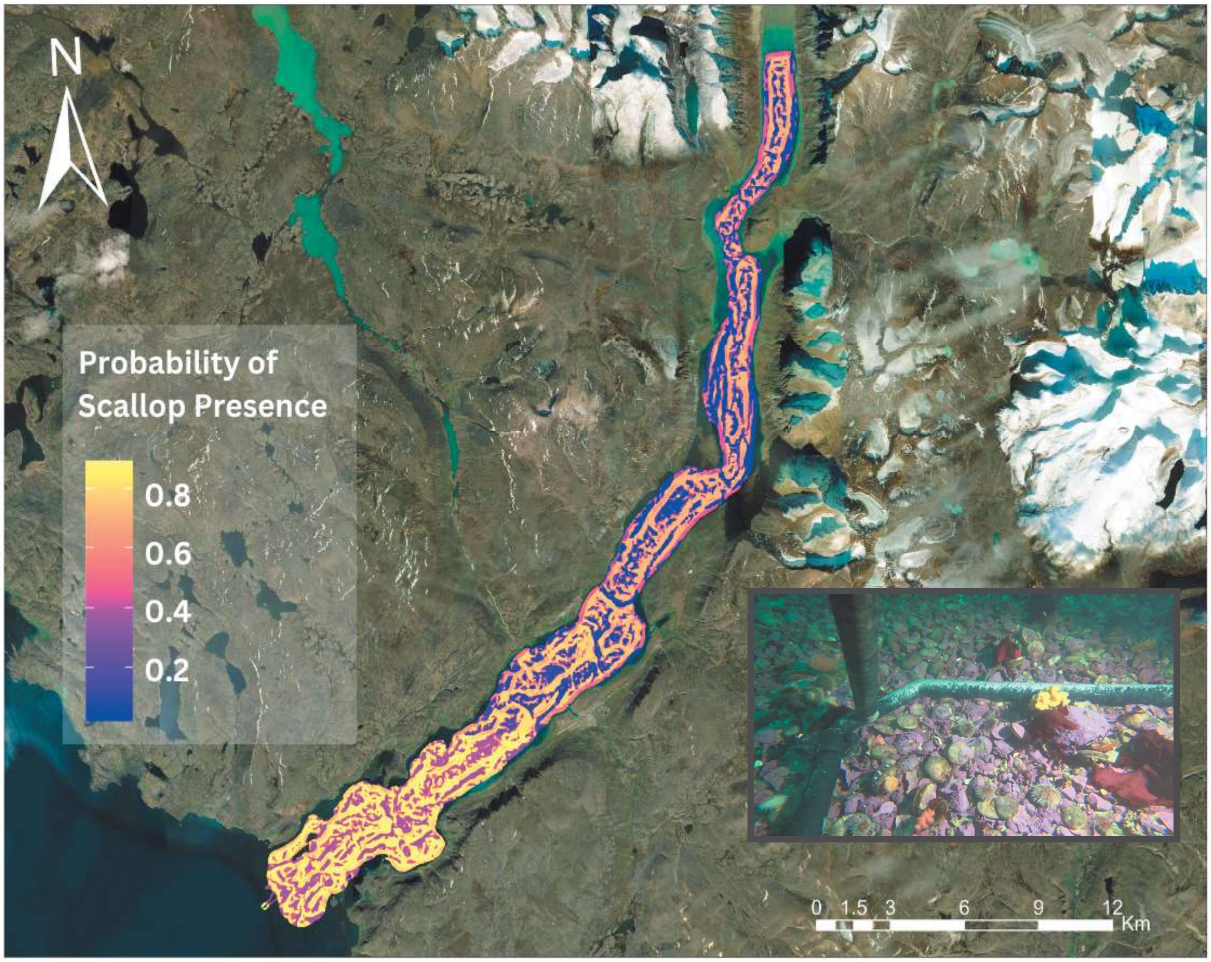


Figure 9: Species distribution of scallops in Pangnirtung Fjord. Inset is a high-density scallop area near the mouth of the fjord.

3.3.2 Benthic Habitat Model

The predictor variables selected by the Boruta wrapper were plane curvature (13x13 cell window), backscatter and eastness (35x35 cell window). Areas with higher backscatter values and flat surfaces were associated with the more diverse Cluster 1, while those with lower backscatter values and curved terrain were populated by the benthos of Clusters 2 and 3 (Figure 10). Clusters 1 and 2 were slightly more prevalent on western-facing terrain, while Cluster 3 was more often observed on easterly slopes (Figure 10).

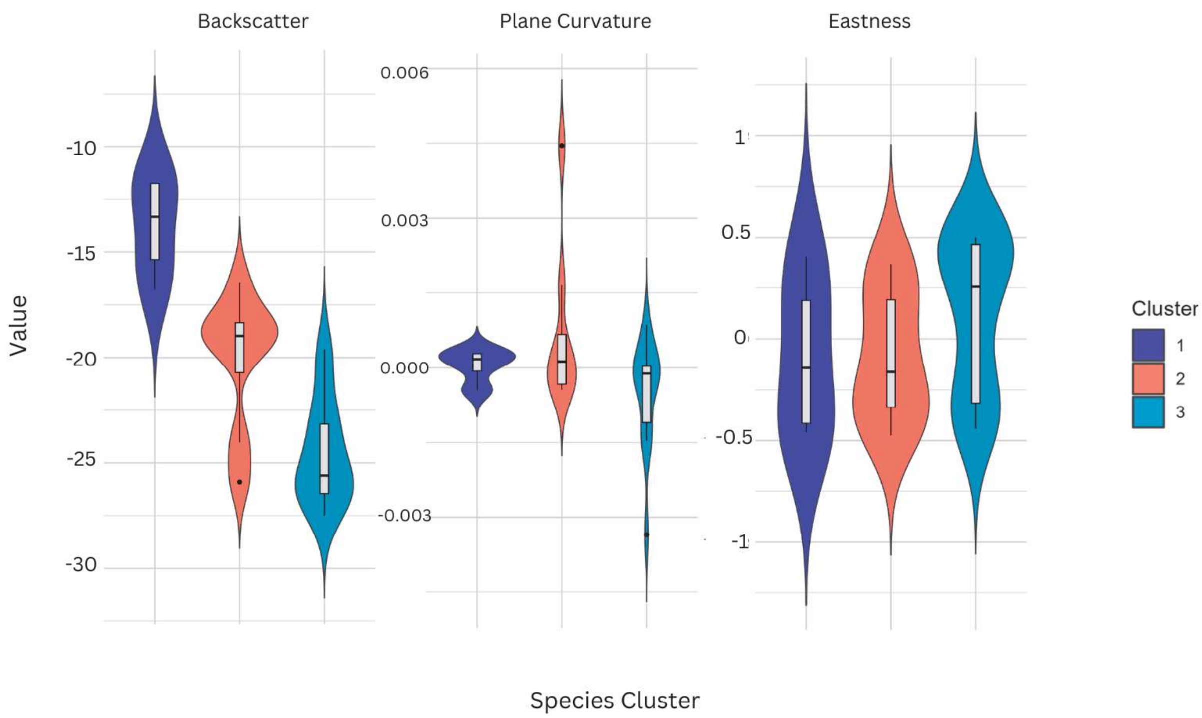


Figure 10: Violin plots of important environmental variables per species cluster in Pangnirtung Fjord. Cluster 1 represents sponges, sea cucumbers, red brittle star, coral and anemone. Cluster 2 is made up of bryozoan, feather star and whelk, and Cluster 3 is brittle stars and shrimp.

The model's overall accuracy was 69.2%, with brittle stars (71.5%) and feather stars (6.03%) being the dominant species. Cluster 1 was predicted more confidently by the model, with a high F1 score (0.75) and the highest balanced accuracy (0.85). As the most "varied in indicator species" cluster in the fjord, the model predicted Cluster 1 near the mouth of the fjord and on the sill (Figure 11). Although no samples were taken on the sill, ground truthing sites at the mouth of the fjord, likely similar in environmental characteristics, were also assigned to Cluster 1 (Figure 6). These sites at the mouth of the fjord (1,4,5,7) also had the highest seafloor heterogeneity. Cluster 3 was found throughout the inner portion of the fjord, at sites that were dominated by soft sediment (Figure 3 and Figure 6). The seafloor types seen at Cluster 2 sites had varying amounts of hardness, and were seen in the deeper portions of the outer fjord (Figures 6 and 11). Cluster 2 was the most challenging to predict, as seen in its sparse peripheral distribution in the habitat map and lower performance metrics (F1 score 0.5) (Table 2).

Table 2: Confusion matrix and metrics for the Random Forest model of Pangnirtung Fjord.

		Observed Species Cluster				
Predicted Species Cluster		Cluster 1	Cluster 2	Cluster 3	**F1 Score**	**Balanced Accuracy**
	Cluster 1	**3**	1	0	0.75	0.85
	Cluster 2	1	**4**	3	0.50	0.72
	Cluster 3	0	3	**11**	0.79	0.77

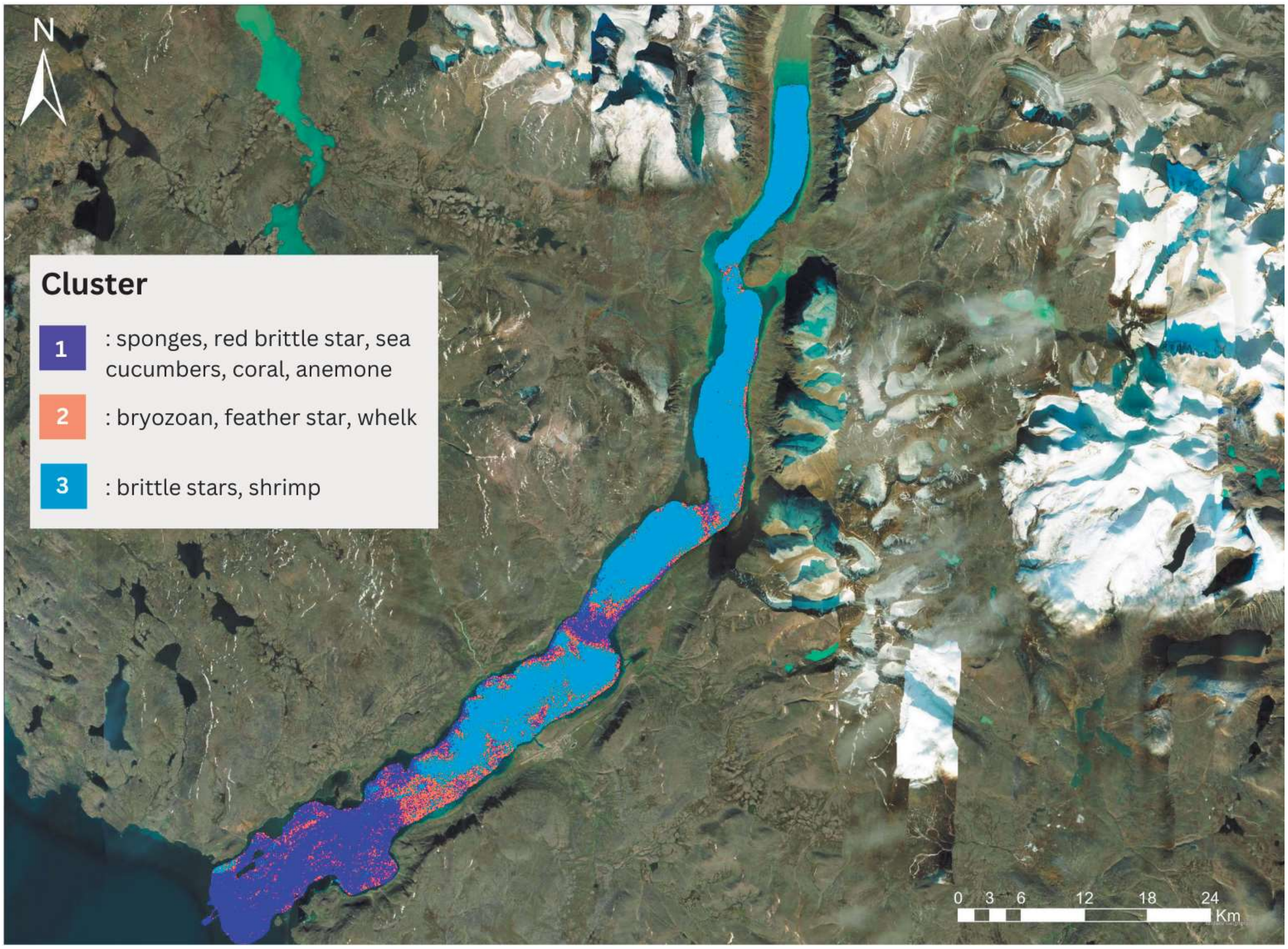


Figure 11: Benthic habitat map of Pangnirtung Fjord.

3.4 Nunatsiavut Model

3.4.1 Benthic Habitat Model

The final terrain features selected by the Boruta wrapper and correlation analysis process were depth, backscatter, profile curvature (21x21 cell window), plane curvature (35x35 cell window), Bathymetric Position Index (BPI) (21x21 cell window) and northness (35x35 cell window) (Figure 12). Overall, the bay was mainly populated by brittle stars (52.2%) and shrimp (26.5%), with snakeblennys (4.4%) and isopods (6.5%) being the next most abundant species. Cluster 1 was distributed in the shallower, north-facing portions of the bay. The worms, anemone, isopods, benthic jellyfish and anemone had the narrowest range of terrain feature preference, and were associated with softer sediments on flat surfaces. The shrimp of Cluster 2 were seen in the deepest regions with harder seafloor types, though some outliers could be found on mounds and depressions. Cluster 3's brittle stars and hermit crabs had a wide distribution throughout the bay's terrain features (Figure 12 and Figure 13).

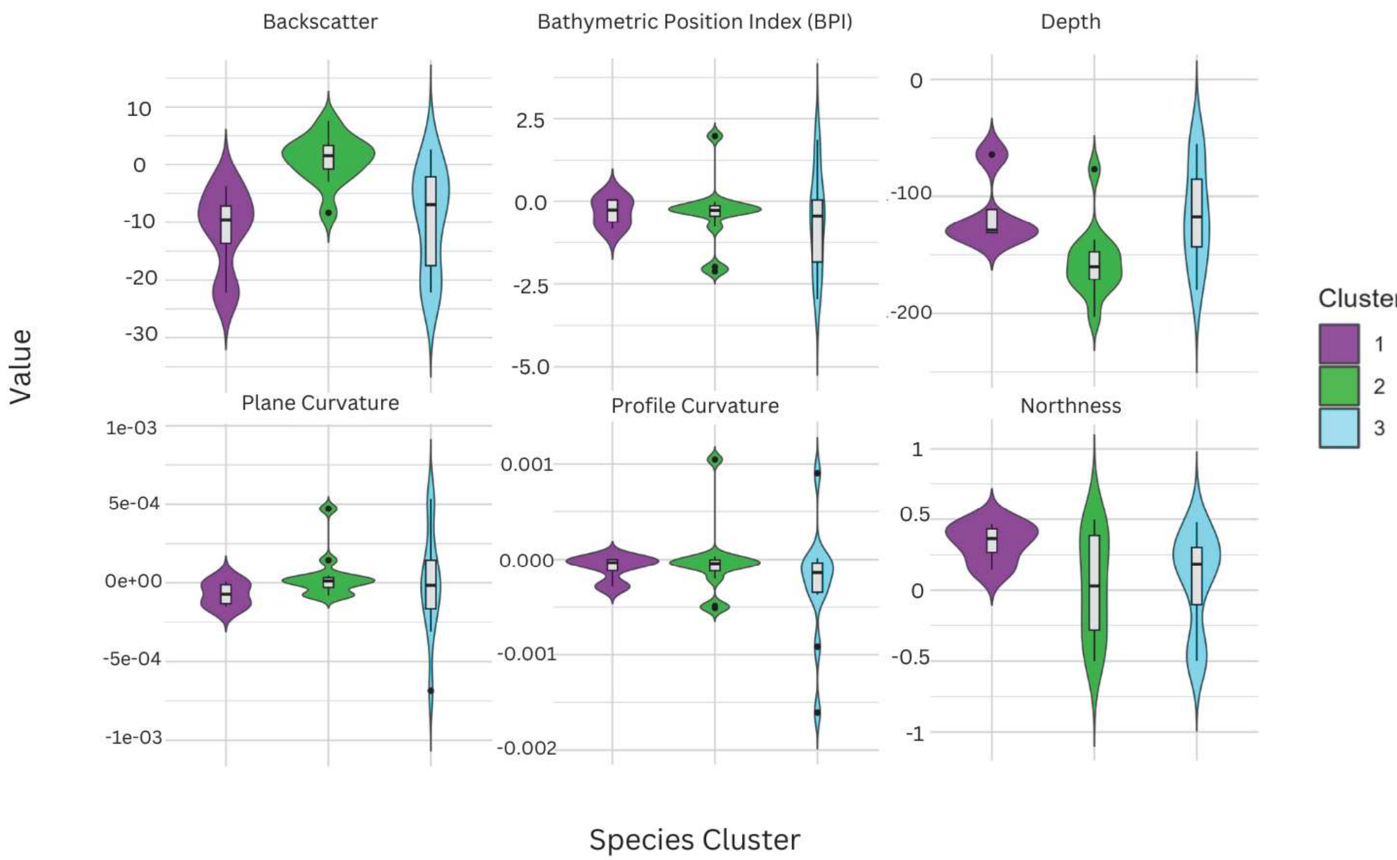


Figure 12: Violin plots of important environmental variables per species cluster in Ramah Bay. Cluster 1 is represented by worms, isopods, anemone and benthic jellyfish. Cluster 2 is shrimp and Cluster 3 is brittle stars and hermit crab.

The final RF model had an overall accuracy of 60.71% indicating a moderate performance with predictions that are better than random. However, there were differences in model performance among the predicted clusters (Table 3). Cluster 2 showed the best performance with the highest F1 score (0.67) and fairly high balanced accuracy (0.71). Cluster 3 performed the least well, with the model often confusing Cluster 3 and Cluster 2. Cluster 3 was mainly predicted along the peripheries of the bay, surrounding the other clusters (Figure 13). Finally, Cluster 1 was easier to predict where it was not, rather than where it was. This cluster had the most indicator species, and was forecasted in the inner-most portions of the Ramah Bay and Little Ramah Bay arms (Figure 13). Two sites (30 and 31) were removed from this analysis as they were not within the multibeam swatch, hindering our ability to make any predictions using those sites.

Table 3: Confusion matrix and metrics for the Random Forest model of Ramah Bay.

		Observed Species Cluster				
		Cluster 1	Cluster 2	Cluster 3	**F1 Score**	**Balanced Accuracy**
Predicted Species Cluster	Cluster 1	**2**	0	2	0.57	0.79
	Cluster 2	0	**8**	4	0.67	0.71
	Cluster 3	1	4	**7**	0.56	0.60

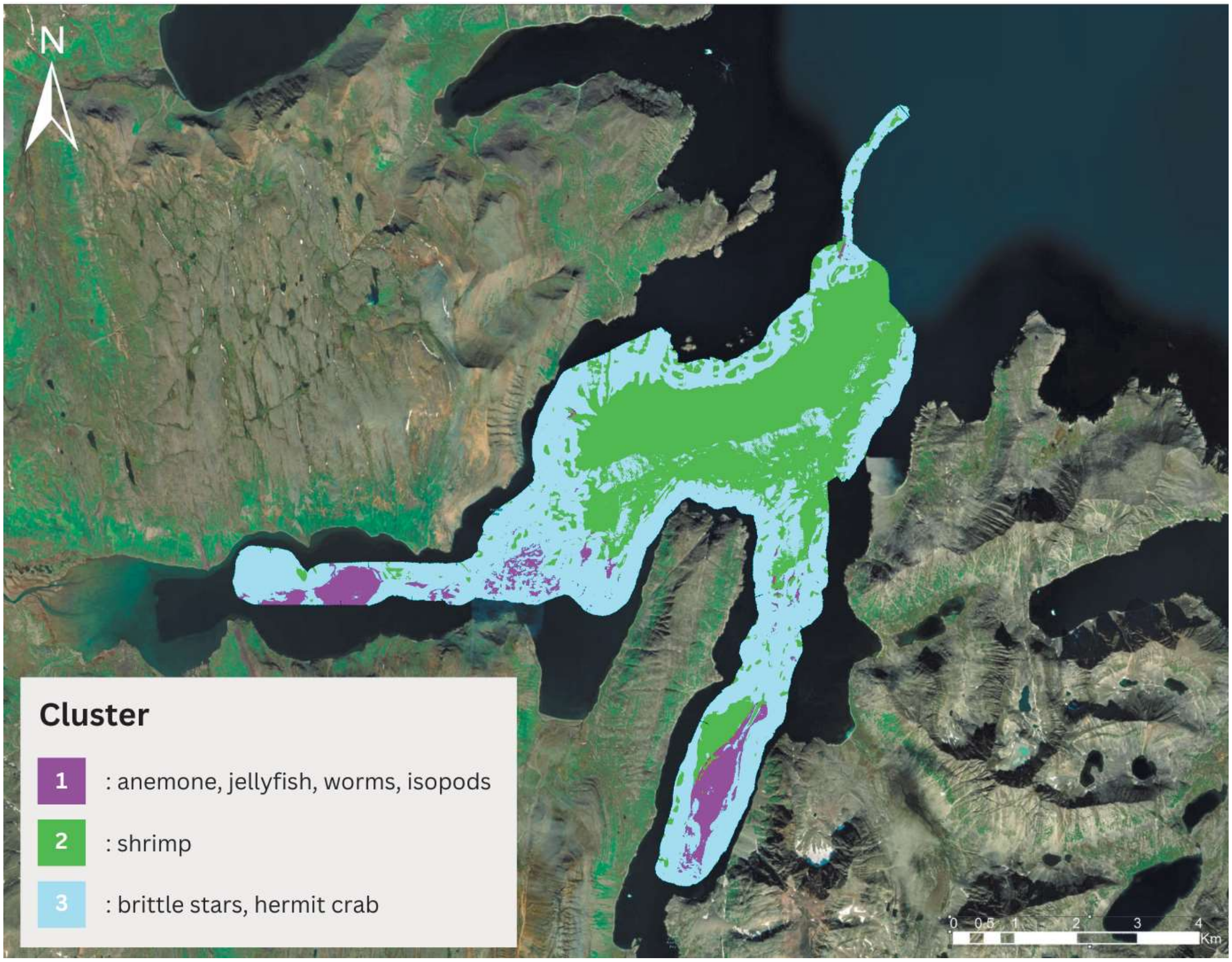


Figure 13: Benthic habitat map of Ramah Bay

Chapter 4: Discussion

The benthic ecology of three estuaries in the eastern Canadian Arctic was studied. The main terrain features which informed predictions on benthic distribution in all areas were the relative locations within the fjord, terrain curvature, and the general profile and orientation of the estuary to dominant oceanographic forces. The more sheltered, narrow and heterogeneous seafloor environment of Pangnirtung Fjord contained the most benthic species morphotypes.

4.1 The Spatial Ecology of Arctic Bays and Fjords

Estuaries in the Arctic vary in their shapes, sizes and orientations to the prevailing oceanographic forces. In turn, estuary geomorphology and circulation influence the environmental conditions present, which impacts the life which can take hold on the seafloor in these areas (Bianchi et al., 2020). Of all three estuaries in this study, Pangnirtung Fjord contained the most heterogeneous seafloor sediment types and the highest number of morphotypes, nearly double the number observed in Southwind Fjord and Ramah Bay. It was also the most sheltered from the influence of open ocean forces, tucked away in Cumberland Sound. Still, similar seafloor terrain characteristics exerted influence on benthic distribution probabilities in all three regions surveyed.

4.1.1 Influence of Terrain on Fjord Circulation

Positioning within the bay or fjord was important across all study sites. However, the derived predictor terrain features varied (latitude, longitude, eastness and northness) likely as a result of the different orientation of these estuaries. In Ramah Bay, northness could signal that the northerly slope orientation relative to the dominant northward hydrodynamic forces from the

Labrador Sea were more suitable habitats for the benthic community of Cluster 1. Perhaps these sessile benthos appreciated less harsh inflow of water and thus less physical disturbance from the Labrador Current, thereby colonizing northern-facing slopes and aggregating in more southerly portions of the bay (Atkinson et al., 2024). However, eastness exerted a strong influence on Pangnirtung's benthic habitat distribution, with the more species-rich Clusters 1 and 2, as well as diatomaceous sediment occurring predominantly on the westerly slopes. This could be because Arctic fjords often have stronger currents along their right-hand shores from the Coriolis effect, which is the western shore in Pangnirtung (Bianchi et al., 2020). Currents are an important environmental factor, as they help to limit sediment accumulation while acting like food conveyor belts for the filter feeding mouths of stationary benthos. Latitude and longitude also had an influence on Iceland scallop distribution in Pangnirtung Fjord, and the apparent distribution of the species clusters in Southwind Fjord. More scallops and sessile species were found in the outer region, and less scallops and more mobile species found in the inner fjords. Similar patterns of decreasing benthic abundance and diversity have been demonstrated in other areas of the Arctic (Molis et al., 2019; Wesławski et al, 2011) and within Pangnirtung Fjord itself (Dale et al., 1989). This pattern may be explained by three factors in the outer areas: stronger currents aiding larval dispersion, shallower depths supporting phytoplankton growth, and gravelly substrates facilitating larval settlement while reducing sediment resuspension that can hinder benthos feeding and anchoring (Kostylev et al., 2003).

Terrain curvature exerted an influence on the benthic ecology in all three surveyed regions. Terrain curvature, as represented by the plane curvature metric, influences the flow of water in the estuary, and thus sedimentation and nutrient deposition (Lecours et al., 2016). This can lead to important differences in resource distribution, particularly for filter feeding organisms such as coral and anemones, which rely on water flow to receive nutrients and were found on terrain with more neutral plane curvature values (Molis et al., 2019). Neutral curvature might be an indication that there is an optimal balance between nutrient deposition and sediment balance, ensuring sessile benthos are receiving enough nutrients without being smothered. Curvature, bathymetry and relative terrain elevations showed variable relationships with the distribution of benthic communities in Ramah Bay and the scallops of Pangnirtung Fjord. Positive curvature values likely represent proxies for areas with good water flow and reduced sedimentation; characteristics of areas where scallops thrive (Crawford, 1992). Depth is a common proxy for environmental influences such as temperature, sunlight availability, and salinity gradients (Misiuk & Brown, 2024). In Ramah Bay, the more generalist brittle stars and hermit crabs were found at all depths, but the worms, isopods, benthic jellies and anemones were mostly found in the narrow range of 125-140 m. This depth-specific distribution may be influenced by the fjord's circulation patterns, where the interaction between freshwater input and tidal mixing creates distinct layers of water with varying properties (Cottier et al., 2010). These morphological characteristics, (terrain curvature, bathymetry and relative terrain elevations), also guide the circulation patterns in the bay, which in turn influences the flow of nutrients (Rangeley et al., 2022; Buhl-Mortensen et al., 2020). Since more nutrients reach benthos through lateral water currents than from marine snow falling through the water column, we can surmise that water flow, as possibly represented by surface morphology parameters, is important to the benthos in the eastern Canadian Arctic (Kelly et al., 2021; Graf, 1992).

4.1.2 Influence of Sediment on Benthic Community Distribution

Fjord orientation and circulation patterns can influence sediment deposition, and thus benthic distribution. Although estuary orientation and hydrodynamics were not directly studied, observations of the sediment dispersal in each region could explain differences in benthic distribution and abundance as influenced by fjord circulation (Bianchi et al., 2020; Gilbert, 1983). As a distinguishing feature, Pangnirtung Fjord's orientation to prevailing waters is more sheltered, instead being exposed to the relatively calmer Cumberland Sound (Bedard et al., 2015). Conversely, Southwind Fjord's exposure to the open ocean of Davis Strait means it is influenced by stronger hydrodynamic forces (Hamilton & Wu, 2013). This difference in fjord circulation intensity may indirectly account for Southwind Fjord having the lowest amount of species morphotypes. Research by the Geological Survey of Canada found heavy erosion and deposition from turbidity currents, at least 500 iceberg scour pits down to 90 m and a recent (2018) submarine landslide in Southwind Fjord (Normandeau et al., 2020). The dynamic geomorphology of Southwind Fjord could be the reason for the low presence of sessile benthos, through sheer physical disturbance which is unimpeded until the first sill 214 m into the fjord (Normandeau et al, 2019). Similarly, the open profile of Ramah Bay is directly exposed to the Labrador Sea with an even wider mouth and no sill, as opposed to the narrow inlets and shallow sills of Southwind Fjord and Pangnirtung Fjord. While moderate currents are essential for filter-feeding benthos to obtain nutrients, a strongly dynamic environment including iceberg scouring and submarine landslides could make it more difficult for slow-growing sessile benthos such as sponges and coral to inhabit the seafloor in this area, especially with high and frequent turbulence shifting and disturbing the seafloor sediment (Molis et al., 2019; Cochrane et al., 2012).

Sediment deposition and redistribution is largely controlled by circulation patterns, with a general trend of softer sediments at the head, and coarser sediments near the mouth and sill; a trend we see in Pangnirtung Fjord (Cottier et al., 2010; Gilbert, 1978). Moreover, backscatter was shown to be an important predictor variable in the distribution of benthic communities in Ramah Bay and Pangnirtung Fjord. For example, Pangnirtung Fjord's Cluster 1, with its eight indicator species, occurred in areas of harder and coarser substrate, while Cluster 3, characterized mainly by brittle stars, was found on the softer sediment planes of the fjord (Figure 14).

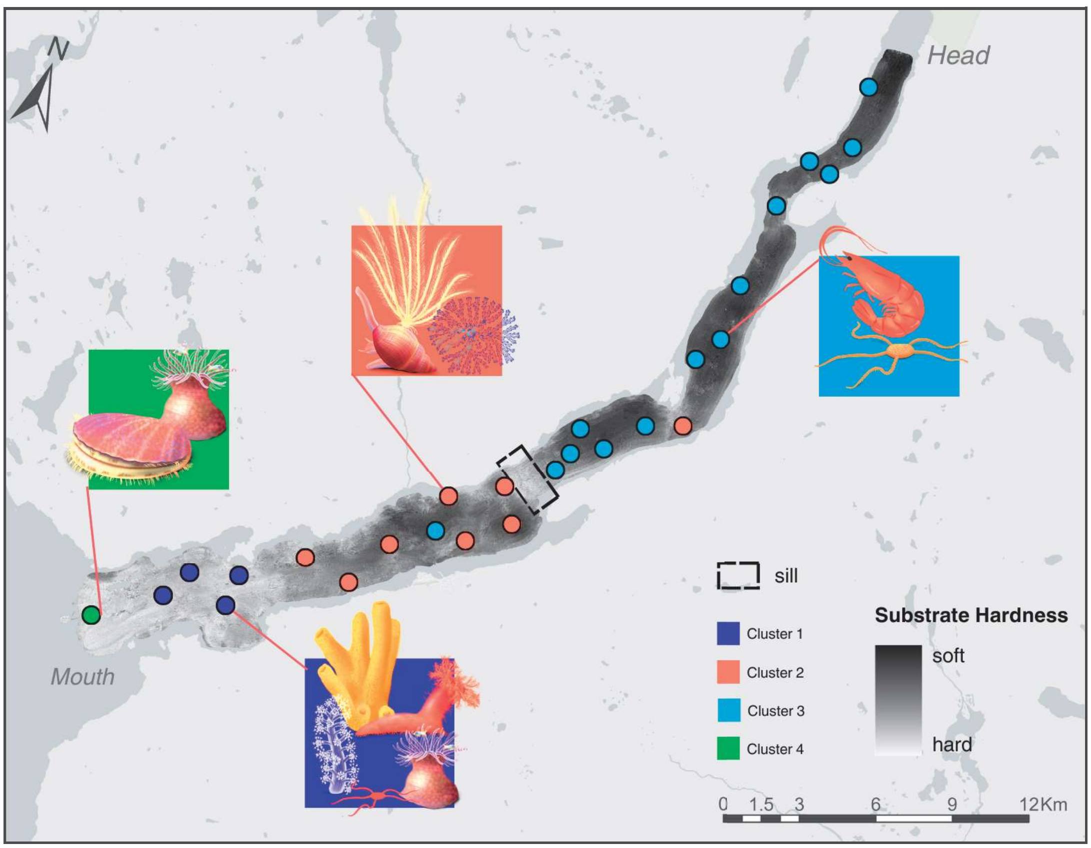


Figure 14: Spatial distribution of benthic community clusters and sediment hardness in Pangnirtung Fjord, as interpreted through backscatter data. Benthos illustrations by Misha Donohoe.

Sediment plumes were photographed going towards the western bank of Pangnirtung Fjord, with the asymmetry of the depths between banks confirming higher sedimentary deposits on the western side (Gilbert, 1982). These sediment plumes occur mainly at the head of the fjord and can reduce primary production during times of increased deposition, such as the spring thaw (Syvitski, 1989). It is also where we see less sessile benthos, instead being populated by shrimp and brittle stars (Figure 14). The large tidal range in Pangnirtung Fjord (up to 6.7 m) drives continuous circulation throughout the year, which helps prevent excessive fine sediment accumulation that could smother sessile benthic organisms living away from the head (Gilbert and Church, 1983). This circulation also ensures a steady supply of nutrients and oxygen for filter-feeding benthos living farther away from the fjord head, as seen in Clusters 1 and 2 near the mouth and sill of the fjord (Figure 14). The presence of gravel in these areas is likely due to a combination of factors, including mass wasting from valley sidewalls and ice transport of coarser sediments from the wide tidal flats (Gilbert, 1983). These substrates are suitable for hosting abundant benthic communities such as Cluster 1 and 4 in Pangnirtung Fjord (Dale et al., 1989). Further research could work to better understand the connection between the estuary geomorphology and circulation dynamics, and the resulting sedimentation patterns and their influence on benthic distribution.

4.2 Arctic Marine Management

The benthic habitat maps and species distribution map generated capture general spatial patterns in habitat-species assemblage relationships in the Canadian Arctic. However, these benthic habitat models should be interpreted with caution, as the moderate accuracy (69.2% in Pangnirtung, 60.71% in Ramah) means they have room for improvement. This is likely due to the small sample size, which has been shown to decrease model predictive accuracy (Wisz et al., 2008). Furthermore, sampling was done across two separate years in late summer (August-September), therefore these maps do not represent the spatial distribution of benthos across multiple seasons, nor do they account for seasonal variability over time. Future studies should conduct sampling across multiple seasons, as well as account for species-specific seasonal patterns in order to surpass this limitation (Charmley, 2023).

The Iceland scallop SDM had the highest accuracy (83.3%), allowing for higher confidence in its predictions of scallop presence probabilities. A total of 882 Iceland scallops were counted throughout the 28 sample sites in Pangnirtung Fjord, with the highest abundances observed along the eastern banks for the fjord and predicted to be nearer the mouth of the fjord. These results corroborate the Nunavut Coastal Resource Inventory, which was published in 2013 for the Pangnirtung region by the Government of Nunavut. Based on nine interviewees, the probability of occurrence of *Chlamys islandica* was mapped to be adjacent to our highest scallop probability region on the outer eastern bank (NCRI, 2013). Scallops were often found next to Clusters 1 and 2, which were observed to contain multiple overlapping species. For example, frequently observed near high-probability scallop grounds were agglomerations of tiny *Ophicantha* under the cirri of feather stars in regions representing Cluster 2 (Figure 15). These brittle stars were not counted due to their small size (<2.5 cm), but were nevertheless observed in great clumps, a behavior only seen around *Heliometra glacialis*. Commensal species associations between brittle stars and feather stars have been documented before, whereby feather stars provide shelter and microhabitats, (Potts, 1915; Britayev & Mekhova, 2011) though this has not been observed in the Canadian Arctic. Since Clusters 1 & 2 were predicted to be interspersed within high scallop probability grounds, scallop dredging in these areas could be detrimental to the symbiotic relationships observed in these areas.

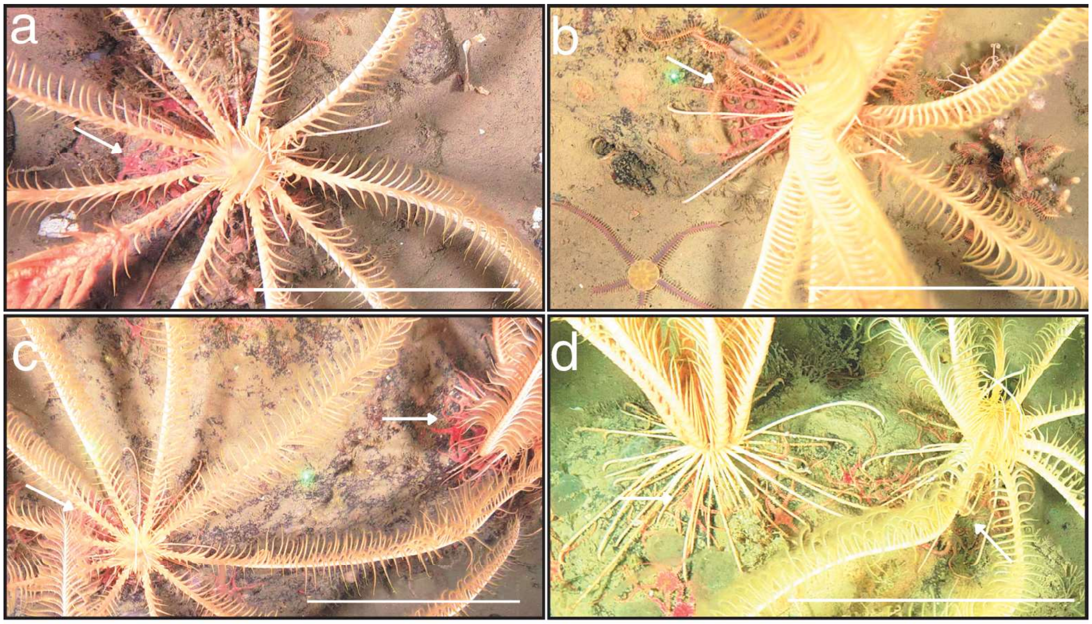


Figure 15: Representative images of species association of *Heliometra glacialis* and *Ophicantha* from site 20 in Pangnirtung Fjord. Bar represents 10cm. Arrows are pointing to clusters of *Ophicantha* under feather stars.

In Nunatsiavut, potential benthic harvestable food sources in Ramah Bay were limited to shrimp. Although 3817 counts of shrimp were annotated in Ramah Bay, future fisheries resource studies would be needed to validate the area as viable shrimping grounds. Additionally, it was evident from the footage that krill were present in large swarms during the 2023 sampling period, as they obstructed the camera lens on multiple occasions. Because shrimp and krill are highly mobile species and their density was not calculated, it is not possible to validate Ramah Bay as containing potential for fisheries within this study.

With regards to VME indicator species, 33 sponges (Massive sp.1) were counted at sites along the shallower perimeters of the multibeam of Ramah Bay and four soft corals were observed in Little Ramah Bay. These low counts do not necessarily warrant marine protection, as the presence of these species depend on the density present (FAO 2009). As a precaution, cruise ships visiting this area could avoid anchoring in Little Ramah Bay and in areas containing Cluster 1 in order to not damage these delicate benthos.

Chapter 5: Conclusions

This master's thesis provides spatial and descriptive insights into the benthic ecology of three estuaries in the eastern Canadian Arctic, contributing to our understanding of one of the world's most underexplored and rapidly changing ecosystems. Our findings support the notion that the outer portion of Pangnirtung Fjord has higher species abundance compared to the inner portion, as observed by previous research (Dale et al., 1989; Gilbert et al., 1978). This study revealed intricate relationships between estuary geomorphology, environmental conditions, and benthic community distribution, emphasizing the importance of factors such as terrain curvature, positioning within the fjord, and oceanographic forces. The potential reason for these patterns is likely in part due to the terrain influencing currents in the bay, which in turn impact sediment deposition and composition (Kostylev et al., 2003; Syvitski et al., 1989).

This study also addressed a critical need in Arctic marine management: understanding what exists on the seafloor and how it relates to community interests. The characterization of Ramah Bay's benthos, was submitted as part of the Torngat Area of Interest (T-AOI) Feasibility Assessment Report. The T-AOI was approved in March of 2024 under the National Marine Conservation Areas Act, which marks the historic milestone of being the first Inuit Protected Area (IPA) (Nunatsiavut Government, 2024). As the first genuine co-management IPA in Canada, the data presented here will add to existing local knowledge of Ramah Bay, ensuring that marine management efforts include scientific ecological characterization (Laing, 2024). In mapping the distribution of scallops and benthic habitats in Pangnirtung Fjord and Ramah Bay, this study provides valuable information for both ecological conservation and resource management. The identification of a substantial scallop population in Pangnirtung Fjord has significant implications for Inuit livelihoods and cultural practices, demonstrating the importance of such ecological research in supporting local interests. This also aligns with the broader goals of marine conservation aimed at preserving ecosystems and regulating extraction in a manner that balances ecological integrity with community needs.

These findings were shared with the communities of Pangnirtung and Nain, as they both had a keen interest in the benthic ecology of our study areas. The Hamlet Office and HTA in Pangnirtung, and the Nunatsiavut Government Research Center in Nain received the maps, data and outreach materials. Visits before, during and after the research took place ensured a continuum of communication throughout the process. At the local high schools, underwater footage was shared with youth, as well as presentations and hands-on activities with ROV and drop camera equipment. "Benthic Bingo" events were facilitated, whereby the benthos replaced the numbers in traditional bingo (Appendix C). This was done in the evening at a community hall, and during the day with younger students at the local schools. These events served to directly share the maps in the room, as well as provide a relaxed and fun environment where people felt comfortable asking questions and sharing opinions. Additionally, a comic illustration-style depicted the process of habitat mapping in the North, in a storytelling and locally relevant way in English, French, Inuktitut and Inuttitut (Appendix C). These comics were printed on cardstock in postcard format, and large-scale on fabric banners for hanging in the schools. Following this, benthos playing cards were designed and printed based on the locally observed benthos and shared in the community (Appendix C). Finally, videos of the underwater footage and maps were posted on local Facebook pages, so that anyone interested could view our research.

In conclusion, this research not only advances our understanding of Arctic marine ecosystems but also provides valuable information for community-based resource management and conservation efforts. As climate change continues to impact Arctic environments across Inuit Nunangat, such knowledge becomes increasingly crucial for developing effective, culturally sensitive, and ecologically sound management strategies. The study sets a foundation for future research that can further explore the complex dynamics of Arctic marine ecosystems and support sustainable management practices in these rapidly changing environments.

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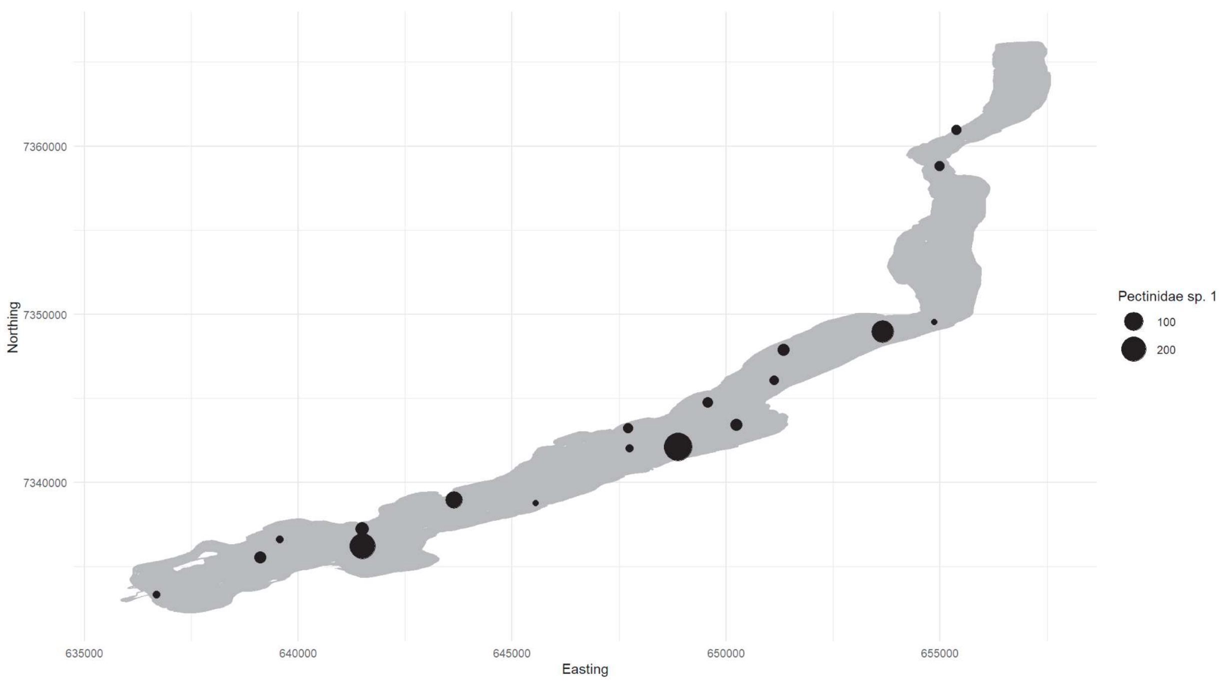
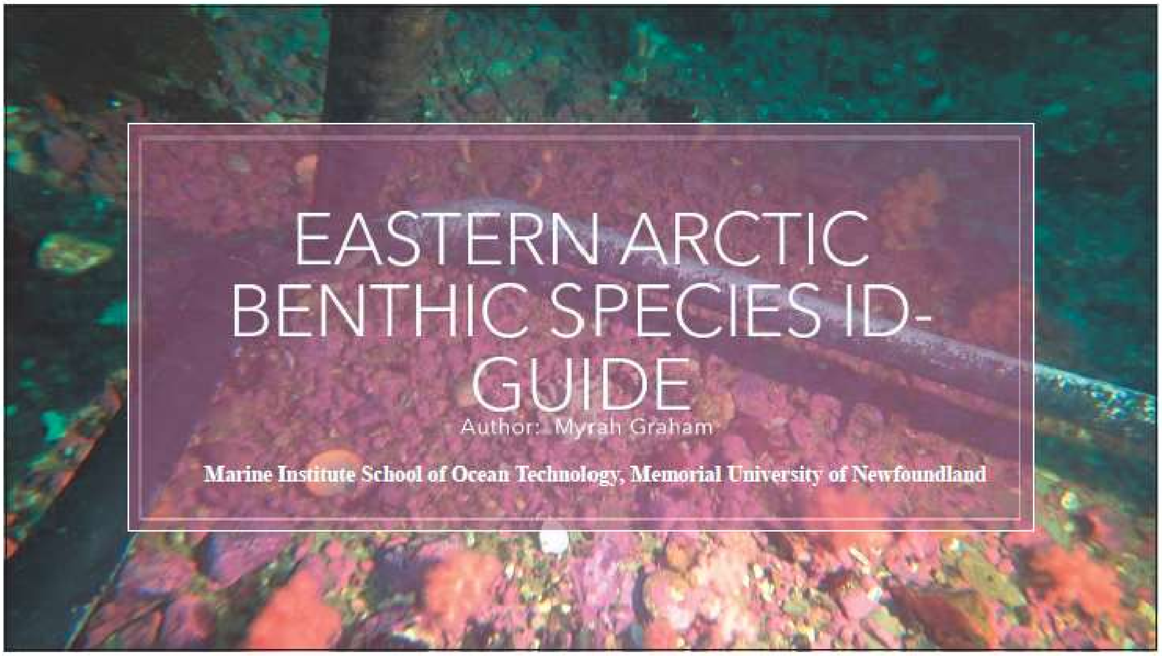
Appendix A

Figure A: Proportional symbol map of the distribution of Iceland scallops (*Pectinidae* sp.1) at ground truth sites in Pangnirtung Fjord. The gray shaded area is the region covered by multibeam sonar in the survey. The circles are relatively proportional to the abundance of Iceland scallops observed during surveys.



Appendix B

Figure B. Eastern Arctic Benthic Species Catalogue. Includes all benthic morphotaxa identified in Pangnirtung fjord, Southwind Fjord and Ramah Bay. Using multiple benthic imagery identification guides and websites (see section 2.5), species were identified to the lowest taxonomic level, but labeled at the taxonomic level with the highest certainty. This was an iterative process, where each new species annotated in the footage was then saved into the eastern Arctic Benthic Species Catalogue, and cross-referenced with available visual guides. This visual aid served as a personal reference to ensure standardization across sites and study areas in this thesis. This guide was not cross verified with taxonomists, and the taxonomic information listed below the species label is a best estimate from a novice student.



1

Outline

I. Annelida
II. Arthropoda
III. Bryozoa
IV. Chordata
V. Cnidaria
VI. Echinodermata
VII. Mollusca
VIII. Porifera

2

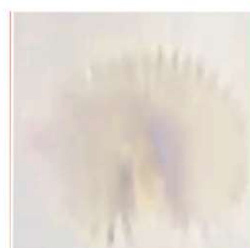
Annelida

Worms
Kupigguit

Annelida

Sabellidae sp. 1

- **Phylum:** Annelida
- **Class:** Polychaeta
- **Order:** Sabellida
- **Family:** Sabellidae
- **Genus:** *Chone*
- **Species:**



6

Annelida

Sabellidae sp. 2

- **Phylum:** Annelida
- **Class:** Polychaeta
- **Order:** Sabellida
- **Family:** Sabellidae
- **Genus:** *Chone*
- **Species:** *Chone infundibuliformis*

7

Annelida

Sabellidae sp. 3

- **Phylum:** Annelida
- **Class:** Polychaeta
- **Order:** Sabellida
- **Family:** Sabellidae
- **Genus:**
- **Species:**

8

Annelida

Sabellidae sp. 4

- **Phylum:** Annelida
- **Class:** Polychaeta
- **Order:** Sabellida
- **Family:** Sabellidae
- **Genus:**
- **Species:**

9

Annelida

Sedentaria sp. 7

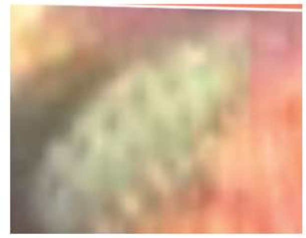
- **Phylum:** Annelida
- **Class:** Polychaeta
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

10

Annelida

Polynoidae sp. 1

- **Phylum:** Annelida
- **Class:** Polychaeta
- **Order:** Phyllodocida
- **Family:** Polynoidae
- **Genus:** *Aphroditiformia*
- **Species:**

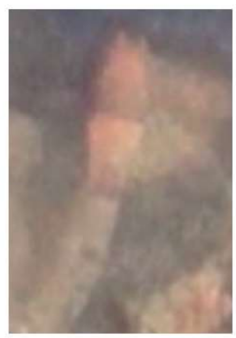


11

Annelida

Polychaeta sp. 1

- **Phylum:** Annelida
- **Class:** Polychaeta
- **Order:**
- **Family:**
- **Genus:**
- **Species:**



12

Annelida

Sipuncula sp. 1

- **Phylum:** Annelida
- **Class:** Sipunculidea
- **Order:** Sipuncula
- **Family:** Golfingiidae
- **Genus:**
- **Species:**

13

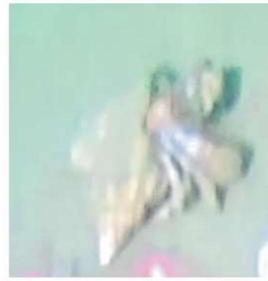
Arthropoda

Crustaceans, Sea spiders
Kingupvak/Putjotik

Arthropoda

Pagurus sp. 1

- **Phylum:** Arthropoda
- **Class:** Malacostraca
- **Order:** Decapoda
- **Family:** Paguridae
- **Genus:** *Pagurus*
- **Species:** *Pagarus fabricius*



15

Arthropoda

Pagurus sp.2

- **Phylum:** Arthropoda
- **Class:** Malacostraca
- **Order:** Decapoda
- **Family:** Paguridae
- **Genus:** *Pagurus*
- **Species:** *Pagarus pubescens*

16

Arthropoda

Hyas coarctatus

- **Phylum:** Arthropoda
- **Class:** Malacostraca
- **Order:** Decapoda
- **Family:** Oregoniidae
- **Genus:** *Hyas*
- **Species:** *Hyas coarctatus*

17

Arthropoda

Pandalus sp. 1

- **Phylum:** Arthropoda
- **Class:** Malacostraca
- **Order:** Decapoda
- **Family:** Pandalidae
- **Genus:** *Pandalus*
- **Species:** *Pandalus borealis / Pandalus montagui*

18

Arthropoda

Decapoda sp. 1

- **Phylum:** Arthropoda
- **Class:** Malacostraca
- **Order:** Decapoda
- **Family:** Thoridae
- **Genus:** *Eualus*
- **Species:** *Eualus gaimardii (belcheri)*

19

Arthropoda

Isopoda sp. 2

- **Phylum:** Arthropoda
- **Class:** Malacostraca
- **Order:** Isopoda
- **Family:** Chaetiliidae
- **Genus:** *Saduria*
- **Species:** *Saduria sabini or sibrica*

20

Arthropoda

Pycnogonida sp. 2

- **Phylum:** Arthropoda
- **Class:** Pycnogonida
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

21

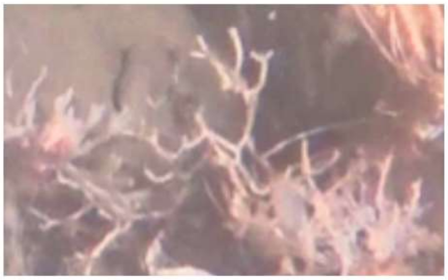
Bryozoa

Moss animals

Bryozoa

Bryozoa sp.1

- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatida
- **Family:** Myriaporidae
- **Genus:** *Myriapora*
- **Species:**

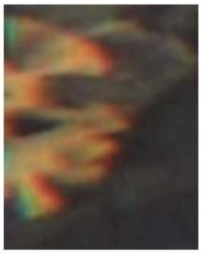


23

Bryozoa

Bryozoa sp.2

- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatida
- **Family:** Flustroidae
- **Genus:** *Securiflustra*
- **Species:** *Securiflustra securifrons*



24

Bryozoa

Bryozoa sp.3

- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatida
- **Family:** Bryocryptellidae
- **Genus:** *Cystisella*
- **Species:** *Cystisella saccata*

25

Bryozoa

Bryozoa sp.4

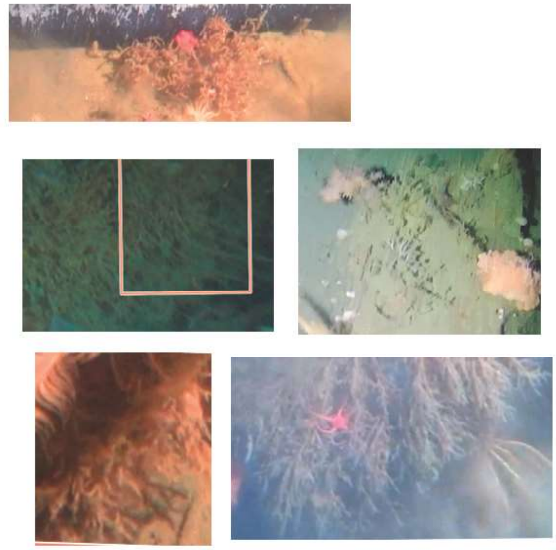
- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatida
- **Family:** Eucrateidae
- **Genus:** *Eucratea*
- **Species:** *Eucratea loricata*

26

Bryozoa

Bryozoa sp.5

- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatida
- **Family:** Candidae
- **Genus:** *Scrupocellaria or Tricellaria*
- **Species:**



27

Bryozoa

Bryozoa sp.6

- **Phylum:** Bryozoa
- **Class:** Stenolaemata
- **Order:** Cyclostomatida
- **Family:** Horneridae
- **Genus:** *Hornera*
- **Species:** *Hornera lichenoides*

28

Bryozoa

Bryozoa sp.7

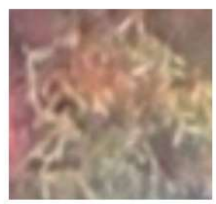
- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatidae
- **Family:** Flustridae
- **Genus:**
- **Species:**

29

Bryozoa

Bryozoa sp.8

- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatida
- **Family:** Myriaporidae
- **Genus:** *Leieschara*
- **Species:** *Leieschara coarctata*



30

Bryozoa

Bryozoa sp.9

- **Phylum:** Bryozoa
- **Class:** Stenolaemata
- **Order:** Cyclostomatida
- **Family:** Horneridae
- **Genus:** *Hornera*
- **Species:**

31

Bryozoa

Bryozoa sp.10

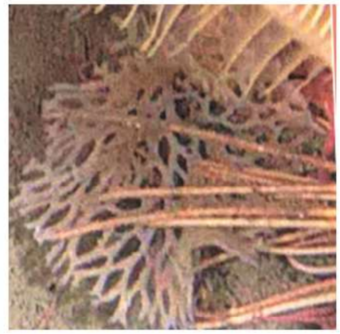
- **Phylum:** Bryozoa
- **Class:**
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

32

Bryozoa

Bryozoa sp.11

- **Phylum:** Bryozoa
- **Class:** Gymnolaemata
- **Order:** Cheilostomatida
- **Family:** Phidoloporidae
- **Genus:**
- **Species:**



33

Chordata

Fish, tunicates
Ogagalait, Imappimiutait sauniKangitut

Chordata

Cottidae sp.1

- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Perciformes
- **Family:** Cottiidae
- **Genus:** *Myoxocephalus*
- **Species:**

35

Chordata

Lycodes sp.1

- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Perciformes
- **Family:** Zoarcidae
- **Genus:** *Lycodes*
- **Species:** *Lycodes esmarkii*

36

Chordata

Lycodes sp.2

- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Perciformes
- **Family:** Zoarcidae
- **Genus:**
- **Species:**

37

Chordata

Chordata sp.2

- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Perciformes
- **Family:** Zoarcidae
- **Genus:**
- **Species:**

38

Chordata

Chordata sp.3

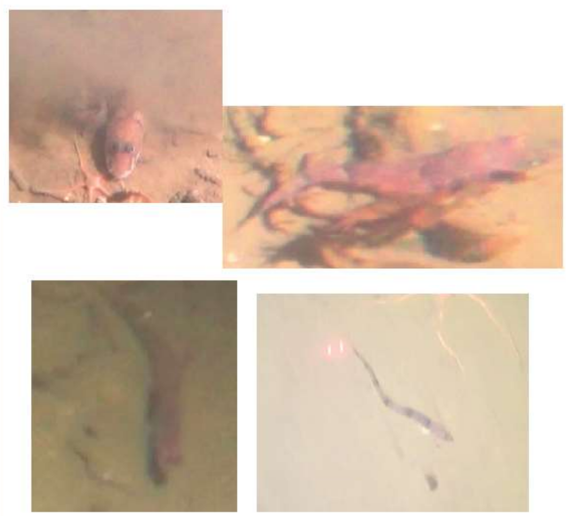
- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Perciformes
- **Family:** Zoarcidae
- **Genus:** *Lycodes*
- **Species:** *Lycodes vahlii*

39

Chordata

Chordata sp.9

- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Perciformes
- **Family:** Stichaeidae
- **Genus:** *Lumpenus*
- **Species:** *Lumpenus lampretaeformis*



40

Chordata

Myoxocephalus sp. 5

- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Perciformes
- **Family:** Cottiidae
- **Genus:** *Myoxocephalus*
- **Species:**

41

Chordata

Anguilliformes

- **Phylum:** Chordata
- **Class:** Teleostei
- **Order:** Anguilliformes
- **Family:** Synaphobranchidae
- **Genus:**
- **Species:**

42

Chordata

Tunicata sp.1

- **Phylum:** Chordata
- **Class:** Ascidiacea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

43

Chordata

Tunicata sp.2

- **Phylum:** Chordata
- **Class:** Ascidiacea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

44

Chordata

Tunicata sp.3

- **Phylum:** Chordata
- **Class:** Ascidiacea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

45

Chordata

Ascidiacea sp.3

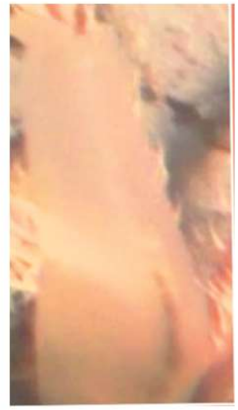
- **Phylum:** Chordata
- **Class:** Ascidiacea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

46

Chordata

Ascidiacea sp.4

- **Phylum:** Chordata
- **Class:** Ascidiacea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**



47

Chordata

Ascidiacea sp.5

- **Phylum:** Chordata
- **Class:** Ascidiacea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

48

Chordata

Ascidiacea sp.6

- **Phylum:** Chordata
- **Class:** Ascidiacea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

49

Cnidaria

Anemone, coral, jellyfish
Akittut ikKamiutak

Cnidaria

Cerianthidae sp.2

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Ceriantharia
- **Family:** Cerianthidae
- **Genus:** *Cerianthus*
- **Species:**

51

Cnidaria

Ceriantharia sp.3

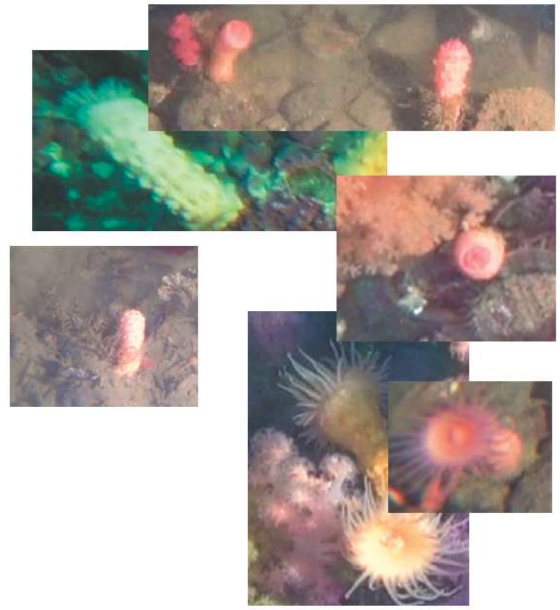
- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Ceriantharia
- **Family:** Synarachnactidae
- **Genus:** *Synarachnactis*
- **Species:** *Synarachnatis lloydii*

52

Cnidaria

Hormathia nodosa

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Hormathiidae
- **Genus:** *Hormathia*
- **Species:** *Hormathia nodosa*



53

Cnidaria

Hormathiidae sp. 3

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Hormathiidae
- **Genus:**
- **Species:**

54

Cnidaria

Actiniaria sp.1

- **Phylum:** Cnidaria
- **Class:** Anthozoa
- **Order:** Actiniaria
- **Family:**
- **Genus:**
- **Species:**

55

Cnidaria

Actiniaria sp.2

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Metridiidae
- **Genus:** *Metridium*
- **Species:**

56

Cnidaria

Actiniaria sp. 3

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:**
- **Genus:**
- **Species:**

57

Cnidaria

Actiniaria sp.6

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actiniidae
- **Genus:** *Cribinopsis or Urticina*
- **Species:**

58

Cnidaria

Actiniaria sp.7

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actiniidae
- **Genus:**
- **Species:**

59

Cnidaria

Actiniaria sp.8

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actiniidae
- **Genus:** *Urticina*
- **Species:** *Urticina felina*

60

Cnidaria

Actiniaria sp.9

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Halcampidae
- **Genus:** *Halcampa*
- **Species:** *Halcampa arctica*

61

Cnidaria

Actiniaria sp.10

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actinostolidae
- **Genus:** *Stomphia*
- **Species:** *Stomphia coccinea*

62

Cnidaria

Actiniaria sp.11

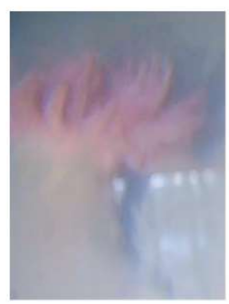
- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actiniidae
- **Genus:**
- **Species:**

63

Cnidaria

Actiniaria sp.12

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actinostolidae
- **Genus:** *Actinostola*
- **Species:** *Actinostola verrill*



64

Cnidaria

Actiniaria sp.13

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actinostolidae
- **Genus:** *Glandulactis*
- **Species:** *Glandulactis spetsbergensis*

65

Cnidaria

Actiniaria sp. 16

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Actiniaria
- **Family:** Actinostolidae
- **Genus:** *Stomphia*
- **Species:**

66

Cnidaria

Cnidaria sp.1

- **Phylum:** Cnidaria
- **Class:** Hexacorallia
- **Order:** Ceriantharia
- **Family:**
- **Genus:**
- **Species:**

67

Cnidaria

Umbellula sp.1

- **Phylum:** Cnidaria
- **Class:** Octocorallia
- **Order:** Scleralcyonacea
- **Family:** Umbellulidae
- **Genus:** *Umbellula*
- **Species:** *Umbellula encrinus*

68

Cnidaria

Anthomastus

- **Phylum:** Cnidaria
- **Class:** Octocorallia
- **Order:** Scleralcyonacea
- **Family:** Corallidae
- **Genus:** *Anthomastus*
- **Species:**

69

Cnidaria

Gersemia sp.1

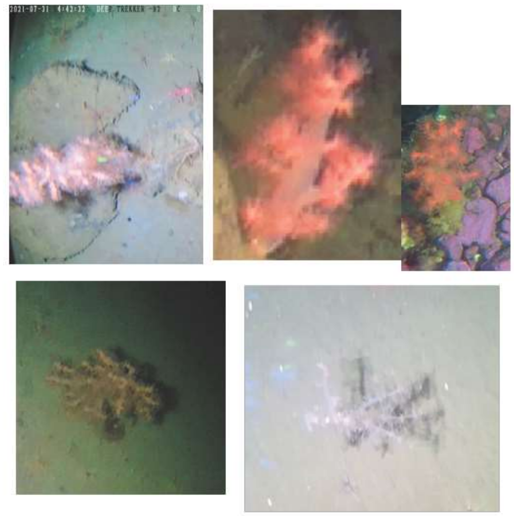
- **Phylum:** Cnidaria
- **Class:** Octocorallia
- **Order:** Malacalcyonacea
- **Family:** Alcyoniidae
- **Genus:** *Gersemia*
- **Species:** *Gersemia rubiformis*

70

Cnidaria

Nephtheidae sp.1

- **Phylum:** Cnidaria
- **Class:** Octocorallia
- **Order:** Malacalcyonacea
- **Family:** Alcyoniidae
- **Genus:** *Gersemia*
- **Species:** *Gersemia fruticosa*



71

Cnidaria

Nephtheidae sp.2

- **Phylum:** Cnidaria
- **Class:** Octocorallia
- **Order:** Malacalcyonacea
- **Family:** Capnellidae
- **Genus:** *Pseudodrifa*
- **Species:**

72

Cnidaria

Nephtheidae sp.3

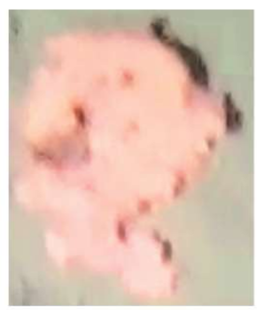
- **Phylum:** Cnidaria
- **Class:** Octocorallia
- **Order:** Malacalcyonacea
- **Family:** Capnellidae
- **Genus:** *Drifa*
- **Species:** *Drifa glomerata*

73

Cnidaria

Cnidaria sp.2

- **Phylum:** Cnidaria
- **Class:** Octocorallia
- **Order:** Malacalcyonacea
- **Family:** Capnellidae
- **Genus:** *Duva*
- **Species:** *Duva florida*

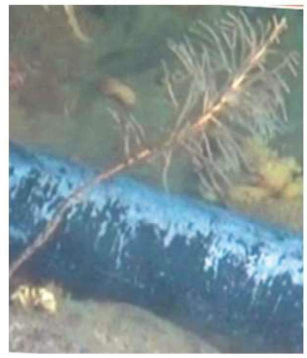


74

Cnidaria

Hydrozoa sp.1

- **Phylum:** Cnidaria
- **Class:** Hydrozoa
- **Order:** Leptothecata
- **Family:** Sertulariidae
- **Genus:** *Thuiaria*
- **Species:** *Thuiaria thuja*

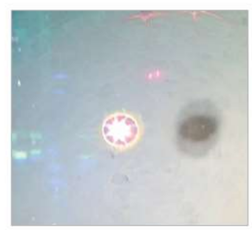


75

Cnidaria

Hydrozoa sp.2

- **Phylum:** Cnidaria
- **Class:** Hydrozoa
- **Order:** Trachymedusae
- **Family:** Ptychogastriidae
- **Genus:** *Ptychogastria*
- **Species:** *Ptychogastria polaris*

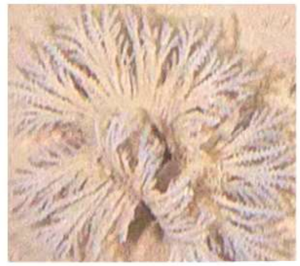


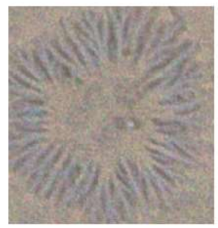
76

Cnidaria

Hydrozoa sp.3

- **Phylum:** Cnidaria
- **Class:** Hydrozoa
- **Order:** Leptothecata
- **Family:**
- **Genus:**
- **Species:**





77

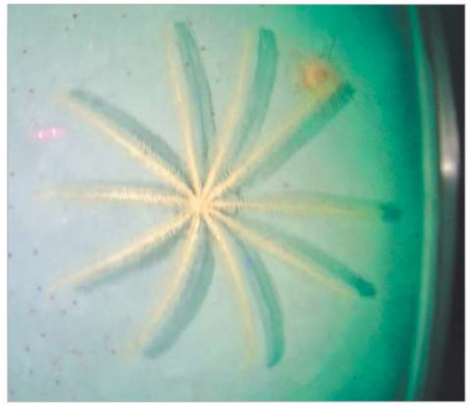
Echinodermata

stars, cucumbers, feathers, urchins
Aggajaat, Ammangituatsuk, Imammiutait piguttut ammalu imammiutait suluit, Itik

Echinodermata

Heliometra glacialis

- **Phylum:** Echinodermata
- **Class:** Crinoidea
- **Order:** Comatulida
- **Family:** Antedonidae
- **Genus:** *Heliometra*
- **Species:** *Heliometra glacialis*

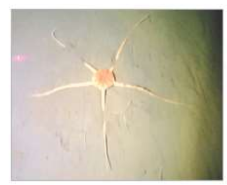


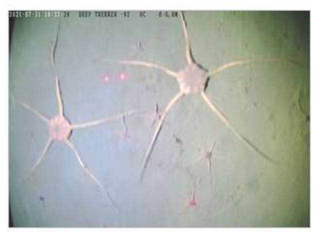
79

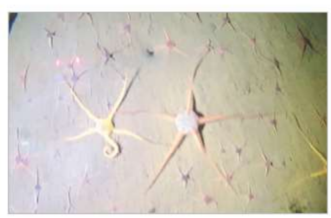
Echinodermata

Ophiura sp.1

- **Phylum:** Echinodermata
- **Class:** Ophiuroidea
- **Order:** Ophiurida
- **Family:** Ophiuridae
- **Genus:** *Ophiura*
- **Species:** *Ophiura sarsii*







80

Echinodermata

Ophicantha sp.2

- **Phylum:** Echinodermata
- **Class:** Ophiuroidea
- **Order:** Ophiacanthida
- **Family:** Ophiacanthidae
- **Genus:** *Ophiacantha*
- **Species:** *Ophiacantha bidentata*

81

Echinodermata

Ophiuroidea sp.1

- **Phylum:** Echinodermata
- **Class:** Ophiuroidea
- **Order:** Euryalida
- **Family:** Euryalidae
- **Genus:** *Asteroschema*
- **Species:**

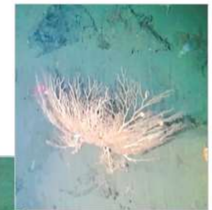
82

Echinodermata

Gorgonocephalus

- **Phylum:** Echinodermata
- **Class:** Ophiuroidea
- **Order:** Euryalida
- **Family:** Gorgoncephalidae
- **Genus:** *Gorgonocephalus*
- **Species:**






83

Echinodermata

Crossaster papposus

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Valvatida
- **Family:** Solasteridae
- **Genus:** *Crossaster*
- **Species:** *Crossaster papposus*



84

Echinodermata

Solaster endeca

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Valvatida
- **Family:** Solasteridae
- **Genus:** *Solaster*
- **Species:** *Solaster endeca*

85

Echinodermata

Asteroidea sp. 3

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Spinulosida
- **Family:** Echinasteridae
- **Genus:** *Henricia*
- **Species:**

86

Echinodermata

Asteroidea sp. 9

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Valvatida
- **Family:** Poraniidae
- **Genus:**
- **Species:**

87

Echinodermata

Asteroidea sp. 10

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Paxillosida
- **Family:** Astropectinidae
- **Genus:** *Leptychaster*
- **Species:** *Leptychaster arcticus*

88

Echinodermata

Asteroidea sp.11

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Velatida
- **Family:** Pterasteridae
- **Genus:** *Pteraster*
- **Species:** *Pteraster militaris*

89

Echinodermata

Asteroidea sp. 12

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Paxillosida
- **Family:** Ctenodiscidae
- **Genus:** *Ctenodiscus*
- **Species:** *Ctenodiscus crispatus*

90

Echinodermata

Asteroidea sp. 13

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Velatida
- **Family:** Pterasteridae
- **Genus:** *Diplopteraster*
- **Species:** *Diplopteraster multiples*

91

Echinodermata

Asteroidea sp. 14

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Forcipulatida
- **Family:** Asteriidae
- **Genus:** *Leptasterias*
- **Species:** *Leptasterias groenlandica*

92

Echinodermata

Asterias forbesi

- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Forcipulatida
- **Family:** Asteriidae
- **Genus:** *Asterias*
- **Species:** *Asterias forbesi*

93

Echinodermata

Asteroidea sp. 15

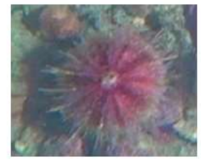
- **Phylum:** Echinodermata
- **Class:** Asteroidea
- **Order:** Valvatida
- **Family:** Solasteridae
- **Genus:** *Lophaster*
- **Species:**

94

Echinodermata

Echinoidea sp.1

- **Phylum:** Echinodermata
- **Class:** Echinoidea
- **Order:** Camarodonta
- **Family:** Strongylocentrotidae
- **Genus:** *Strongylocentrotus*
- **Species:**



95

Echinodermata

Echinoidea sp.2

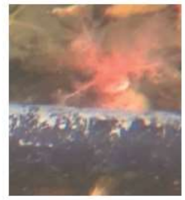
- **Phylum:** Echinodermata
- **Class:** Echinoidea
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

96

Echinodermata

Psolus sp.1

- **Phylum:** Echinodermata
- **Class:** Holothuroidea
- **Order:** Dendrochirotida
- **Family:** Psolidae
- **Genus:** *Psolus*
- **Species:** *Psolus squamatus*

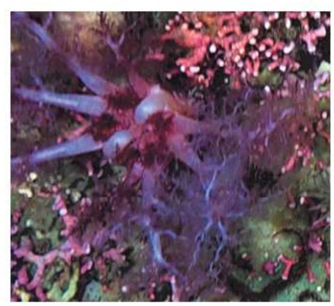


97

Echinodermata

Psolus sp.2

- **Phylum:** Echinodermata
- **Class:** Holothuroidea
- **Order:** Dendrochirotida
- **Family:** Psolidae
- **Genus:** *Psolus*
- **Species:** *Psolus phantapus*



98

Echinodermata

Cucumaria sp.1

- **Phylum:** Echinodermata
- **Class:** Holothuroidea
- **Order:** Dendrochirotida
- **Family:** Cucumariidae
- **Genus:** *Cucumaria*
- **Species:** *Cucumaria frondosa*

99

Echinodermata

Cucumber sp.12

- **Phylum:** Echinodermata
- **Class:** Holothuroidea
- **Order:** Dendrochirotida
- **Family:** Psolidae
- **Genus:** *Psolus*
- **Species:** *Psolus fabricii*

100

Mollusca

Bivalves, squid, octopus, snails, slugs
Uvilulet

Mollusca

Bivalvia sp.8

- **Phylum:** Mollusca
- **Class:** Bivalvia
- **Order:** Myida
- **Family:** Myidae
- **Genus:** *Mya*
- **Species:** *Mya truncata*

102

Mollusca

Bivalvia sp.9

- **Phylum:** Mollusca
- **Class:** Bivalvia
- **Order:** Venerida
- **Family:** Arcticidae
- **Genus:** *Arctica*
- **Species:** *Arctica islandica*



103

Mollusca

Bivalvia sp.10

- **Phylum:** Mollusca
- **Class:** Bivalvia
- **Order:** Nuculanida
- **Family:** Yoldiidae
- **Genus:** *Yoldia*
- **Species:** *Yoldia hyperborea*



104

Mollusca

Bivalvia sp.11

- **Phylum:** Mollusca
- **Class:** Bivalvia
- **Order:** Cardiida
- **Family:** Cardiidae
- **Genus:** *Clinocardium*
- **Species:**

105

Mollusca

Pectinidae sp.1

- **Phylum:** Mollusca
- **Class:** Bivalvia
- **Order:** Pectinida
- **Family:** Pectinidae
- **Genus:** *Chlamys*
- **Species:** *Chlamys islandica*

106

Mollusca

Gastropoda sp.1

- **Phylum:** Mollusca
- **Class:** Gastropoda
- **Order:** Neogastropoda
- **Family:** Buccinidae
- **Genus:** *Buccinum*
- **Species:**




107

Mollusca

Gastropoda sp.3

- **Phylum:** Mollusca
- **Class:** Gastropoda
- **Order:** Trochida
- **Family:** Trochidae
- **Genus:**
- **Species:**


108

Mollusca

Nudibranchia sp.1

- **Phylum:** Mollusca
- **Class:** Gastropoda
- **Order:** Nudibranchia
- **Family:** Dendronotidae
- **Genus:** *Dendronotus*
- **Species:** *Dendronotus elegans*

109

Mollusca

Nudibranchia sp.2

- **Phylum:** Mollusca
- **Class:** Gastropoda
- **Order:** Nudibranchia
- **Family:** Dendronotidae
- **Genus:**
- **Species:**

110

Mollusca

Nudibranchia sp.3

- **Phylum:** Mollusca
- **Class:** Gastropoda
- **Order:** Nudibranchia
- **Family:**
- **Genus:**
- **Species:**

111

Mollusca

Octopoda sp.1

- **Phylum:** Mollusca
- **Class:** Cephalopoda
- **Order:** Octopoda
- **Family:** Bathypolypodidae
- **Genus:** *Bathypolypus*
- **Species:** *Bathypolypus bairdii*

112

Porifera

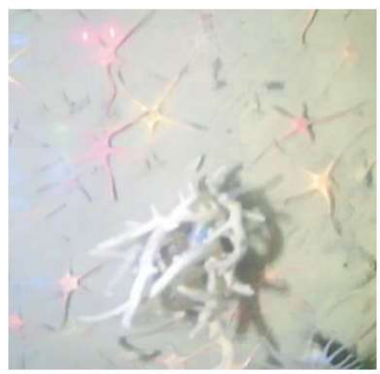
Sponges
AKittuk

Porifera

Erect

Branching sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:** Haplosclerida
- **Family:** Chalinidae
- **Genus:** *Haliclona*
- **Species:** *Haliclona (Haliclona) oculata*



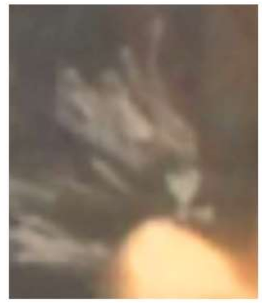
114

Porifera

Erect

Branching sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**



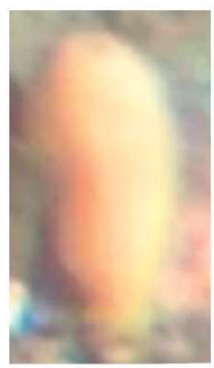
115

Porifera

Erect

Simple sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**



116

Porifera

Erect

Simple sp.3

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:** Poecilosclerida
- **Family:** Hymedesmiidae
- **Genus:** *Hymedesmia*
- **Species:**

117

Porifera

Erect

Simple sp.4

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

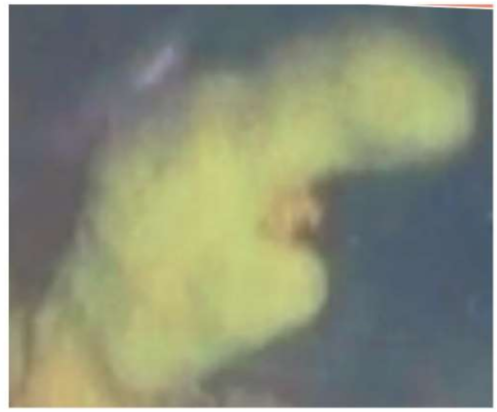
118

Porifera

Erect

Simple sp.5

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**



119

Porifera

Erect

Simple sp.6

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

120

Porifera

Erect

Simple sp.7

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

121

Porifera

Erect

Laminar sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

122

Porifera

Crust

Encrusting sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

123

Porifera

Crust

Encrusting sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

124

Porifera

Crust

Encrusting sp.3

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species: *encrusts scallop shells**

125

Porifera

Crust

Encrusting sp.4

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

126

Porifera

Crust

Encrusting sp.5

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

127

Porifera

Crust

Encrusting sp.6

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

128

Porifera

Crust

Creeping sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**





129

Porifera

Crust

Creeping sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**


130

Porifera

Crust

Creeping sp.3

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

131

Porifera

Cups

Barrel sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

132

Porifera

Cups

Cup sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

133

Porifera

Cups

Cup sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

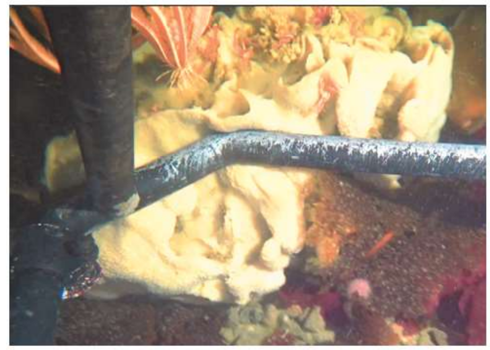
134

Porifera

Cups

Cup sp.3

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**



135

Porifera

Cups

Cup sp.4

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

136

Porifera

Cups

Cup sp.5

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

137

Porifera

Cups

Cup sp.6

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

138

Porifera

Cups

Cup sp.7

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

139

Porifera

Massive

Massive sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

140

Porifera

Massive

Massive sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

141

Porifera

Massive

Massive sp.3

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

142

Porifera

Massive

Composite sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

143

Porifera

Massive

Composite sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

144

Porifera

Massive

Composite sp.3

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

145

Porifera

Massive

Globular sp.1

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

146

Porifera

Massive

Globular sp.2

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:** Poecilosclerida
- **Family:** Hymedesmiidae
- **Genus:** *Hymedesmia*
- **Species:** *Hymedesmia curvichela*

147

Porifera

Massive

Globular sp.3

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:** Poecilosclerida
- **Family:** Hymedesmiidae
- **Genus:** *Hymedesmia*
- **Species:**

148

Porifera

Massive

Globular sp.4

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

149

Porifera

Massive

Globular sp.5

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

150

Porifera

Massive

Globular sp.6

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

151

Porifera

Massive

Globular sp.7

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

152

Porifera

Massive

Globular sp.8

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

153

Porifera

Massive

Globular sp.9

- **Phylum:** Porifera
- **Class:** Demospongiae
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

154

Unknowns

Unkown

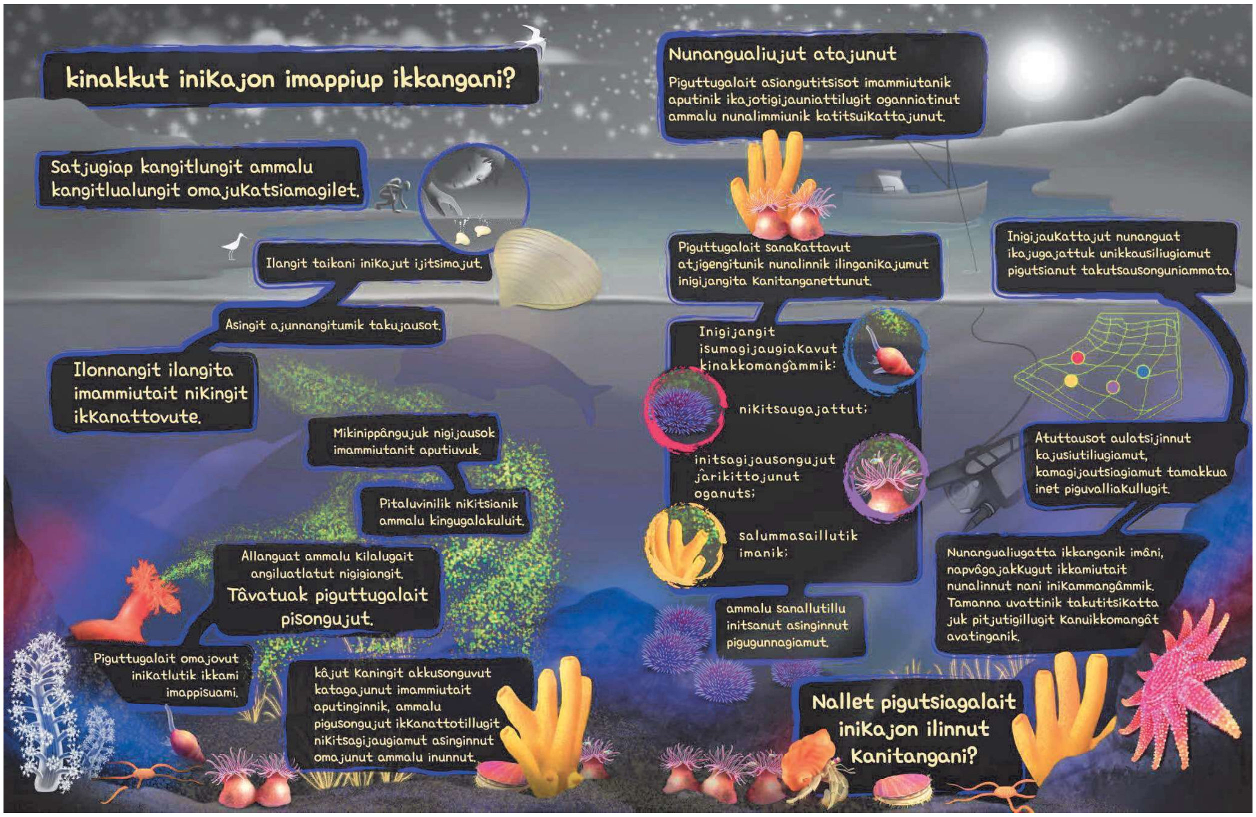
Unknown sp.1

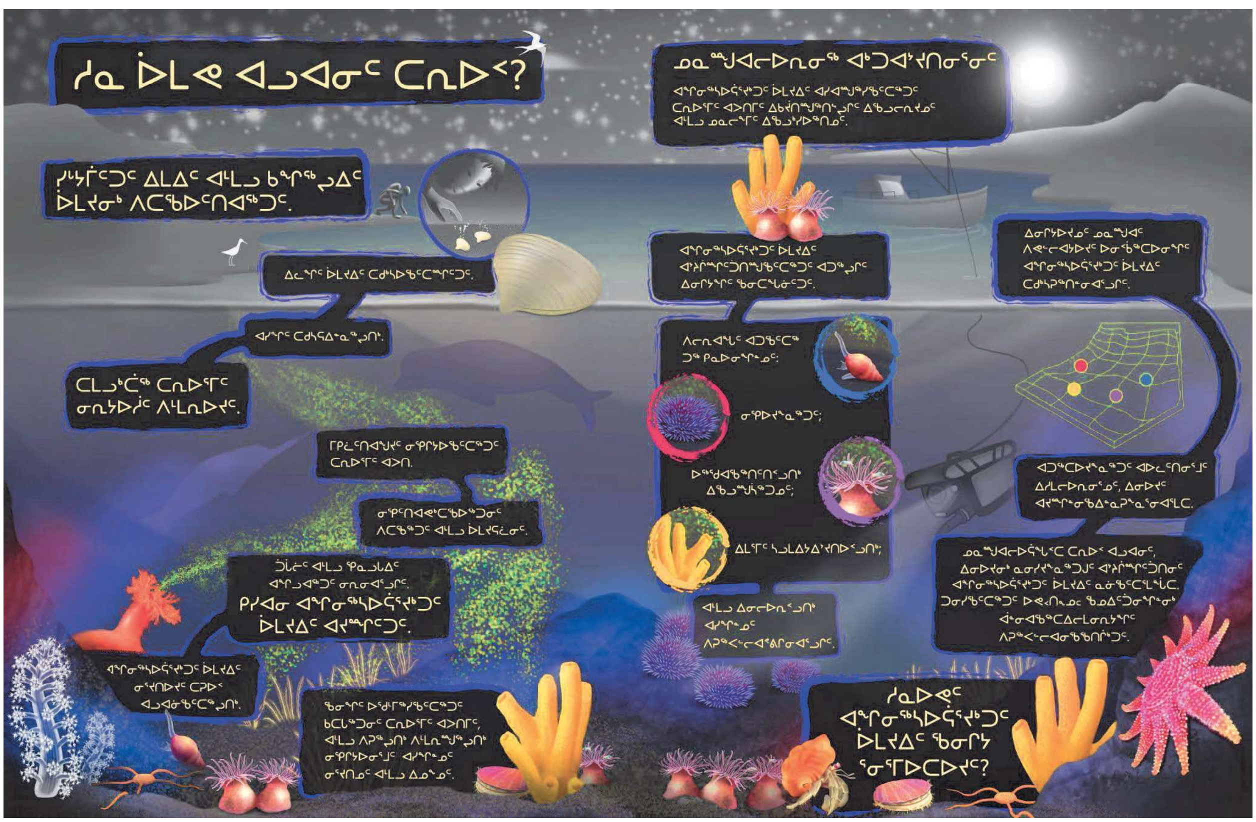
- **Phylum:**
- **Class:**
- **Order:**
- **Family:**
- **Genus:**
- **Species:**

156

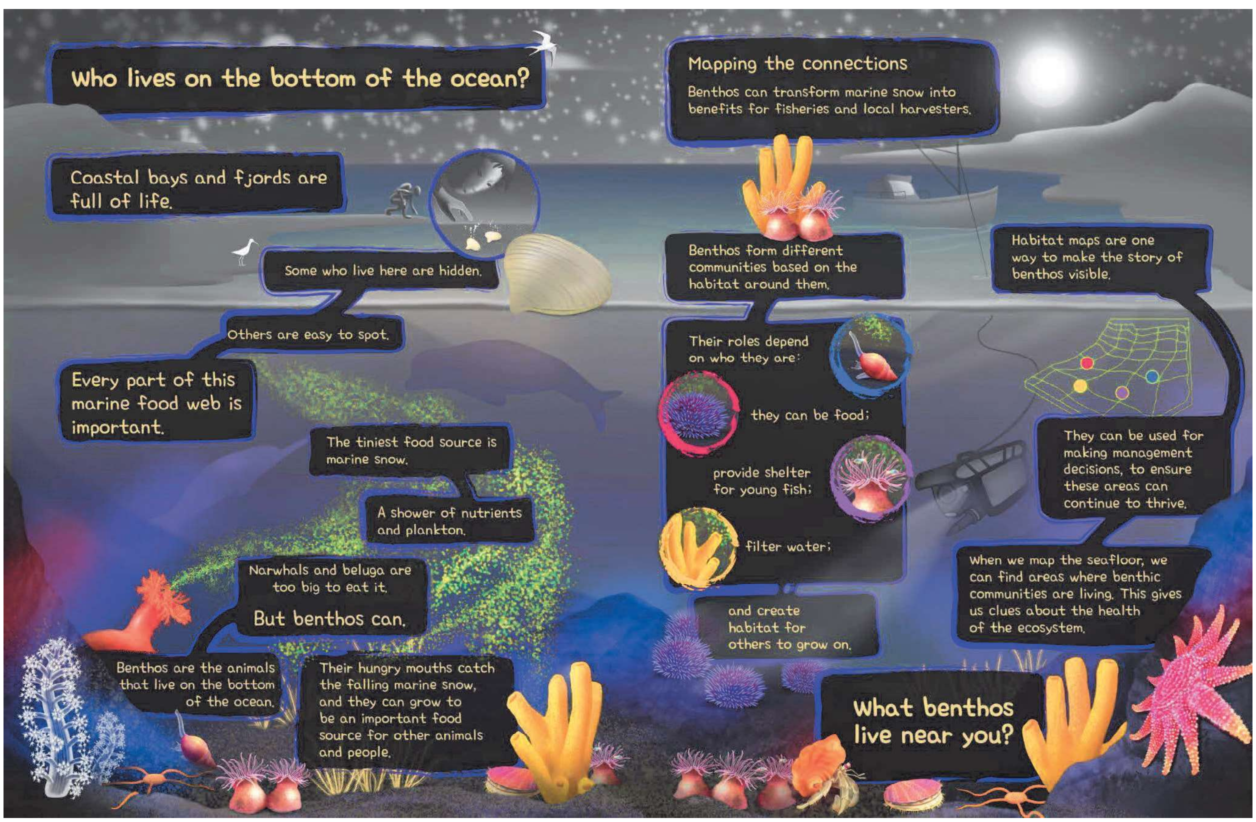
Appendix C

Figure C.1: Benthic Habitat Mapping Comic, created through the "Science to Art" 2023 contest run by the Association of Polar Early Career Scientists (APECS) and the Association of Canadian Universities for Northern Studies (ACUNS). Illustrations of the story of my work done by artist Misha Donohoe. Translated into Inuttitut and Inuktitut by WIN translations. French translated by myself. These banners were printed on fabric and shown at international conferences, and gifted to the Jens Haven Memorial high school in Nain, and Attagoyuk Illasivik high school in Pangnirtung.


kinakkut iniKajon imappiup ikkangani?
Satjugiap kangitlungit ammalu kangitlualungit omajuKatsiamagilet.
Ilangit taikani iniKajut ijitsimajut.
Asingit ajunnangitumik takujausot.
Ilonnangit ilangita imammiutait niKingit ikKanattovute.
Mikinippângujuk nigijausok imammiutanit aputiuvuk.
Pitaluvinilik niKitsianik ammalu kingugalakuluit.
Allanguat ammalu Kilalugait angiluatlatut nigigiangit.
Tâvatuak piguttugalait pisongujut.
Piguttugalait omajovut iniKatlutik ikkami imappisuami.
kâjut Kaningit akkusonguvut katagajunut imammiutait aputinginnik, ammalu pigusongujut ikKanattotillugit niKitsagijaugiamut asinginnut omajunut ammalu inunnut.
Nunangualiujut atajunut
Piguttugalait asiangutitsisot imammiutanik aputinik ikajotigijauniattilugit oganniatinut ammalu nunalimmiunik katitsuiKattajunut.
Piguttugalait sanaKattavut atjigengitunik nunalinnik ilinganiKajumut inigijangita Kanitanganettunut.
Inigijangit isumagijaugiaKavut kinakkomangâmmik:
niKitsaugajattut;
initsagijausongujut jârikittojunut oganuts;
salummasaillutik imanik;
ammalu sanallutillu initsanut asinginnut pigugunnagiamut.
InigijauKattajut nunanguat ikajugajattuk unikkausiliugiamut pigutsianut takutsausonguniammata.
Atuttausot aulatsijinnut kajusiutiliugiamut, kamagijautsiagiamut tamakkua inet piguvalliaKullugit.
Nunangualiugatta ikkanganik imâni, napvâgajakKugut ikkamiutait nunalinnut nani iniKammangâmmik. Tamanna uvattinik takutitsiKatta juk pitjutigillugit Kanuikkomangât avatinganik.
Nallet pigutsiagalait iniKajon ilinnut Kanitangani?



Qui vit au fond de l'océan?
Les baies côtiorès et les fjords regorgent de vie.
Certains qui y vivent sont cachés.
D'autres sont faciles à voir.
Chaque partie du réseau alimentaire marin est d'importance.
La neige marine, c'est la source de nourriture la plus minuscule.
Une averse de nutriments et de plancton.
Les narvals et les bélugas sont trop énormes pour les manger.
Par contre, les benthos s'en régalent.
Les benthos, c'est les animaux qui habitent au fond de l'océan.
Ils s'engouffrent de neige marine, et grandissent jusqu'à devenir une source de nourriture importante pour d'autres animaux et les humains.
La cartographie des connexions
Les animaux benthiques peuvent transformer la neige marine en bénéfices pour les pêcheries et les récoltes locales.
Les benthos forment des communautés diférentes en fonction de l'habitat qui les entoure.
Leurs rôles dépendent de leur identité:
Nourriture;
Abri pour poissons juvenilés;
Filtre à eau;
Habitat sur lequel d'autres peuvent grandir.
Les cartes d'habitat marin sont une façon de rendre l'histoire des benthos accessible à nos yeux.
Ces cartes peuvent être utiles pour prendre des décisions de gestion environnementale, question d'assurer que ces lieux restent prospères pour les générations à venir.
Lorsque l'on cartographie le fond marin, nous trouvons des endroits où les communautés benthiques y vivent en grand nombre. Cela nous laisse des indices sur la santé de l'écosystème.
Quels benthos vivent près de vous?



Who lives on the bottom of the ocean?
Coastal bays and fjords are full of life.
Some who live here are hidden.
Others are easy to spot.
Every part of this marine food web is important.
The tiniest food source is marine snow.
A shower of nutrients and plankton.
Narwhals and beluga are too big to eat it.
But benthos can.
Benthos are the animals that live on the bottom of the ocean.
Their hungry mouths catch the falling marine snow, and they can grow to be an important food source for other animals and people.
Mapping the connections
Benthos can transform marine snow into benefits for fisheries and local harvesters.
Benthos form different communities based on the habitat around them.
Their roles depend on who they are:
they can be food;
provide shelter for young fish;
filter water;
and create habitat for others to grow on.
Habitat maps are one way to make the story of benthos visible.
They can be used for making management decisions, to ensure these areas can continue to thrive.
When we map the seafloor, we can find areas where benthic communities are living. This gives us clues about the health of the ecosystem.
What benthos live near you?

Figure C.2: Benthos Playing cards designed with Misha Donohoe's illustrations, and an extra sculpin illustration by architect Di Hua. Production and printing by the Playing Card Factory. The cards themselves are a tool to show some of the benthos seen in both Nain and Pangnirtung. Beyond that they are a language tool, with English, French, Inuktitut and Inuttitut cycling through each benthos throughout the suites.

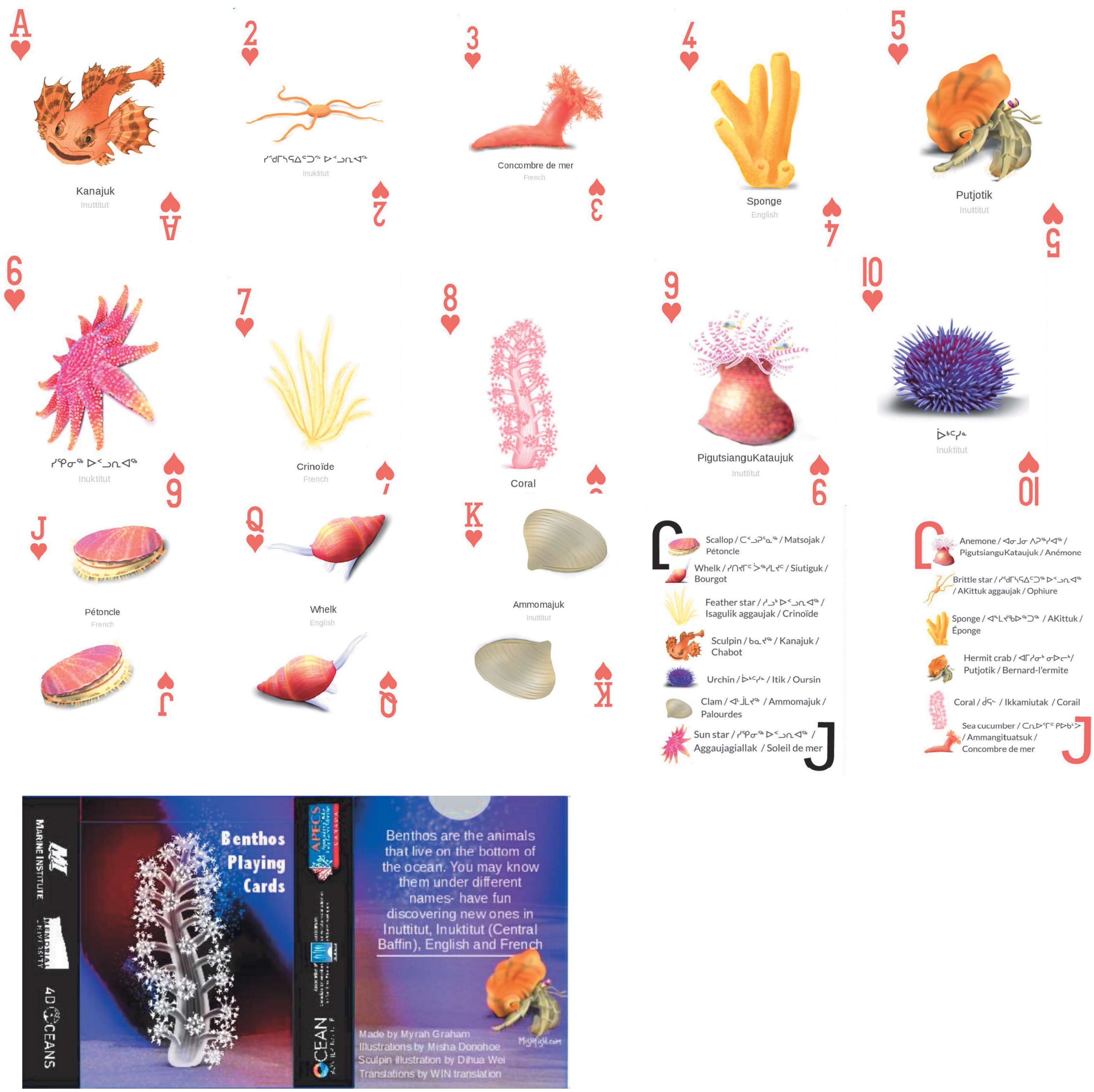


Figure C.3: Benthos Bingo Game and event flyer. Two versions of the game were created, one for younger students (images) and one with words in both English and Inuktitut. Variations in dialects were accommodated for each region. These events were run on week-day evenings, on nights where regular bingo was not happening. This was to ensure more people could attend, such as parents and working people, as well as hunters and trappers who would otherwise be away on the week-end.

Benthic Bingo

B	I	N	G	O
sun star	itik	eelpout	whelk	killotik
kuannik	matsojak	coral	sculpin	hermit crab
putjotik	scallop	Free space!	brittle star	anemone
clam	sea cucumber	sponge	siutiguk	ikkamiutak
aKittuk	urchin	feather star	kanajuk	kelp

Benthic Bingo