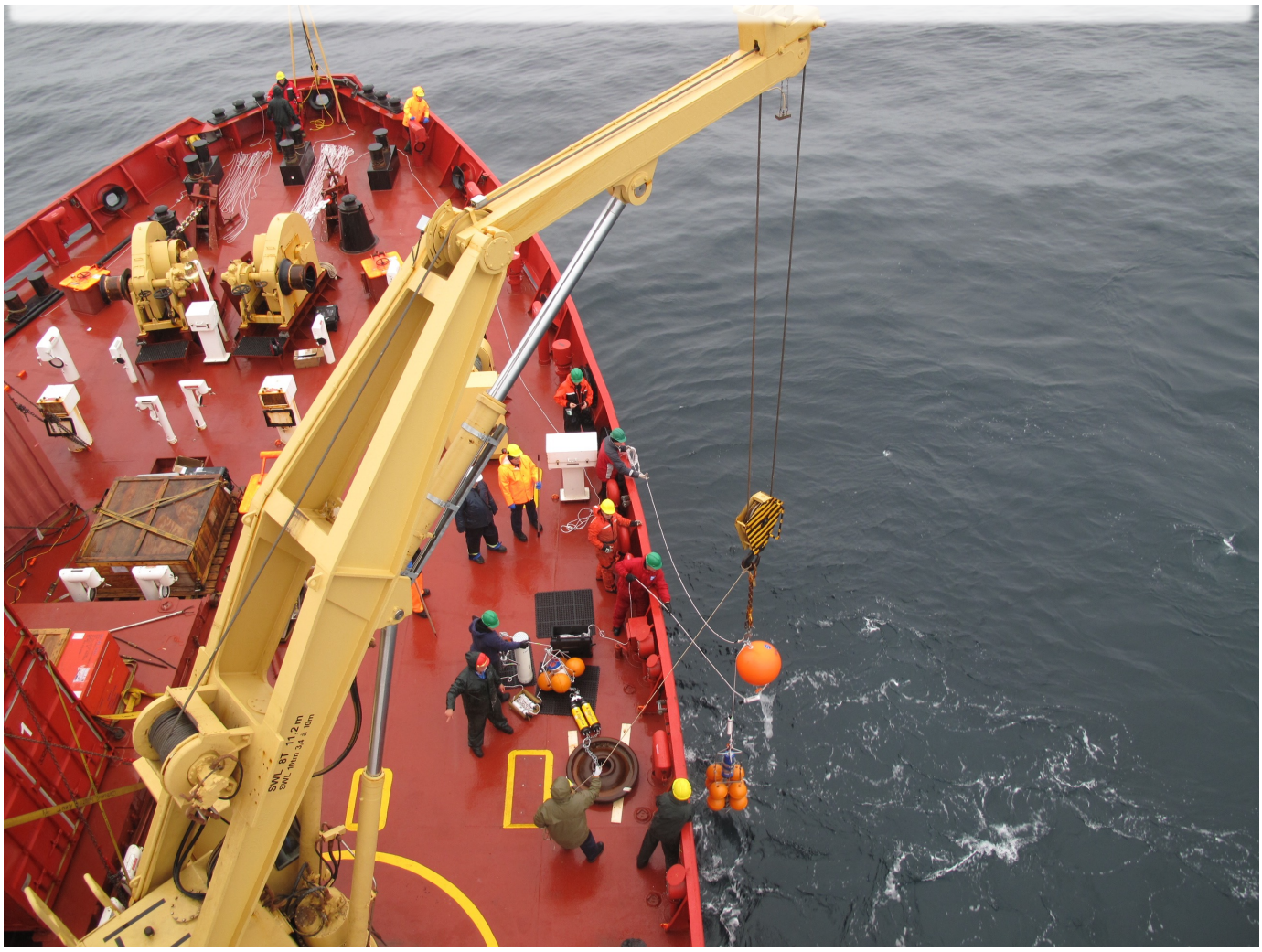
BaySys 2016 Mooring Program Cruise Report



The BaySys mooring team and crew onboard the CCGS Des Groseilliers. Five oceanographic moorings were deployed from September 26-October 3, 2016. The team attempted to retrieve the lost ArcticNet mooring, AN01, but were not successful. Opportunistic water and sediment sampling were executed at each possible station.

ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑎᑦᑕ
Université Laval, 1045 Ave. Médicine,
Québec, QC, G1V 0A6
1.418.656.7647
1.418.656.2334

UNIVERSITY OF MANITOBA

Manitoba Hydro

Table of Contents

List of Figures

BaySys 2016 Mooring Program Cruise Report

Drafted by Claire Hornby

Project PIs:	David Barber[1] (Project lead), Jens Ehn[1] (Team 1), Jean-Éric Tremblay[3] (Team 3), Tim Papakyriakou[1] (Team 4), Celine Gueguen[4] (Team 4), Zou Zou Kuyzk[1] (Team 4/5), Fei Wang[1] (Team 5), David Lobb (Team 5)
Field/Ship Coordination:	Jens Ehn (Chief Scientist), Claire Hornby[1] (Project Coordinator)
Mooring Operations:	Sergei Kirillov[1] (RA), Igor Dmitrenko[1] (Prof), Jens Ehn (Prof), Sylvain Blondeau[3] (Tech)
Rosette Operator:	Sylvain Blondeau
Water Sampling Team:	Lisa Matthes[1] (Phd), Atreya Basu[1] (Phd), Michelle Kamula[1] (RA), Zakhar Kazmiruk[1] (MSc), Jake (Janghan) Lee[3] (PhD), Masoud Goharrokhi[2] (PhD), Mary O'Brien (ISO, DFO)
Report Authors:	Hornby C, Ehn J, Matthes L, Kamula K, Lee J, Blondeau S, Basu A, Goharrokhi M, Kazmiruk Z, and Kirilov S
Research Vessel:	Canadian Coast Guard Ship (CCGS) *Des Groseilliers*

[1] Centre for Earth Observation Science, University of Manitoba, 535 Wallace Building, Winnipeg, MB

[2] Department of Soil Science, University of Manitoba, 535 Wallace Building, Winnipeg, MB

[3] Québec-Océan, Department of Biology, Pavillon Alexandre-Vachon, 1045, Avenue de la Médecine, Local 2078, Université Laval, Québec, QC

1. Introduction

1.1 Program Objectives

BaySys is a 4-year collaboration among industry partner Manitoba Hydro (Hydro Québec and Ouranos) and the Universities of Manitoba, Northern British Columbia, Québec à Rimouski, Alberta, Calgary, Laval and Trent to conduct research on Hudson Bay. The overarching goal of the project is to understand the role of freshwater in Hudson Bay marine and coastal systems, and in particular, to create a scientific basis to distinguish climate change effects from those of hydroelectric regulation of freshwater on physical, biological and biogeochemical conditions in Hudson Bay.

This project will address the main objective from a "systems" perspective, with sub-objectives to examine the climate, marine, and freshwater systems, and to study the cycling of carbon and contaminants. As such, five research teams have been organized to investigate five inter-connected subsystems, with continuous consultation, integration and feedback from Manitoba Hydro and other project participants: (Team 1) Marine and Climate Systems, (Team 2) Freshwater System (not involved in field work), (Team 3) Marine Ecosystem, (Team 4) Carbon Cycling and (Team 5) Contaminants.

1.2 Background and Regional Setting

As the largest continental shelf sea in the world, Hudson Bay (low Arctic, Canada) receives an annual freshwater loading of about 760 km^3 from more than 42 rivers within a drainage basin of over 3×106 km^2 in area. An even larger seasonal freshwater flux, estimated at 1200 km^3 or more, is withdrawn from or added to the water column due to the formation or decay of sea ice in the Bay. The timing, duration, volume and location of freshwater loading to Hudson Bay thus have a major influence on the properties and processes of the marine waters and the dynamics of sea ice, which in turn strongly influence primary productivity, carbon and contaminant cycling in the Bay. Distinguishing between runoff and sea-ice melt is especially important in Hudson Bay because each contribute considerable annual fluxes of freshwater to Hudson Bay, and yet they may be affected differently by climate change and regulation. To address the overarching goal of providing a scientific basis to separate climate change and regulation impacts on the Hudson Bay

system, BaySys (2015-2019) will integrate field-based experimentation with coupled climatic-hydrological-oceanographic-biogeochemical modeling.

The 2016 mooring field program took place in southern Hudson Bay from September 26 (Churchill) to October 4 (Kujjaurapik) (Figure 1). Opportunistic sampling continued from October 5 to October 12 in northern Hudson Bay (Figure 1), after which the ship returned to Iqaluit for crew change and all scientists disembarked. During the main eight-day cruise, members of all five multi-disciplinary teams collected CTD profiles, water and sediment samples, and deployed oceanographic moorings along the full length of the southern coast of Hudson Bay. The focus of this field program was on the Nelson Estuary region and James Bay mouth, which are the major sources of riverine fresh water to the Hudson Bay system.

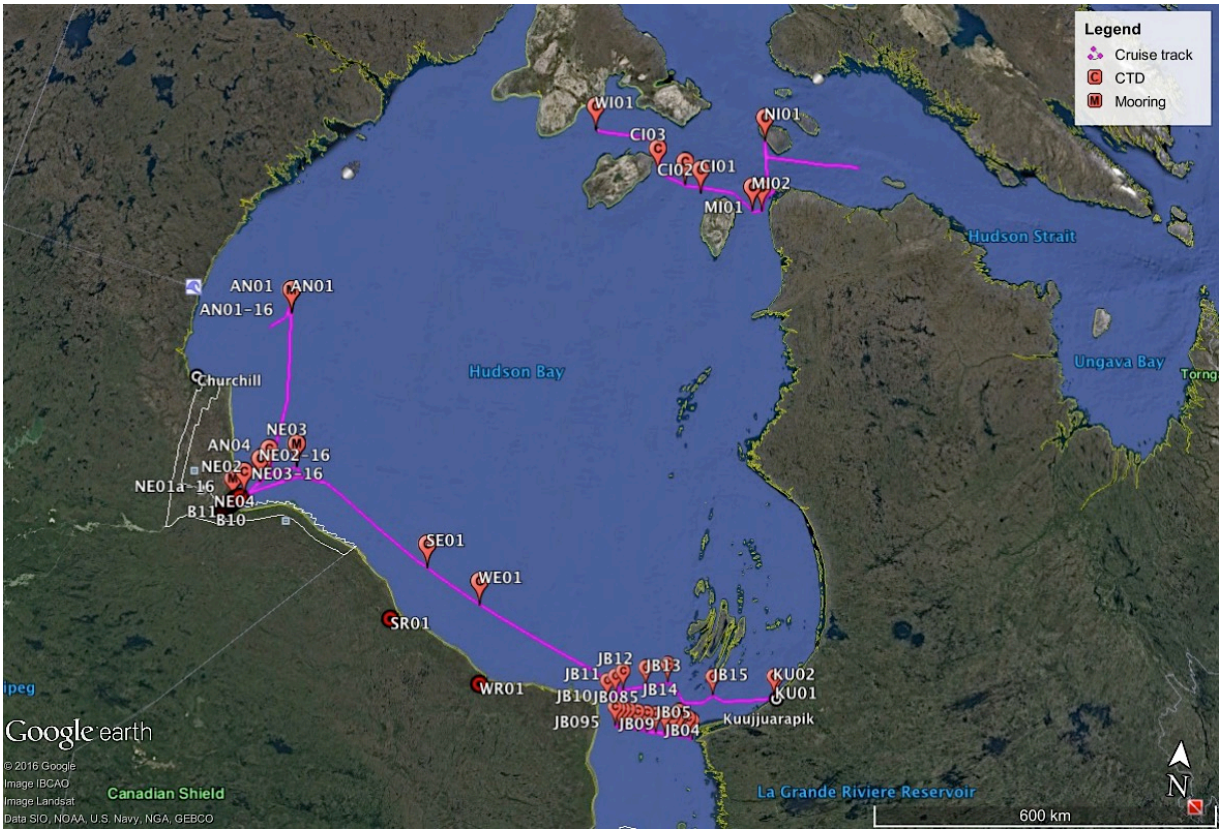


Figure 1. BaySys 2016 cruise track, mooring sites and CTD stations

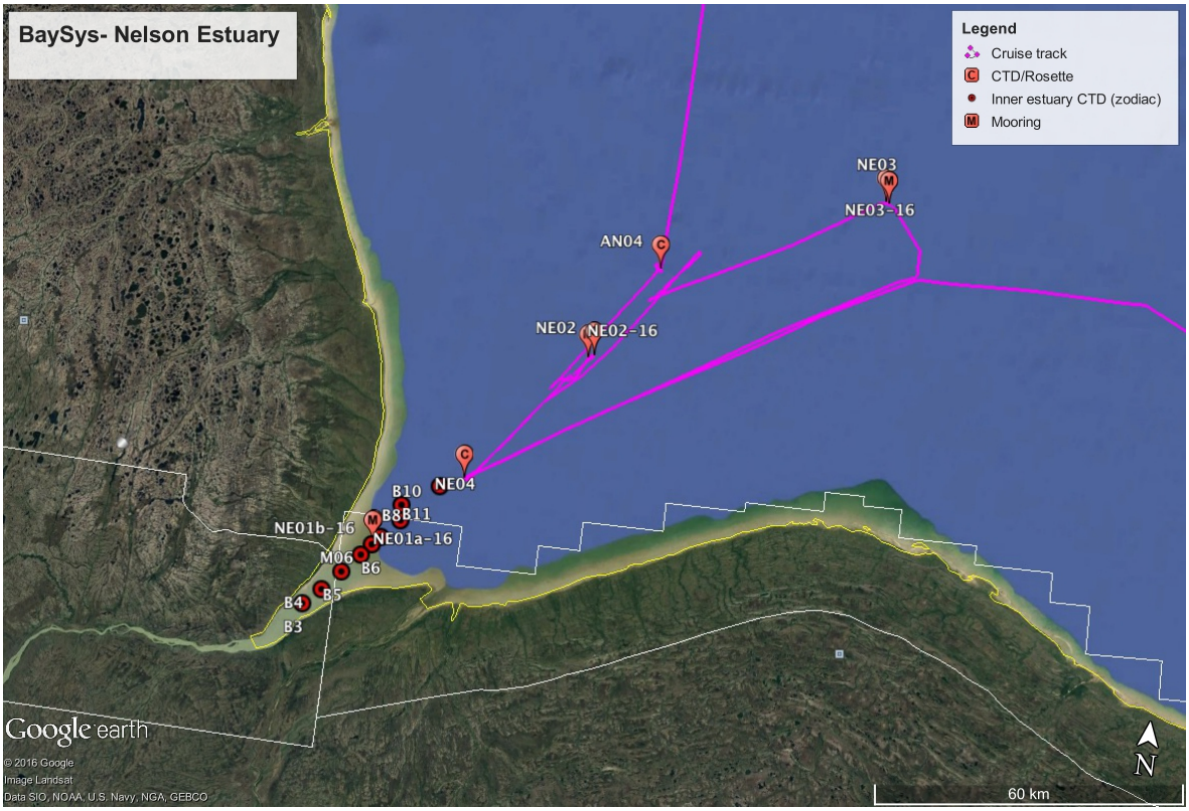


Figure 2. CTD water sampling (by zodiac) and mooring sites in the Nelson River Estaury

2. Mooring Operations

2.1 Mooring Instrumentation

Five oceanographic moorings were deployed from September 26- October 1, 2016 (Table 1). All mooring components and their depths are show in Figures 3-7. Three of the moorings located in deeper waters (i.e. AN01, NE03 and JB02) included custom-built buoyant mooring frames with upward looking Nortek Signature 500 Acoustic Doppler Current Meters (ADCPs). These are capable of measuring high-resolution near surface current profiles, ice draft and surface wave characterization. The TRDI Workhorse ADCPs, located further below mounted inline or in trawl-resistant bottom mounts, provide an additional current profile of the water column and surface tracking. Only the JB02 lacked a TRDI Workhorse ADCP; however instead it included a downward looking Nortek Aquadopp 600 kHz ADCP to provide observations of the currents below ~50 m depth (Figure 7). Trawl-resistant bottom mounts were deployed in the

inner (NE01; Figure 5) and outer estuary (NE02; Figure 6) stations where higher water column dynamics are expected leading to high current speeds and ice ridging. Numerous RBR conductivity (C) and temperature (T) loggers, some with an additional Seapoint turbidity meter (Tu), were provided in-kind by Manitoba Hydro and attached to the mooring lines at select locations. In addition, 7 Wetlabs ECO triplet loggers were attached to near surface locations and on the trawl-resistant bottom mount on NE01 (inner estuary, Figure 5) to record chlorophyll-*a* fluorescence, CDOM fluorescence and turbidity.

A special addition to AN01, NE01 (however lost), NE02 and NE03, were the buoyant tubes moored at depths near the surface so that instrument imbedded within the tubes can record surface layer properties near the ice cover. Due to the length and smoothness of the tubes, they will resist being caught and carried off by drifting ice ridges. The drifting ice ridges, with sufficient draft to reach the tubes, will (hopefully) push down the tubes instead of catching them. However, in the event of tubes getting trapped and dragged by drifting, weak links were placed on the lines connecting the tubes to the moorings so that only the tube component of the moorings would be lost. Four sediment traps (see next section) were attached to AN01, NE02, NE03 and JB02 (Table 1), and are a contribution from Dr. Zou Zou Kuzyk of BaySys Team 4/5.

The mooring components are programmed for a one-year deployment with the planned recovery in the fall 2017. However, in the event that there is no suitable ship available for the fall 2017, they will be recovered in June/July 2017 during the CCGS *Amundsen* cruise in Hudson Bay.

Table 1. Summary of BaySys mooring locations, station IDs, sediment trap depths, and bottom depth at deployment

Date	Mooring location	ID	Latitude	Longitude	Bottom Depth (m)	Sediment trap depth (m)	Trap serial number
Sept 26	Churchill Estuary	AN01	59°58.156'N	91°57.144'W	109	85	718630
Sept 27	Nelson Estuary (outer)	NE02	57°30.007'N	91°48.095'W	46	35	718631
Sept 28	Nelson Estuary (shelf)	NE03	57°49.762'N	90°52.888'W	54	28	718632*
Sept 29	Nelson Estuary (inner)	NE01	57°07.923'N	92°24.704'	29.7	No trap	
Oct 1	James Bay	JB02	54°40.973'N	80°11.226'W	101	75	718633*

*Note: The rosette and motors for these two sediment traps were accidently swapped.

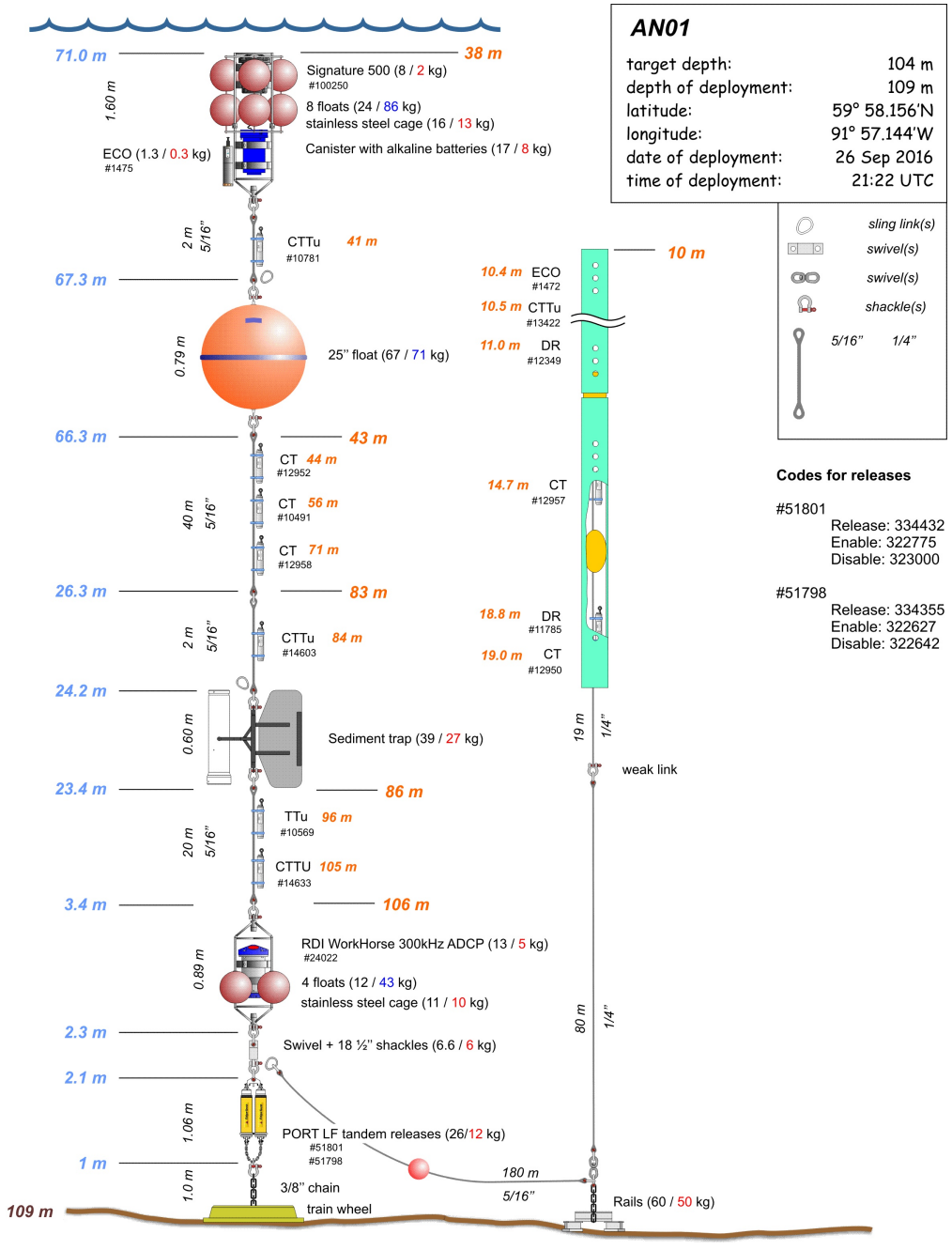


Figure 3. AN01 (Churchill shelf) mooring configuration, location and depth

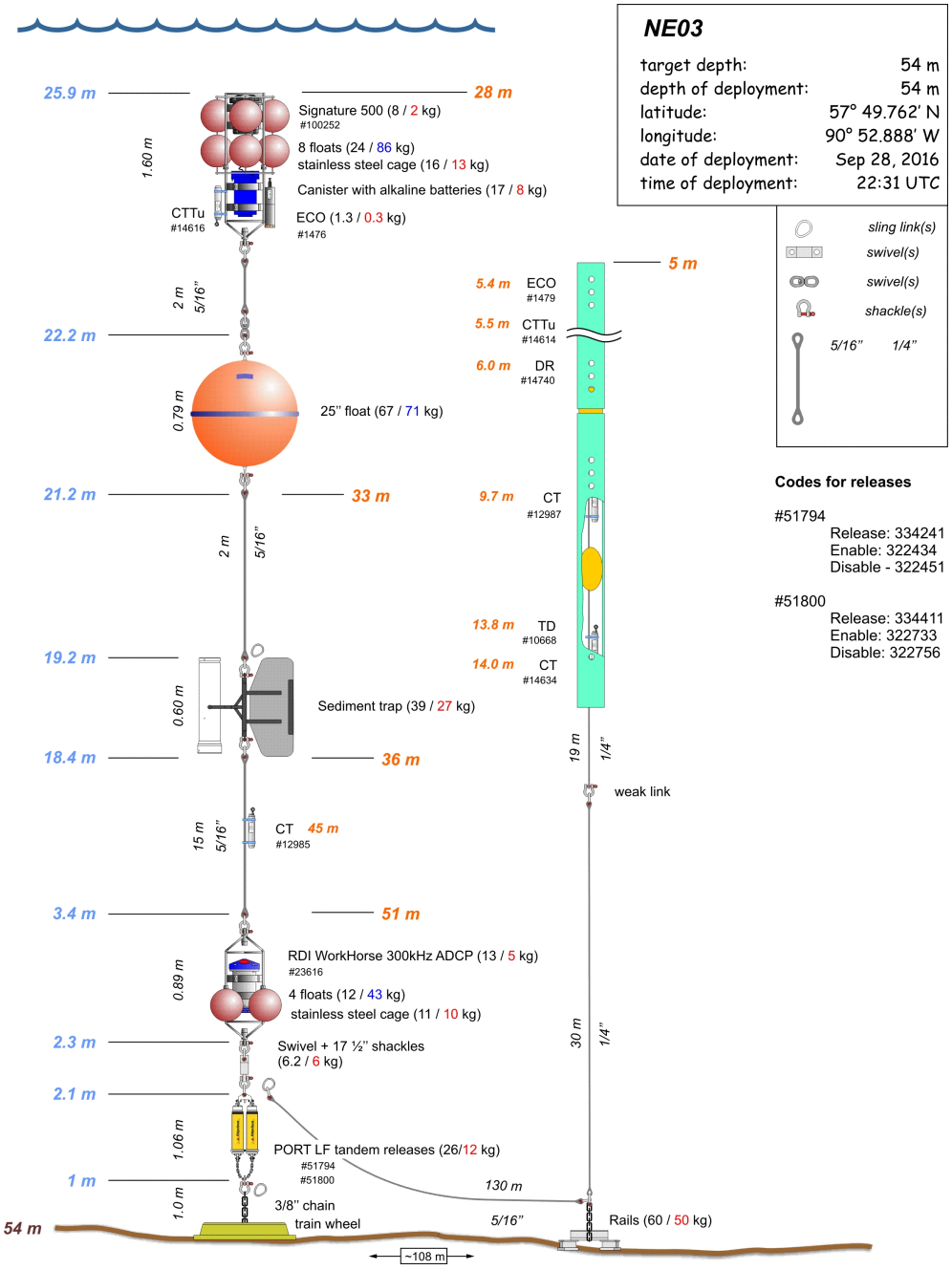


Figure 4. NE03 (Nelson River outer shelf) mooring configuration, location and depth

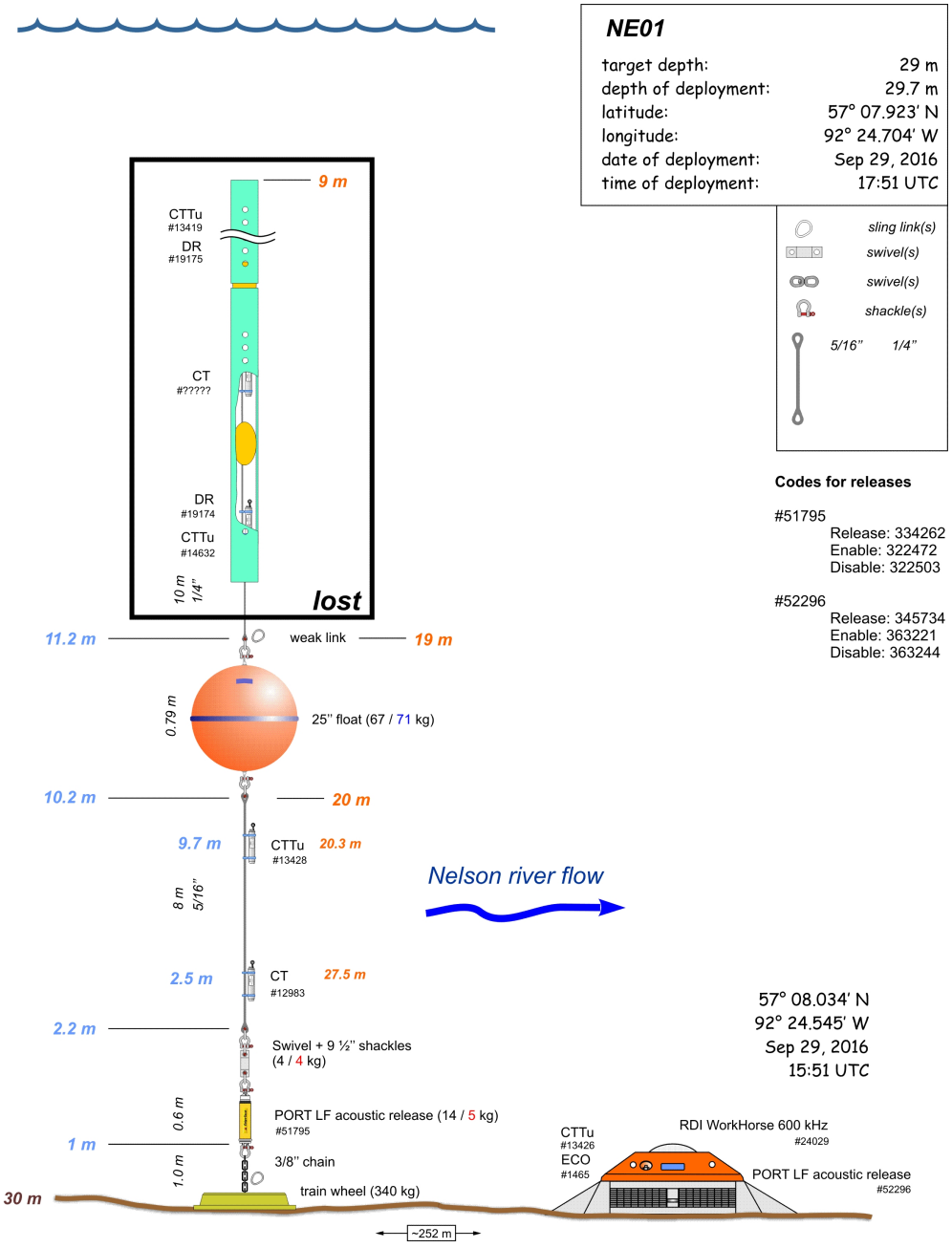


Figure 5. NE01 (Nelson Inner Estuary) mooring configuration, location and depth. Top tube was lost during helicopter transit.

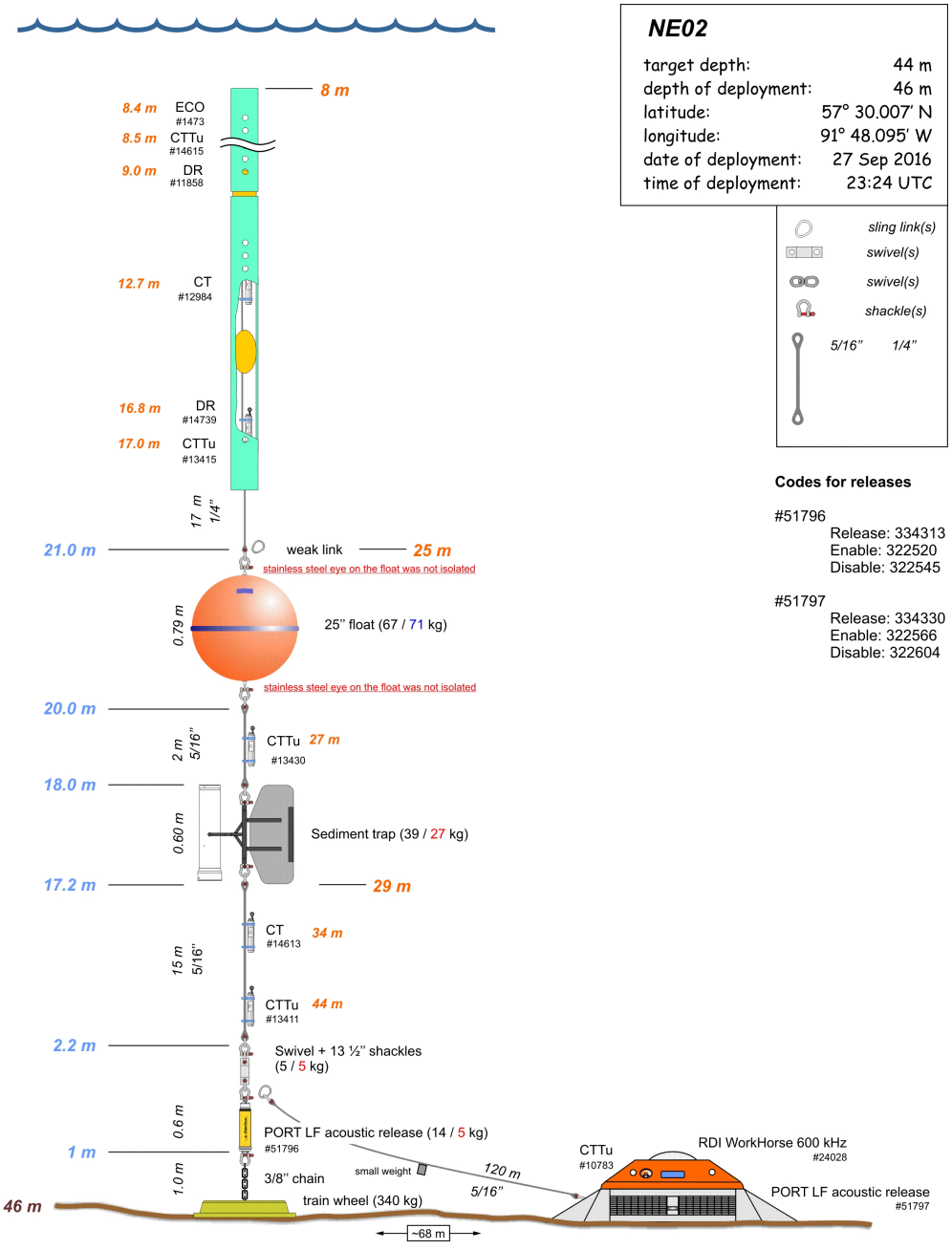


Figure 6. NE02 (Nelson Outer Estuary) mooring configuration, location and depth

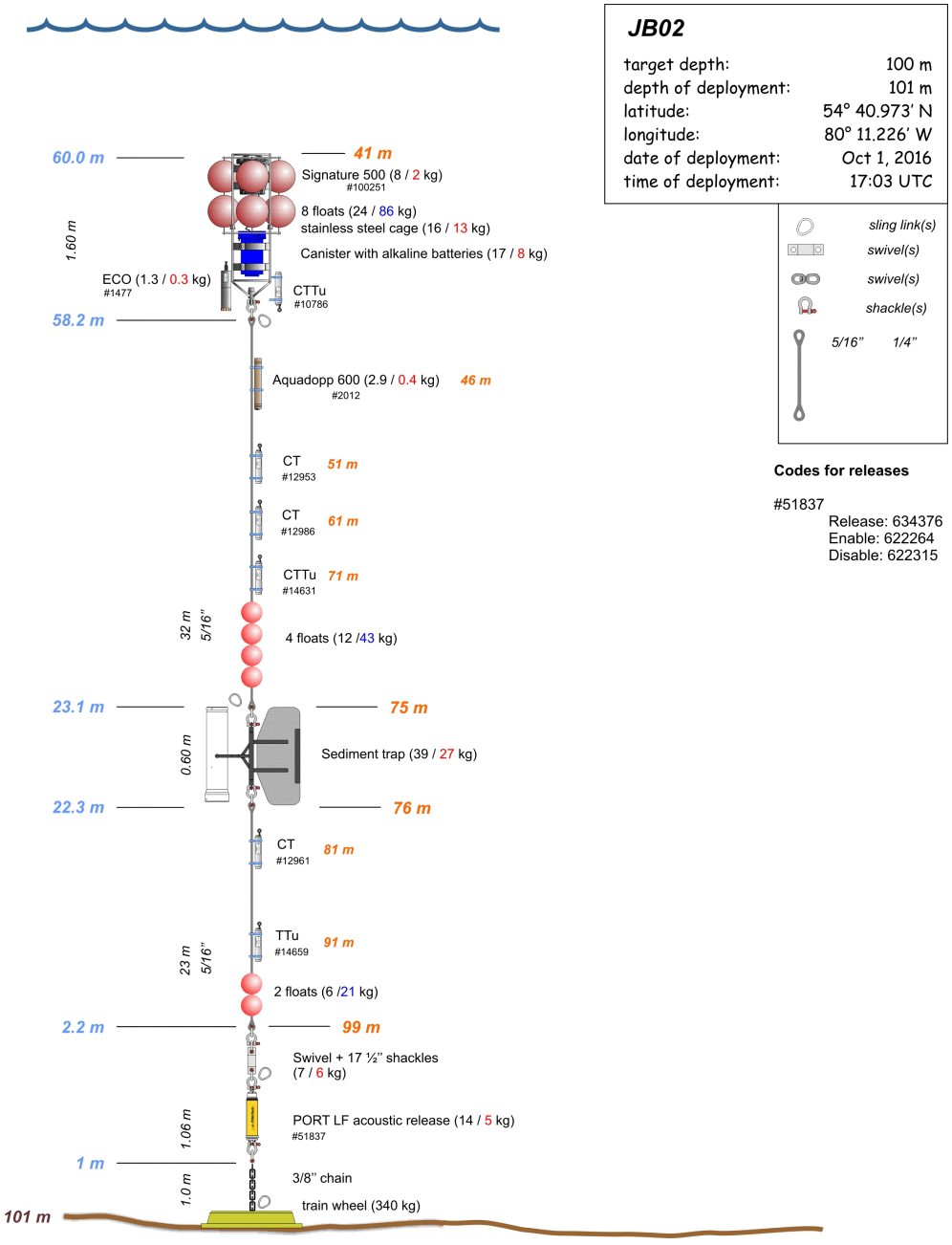


Figure 7. JB02 (James Bay) mooring configuration, location and depth

2.2 Mooring Deployment

All moorings (except NE01) were deployed from the foredeck by using the crane at the starboard side of the ship. The relatively short length of all moorings allowed deploying them "anchor last". The design of mooring AN04, NE02 and NE03 included a second component (surface buoyant tubes or TRBM) connected to a major line with a long rope near the bottom. Since each mooring carries two acoustic releases only, such a connection aims to increase the mooring survivability in a case of one of releases failure. The connecting line also facilitates the recovery by dragging in a case of both releases fail to respond at the moment of recovery.

Two elements of mooring NE01 were deployed separately in the inner estuarine area from helicopter. The deployment was supported by crew and scientist in the zodiac: the mooring elements were smoothly dropped into the water in the designated areas marked from zodiac with the small anchored surface floats.

2.3 Sediment Traps

The objective of the sediment trap program, as part of BaySys Team 4/5, is to determine the sinking fluxes of particulates (organic and lithogenic) through the water column. Four Gurney Instrument "Baker Type" sequential type sediment traps were deployed from the CCGS *Des Groseilliers* fixed to moorings AN01, NE02, NE03 and JB02 at depths ranging from 28 to 85 m below the water surface (Table 1).

2.3.1 Methods

Prior to embarking the ship, sediment trap solution, or density gradient solution, was prepared at the Churchill Norther Studies Centre (CNSC). To prepare the solution, 10L of sea water was collected from the port wharf and filtered through 0.7 um GF/F filter. The salinity of the filtered seawater was adjusted from 26.7 psu to 37 psu with 88.065g of ultra clean sea salt. Borax (44.4 g) was slowly added to 37% formaldehyde (0.45L) and placed on a magnetic stir plate overnight to dissolve. The solution was removed from the stir plate and, after settling for approx. 4 hours, was decanted and poured into 8.55 L of filtered sea water. The solution was stored in a 10L polypropylene aqua pak water container until sediment traps were ready to be assembled, which took place before deployed.

Once onboard the ship, all four sediment trap motor/timers were removed from their cases, checked over, including batteries and o-rings, and timer intervals were set simultaneously in central standard time (See table 2). All four sediment trap motors (see Figure 8AB) were turned on at exactly 18:00 on 25-September-16 (interval 0) so that, simultaneously, they would began collecting particulates at 0:00 CST 4-October-16 (interval 1).

Table 2. Sediment trap sample intervals

Interval	Start Date	Start Time (CST)	End Date	End Time (CST)	Interval Days	Collection Area
delay	25-Sep-16	18:00	4-Oct-16	0:00	8.25	N/A
1	4-Oct-16	0:00	8-Nov-16	0:00	35	0.032 m^2
2	8-Nov-16	0:00	13-Dec-16	0:00	35	0.032 m^2
3	13-Dec-16	0:00	17-Jan-17	0:00	35	0.032 m^2
4	17-Jan-17	0:00	21-Feb-17	0:00	35	0.032 m^2
5	21-Feb-17	0:00	28-Mar-17	0:00	35	0.032 m^2
6	28-Mar-17	0:00	2-May-17	0:00	35	0.032 m^2
7	2-May-17	0:00	6-Jun-17	0:00	35	0.032 m^2
8	6-Jun-17	0:00	11-Jul-17	0:00	35	0.032 m^2
9	11-Jul-17	0:00	15-Aug-17	0:00	35	0.032 m^2
10	15-Aug-17	0:00	19-Sep-17	0:00	35	0.032 m^2

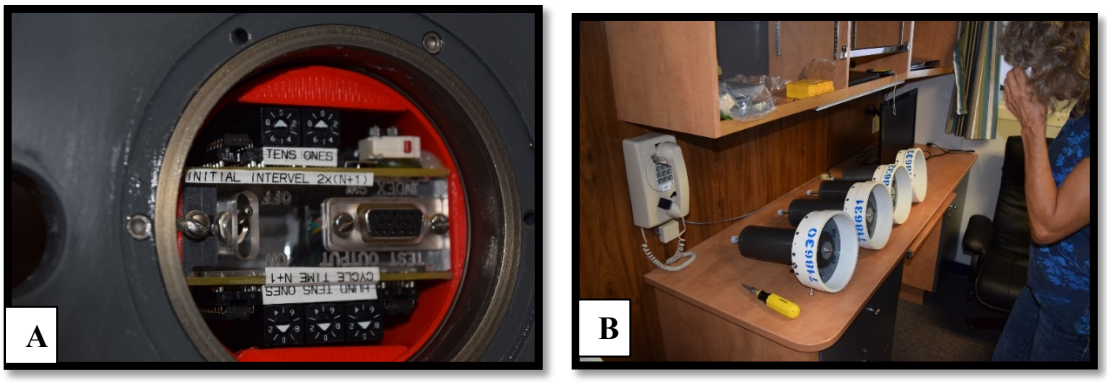


Figure 8. Sediment trap timers
All timers were set simultaneously and turned on at the exact same time at 0:00 Hr on 4-October-2016.

Figure 9. Sediment trap equipment, methods and deployment

(A) Mary O'Brien fills sediment trap tubes with density gradient solution that are housed in a rosette assembly that also contains the motor/timer, and (B) then places and secures the corresponding PVC tube that houses an asymmetrical funnel over the sediment trap tubes. (C) Michelle Kamula and Mary O'Brien ensure the sediment trap tubes are lined up with the asymmetrical funnel and that the rosette, motor/timer smoothly rotates inside the PVC tube. (D) Prior to deployment, a fin is secure fastened to the sediment trap and attached to the mooring line

Prior to deployment, each sediment trap was assembled by placing 10 sample tubes in the corresponding sediment trap rosette and filled to the surface with density gradient solution, , leaving no head space (see preparation above and Figure 9A). The rosette was set to position "0" or the start position, which held no tube. The corresponding PVC tube that houses an asymmetrical Teflon funnel was washed thoroughly using fresh water to remove any dust or particles and placed over top of the motor/timer and sample tube rosette assembly (Figure 9B). Using a magnet, the rosette was turned slowly and each sample tube was checked to ensure it lined up with the funnel and that the rosette rotated smoothly inside the PVC tube housing (Figure 9C). Fins containing a weight at the bottom were assembled and attached to the sediment trap directly before deployment (Figure 9D). The sediment trap assembly was attached to the mooring by shackles and lowered into the water by crew and crane operator.

2.4 Attempted Mooring Retrieval

On September 26, the BaySys and Des Groseilliers crew attempted to retrieve lost ArcticNet mooring AN01. Several efforts were made to communicate with the mooring with the use of an acoustic release. Unfortunately, no signal was located. The ship then attempted to dredge for the mooring (Figure 10) and were unsuccessful. We will attempt to retrieve this mooring again using a multibeam survey with the CCGS *Amundsen* in June 2017.

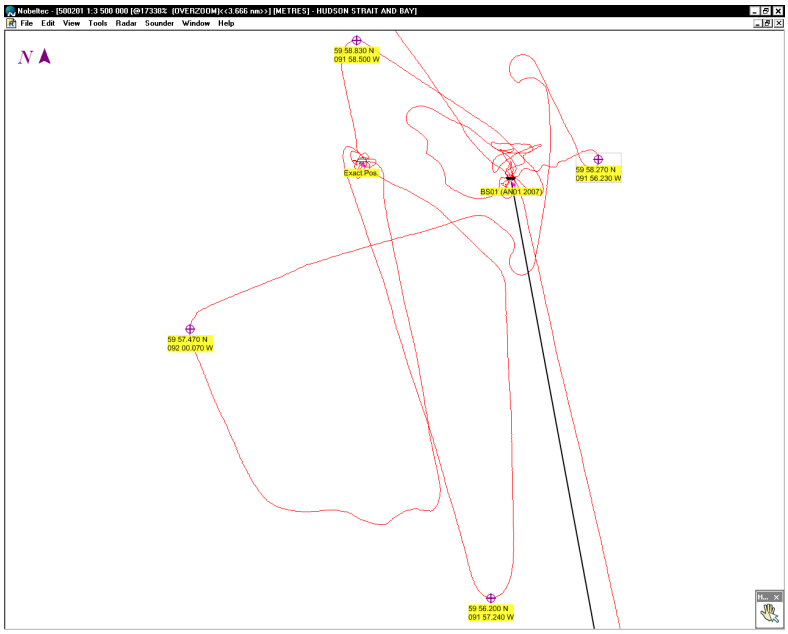


Figure 10. Map of dredging locations in attempt to locate lost AN01 mooring

3. Water Sampling

The second objective of our shipboard fieldwork was to characterize the physical and chemical properties in the water column, such as temperature, salinity, fluorescence, dissolved oxygen concentration, light penetration and turbidity. Water sampling was carried out using a CTD-Rosette (donated by Quebec Ocean), niskin bottles and bucket (in the river systems).

Table 3. Water sampling parameters collected by BaySys teams 1,3,4,5 (see Appendix 1 for full list of stations and parameters)

CTD	Conductivity temperature depth probe of two manufacturers (Seabird, Idronaut)
SPM	Suspended particular matter
CDOM	Colored dissolved organic matter
O18	Oxygen Isotopes
a_p	Particle absorption
HPLC	High-performance liquid chromatography
POC	Particular organic carbon/ nitrogen
Lugol	Preserved phytoplankton samples
FlowCam	Dynamic imaging particle analyzer
NO^3, NO^2, Si, PO^4	Nitrite, nitrate, orthophosphate and orthosilicic acid
NH^4	Ammonium
Chl *a*	Chlorophyll *a*

3.1 CTD-Rosette

We used a SBE 25CTD with various other sensors (see Table 4-5) mounted on a cylindrical frame known as a rosette. The rosette frame was originally equipped with 12 x 8 liter bottles but due to the maximum safe working load of the winch, it was limited to 10 bottles (Figure 11). The rosette supplied water samples, surface and at depth, for the teams on board.

3.1.1 Probes calibration

1. Seabird CT Probes temperature, conductivity and oxygen have been calibrated at the Sea-Bird factory prior the ship departure from Quebec City.
2. Seabird Pressure sensor have been calibrated at Laval University prior the ship departure from Quebec City
3. Biospherical light sensor was new
4. Seatech fluorometer and transmissometer couldn't be calibrated but verified for min and max measurement and worked properly.

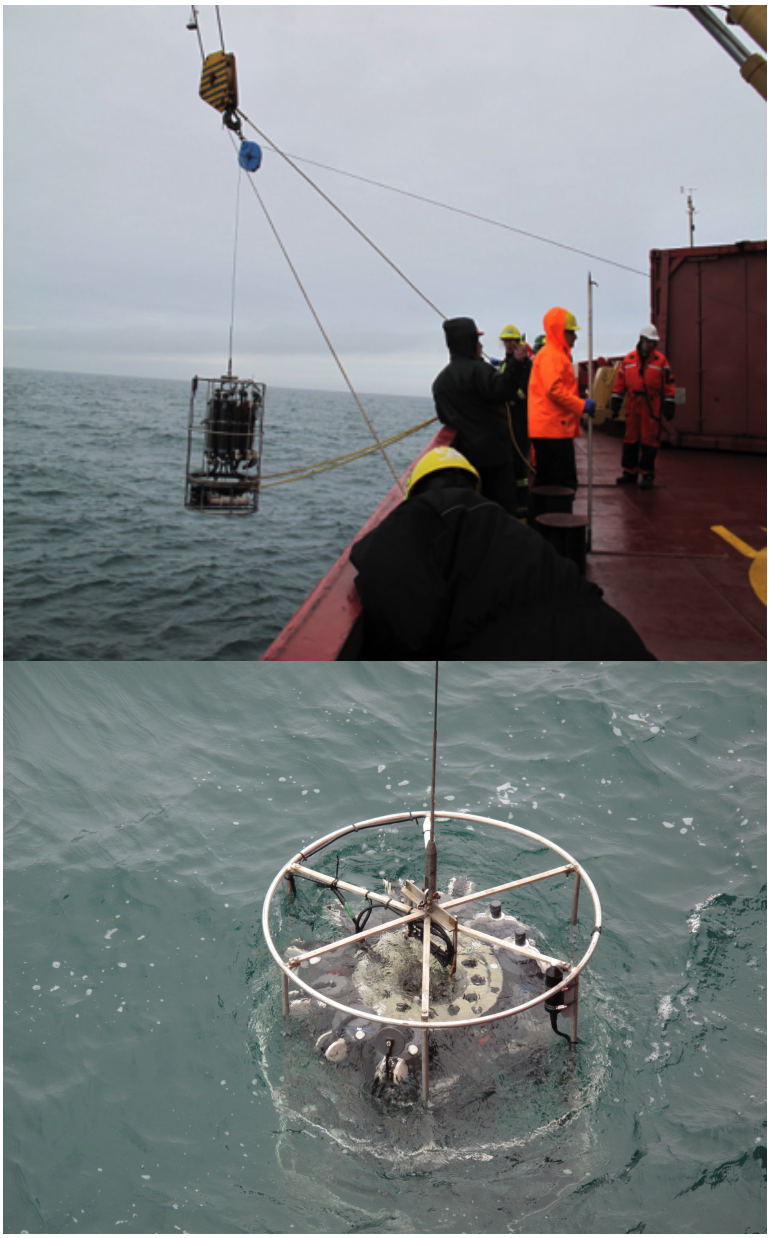


Figure 11. Rosette (10 bottle) operations on board *CCGS Des Groseilliers*

Table 4. Rosette sensors

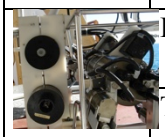
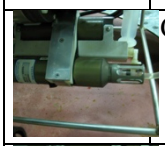
Photo	Instrument	Manufacturer	Type & Properties	Serial Number
	Data Logger	SeaBird	SBE-25 Sampling rate : 8 Hz	0039
	Temperature	SeaBird	SBE 3 Range: -5°C to + 35°C Accuracy: 0.001	031116
	Pressure	SeaBird	Accuracy: 0.015% of full range	290114
	Conductivity	SeaBird	SBE 4C Range: 0 to 7 S/m Accuracy: 0.0003	040819
	Oxygen	SeaBird	SBE-43 Range: 120% of saturation Accuracy: 2% of saturation	431007
	PAR	Biospherical	QSP2300	70422
	Fluorometer	Sea Tech	Minimum Detectable Level 0.02 µg/l Gain Sens, V/(µg/l) Range/(µg/l), 30x 1.0 5 10x 0.33 15 3x 0.1 50 1x 0.033 150	149
	Transmissometer	SeaTech	Path length: 25 cm Sensitivity: 1.25 mV	171

Table 5 Sensor specifications

Parameter	Sensor Company	Sensor Instrument Type	Range	Accuracy	Resolution
Attached to the Rosette					
Data Logger	SeaBird	SBE-25 [1]	600 m		
Temperature	SeaBird	SBE-03 [2]	-5°C à +35°C	0.001°C	0.0002°C
Conductivity	SeaBird	SBE-4C [2]	0-7 S/m (0-70mmho/cm)	0.0003 S/m (0.003mmho/cm)	0.00004 S/m (0.0004 mmho/cm)
Pressure			up to 600m (1 000psia)	0.015% of full scale	0.01% of full scale
Dissolved oxygen	SeaBird	SBE-43 [2]	120% of surface saturation[4]	2% of saturation	unknown
Light intensity (PAR)	Biospherical	QSP-2300[3]	400-700 nm		
Fluorescence	SeaTech	Chlorophyll-fluorometer	0-5 V	unknown	
Transmissiometer	SeaTech		0-5 V	unknown	

Notes: [1] Maximum depth of 600m; [2] Maximum depth of 6800m; [3] Maximum depth of 2000m

3.1.2 Salinity samples

Salinity samples have been taken on most of the rosette cast for comparison with the conductivity sensor on the rosette.

3.1.3 Rosette water sampling

Water was sampled with the rosette according to each team's requests. To identify each water sample, we used the term "rosette cast" to describe one CTD-rosette operation. A different cast number is associated with each cast. The cast number is incremented every time the rosette is lowered in the water. The cast number is a seven-digit number: **xxyyzzz,** with xx: The last two digits of the current year; yy: A sequential (Québec-Océan) cruise number; zzz: The sequential cast number. For this cruise, the first cast number is: **1606001.** To identify the nine rosette bottles on this cast we simply append the bottle number: **1606001nn,** where "nn" is the bottle number (01 to 09).

Two types of CTD-Rosette casts are defined as follows:

CTD casts: CTD profiles are only to collect data from water column

Rosette casts: Samples are obtained for Chlorophyll, Nutriment, Dissolved Oxygen, CDOM, Salinity, Flow Cam etc.

3.1.4 Sampling stations (Leg 1)

All the information concerning the Rosette casts is summarized in the *CTD Logbook* (one line per cast) and an example shown here in Figure 12. The information includes the cast number and station ID, date and time of sampling in UTC, latitude and longitude, bottom and cast depths, and comments concerning the casts.

AJOUTER UN CAST | COPIE DE SAUVEGARDE | AIDE | Québec Océan

Cruise ID: 1407 | SUPPRIMER UN CAST | FERMER LE FICHIER | SAUVER LE FICHIER

Cruise NAME: ArcticNet

Cast	Station	Date début UTC	Heure UTC	Lat. (N)	Long. (W)	Fond (m)	Prof. cast (db)	Commentaires	Type	Init
001	pcbc2	30 / 09 /	19 : 43	71 ° 5.450	071 ° 50.920	696	697		Full	SB
002	pcbc3	01 / 10 /	13 : 11	70 ° 46.042	072 ° 15.617	444	437		basic	LB
003	Gibbs N	01 / 10 /	22 : 58	71 ° 7.378	070 ° 57.670	446	439		Nutrient	LB
004	176	02 / 10 /	13 : 13	69 ° 35.527	065 ° 26.024	195	187		Nutrient	LB
005	179a	03 / 10 /	08 : 34	67 ° 20.380	062 ° 36.947	110	96.4		Nutrient	LB
006	179	03 / 10 /	10 : 22	67 ° 24.974	062 ° 11.004	190	182		Nutrient	SB
007	180	03 / 10 /	13 : 55	67 ° 28.666	061 ° 45.314	210	200		basic-n	SB
008	181	03 / 10 /	16 : 41	67 ° 33.199	061 ° 22.589	1140	1130		Nutrient	LB
009	640	07 / 10 /	17 : 20	58 ° 55.486	062 ° 9.276	143	135.6		Nutrient	LB
010	645	08 / 10 /	04 : 16	56 ° 42.206	059 ° 42.230	119	109		Nutrient	SB
011	650	08 / 10 /	19 : 51	53 ° 48.293	055 ° 26.112	204	195		Nutrient	LB

Figure 12. CTD Logbook example, one line per cast

An Excel® *Rosette Sheet* was created for every single cast. This file includes the same information as the CTD Logbook, plus a table of what was sampled and at what depth. Weather information at sampling time was also included in each Rosette Sheet, and is summarized in a *Meteorological Logbook* (one line per cast). For every cast, data from three seconds after a bottle is closed, to seven seconds later, is averaged and recorded in the ascii '*bottle files'* (files with a *btl* extension). The information includes the bottle number, time and date, trip pressure, temperature, salinity, light transmission, fluorescence, dissolved oxygen. These files will be made available as soon as the data is processed and corrected, if necessary.

3.1.5 Problems encountered with CTD-Rosette

We encountered a transistor failure in the power supply of the transmissometer and fluorometer sensors at the beginning of the cruise. In order to fix the problem technician Sylvain Blondeau had to short-cut the transistor circuit to bring power back to the sensors. However, when the pump was activated after some time in the salt water, the current drawn to the batteries

was too much causing it to lose memory and configuration of the ctd, ultimately stopping the connectivity with the computer on deck. After a few casts, the pump finally burst. After this, the oxygen and conductivity had to be disconnected from the pump and positioned vertically so that water could pass thru them during the cast. The ctd was then configured so that it would not activate the pump during the cast.

3.1.6 Preliminary results of thermohaline stratification in Hudson Bay (CTD profiles)

Temperature and salinity was recorded from the inner to the outer Nelson estuary as well as at James Bay mouth by the Idronaut CTD probe. Vertical CTD profiles show the distribution of riverine freshwater coming from Nelson river into Hudson Bay (fig. 13). Fresh and salty water start mixing in shallow water, whereby a strong outflow current of Nelson river might be the reason why salinity above 20 is measured in deeper water further away from the estuary. The warmer temperatures of the river water are following the same trend.

The high riverine freshwater input in James Bay is causing a strong thermohaline stratification at the entrance to Hudson Bay (fig 14). A 20 m thick layer of less salty, warm water was found at the surface. According to the five CTD profiles in centre of James Bay mouth, the halocline was slightly lower (30 m) than the thermocline (20 m).

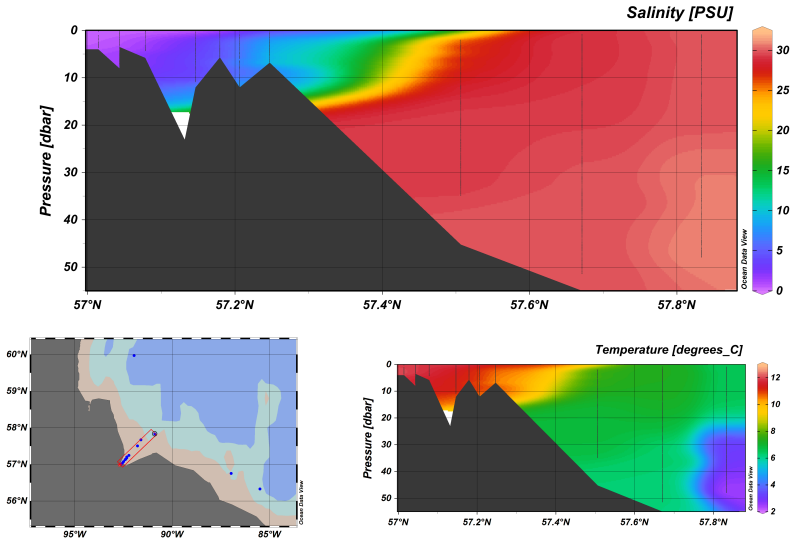


Figure 13.Temperature and salinity profile of Nelson Estuary
CTD profiles (black lines) were taken in the inner and outer estuary

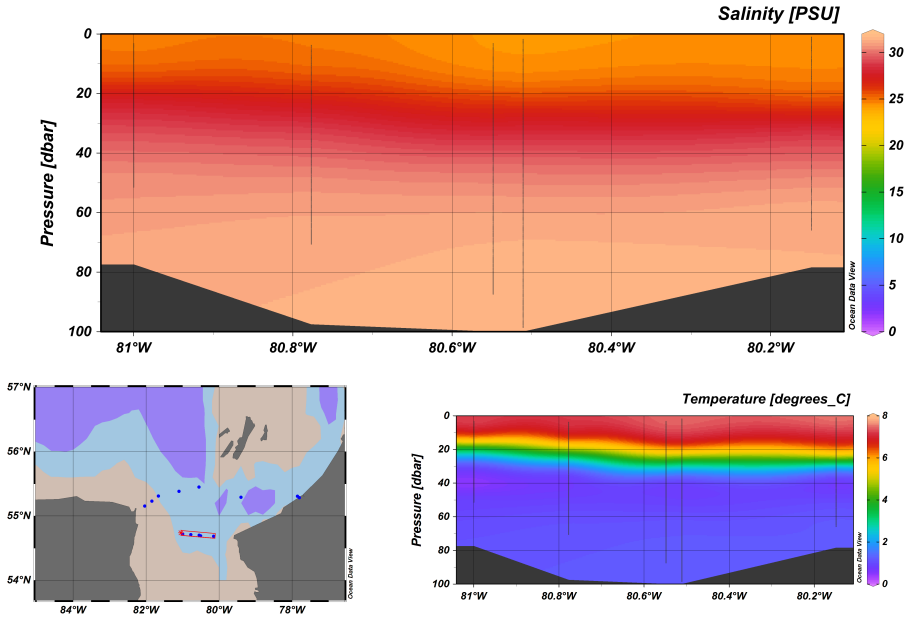


Figure 14. Temperature and salinity profile of James Bay mouth
CTD profiles (black lines) were taken in the deep center of the opening to Hudson Bay

3.2 Freshwater Dynamics

In order to understand the freshwater dynamics of the Hudson Bay before the onset of winter, water samplings were carried out by members of Team 1 all along the south and south-east coastal belt of Hudson Bay. The emphasis was on assessing the distribution of runoff from the Nelson and Churchill River and also from the James Bay which normally accounts for 80% of the riverine input into the Hudson Bay. Few water samples were also collected in the northern Hudson Bay, near Coats and Mancel Island. Water samples collected, were intended for Total Suspended Solid (TSS) analysis along with CDOM and O_{18} measurement. In field processing of the water samples was carried out for TSS retrieval, using vacuum filtration technique. Filters of pore size of 0.7 µm were used, and the filtered samples were stored in -4°C freezer. CDOM samples were prepared by syringe filtration using a 0.2 µm filter in 40ml amber coloured bottle. The filtered CDOM samples were stored in the +4°C refrigerator. Also O_{18} and salinity samples were prepared. Salinity samples will serve as a calibration for the field measured salinity profile using the idranaut/ Rosette CTD. The filtered TSS and CDOM samples along with the O_{18} and salinity has been brought back to CEOS for laboratory analysis.

3.3 Nutrients and Biological Sampling

The composition and distribution of the phytoplankton community in Hudson Bay fluctuates throughout the year depending on the thermohaline stratification, nutrient supply and the availability of solar radiation. The main goals for BaySys Team 3 were to assess the nutrient loading, phytoplankton biomass and size distribution of the micro- and nanofraction with respect to inshore/ offshore gradients in oceanographic parameters (main focus on underwater downwelling irradiance) and the influence of regulated or unregulated rivers. The aim of the participation in the fall cruise was to gain a baseline in biological productivity when there is sufficient light but a likely low nutrient concentration found in the upper water column.

3.3.1 Optical and Biological Characterization of pre-freezing Conditions

The spectral light climate of the euphotic zone was investigated by *in situ* measurements of downwelling and upwelling irradiance as well as hyperspectral attenuation and transmission along the coast of southern Hudson Bay from Churchill, crossing James Bay, to Kuujjuarapik and at the entrance of the Bay between Coats Island, Mansel Island and Ivujivik. In Hudson Bay, a massive freshwater input by river runoff causes a strong stratification restricting upward nutrient flux into the surface layer and limiting phytoplankton production particularly in summer. The resulting low chlorophyll *a* concentration is expected to cause a high light transmission in the upper water column. However, coastal waters are strongly influenced by the sediment load from the numerous rivers which has a direct effect on the light attenuation coefficient. The aim of this investigation (under Team 1) was to describe the light conditions and inherent optical properties of the upper euphotic zone of Hudson Bay in fall before sea ice starts to form. To do so, a metal frame equipped with two UV-visible spectral radiometers (spherical RAMSES-ASC, TriOS GmbH, Germany) and one hyperspectral VIS photometer (VIPER G2, TriOS) was lowered from the front of the vessel in the direction of the sun.

Measurements were taken from the surface to a depth of 30 m every 0.5 m, roughly. Incident solar radiation was recorded with one UV-visible spectral radiometer (Cosine RAMSES-ACC, TriOS GmbH, Germany) at the same time. Inherent optical properties of the water column were investigated in terms of particle absorption, chlorophyll *a* concentration and the content of particulate organic carbon and nitrogen. Water for filtration was sampled by a rosette at three different depth levels: surface water between 1 m and 5 m, the depth of the chlorophyll maximum and 10 m above the bottom. For laboratory analysis of particle absorption (a_p) by

spectrophotometry as well as the analysis of chlorophyll a concentration by high-performance liquid chromatography (HPLC) at the University of Manitoba, water samples of 1L were filtered through 25 mm Whatman GF/F filters and stored in a -80 °C freezer. Particular organic carbon and nitrogen (POC/N) samples (0.5L) were filtered through 21 mm Whatman GF/F filters and stored at -80 °C.

Figure 15. Measurements of incident solar radiation (left, radiometer attached to a stick pointing upward), total underwater irradiance and hyperspectral absorption and transmission within the water column (right, radiometers mounted to a metal frame and lowered with a weight a straight alignment)

3.3.2 Characterizing the size distribution of the present micro- and nanophytoplankton

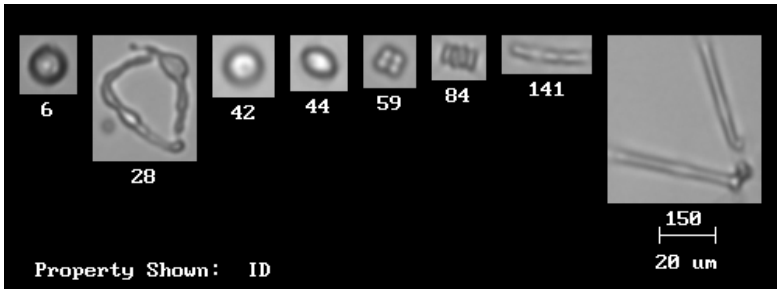
Water samples (100 mL) from the three depths were preserved with Lugol's solution in Amber bottles for later microscopic analysis. Furthermore, particles in the water from the same depth levels were directly analyzed by automated imaging technology (FlowCam, Fluid Imaging Technologies, INC., USA). The FlowCam as a dynamic imaging particle analyzer examines a fluid under a microscope which is pumped through a flow cell. An integrated camera takes images of particles within the fluid and characterizes them in terms of particle size and shape. For this project, water samples of 10mL were pre-filtered through a 100 μm mesh to analyze the particle size fraction between 10 – 100 μm.

Preliminary FlowCam results support the assumption of a low number of phytoplankton in the water column. Many particles of the investigated size fraction were identified as zooplankton (protozoa), detrital organic matter and inorganic sediment. Additionally, plankton appeared to differ in size and composition between Southern and Northern Hudson Bay. One

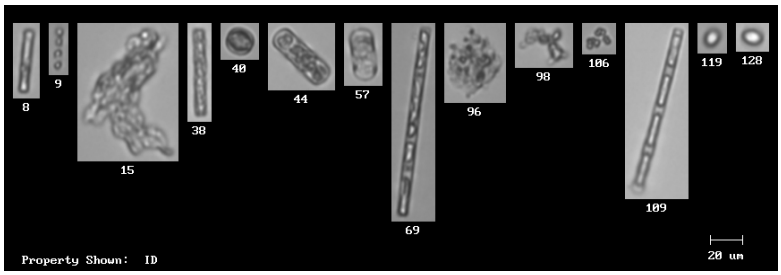
reason might be the massive river runoff in the South flushing freshwater species into the Bay while in the northern part marine species are mainly found due to the strong inflow of seawater from the Atlantic Ocean. Differences in size might be linked with the low nutrient supply in the stratified southern Hudson Bay and the high nutrient concentration of the salty Atlantic water in the North. Particle composition also varied with depth. Small sediments as well as plankton with extensions (spikes, flagella) were mainly found in the upper water column. Penetrate phytoplankton of high abundance was often found in the bottom water. The following images represent a selection of imaged particles from different stations and depth levels.

Station M06 – Nelson estuary

Surface water (1 m)

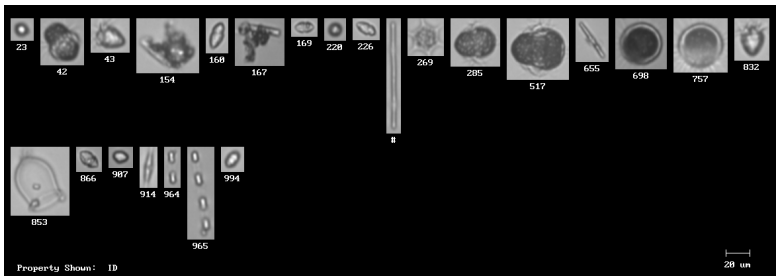


Bottom water (20 m)

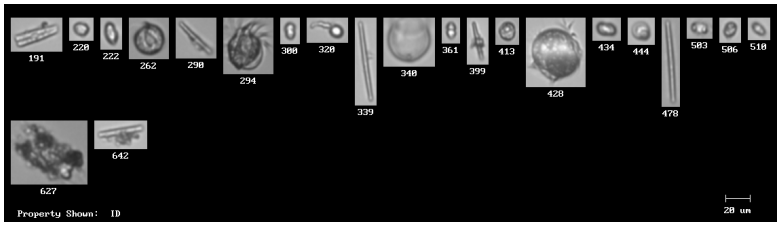


Station NE03 – Outer Nelson estuary

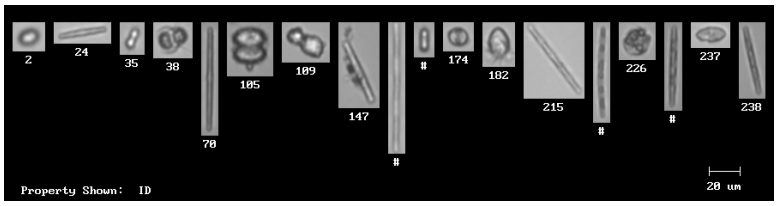
Surface water (1 m)



Chlorophyll maximum depth (20 m)

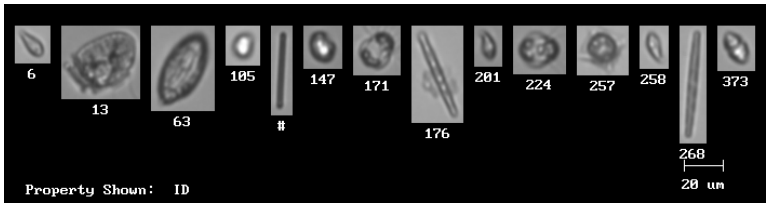


Bottom water (50 m)

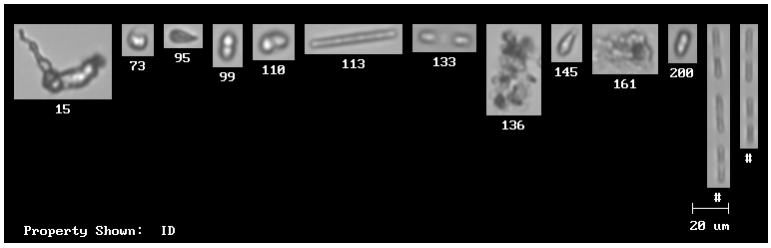


JB05 – James Bay

Surface water (1 m)

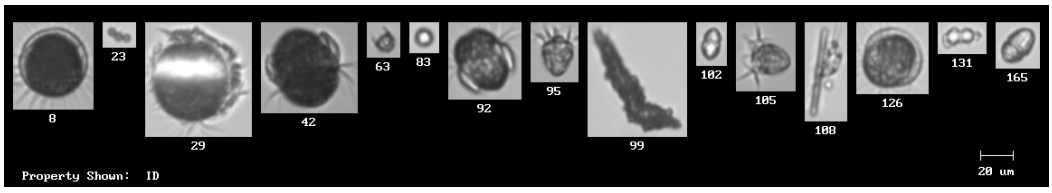


Bottom water (20 m)

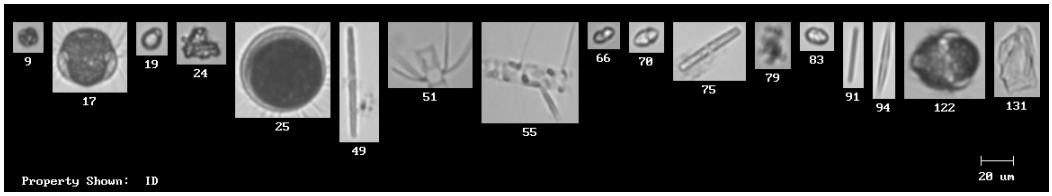


CI01 – Coats Island, Northern Hudson Bay

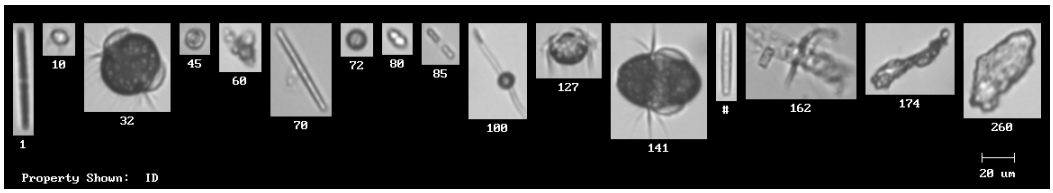
Surface water (1 m)



Chlorophyll maximum depth (40 m)



Bottom water (184 m)



3.3.3 Distribution of phytoplankton

Samples for inorganic nutrients (ammonium, nitrite, nitrate, orthophosphate and orthosilicic acid) were taken at the stations (see Appendix 1) to establish detailed vertical profiles. Nitrite, nitrate, orthophosphate and orthosilicic acid samples were stored at -20 °C in a freezer and sent for analysis using a Bran+Luebbe AutoAnalyzer 3 based on standard colorimetric methods adapted for the analyzer (Grasshoff et al. 1999) at home laboratory. Ammonium samples were processed immediately after collection using the fluorometric method of Holmes et al. (1999). Water samples for chl a in the water column (maximum 100 m depth) were filtered through 25mm GF/F filters and the filters were incubated in 90% acetone in a fridge (4 °C) for 24 h. Chl a concentrations were measured using the fluorometric method of Parsons et al. 1984.

3.4 Carbon Cycling

The objective of Team 4 was to collect dissolved inorganic carbon (DIC) and dissolved organic carbon (DOC) in order to understand the carbon cycle in the costal Arctic ocean environment.

3.4.1 Methods

We collected almost 100 DIC and DOC samples along the coast of Hudson Bay, from the Churchill River to James Bay. A novel experimental incubation approach, involving Pyro Science technology, was used to measure dissolved oxygen (DO) (see Figure 16 A, B, C). The objective of this experimental approach is to evaluate the rates of terrestrial OC remineralization in the Hudson Bay coastal waters during the June 2017 cruise.

Figure 16. Incubation setup, method and equipment

3.5 Sediment Sampling

One of Team 5's main sampling objectives was to collect significant quantity of suspended sediment in the Hudson Bay by applying two techniques.

3.5.1 Methods

One approach was to use an industrial centrifuge device (3'W * 4'L * 2'H; weighs 315 kg; 2 hp motor; 115/230 V; 22.6/11.3 amp AC power), which was fixed to the deck of the ship with straps (Figure 17A). Fortunately, no electrical modifications needed to accommodate the centrifuge. The other form of sediment collection was the filtration system.

In order to run whole suspended sediment collection while the ship was moving, an inline water system (fire hydrant on the forward deck) was used to draw seawater from the ship's plumbing. During the entire period of the trip, suspended sediments were frequently collected and stored, approximately every 12 hours (Figure 17 B). Later, by matching the ship track to the

time of sample collections (Figure 1), the physical and chemical properties of the suspended sediments will be linked back to the locations and the origin (source) of the materials in the suspended sediment can be determined by using fingerprinting technique.

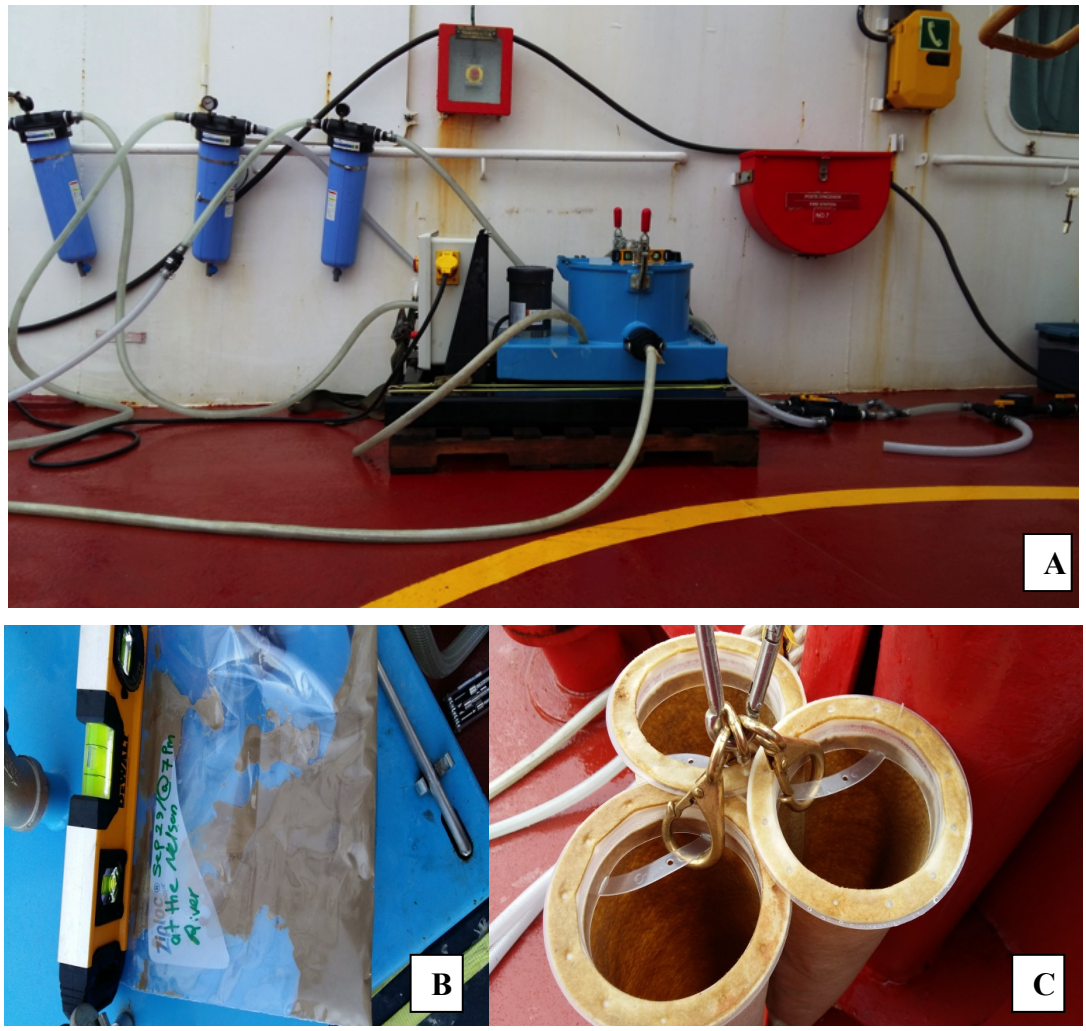


Figure 17. Industrial centrifuge set up, suspended sediment samples, and collection tubes

4. Acknowledgements

The BaySys teams would like to thank the Captain and crew of the Des Groseilliers for their commitment to this field project and ensuring safe deployment of the moorings. We would like to acknowledge Manitoba Hydro and Churchill Northern Studies Centre (CNSC) for their extensive logistical and in-kind support to this field program. Lastly, we are grateful to the Natural Sciences and Engineering Research Council of Canada (NSERC) and ArcticNet Ancillary Ship Time Fund for providing financial support for this cruise and research.