Northwest Passage Project Science Plan, 2019

1.0 Northwest Passage Project Overview

The Northwest Passage Project (NPP) is a US National Science Foundation funded program to explore the changing Arctic through an innovative expedition that will engage diverse audiences through real time interactions from sea, a high definition 2-hour documentary, and related community events. The expedition will be conducted onboard the *RVIB Oden*, which will be fully equipped with telepresence technologies for shore-based participation in the project. Undergraduate and graduate students will participate in the expedition along with scientists, historians, journalists, and a documentary film crew.

2.0 Scientific Overview

The science activities are motivated by the overarching goal to understand how waters of the Canadian Arctic Archipelago (CAA) have changed as a consequence of the secular warming trend over the Arctic Circle. We approach this goal using an interdisciplinary ocean-based research program to explore the changes in four (4) thematic areas:

1. Water mass properties and circulation inside the CAA. Science leads: D. Gong (VIMS), Cristin Wright (VIMS).
2. Microscopic communities in transition due to a changing Arctic climate. Science leads: TBD, Z. Kerrigan (URI).
3. At-sea distributions of marine birds and mammals in Canadian Arctic waters. Science leads: Rick Ludkin, H. Morin (URI, ISC).
4. Greenhouse gas chemistry, and microbial activity of the melting Arctic and marginal seas. Science leads: Brice Loose (URI), Cynthia Garcia (UIC), A. D'Angelo (URI).

Motivation, description and an outline of activities in each thematic area are described below.

Typical Daily Science Activities

2.1 Narrative of "Typical" Daily Science Activities

The chief scientist will post a plan of the day around 00:00 for each upcoming 24 hour period, beginning at the start of the first watch at 5am. *The plan of the day will incorporate discussions with Oden Master, plans for videography and telepresence, and weather and ice forecasts for the upcoming period.*

Location (Lat/Lon) for the upcoming day's water sampling will be determined based upon discussions between Oden Master, Chief Scientist, and Dave Clark so that a time window when the vessel can be dedicated to operating in deep water for a ~3-4 hour period. Every effort will be made to space the points evenly and in the most scientifically relevant distribution. Table 1 contains a list of all science activities and anticipated time involved:

A 24 hour period of science activities will unfold as follows:

1. **Continuous measurements:** Atmospheric gas measurements will occur in a continuous manner, whether the boat is stopped or in motion. Flowing seawater measurements for T, S, Chla, and fluorometric POC will be made continuously from the Oden clean seawater supply system. NPP personnel will monitor and calibrate instrumentation as needed.
2. **Marine mammal and seabird observations** will occur when ship is moving and during daylight hours. Rick Ludkin will be main observer, assisted by team of four undergraduates. Students will use notebooks and binoculars.
3. **Water column profiling/sampling:** Every 24 hours or 100 nautical miles, a vertical "profile" of water properties and water samples will be collected. The hydrographic measurements will be done using RVIB Oden's CTD Rosette. A typical CTD cast will unfold as follows:
    a. NPP expedition will request that Oden Marine technician arrange for the vessel to stop and hold position or drift slowly in vicinity of waypoint.
    b. Conductivity-Temperature-Depth (CTD) rosette will be deployed to obtain a full water-column profile. Niskin bottle depths will be chosen based on the trace from the downcast and closed on the upcast. Each **CTD deployment and recovery will require 1 to 3 hours depending on water depths and station distances.**
    c. When the rosette is aboard, the zooplankton net tow will commence. The zooplankton net will be lowered over the side to the same depth as Niskin sampling, and net tow will commence by reeling in the net to recover organisms in the water (Figure 2). **Net tow and recovery will take 30 minutes.**
    d. **We anticipate that 2 - 4 hours of vessel time will be required to complete over the side water sampling.** It is essential that the vessel not be underway during these water sampling operations, but we understand that Oden does not have Dynamic Positioning, so drift will happen. Vessel motion, aside from routine station-holding or slow way made to counteract the currents, can result in serious damage to equipment and harm to deck personnel.

e. Rosette water sampling will follow the standard CLIVAR/GO-SHIP sampling protocol with “water cop” keeping track of sample order and taking metadata notes. Dissolved gases will be sampled first, followed by nutrients, oxygen-18, and finally large volume microbiology samples.

4. Shore-to-shore CTD/ADCP cross-sections. We will conduct cross-section at 6 locations marked in Figure 1 (X01 to X06). These will involve high-resolution CTD casts to resolve water mass properties along with the CTD rosette mounted LADCP. These will take longer as sample stations will be closely spaced. Water sampling will adopt an abbreviated version of that planned for other water column casts. Water sampling will focus on O-18 and nutrients, with in-situ methane collected on only a subset of the CTD casts.
5. Following water sampling and net tows, water and plankton samples will be collected and stored/filtered/analyzed.

Table 1: Master list of activities for during the NPP project while onboard the RVIB Oden. The “Ship Time” column indicates the number of hours the vessel would be committed by the activity (per day); “Reps” are the number of anticipated repetitions during the cruise; and “TotalTime” is an estimate of ship time that may be consumed by each science activity.

Description	Ship Time	Reps	Total time	Comment
Continuous Measurements				
Multibeam	0	N/A	0	Hull mounted instrument. Continuous when in use. See Appendix 3
Mid-water sonar	0	N/A	0	Hull mounted instrument. Continuous when in use. See Appendix 3
Flowing seawater CH_4/CO_2	0	N/A	0	Happens continually
p[op[Salinity and temperature of seawater	0	N/A	0	Happens continually
Seawater chlorophyll a	0	N/A	0	Happens continually
Seawater CDOM	0	N/A	0	Happens continually
Seawater pCO_2	0	N/A	0	Happens continually
Seawater pH	0	N/A	0	Happens continually
Atmospheric sampling	0	N/A	0	Happens continually
Marine Bird surveys from bridge	0	N/A	0	Happens underway

Marine mammal surveys from the bridge	0	N/A	0	Happens underway
Water Column Profiles				
CTD Cast to bottom	1.5	29	54	1 hour per cast, not including transit, or positioning
LADCP	0	28	0	This instrument is deployed with the CTD rosette. See Appendix 3
DNA staining with SYBR for bacteria counting	0	29	0	Happens underway
Visible light microscopy for phyto/zooplankton	0	29	0	Happens underway
Nucleic Acid sampling and preservation	0	29	0	4 hrs per CTD cast, but happens underway
Oxygen Isotope Measurement	0	29	0	Happens underway
Nutrient analysis of rosette CTD water	0	29	0	Happens underway
Plankton profiles				
Zooplankton Net tows	1	10	8.5	0.5 hours per cast
Flow cam surveys	0	10	0	Happens underway
Shore-to-shore CTD hydrographic sections	8	6	30	Plan 5 CTD casts in each channel section. Casts will include coarse resolution CTD rosette hydrography for Nutrients and O-18, as well as fine resolution, T, S, DO.
Ad Hoc or single event				
Sea ice sampling	2	4	8	This will occur on an opportunistic basis, could take place during shore visits.
Multi-core sediment samples for benthic microbiology.	1	4	4	Will take place subsequent to selected CTD casts.
ROV deployment	0	6	0	Location subject to change, can deploy from Oden, or ice. Will be carried out concurrent with other activities, so doesn't directly consume ship time.
Drone surveys of coastlines and ice floes	0	6	0	This can be done concurrently with other water column sampling, ice sampling, or on its own. The drone can operate from vessel or ice.

3.0 Detailed Description of Science Themes

Theme 1: Water mass properties and circulation inside Canadian Arctic Archipelago

Team leads: Donglai Gong (VIMS); Cristin Wright (VIMS)

One impact of a warming Arctic that the NPP expedition will be looking to assess is the increased freshwater storage in and export from the upper Arctic ocean. Increased melting, river discharge, as well as changing wind patterns lead to increased freshwater accumulation in the western Arctic in recent years. However, changing coupled ice-ocean-atmosphere dynamics due to warming could result in significant export of this freshwater through the CAA. Freshwater export from the Arctic can have dramatic impacts on ocean circulation both regionally inside the CAA as well as globally when discharged to the North Atlantic Ocean near sites of deep water formation. The CAA and particularly the Northwest Passage through Parry Channel and Lancaster Sound is one of the principle conduits for freshwater transport from the Arctic Ocean to the North Atlantic. There are uncertainties about the property of the water masses and the magnitude of transport through the various flow pathways exiting the Arctic. Some of these potential flow pathways can be observed and studied throughout the Northwest Passage along the cruise track for the NPP expedition using a CTD and a LADCP. The following equipment will be used to study aspects of this research.

Lowered Acoustic Doppler Current Profiler (LADCP) data will be collected during CTD casts, especially during cross-channel CTD sections.

O-18: To observe the inputs of freshwater into Arctic seawater, we will measure stable isotopes of hydrogen and oxygen on seawater using laser absorption spectrometers. Freshwater runoff, precipitation-evaporation, sea-ice formation and melting ice produce water masses with unique slopes along the relationship between the stable isotopic ratio and salinity. These discrete measurements of liquid water will be taken from sample pumping, CTD casts and precipitation.

Distributions of Pacific and Atlantic water will be distinguished using the dissolved inorganic nutrient concentrations NO_3^-, PO_4^{3-}, N:P ratio and/or nutrient properties corrected for remineralization processes.

Theme 2: Microscopic Communities in Transition

Science leads: TBD ; Zak Kerrigan (URI)

As the waters of the Arctic warm and the sea ice cover decreases, the surface ocean ecosystem is undergoing considerable changes. Habitats are changing and moving, perhaps disappearing, and species distributions and abundance may be changing rapidly. Examination of the habitats along the NPP cruise track will have a three pronged approach. Zooplankton nets will be periodically towed vertically in the upper water column (100m and less). The contents of the nets will be catalogued. The net observations will be augmented with a laboratory bench-top flow cam which can identify and quantify 'particles' from a volume of seawater. These particles can be sediments, phytoplankton, or even zooplankton. In addition, the *IB Oden* is equipped with a high frequency sonar system that can observe zooplankton and fish in the water column. The sonar system allows real time observation of the abundance and patterns of distribution of zooplankton and fish. This sonar system will be used to make observations that can be compared to past studies and serve as a baseline in locations without previous data. Combining these approaches to an ecosystem studies will make the results more robust. In addition to the water column studies, there will be a marine bird study.

FlowCam: To observe phytoplankton and zooplankton, we will conduct regular zooplankton net tows (**Figure 2**) for shipboard analysis via Flowcam. The Flowcam counts and images micrometer size particles using an imaging microscope. This provides the ability to identify and quantify 'particles' from some sampled volume. These particles can be sediments, phytoplankton, or even zooplankton. This imaging system will generate a library of images for each net tow and store them for processing later.

Conductivity, Temperature, Depth (CTD) samples: CTD rosette bottles will be sampled for bacteria, archaea, and protists to analyze via the DNA-staining dye DAPI and counting by epifluorescence microscopy. Biotic material will be filtered onto polycarbonate filters for later nucleic acids extraction. Additional science and education activities include, understanding autofluorescent pigments like chlorophyll and phycobilins, recognizing major phytoplankton groups e.g. diatoms, cryptophytes and dinoflagellates, and grid counting and calculating cell concentrations

Multi-core sediment samples will be collected from 4-5 individual sites, following CTD casts. The sediment multi-core device allows for benthic sampling of approximately 0.5 m of the surface layer of sediment. The multicorer is deployed over the side by winch and cable.

We will re-occupy the long time series station in Lancaster Sound: Station 323: Lancaster Sound, 74.2, -79.75.

Theme 3: At-sea Distributions of Marine Birds and Mammals in Canadian Arctic Waters

Science leads: Rick Ludkin; Holly Morin (URI)

Marine birds play an important role in marine ecosystems. Their abundance and distribution can be used to monitor changes and variability in marine ecosystems. We intend to characterize the distribution and abundance of marine birds (and mammals) along the survey route during the post-breeding period in late September. We plan to identify the associations between the marine bird community and the physical and biological properties of their marine environment. Changes in marine bird abundance and distribution using data collected from the same area over 30 years ago will be described.

The NPP cruise will use a standard method to perform seabird counts and contribute to the sea bird database of the Canadian Wildlife Service.

Data will be collected from the bridge using a laptop computer while ship is underway (daylight hours). We will collaborate with oceanographers to investigate bird-habitat associations (analyses likely to commence post expedition), and we will compare historical datasets to current survey data (analysis likely to commence post expedition).

Theme 4: Water Column Chemistry Affecting Greenhouse Gas Fluxes and Ocean Acidification

Science leads: Brice Loose (URI), Cynthia Garcia (UIC), Alessandra D’Angelo (URI)

The concentration and isotopic composition of methane and carbon dioxide in the Arctic Ocean and atmosphere are of great interest as both are greenhouse gases and the sources and flux of both between the ocean and atmosphere are important components in the climate system. The Arctic Ocean generally absorbs carbon dioxide but ice over-limits air-sea exchange. Measuring carbon dioxide and its isotopic composition can give information about the carbon system sources and fluxes of carbon to the atmosphere. Methane – an even more potent greenhouse gas than carbon dioxide – is found throughout the Arctic circle, and the Arctic appears to be an ever growing source of methane to the atmosphere. Methane is found in land-based permafrost, and as methane ice or methane hydrate, which is distributed along the seafloor. With less sea ice cover, there can be an increased flux of methane from the ocean. However, some microbes in ocean water use methane as a food source. If microbial breakdown of methane is rapid enough, it may serve to offset the methane that escapes to the atmosphere. The estimates of this methane breakdown in Arctic water temperatures are are very few.

Atmospheric gas sampling: Two laser absorption spectrometers to analyze (1) the stable isotopic ratio ($^{2}H/^{1}H$ and $^{18}O/^{16}O$) of seawater and water vapor and (2) the stable isotopic ratios (^{13}C) of CO_2 and CH_4. These analyzers are small, approximately the size of a desktop computer, and designed to make continuous measurements in field settings. They can be operated remotely and log continually during the course of the cruise. The work proposed here will support the science mission by using water isotopes along with salinity to differentiate water masses. Freshwater runoff, precipitation-evaporation, sea-ice formation, and melting ice produce water masses with unique slopes along the relationship between the stable isotopic ratio and salinity. The carbon isotope values will be used to fingerprint changes in the methane production pathways as oxidation generates a distinct fractionation signature.

Seawater sampling: 13-CH_4, and 13-CO_2 will be continuously sampled using a third laser absorption spectrometers and membrane contactor attached to the flowing seawater system. The same instrument will be used to analyze discrete profiles of 13-CH_4 and 13-CO_2 concentration collected using the CTD rosette. To measure methane in seawater, water will be continuously pumped into the wet lab I/B Oden's clean underway seawater system (Figure 3). This will provide a continuous record of surface methane concentrations and serve to illuminate interesting features that emerge as the ship transits. Students will collect ice core samples to look for methane trapped in sea ice and they will repeat bacterial methane oxidation experiments to compare with the abnormally large values observed by Kitidis et al. (2010).

Methane oxidation rate measurements: Shipboard incubations will be used to measure the rate of methane oxidation following the procedure of Uhlig & Loose (2017). Gas-tight foil bags will evacuated and filled with seawater, then spiked with an isotopically-labeled methane gas standard and allowed to equilibrate with the seawater. Incubation bags will be sampled every 12-24 hours to determine the time rate of change of methane in the incubation chamber.

In order to characterize the effects of meltwater on the base of food web (microbes and phytoplankton), carbon cycling, and ocean acidification state, we will employ a sensor package attached to I/B Oden's clean underway seawater system and collect samples from CTD-rosette casts. The sensor data and discrete samples will enable us to determine the extent and source of meltwater (glacial or meteoric water via $\delta^{18}O$), the major geochemical consequences of freshwater input, as well as the biological response to this input (in cooperation with Theme 2). Due to the projected future decline in ice cover in the Northwest Passage will, the combined dataset will also support validation and ground-truthing of increasingly-available remote sensing satellite observations of the ocean in the region (e.g., sea surface temperature, sea surface salinity, ocean color, turbidity, etc.).

The underway sensor package will measure salinity, temperature, chlorophyll a (chl a) fluorescence, colored dissolved organic matter (cDOM) fluorescence, partial pressure of carbon dioxide (pCO_2), and pH from the clean seawater inlet during the entirety of the cruise (sensors to be confirmed). Additionally, we will collect samples from CTD-rosette casts at various locations to capture the major oceanographic gradients: south-north gradient (i.e., open water to ice cover), the east-west gradient into the Arctic Ocean (e.g., through the Lancaster Sound, Barrow Strait, and Melville Sound), as well as the land-ocean gradient in regions with high meltwater input (i.e., low salinity to high salinity gradients). The sampling campaign will include the collection of water samples from multiple depths for lab-based analysis of $\delta^{18}O$ of seawater, particulate organic C and N (concentration and isotopic fractionation), nutrients (NO_3, PO_4, and $Si(OH)_4$), dissolved organic carbon (DOC), and cDOM. Opportunistic sampling of floating ice will also be carried out (e.g., using hand held dip nets or by small inflatable boats). Ice samples will be thawed and collected for analysis of $\delta^{18}O$, nutrients, DOC, and cDOM.

3.1 Open Data Policy

We will disseminate scientific data and results through the NPP website. All processed measurements will be stored in the NSF-supported Arctic Data Portal (https://arcticdata.io) and all appropriate Canadian and Inuit science databases such as the Canadian Wildlife Service sea bird database.

3.2 References

Kitidis, V., Upstill-Goddard, R. C., & Anderson, L. G. (2010). Methane and nitrous oxide in surface water along the North-West Passage, Arctic Ocean. Marine Chemistry, 121(1–4), 80– 86. https://doi.org/10.1016/j.marchem.2010.03.006

Uhlig, C., & Loose, B. (2017). Using stable isotopes and gas concentrations for independent constraints on microbial methane oxidation at Arctic Ocean temperatures. Limnology and Oceanography: Methods, 15(8), 737–751. https://doi.org/10.1002/lom3.10199

Appendices:

Appendix 1.0: NPP ROV Drone Information. This appendix describes the criteria and qualifications of the NPP drone and ROV operations and operators in order to ensure safe, effective use of both assets while minimizing the risk of loss and having the tools be left in the environment.

Appendix 2.0: NPP Rosette Microbiology Sampling describes activities that will take place in collecting water for filtration for DNA and or Chla samples.

Appendix 3.0: Research Sonar. This appendix describes the acoustic sources to be used on the *RVIB Oden* and the procedures for their operation.

Figures

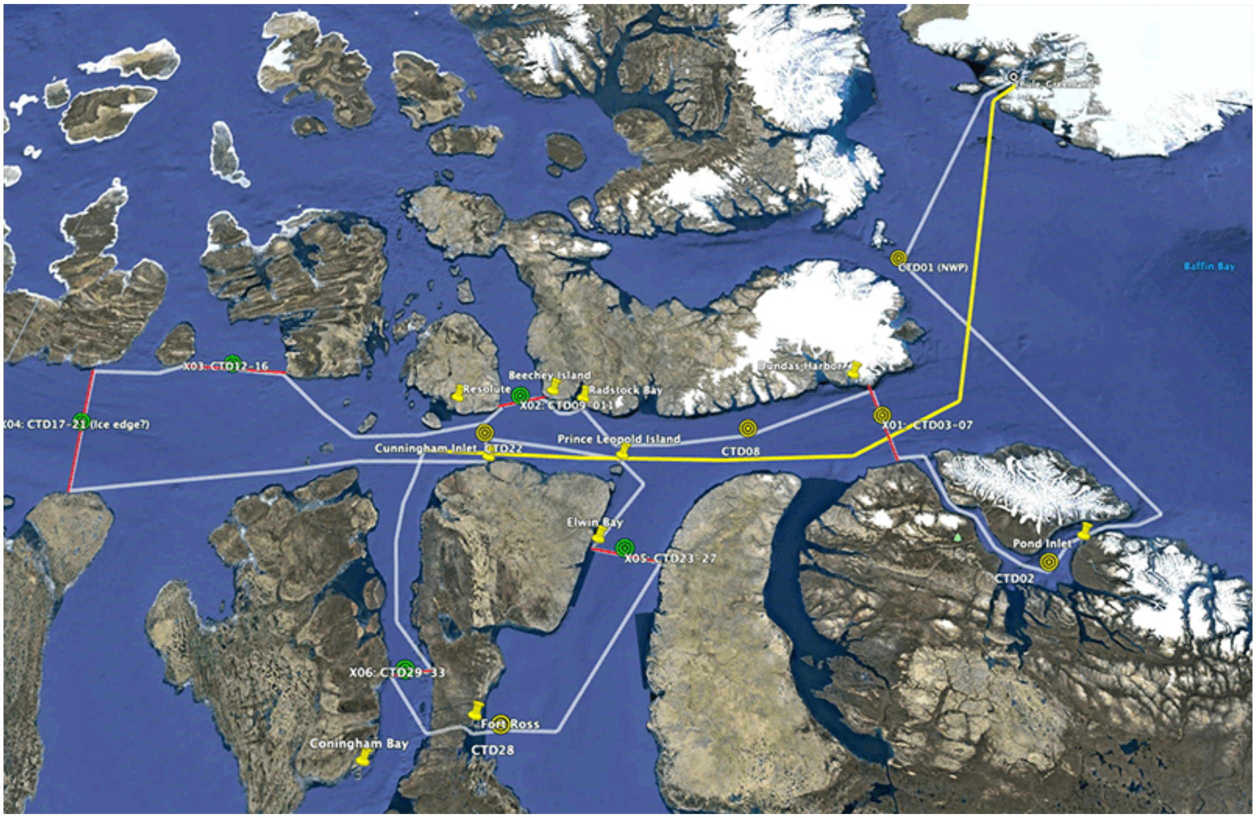

Figure 1. Proposed cruise track during the 2019 NPP expedition, based on an 18-day itinerary with shore stops following itinerary. The cruise track including six cross sections to map water mass properties (indicated in red). Water sampling stations are indicated with a bullseye symbol. The yellow part of the cruise track indicates transit back to Thule at the end of the expedition.

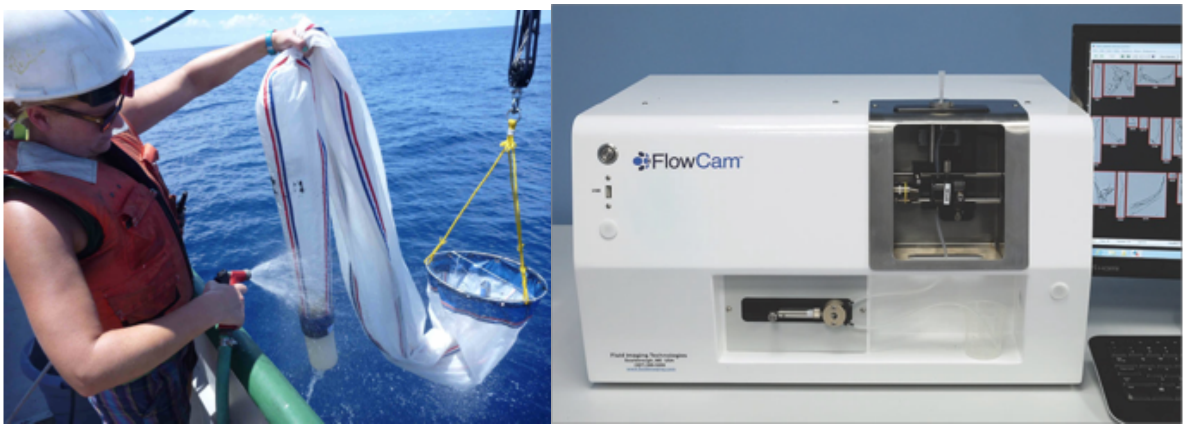

Figure 2. (Left panel) Plankton net tows are used to capture small particles in the water column. An imaging microscope known as the FlowCam™ (right panel) is used to identify and count these particles.

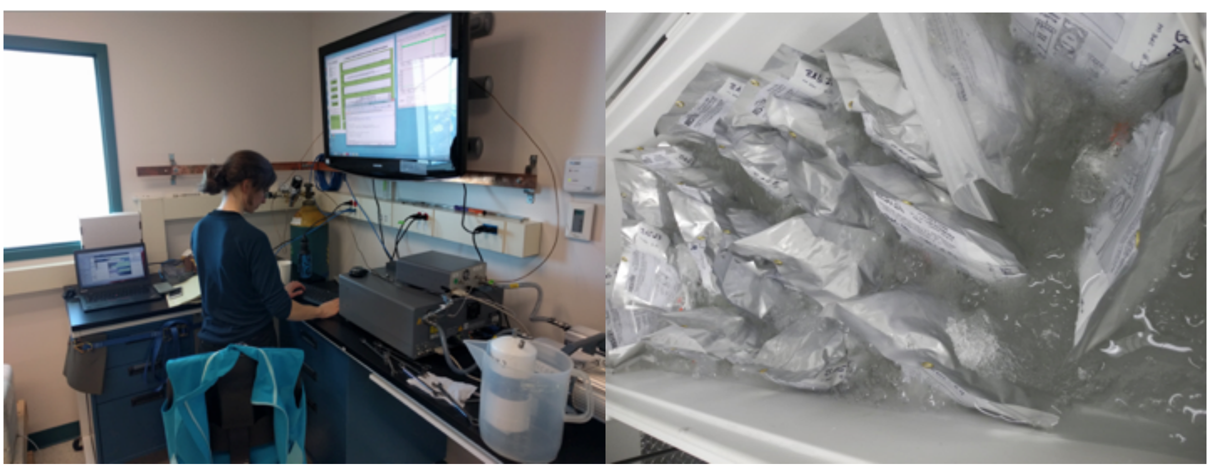

Figure 3. (Left panel) Ship or lab-board analysis of methane and carbon dioxide. (Right panel) Incubators in an ice-water bath for analysis of methane oxidation.

Appendix 1.0: NPP ROV Drone Information

1.0 Remotely Operated Vehicle (ROV)

The NPP science team will use a Blue Robotics BlueROV2 during the 2019 NPP cruise (https://www.bluerobotics.com/store/rov/bluerov2/bluerov2/).

ROV specifications:
Length: 457mm
Width: 388mm
Height:254mm
Weight (in air with ballast): 10-11kg

Operating Envelope: Max depth: 100 m. Max tether length: 300 m. Max forward speed: 1 m/s

Operator Qualification: Dr. Gong will be certified to operate it with assistance from Blue Robotics.

Deployment criteria:
- The ROV team will consult with ship's officer of the deck and Chief Scientist assess the mission parameters, risks, and operating procedures prior to every ROV deployment.
- Vessel-based deployment scenario: when the vessel is on station for science activity & ROV activity is assess to be low risk to other operations. In ice covered regions, the ROV will only be deployed if the ice field is deemed stable and not rapidly changing and there is a sufficient area of open water close to the vessel.
- All deployment effort will be closely coordinated with vessel officers and other science teams via handheld radio communication

Contingency Plan:
Specific risk during deployment may include:
- Vehicle system malfunction, becomes unmanuverable - in this case, the vehicle will be immediately retrieved using the tether and assessed once onboard.
- Vehicle encounters strong currents and cannot be return on its own power - an assessment of the surface drift and current will be done prior to deployment. If the current exceeds 0.5 m/s, the ROV will not be deployed. And if it does encounter strong current >0.5 m/s after deployment, it will return to safe space immediately and recover if necessary.

- Entanglement with vessel/science instruments - to avoid this scenario, the ROV will only be deployed if the current is weak enough so that the control of the vehicle can be maintained throughout its mission profile. There will be an assistant operator focused on tether management for each deployment. If there is ever a risk of entanglement, the ROV will be recovered immediately.
- Gong's team will have satellite (Iridium) communication with engineers at Blue Robotics whenever their assistance and advice is needed. Consultation with Blue Robotics engineers may take place during mission planning stage depending on anticipated risks.

2.0 Small Unmanned Aircraft System (aka drone):

Product Information:
DJI Mavic 2 Enterprise & DJI Phantom 4 Advanced

Operating Envelope:
All drone operations will strictly adhere to the upcoming Canadian small UAS regulations published by Transport Canada:
https://www.tc.gc.ca/en/services/aviation/drone-safety/flying-drone-safely-legally.html

Specifically for operations from the Oden, all operations will be discussed and cleared with ship's officer on the deck and the chief scientist. Each deployment prioritize safety of people and the vessel. Operating envelope will be adjusted accordingly to meet operating and situational demands.

Operator Qualification:
Gong is a certified U.S. FAA Remote Pilot and he will be the Pilot In Command (PIC) for all science drone operations.

Deployment criteria:
- All drone operations will be cleared with Officer on the Deck and the Chief Scientist during the NPP cruise.
- The ROV team consists of a minimum of 2 people per deployment. The operator or PIC and an observer. A forward observer may also be deployed if deemed necessary.
- For deployment from the vessel, agreed upon safe deployment and recovery location(s) on the vessel will be used for all operations.
- The science UAS will never be deployed when helicopter operation or other film aerial operations are taking place. Only one drone will be in the air at any given time.
- **The drone will not be deployed from land or fly over land.**

- The drone may be deployed from sea ice during ice sampling if the operation is deemed safe and low impact on other ship operations and science activities.

Contingency Plan:

Specific risk during deployment may include:

- Loss of communication with vehicle - if the drone is still operational, it will return to its ‘home point’ automatically. The home point will continually updated during the flight to ensure it stays close to the operator. The vessel will be notified if the loss of communication exceeds 20 secs in duration.
- Collision with vessel or other structures - the drone when deployed will be send to a safe distance away from the vessel as soon as possible after take off. During science observations, the drone will not fly over the vessel. During landing, the operator will be directly assisted by observer(s) to make sure it is approaching the vessel safely. If the wind is deemed too high (> 10 m/s) or if the vessel is moving too fast (> 12 knots) the drones will not be deployed.
- To minimize drone related risks to other people on the vessel or on ice, the drone operating vicinity will be cleared during take off and landing.
- All drone and remote control systems will be fully charged and checked prior to every deployment to ensure maximum safety envelope.

Appendix 2.0: NPP Rosette Microbiology Sampling.

Description of activities that will take place when collecting water for filtration for DNA and or Chla samples.

After the rosette is secured back on deck, bar clamps are placed on the Niskin bottles starting with the inside ring of bottles (Fig. A-1). The clamps for the inner ring of 12 Niskin bottles are placed inside the ring (closer to the pylon). Bar clamps are then placed on the Niskin bottles on the outer ring. This arrangement prevents the clamps from interfering with each other.

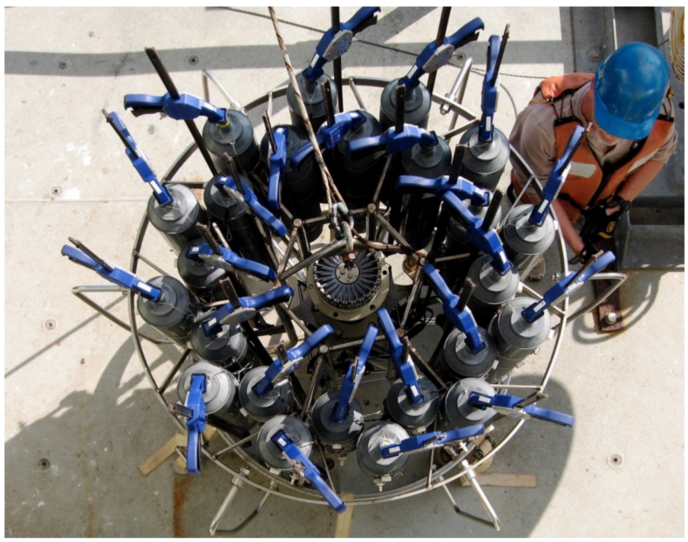

Figure A-1. Top view of rosette showing arrangements of bar clamps.

The vent plugs are removed and replaced with t-fittings (Fig. A-2). A ring of plastic tubing (1/4” inner diameter) is used to construct a manifold to deliver pressure to each Niskin bottle. Each bottle is connected individually to the manifold to prevent any potential mixing between bottles.

The compressor is connected to the initial t-valve in the series (Fig. A-2) and the final t-valve was plugged. The compressor is set to 8 - 10 psi.

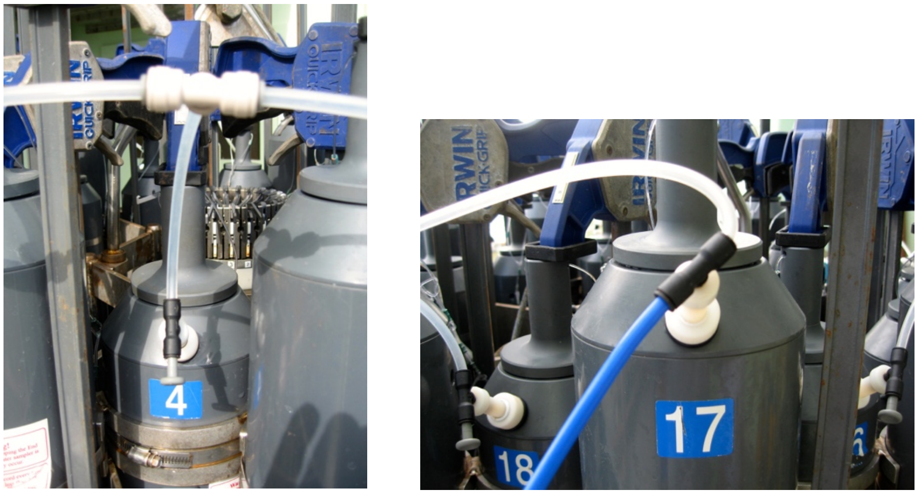

Figure A-2. T-fittings used to plumb pressure manifold to Niskin bottles.

Cylindrical, 0.2 µm retention membrane filters (Sterivex) are attached to the petcock valve of the Niskin bottles with 1/4” tubing (Fig. A-3). The valves are opened and the water was pushed through the filters with the compressed air. The filtration rate is ~200 mL min^{-1}. When the water stops dripping through the filter, the filters are removed, capped at both ends, placed into freezer boxes and stored at -70 °C in the main lab freezer.

Figure A-3. Sterivex 0.2 µm retention filters used in-line from Niskin bottle.

Appendix 3.0: Research sonar

1. Research sonar background

As part of the proposed University of Rhode Island Northwest Passage Project (NPP) 2019 expedition aboard the *IB Oden*, the science team will utilize three scientific sonar instruments:

1) A hull mounted Kongsberg EM122 1°x1° 12 kHz multibeam echo sounder, used to map the seafloor.
2)A hull mounted Simrad EK-80 with a 18kHz transducer, used to examine the mid-water for fish and zooplankton. The Simrad EK80 is a split-beam echo sounder that can operate at a range of frequencies and may also be able to operate at 38kHz and 70kHz if the transducers are installed before the cruise.
3) A Lowered Acoustic Doppler Current Profiler (LADCP) that is attached to the CTD Rosette and used to measure ocean currents. The LADCP operates only during the CTD casts. The instrument will likely be a 300kHz system.

The NPP expedition is aware of concerns about the potential for research acoustic sources to have a behavioral impact on marine organisms, particularly marine mammals. The operating frequencies of the proposed sonar instruments (particularly the Kongsberg EM122 and Simrad EK-80 sonars) can be detected by some marine mammals (such as narwhals and belugas) and operate at an intensity where an animal in the vicinity of the vessel could hear the signal.

The hull mounted instruments produce sounds at a frequency that marine mammals are able to detect. However, the sound intensity is focused downward, below the ship, and decreases with distance from the ship. More importantly, the sound radiating away from the ship horizontally, in the surface layer where marine mammals are more likely to be found, will be much lower than the sound on axis under the ship and will continue to decrease with distance from the ship due to spreading and absorption. At the sound levels generated by these instruments, marine mammals, such as narwhals, will be able to detect the sound from the instrument if they are close to the ship. The sound will not be particularly “loud” for the marine mammals, as narwhals are known to echolocate with source levels at 1 meter up to 218dB re 1 micro-Pascal. However, the marine mammals may find the sound unusual and could react to it by temporarily changing their behavior (such as by moving away from the sound source). The methodologies proposed for this expedition include common mitigation measures and should minimize any potential disruption.

There are several procedures that can be used to reduce or eliminate any impact on marine organisms that may exist from the use of the sonar.

• First, the sonar can be run intermittently, with a focus on the times when it would be most important to collect acoustic data.

• Second, the sonar can have a soft start plan where the sonar starts at lower intensities when it is first turned on to reduce the potential to startle animals near the ship. The Kongsberg EM122 multibeam echo sounder on the *IB Oden* always starts in this mode.

• Finally, the sonar can be turned off and not used in areas or situations where it is deemed that the sonar may pose an unacceptable risk of impact.

2. Proposed Operating Procedures

The proposed standard procedure for the NPP 2019 expedition will be to have the hull mounted 18kHz sonar (or potentially 38kHz or 70kHz) and the hull mounted 12kHz multibeam sonar operating when the ship is underway, except under these conditions:

1) Sonar operation will cease when marine mammals are detected within 500m of the ship.

2) The sonar will be off when within 5 km of any Nunavut community.

3) Out of respect for concerns about the sonar in regard to a group of narwhals that moves between the Arctic Bay and Pond Inlet areas, the sonars will be off while in Navy Board Inlet, Eclipse Sound, and Pond Inlet. This includes turning off the CTD mounted LADCP during the hydrographic station at CTD Station 02.

4) Due to the potentially high concentration of marine mammals in Bellot Strait, research sonars will not be used in Bellot Strait or within 5 km of the entrance on either side.

5) When in restricted waters of the Price Leopold Island and Bylot Island Migratory Bird Sanctuaries or Parks Canada Waters, the sonars will be off.

6) The LADCP can be used only during CTD deployments. If marine mammals are detected within 200m of the ship the LADCP will not be deployed.

3. Acoustic Source Details.

Simrad EK80 hull mounted echosounder

The Simrad Ek-80 is a split-beam echo sounder that operates at a range of frequencies. An 18kHz transducer is installed on *IB Oden*. There is a possibility that 38kHz and 70kHz transducers will be added to the ship before the NPP expedition in July. If the 38kHz and 70kHz transducers are installed, the higher frequencies would be the preferred operating method and the 18kHz frequency would not be used.

At 18kHz the source level is 226 dB re micro-Pascal @ 1 meter

At 38kHz the source level is 229 dB re micro-Pascal @ 1 meter
At 70kHz the source level is 226 dB re micro-Pascal @ 1 meter

Kongsberg EM122 1°x1° 12 kHz hull mounted multibeam echo sounder

The system includes a Seatex Seapath 320 for navigation using GLONASS/GPS and motion sensor logging (roll, pitch and heave). The motion sensor unit is a Seatex MRU5.

The source level is 211 dB re micro-Pascal @ 1 meter
At 100m on axis, the intensity will decrease to 195 dB re micro-Pascal

A 300kHz Lowered Acoustic Doppler Current profiler (LADCP)

The LADCP will be mounted on the CTD rosette and will only be used during CTD casts. The system may have both a downward and upward pointing source. This instrument operates at a higher frequency and while the center frequency is not detectable by marine mammals, there are likely side bands (which will have lower intensities than the center frequency) that can be detected by narwhals. The higher frequency of this instrument results in greater attenuation with distance and combined with the frequencies produced results in a lower likelihood that marine mammals will detect this instrument unless closer.

The source level along each beam is estimated at 215 dB re micro-Pascal @ 1 meter, with a typical pulse duration of 5.7 milliseconds, and a typical pulse repetition rate of 0.75 seconds.
At 20 degrees off of the main lobe of each beam the level is estimated at 180.0dB re micro-Pascal @ 1.8 meters.
At 40 meters the level along each beam is estimated at 180.0dB re micro-Pascal.