Advancing Seabed Mapping & Fjord Ecosystem Characterization across Nunavut's Glaciated Coast

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Background

1. Introduction

The GO-MARIE (Glacier-Ocean Mapping and Research Interdisciplinary Effort) is led by Ocean Research Project (ORP), a nonprofit organization based in Annapolis, Maryland. ORP conducts scientific research aboard a low-environmental impact sailing platform, The sailing research vessel (SRV) Marie Tharp. The mission of ORP's GO-MARIE project is to map the seabed and characterize the marine environmental conditions of the glacier fjords of the coastal Arctic Ocean. Glacial fjords are considered hotspots for carbon burial and are undergoing significant transformation due to a warming Arctic. The subterranean controlling depths of a glacial fjord and the adjoining continental shelf influence the circulation of water masses that directly impact glacial retreat and fjord ecosystem conditions.

Nicole Trenholm, field scientist and co-director, along with Matthew Rutherford, co-director and Captain for ORP, lead a team responding to the urgent need for international polar-ocean mapping and scientific process studies of glaciated fjords during targeted scientific research operations. The SRV Marie Tharp was launched in 2022 to address the need for these crucial geophysical and biogeochemical datasets. In the Spring of 2022, operations commenced in the sub-Arctic glaciated region of southwest Greenland.

The overall goal of the GO-MARIE 2023 campaign is to expand its seabed mapping program beyond the borders of the Arctic Ocean and above the Arctic Circle into Canadian Nunavut coastal areas. This expansion aims to diversify our team, and to effectively promote and present new ocean data for global public use in alignment with the priorities of the United Nations Sustainable Development Goals.

2. Team

Principal Investigator: Nicole Trenholm, Science Director for Ocean Research Project & PhD. Student, University of Maryland Center for Environmental Science
Captain: Matthew Rutherford, Executive Director, Ocean Research Project
Marine Technician: Anna D'Agostino, Marine Technician Intern, BEAMS Program, College of Charleston 2023
Crew: Adnaan Stumo, Allie Gretzinger, Anne Conover, and Nick Radtka
Technical Support: Konstantin Salenkov

*Relative to Objective 5. with an over 60% female crew, our campaign has increased career experience opportunities for female mariners and early hydrographic scientists.

3. Survey Location Overview

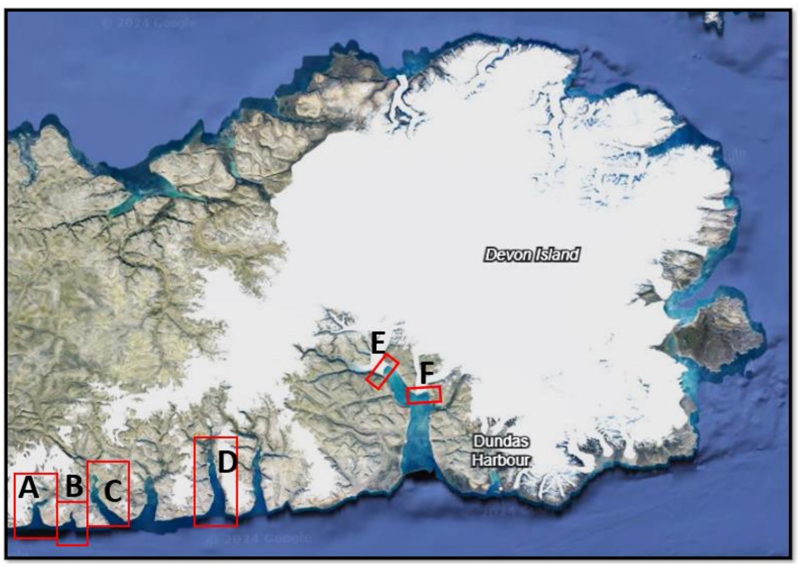
Devon Island is in the Baffin Bay, Qikiqtaaluk Region, Nunavut, Canada. With an area of over 55,000 km^2, Devon Island is the 6th largest island in Canada and the largest uninhabited island in the world. This area is part of Talluriuptiup Imanga, Canada's largest marine preservation area. The Nunavut community hunting culture of seal, walrus, polar bear, whale, and reindeer extends to the survey area. These areas of glacier retreat are a strong indicator for global sea level rise because of ice sheet loss due to a warming atmosphere. The survey region includes several fjords and areas where bathymetric seafloor and water column data are missing from present day seabed and ocean circulation models. Acquiring bathymetric data of these uncharted glacier fjords provides insight into the rate of sea level rise from climate change and can reveal the present the physical and biogeochemical ecosystem conditions significant to marine species and coastal community livelihood.

Devon Island; Nunavut, Canada

(**A**)Blanely Bay - Devon 1, (**B**) Hobhouse Inlet - Devon 2, (**C**) Statton Inlet - Devon -3, (**D**) Powell Inlet - Devon - 4, and (**E** & **F**) Croker Bay Fjords.

Latitude: 74.47495° N & 74.907717° N., *Longitude:* -87.41873° W & -83.1929° W

Figure 1: Devon Island Sub-region Multibeam Survey Coverage and Hydrographic Profiling/Sampling Areas (red boxes). Letters correspond with survey areas in sub-region images in Figure 2 & 3.



a. Regional Overview Map

The map (Fig. 1) depicts the survey areas along Devon Island coastline, where the nearest hamlets (not pictured) include Pond Inlet to the South and Resolute to the West in Nunavut, Canada.

b. Survey Coverage Overview Map

Figure 2. and 3. are maps that depict sub-survey areas along Devon Island in Nunavut, Canada. Blue pins indicate CTD profile locations, orange pins indicate CTD profile and water stations; and red pins indicate where a seabed core was taken. Survey fjords/inlets from west to east (left

to right) include: (A) 1. Blanely Bay, (B) 2. Hobhouse Inlet, (C) 3. Stratton Inlet, (D) 4. Powell Inlet, and (E & F) Croker Bay.

Figure 2: Devon Island Sub-region Multibeam Survey Coverage and Hydrographic Profiling/Sampling Areas. Letters correspond with survey areas in sub-region images.

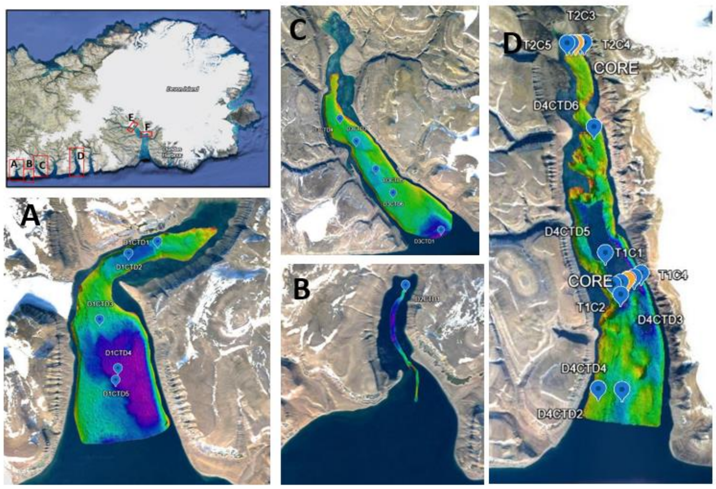
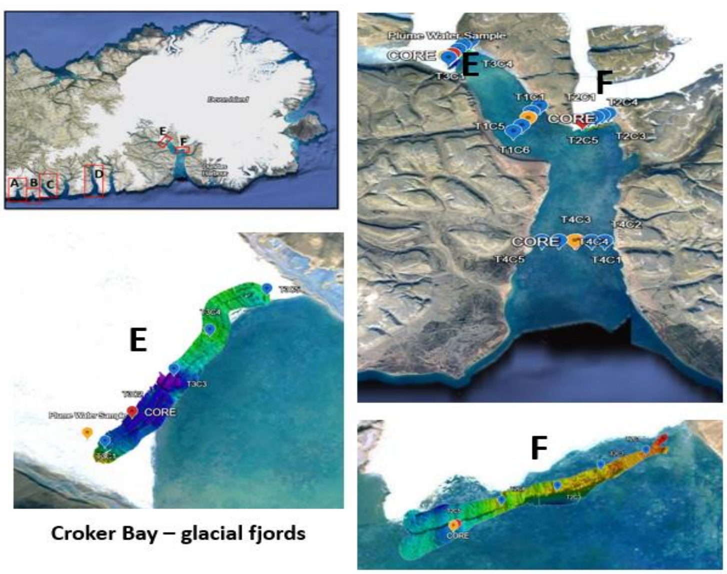


Figure 3: Devon Island Sub-region Multibeam Survey Coverage and Hydrographic Profiling/Sampling Areas in Croker Bay. Letters correspond with survey areas in sub-region images. Seabed bathymetry cooler colors are deeper areas.



c. Survey Coverage Metrics

Survey Project Area	Survey Area (km^2)
A. Devon 1	12.90
B. Devon 2	0.30
C. Devon 3	27.15
D. Devon 4	37.94
E. Croker North	1.09
F. Croker South	1.0
Total	**80.38**

d. Survey Period (July 31st- August 9th, 2023)

e. Stations (47 CTD stations, 18 water samples collected at specific depths at transects within Powell Inlet and Croker Bay and 6 seabed cores)

4. GO-MARIE 2023 Sponsors

- **Heising-Simons Foundation** funded the expansion of our GO-MARIE mission to conduct observations in the Canadian Arctic Archipelago with advanced geospatial positioning technology. Their support spurs our commitment to investigate a changing Arctic with a targeted effort throughout the ocean decade to 2030.
- **Hypack** and **QPS** continued to provide in-kind software for hydrographic data management and data product generation.
- **Fugro** provided an in-kind satellite constellation license for the remote satellite constellation solution needed for the best geospatial positioning of our data during the project, an OmniStar ESAT or AMSAT solution.

5. Diplomatic Clearance

The following permits entities were required obtain clearance to conduct the marine survey in Nunavut, Canada. Please refer to Appendix IV. regarding permitting correspondence.

- Canadian-US Embassy
- Department of Fish and Oceans, Canada
- Nunavut Planning Commission
- Nunavut Impact Review Board

2023 Objectives

1. To expand the **GO-MARIE** mapping activity and mapping collaborations from Greenland to Canada to eliminate coastal seabed bathymetry gaps in Canada's Arctic Nunavut territories, and particularly Devon Island.
2. To advance our range of seafloor mapping operations from sub-polar to polar environmental conditions and to increase our mapping coverage among a greater density of ice mélange and numerous larger icebergs within and along coastal fjords. ORP expands mapping coverage from a singlebeam echosounder used during NASA's Oceans Melting Greenland (OMG) mission surveys in 2015 and 2016 to multibeam echosounder. The multibeam echosounder that is integrated into RV Marie Tharp's ship hull improves upon a pole-mount at risk for ice strikes.
3. To advance our scientific research collaborations in the Canadian Arctic by returning to Devon Island coastal glacial fjords where ORP conducted a reconnaissance study in 2018, where ORP's PI participated in the Heising-Simons Foundation's Northwest Passage and furthered relationships with Nunavut locals and researchers.
4. To work towards streamlining data availability globally for our polar seabed observations.
5. To work towards gender equality for the enhanced participation of women in ocean mapping and polar exploration.

Hypotheses & Questions

The overarching science hypotheses and questions pursued during the GO-MARIE 2023 mission along the coastal land-ice margin of the eastern Canadian Arctic Archipelago are as follows:

Hypothesis 1.: Ocean currents of Atlantic Ocean origin decrease in their influence across southern Devon Island glacial fjords due to the seabed restrictions in current circulation west of Croker Bay.

> **Question 1**. What are the controlling depths and seabed features that influence fjord circulation and how does that vary between glacial fjords of varying degrees of deglaciation?

Hypothesis 2: Devon Island glaciated fjords are likely to have a greater concentration of organic carbon burial than deglaciated fjords.

> **Question 2:** How do the glacial fjord ecosystems differ in carbon burial capacity in fjords of varying degrees of deglaciation?

Scientific Approaches

A. Conduct multibeam surveying to generate a subterranean three-dimensional grid of uncharted glacier fjords in Arctic Canada using Hypack and QPS software.

B. Collect water column observations to assess the physical ocean controls and geochemical characteristics necessary for interpreting the factors influencing the rate of organic carbon burial through the following means:

    a. Physical Sampling of water
    b. CTD Sensor Profiling
    c. Continuous flow-through sea surface sensor observations

C. Collect seabed sediment cores to identify the degree of organic carbon burial and carbon origin associated with the fjord's degree of deglaciation.

Methods

Shipboard Observations: Data collection was conducted onboard Ocean Research Project's SRV Marie Tharp. The 22 m steel-schooner is outfitted with a singlebeam and multibeam sonar. ORP conducts water column sensor profiling and physical sampling, flow-through sensing and sampling, and wet lab filtration capacity. Vessel modifications were conducted before the expedition to reinforce the hull and keel with steel support, enhancing vessel strength to facilitate multibeam sonar surveying in icy waters. Specifically, a steel guard for ice deflection was welded around the sonar and the propeller.

A. ***Hydrographic CTD Profiles:*** Two RBR Concerto CTD instruments were lowered on the same cage to just above the seafloor. S/N 060671 was calibrated in June 2023 and possesses a turbidity sensor (NTU) that takes measurements every 3 seconds. S/N 204223 was calibrated in spring 2022 and has a Chlorophyll sensor. Both Concerto instruments take traditional physical ocean measurements and have an auxiliary dissolved oxygen (D.O.) concentration sensor (umol/L). CTD S/N 204223 was deployed at all stations, while CTD S/N 060671 was deployed alongside S/N 204223 at all stations post Stratton Inlet (Devon 3). CTDs were pressure rated to 600m due to D.O. sensor.

    a. ***CTD Data Acquisition***

CTDs were conducted throughout the survey and along six transects (2 transects within Powell Inlet at 4 transects within Croker Bay). CTD profiles were collected approximately every four hours and at the start, and conclusion of each multibeam survey in the survey area; Project: Devon (A)1, (B) 2, (C) 3, and (D) 4. CTD Transect profiles were acquired in an across-fjord orientation at varying distances from the glacier face. Transects 1 and 2 in Devon 4 were conducted 0 km and 13 km from the glacier respectively. Transects 1 and 4 within Croker Bay (Project E and F) were conducted 9 km and 15 km while transects 2 and 3 were conducted directly in front of the glacier. Profiling and water stations overlapped within transect stations.

    b. ***CTD Data Processing***

Preliminary data processing was conducted for the isolation of sound velocity measurements for multibeam survey data processing and for preliminary section plots of transect data using Ocean Data Viewer. (See Appendix 1.)

Table 1: CTD Profile Table

Project	Transect ID	Station ID	Latitude (DD)	Longitude (DD)	RBR CTD S/N 060671 File Name (.rsk)	RBR CTD S/N 204223 File Name (.rsk)
Devon 1	CTD1	D1C1	74.530233	-87.362167	n/a	204223_20230731_1544
Devon 1	CTD2	D1C2	74.527083	-87.390517	n/a	204223_20230731_2103
Devon 1	CTD3	D1C3	74.5093	-87.418733	n/a	204223_20230801_0103

Devon 1	CTD4	D1C4	74.496133	-87.400933	n/a	204223_20230801_0545
Devon 1	CTD3	D1C5	74.492983	-87.403167	n/a	204223_20230801_1011
Devon 2	CTD1	D2C1	74.5012	-87.019867	n/a	204223_20230801_1437
Devon 3	CTD1	D3C1	74.47495	-86.533383	n/a	204223_20230801_1639
Devon 3	CTD3	D3C3	74.530483	-86.7354	n/a	204223_20230801_0144
Devon 3	CTD4	D3C4	74.544683	-86.774233	060671_20230802_0712	n/a
Devon 3	CTD5	D3C5	74.513267	-86.688333	n/a	204223_20230802_1209_01
Devon 3	CTD6	D3C6	74.498333	-86.647417	060671_20230802_1730	n/a
Devon 4	CTD2	D4C2	74.522917	-85.486683	060671_20230803_1218	204223_20230803_1218
Devon 4	CTD3	D4C3	74.564217	-85.4486	060671_20230803_1808	204223_20230803_1738
Devon 4	CTD4	D4C4	74.52245	-85.477483	060671_20230803_2207	n/a
Devon 4	CTD5	D4C5	74.582567	-85.4734	060671_20230803_0658	n/a
Devon 4	CTD6	D4C6	74.63785	-85.49065	060671_20230803_1508	204223_20230803_1510
Devon 4	T1	T1C1	74.570533	-85.43807	060671_20230804_0401	204223_20230804_0340
Devon 4	T1	T1C2	74.569617	-85.447667	060671_20230804_0538	204223_20230804_0539
Devon 4	T1	T1C3	74.571767	-85.426167	060671_20230804_0605	204223_20230804_0607
Devon 4	T1	T1C4	74.573517	-85.414567	060671_20230804_0634	204223_20230804_0612
Devon 4	T1	T1C5	74.5686	-85.45995	060671_20230804_0701	204223_20230804_0658
Devon 4	T2	T2C1	74.6747	-85.519983	060671_20230804_0828	204223_20230804_0825
Devon 4	T2	T2C2	74.674717	-85.527367	060671_20230804_1021	204223_20230804_1019
Devon 4	T2	T2C3	74.674783	-85.512567	060671_20230804_0950	204223_20230804_0953
Devon 4	T2	T2C4	74.674883	-85.50585	060671_20230804_1006	204223_20230804_1010
Devon 4	T2	T2C5	74.674667	-85.534317	060671_20230804_1032	204223_20230804_1019
Croker	T1	T1C1	74.820867	-83.377	060671_20230806_0231	204223_20230806_0231
Croker	T1	T1C3	74.827833	-83.366667	060671_20230806_0231	204223_20230806_0231
Croker	T1	T1C4	74.834367	-83.342283	060671_20230806_0231	204223_20230806_0231
Croker	T1	T1C5	74.813083	-83.3961	060671_20230806_0231	204223_20230806_0231
Croker	T1	T1C6	74.806433	-83.4219	060671_20230806_0231	204223_20230806_0231
Croker	T2	T2C1	74.8256	-83.159817	060671_20230806_0231	204223_20230806_0231
Croker	T2	T2C2	74.823567	-83.15545	060671_20230807_0236	204223_20230807_0223
Croker	T2	T2C3	74.8213	-83.173383	060671_20230807_0256	204223_20230807_0239
Croker	T2	T2C4	74.8197	-83.196467	060671_20230807_0325	204223_20230807_0257
Croker	T2	T2C5	74.816717	-83.216417	060671_20230807_0346	204223_20230807_0328
Croker	T3	T3C1	74.888983	-83.614617	060671_20230808_1820	204223_20230808_1802
Croker	T3	T3C2	74.8926	-83.603283	060671_20230808_1731	204223_20230808_1718
Croker	T3	T3C3	74.89785	-83.585883	060671_20230808_1718	204223_20230808_1717
Croker	T3	T3C4	74.902683	-83.570863	060671_20230808_1656	204223_20230808_1658
Croker	T3	T3C5	74.907717	-83.546933	060671_20230808_1638	204223_20230808_1638
Croker	T4	T4C1	74.682933	-83.154067	060671_20230809_1249	204223_20230809_1227
Croker	T4	T4C2	74.6833	-83.1929	060671_20230809_1319	204223_20230809_1318
Croker	T4	T4C3	74.683883	-83.243663	060671_20230809_1347	204223_20230809_1347

Croker	T4	T4C4	74.684033	-83.290367	060671_20230809_1516	204223_20230809_1459
Croker	T4	T4C5	74.684117	-83.341367	060671_20230809_1534	204223_20230809_1521

B. ***Water Sampling**:* Manual 5L or 10L- Niskin bottles were lowered to collect water at discrete depths, using a bronze trigger weight to manually close the sample bottle at the desired depths. Water samples were typically collected at 1 m below the surface and at designated intermediate and deep depths. Choosing the deeper samples were determined based on turbidity, chlorophyll and dissolved oxygen readings from CTD measurements. Samples were collected at 18 stations within Powell Inlet and Croker Bay.

Figure 4 Filtered suspended sediment

C. ***Shipboard Lab Filtration**:* At designated water sampling stations, collected samples were filtered in the ship's lab for suspended particulate matter and dissolved geochemical species. Water samples were filtered using a 0.7-micron Millipore cellulose filter which were then stored in a 4°C refrigerator. Filtration instruments were routinely rinsed with ship made DI water in between each sample filtering. Lab water can be defined as ship desalination water that has been pre-filtered by 0.7 and 0.2-micron GF/F. Samples were run until a filter clogged then the volume, station, and filter ID were logged in a master log.

Table 2: Water Sample Stations

Project	**Transect ID**	**Station ID**	**Water Sample Depths (m)**
Devon 4	T1	T1C1	1, 50, 250
Devon 4	T2	T2C1	1, 25, 100
Croker	T1	T1C1	1, 25, 150
Croker	T2	T2C5	1, 50
Croker	T3	T3C2	1, 25, 150
Croker	T4	T4C3	1, 47, 250
Croker	n/a	N Plume	0

D. ***Seabed Cores***

***Acquisition**:* 6 core samples were taken with a Uwitec Gravity Corer at one station per CTD/water sampling transect. Cores were stored in an onboard refrigerator during the cruise. In Croker Bay cores were strategically collected near a glacier face and downstream of the glacier face within the fjord. At Project, Devon 4, Powell Inlet, cores were collected near the fjord beginning and closer to the fjord end. At Devon 1 at seafloor of 112 m deep, a grab sample was acquired but with a corer and it was highly coarse sediment. This grab sample was collected at 74 30.334 N, 87 25.180 W.

Table 3: Core Sample Table

Project	Transect ID	Station ID	Latitude (DD)	Longitude (DD)	Depth (m)	Core Length (cm)
Devon 4	T1	T1C1	74.570533	-85.43807	255	23
Devon 4	T2	T2C1	74.6747	-85.519983	105	13
Croker	T1	T1C1	74.820867	-83.377	175	26
Croker	T2	T2C5	74.816717	-83.216417	130	40
Croker	T3	T3C2	74.8926	-83.603283	150	15.5
Croker	T4	T4C3	74.683883	-83.243663	300	33

Seabed Core Processing Objectives:

1. General macro-assessment of cores will be conducted such as first grain size analysis, ice-rafted debris deposits observations, and bioturbation.
2. Carbon burial rates will be determined of the deglaciated fjord D. Devon 4 (Powell Inlet) and in marine-terminating glacier fjord Croker Bay.

   Samples will be sent during Winter of 2024 of the major lamination changes in sediment composition after the 5 cm surface mixed layer. for the following analyses:

   a. sediment accumulation rate via ^{210}Pb radioisotope analysis at University of Florida
   b. Carbon isotope C14 and Carbon to Nitrogen bulk abundance assessment at University of Florida.

Figure 5 Split cores

3. Biological presence and absence of in-situ marine productivity the fjord ecosystem between deglaciated and marine-terminating glacial fjords will be detected through the assessment of biogenic silica variation in the seabed cores. The analysis will be conducted at the University of Maryland Center for Environmental Science, Horn Point Laboratory, set to begin in Spring 2024.
4. Microfossils species abundance of foraminifera will indicate a more terrigenous or marine influence on a fjord ecosystem through foram microscopy analysis set to begin in Spring 2024.

Figure 6 ADCP on pole in Blanely Bay

E. ***ADCP**:* Acoustic Doppler Current Profiler Teledyne Workhorse 600 KHz with a 70 m range and 4 m bin size. The ADCP was used to collect the current velocity and water column backscatter derived from suspended sediment concentration measurements to acquire a proxy in the magnitude of suspended material in flow.

   a. ADCP transect was conducted at A., Devon 1 just in front of the land-retreated glacier and in F. Croker Bay South in front of the marine-terminating glaciers (for the shallower part of the transect).

Figure 6: ADCP transects.

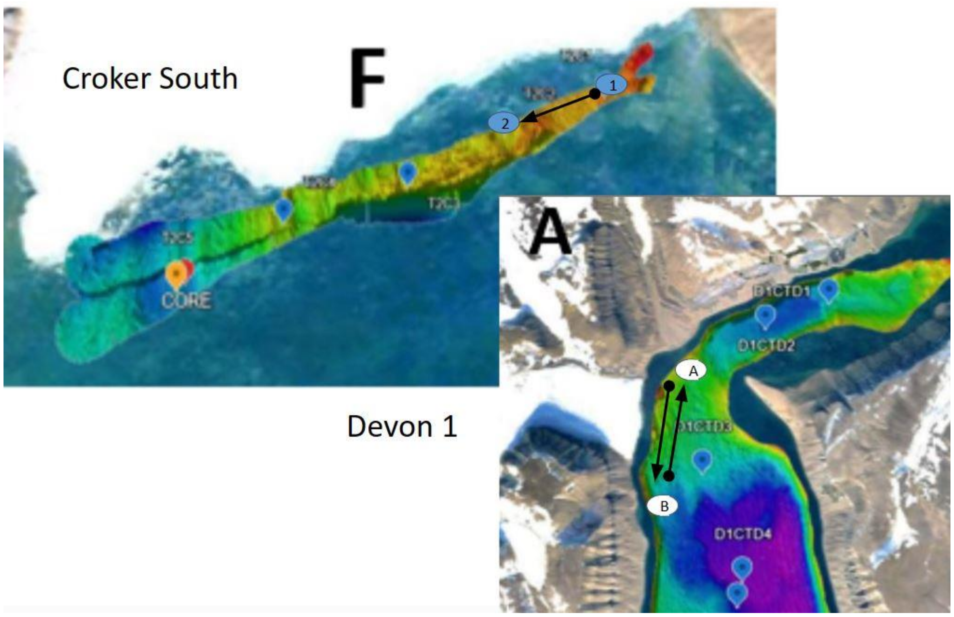


Table 4: ADCP Stations

Station	Time Start/End (UTC)	Latitude N	Longitude W
Devon 1 - Station A	11:14	74° 31’ 12.464	87° 26’ 12.558
Devon 1 - Station B	11:25, 11:30	74° 30’ 44.636	87° 26’ 27.181
Croker South Station 1.	23:00	74° 49.536	83° 08.589
Croker South Station 2.	n/a	74° 49.414	83° 09.327

Table 5: ADCP Stations

Project and ADCP data collection pathway relative to Station information	Filename .PD0, *files include .mmt and associated GPS txt.	File size (mb)

A. Devon 1 from Station A->B	Devon_1_0_001.PD0	1.98
B. Devon 1 from Station B->A	Devon_1_0_002.PD0	
F. Croker South from Station 1. to 2.	CrokerSouth_0_000.PD0	4.44
F. Croker South from Station 2 to 1	CrokerSouth_0_001.PD0	

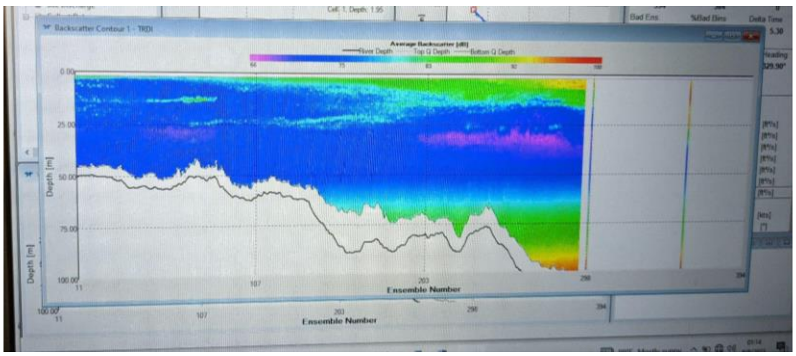


Figure 7 Backscatter image proxy for suspended sediment (artifacts > 100 m) from Station 1 to Station 2 in front of Croker Bay Glacier South.

Xylem YSI ProQuatro Handheld Meter: Measurements included water quality parameters, pH, salinity, temperature and dissolved oxygen. The meter was calibrated daily and was continuously run through surface waters throughout the survey and during transect stations.

F. ***Single-beam Echosounder***: A Raymarine/AIRMAR Frequency (50-200 kw) Echosounder with DGPS was used for ship positioning. Single-beam depth data was monitored to obtain maximum depth profiles and locations for water sampling activities in the water column.

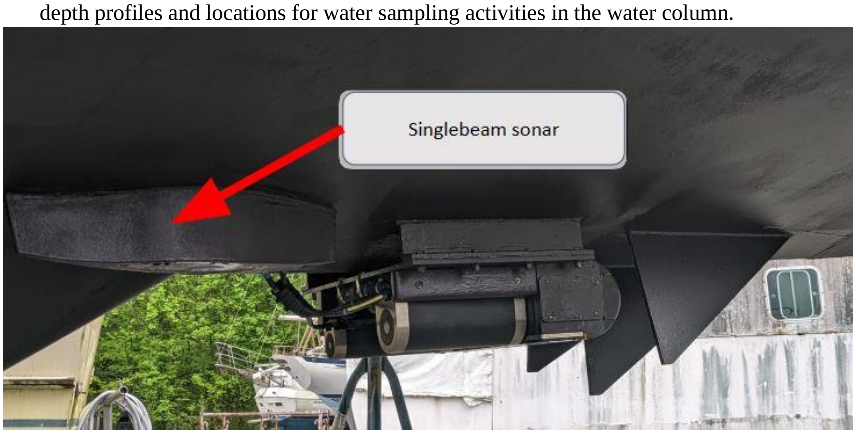


Figure 8 Singlebeam Sonar location (starboard hull)

G. ***Multibeam Echosounder:*** A Reson Seabat 7125 V4 200 kHz sonar with an Ekinox SBG Inertial Motion Unit and Trimble DGPS with OmniSTAR positioning was used to collect bathymetric data. The data coordinate system was in WGS-84 ellipsoid UTM 16 North for data acquisition and product generation in Hypack. **Refer to Appendix III**. **Multibeam System Integration, Calibration and Data Report.**

Results

1. Objective 1-3. Survey Highlights

Multiple fjords were selected for survey for the purpose of supporting contributions to the bathymetric seabed map. Collecting bathymetry data within glacier fjords are the key additions to GEBCO and IBCAO coastal maps along towards current and future climate predictions and research on ice sheet mass loss. An area the size of Disneyland (around 80 km^2) was mapped with the multibeam echosounder. Stormy weather week limited survey up to several days, pack-ice obstacles appeared during survey activity and the requirement for a deeper range multibeam sonar to ensonify the full fjord depth range limited maximum seabed mapping potential during our project period. However, the constrained time for data collection afforded us the time to enhance relationships with the Nunavut community researchers, teachers, and hunters in Nunavut's hamlet of Pond Inlet.

Multibeam Survey: We completed multibeam echosounder survey coverage in three entire fjords and partial areas within other fjords. Full multibeam surveys were conducted within Blanely Bay, Stratton Inlet, and Powell Inlet. One line of multibeam survey was conducted within Hobhouse Inlet due to shallow water risks, and two separate surveys were conducted within Croker Bay, in front of each glacier's terminating face.

Significant Multibeam Fjord Surveys: Surveys conducted within Blaney Bay, Hobhouse Inlet, Stratton Inlet, and Powell Inlet filled gaps missing within current bathymetric maps. Three of the five fjords surveyed contained one or two full glaciers while others had land retreating or fully retreated glaciers.

Figure 9 Blanely Bay sediment-rich glacial meltwater plume

Devon 1: Blanely Bay (A.)

Blanely Bay has a recently land-retreated glacier fjord during the Holocene. The fjord was mapped in its entirety with a depth range of 35m to 150 m. A total of five CTDs were taken during the survey and converted to SVPs, interpolated for closest in time and position to account for offsets in depth refraction of sound. Bathymetry showed two over deepening features downstream of the glacier sites. Pro-glacial streams remain as the sole indicator of a once land-retreated glacier at the beginning of the fjord. There is no longer a glacier at the far end and these streams interconnect and originate from the Devon Ice Cap. The base of the fjord a second greater deepening contains depths over 150 m, while the upstream deepening contains depths around 100 m. Indications of submarine canyons in front of the visible land-retreated glacier appear at around 90 m depth. There are also some indentations near the mouth of the fjord which could indicate the glacier once scraping the floor or icebergs. Seabed line multibeam swaths generally line up well, however tidal variation is not resolved and additional sound velocity profiles would have improved the seabed surface alignment.

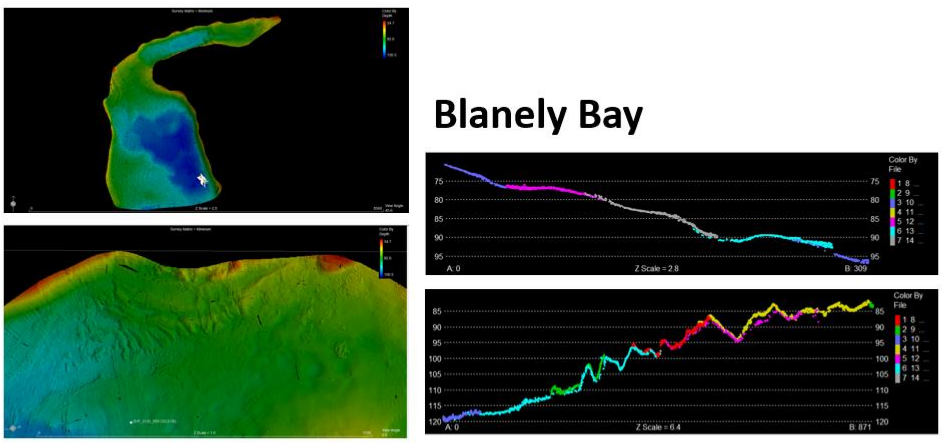


Figure 10 Blanely Bay - Bathymetry and across track sonar swath seabed alignment

Devon 3: Stratton Inlet (C.)

Stratton Inlet did not have a glacier and ranged in depth from 40 m to 250 m. Stratton was mapped in its entirety and consisted of five CTDS (refer to Table 1) taken throughout the two-day survey. SVPs were applied in HYPACK editor based on closest time and position. Bathymetry characteristics included three noticeable deepening's located within the middle and mouth of the fjord. Deepened areas were around 200 m. The sides were shallow with a change in depth of 100 m. A cross-section shows the 2 m (6ft) offset.

Stratton Inlet

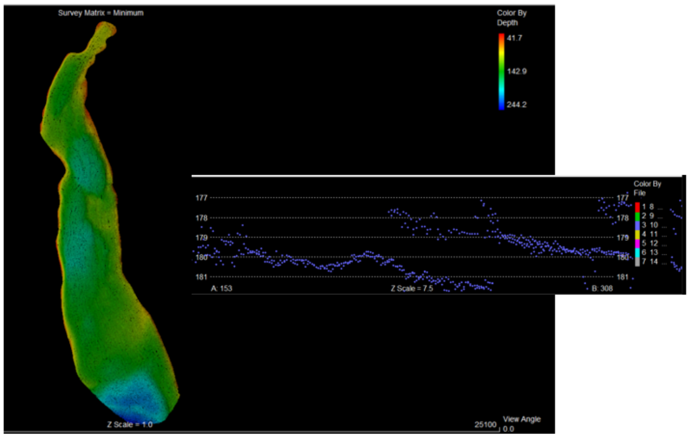


Figure 11 Stratton Inlet- Bathymetry and across track sonar swath seabed alignment

Devon 4: Powell Inlet (D.)

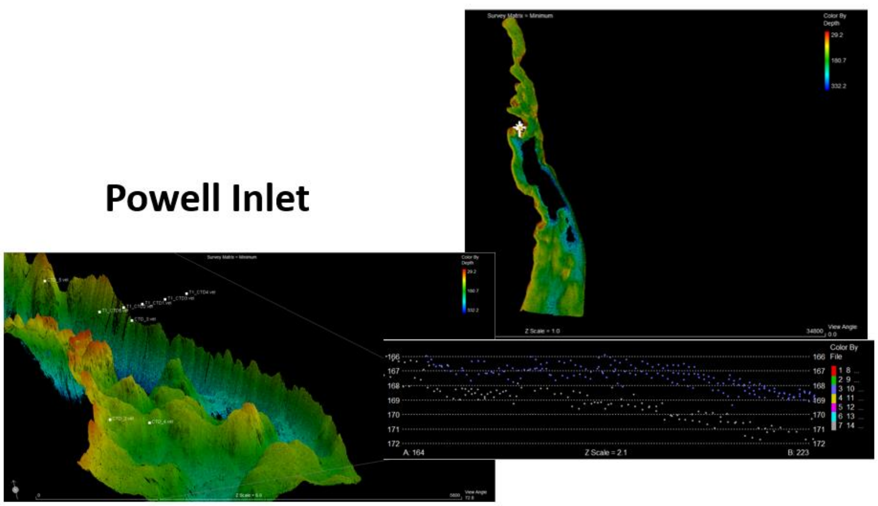


Figure 12 Powell Inlet - Bathymetry and across track sonar swath seabed alignment

Powell Inlet had a land retreating glacier with the fjord ranging from 30 m to over 350 m. There is a hole in the middle of the bathymetric map due to depths undetected by the sonar. There was a total of 15 CTDs (table 1) taken within the fjord, with 10 CTDs belonging to 2 transects taken close to and far from the glacier (table 1). Both transects also had one sediment core (table 3) and one water station with 3 depth samples (table 2). The fjord displayed a very rocky seabed, with many large shallow areas. Rocky areas typically ranged in over 100 m from shallowest to deepest point. The patch test was conducted within Powell Inlet to determine offsets. Similar to Stratton, Powell Inlet had an offset of 2 m (6ft). SVPs were applied based on their data acquisition time choosing the closest in time profile for data processing.

(E.) Croker Bay North and (F.) South

The survey was only conducted in front of the glaciers within Croker Bay due the understanding that the Canadian Icebreaker Amundsen would map the deeper fjords areas of Croker Bay in Fall of 2023. Depths ranged from 25 m to 185 m. Each glacier was passed in front four times for each survey. There was a total of four transects within Croker Bay, one in front of each glacier, one in the middle, and the other closer toward the mouth. Each transect had 5 CTDs (table 1), 1 water station with 3 depth samples (table 2), and 1 sediment core (table 3). There was one extra water sample taken at the plume surface (table 2) near Croker Bay Glacier North. Both surveys were under the same offsets with SVPs applied based on closest time and position.

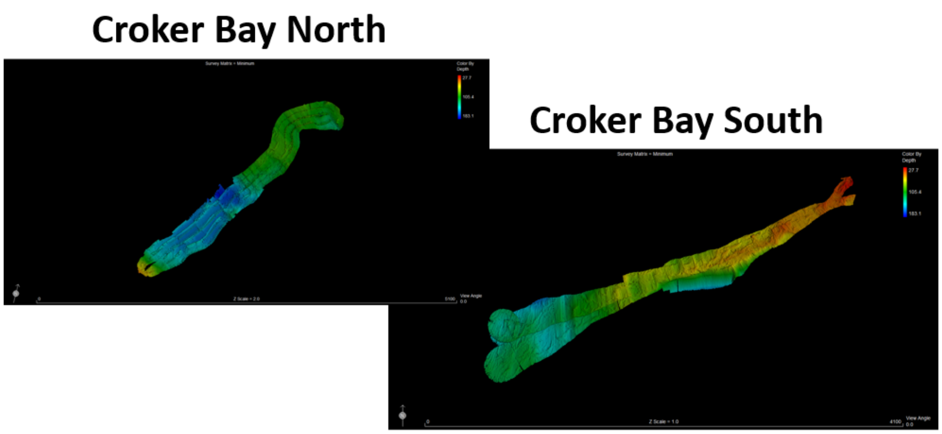
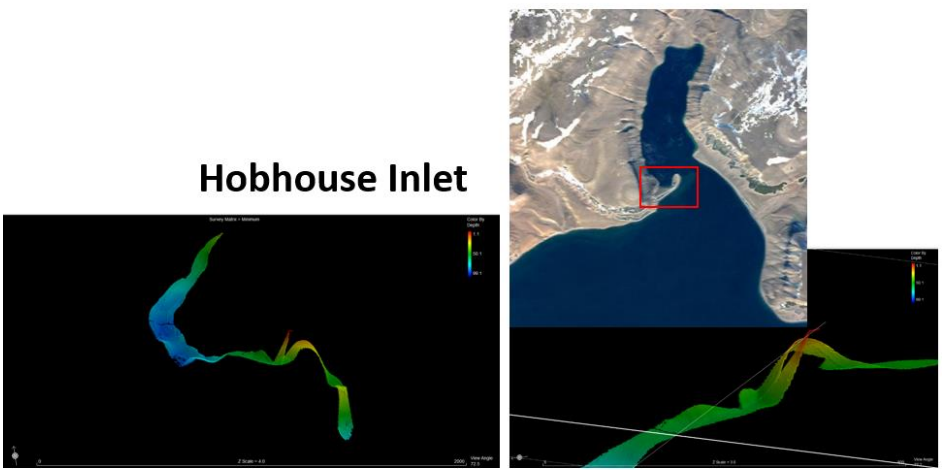


Figure 13 Croker Bay - Bathymetry& Photos, Left: Croker Bay North Glacier Right: Croker Bay Sound Glacier

(B.) Devon 2: Hobhouse Inlet

Hazardous peninsula submerged sandbar in Hobhouse Inlet: A shallow area, not visible by satellite, especially during high tide, existed within Hobhouse Inlet. As an uncharted area, coastal shelves that emerge only during high tides pose navigation within Hobhouse and similar inlets. Mapping of these areas is of great importance to prevent future maritime accidents. Most of Hobhouse Inlet remained unmapped due to shallow depths not safe for navigation by SRV Marie Tharp. Depths recorded through one line of survey were < 5 m during low tide.

Hobhouse Inlet is a small fjord ranging in depth from <1 m to 90 m. There is no remaining glacier within Hobhouse Inlet. This survey was cut after one line due to recognition of a potential hazard to navigation, located at 79° 29’ 5.5299 N and 087° 00’ 57.98W. Only five lines were taken due to this hazard. One CTD was taken at the very beginning of the survey and was applied as an SVP closest in time and position. There were no transects or other data taken within the fjord. Patch test values were applied in Read Parameters.



2. Objective 4. Products & Deliverables

To meet Objective 4. for efficient data dispersal and availability have distributed the following products and deliverables. We list the bathymetric data products as raster (.TIF) files and point cloud text files (.xyz) generated from HYPACK. The .xyz files were imported into Fledermaus to create some fly through videos to further evaluate of seabed features within each survey. The total data size in bathymetric products amounted to 6.6 (gb), with 4.35 gb in (.xyz) files and 6.62 mb in (.TIF) files. To meet permitting and diplomatic clearances as well as data sharing intention with models and Arctic state collaborators note the products, recipients, and data submission dates below. Please refer **to Appendix IV. Correspondence & Permitting and Diplomatic Clearance** section for further information.

1. Mittimatalik HTO Hunters and Trappers Organization, (pond@baffinhto.ca) - They requested we acquire a letter of support in advance for continued research activity.

Commented [nt2]: Check this

2. Fisheries & Oceans Canada: License to Fish for Scientific Purposes was acquired (due to water sample and seabed core sample collection) through correspondence with (DFO.ArcticLicensing-PermisArctique.MPO@dfo-mpo.gc.ca)

The bathymetric data submission, metadata and report was sent to, (DFO.CHSOPADataCentre-CentreDeDonneesCHSOPA.MPO@dfo-mpo.gc.ca) via an external hard drive addressed to Canadian Hydrographic Service headquarters on 2/23/2024 after initial contact via email correspondence. Guidance was provided by Dana Gallant the Manager of the Hydrographic Data Access and Contracting and Greg Dixon, Engineering Project Supervisor with attention to Marcus Beach at 867 Lakeshore Rd. Burlington, ON, Canada L7S 1A1.

3. Nunavut Research Institute - Scientific Research License was acquired.
4. Nunavut Planning Commission - exempt from screening by the NIRB

GEBCO IBCAO – The .TIF and .xyz files were submitted to IBCAO on November 6th, 2023 through online submission.

5. Dr. Andrew Hamilton of University of Alberta, akhamilt@ualberta.ca is also provided the hydrographic data through an online cloud storage folder.
6. Data is prepared for submission to NOAA NCEI for archive before 2/29/2024 utilizing these guidelines and in coordination with Bathymetric Data Manager, Christie Reiser.
7. A report is submitted to the US, Canadian and Danish Embassy as required before 2/29/2024.

Table 5 Data submission formats

Project	File names and formats	Data size (TIF, .xyz)
Devon 1	Devon1_3m.xyz, Devon1_3m.TIF	1.32, 675 (mb)
Devon 2	Devon2_3m.xyz, Devon2_3m.TIF	1.32, 64.3 (mb)
Devon 3	Devon3_3m.xyz, Devon3_3m.TIF	1.32 (mb), 1.67 (gb)
Devon 4	Devon4_3m.xyz, Devon4_3m.TIF	1.32 (mb), 1.82 (gb)
Croker North & Croker South	Croker_3m.xyz, Croker_3m.TIF	1.32 (mb), 418 (gb)
Total		**6.6 (mb), 4.35 (gb)**

Appendix I: CTD to Multibeam Sound Velocity Profiles in Hypack/Hysweep Processing

Table 4: Devon 1 SVP

Time	Date	X	Y	File
01:03	08/01/2023	487516.7	8268902.7	SVP_0103_08012023.VEL
05:00	08/01/2023	488037.4	8267430.1	SVP_0500_08012023.VEL
10:12	08/01/2023	487968.4	8267079.1	SVP_1012_08012023.VEL
15:44	07/31/2023	489217.2	8271227.1	SVP_1544_07312023.VEL
21:06	07/31/2023	488370.9	8270881.0	SVP_2106_07312023.VEL

Table 5: Devon 2 SVP

Time	Date	X	Y	File
14:38	08/01/2023	499407.4	8267955.2	CTD1.vel

Table 6: Devon 3 SVP

Time	Date	X	Y	File
16:45	08/01/2023	513940.9	8265081.1	CTD_1.VEL
01:48	08/02/2023	507877.8	8271239.7	CTD_3.VEL
06:41	08/02/2023	506715.6	8272819.2	CTD_4.VEL
12:13	08/02/2023	509289.2	8269325.7	CTD_5.VEL
17:25	08/02/2023	510518.5	8267666.4	CTD_6.VEL

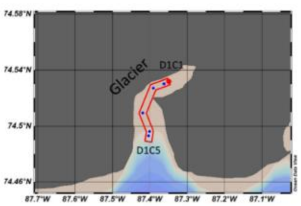
Table 7: Devon 4 SVP				
Time	Date	X	Y	File
12:01	08/03/2023	544850.7	8271159.2	CTD_2.vel
17:50	08/03/2023	546086.1	8275587.3	CTD_3.vel
22:00	08/03/2023	545347.7	8270906.6	CTD_4.vel
06:50	08/04/2023	545297.0	8277614.9	CTD_5.vel
15:00	08/05/2023	544628.6	8283767.9	CTD_6.vel
03:40	08/04/2023	546382.0	8276300.0	T1_CTD1.vel
05:39	08/04/2023	546098.1	8276190.3	T1_CTD2.vel
06:05	08/04/2023	546730.1	8276446.9	T1_CTD3.vel
06:34	08/04/2023	547069.3	8276651.2	T1_CTD4.vel
06:50	08/04/2023	545736.4	8276067.4	T1_CTD5.vel
08:26	08/04/2023	543659.1	8287856.3	T2_CTD1.vel
10:20	08/04/2023	543441.2	8287852.7	T2_CTD2.vel
09:53	08/04/2023	543877.6	8287871.0	T2_CTD3.vel
10:00	08/04/2023	544075.4	8287887.2	T2_CTD4.vel
10:19	08/04/2023	543236.4	8287842.1	T2_CTD5.vel

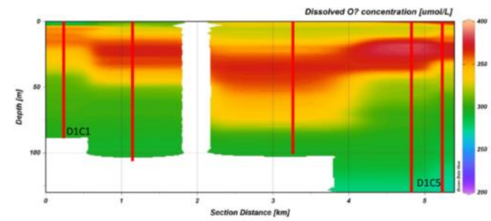
Table 8: Croker Bay SVP				
Time	**Date**	**X**	**Y**	**File**
00:10	08/07/2023	612618.1	8307797.2	T2C1.vel
02:28	08/07/2023	612273.3	8307558.6	T2C2.vel
02:02	08/07/2023	611766.6	8307272.3	T2C3.vel
16:53	08/08/2023	611104.7	8307050.8	T2C4.vel
03:29	08/07/2023	610543.9	8306681.4	T2C5.vel
18:10	08/08/2023	598462.4	8314029.6	T3C1.vel
17:22	08/08/2023	598768.7	8314451.3	T3C2.VEL
17:06	08/08/2023	599240.4	8315065.2	T3C3.vel
16:53	08/08/2023	599645.3	8315628.8	T3C4.VEL
16:38	08/08/2023	600307.4	8316229.8	T3C5.vel

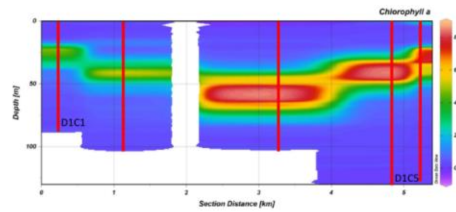
Appendix II: CTD Profile Cross-Transect Plots with ODV

CTD txt files were converted to .csv files within Excel workbook. Each file was modified to display correct headings and to incorporate latitude and longitude for Ocean Data View (ODV) to read. ODV was used to evaluate changes across transects taken within Devon 4 and Croker Bay, along with throughout the fjords of Devon 1 and Devon 3. Graphs were made comparing temperature (°C), salinity (psu), chlorophyll a (ug/l), dissolved O2 (umol/L), and turbidity.

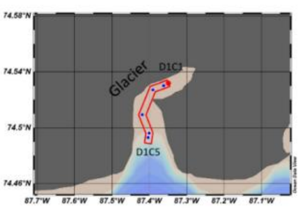
Devon 1: Blanely Bay- DO and Chlorophyll a

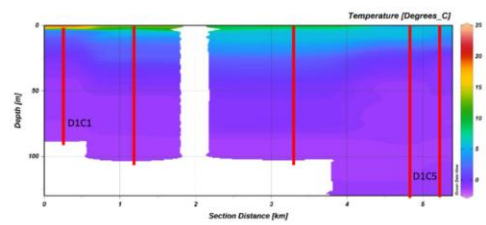


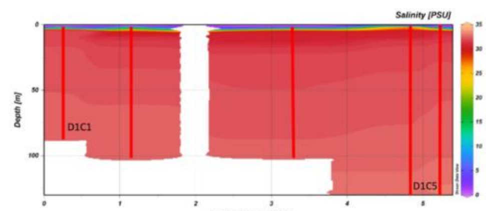




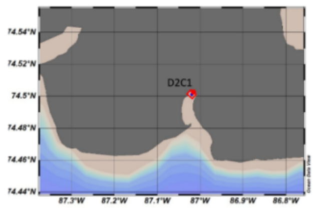
Devon 1: Blanely Bay- Temperature and Salinity

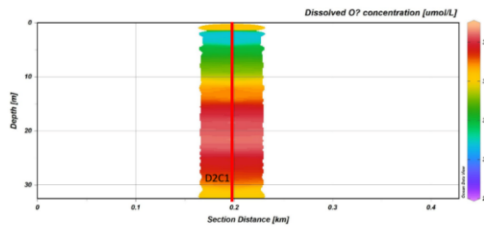


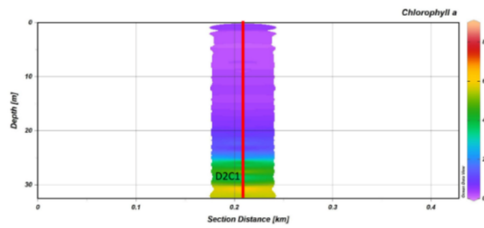




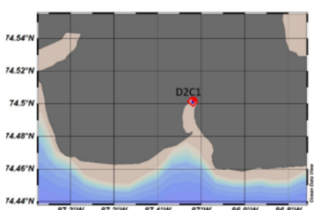
Devon 2: Hobhouse Inlet- DO and Chlorophyll a

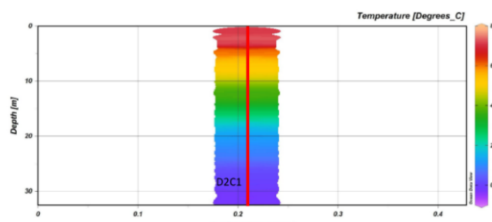


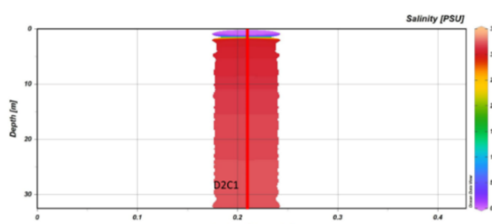




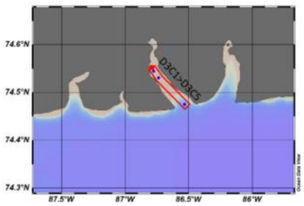
Devon 2: Hobhouse Inlet- Temperature and Salinity

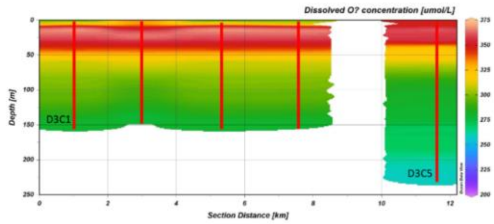


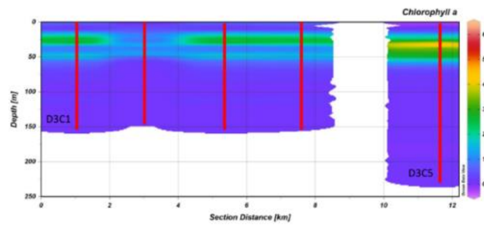




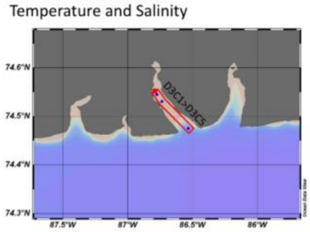
Devon 3: Stratton Inlet- DO and Chlorophyll a

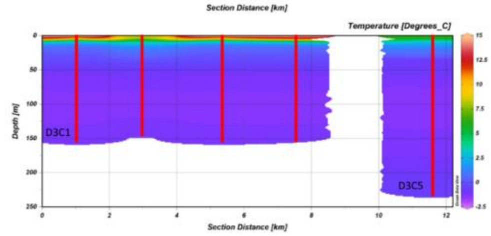


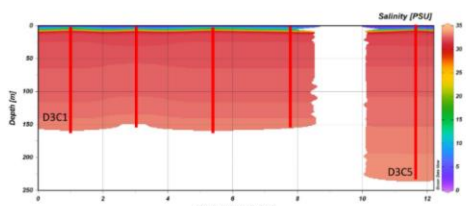




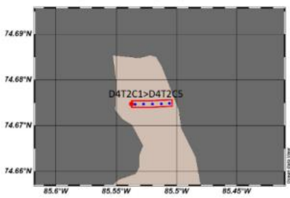
Devon 3: Stratton Inlet- Temperature and Salinity

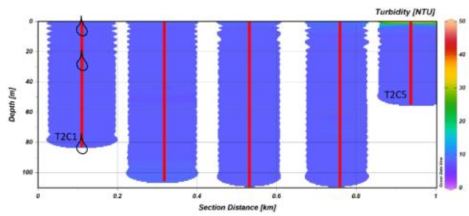


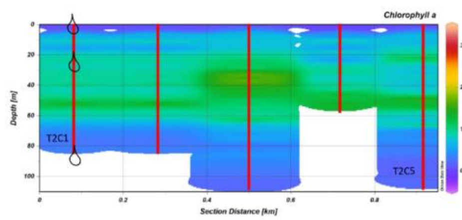




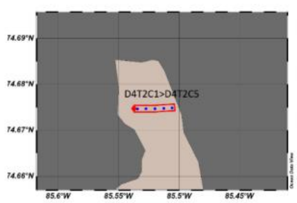
Devon 4: Powell Inlet Transect
2- Turbidity and Chlorophyll a

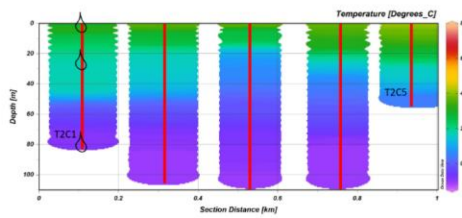


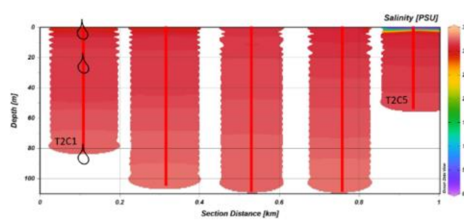




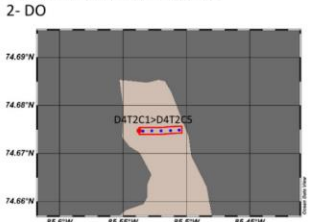
Devon 4: Powell Inlet Transect
2- Temperature and Salinity

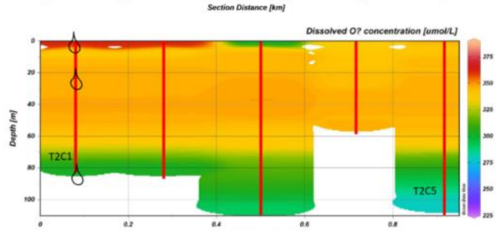




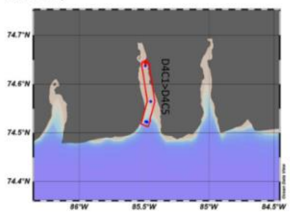


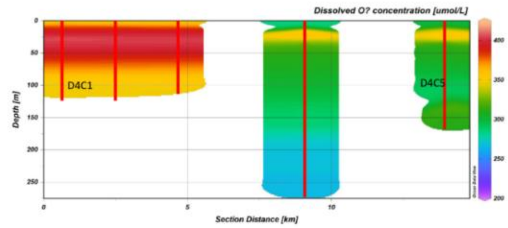
Devon 4: Powell Inlet Transect
2- DO

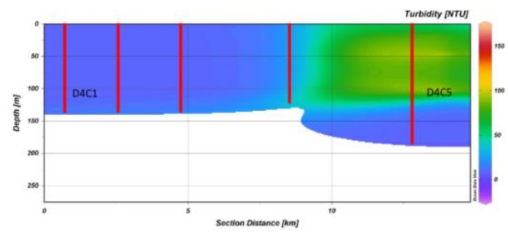




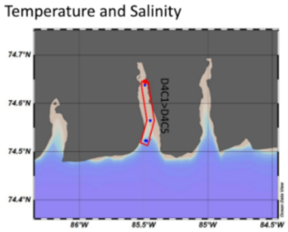
Devon 4: Powell Inlet- DO and Turbidity

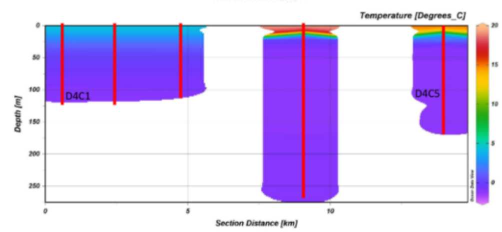


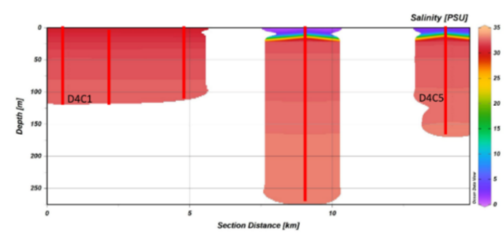




Devon 4: Powell Inlet- Temperature and Salinity

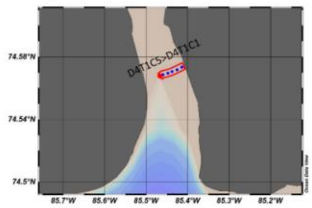


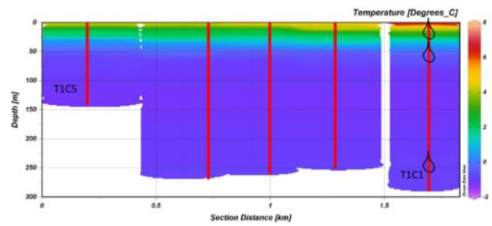


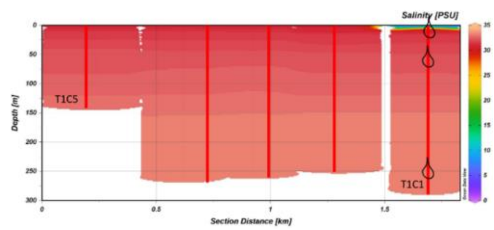


Devon 4: Powell Inlet Transect

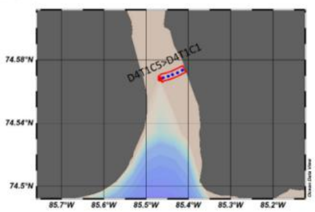
1- Temperature and Salinity

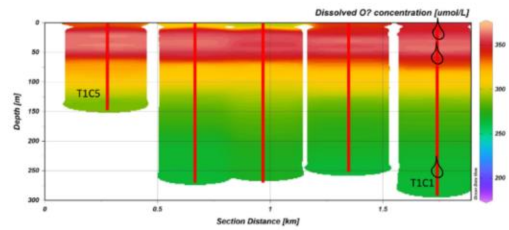




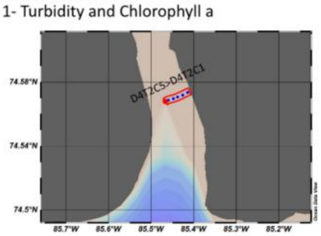


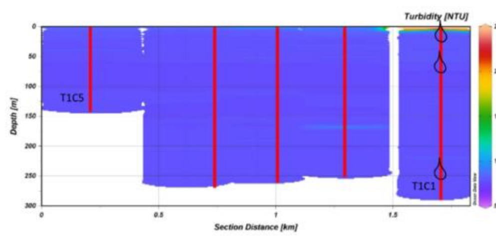
Devon 4: Powell Inlet Transect
1- DO

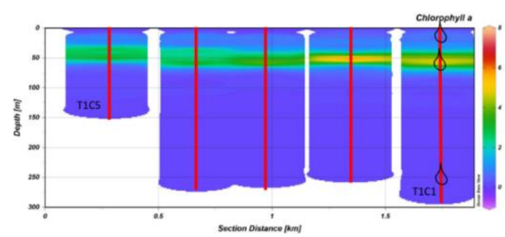




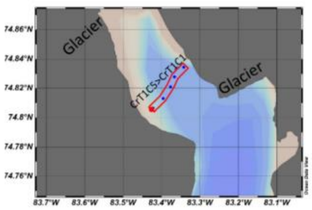
Devon 4: Powell Inlet Transect
1- Turbidity and Chlorophyll a

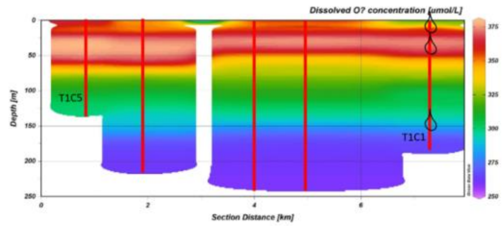




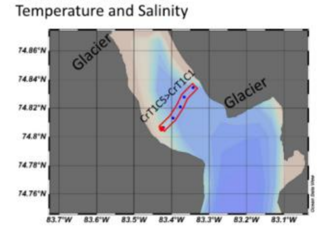


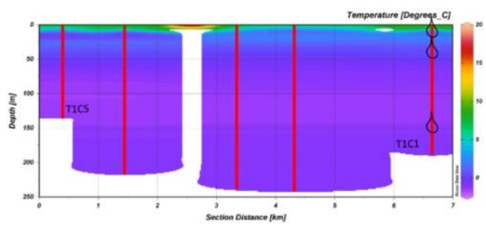
Croker Bay: Transect 1- DO

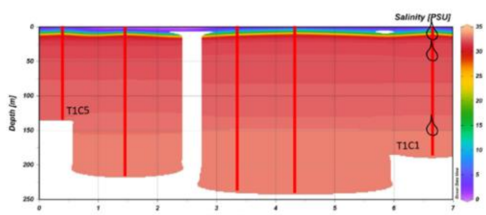




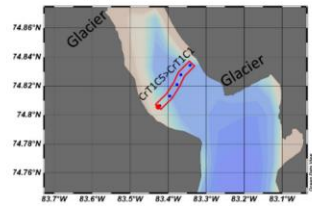
Croker Bay: Transect 1-
Temperature and Salinity

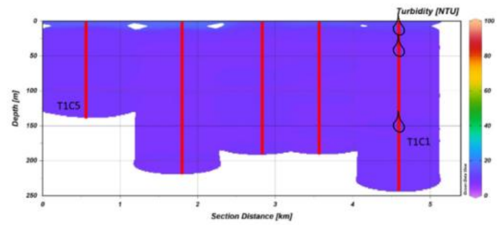


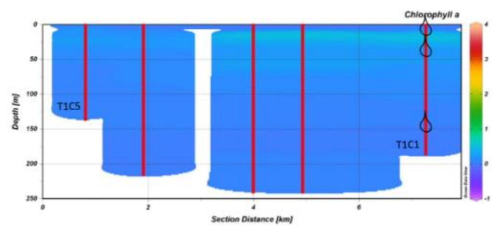




Croker Bay: Transect 1- Turbidity and Chlorophyll a







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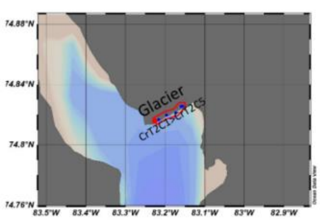
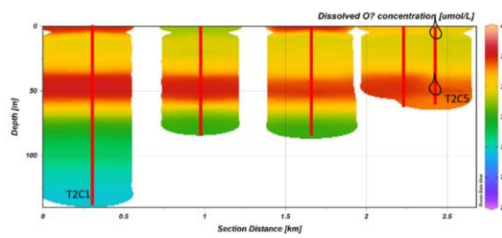
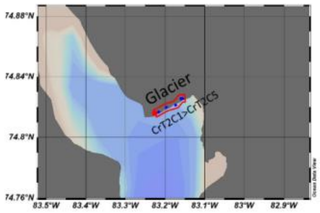
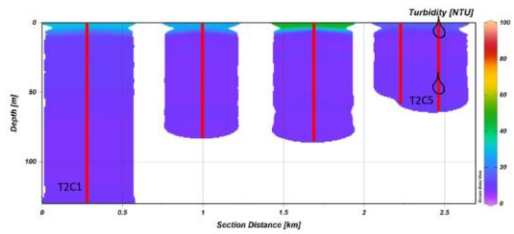
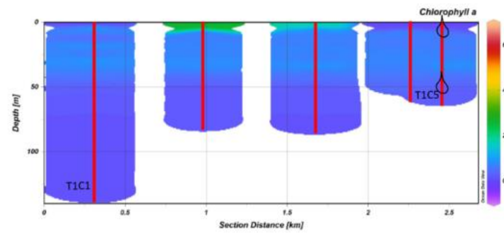




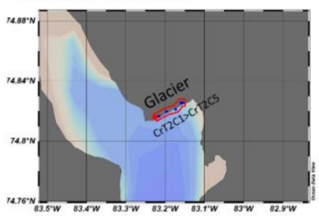
Croker Bay: Transect 2- Turbidity and Chlorophyll a

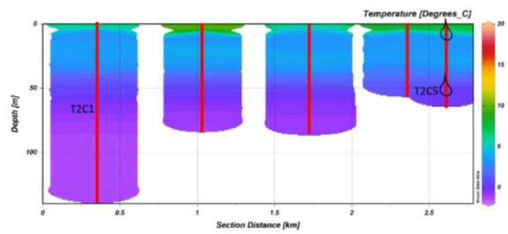


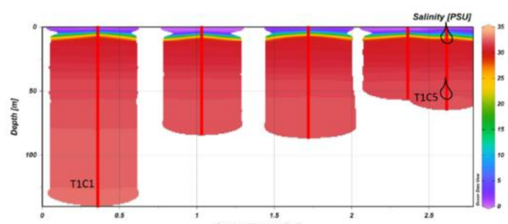




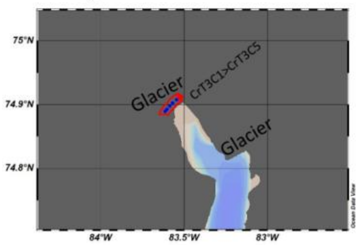
Croker Bay: Transect 2- Temperature and Salinity

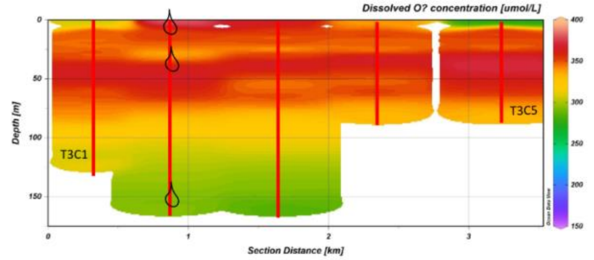




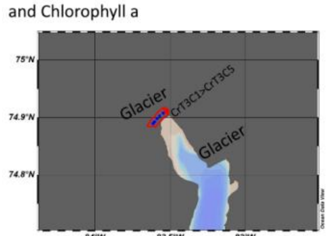


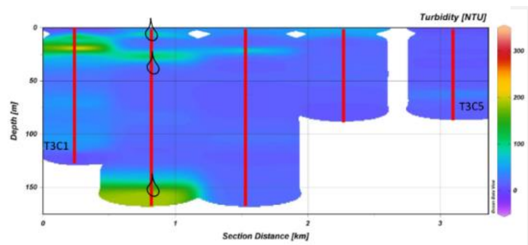
Croker Bay: Transect 3- DO

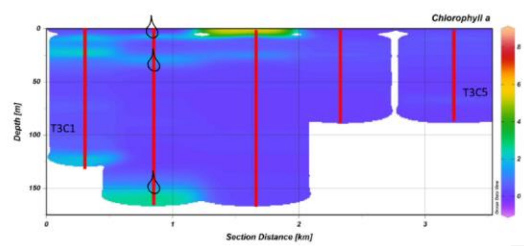




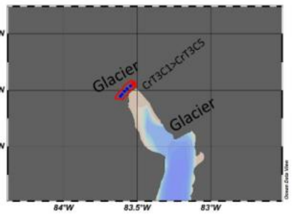
Croker Bay: Transect 3- Turbidity and Chlorophyll a

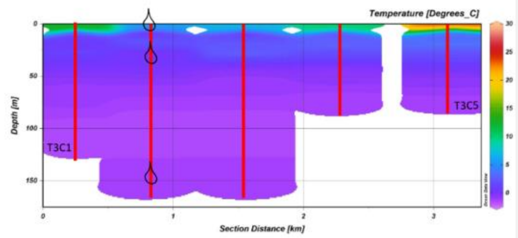


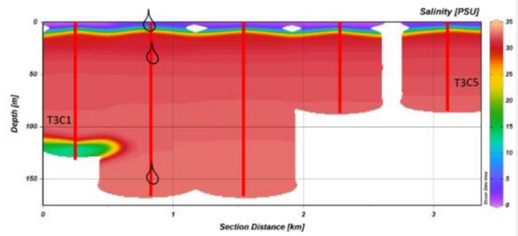




Croker Bay: Transect 3-
Temperature and Salinity







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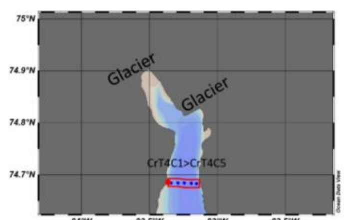
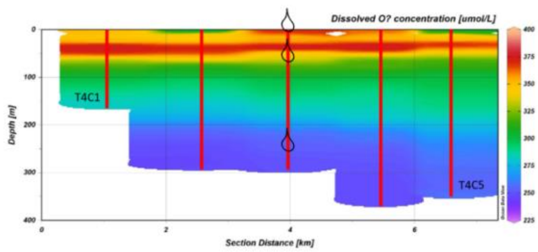
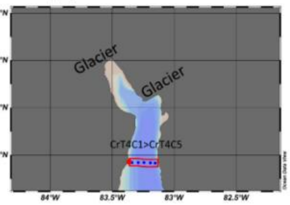
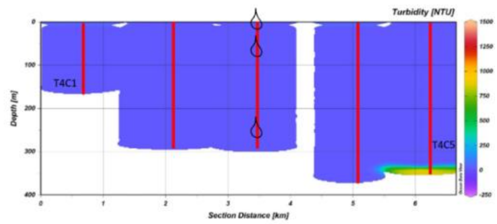
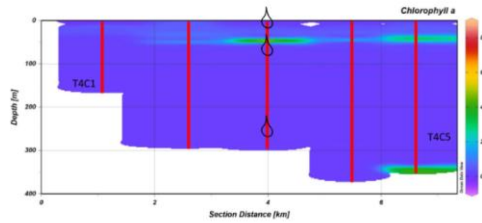




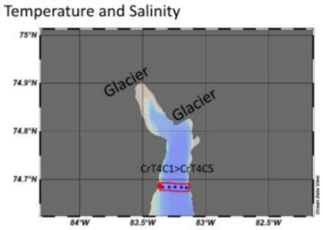
Croker Bay: Transect 4- Turbidity and Chlorophyll a

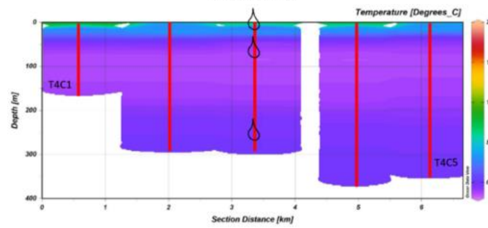


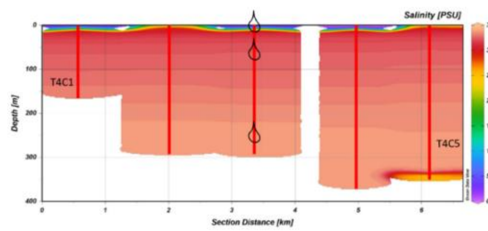




Croker Bay: Transect 4- Temperature and Salinity







Appendix III: Multibeam Integration, Calibration, and Data Report: SRV Marie Tharp & Reson 7125

Table of Contents:

1. Introduction

SRV Marie Tharp is the home and transportation for Ocean Research Project's GO-MARIE 2023 expedition. The 22m Bruce Roberts steel schooner is responsible for the collection of bathymetric data within uncharted areas in Arctic Canada. Calibration of the Reson Sebat 7125, SBG, and Trimble was conducted during the survey period onboard the RV Marie Tharp, a 22m Bruce Roberts steel schooner. System integration of the inertial and geospatial instrumentation and project configuration was conducted during the field campaign. A patch test was performed over a feature during the survey period to determine offsets.

2. Multibeam Survey System

a. **Survey System Components** includes several components connected to achieve reliable, acceptable, and consistent reading. The mapping system consists of the following components:

1. Reson 7125 SV FP1.4 multibeam echosounder
2. SBG Ekinox-A inertial motion sensor
3. Trimble BX992 RTK / Heading Receiver
4. Hypack data acquisition software

b. Components Overview

i. **Multibeam Echosounder (Reson Seabat 7125)**: A dual-frequency transducer that is configurable to 200 or 400 kHz and is responsible for emitting and receiving the sonar pulses. The underwater transducer, mounted on the hull of the vessel, and a topside unit installed within the vessel's lab records the data and acts as the interface for sonar tuning and geopositioning. A sound velocity sensor, installed between the two projectors, allows for entry of the externally measured speed of sound data through the local water of the sonar head.

- Up to 512 beams in selectable modes optimizes operations.
- High ping rate allows high speed operations without compromising data density
- Depth rated to 500 m however, sonar was unable to yield depth detection greater than 250 m

ii. **Motion Sensor (IMU):** To correct for the motion of the vessel, a motion sensor (inertial measurement unit) is used. This helps ensure accurate positioning of the sonar data.

<u>Inertial Measurement Unit used in the setup</u>:

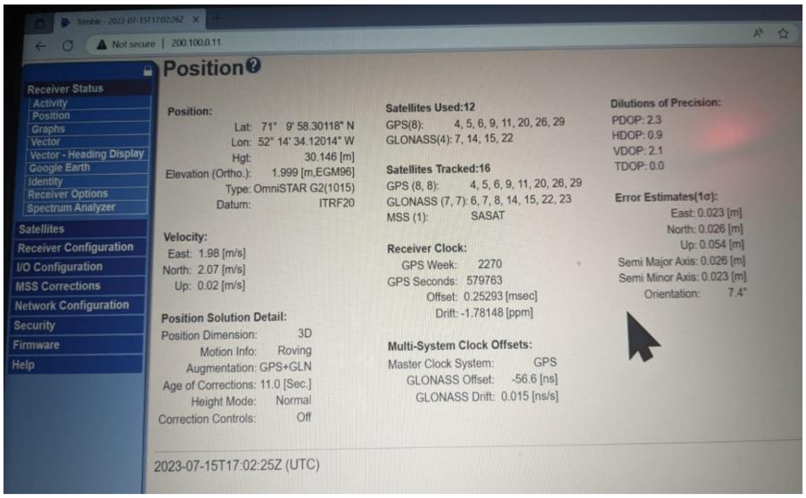
SBG Ekinox-A is an advanced Attitude & Heading Reference System. It combines high end gyroscopes and accelerometers, and runs an enhanced

Extended Kalman Filter (EKF) to provide Roll, Pitch, Heave, and Heading when connected to an external GNSS receiver.

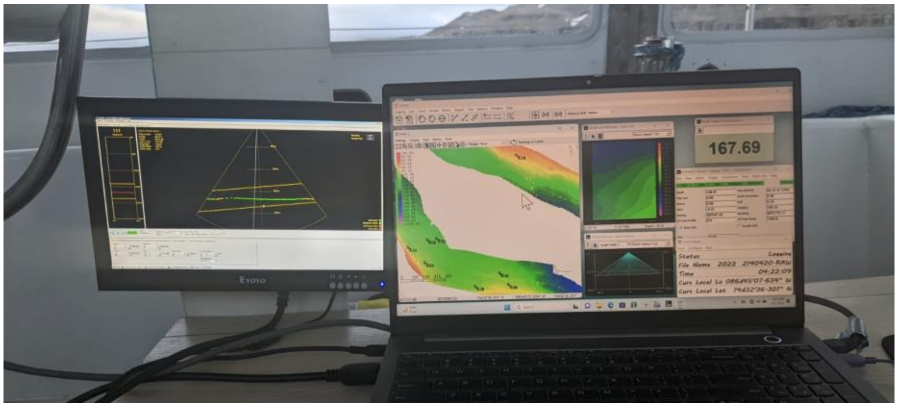
iii. **Geospatial-Positioning System**: The Multibeam echosounder needs accurate navigation data to correlate the depth measurements with specific geographic locations. A Trimble BX992 RTK is used in combination with OmniStar subscription to achieve real-time high accuracy position information.

The Trimble BX992 is a dual-antenna receiver enclosure with integrated inertial navigation system powered by the BD992-INS. One of the two antennas is pictured below on the top of the pilothouse.

- **Vertical Datum:** EGM96 is a gravity-related vertical coordinate system based on WGS84
  - **Horizontal Datum:** International Terrestrial Reference Frame 2020 (ITRF20)



iv. **Data Acquisition System**: The data collected by the Reson Seabat 7125 is recorded and processed in the Hypack software.



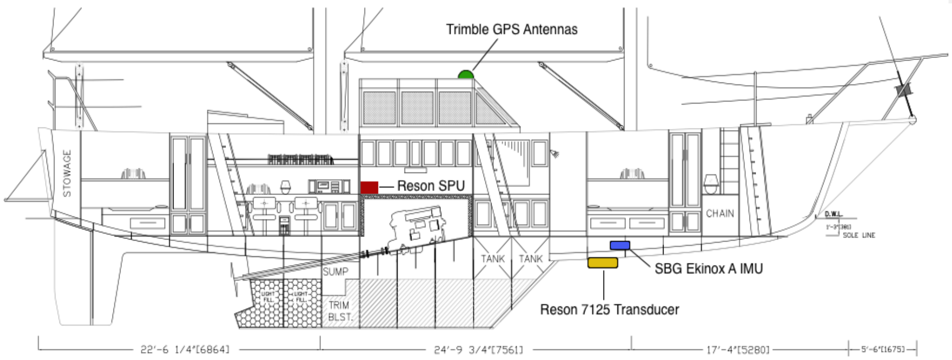
3. Multibeam Reson Seabat 7125 - Installation

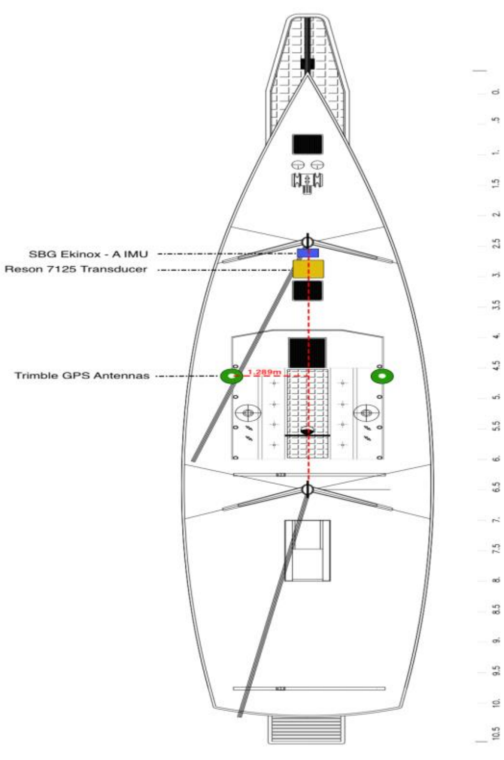
The system was a Hull-Mounted Echosunder, manufactured by **Teledyne.** It was attached to the vessel's hull with a custom welded mount preventing underwater damages during ice collision and other underwater hazards.

The GNSS antennas were installed over the Marie Tharp's cockpit on top of the pilothouse. The Sonar Processor Unit (SPU) was installed in the Science Lab.

a. Sonar Head Assembly Orientation

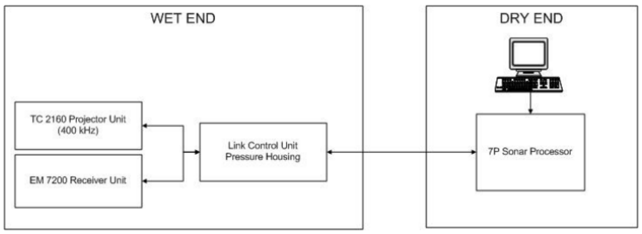
The sonar head assembly is mounted with the faces of the arrays oriented vertically downwards. The receiver is mounted across track, and the projectors are mounted along track and aft of the receiver. The sound velocity probe is installed between both projectors.

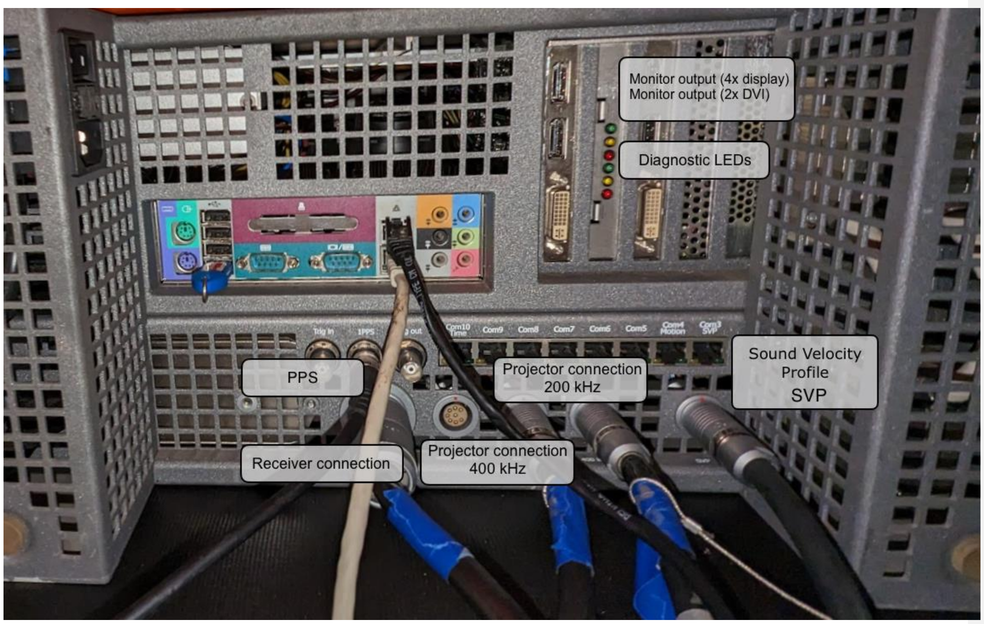

Trimble GPS Antennas
Reson SPU
STOWAGE
CHAIN
TANK
TANK
SUMP
TRIM BLST.
SBG Ekinox A IMU
Reson 7125 Transducer
22'-6 1/4"[6864]
24'-9 3/4"[7561]
17'-4"[5280]
5'-6"[1675]


SBG Ekinox - A IMU
Reson 7125 Transducer
Trimble GPS Antennas
1.289m

b. Sonar Processing System – Reson Seabat 7125

The sonar processing system is the **Reson Seabat 7125** top unit. The Reson 7125 processing and interface are integrated into the Sonar Processing Unit (SPU). The SPU has connections in use, including the ports for receiver, various frequency projectors, sound velocity logging, PPS, as well as ethernet and serial input/output ports. The SPU is installed within the vessel's science lab.





c. Reson SeaBat 7125 System Components:

- EM 7200 Receiver Unit
- TC 2160 400 kHz Projector Unit & TC2163 200kHz projector
- 7-L Link Control Unit
- 7-P Sonar Processor Unit (SPU) with Display, Keyboard, and Pointer Device
- Cable Set

4. System Alignment - Ship Reference System

a. Center of Rotation (CoR)

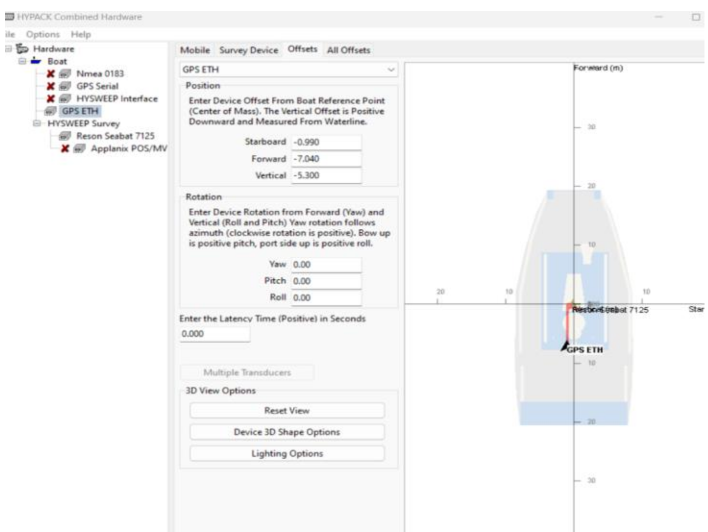
The Vessel CoR. Is at the base and center of the IMU.
The coordinate reference frame established is right handed: X-axis is + forward, Y + starboard, and Z + downward.

b. Static Offsets

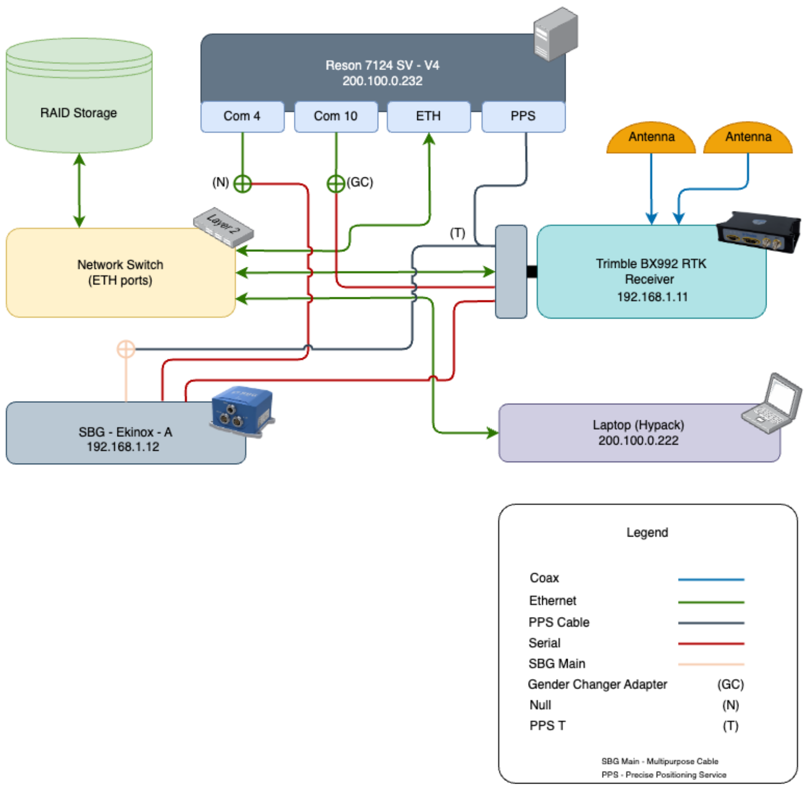
Table 1: Marie Tharp Static Offsets

Hydrographic System Component	X (m)	Y (m)	Z (m)
Sonar transceiver	-0.146	-0.174	-0.336
Trimble GPS	-7.04	-0.99	-5.3

Commented [3]: nicole all tables will have to be improved in formatting offline and consistency...and pictures will have to be oriented in final position



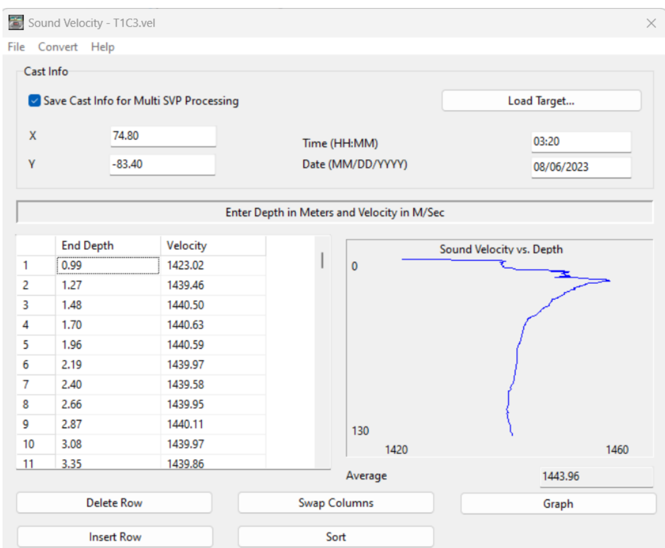
5. Wiring Diagram



6. Sound Velocity Acquisition: Conductivity Temperature Depth (CTD) Profiler

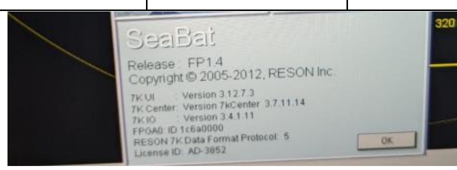
Sound velocity was obtained from RBR concerto C.T.D profilers which at base measure conductivity, temperature, and depth up to 600m (dbar).

CTD casts were uploaded to the RBR Ruskin Software directly or from an airdrop feature of an Apple Ipad where the CTD profile was collected with the Ruskin App. Casts were downloaded from the CTD instrument via Bluetooth for CTD S/N #204223 and USB type C connection for CTD S/N 060671. Data was exported as a txt. file, made into a .csv through Microsoft Excel workbook, and made into .vel files in HYPACK processing. Each .vel file name, date, time, and location can be found in each survey section (Appendix I., Tables 4-8). SVP files were applied based on nearest in distance, time or nearest in distance and time based on the condition that best reduces sound velocity artifacts. Refer to each survey for a specific SVP application. The csv would need to be manipulated within excel workbook by deleting all but the Depth and Speed of Sound columns so HYPACK could make a vel file. The CTD also tended to take extra measurements at the surface and would need to be deleted within the csv as HYPACK vel files only read so many lines of data.

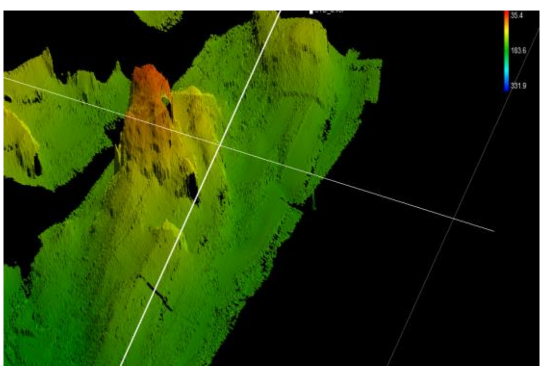


7. Computer Software

Manufacturer	Software Name	Version	Use
RBR	Ruskin	6.13	CTD raw data exported for generic file type.
Xylem	HYPACK	HYPACK 2023	Data acquisition and processing.
Microsoft	MS Excel, Office	2023	Filtering CTD data sound velocity only .csv, report writing.
Trimble	OmniSTAR	3.5.9	Most accurate location and orientation for survey region.
RESON	SeaBat	FP1.4	Sonar tuning for data acquisition



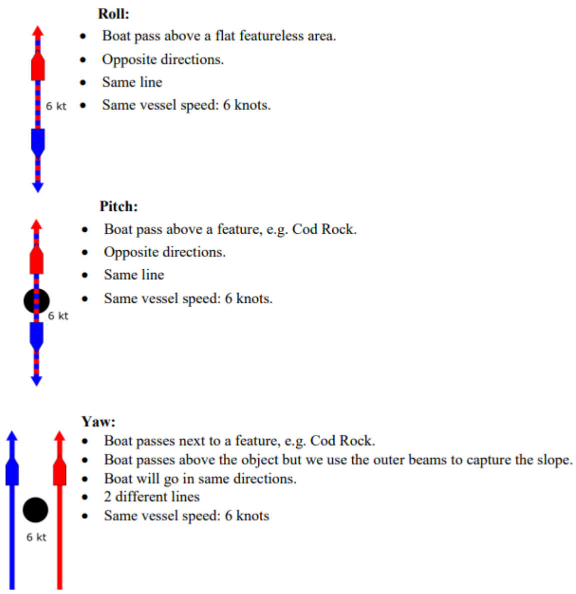
8. Multibeam Sonar - Patch Test



A patch test was conducted within Powell Inlet, a distinctive rock was selected for the patch test in the northwestern region. Lines were conducted over a featureless area, the large rock feature, and on both sides of the feature to determine the roll, pitch, and yaw offset values respectively. Graphics and navigation details are summarized in the below graphic. A latency value was also produced from the patch test. Refer to Table 3 for the offset values. There were inconsistencies during processing that required fine-tuning to produce the best products.

Approximate patch test offset values were applied for all surveys.

GPS Latency	Roll (m)	Pitch (m)	Yaw (m)
-2.6	-6.1	5.5	-2.0



9. Multibeam Sonar Data Acquisition

Positioning was acquired and fine-tuned to the best ability using OmniSTAR. OmniSTAR satellite constellation orientation needed adjustment to 90° for correct boat heading. Limited satellite access to remote locations such as high-latitude glacier fjords resulted in slightly lower satellite positioning accuracy. Accuracy was improved after the Devon 2 survey. We made efforts to achieve sub-meter accuracy. Within the HYPACK Survey, a 5x5m matrix was created with a 3 m cell size. The area could be filled in by the survey team while navigating without the need of line planning. The shallower perimeter of the survey region was conducted at each new survey site. The logging of the multibeam data was segmented every few minutes to keep file sizes manageable for data processing. CTDs were taken every 4 hours to ensure appropriate sound velocity observations across fjord length to eliminate sound velocity artifacts. Nearly 25-50% overlap of multibeam coverage was completed for 100% coverage and minimizing data gaps.

10. Multibeam Data Processing

Preliminary processing was done onboard the vessel during transit when surveying was not being conducted. The HYPACK software was also utilized for processing bathymetric data. The patch test performed was used to correct offsets in ship motion artifacts and positioning. Patch test values for roll, pitch, and yaw were incorporated into the processing software, rectifying most, but not all the position offsets. Raw data was imported into HYPACK HYSWEEP Editor (64 bit) which created a .LOG file. The files contain all edits made to soundings within each survey. Sound Velocity Profiles were made within HYPACK processing and applied to targets made in target editor. This was necessary due to insufficient overlap of patch test lines or errors within offset settings in post-processing, Due to no tidal or satellite solutions in positioning. Each project was imported into HYPACK's HYSWEEP Editor, with offsets applied from the patch test and for the sonar head static offsets. Extensive data flier cleaning was performed. Generation of 3 m bathymetric grids was a result of 1-3 m positioning accuracy.

Appendix IV: Correspondence & Permitting

1) Fisheries & Oceans Canada: License to Fish for Scientific Purposes - Report goes to All documents should be sent to: DFO.ArcticLicensing-PermisArctique.MPO@dfo-mpo.gc.ca

2) Mittimatalik HTO Hunters and Trappers Organization, sent to: pond@baffinhto.ca - They requested we acquire a letter of support in advance for future projects.
3) Nunavut Research Institute - Scientific Research License
4) Nunavut Planning Commission - is exempt from screening by the NIRB

License #: S-23/24-1026-NU

Nicole Trenholm
P.O. Box 3612
Annapolis, MD, USA 21654

Dear Nicole Trenholm,

Enclosed is your Licence to Fish for Scientific Purposes issued pursuant to Section 52 of the Fishery (General) Regulations.

Failure to comply with any of the conditions specified on the attached licence may result in a contravention of the Fishery (General) Regulations.

Please be advised that this licence only permits those activities stated on your licence. Any other activity may require approval under the Fisheries Act or other legislation. It is the Project Authority's responsibility to obtain any other approvals.

Please ensure that you include the licence number and project title in any future correspondence and that you complete the Summary Harvest Report upon completion of activities under this licence.

Yours truly,

______________________________ ______________________________

Colin Charles Date

Fisheries Management

Arctic Region

Fisheries and Oceans Canada

Enclosure

LICENCE TO FISH FOR SCIENTIFIC PURPOSES

S-23/24-1026-NU

Pursuant to Section 52 of the Fishery (General) Regulations, the Minister of Fisheries and Oceans hereby authorizes the individual(s) listed below to fish for scientific purposes, subject to the conditions specified.

Project Authority: Nicole Trenholm Ocean Research Project Inc.

P.O. Box 3612

Annapolis, MD, USA 21654

Other Personnel: Nicole Trenholm, Matthew Rutherford

Objectives: Canada Collaborative Croker Bay & Northern Ellesmere Island Glacial Fjord Surveys

To collect water column with a CTD sensor probe and to collect water samples of geochemical observations.

To collect seabed grab samples or cores from a gravity corer in glacial fjords.

To map the seafloor in uncharted areas with a multi-beam sonar in less than 300m.

CONDITIONS

Specified Conditions:

See Appendix A for map of authorized areas

Sampling Locations: Fjords of Ellesmere and Croker Bay

Vessel Information:
Name: Marie Tharp
Country of Registration: USA

Waters:

Water Body: Ellesmere Island Area
Point A: 0° 0′ N, 0° 0′ W

Species: Benthos

Gear: Echosounder
Van Veen Grab

Total Weight	Weight Live	Weight Dead	Number Alive	Number Dead	Number Tows	Number Sets	Hours	Minutes
2.00								

Fishing Period: July 26, 2023 to August 22, 2023

A copy of this licence must be available at the study site and produced at the request of a fishery officer.

Live fish may not be retained unless specified in the conditions of this licence.

The licence holder shall immediately cease fishing when the total fish killed or live sampled reaches any of the maximums set for any of the species listed.

Transportation:

Other approvals/permits may be necessary to collect or transport certain species, such as Marine Mammal Transportation Permits. For marine mammal parts, products and derivatives a Marine Mammal Transportation Licence is required for domestic transport and, for international transport a Canadian CITES Export Permit is also required.

Disposal of Fish Caught:

Fish not required for the purpose of dead sampling and/or retention MUST be returned to the water at the site of capture.

Retained fish may be made available to the nearest settlement for domestic consumption or sold commercially within the Territory. Any dead fish for commercial sale beyond the Territory in which it was caught requires authorization under the Fish Inspection Regulations. Disposal of any fish remains must be in accordance with local land use regulations.

Retention & Disposal of Fish Caught:

Fish not required for the purpose of dead sampling and/or retention MUST be returned to the water at the site of capture.

Retained fish may be made available to the nearest settlement for domestic consumption or sold commercially within the Territory. Any dead fish for commercial sale beyond the Territory in which it was caught requires authorization under the Fish Inspection Regulations. Disposal of any fish remains must be in accordance with local land use regulations.

Report on Activities:

The Project Authority will submit to the Area Licensing Coordinator, Department of Fisheries and Oceans, within one month of the expiry date, a report stating:

i) whether or not the field work was conducted; and if conducted ii) waterbody location, fishing coordinates, gear types used at each coordinate, numbers or amount of fish (by

species) collected and/or marked and the date or period of collection.

A Summary Harvest Report template is provided by the Licensing Coordinator at time of issuance of this licence.

The Project Authority also will provide a copy of any published or public access documents which result from the project . Information supplied will be used for population management purposes by the Department of Fisheries and Oceans and becomes part of the public record.

All documents should be sent to:

DFO.ArcticLicensing-PermisArctique.MPO@dfo-mpo.gc.ca

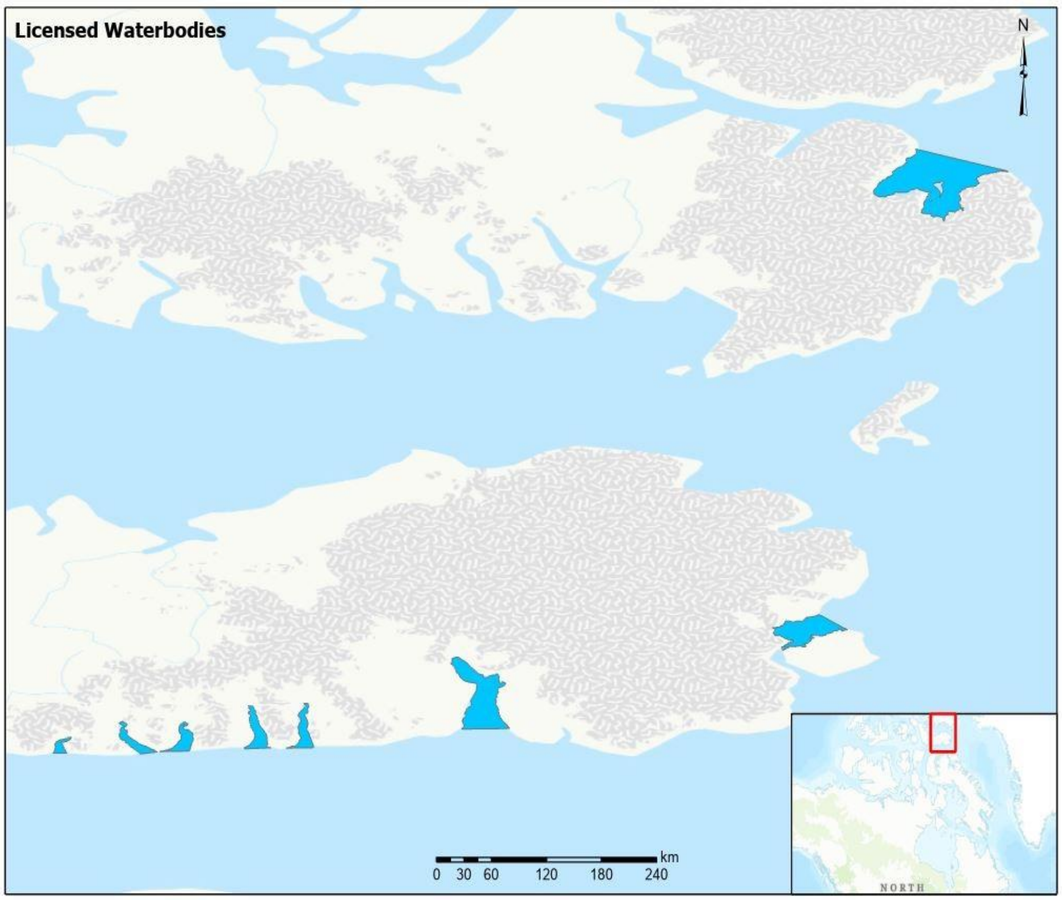
Kevin Tallon | Date

A/ Regional Director, Fisheries Management

Arctic Region

Fisheries and Oceans Canada

For the Minister of Fisheries and Oceans.
Pursuant to Section 52 of the Fishery (General) Regulations.



Licensed Waterbodies
N
km
0 30 60 120 180 240
NORTH

Nunavut Research Institute I

Box 1720, Iqaluit, NU XOA OHO phone:(867) 979-7279 fax: (867) 979-7109 e-mail:

SCIENTIFIC RESEARCH LICENSE

LICENSE NUMBER 02 038 23R-M

ISSUED TO: Nicole Trenholm

Geographic Environment Systems

University Maryland Baltimore County
990 Awald Road

Annapolis, Maryland

21403 USA

TEAM MEMBERS: M.Rutherford,D.DAgostino,A.Stumo,A.Getzinger,

A. Conover,N.Radka

TITLE: Canada Collborative Croker Bay & Northern Ellesmere Island Glacial Fjord Surveys

OBJECTIVES OF RESEARCH:

When the glacial fjord landfast ice is clear we will enter the fjords and conduct our observations and sampling activity minding all permit restrictions after checking into the country. Lab analyses will occur between Fall-Spring and seabed depth data and oceanic RBR CTD profiles will take post-processing will occur over winter to complete. Unless a better archive is identified oceanic data will be prepared for the Polar Data Catalogue. Seabed bathymetry data will be shared with the Canadian Hydrographic Office and the GEBCO IBCAO seabed model. We intend to make the data turn around quicker as we can add more researchers to the team who will benefit from the data and aid in data processing and publication. The Ocean Research Project will have the data available for those who seek the information and will submit the data to the appropriate archives.

TERMS & CONDITIONS:

The holder of the licence will be bound by the terms and conditions of the Nunavut Impact Review Board Screening Decision Report and the Department of Culture & Heritage archaeological sites terms and conditions. These terms and conditions will form part of this licence.

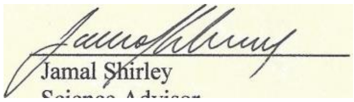
DATA COLLECTION IN NU:

DATES: July 26,2023 to August 31 ,2023

LOCATION: Croker Bay,Northern Ellesmere Island & Eastern Devon Island Glacial Fiords

Scientific Research License 02 038 23R-M expires on December 31,2023 Issued at Iqaluit, NU on July 11,2023

Science Advisor



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Nunavunmi Parnaiyiit
Nunavut Planning Commission
Commission d'Aménagement du Nunavut

May 31, 2023
NPC FILE No: 150093

Mosha Cote
Manager-Research Liaison
Nunavut Research Institute
P.O. Box 1720
Iqaluit, NU X0A 0H0
By email: mosha.cote@arcticcollege.ca

Christopher Gerlach
Manager, Tourism Development
Dept of Economic Dev. & Transportation (EDT)
Tourism and Cultural Industries Division
P.O. Box 1000, Iqaluit, NU X0A 0H0
By email: cgerlach@gov.nu.ca;
cruisenunavut@gov.nu.ca

Jared Ottenhof
Director, Qikiqtani Nunalirijikkut
Qikiqtani Inuit Association (QIA)
P.O. Box 1340, Iqaluit NU X0A 0H0
By email: jottenhof@qia.ca; dmp@qia.ca;
JSimic@qia.ca

Francis Emingak
Acting Manager, Technical Administration
Nunavut Impact Review Board (NIRB)
P.O. Box 1360, Cambridge Bay, NU X0B 0C0
By email: femingak@nirb.ca ; info@nirb.ca ;
kmorrison@nirb.ca

Nicole Trenholm
University Maryland Baltimore County
990 Awald Rd
Annapolis MD 21403 USA
By email: nicolet3@umbc.edu

Dear Mosha Cote, Christopher Gerlach, Jared Ottenhof, Francis Emingak, and Nicole Trenholm:

RE: NPC File No: 150093 [Canada Collaborative Croker Bay & Northern Ellesmere Island Glacial Fjord Surveys]

The following works and activities have been proposed in the above-noted project proposal:

1. Marine Based Scientific Research: Renewal to further investigation of current influence on the Devon Ice Cap glaciers, on board of the SRV Marie Tharp ship. The research group intends to conduct oceanographic surveys to better understand the ice and ocean physical and environmental conditions in Croker Bay, in the Northwest Passage, and Northern Ellesmere Island Glacial Fjord Surveys .
2. Summary of Modifications: Addition of surveys areas in North Ellesmere Island glacial fjords, and Eastern Devon Islands glacial fjords.
3. Associated NPC File No: 148838, and 149317; Associated NIRB File No: 18YN040.
4. Location: Qikiqtani Region (North Baffin); [various locations in High Arctic, Near the communities of Grise Fjord, Resolute Bay, Arctic Bay and Pond Inlet]

A complete description of the project proposal reviewed by the NPC can be accessed online using the link below.

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Cambridge Bay, NU X0B 0C0
☎ 867-983-4625
Fax 867-983-4626

P.O. Box 2101
Ikaluktutiak, NU X0B 0C0
☎ 867-983-4625
Fax 867-983-4626

The Nunavut Planning Commission (NPC) has completed its review of the above noted project proposal. The NPC previously reviewed works and activities associated with the current proposal and conformity determinations issued on June 19, 2018, and Marc 4, 2020 which still apply. In addition, associated activities were previously screened by the Nunavut Impact Review Board, including oceanographic surveys s in Croker Bay and the Northwest Passage (NIRB FILE NO.: 18YN040). It conforms to the North Baffin Regional Land Use Plan (NBRLUP). The proponent has undertaken to comply with the applicable conformity requirements of Appendix C, H, and I of the NBRLUP.

The above-noted project proposal is exempt from screening by the NIRB because the NPC is of the understanding that the addition of North Ellesmere Island, and Eastern Devon Islands glacial fjords survey areas does not change the general scope of the original project activities, and the exceptions noted in Section 12.4.3 (a) and (b) of the Nunavut Agreement do not apply.

By way of this letter, the NPC is forwarding the project proposal to the regulatory authorities identified by the proponent. Project materials, including the applicable conformity requirements, are available at the following address:
https://lupit.nunavut.ca/portal/project-dashboard.php?appid=150093&sessionid=

The regulatory authorities to which this letter is addressed are responsible under the Nunavut Planning and Project Assessment Act (NUPPAA) to implement any of the applicable requirements by incorporating the requirements directly, or otherwise ensuring that they must be met, in the terms and conditions of any authorizations issued.

This conformity determination applies only to the above noted project proposal as submitted. Proponents may not carry out projects and regulatory authorities may not issue licenses, permits and other authorizations in respect of projects if a review by the NPC is required. Regulatory authorities may consult with the NPC to obtain recommendations on their duties to implement the existing land use plans prior to issuing licenses, permits and other authorizations under subsection 69(6) of the NUPPAA.

My office would be pleased to discuss how best to implement the applicable requirements and to review any draft authorizations that regulatory authorities wish to provide for that purpose. If you have any questions, please do not hesitate to contact me at (867) 979-3444.

Sincerely,

Goump Djalogue
Senior Planner, MCIP, RPP
Nunavut Planning Commission