CASES

CANADIAN ARCTIC SHELF EXCHANGE STUDY

CASES2002 cruise report & preliminary data report

20 September to 14 October 2002 expedition

onboard the CCGS *Pierre Radisson*

Edited by Dr. Martin Fortier, Chief Scientist, CASES2002

Table of Contents

Part 1: General overview & synopsis of operations

Introduction

The extent and thickness of Arctic sea ice vary considerably from year to year and over decadal time scales. Assessing the effects of present variability in sea ice cover on Arctic marine ecosystems and regional climate requires a substantial improvement in our understanding of the links between freshwater and sea ice, sea ice and climate, and sea ice and biogeochemical fluxes. The need for data is particularly strong for the shallow coastal shelf regions (30% of the Arctic basin) where variability in the extent, thickness and duration of sea ice is most pronounced and where Arctic marine food webs are most vulnerable to change.

Toward that goal, the CASES Research Network was funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) to conduct the Canadian Arctic Shelf Exchange Study (CASES), an international effort under Canadian leadership to understand the biogeochemical and ecological consequences of sea ice variability and change on the Mackenzie Shelf/Amundsen Gulf area.

A central aim of the CASES field program is to study the fall and winter pre-conditioning of the Mackenzie Shelf/Amundsen Gulf ecosystem by the minimum fall and winter discharge of the Mackenzie River, and its spring and summer development in response to the intense freshet and the variable ice break-up. Because the area cannot be reached from southern ports until August when the ice retreats, the only possible way to achieve this is by over-wintering a research icebreaker in the area.

In preparation for the 2003-2004 over-wintering expedition, two expeditions were conducted in the fall of 2002 to 1) deploy 8 mooring arrays supporting current meters and sediment traps and 2) conduct a synoptic survey of the physical & biogeochemical properties of the study area at the end of the primary production season. The mooring component of CASES2002 was completed during the 6 September to 24 September expedition of the *CCGS Sir Wilfrid Laurier* to the study area. A detailed cruise report for this expedition is available on the CASES website at (http://www.cases.quebec-ocean.ulaval.ca/fieldwor.asp).

The present document mostly reports on the physical & biogeochemical survey of the study area conducted during the 22 September to 14 October expedition of the *CCGS Pierre Radisson*.

CASES general objectives

Based on the general hypothesis that the atmospheric, oceanic and hydrologic forcing of sea ice variability dictates the nature and magnitude of biogeochemical carbon fluxes on and at the edge of the Mackenzie Shelf, the major objectives of the CASES program are to assess:

- The role of hydrologic, oceanographic and meteorological processes in ice accretion, ablation and transport on the shelf and beyond
- The hydrodynamic (including ice and snow cover dynamics) control of Arctic shelf photosynthetic production and its exportation to the benthos and the pelagic food web
- The potential impact of increased UV radiation on biological productivity
- The role of microheterotrophs and mesozooplankton in transforming autochthonous and allochthonous particulate and dissolved matter on the shelf
- The fluxes of particulate matter and carbon across the shelf to the deep basins
- The distribution of riverine and air-borne contaminants in the trophic web

- The potential impact of a reduction in ice habitat on birds and marine mammals
- The decadal and millennial variations in ice cover and their impact on ecosystem productivity

Physical and biological measurements will also be used to constrain and calibrate:

- Regional models of climate and ice dynamics in the western Canadian Arctic
- Biophysical models of the carbon flows on the Canadian Arctic shelf.

Ship characteristics & scientific equipment pool

At 98 m overall length and developing 10 142 kW, the CCGS *Pierre Radisson* (http://www.ccg-gcc.gc.ca/fleet/details_e.asp?name=PIERRE+RADISSON) is classified as a medium Gulf icebreaker. Like her sister ship the *Des Groseilliers*, the main platform for the American-led SHEBA program, the *Radisson* has proven an efficient, versatile and cost-effective ship to conduct scientific research of international calibre in the Canadian Arctic. She was the main vessel used during the Canadian-led International North Water Polynya Study (NOW) program (www.fsg.ulaval.ca/giroq/now). The third sister ship of the Radisson, the former *Sir John Franklin*, is now being modernized, modified and refitted in a state-of–the–art research icebreaker. The newly refitted Canadian research icebreaker will be the platform used for the 2003-2004 CASES expedition.

For CASES2002, the *Radisson* was mobilized for science before the start of her Arctic voyage in late June 2002. Most instruments and laboratories used during CASES2002 are part of a mobile mobilization kit acquired from a Canada Foundation for Innovation & Ministère de l'Éducation du Québec Grant awarded in 2000. Other gear was acquired during the NOW study.

The pool of new equipment consisted of:

- A Seabird Electronics (SBE) Carousel multi-bottle sampler (24 x 12L bottles) equipped with a SBE911plus CTD with transmissometer, fluorometer, oxygen sensor, PAR sensor & PH sensor (all rated for over 6000m depth).
- A SBE Carousel multi-bottle sampler (12 x 12L bottles) equipped with a SBE25 CTD with transmissometer, fluorometer, oxygen sensor, PAR sensor & PH sensor (all rated for over 6000m depth).
- A heavy-duty winch (Hawbolt Industries; SPR-3842/S; 60HP) with 4000m of 3/8" AracomT Kevlar wire.
- A medium duty winch (Hawbolt Industries; SPR-2942/S; 40HP) with 4500m of 0.322" electromechanic wire (Rochester Corp.)
- 3 new 8' x 16' laboratory steel containers with stainless steel interior

Additional mobilization equipment previously acquired included:

- Three 8' x 20' laboratory containers (2 refrigerated vans & 1 radioactivity van)
- Other large sampling gear such as plankton nets, box core….

Synopsis of operations

N.B.: A detailed cruise log off the expedition can be found in Appendix 1.

The CASES2002 expedition began in the early hours of 18 September 2002 with the boarding of the chartered jet that took 32 scientists and over 30 Coast guard officers and crew from Quebec City to Resolute Bay NU. After boarding the ship and loading the gear on the evening of 18 September, the ship slowly made its way towards the study area by entering Peel Sound to the South. The next 3 days were spent setting up the labs and equipment while steaming through the Northwest Passage. The *Radisson* reached Amundsen Gulf on the morning of 22 September.

The ambitious cruise plan for the 22-day expedition called for 110 oceanographic survey stations distributed along the Mackenzie Shelf/Amundsen Gulf area (Figure 1). The sampling grid was composed of three types of sampling stations: At **CTD Stations**, a bottom-surface profile of temperature, salinity, light transmittance, PAR, chlorophyll *a* fluorescence, oxygen & pH was conducted by deploying the Seabird 911+ profiler. Sampling at **Basic stations** included the same CTD profile plus Rosette bottle sampling of DOC, DIC, nutrients, total and fractionated Chl *a,* viral, bacterial, microbial and picoplankton densities at selected depths. Single vertical and horizontal plankton net tows for the determination of zooplankton and juvenile fish densities were also conducted. Operations at **Full stations** included Basic sampling plus bacterial, phytoplankton and zooplankton physiological rates, the deployment of floating sediment traps, floating contaminant pump arrays, box coring of bottom sediments & thorium pumping profiles, UV profiles, ice algal sampling and satellite validation helicopter surveys. Atmospheric conditions, heat & gaz fluxes and atmospheric contaminant levels were continuously monitored along the ship's track in the study area.

Unfortunately, the start of our sampling operations on 22 September coincided with the occurrence of a "Monster Low" pressure system over the eastern Arctic. Caught in the tail of the major feature, we encountered winds of over 40 knots gusting at over 45 knots. Based on weather observation and predictions, we opted to postpone the Franklin Bay stations (Stn 3 to 17) and attack the transect extending from Cape Bathurst (Stn18) to the northeastern tip of our sampling grid (Stn 34).

On 23 September, at Station 21, we took advantage of the proximity of Cape Bathurst to fly over Baillie Island and the tip of Cape Bathurst in anticipation of the 2003-04 ice camp operations (Figure 1). The reconnaissance flight was a real eye opener, with Baillie Island and most of the eastern shore of Cape Bathurst proving very unsuitable for deploying a land based ice camp. The high, eroding cliffs and strong relief would prevent both access to shore and twin otter landing. It is now very unlikely that we will be able to set-up the spring 2004 ice camp operations as originally planned in the CASES proposal. These operations will probably be moved west towards Tuktoyaktuk.

On 24 September, Mary-Ann Francey, a northern student from Inuvik, was picked up in Tuktoyaktuk as part of a mentoring program jointly supported by the Fisheries Joint Management Committee & CASES.

After completing the first Full station (Stn 24) on 24 September, we continued our sampling transect North and reached the ice edge at Station 34. While moving west towards Station 48, we pushed our original sampling stations northwards in order to follow the ice edge position. This entire transect was conducted in pack-ice, within 10 nautical miles of the ice edge. The excellent weather encountered during this east-west transect allowed us to carry out numerous helicopter operations. Remote sensing validation transects were conducted once or twice daily and remote multiyear ice floes were sampled for ice algae and extremophile activity (See Section 2 for details). At the end of the transect (27 September), the strong southerly winds pushed the ice edge north and allowed us to sample in 1600m of water at Station 48 (our deepest station), without having to enter the dense Arctic pack. After our second Full station (Stn 49) on 29 September, we started our 140 nautical mile north-south transect across the Mackenzie Shelf, towards Station 65 (35m) offshore from Tuktoyaktuk & Kugmallit Bay at the mouth of the eastern channel of the Mackenzie River (Figure 1). On 02 October, Mary-Ann Francey & two scientists debarked in Tuktoyaktuk. They were replaced by a 3-man film crew from the SednaIV project that came onboard to take footage of the project. On 03 October, under a dead calm sea, we extended our sampling transect inshore by using

the 7.33-m zodiac launch. Equipped with a 5L Go-Flow bottle, a Seabird 19CTD, a 1m diam. ring net (750µm mesh) and an albedometer, the 4-man party sampled 7 stations spread approximately 10km apart. The most inshore station (Z2) was in 4m of water in Kugmallit Bay, in front of Tuktoyaktuk. An additional inshore station (Z1) was sampled by hand deploying the SBE19 CTD and a 5L Go-Flow bottle form the hovering helicopter (Figure 1). Over 30 different measurements were made out of this precious inshore water sample, demonstrating the true multidisciplinary of the CASES study.

After a well deserved mid-cruise break, we started the second half of the expedition at Station 66 (Full) on 04 October. With the ice edge moving south, most of the transect was conducted in ice-covered waters (Figure 2). Again, this transect went without a glitch and we completed the 24 stations (including 2 full stations) in less that 4.5 days. On 08 October, we took advantage of the great weather and some coast guard operational needs to conduct the Mackenzie River sampling program of CASES2002 (led by Prof. Warwick Vincent, see section 2). Three scientists and the pilot travelled to Inuvik and back in order to collect freshwater surface samples at two stations in the east and main channels of the Mackenzie River (see Figure 1). Young ice started to form very quickly after 08 October with most of the Mackenzie Shelf being covered with slush ice & pancake ice (Figure 2). We reached Full station 101 on the evening of 09 October, in the only ice-free region left in the sampling area. Increasing winds 40knts (gusting over 50knts) and deteriorating sea state during the night prevented us from fully completing the full station. We decided to move southwest towards sheltered Franklin Bay to sample Stations 4-17, postponed early in the cruise. Franklin Bay operations were conducted almost completely under a drifting pack that was flushed in the bay from the north. After carrying out all of the Franklin Bay stations (including an additional Full stations at Station 12), we sailed back to Station 102 in Amundsen Gulf to conclude our last sampling transect. The completion of Station 110 at 03:00am on 14 October marked the end of the CASES2002 expedition. We started our trip back to Quebec City on the morning of 14 October by entering the Northwest Passage in Dolphin and Union Strait. Five scientists debarked in Kugkluktuk (Coppermine) on the morning of 15 October; with the remainder of the group making the 12-day trip back to Quebec City onboard the ship. Two additional CTD-Rosette casts were conducted in Coronation Gulf & Franklin Strait, on our way through the Northwest Passage.

From 22 September to 14 October, the *Pierre Radisson* and all onboard worked almost non-stop, day and night, to complete (and exceed) the ambitious cruise plan of 110 oceanographic survey stations (Figure 1). From their boarding the ship on 18 September until their return in Quebec City on 26 October, CASES scientists and the *Pierre Radisson* crew members travelled over 5300 nautical miles (over 800 in the study area) and crossed the Northwest Passage in both directions. Although the great weather played an important role in reaching our objectives, the hard work and professionalism of all onboard were the main reasons for our success. As for previous expeditions completed on their ships, the Coast Guard officers and crew of the Quebec Region showed remarkable dedication and support towards the scientific work conducted onboard. Our sincere thanks go to Captain Serge Brûlé and the entire crew of the *Pierre Radisson*. The stage is well set for next years CASES2003-2004 overwintering expedition,

Martin Fortier, Chief Scientist-CASES2002
CCGS *Pierre Radisson*

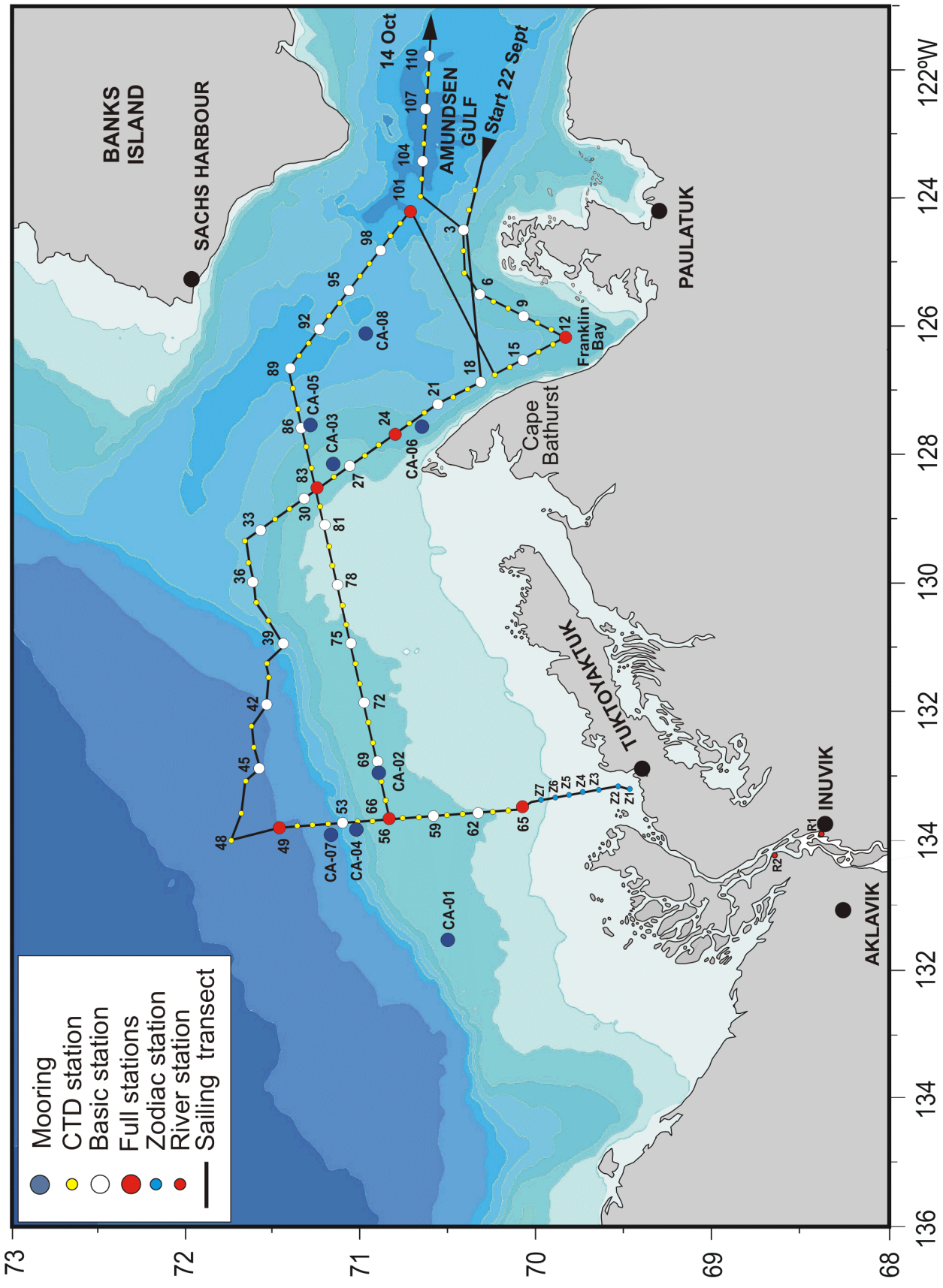


Figure 1. Sailing transect and types of stations sampled during the 22 September to 14 October CASES2002 expedition onboard the CCGS *Pierre Radisson*. Blue circles (CA-01 to CA-08) indicate the location of CASES moorings deployed from the CCGS *Sir Wilfrid Laurier*.

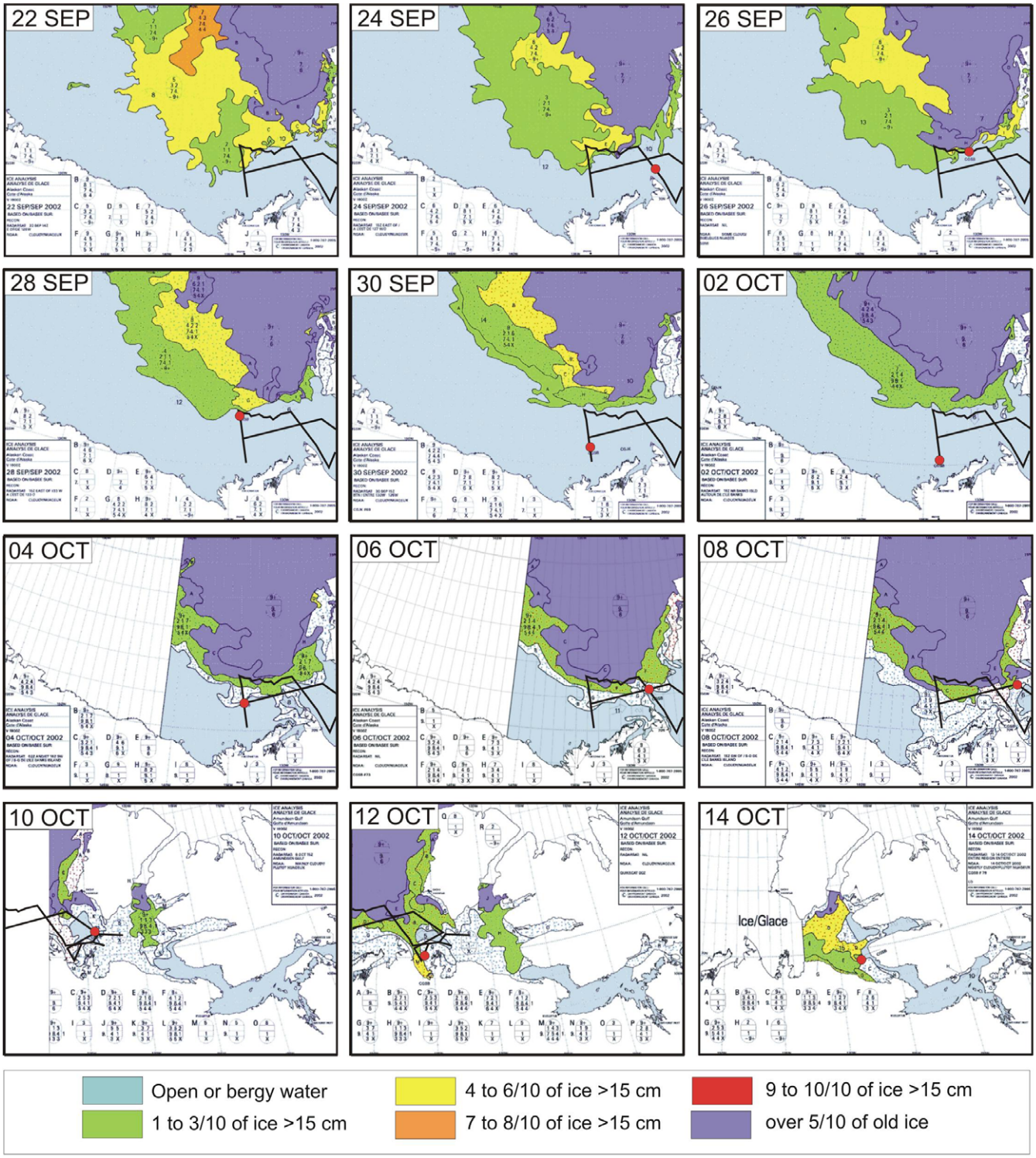


Figure 2. Position (●) & cruise track (—) of the CCGS *Pierre Radisson* in relation to sea ice conditions during the September 22 to October 14 CASES2002 expedition. Sea ice data courtesy of Canadian Ice Service.

Part 2: Individual project reports

The CASES overall project is composed of nine sub-projects, all linked to the general hypothesis that the atmospheric, oceanic and hydrologic forcing of sea ice variability dictates the nature and magnitude of biogeochemical carbon fluxes on and at the edge of the Mackenzie Shelf (Figure 3).

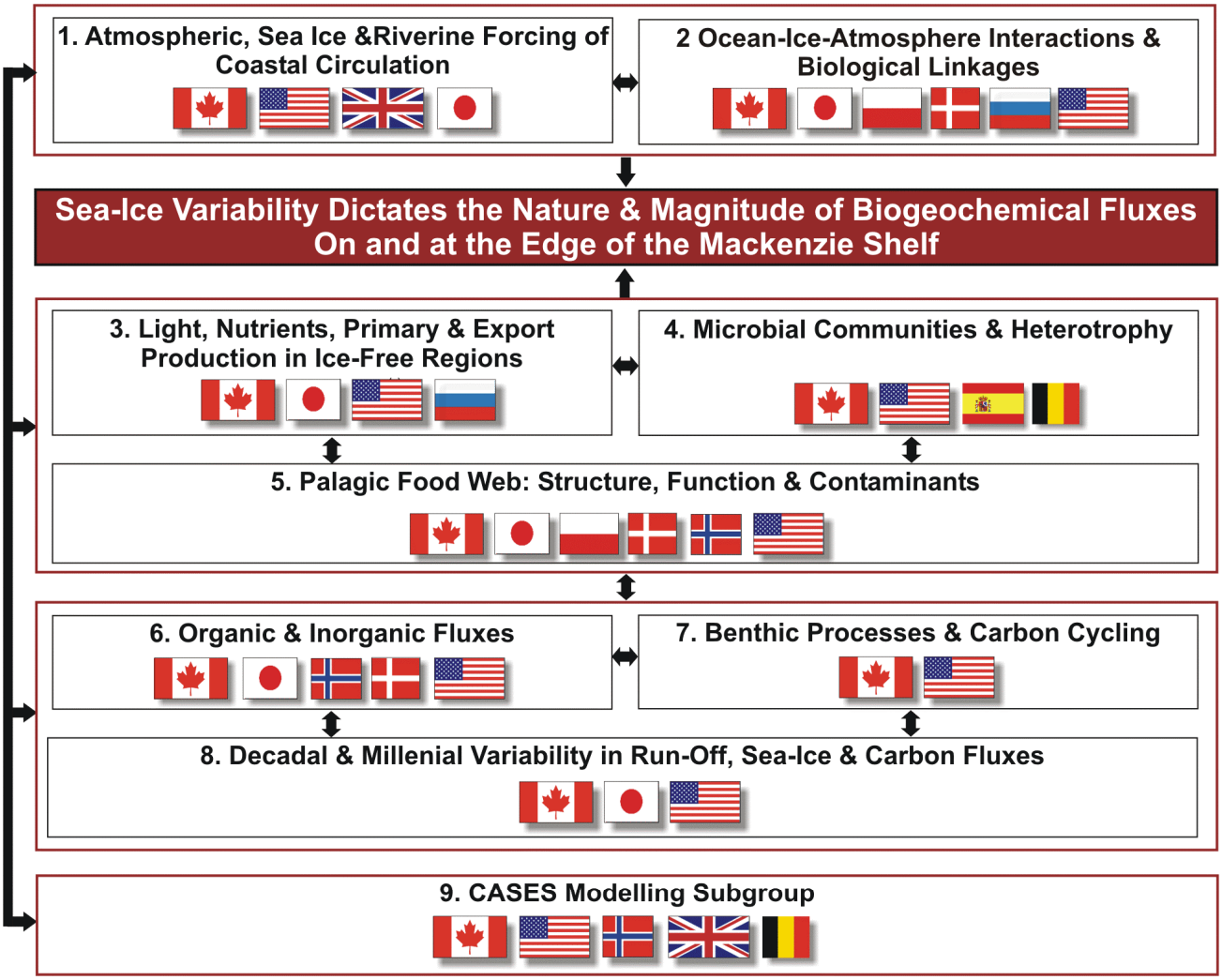


Figure 3. The Canadian Arctic Shelf Exchange Study (CASES) International Research Network

All 9 subprojects were represented onboard during the CASES2002 expedition. The following section is a compilation of individual project reports provided by representatives of each CASES sub-project.

1. Atmospheric and Sea Ice Forcing of Coastal Circulation

Subproject leaders: Grant Ingram & Eddie Carmack

1.1 Mooring deployment (on CCGS *Sir Wilfrid Laurier*)

Principal investigators: Grant Ingram, Eddy Carmack, Humphrey Melling, Yves Gratton
Cruise participants: Humphrey Melling (Chief Scientist), Doug Sieberg, Makoto Sempei

CASES2002 moorings were deployed from the CCGS *Sir Wilfrid Laurier* (Fig 1). The position and details of mooring locations are given in Table 1 & Figure 4. Details on the mooring operations and other *Laurier* cruise activities are available in the *Laurier* cruise report available on the CASES website (http://www.cases.quebec-ocean.ulaval.ca/fieldwor.asp).

Table 1. Description of moorings deployed during the CASES2002 expedition

Station	Date	UTC	Latitude	Longitude	Top (m)	Depth (m)
CA-01	12/Sep/02	15:03	70°30.000’	135°30.000’	29	59.3
CA-02	15/Sep/02	04:02	70°53.707’	132°54.829’	31	61.9
CA-03	18/Sep/02	19:18	71°08.996’	128°08.021’	29	60.0
CA-04	15/Sep/02	19:36	71°01.335’	133°46.443’	27	203.0
CA-05	18/Sep/02	16:35	71°16.954’	127°32.139’	26	202.0
CA-06	19/Sep/02	00:49	70°38.996’	127°32.854’	43	206.0
CA-07	16/Sep/02	02:35	71°09.745’	133°52.630’	30	516.0
CA-08	19/Sep/02	17:42	70°58.383’	126°06.720’	27	397.0

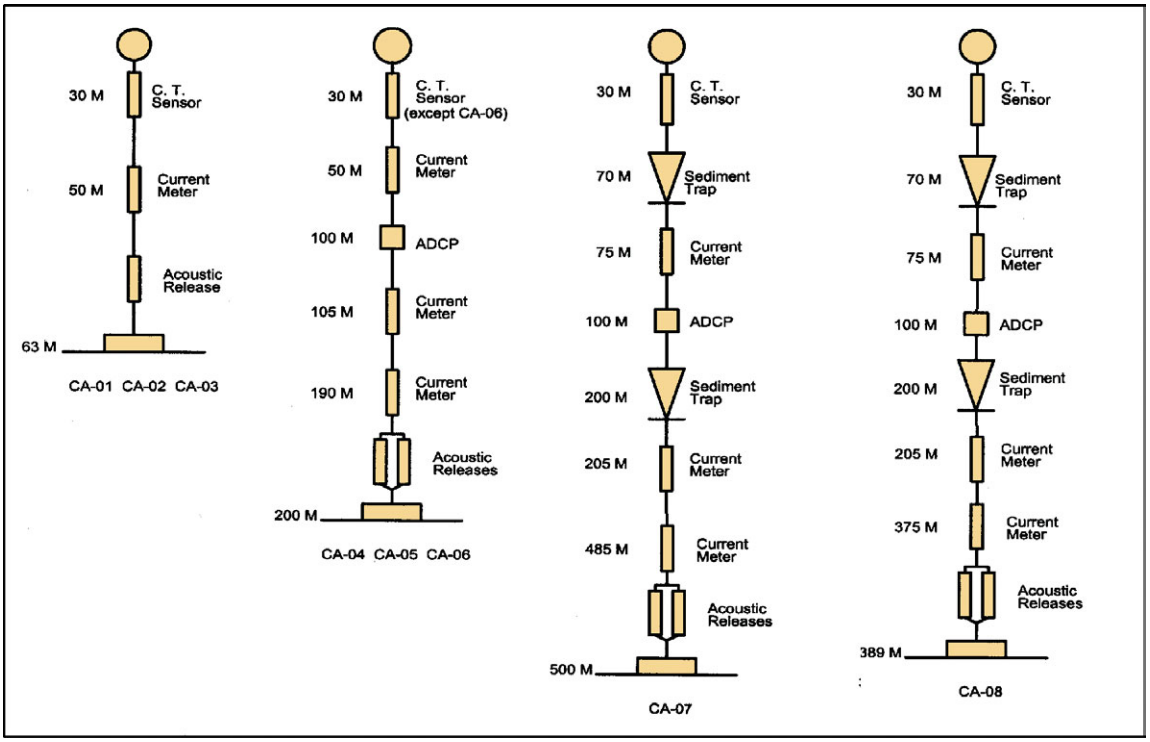


Figure 4. Schematic representation of the 8 CASES moorings deployed from the CCGS Sir Wilfrid Laurier from 12 September to 19 September 2002 (courtesy of Ingram, Carmack, van Hardenberg).

1.2 CTD/Rosette Sampling

Principal investigators: Yves Gratton, Grant Ingram, Eddy Carmack, Humphrey Melling, Peter Galbraith, Rick Marsden

Cruise participants: *Lisa Miller, Gilles Desmeules, Emmanuelle Rail, François Bazinet and Marie Robert*

The CTD/rosette sampling program was a great success. We successfully completed 110 sampling station with 138 CTD/Rosette casts (all stations planned and more), with 1465 bottles closed on 82 of those casts. As a general template, we closed bottles at the following canonical depths: 0, 5, 10, 25, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, and 1000 m, but these depths were guidelines only and were often replaced by special features, such as temperature inversions, transmissivity minima, fluorescence maxima, and water at a salinity of 33.1 (generally characterized by high silicate levels). The rosette/CTD logsheet is available in Appendix 2. CTD data for the CASES2002 expedition is available on the CASES FTP site (please contact Martin Fortier for details).

The new CTD/rosette system and winch (see Table 1 for description) proved extremely reliable and very few problems were encountered. Problems were mainly associated with water leaks in electrical connections and at later stations, with water freezing in the CTD pump line between casts. The main problem we encountered with the system was that the bottom contact often did not work. It was not clear to what extent this was due to soft bottom materials, descent speed and wire angle, or simple freezing (either thermodynamic or mechanical) of the sensor rocking mechanism. Our suggestion is that in the future the rosette be fit with a pinger for acoustic bottom detection. The connection problems required occasional replacement of plugs, as well as vigilance and cleaning of the connections, while the freezing problem was eased by keeping the rosette shack warmer and by leaving the pump line drained (although with the syringe still attached, to inhibit complete drying). In a few cases, even these precautions were not sufficient, and the CTD would have to sit for up to 5 minutes in a relatively warm, sub-surface water mass to thaw before the pump would start. This problem should be resolved on the new ship in 2003-04 by the possibility to deploy the rosette from the interior moonpool in the cold season.

Our initial protocol was to open a new data file while the rosette was at the bottom, giving two data files for each cast. However, this protocol produced a number of problems, including long delays during which the rosette sometimes hit the bottom in uneven bathymetry and loss of the downcast traces, which inhibited accurate sampling of special features during the upcasts. Therefore, starting with cast 120, we no longer started a new file at the bottom, but during each cast collected only 1 data file, which included both the down- and up-cast data.

With the exception of pH, the Seabird sensors all appeared to perform well, although we have confident confirmation of good performance only for oxygen (Figure 5). During the first half of the cruise, the pH sensor was very spiky, often giving 'curtain' profiles. This problem appeared to decrease through the cruise, but the readings would still jump suddenly to values more than 0.5 higher or lower; often several times in a single cast. Such large drops were often seen just below the pycnocline, but were not reproduced on the upcast. We did not have a system for analyzing pH on

discrete bottles samples in order to calibrate or check the pH sensor. The results from the oxygen sensor were very well correlated with the bottle oxygen measurements (Figure 5), promising straightforward calibration. Salinity samples were taken at every depth sampled (over 500 samples), except at stations classified as 'CTD' stations. These samples were analyzed at the Maurice-Lamontagne Institute in December 2002 and those from well-mixed water masses will be used to calibrate the conductivity sensor. Similarly, discrete Chl *a* samples were collected at most 'Basic' stations, allowing a check of the fluorescence sensor, while the optical profiles could provide some validation for the two PAR sensors, both surface and underwater.

Table 2. Description of CTD/Rosette system deployed during the CASES2002 expedition

Item description	**Make/Model**
CTD underwater unit with aluminium housing (6800m depth rating)	SBE-911plus
Temperature & Conductivity sensors with TC duct	SBE
Submersible pump	SBE-5T
Pressure sensor (6800m depth rating)	SBE
Dissolved Oxygen Sensor (7000m depth rating)	SBE 43
pH sensor (6000m depth rating)	AMT
Transmissometer (6000m depth rating, 25 cm path)	WETlabs cs-25-660 (red) C-STAR
Chlorophyll Fluorometer (6000m depth rating)	Seapoint
PAR sensor (High pressure connector)	Biospherical Inst. QCP-2300L (cosine)
Bottom contact switch	SBE-32X24
24 bottle sampler	SBE Caroussel
12-liter PVC sample bottles (24)	Ocean Test Equipment Inc.

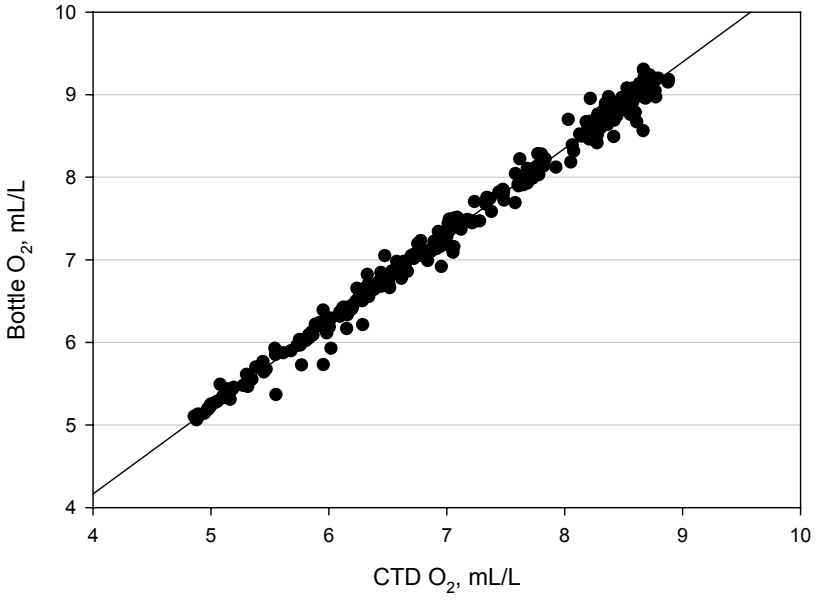


Figure 5. Correlation between dissolved oxygen (O_2) determined by colorimetric Winkler titration and Seabird O_2 sensor. Slope: 1.05; $r^2 = 0.993$. (*Preliminary data: Lisa Miller*)

2. Ice-Atmosphere Interactions and Biological Linkages

Subproject leader: David Barber

2.1 Surface meteorology /exchanges & Satellite validation

Principal investigators: David Barber, Tim Papakyriakou, Peter Minnet, John Hanesiak, John Yackel, Roger DeAbreu, Dean Flett, Bruce Ramsay

Cruise participants: David Barber, Tim Papakyriakou, Peter Minnet, Chris Konig & Owen Owens

Introduction

Better measurements of the surface heat budget of the Arctic are fundamental to improving our understanding of the coupling between ocean, ice and atmosphere, and the feedback loops that connect them and govern the response of the Arctic to climate change. The surface heat budget can be conveniently divided into two components: radiative and turbulent exchanges (ignoring heat flow by conduction). The radiative term has two components: that which is largely in the visible part of the spectrum and which is controlled by the incident sunlight and surface reflectance, and that in the infrared, which is controlled by temperature and composition of the surface and atmosphere, including clouds. The turbulent heat exchange has two components: the sensible heat exchange caused by the temperature difference across the interface at the base of the atmosphere, and the latent heat exchange which is associated with phase changes of water at the base of the atmosphere. Closely linked with these is the turbulent exchange of gases between the ocean, ice cover and the atmosphere above. Of especial interest is carbon dioxide. In the organization of this report we differentiate between sensors associated with meteorological towers and those situated elsewhere on the ship.

Tower Sensors

Instruments to measure the components of the surface heat budget and CO_2 flux were mounted on the *Pierre Radisson* and are depicted in Figure 1. Equipment details and heights are inventoried in Table 1. The sonic anemometer and open path H_2O/CO_2 sensor were extended 1.8 m beyond the bow of the ship by a 2" diameter aluminium pipe (Fig. 6).

The signals from those sensors on the meteorological tower were recorded by a Campbell Scientific (Model 21X) micrologger. Measurements of incoming radiation, wind speed and direction and temperature and relative humidity were recorded every 2 s. A barometric pressure sensor was housed within the logger enclosure at the base of the meteorological tower (Fig. 6). Atmospheric pressure was recorded every minute and data were stored as 30-minute averages. Data from the CR21X were transferred to personal computer every 15 minutes using Campbell Scientifics' PC208W software and multi-drop modem network.

Signals from the sonic anemometer, open-path H_2O/CO_2 sensor, inertial displacement sensor and fine wire thermocouple on the flux tower were sampled by a Campbell Scientific Model 23X micrologger at 10 Hz frequency. The wind monitor was also logged by the CR23X three times every second. Data were directly placed in final memory of the micrologger and transfer to personal computer by multi-drop modem network every 15 minutes. The output from the temperature and relative humidity probe on the flux tower (refer to Fig. 6) was sampled every 2 s by a Campbell Scientific (Model 10X) micrologger. Again, data were transferred to personal computer via the multi-drop modem network every 15 minutes.

The duration that each sensor was operational for is listed in Table 3. The data series is not continuous for each sensor between these dates because of any combination of sensor malfunction

and severe weather. Data must be processed and analyzed at the University of Manitoba before the number of 'good' hours of operation can be made available.

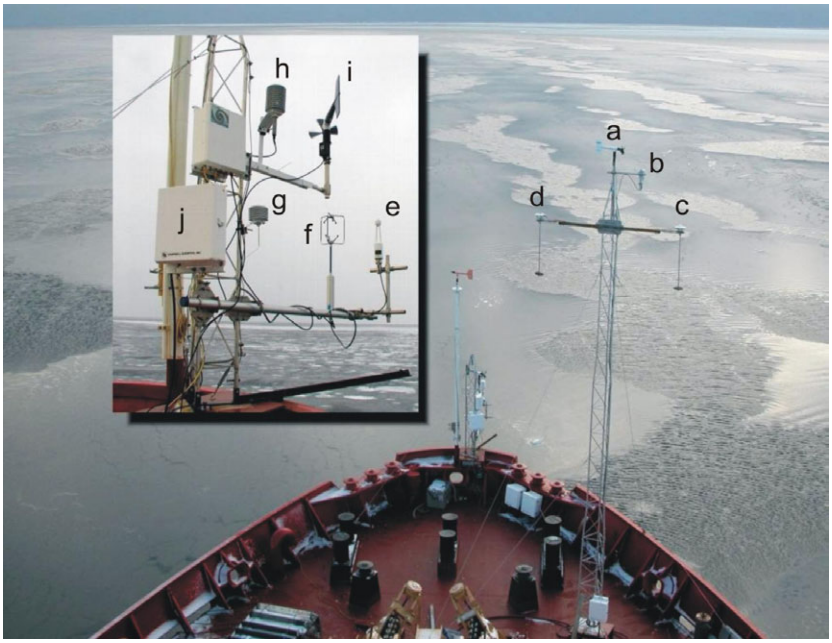


Figure 6 The foredeck of the Pierre Radisson equipped with a 10 m (nominal) meteorological tower and a 2 m (nominal) tower at the bow of the ship that was used for flux measurements (in medallion). See table 1 for details on sensors.

Table 3. Select meteorological variables monitored during CASES'02. Item letter corresponds to sensor depicted in Figure 6. Heights for items (a) to (d) represent distance to the ship's deck (add 7 m to each for distance to the sea surface), heights for items (e) to (j) represent distances to the tower base (add 7.7 m for distance to the water surface); operation dates are given in calendar day number.

Item in Fig. 1	Variable measured	Sensor Manufacturer (model)	Height (m)	Operation Dates (Start/Stop)
a	horizontal wind speed and direction	wind monitor - RM Young (model 05106 MA)	9.95	267/294
b	temperature and relative humidity	Vaisala (model HMP45C212)	9.50	267/294
c	global radiation	Eppley pyranometer (model PSP)	8.60	267/294
d	down-welling terrestrial (long-wave) radiation	Eppley pyrgeometer (model PIR)	8.60	267/294
not shown	atmospheric pressure	pressure transducer – Vaisala (model PTB101)	1.80	267/294
e	CO_2 and H_2O concentration	LI-COR (model LI-7500)	1.10	273/283
f	wind vector (x, y, and z coordinates)	sonic anemometer - Solent (model R3-50)	1.15	273/294
g	fast response air temperature	fine wire (.008") thermcouple (Type T) - Omega (model HYP-0)	0.90	273/294
h	temperature and relative humidity	Vaisala (model HMP45C212)	1.60	273/294
i	fast response horizontal wind speed and direction	wind monitor - RM Young (model 05701-10 RA)	1.70	273/294
j	multi-axis inertial sensing system	BEI Systron Donner (MotionPak model MP-GCCCQBBB-100)	0.80	270/294

The Marine-Atmospheric Emitted Radiance Interferometer (M-AERI)

We deployed a spectraradiometer to measure the spectral quality of infrared radiation, both emitted by the surface and by the atmosphere for the accurate solution to the radiation balance of polar marine surfaces. The sensor, the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI; Minnett et al, 2001) was mounted on the starboard side of the ship's foredeck. The M-AERI is a Fourier Transform Infrared (FTIR) Spectraradiometer that operates in the range of infrared wavelengths from ~3 to ~18μm and measures spectra with a resolution of ~0.5 cm^{-1}. It uses two infrared detectors to achieve this wide spectral range, and these are cooled to ~78^{o}K (*i.e.* close to the boiling point of liquid nitrogen) by a Stirling cycle mechanical cooler to reduce the noise equivalent temperature difference to levels well below 0.1K. The M-AERI includes two internal black-body cavities for accurate real-time calibration. A scan mirror directs the field of view from the interferometer to either of the black-body calibration targets or to the environment from nadir to zenith. The mirror is programmed to step through a pre-selected range of angles. A M-AERI was mounted on the foredeck of the Pierre Radisson, on the starboard side ahead of the bow wave and bow thrusters so that the measurements taken of the sea surface at an angle of 55^{o} from nadir were uncontaminated by the surface disturbance of the ship. The spectra are processed in real-time to determine the surface temperature of the ocean or ice, and the air temperature at the height of the sensor, several meters away from the ship. They are also processed, after the fact, to derive profiles of atmospheric temperature and humidity in cloud-free conditions to a height of about 3km. Of particular relevance to surface heat budget studies in the CASES region is the air-surface temperature difference, which is related to the turbulent fluxes The M-AERI operated for 26 days and a total of 2628 sets of spectra of the surface at 55^{o} emission angle, of the atmosphere at 55^{o} and at 0^{o} (zenith) were taken. Figure 7 shows a histogram of the air-surface temperature difference. To assist in the data interpretation a time-lapse video system was installed with the camera mounted on the forward railing above the bridge, pointing down to the field of view of the M-AERI. This provides a record of the surface conditions at the times of the M-AERI measurements.

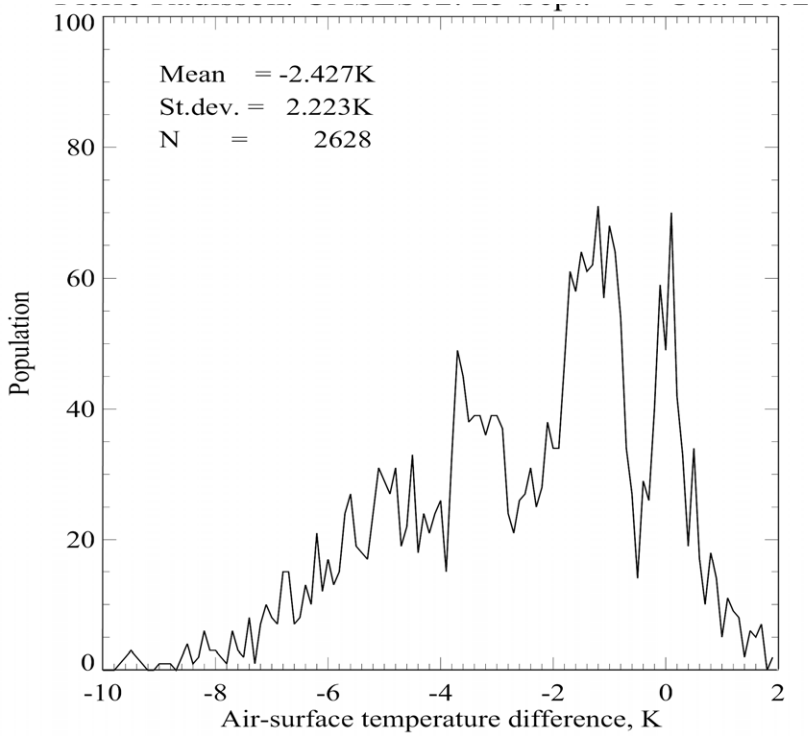
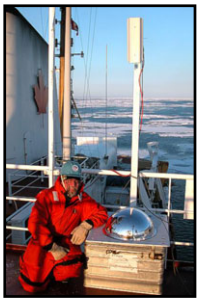


Figure 7. Histogram of the air-surface temperature difference measured by the M-AERI between 23 September and 18 October 2002.

All sky camera.



Clouds play an important role in modulating the incident solar radiation and augmenting the downwelling atmospheric infrared radiance. An all sky camera was mounted on the top of the bridge. This is a video camera directed downwards to a hemispheric mirror that provides a view of the entire sky. The images are recorded for daylight conditions on a time-lapse video recorder at ~17s intervals. These images will be analyzed later to determine cloud type and cloud fraction.

Radiosondes.

The state of the atmosphere was measured by radiosondes, which are self-contained instrument packages carried aloft by helium a balloon (Fig.3). The sensors collects pressure, temperature and humidity data, which are radioed back to a receiver on the ship which decodes the signal and supplies the data to a computer. An example of a radiosonde profile is given in Figure 8. The radiosonde launches, generally timed to coincide with satellite overpasses, are listed in Table 4.

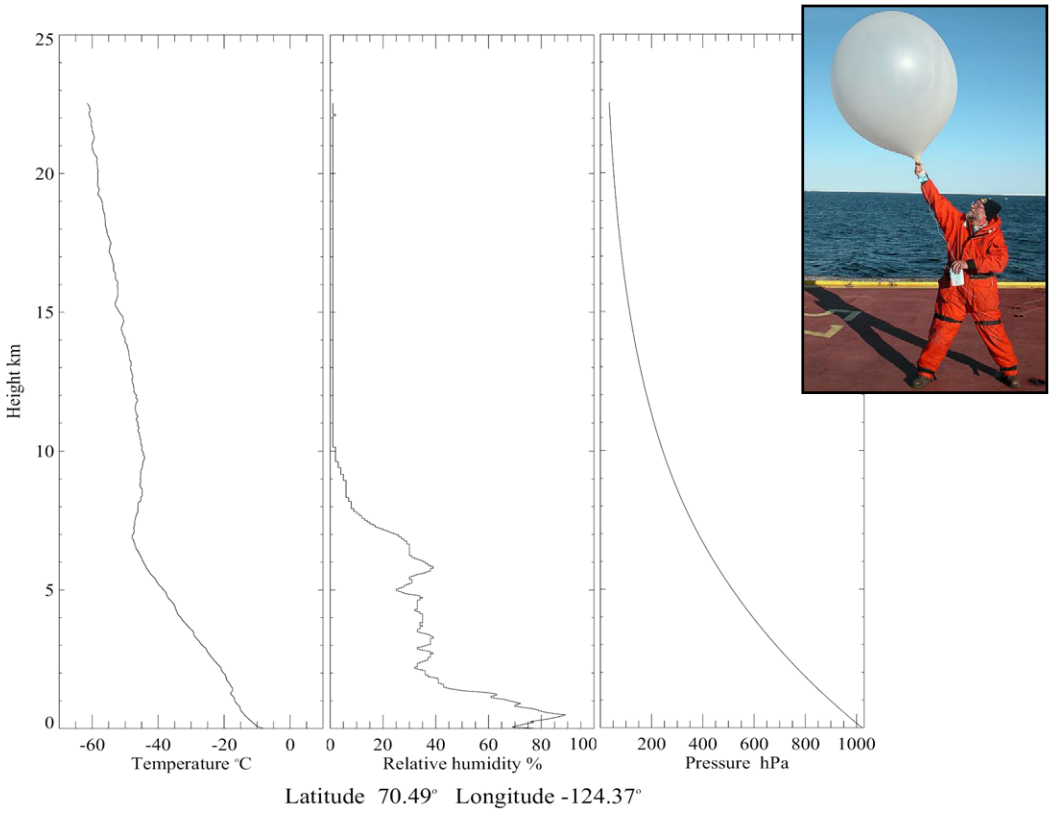


Figure 8. An example of a radiosonde profile, showing atmospheric temperature, humidity and pressure as a function of height. (13 October 2002, 11:52 GMT)

Table 4. Radiosonde profiles details

	Time		Location		Surface Measurements			Termination		
	Launch date and time UTC		Latitude °N	Longitude °W	T_o °C	Rh %	P_o hPa	Duration Minutes	Max height km	Min P hPa
1	25 September 2002	19:40	71.53	129.08	-2.7	89	1023.0	54.00	8.65	318.6
2	26 September 2002	5:12	71.62	130.00	-1.3	88	1023.6	73.50	15.099	118.4
3	26 September 2002	21:16	71.54	131.85	-0.9	87	1018.8	69.83	16.442	96.7
4	27 September 2002	15:18	71.62	132.18	-1.4	92	1011.4	90.00	20.029	55.1
5	27 September 2002	21:30	71.71	133.63	-1.3	92	998.5	108.50	12.405	178.3
6	30 September 2002	21:57	70.25	133.53	-0.8	83	1010.9	104.50	23.521	31.2
7	08 October 2002	0:12	71.30	128.10	-9.5	85	992.0	77.00	19.509	55.5
8	08 October 2002	8:28	71.30	127.60	-11.7	85	994.0	101.00	20.384	48.1
9	09 October 2002	12:27	71.00	135.30	-5.6	72	998.2	63.60	9.874	240.7
10	11 October 2002	12:21	70.02	126.43	-11.3	89	996.4	84.00	20.999	42.4
11	12 October 2002	20:52	70.01	125.95	-5.6	86	1018.3	66.67	11.786	187.3
12	13 October 2002	11:52	70.49	124.37	-8.2	77	1021.0	99.00	22.536	37.4
13	13 October 2002	21:37	70.64	123.35	-8.5	58	1024.0	106.00	22.516	34.9
14	15 October 2002	20:31	68.33	113.06	-5.8	85	1014.3	72.17	16.494	90.4
15	16 October 2002	10:39	68.69	103.95	-6.3	85	1022.7	54.50	10.872	214.1
16	16 October 2002	18:48	69.30	99.58	-10.0	90	1029.7	27.83	5.807	470.5
17	17 October 2002	20:00	72.84	96.22	-2.3	94	1028.4	38.00	6.311	445.7
18	20 October 2002	8:31	68.92	64.13	-0.1	86	1030.2	76.00	20.156	51.5
19	20 October 2002	16:27	66.71	60.81	-0.1	89	1028.1	83.50	21.586	41.2
20	21 October 2002	5:44	63.53	62.14	0.8	97	1024.4	33.17	8.837	304.4
21	21 October 2002	15:35	61.40	64.10	3.2	88	1020.0	26.17	6.311	440.8
22	21 October 2002	17:15	61.04	61.06	2.8	87	1018.9	74.50	21.266	43.4
23	22 October 2002	6:33	59.74	63.02	3.1	85	1019.6	83.83	22.197	37.1

Satellite validation

A highly instrumented ship, such as the *Pierre Radisson*, provides a valuable platform for taking high-quality measurements of many important parameters in the Arctic system, but these are perforce limited in space and time. Sensors on polar-orbiting earth-observation satellites provide a mechanism for extending the measurements of certain key variables over the whole Arctic for long periods. These variables include surface reflectivity, surface temperature, ocean color (and derived quantities such as chlorophyll concentration, suspended sediments), and atmospheric temperature and humidity profiles. These parameters are derived form the spacecraft sensor data using algorithms derived in a variety of ways, but to determine the accuracy of the derived parameters requires comparison with independent high-quality measurements. Such measurements were taken from the *Pierre Radisson* and from the helicopter.

The skin temperature of the surface was measured using the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI – see section on Surface Meteorology and Fluxes), with the surface type being monitored using a time-lapse video system.

Atmospheric profiles of temperature and humidity were measured by radiosondes, generally launched to coincide with the overpasses of relevant satellites. See Surface Meteorology and Fluxes section of this report for a summary of the radiosonde data. An all-sky camera (also in the Surface Meteorology and Fluxes) provides information on the clouds at the times of the satellite overpasses, at least during the daytime.

The surface albedo was periodically measured from a cage lowered to approximately 1-2 m from the ocean surface using an albedometer. In each instance a digital picture was taken of surface within the sensor's immediate field of view. Albedo was also measured from the side of the ship's zodiac as part of a distributed sampling program. Albedo measurements were coupled with measurements

of spectral reflectance and irradiance over the same field of view. High-resolution (1.4 nm) measurements of irradiance and reflectance were made between 350 and 1064 nm using an Analytical Spectral Device (ASD) Personal Spectrometer. . The instrument uses a fiber optic bundle to collect and project light onto a holographic dispersion grating. A silicon photo-diode detector measures the diffracted light. Detector noise (dark current) was removed from each of the measurements. A calibrated cosine receptor (180° FOV) was used for both the irradiance and reflectance measurements.

Helicopter-based sampling was used to obtain an observational data set of the surface temperature and reflectance of surface areas commensurate in size with the footprint of spaceborne optical, thermal and microwave sensors. Together with ship-based measurements, these data will be used to develop retrieval algorithms for surface state variables using remotely sensed data. Flight plans followed a 25 km x 25 km square grid pattern flying at a height of 1000 ft. Sensors were affixed to a boom that extended approximately 4 ft from the helicopter cargo bay. The components of the instrument package are listed in Table 5. A portable GPS (Trimble) included an Everest IR temperature transducer with an operating sensitivity of –40 to +100 C at an accuracy of ±0.5 C. There is also a manual emissivity dial which was set at 0.98 (the sensor's highest setting). The IR transducer and pyranometer were fastened to a custom made aluminum bracket that extended approximately 4 feet from the end of the helicopter cargo bay, while the video camera was positioned beside this on its own custom bracket.

Table 5 Sensors mounted off the cargo bay of the CCGS *Pierre Radisson* based helicopter during CASES'02.

Sensor	Variable	Units	Spectral Range (nm)
Everest 4000.4GL IRTransducer	Surface Temperature	C	800-1400
LiCor pyranometer	Reflected Solar Radiation	$W \cdot m^{-2}$	400-1100
Canon DV	Video	N/A	N/A

Table 6 Summary of satellite validation activities.

Variable	Instrument	Satellite sensor	Satellite
Surface temperature	M-AERI	MODIS – Moderate Resolution Imaging Spectroradiometer	NASA Terra, NASA Aqua
		AIRS – Atmospheric Infrared Sounder	NASA Aqua
		AMSR – Advanced Microwave Scanning Radiometer	NASA Aqua
		AATSR – Advanced Along-Track Scanning Radiometer	ESA Envisat
Surface Albedo	shortwave	MODIS – Moderate Resolution Imaging Spectroradiometer	NASA Terra, NASA Aqua
Ocean Color	Seawifs cal., ASD	MODIS – Moderate Resolution Imaging Spectroradiometer	NASA Terra, NASA Aqua
		SeaWiFS – Sea-viewing Wide Field of View Scanner	SeaStar
Atmospheric Temperature and humidity profiles	Radiosondes	AIRS – Atmospheric Infrared Sounder	NASA Aqua
		AMSU – Advanced Microwave Sounding Unit	NASA Aqua

Example Datasets (note that the data are preliminary and have not yet been QA'd).

Data from the aerial video worked very well for two dates (Sept 26 and 27). All aircraft sensors worked fine and the dataset which resulted will provide a unique dataset for the calibration of both active and passive microwave sea ice algorithms. Our intention in this analysis is to examine the electrical, geophysical and SEB of a freezing ice front. The data will allow us to examine subpixel mixing issues in passive and active microwave RS data. Figure 1 shows a still image extracted from the DV stream on Sept 26

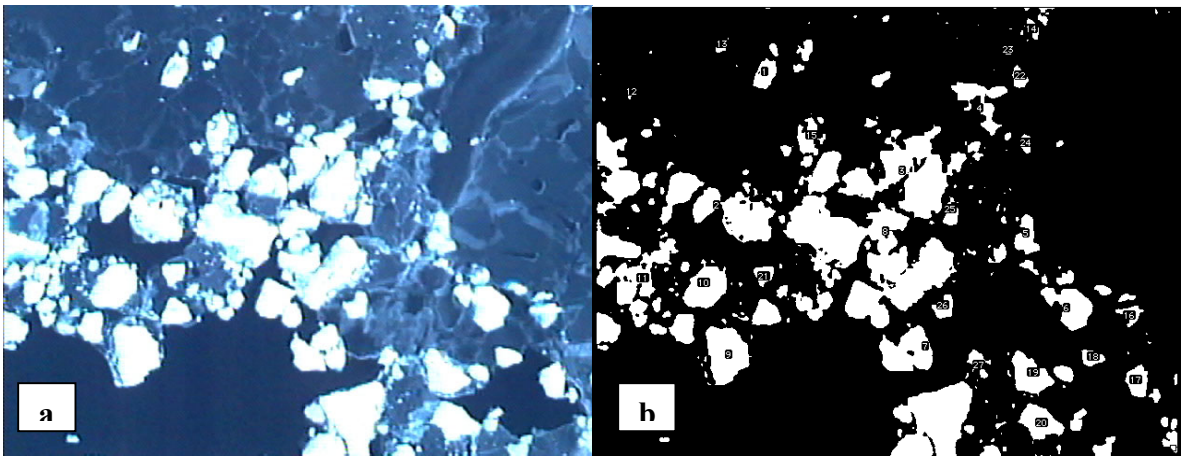


Figure 9. a) Bright floes are old multiyear pieces (3-5m thick), dark areas are open water, grey and grey white returns are thin and rafted thin ice types. The size distribution of floes and the relationship between floes and new ice formation will be examined using digital image analysis. Scale is approx 1.2 by 0.8 km.; b) Particle analysis example showing floe size distributions within a single video frame. The table below shows the size parameters for individual particles (label numerically in the image and table). Units are in pixel dimensions and will later be calibrated to meters using the GPS altitude data.

Table 7. Example morphometry from individual floes for floe 1 to 10 (floe ID corresponds to Figure 2).

Floe ID	Area	Mean Reflectance	Perimeter Length	Major axis	Minor axis
1	0.2	74.4	1.5	0.6	0.4
2	2.0	104.9	8.0	2.0	1.3
3	2.8	94.6	10.2	2.2	1.6
4	0.7	113.2	4.3	1.0	0.9
5	0.3	76.2	2.1	0.7	0.5
6	0.6	81.0	2.8	0.9	0.8
7	0.0	93.5	0.1	0.0	0.0
8	59.3	161.3	35.3	10.0	7.5
9	0.7	60.4	3.2	1.1	0.8
10	0.5	62.9	2.7	0.9	0.8

The particle analysis will be combined with surface classification to create a statistical surface which couple ice floe geometry with surface radiation properties. The ice classes are based on WMO classification of age. Coupled spectral reflectance data provides information on the surface spectral characteristics as a function of the statistical properties of the surface (size classes and type).

2.2 Biological Ice Program

Principal investigators: Christine Michel, Michel Gosselin, Jody Deming
Cruise participants: Christine Michel, Bernard Leblanc, Gitane Caron, Jody Deming & Llyd Wells

Most of the biological ice program that was carried out during the CASES 2002 fall expedition was not initially planned. It is in response to the exceptional and diverse ice conditions encountered, that an opportunistic biological ice program was developed and carried out. The biological ice sampling covered two distinct, albeit complementary, aspects of biological ice processes, i.e., early stages of ice formation and vertical structure within multi-year ice floes.

We investigated the incorporation of biological material in different types of newly forming ice, including slush ice, pancake ice, plate and fast ice, at 11 stations (Table 8). The sampling took place from a "cage" which was lowered from deck and kept suspended over the sampling area. The thickness of the ice sampled ranged from 0 (unconsolidated slush) to 17 cm (see Table 8). The consolidated ice was sampled with a SIPRE ice corer (Kovacs Enterprises, Lebanon, NH) while unconsolidated slush was collected with a spoon or strainer. The ice samples were transferred in isothermal containers and were slowly melted before being processed. Similar analyses were performed on surface water which was also collected at the time of sampling. Salinity of surface water and melted ice cores was measured with an Orion portable salinometer. Duplicate subsamples were filtered on Whatman GF/F and on Nuclepore 5µm filters, for size-fraction determination of chl *a* and phaeopigments, using the same method as described for the FSTs. Subsamples stained with DAPI were filtered on black Nuclepore 0.2µm filters; these were mounted on slides and frozen at -80°C for later bacteria counts. Subsamples were also preserved in acidic Lugol's solution for later cell identification and counts.

Multi-year ice stations were visited by helicopter. Complete cores were taken and cut into sections of 5 cm thickness, each at 5 of 10 cm interval. These sections were placed in sterile bags and slowly melted until analysis. Total organic carbon (TOC) and dissolved organic carbon (DOC) of the melted sea ice will be measured on a Shimadzu TOC-5000 analyzer. Subsamples were either not filtered (TOC) or filtered through 0.2 um sterile syringe filters (DOC), and kept in acid washed amber bottles with a Teflon cap, after adding 50% v/v of H_3PO_4 (5 µL mL^{-1}). Duplicate subsamples stained with DAPI were filtered on black Nuclepore 0.2 µm filters, mounted on slides and frozen at -80°C, for later bacteria counts. Subsamples were also preserved in acidic Lugol's solution for cell identification and counts. We collected only two ice cores for vertical profiles. We also collected four additional complete cores, which were kept frozen on the ship. Unfortunately, these cores were broken and lost during a spectacular storm encountered along the Labrador Coast as the ship transited back to Québec City.

The vertical core profiles have not been analysed yet. However, preliminary results from the new ice program suggest that the type of ice might influence the incorporation of biological material within the ice matrix. Results also reflect size differences in the incorporation of biological material, with a selection towards larger cells. The latter concurs with limited observations and published literature for Arctic sea ice (Gradinger et al., 1998). This original research on incorporation of material within different types of newly forming ice will provide insights into poorly documented processes

associated with ice formation and its significance for sea-ice communities and related bio-geochemical processes.

Table 8: Details of new ice sampling program during the CASES 2002 fall expedition.

Station	Date	Lat (N)	Long (W)	Ice type	Ice thickness (cm)
1	9/26/02	71°32.9'	131° 11.7'	Fast ice	8
2	9/27/02	71° 40.0'	133° 03.1'	Fast ice	10
3	9/27/02	71° 39.4'	133° 00.2'	Fast ice	≅12
4A	10/5/02	70° 57.7'	133° 03.0'	Pancake ice, semi-consolidated	4-5 + slush
4B	10/5/02	70° 57.7'	133° 03.0'	Pancake ice, semi-consolidated	6-7 + slush
5A	10/6/02	71° 12.4'	129° 04.2'	Slush frazil	na
5B	10/6/02	71° 12.4'	129° 04.2'	Pancake ice, non-consolidated	≅ 6
6	10/6/02	71° 15.9'	128° 28.4'	Pancake ice, consolidated	5 & 9
7A	10/7/02	71° 16.8'	128° 32.9'	Slush frazil	n.a.
7B	10/7/02	71° 16.8'	128° 32.9'	Pancake ice	7
8A	10/8/02	71° 21.6'	126°26.5'	Rafted ice	2
8B	10/8/02	71° 21.6'	126° 26.5'	Rafted ice	2
9A	10/11/02	69°49.5'	126° 07.8'	Large consolidated plate	17
9B	10/11/02	69° 49.5'	126° 07.8'	Large consolidated plate	17
10	10/11/02	69° 49.2'	126° 09.9'	Grease ice	na
11	10/12/02	69° 54.2'	126° 02.7'	Large plate	14

Acknowledgements

This research was made possible by the CASES Research Network grant by NSERC and by the Science Strategic Fund of Fisheries and Oceans, Canada. We gratefully acknowledge Martin Fortier, chief scientist and scientific coordinator of the CASES Network for his dedicated efforts in preparation for, and during the expedition. The success of the expedition also draws from the skills and dedication of the captain, officers and crew of the CCGS *Pierre Radisson*, and on the collaborative spirit among scientists aboard the ship. Special thanks go to the FST team, Jody Deming and Bernard Leblanc, for the trap deployments, and to Gitane Caron and Bernard Leblanc for help in ice sampling and in the laboratory.

This was made possible by the generous commitment of the captain of the CCGS *Pierre Radisson*, Serge Brulé, who provided us with extra helicopter time in order to circumvent helicopter time constraints that would have precluded any biological ice sampling. This program was entirely contingent upon this initiative and we gratefully acknowledge our captain, Serge Brulé, for his dedicated support.

References

Gradinger, R. and J. Ikävalko, 1998. Organism incorporation into newly forming Arctic sea ice in the Greenland Sea. J. Plankton Res. 20: 871-886.

Parsons TR, Maita Y and CM Lalli, 1984. A manual of chemical and biological methods for seawater analysis. Pergamon Press, Toronto, 173 p.

3. Light, Nutrients, Primary and Export Production

Subproject leader: Serge Demers

3.1 Nutrients and New Production

Principal investigator : Neil Price
Cruise participant: Jean-Eric Tremblay & Bernard Leblanc

Introduction

In the nitrogen-limited waters of the Arctic Ocean, the upper limit to carbon transfers to top consumers and deep waters (i.e. the biological CO_2 pump) is considered to be equivalent to new production, i.e. the fraction of total primary production derived from allochthonous nitrogen inputs to the euphotic zone (Tremblay et al., 2002a; Smith et al., 1990). On the Mackenzie shelf and in the Cape Bathurst Polynya, the availability of nitrogen can be influenced by a host of factors including the large-scale circulation, river discharge and local mixing processes, all of which are related to climate. Understanding the relationship between biological productivity and nutrient supply is thus a critical step in assessing the response of the ecosystem to climate variability and change. Recent work has shown that the contribution of different waters to biological productivity in the southwestern Arctic can be established from nutrient signatures since the chemical properties of Pacific-derived waters differ markedly from those of the Mackenzie river and waters of Atlantic origin (Tremblay et al., 2002b; Jones et al., 1999).

Objectives

Our objectives for CASES 2002 were to measure nitrogen uptake and establish nutrient distributions on the Mackenzie shelf and the Cape Bathurst Polynya in relation to river discharge and the general Arctic circulation in Autumn.

Methods

Samples for nutrient analyses were obtained from vertical profiles at each station (see Table 9 for location of sampling stations). The concentrations of nitrate, orthophosphate and orthosilicic acid were determined on board in fresh samples using an ALPKEM autoanalyzer with routine colorimetric methods (Grasshof 1999). Samples for nitrate and ammonium uptake measurements were taken at 7 photic depths (100, 40, 20, 10, 5, 1, 0.1% of incident light) at a subset of stations (Table 9). Uptake rates of nitrate were estimated *in-vitro* using the ^{15}N labelling method. Subsamples from the 7 photic depths were spiked with ^{15}N-KNO_3 at 10% of ambient concentration and incubated during 24 h in 600-ml polycarbonate bottles placed in deck incubators. Temperature was maintained by circulating water from the upper mixed layer through the incubators and *in-situ* irradiance was simulated using combinations of neutral density filters. Incubations were terminated by low vacuum (< 100 mm Hg) filtration onto pre-combusted 25-mm GF/F filters (total phytoplankton) and copious rinsing with 0.4-µm filtered sea water. Filters were stored frozen for post-cruise determination of ^{15}N enrichment and POC and PON content by mass spectrometry.

Table 9. List of stations and measurements

Station	Date	Longitude	Latitude	Measurement
3	10/12	124º30.85'	70º25.62'	Nut.
6	10/13	125º30.26'	70º20.91'	Nut.
9	10/12	125º51.2'	70º5.76'	Nut.
12	10/12	126º9.65'	69º50.22'	Nut., N uptake
15	10/11	126º30.92'	70º4.64'	Nut.
18	09/22	126º49.93'	70º18.71'	Nut.
21	09/22	127º12.86'	70º34.12'	Nut.
24	09/23	127º33.88'	70º46.73'	Nut., N uptake
27	09/23	128º10.01'	71º4.41'	Nut.
30	09/23	128º40.33'	71º19.87'	Nut.
33	09/23	129º11.65'	71º34.87'	Nut.
36	09/26	129º58.4'	71º37.24'	Nut.
39	09/26	130º55.64'	71º26.03'	Nut.
42	09/26	131º52.59'	71º32'	Nut.
45	09/27	132º54.16'	71º35.38'	Nut.
49	09/29	133º47.17'	71º26.71'	Nut., N uptake
53	09/30	133º43.03'	71º6.38'	Nut.
56	09/30	133º39.9'	70º51.28'	Nut.
59	09/30	133º35.49'	70º35.51'	Nut.
65	10/02	133º31.32'	70º8.67'	Nut., N uptake
66	10/04	133º39.11'	70º51.13'	Nut., N uptake
69	10/05	132º45.65'	70º54.88'	Nut.
72	10/05	131º48.06'	70º58.9'	Nut.
75	10/05	130º54.64'	71º3.89'	Nut.
78	10/06	130º1.14'	71º8.32'	Nut.
81	10/06	129º8.36'	71º12.43'	Nut.
83	10/06	128º30.35'	71º15.56'	Nut., N uptake
86	10/08	127º30.18'	71º22.96'	Nut.
89	10/08	126º46.48'	71º24.13'	Nut.
92	10/09	125º57.8'	71º14.57'	Nut.
95	10/09	125º26.55'	71º4.33'	Nut.
98	10/09	124º49.59'	70º53.46'	Nut.
101	10/10	124º10.95'	70º43.46'	Nut., N uptake
104	10/12	123º28.13'	70º39.69'	Nut.
107	10/14	122º37.8'	70º37.63'	Nut.
110	10/14	121º50.68'	70º35.1'	Nut.
101ex	10/15	112º45.7'	68º22.64'	Nut.
112	10/17	96º4.35'	72º8.66'	Nut.
Z1	10/02	133º13.8'	69º30.3'	Nut.
Z2	10/03	133º13.8'	69º30.6'	Nut.
Z5	10/03	133º22.2'	69º48'	Nut.
Z7	10/03	133º25.8'	69º58.8'	Nut.

Preliminary Results and Conclusions

Figure 10 shows the distribution of nitrate and silicate along a sampling transect between the Mackenzie delta and the Arctic ice pack. Offshore stations exhibited silicate profiles typical of the Arctic halocline, with a distinct maximum at ca. 150 m (Fig. 10a). Some of this silicate-rich water extended along the bottom over the shelf (Fig. 10b). A tongue of intermediate silicate concentrations was observed in the river plume, which flowed northward over the low-silicate polar surface water. The levels of silicate (ca. 11 μM) in the plume suggested a weak influence of the river discharge on the nutrient field since riverine concentrations upstream at Inuvik were in the order of 60 μM (not shown). In contrast, the concentrations of nitrate were not elevated in the river plume (Fig. 10c,d), reflecting the relatively low concentrations at Inuvik (ca. 2 μM). Nitrate levels in the upper 40 m hovered slightly above the analytical detection limit, presumably owing to biological consumption in the euphotic zone. Overall, these preliminary results are indicative of a shelf ecosystem in the late stages of the productive season (i.e. nitrate depletion), were the nutrient field is largely controlled by the influx of offshore waters onto the shelf. Nitrate is also likely to be the limiting nutrient in this region since silicate remained in excess at sites where the former was nearly exhausted.

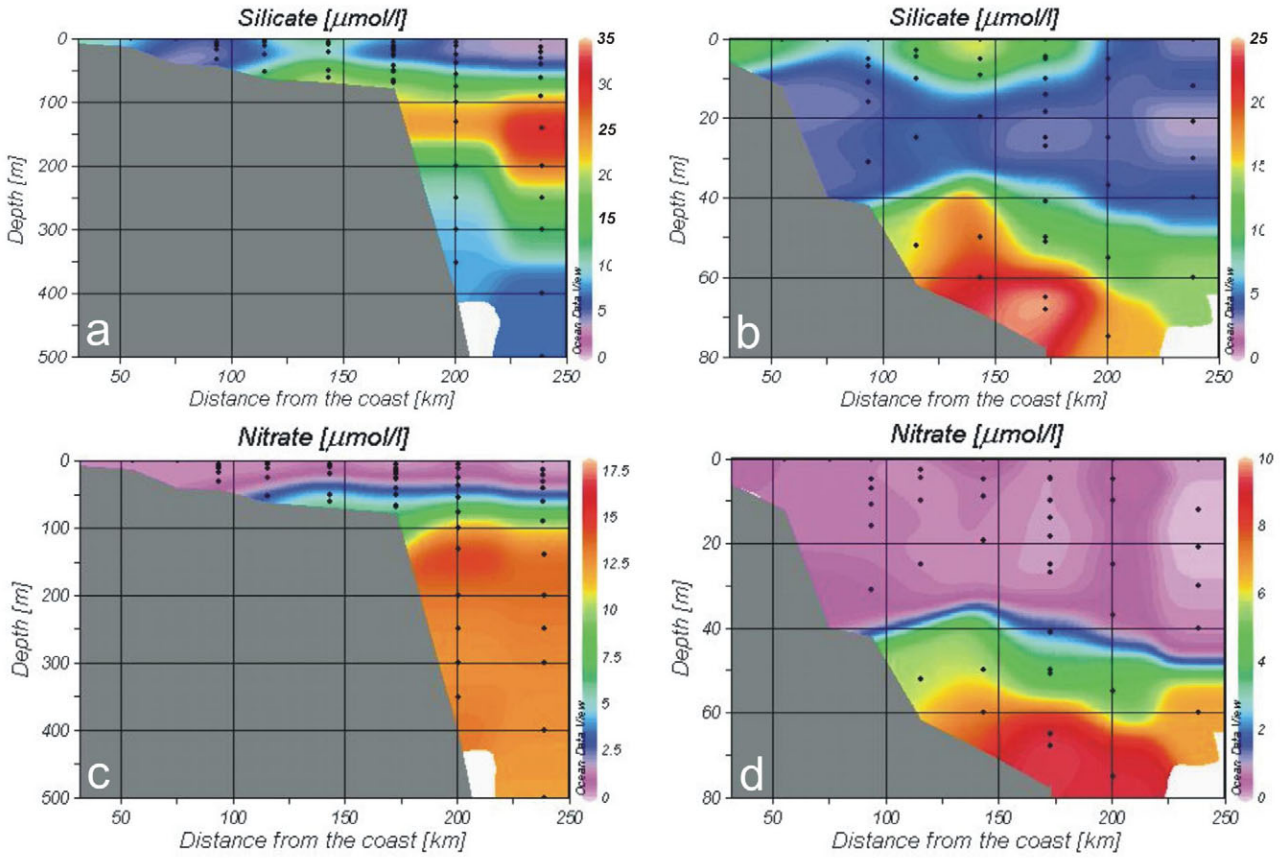


Figure 10. Distribution of nitrate and silicate along a transect from the Mackenzie river during autumn 2002.

References

Grasshoff, K., Methods of seawater analyses, Weinheim, New-York, 600 p., 1999.

Jones, E. P., L. G. Anderson and J. H. Swift, Distribution of Atlantic and Pacific waters in the upper Arctic Ocean: Implications for circulation, *Geophys. Res. Lett.*, 25 , 765-768, 1998.

Smith, W. O., and E. Sakshaug, Polar Phytoplankton, *in Polar Oceanography, Part B: Chemistry, Biology and Geology*, edited by W. O. Smith, Academic Press, 1990.

Tremblay, J.-E., Y. Gratton, J. Fauchot and N.M. Price, Climatic and oceanic forcing of new, net, and diatom production in the North Water, *Deep-Sea Res. II*, 49, 4927-4946 , 2002a.

Tremblay, J.-E., Y. Gratton, E.C. Carmack, C.D. Payne, and N.M. Price, Impact of the large-scale Arctic circulation and the North Water Polynya on nutrient inventories in Baffin Bay. J. Geophys. Res.*, 107, 2002b.*

3.2 Phytoplankton and microphytobenthos characteristics

Principal investigators: Serge Demers, Christine Michel, Michel Gosselin, Pierre Larouche, Michel Poulin,
Cruise participants: Christian Nozais, Karine Lacoste, Gitane Caron, Christine Michel, Bernard Leblanc

Objectives

This part of the CASES project is based more specifically on understanding the dynamics of the development of planktonic and benthic algal communities in polar ecosystems and the role of these biological components in biogeochemical processes. Planktonic and benthic microalgae production estimates for the arctic continental shelves are scarce (Grebmeier *et al.* 1995; Horner & Schrader 1982; Legendre *et al.* 1992; Macdonald *et al*. 1998), due to the difficulties associated with access to these areas. Furthermore, the mechanisms related to the inter-annual variability of primary production with regard to natural physical and/or biological forcing are not well known. Finally, the level of contribution of phytoplanktonic cells to the vertical biogenic carbon flux and the present and future role of the biological pump in the arctic waters in response to the variability of ice cover are not well documented. Therefore, the main objectives of our group were:

- to determine the biomass and the production of pico-, nano- and microphytoplanktonic cells in the photic zone over the Mackenzie Shelf and in the Cape Bathurst polynya area
- to evaluate the relative contribution of phytoplankton and microphytobenthos to the total primary production in these same areas
- to assess the effects of the bio-optical factors on the vertical attenuation of the ultraviolet component of the solar spectrum in the water column, and
- to define the bio-optic characteristics of the assemblages of pico- and nanophytoplanktonic cells by flow cytometry, to calibrate SeaWifs satellite images which reflect the local characteristics of the Beaufort Sea (collaboration with Pierre Larouche of the Maurice Lamontagne Institute).

Methods

Study site

This study was conducted in the Beaufort Sea from 23 September to 14 October 2002. Forty one stations were visited: 30 basic stations, 7 full stations, 2 coastal stations (Z5 and Z2), and 2 river stations (R1 and R2) (Table 10).

Water column sampling and analyses

Vertical light profiles were performed at 14 stations (Table 10) using a PUV-511 underwater radiometer (Biospherical Instruments) that provides a measure of cosine-corrected downwelling irradiance in 5 discrete channels in the UVR range (305, 313, 320, 340 and 380nm) and a measurement of cosine-corrected PAR. Irradiances were corrected by the dark values and normalized to the ambient conditions at the beginning of the profile, using ambient values given by a GUV-510 surface radiometer (Biospherical Instruments).

Water samples were prefiltered after having been collected with a rosette sampler (24 bottles of 12L each) at different depths, for the determination of chlorophyll *a* (chl *a*), phaeopigments, particulate organic carbon and nitrogen (POC and PON, respectively), algal cell size, fluorescence and species composition, and ^{14}C uptake rates (Table 10).

Chl *a* concentration was used as a proxy for phytoplankton biomass. Samples were filtered (250ml or more) onto Whatman GF/F filters (Total phytoplankton biomass) and onto 5µm polycarbonate filters (Poretics) (Large phytoplankton biomass). Chl *a* concentrations for both fraction were determined with a 10-AU Turner Designs fluorometer following 24h extraction in 90% acetone at 5°C without grinding. To determine POC and PON concentrations, water samples were filtered (250mL or more) through pre-combusted (5h at 500°C) Whatman GF/F glass fiber filters. Filters were then folded into pre-combusted paper foil and frozen at -80°C for later analyses. To determine pico- and nanophytoplankton cell abundance and fluorescence, water samples were collected at different depths of the photic zone and preserved with paraformaldehyde for later analysis using a FACSORT Analyser flow cytometer (Becton-Dickinson) fitted with a 488nm laser. Finally, 250ml subsamples of water were collected at three depths (surface, 25 and 50m) for phytoplankton cell identification and enumeration. The samples were fixed with acid Lugol and maintained in a darkroom at 4°C.

The potential and the actual photochemical efficiency of the reaction centres of PSII (Fv/Fm and ΔF/F'm, respectively) of phytoplankton cells (collected at all stations at different euphotic depths) were determined by Pulse Amplitude Modulated (PAM) fluorescence. The instrumentation used consisted in an Optisciences pulse-amplitude fluorometer (model OS5-FL Opti-Sciences, Inc., Tyngsboro, Massachusetts, U.S.A). The ratio of variable to maximal fluorescence (Fv/Fm) was determined in dark-acclimated phytoplankton (45 minutes) and used as an indicator for the potential photochemical efficiency of the reaction centres of PSII. $Fv = Fm - F_0$, F_0 is the initial sample fluorescence (all reaction centres of photosystem II are oxidized or "opened") and Fm is the maximal fluorescence reached under strong light irradiance e.g. saturating pulse of white light (all reaction centres of photosystem II are reduced or "closed"). Under actinic intensity, the photosynthetic yield (Y e.g. ΔF/F'm) or actual photochemical efficiency of the reaction centres of PSII, which corresponds to the ratio of variable Fv to maximal fluorescence Fm under actinic light was evaluated.

Primary production rates were determined at full stations. Particulate pelagic primary production was estimated for 7 euphotic depths (i.e. 100%, 40%, 20%, 10%, 5%, 1% and 0.1%) using the ^{14}C uptake method. These depths were determined after calculating the light attenuation coefficient, K_d, using data either from an optical profile done with a PUV 500 or from a Secchi disk. Measurements of simulated *in situ* carbon fixation by phytoplankton were made in 250 ml polycarbonate bottles (two light and one dark; inoculated with 10µCi of $NaH^{14}CO_3^-$) placed into 7 deck incubators (each corresponding to an euphotic depth). The total added activity was determined in triplicates by adding 250µl of the inoculated water subsample into 10ml Ecolume scintillation fluid (ICN) containing 250µl of Ethanolamine. After 24 hours of incubation, subsamples (100ml or more) were filtered onto GF/F glass-fiber filters (Total particulate primary production) and 5µm polycarbonate filters (Poretics) (Large particulate primary production). Non-incorporated ^{14}C was removed by addition of 250µl of 0.5N HCl. Upon evaporation of the acid, 10ml of Ecolume scintillation liquid were added. Activity will be determined using a Beckman Liquid scintillation system 3801 Series. All counts will be dark-corrected.

The response of photosynthetic carbon assimilation to light was obtained by ^{14}C uptake using a small-volume, short-incubation time method. This experiment was conducted at all full stations for 3 euphotic depths of which corresponded the irradiances 100%, 10% and 1%. The light in the incubators varied from 0 to 5000µE m^{-2} s^{-1} over 20 positions. In dim light, one 30ml water subsample was poured into a 60ml flask to which 30µCi of $NaH^{14}CO_3^-$ were added (final activity of 1 µCi ml^{-1}). After a gentle homogenisation, 1 ml-aliquots were dispensed into 23 clean 20 ml-borosilicate scintillation vials. The vials were then placed under a light gradient ranging from 20 to

2500µE m^{-2} s^{-1} in a linear incubator. Three scintillation vials were incubated in the dark. The total added activity was determined (triplicates) by adding 250µl of the inoculated water subsample into 10ml Ecolume scintillation fluid (ICN) containing 250µl Ethanolamine. After 30 min of incubation, non-incorporated ^{14}C was removed by adding 250µl of 6N HCl. After 30 min, 250µl of 6 N NaOH was added to the samples to avoid pH changes. 10ml of scintillation cocktail were then added. The samples will be counted using a Beckman Liquid scintillation system 3801 Series.

Sediment sampling and analyses

Sediment samples were collected with a Box core (USNEL) at 7 stations (Table 11) for the determination of sediment size structure, chl *a,* phaeopigments, species composition, and ^{14}C uptake rates, and meiofauna.

The top first cm of a sediment subsample was taken for granulometric analysis, using a hand-held perspex corer of 25mm internal diameter. Microphytobenthic biomass was estimated as chlorophyll *a* (chl *a*) concentration. Three replicate sediment subsamples were collected with the corer described above. The top first cm of sediment was cut and placed in a 50ml polyethylene bottle with 30ml of 90% acetone for the extraction of pigments. Chl *a* concentrations were measured using a 10-AU Turner Designs fluorometer. Two sediment subsamples were collected for microphytobenthic cell identification and enumeration. The samples were fixed with acid Lugol.

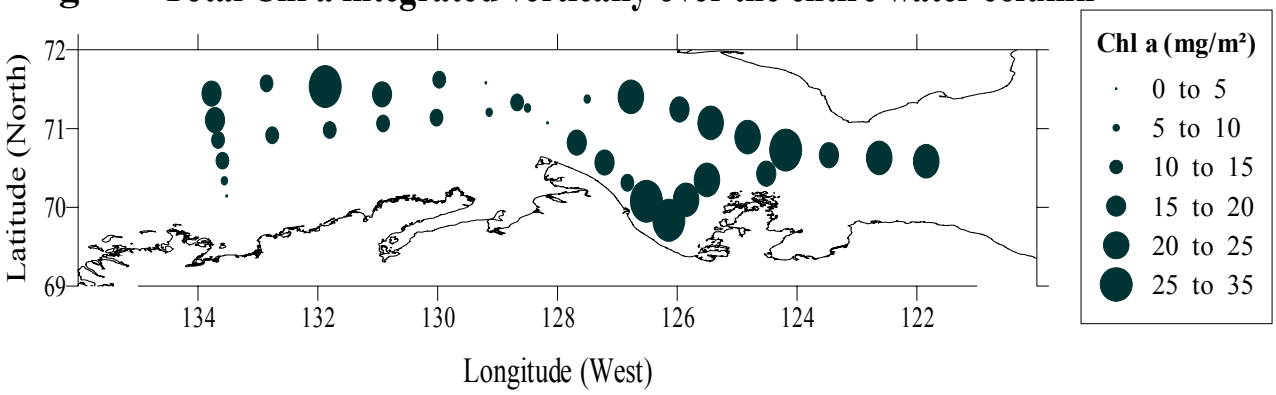
The response of photosynthetic carbon assimilation to light was obtained by ^{14}C uptake using the same method as described above for phytoplankton. Briefly, the top first cm of sediment was mixed in 60mL of filtered seawater (Whatman GF/F) contained in a dark bottle. The sample was gently mixed and 3mL of $NaH^{14}CO_3$ (1 µCi mL^{-1}) was added. After a gentle homogenisation, 1 ml-aliquots were dispensed into 23 clean 20 ml-borosilicate scintillation vials. The vials were then placed under a light gradient ranging from 20 to 2500µE m^{-2} s^{-1} in a linear incubator. Three scintillation vials were incubated in the dark. The total added activity was determined (triplicates) by adding 250µl of the inoculated water subsample into 10 ml Ecolume scintillation fluid (ICN) containing 250µl Ethanolamine. After 30 min of incubation, non-incorporated ^{14}C was removed by adding 250µl of 6N HCl. After 30 min, 250µl of 6N NaOH was added to the samples to avoid pH changes. Ten ml of scintillation cocktail were then added. The samples will be counted using a Beckman Liquid scintillation system 3801 Series.

For the meiofaunal analyses, another three sediment samples were collected, at each full station, with the corer described above. The top 1-cm layer of each sediment core was preserved in a 1:500 (v/v) buffered freshwater formalin (5%) solution stained with Rose Bengal.

Preliminary results

Total chl *a* concentrations varied between 0 and 1.6µg L^{-1}. Chl *a* maxima were found within the first 10m of the water column for 31 stations, within the 50-60m layer for stations 36, 42, 45, and 49 (more offshore stations) and close to the bottom for stations 62 and 65 (stations close to the Mackenzie river). In waters deeper than 78m, chl *a* concentrations were always less than 0.1µg L^{-1}. Except for more coastal stations, phytoplankton biomass was mostly attributed to cells smaller than 5µm. Chl *a* concentrations vertically integrated over the entire water column varied between 1.8 (station 33) and 31.8 (station 12) mg m^{-2} (Figure 1). In the present study, the Franklin Bay, the southwestern Banks Island area, Amundsen Gulf, and station 42 were clearly identified as exhibiting the greatest phytoplankton biomass. POC concentrations varied between 82 and 1686 µgC L^{-1} with lowest concentrations found in the outer-shelf area, higher concentrations found in surface and bottom waters, and highest concentrations close to the Mackenzie Delta. Chl *a* and POC values recorded in our study are similar to those reported by Iseki *et al*. (1987) who studied only the western section of our study area.

Fig.11 Total Chl a integrated vertically over the entire water column



Acknowledgements.

This project was supported by a Research Network Grant and by an individual grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada to Serge Demers. We are grateful to the Canadian Coast Guard officers and crew of the CCGS 'Pierre Esprit Radisson' for their skilful support during the expedition. We acknowledge the invaluable support of the chief scientist, Martin Fortier, during the expedition. This is a contribution to the research programs of the Institut des sciences de la mer de Rimouski and Québec-Océan.

References

Grebmeier JM, Smith WO Jr, Conover RJ (1995) Biological processes on Arctic continental shelves: Ice-ocean-biotic interactions. Coast. Estuar. Studies 49:231-261

Horner R, Schrader GC (1982) Relative contributions of ice algae, phytoplankton and benthic microalgae to primary production in nearshore regions of the Beaufort sea. Arctic 35:485-503

Iseki K, Macdonald R.W, Carmack E (1987) Distribution of particulate matter in the southeastern Beaufort Sea in late summer. Proc. NIPR Symp. Polar Biol.1:35-46

Legendre L, Ackley SF, Dieckmann GS, Gulliksen B, Horner R, Hoshiai T, Melnikov IA, Reeburg WS, Spindler M, Sullivan CW (1992) Ecology of sea ice biota. 2 Global significance. Polar Biol. 12:429-444

Macdonald RW, Solomon SM, Cranston RE, Welch HE, Yunker MB, Gobeil C (1998) A sediment and organic carbon budget for the Canadian Beaufort shelf. Mar. Geol. 144:255-273

Table 10. The water column sampling program. Chl a: Biomass of phytoplankton (size fractionated); CHN: POC, PON; Cells: Taxonomy; PAM: Pulse amplitude modulated fluorescence; PPP: Particulate primary production; PI: photosynthesis-irradiance relationships. Full stations: underlined station numbers.

Station	Date	Chl *a*	CHN	Cells	Cytometry (Phyto.)	Cytometry (Bacteria)	PAM	Optical profile	PPP	PI
3	22/09							**X**		
18	23/09	**X**	**X**	**X**	**X**	**X**	**X**			
21	23/09	**X**	**X**	**X**	**X**	**X**	**X**			
24	24/09	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
27	25/09	**X**	**X**	**X**		**X**	**X**			
30	25/09	**X**	**X**	**X**	**X**	**X**	**X**			
33	25/09	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
36	25/09	**X**	**X**	**X**	**X**	**X**	**X**			
39	26/09	**X**	**X**	**X**	**X**	**X**	**X**			
42	26/09	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
45	27/09	**X**	**X**	**X**	**X**	**X**	**X**			
49	29/09	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
53	29/09	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
56	30/09	**X**	**X**	**X**	**X**	**X**	**X**			
59	30/09	**X**	**X**	**X**	**X**	**X**	**X**			
62	30/09	**X**	**X**	**X**	**X**	**X**	**X**			
65	02/10	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Z2	03/10	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Z5	03/10	**X**	**X**	**X**						
R1	04/10	**X**	**X**							
R2	04/10	**X**	**X**							
66	04/10	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
69	05/10	**X**	**X**	**X**	**X**	**X**	**X**			
72	05/10	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
75	05/10	**X**	**X**	**X**	**X**	**X**	**X**			
78	06/10	**X**	**X**	**X**	**X**	**X**	**X**			
81	06/10	**X**	**X**	**X**	**X**	**X**	**X**			
83	07/10	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
86	08/10	**X**	**X**	**X**	**X**	**X**	**X**			
89	08/10	**X**	**X**	**X**	**X**	**X**	**X**			
92	08/10	**X**	**X**	**X**	**X**	**X**	**X**			
95	09/10	**X**	**X**	**X**	**X**	**X**	**X**			
98	09/10	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
101	10/10	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**
15	11/10	**X**	**X**	**X**	**X**	**X**	**X**			
12	1210	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
9	12/10	**X**	**X**	**X**	**X**	**X**	**X**			
6	12/10	**X**	**X**	**X**	**X**	**X**	**X**			
3	13/10	**X**	**X**	**X**						
104	13/10	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
107	13/10	**X**	**X**	**X**	**X**	**X**	**X**			
110	14/10	**X**	**X**	**X**	**X**	**X**	**X**			

Table 11. Description of sediment sampling program. Chl a: Biomass of microphytobenthos; Sed.: Sediment granulometry; Cells: Taxonomy; PI: photosynthesis-irradiance relationships

Station	Date	Chl *a*	Sed.	Cells	Meiofauna	PI
24	24/09	**X**	**X**	**X**	**X**	**X**
49	29/09	**X**	**X**	**X**	**X**	**X**
65	02/10	**X**	**X**	**X**	**X**	**X**
66	04/10	**X**	**X**	**X**	**X**	**X**
83	07/10	**X**	**X**	**X**	**X**	**X**
12	11/10	**X**	**X**	**X**	**X**	**X**
104	11/10	**X**	**X**	**X**	**X**	**X**

4.Microbial communities and Heterotrophy

Subproject leaders: Warwick Vincent & Curtis Suttle

4.1 Microbial communities and Heterotrophy

Principal investigators: Warwick F. Vincent, Curtis Suttle, Jody Deming, Carlos Pedros-Alio, Anette Wilmotte, Chris Osburn

Cruise participants: Warwick F. Vincent, Alice Ortmann, Christine Martineau

The central hypothesis in CASES concerns the processing of organic matter in the Mackenzie delta versus offshore waters and its relationships with sea ice conditions. Micro-organisms are likely to contribute substantially to the biological carbon stocks across this region, and to play a leading role in the biogeochemical fluxes of organic matter. The microbial ecology subprogram was therefore formulated to measure microbial community structure and production dynamics throughout the CASES study region, including comparative measurements in the inshore delta and Mackenzie River source waters.

Extensive sampling was undertaken during CASES 2002 to determine the distribution, abundance and biodiversity of the following microbial communities within the water column: viruses, Archaea, heterotrophic Eubacteria, picocyanobacteria, picoeukaryotes, and pigmented and non-pigmented protists. Assays were conducted to quantify rates of bacterial heterotrophy and viral production. Cultures were initiated to bring pico-autotrophs and viruses into culture for subsequent laboratory-based analyses and experiments. Samples were also collected to identify (in collaboration with other subprogram teams) the sources and photoreactivity of organic matter across the study region, and the optical variables controlling the underwater attenuation of ultraviolet and photosynthetically available radiation.

4.1.1 Virus studies

Objectives

There were three main components to the virus studies in CASES 2002. The first was to determine the spatial distribution of virus abundances throughout the study area. The second was to look at the composition of the virus community, particularly the algal virus diversity and abundances. Third, experiments were run to estimate the mortality due to viruses in the prokaryotic component of the microbial community.

Viral Abundances

The first objective of the virus studies was to determine the abundance of viruses in the Canadian Shelf area. To do this, surface samples were collected at most of the basic stations as well as at near-shore zodiac stations and river stations. As well as the surface waters, depth profiles for abundances were also collected at all of the full stations, including station 12 and a "mini" profile of 2 depths was done at station Z2. Samples were filtered through a 0.02 µm filter and will be enumerated using epifluorescence microscopy.

Virus Community Composition

To address the question of the diversity of the virus community and look at abundances of specific viruses, viral concentrates were made. These were made at most of the full stations as well as at the near-shore station, Z2, and the Mackenzie River station, R2. The concentrates were made by

prefiltering 20L of water and then concentrating the viruses using tangential flow filtration. The virus-size fraction from the 20 L was concentrated into approximately 200 mL.

The viral concentrate will be used at UBC for two different projects. The first will use PCR to determine the diversity of algal viruses belonging to the Phycodnavirdae. Using similar techniques with different primers, bacteriophage may also be investigated for their genetic diversity. The viral concentrates will also be used to determine the abundance of viruses for a specific host, *Micromonas pusilla*, a photosynthetic flagellate known to persist in Arctic waters. Again, this method may also be applied to specific bacteria to isolate host-specific viruses.

Virus Induced Mortality

To estimate the rate at which viruses are produced and thus kill their hosts, experiments were run at the first four full stations and the inshore station, Z2. These stations, with the exception of Full Station 1 (#24) provide a transect from shore to the ice edge. The bacteria size-fraction was concentrated using tangential flow filtration, enabling the removal of the viruses. The bacterial concentrate was then diluted to the original abundances using virus-free water. The "washed" bacteria were then incubated and subsampled over 36 hours to monitor the production of viruses. Abundances will be determined using both flow cytometry and epifluorescence microscopy to compare the methods.

Conclusions

Although no results are yet available for any of the virus work, the data once obtained will be combined with other microbial data, such as the abundance of picocyanobacteria, total bacterial abundances and chlorophyll a. Diversity studies can also be done on the prefilters from the virus concentrates to determine what potential hosts were present in the water with the viruses.

All of this information can be used to help design the research goals of the doctoral student who will be participating in CASES 2003. This data will provide the starting point for the seasonal studies focusing on virus dynamics, diversity and abundances.

Considerations for CASES 2003

One of the most important items for much of the microbial work next year would be an epifluorescence microscope. Without having a microscope onboard it is impossible to know if methods are working reliably and if such things as nucleic acid stains are viable. Without having a microscope, no data can be collected shipboard, decreasing the efficiency of the program.

Table 12. Summary of Samples

Surface Abundances	Depth Profiles of Abundances	Virus Concentrates	Viral Production Incubations
Basic 3	Full 24 (6 depths)	Full 24 (6 depths)	Full 24
Basic 18-98	Full 49 (9 depths)	Full 49 (5 depths)	Full 49
Basic 9	Full 65 (3 depths)	Full 65 (3 depths)	Full 65
Basic 104	Full 66 (3 depths)	Full 66 (3 depths)	Full 66
Z1, Z2, Z5	Full 83 (3 depths)	Full 101 (4 depths)	Z2
R1, R2	Full 101 (4 depths)	Z2 (1 depth)	
	Full 12 (6 depths)	R2 (1depth)	
	Z2 (2 depths)		

4.1.2 Microbial production & community structure

Objectives

Key objectives of this section of the microbial subprogram were to measure bacterial production in the water column, and the distribution and abundance of microbial taxa throughout the CASES study region. Several microbial groups were targeted for microscopic and molecular analysis. Protist communities were sampled as a guide to the balance of phototrophy versus heterotrophy, and to test the hypothesis that there is a shift in dominance from obligate heterotrophs and particle-based taxa inshore to obligate phototrophs offshore. Picoeukaryotes and picocyanobacteria were sampled to evaluate whether there is an offshore gradient towards dominance by eukaryotic taxa, and a selective loss of prokaryotic phototrophs. A further objective was to apply molecular protocols that are being used elsewhere in the Arctic and Antarctic Oceans to assess the biodiversity of pico-autotrophs. Additional samples were obtained to determine the characteristics, sources and photoreactivity of coloured dissolved organic matter (CDOM), and the influence of CDOM and other optically active constituents on the underwater attenuation of UV and PAR.

Methodology

a. Bacterial Production

Samples were obtained from depths corresponding to 100%, 10%, 1% and 0.1% of the surface incident PAR, and from additional depths including near-bottom, Chlorophyll *a* maximum, nepheloid layer and temperature inversion features, if present. Replicates from each depth were then incubated for 2 h with ^{3}H-thymidine to measure bacterial DNA synthesis and ^{3}H-leucine to measure bacterial protein synthesis, according to JGOFS protocols. The incubations were terminated by addition of formaldehyde and trichloroacetic acid, and then filtered onto 0.2 μm cellulose nitrate membranes. These were rinsed three times with ice-cold TCA, then with cold ethanol before preservation by freezing. Additional T_0 samples were fixed within 30 seconds of the addition of the isotopes.

FULL STATIONS SAMPLED: 24, 49, 65, 66, 83, 101; OTHERS SAMPLED STATIONS: Z2, R1, R2, 12 (Basic)

These data are currently under analysis by Mme Marie-Ève Garneau (ULaval). Preliminary results show that bacterial production rates were much higher in the inshore sea than in the river water. The initial size fraction data (Fig. 12) indicate that most of the heterotrophic activity was associated with bacterial cells attached to particles larger than 3 μm, however this needs to be confirmed at a broader range of sites during CASES 2003.

Table 13. Summary of Samples

Date	Station	# Depths	Samples description
24-09-2000	24-Full	8	100%, 10%, 1%, 0.1%, Bottom, Chla max, inversion and nepheloïd layer
28-09-2002	49-Full	7	100%, 10%, 1%, 0.1%, Bottom, 800m, inversion layer
02-10-2002	65-Full	5	100%, 10%, 1%, 0.1%, Bottom
03-10-2002	Z2	2	100%, 100% (<3 μm particles), Bottom
04-10-2002	66-Full	6	100%, 10%, 1%, 0.1%, Bottom, inversion layer
07-10-2002	83-Full	4	100%, 10%, 0.1%, Bottom
08-10-2002	R1-R2	1	100% for each river station
10-10-2002	101-Full	8	100%, 10%, 1%, 0.1%, Bottom, 400m, 200m, chl a max/inversion layer
12-10-2002	12-Basic	5	100%, 100% (<3 μm particles), 54m, 92m, 107m, Bottom

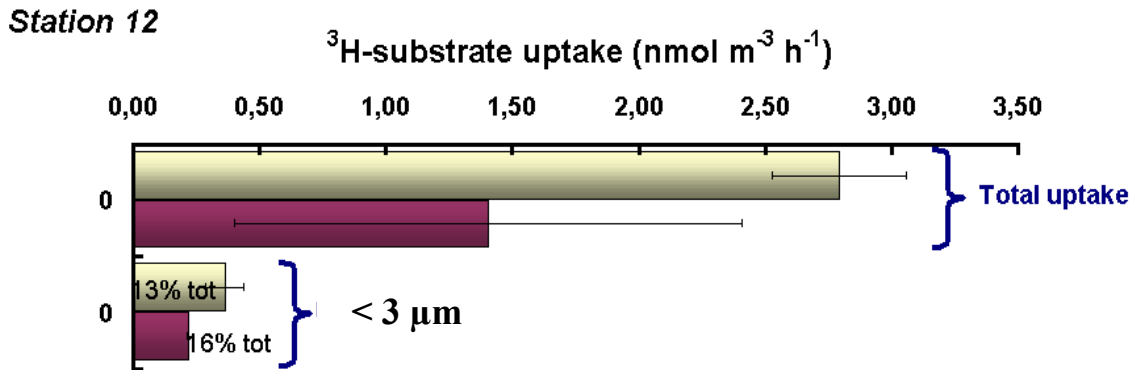


Figure 12. Size-fractionated bacterial production in the surface waters of Station 12 (Franklin Bay, 12 Oct. 2002) measured in terms of protein synthesis (^{3}H-leucine uptake, white bars) and DNA synthesis (^{3}H-thymidine uptake, purple bars).

b. Microbial community structure

At each of the basic stations the following samples were taken from near surface (2-5m depth) waters: picocyanobacteria (Anodisc filters on slides with Aquapolymount); heterotrophic bacteria (fixed then black Nuclepore filters on slides with Aquapolymount); and size-fractionated Chl*a* samples (3 µm to separate *Micromonas* and other picophytoplankton).

At each of the full, zodiac and river stations, surface water samples (0-5 m depth) were prepared for eukaryotic DNA analysis (clone libraries of greater than and less than 3 µm fractions); picocyanobacterial DNA and cultures of picocyanobacteria. Water column profiles were obtained at each full station for the following variables: picocyanobacteria (slides); heterotrophic bacteria (DAPI-slides); protists (preserved for fluorescence-Nomarski-Utermöhl microscopy); size-fractionated Chlorophyll a (3 µm filtration); FISH analysis (fluorescence *in situ* hybridisation) of picoeukaryotes; and FISH analysis of bacteria.

The picocyanobacterial DNA samples will be analysed at the laboratory of Dr Annick Wilmotte at the Center for Protein Engineering, University of Liège, Belgium. These will be compared with her results from the Southern Ocean and Northern Ellesmere Island (the latter in collaboration with W Vincent and P Van Hove).

The picoeukaryote DNA and FISH analyses will be conducted by Dr. Connie Lovejoy and other members of the laboratory of Dr. Carlos Pedros-Alió, Institut Ciènces del Mar, Barcelona, Spain. This forms part of a much broader sampling campaign during 2002 in the Arctic Basin that included JWACS & Ocean Exploration (operations of the CCGS Louis St. Laurent from 13 Aug to 6 Sept in Amundsen Gulf, North Wind Ridge and Canada Basin); JWACS (Mirai, from 7 to 20 Sept in North Wind Ridge, Chukchi Borderlands, Beaufort Sea and Mackenzie Shelf); and PicoDiv Arctic (Johan Hjort, from 18 Aug – 2 Sept in the Norwegian Sea near Svalbard). The same protocols have also been applied by the Barcelona group to the Southern Ocean under the auspices of the Antarctic Research Program of Spain. These data from CASES 2002 will therefore be incorporated into a much broader picture of the microbial ecology of the polar oceans.

4.1.3. Complementary samples

At each of the full, zodiac and river stations, additional samples from the near-surface waters were taken for the UV bio-optical program in collaboration with Dr. Christian Nozais (ISMER, Rimouski) and Leira Retimes (ULaval): FCDOM (for synchronous fluorescence characterization

and sourcing of the dissolved organic matter), CDOM spectral absorption; size-fractionated HPLC samples for measurement of MAAs; and size-fractionated samples for seston spectral absorption.

Further near-surface samples (4L filtered through 0.45 um membranes) were obtained for photochemical action spectra of CDOM photodegradation and hydrogen peroxide formation, at stations 49, 65, Z2, 66, R1 and R2. This work will be conducted by Dr. Chris Osburn, at the Marine Biogeochemistry Section of US Naval Research Laboratory, Washington, DC, in collaboration with Dr Pat Neale, Smithsonian Environmental Research Center, Edgewater, Maryland.

Seston samples for dry weight measurements were taken from 3 depths (surface, mid column and bottom) at each full, basic, zodiac and river stations (in collaboration with Dr. Phil Hill, Natural Resources Canada, Sidney, BC). Surface water samples at full stations were frozen for total phosphorus analysis. Seston samples were obtained on precombusted GF/F filter for stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$) from the water surface at each full station and from surface and bottom water for full stations 49, 65 and 66, as a further guide to the source of DOM.

Conclusions & considerations for CASES 2003

The laboratory analytical phase for all of these measurements is now underway and will help guide our future sampling protocols. No shipboard analysis of microbial samples was possible during CASES 2002 and in our future cruises it will be essential to have both an epifluorescence microscope and liquid scintillation counter onboard. A current gap in our coverage of microbial processes within CASES is an estimate of microzooplankton grazing. The protist enumerations will help in this regard, but some direct rate-variable assays should be considered for inclusion within CASES 2003. Large backgound adsorption of the thymidine label was encountered in our bacterial production assays and we therefore need to refine our methodology for this assay in turbid waters for CASES 2003.

Additional details on CASES 2002 research within the Microbial Communities and Heterotrophy Subprogramme can be found in the following section by J. Deming et al.

4.2 Microbiology & Enzymes

Principal investigator : Jody Deming
Cruise participants: Jody Deming & Llyd Wells

Objectives

As part of the overall microbiology effort on the *Radisson*, our work had these following objectives:

- To collect a diversity of sample types in order to enrich for potentially novel, psychrophilic, extracellular enzyme-producing microorganisms (bacteria), retaining back-up sample volumes, concentrated and frozen, for possible later analysis by DNA extraction and amplification;
- To assess *in situ* bacterial abundance, the fraction of actively respiring cells, and extracellular enzyme activity (EEA) in particle-rich samples, including floating sediment trap (FST) and nepheloid layer samples, in order to assess the role of bacteria in modifying particulate organic matter transported through the river-influenced waters of the Mackenzie Shelf; and
- To evaluate temperature effects on the lifetime of EEA in FST and sea-ice samples
- To collect samples for fluorescent in situ hybridization (FISH) analysis of the prokaryotic community composition, with an emphasis on the domain Archaea and their representation in nepheloid layers (building upon results from a previous cruise to the region in September 2000; Wells and Deming, submitted);

- To concentrate viruses from seawater and assay the concentrates against the psychrophile *Colwellia psychrerythrea* 34H (the only psychrophile for whom a genome is currently available) in order to isolate a phage infecting it;
- To cultivate additional and potentially novel microorganisms, in particular from nepheloid layers;
- To amend seawater with a rich nitrite-containing medium and follow nutrient and Archaeal dynamics over the course of a many-week-long incubation.

All of these goals have been met or are in the process of being met.

Samples of larvacean fecal pellets (in collaboration with Don Deibel), brittlestar guts (acquired from the anchor of an FST array deployed by C. Michel), melts of sea ice at different salinities (from the Arctic ice pack) and melts of "dirty" or sediment-laden sea ice (in Franklin Bay) were used as inocula for a suite of 12 different media designed to select for EE-producing bacteria across a salt gradient. These enrichments continue to incubate at -1°C until further study in the laboratory at UW. Additional enrichments from nepheloid-layer samples were made under 500 atm pressure at -1°C in an attempt by my graduate student, L. Wells, to bring possible nitrifying Archaea into culture.

FST arrays were deployed successfully by C. Michel at all of the six originally planned full stations occupied during the cruise at up to eight depths each, depending on station depth.(see Free-drifting trap section for details). In collaboration with C. Michel, I processed splits of each of the trap samples for a suite of in situ measurements, including incubations to assess bacterial respiratory activity by CTC stain and EEA using fluorescently tagged (MCA or MUF) substrate analogs for protease (L-aminopeptidase), carbohydrase (ß-glucosidase) and chitobiase (glucosamidase) activity. Protease activity was measured routinely on all trap samples, since it is known from many other studies (including the NOW) to dominate in the marine environment, and on selected nepheloid and Zodiac-collected (estuarine) samples; the other enzymes were measured less frequently but at standard FST depths (15, 50, and 100 m). Preliminary results indicate significant EEA in traps at 25-50 m offshore, decreasing at greater trap depths, but elevated EEA in the deepest traps that also captured bottom-resuspended sediments.

Four intensive five-day experiments (pairs in parallel) to assess temperature effects on the lifetime of protease activity were conducted with sea-ice melt and FST samples, in two cases also addressing the effects of the presence of a potential enzyme-stabilizing compound (glycerol). A fifth lifetime experiment was attempted with a 1°C-stored sea-ice melt sample, but protease activity was too low initially (essentially undetectable, itself important lifetime information) to justify the extended effort. Preliminary results of the successful experiments indicate the predominance of cold-adapted enzymes in both sample types, verifying earlier studies (NOW99 and 1998 work in the Chukchi Sea), and a shorter lifetime for psychrophilic enzymes than psychrotolerant ones as the temperature warms, in keeping with biochemical theory.

Although we had planned to take 150 samples for analysis by FISH, we have instead collected 350, from 22 stations, including depth profiles at the 7 Full stations, comprehensive sampling of nepheloid layers, and unexpected in-shore and riverine stations. Samples were also taken from the floating sediment traps and from sea ice (in collaboration with C. Michel). At many sites, including most nepheloid layers, we have distinguished between the free-living and particle-attached communities.

Viral concentrates were collected at five stations in either the chlorophyll maximum (Stns. 33 and 53) or nepheloid layers (Stns. 65, 75 and 12). Additional viral concentrates were generated from melted sea ice collected during helicopter trips on the 26th and 27th of September and from the

stomachs and gills of mussels (provided by M. Simard and dissected by C. Martineau) and the guts of brittlestars. In addition to viral concentrates, some water enrichments were also performed from which to isolate phage. While only a fraction of the concentrates and enrichments have yet been assayed against *Colwellia psychrerythrea* 34H, two sets of enrichments have already yielded plaques consistent with viral infection. As an added bonus, A. Ortmann has kindly permitted me to subsample her viral concentrates for future assay against 34H.

Various attempts were made to cultivate microorganisms from nepheloid layers, surface temperature inversions, bottom water, riverine samples and the guts of organisms using heterotrophic media (50% 2216 Marine Broth) in broth or on 1%-agar plates, nitrite-amended seawater, tryptone/yeast extract, or combinations of the above. Some incubations were performed at high pressure (5000 db; with J. Deming). A number of these attempts have already yielded turbid cultures or colonies, in particular those from nepheloid layers and the mussel and brittlestar guts.

Finally, two enrichment experiments investigating potential nitrification by Archaea have been undertaken with the cooperation of J.-E. Tremblay. These experiments are on-going, with an initial time point taken at the end of September. The next time point is scheduled around the 20th of October.

J. Deming also engaged in "outreach" activities, consistent with funding agency requirements, including interaction with the Inuit (and other) student(s) on board, an interview with film-makers on board, and an open science lecture for all ship residents entitled "Microbial Life at the Poles: on Earth, Mars and Europa (?)." In short, this has been a productive as well as enjoyable cruise. We appreciated and have benefited greatly from the hard work, dedication and collaborative spirit shown by all participants in this cruise. Credit goes to the Chief Scientist, Martin Fortier, for his effective leadership and liaison skills, the strong collaborative spirit onboard, and the dedication of both scientists and crew to the success of each and every operation undertaken.

Recommendations for the Franklin retrofit for CASES 2003-2004:

An ability to incubate, reliably over time, ongoing experiments and live samples at very cold temperatures is essential to work in polar climes. It will be especially important during the overwintering CASES year of 2003-2004, as well as for future programs in the Arctic. In addition to new interior cold labs planned for the Franklin, where the temperature will likely vary as a result of incoming and outgoing traffic as well as regular defrost cyclces, we recommend one or more temperature-controlled incubators to be installed within the chilled labs that can be used for reliable incubations of essential experiments and samples at –1°C. We also recommend installation of temperature-alarm systems, ideally with a continuous temperature recording capability, on each interior cold lab. Extension of the ship's speaker system into all working areas, including interior cold labs and exterior containers, would facilitate communications and safety.

5. Pelagic Food Web: Structure, Function and Contaminants

Subproject leader: Don Deibel

5.1 Zooplankton and larval fish dynamics

Principal investigators: Louis Fortier, Pascal Sirois, Jacques Gagné, Yvan Simard
Cruise participants: Luc Michaud, Nicolas Rolland, Anna Prokopovicz, Gérald Darnis, Louis Létourneau & Martin Fortier

Introduction

Various processes mediated by metazoan zooplankton may modify the magnitude, nature and direction of carbon fluxes. These processes include remineralization of organic carbon into CO_2 by respiration; repackaging of small particles into larger, rapidly-sinking faecal pellets by feeding; the destruction of sinking faecal pellets by coprophagy; the conversion of particulate carbon into DOC by sloppy feeding and excretion; the vertical transport of carbon by vertical migration; and the trophic flux of organic carbon and contaminants from primary producers to large vertebrate predators. The four main zooplankton groups mediating these processes are copepods, appendicularians, macrozooplankton predators, and fish larvae.

In collaboration with the team of Deibel et al. (see next section), our objective for the CASES2002 cruise was to quantify these processes in the CASES study area at the end of the production season in the fall. More precisely, our goals were to:

- determine the abundance & population dynamics of the zooplankton community including larval & juvenile fish
- determine the egg production rates of dominant calanoid copepods
- determine the feeding, growth and survival rates of the early life history stages of fish.
- determine the population dynamics & physiological condition of macrozooplankton predators, mostly the dominant hyperiid amphipod *Themisto libellula*

Mesozooplankton

Sampling

Micro- and mesozooplankton were sampled with a five net sampler (two 200 µm mesh 1-m^2 nets, two 500 µm mesh 1-m^2 nets and one 50µm mesh 10 cm diam.) hauled vertically from bottom to surface at all basic stations where conditions allowed. At full stations, the sampler was deployed twice to collect animals from 2 depth strata (bottom-to-surface and upper mixed layer). 58 vertical tows were conducted in total.

Vertical net samples were dominated by the calanoid copepods *Calanus glacialis, Calanus hyperboreus, Metridia longa, Pseudocalanus* spp., *Microcalanus* sp. and the cyclopoid copepods *Oithona similis* and *Oncaea borealis* (Fig.16). Detailed taxonomic analyses are almost completed for all stations.

Egg production

Egg production experiments were conducted on large calanoid species (*Calanus hyperboreus, Calanus glacialis* and *Metridia longa*). 30 females of each of these species were selected from the 500µ mesh live-codend during vertical tows. Individual females were incubated for 24 hours at -1° C

in a petri dish filled with filtered seawater. A false bottom sieve was placed in the petri dish to prevent cannibalism on the eggs. Eggs were counted at the end of the incubation.

Table 14. Egg production experiments conducted during the CASES2002 expedition .

Stations	Calanus hyperboreus	Calanus glacialis	Metridia longa
	Incubated Females	Incubated Females	Incubated Females
24, 49, 62, 89, 98, 104	30	30	30
30	30		
66	30	30	
12	30		30

No eggs were produced by any of the females of the three Calanoid species. Although this result was to be expected for both *C. hyperboreus* that reproduces in late winter and *C. glacialis* that reproduces during the ice algal bloom & early phytoplankton bloom, we were expecting some females of the omnivorous *M. longa* to produce eggs early in the cruise. *M. longa* had apparently also ceased reproduction by mid-September when our expedition started.

Dry weight:

Copepods CIV, CV and females of the three major calanoid species were picked out at 3 full stations in order to carry out measurements of individual dry weight.

Table 15. Calanoid copepodites & adults preserved for dry weight measurements during CASES2002.

Stations	*Calanus hyperboreus*			*Calanus glacialis*			*Metridia longa*		
	CIV	CV	♀	CIV	CV	♀	CIV	CV	♀
24-B	18	12	15	3	8	15	-	9	15
66-B	18	15	6	11	12	9	1	-	4
12-B	13	17	15	7	10	2	3	15	14

Fresh lipid sac analyses of Calanus hyperboreus

At Stations 42, 49, 66 (2x) and 83, 30 *C. hyperboreus* females were randomly selected for lipid sac analyses. All females were filmed in dorsal and lateral view to evaluate the volume of their lipid sac before their conservation in 4 % Formaldehyde. This will allow us to estimate shrinkage due to preservation and improve our lipid volume estimates measured on preserved "swimmers" collected in the sequential sediment traps moored in the study area.

Juvenile fish & macrozooplankton

In addition to the vertical net tows described above, a high filtering capacity, 2 net sampler (500 µm mesh 1-m^2 net and 1180 µm mesh 1-m diameter net) was hauled horizontally in the surface layer (0-80 m) at all basic & full stations where ice conditions allowed (29 tows total). This sampler allowed us to collect young-of-the-year (YOY) fish and macrozooplankton.

A total of 663 YOY fish were collected including 629 Arctic cod (*Boreogadus saida*) , 16 Liparidae (*Liparis sp.*), and 18 other fish larvae from various species (Table 16).

Table 16. Young of the year fish species collected during the CASES 2002 expedition.

Species	n
Boreogadus saida (Arctic cod)	629
Liparis sp. (Gelatinous snailfish)	16
Lumpenus sp.	7
Stichaeidae (Arctic shanny)	7
Cottidae.(Sculpin)	4
Total	**663**

YOY Arctic cod, ranging in size from 14 to 52 mm (Fig. 13), not only dominated the larval fish biomass but were collected everywhere where a net was deployed (Fig 14). The excellent spatial coverage of YOY fish collected across the study area will allow us to examine links between physical processes, feeding success, growth and survival. Age and growth of YOY fish will be determined from otolith microstructure, and feeding success estimated from gut content analysis.

Forthy-three YOY fish were selected from stations 24, 30 & 83 and kept frozen at -20°C for further analysis of the concentration of some major contaminants (e.g. mercury).

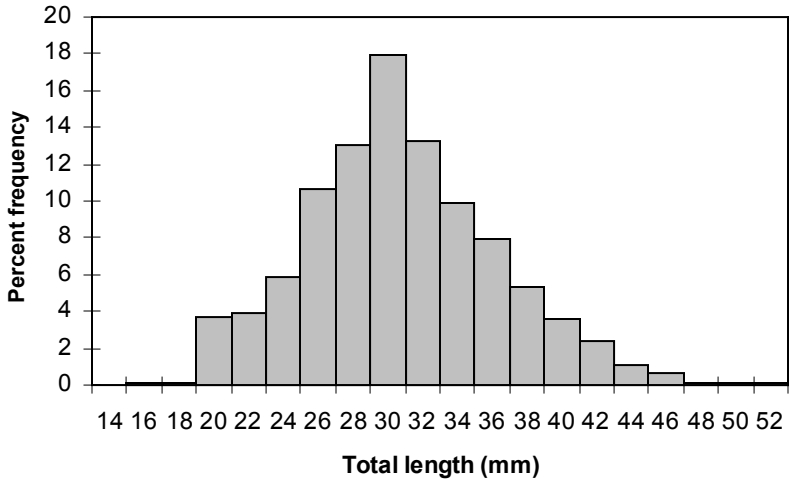


Figure 13. Size-frequency distribution of young-of-the-year Arctic cod sampled during the CASES2002 expedition (n=629).

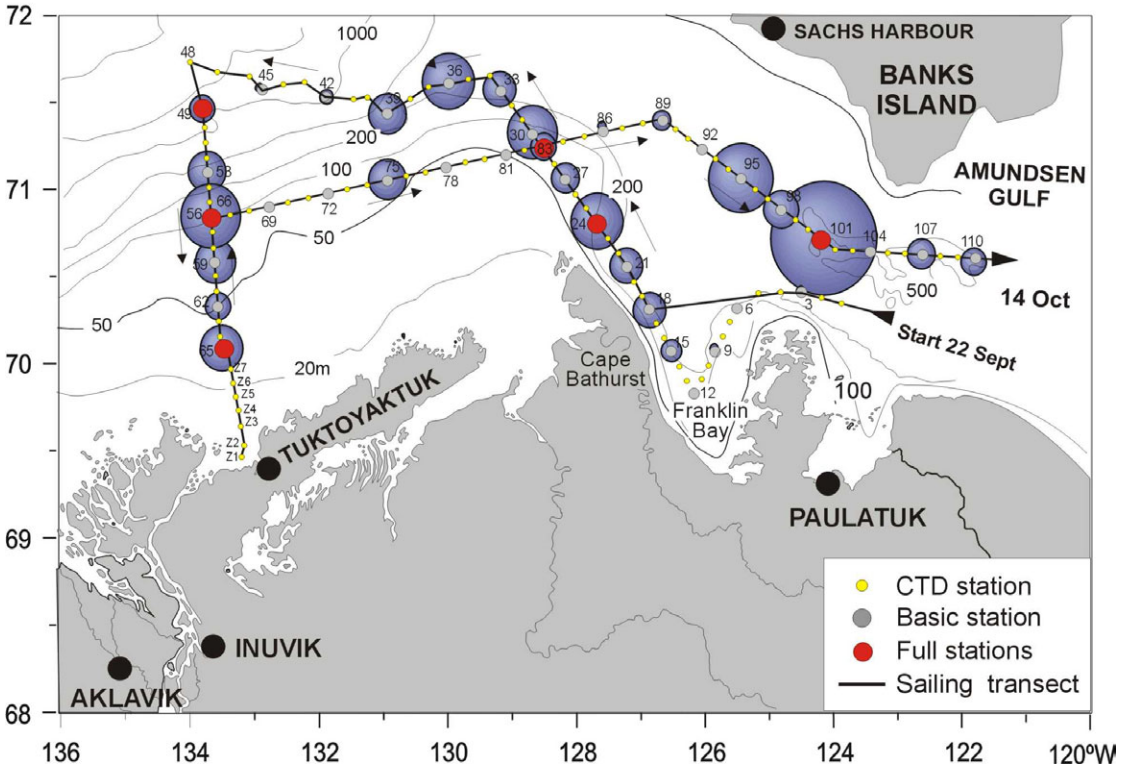


Figure 14. Abundance of Arctic cod (*Boreogadus saida*) catch for each station (1<n>150). Uncorrected for filtered volume.

Macrozooplankton was dominated by the hyperiid amphipod *Themisto libellula* and chaetognaths (arrow worms).

Themisto libellula

The major objectives of this study where to determine the population structure and the physiological condition of *T. libellula* at the end of the production season in the different oceanographic regimes of the study area.

T. libellula specimens were collected form both the vertical & horizontal net tows. At each sampling station where conditions allowed, 2 series of 8 specimens were taken for lipid analysis. Live animals were immediately measured and sexed. Specimens were rinsed with filtered sea water, dried on "fibula paper" and placed into a vial with dichloromethane (7 ml vol., HPLC grade), capped with a Teflon-cap under nitrogen gas and stored at –32°C. 215 specimens were preserved in total and laboratory analysis are underway at Université Laval. Lipids will be extracted with dichloromethane/methanol (2:1 per volume), according to Folch et al. (1957). Lipid classes, hydrocarbons (HC), wax esters (WE), ketones (KET) triacylglycerols (TAG), free fatty acids (FFA), sterols (ST), acetone-mobile polar lipids (AMPL) and phospholipids/polar lipids (PL) will be separated by thin-layer chromatography (TLC) on quartz rods coated with silica and quantified with a flame ionisation detector (FID, Iatroscan MK V) after Parrish (1987).

Over 700 *T. libellula* were also frozen at -30ºC for dry weight-length analysis. All other specimens were preserved in 4% buffered formaldehyde for population dynamic studies. Animal length was measured from the front of the head to tip of longest uropod (exact to 0.1 mm under binocular) (Figure 15).

Sex determination and developmental stage will be made according to Dunbar (1957).

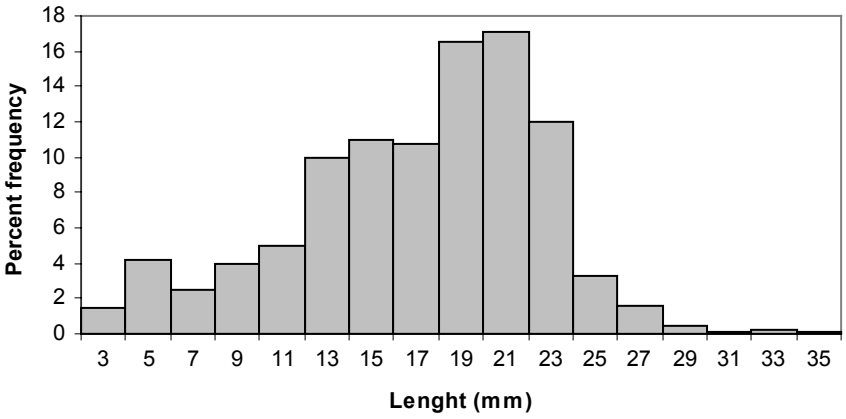


Figure 15. Size-frequency distribution of *Themisto libellula* sampled during the CASES2002 expedition (n=946).

Finally, 87 *T. libellula* individuals were also measured fresh and preserved individually in 4% buffered formaldehyde to assess shrinkage due to preservation.

5.2 Marine and terrestrial source material in seston and zooplankton diets

Principal investigator: Don Deibel
Cruise participants: Don Diebel & Tara Buzinski

Introduction

The goals of our work on this pilot expedition were (1) to determine the abundance, distribution, maturity stage and size composition of the appendicularian tunicate populations, and (2) to determine the source (i.e. terrestrial-based or marine-based) of food material in the diets of copepods and appendicularians, including the composition of the suspended particulate matter (SPM) to obtain biomarker end-member values for available food particles. This was done by taking samples of the zooplankton community in collaboration with the team led by L. Fortier et al. and by looking at the minerology, lipid, fatty acid and sterol composition of marine and terrestrial biomarkers in zooplankton tissue, faecal pellets and in the available SPM. Based upon a sparse existing literature for the Beaufort Sea Shelf (BS), we predicted that herbivorous copepods feed selectively on marine phytoplankton, whereas appendicularians and other non-selective feeders consume particles in proportion to their availability in the water column and therefore feed proportionally on more terrestrial source material than do copepods (Parsons et al., 1989).

Feeding on SPM by zooplankton affects the fate of those particles because zooplankton repackage small, slowly-sinking particles into large, fast-sinking faecal pellets and soma. Pellets and diatoms sink at from 10's to 100's of m d^{-1} (Hamm 2002, Dagg et al., 1996), while small (i.e. < 0.2 μm diameter) lithogenic particles sink at < 1 m d^{-1} (Dagg et al., 1996). This means that food particles that would otherwise be remineralized in the water column may be repackaged into faecal pellets that sink rapidly to the bottom.

Thus, the population size structure of the appendicularians is important because they can have a profound impact on the fate of their small food particles. In accordance with Goal #1 above, we determined the abundance and size structure of the appendicularians and calculated the percent of

the total zooplankton community that they represent in terms of numbers. Biomass calculations are pending.

Methods

We visited 23 basic stations and 7 full stations between 24 September and 14 October 2002 in the Beaufort Sea, between Franklin Bay and the Amundsen Gulf in the East and the east channel of the Mackenzie River in the West (Table 17). All zooplankton samples at basic stations were collected using bottom-to-surface vertical net tows (200 µm mesh, in collaboration with L. Fortier, et al.). Individual appendicularians were picked out of coolers immediately after being brought on board and placed together in a petri dish. When gut contents were present, animals were allowed to produce faecal pellets before ten individuals were staged and trunk lengths measured (i.e. excluding the gonad). All bodies were then transferred to a microcentrifuge tube and frozen at -80°C for later determination of dry weight-to-carbon ratio and lipid biomarkers. Faecal pellets produced after capture were placed in a separate microcentrifuge tube and frozen at -80°C. Lipid biomarker analyses (in collaboration with C. Parrish, MUN) and clay mineralogy (in collaboration with A. Mucci, McGill Univ.) of the pellets will be used to distinguish marine and terrestrial source materials.

At the full stations, zooplankton were collected with vertical net tows (200 µm mesh) from 2 depth strata (bottom-to-surface and upper mixed layer). Animals from the tows were incubated in separate coolers for 8-12 hours. After incubation animals and faecal pellets were separated using a sieve stack with 120 µm mesh for animals and 53 µm mesh for faecal material. The faecal fraction, which was dominated by copepod faecal pellets, was frozen at -80°C. Pellets will be separated by taxa (i.e. separating copepods from appendicularians and among dominant copepod species where possible), and marine vs. terrestrial source material within the pellets determined using lipid and clay mineral markers. The animals from each cooler then were split into halves. One split was fixed in formaldehyde for determination of species composition and population size structure, while individual animals were picked by hand from the other half and transferred to microcentrifuge tubes. Animals in the microcentrifuge tubes and the remainder of the 'live' split were frozen -80°C for later determination of dry-weight-to-carbon ratio and lipid biomarkers.

Suspended particulate matter (SPM), which serves as food for copepods and appendicularians, was collected at 3-6 depths at each full station from Niskin bottles mounted on a rosette. Up to 6-L of water was filtered through each of 4, pre-combusted, pre-weighed GF/F filters at each depth. Filters were frozen at -20°C and will be used to determine marine and terrestrial end member values of lipid and clay mineral markers.

Results and Discussion

Pseudocalanus spp. dominated the composition of the zooplankton community in the upper mixed layer at full stations, except for the head of Franklin Bay at station 12 and offshore at station 49, > 500 m deep, where the community was dominated by *Oithona* spp. (Fig. 16). Copepod nauplii clearly made the largest contribution to the zooplankton community at the mid-shelf and offshore stations on the most westerly transect, offshore from the Mackenzie Delta at stations 66 and 49 (Fig. 16). The *Pseudocalanus* populations were generally dominated by copepodite stages 1-3, particularly at offshore stations (Fig. 17). Over the entire water column, *Oncaea* spp. and the cyclopoid copepod *Oithona* spp. also made up a substantial portion of the zooplankton community (Fig. 18). *Pseudocalanus* made up a very small portion of the total water column community at two of the stations on the most westerly transect (i.e. stations 65 and 49), indicating that at these stations they were found primarily in the upper mixed layer (compare Fig. 18 with Fig. 16). The predominant species and stages reported above were all small, with cephalothorax lengths < 900

µm (data not shown). Thus, they would produce small, relatively slow sinking faecal pellets. For example, in the Baltic Sea, when the zooplankton community was dominated by small cyclopoid copepods, the flux of faecal carbon to the benthos was an order of magnitude less than when large calanoids were most abundant (Viitasalo et al., 1999). This indicates that faecal pellets from these small grazers are primarily remineralized in the mixed layer.

The appendicularian *Oikopleura* spp. was present at all stations we examined, but it was not among the most abundant taxa at any station (Fig. 16, 18). The smaller appendicularian *Fritillaria* spp. was also present at most stations and comprised 4.5% of the upper water column zooplankton community at the deepest station (station 49) just off the shelf break (data not shown). There was no correlation between body size and maturity stage of *Oikopleura* spp. ($p>0.05$, data not shown) as we have observed elsewhere, possibly indicating preferential allocation of food resources by these animals to gonads rather than somatic tissue when food is plentiful (Troedsson et al., 2002).

Two species of *Oikopleura* spp. were observed during the expedition with differing body sizes and spatial ranges. These species have not yet been conclusively identified. The larger of the two, with a trunk length > 1.5 mm, was more abundant at offshore stations, > 200 m water column depth (Fig. 19). This species was never observed with gut contents after net collection and had orange droplets surrounding the gut complex, perhaps some type of depo-lipids (see below). The smaller species was more abundant at mid-shelf stations (Fig. 19). Individuals of this species generally had faecal pellets within the gut after net collection, which were voided in the laboratory onboard ship. Determining the identity and distribution of these two species will be a high priority for us during the one-year expedition.

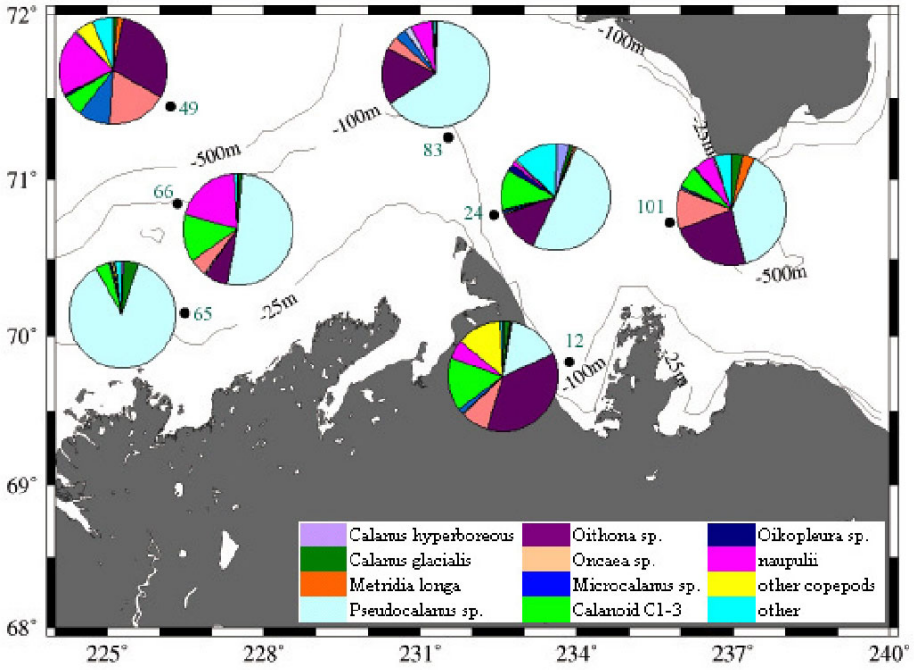


Figure 16. Community composition (% of total numbers) of zooplankton over the upper mixed layer on the Beaufort Sea Shelf during September-October 2002. The latitude and longitude of stations where samples were collected are indicated by the solid black dots and station numbers are written in dark green. These data are from qualitative net tows and therefore are not expressed on a volumetric or areal basis. The 25, 100 and 500 m isobaths are shown by light-blue lines.

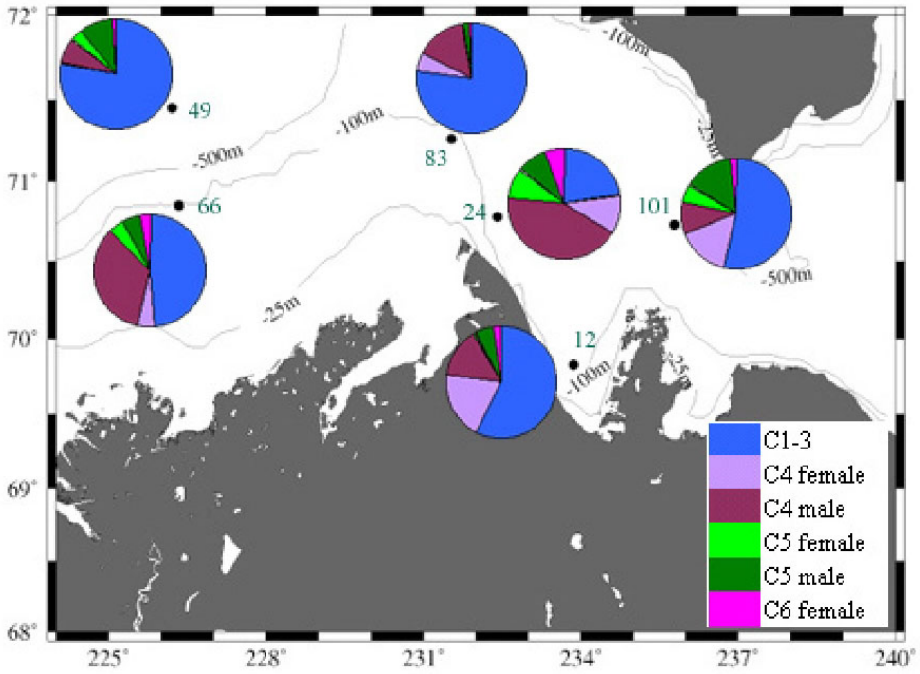


Figure 17. Copepodite stage composition (% of total copepodids) of *Pseudocalanus* spp. in the upper mixed layer on the Beaufort Sea Shelf in September-October 2002. All other information is as for Fig. 1.

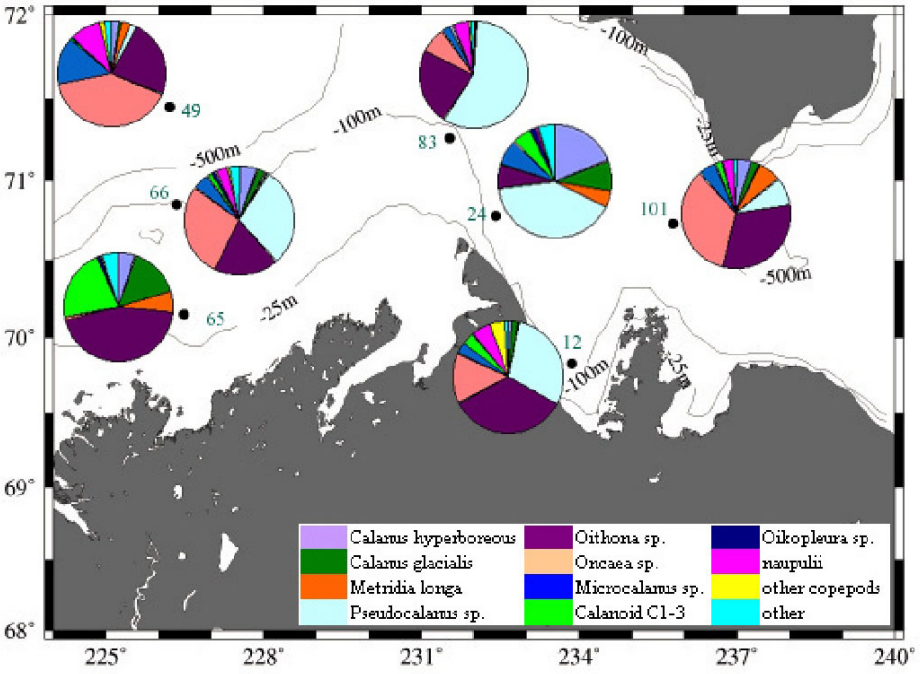


Figure 18. Community composition (% of total numbers) of zooplankton over the entire water column on the Beaufort Sea Shelf during September-October 2002. All other information is as for Fig. 1.

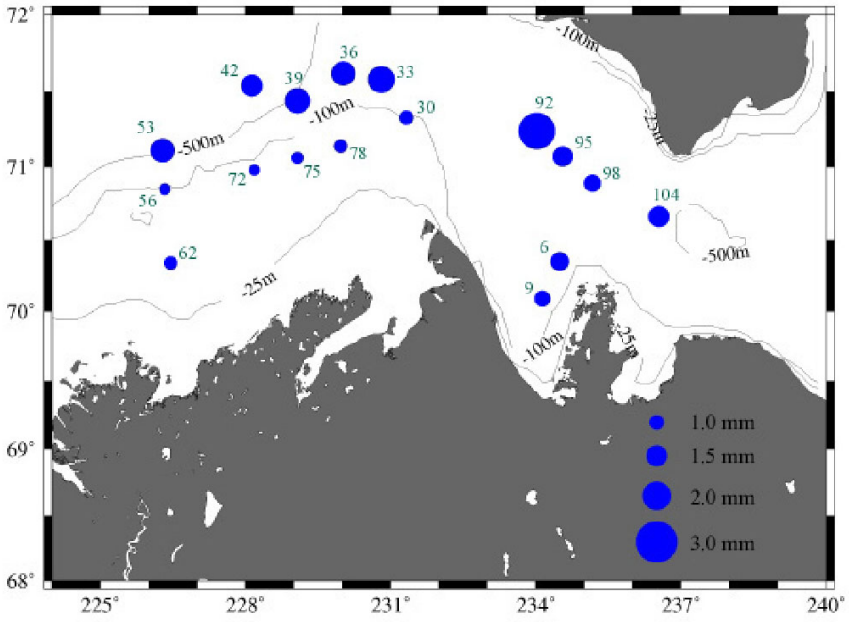


Figure 19. Mean trunk length of *Oikopleura* spp. (mm) on the Beaufort Sea Shelf in September-October 2002. All other labels are as for Fig. 1.

So far only a few appendicularian and copepod samples have been analyzed for lipid and fatty acid (FA) biomarkers. None have been analyzed for their mineralogical content nor have any of the SPM samples yet been analyzed. The preliminary data are however, extremely interesting, and provide an early test of our primary hypothesis. The appendicularians we have analyzed have a relatively high proportion of long-chain (i.e. > C_{24}) FA's (mean ca. 3.5% of total FA's), while the copepod (i.e. *Calanus hyperboreus* stage C6 females), have essentially no long-chain FA's (mean < 0.1% of total FA's) (Fig. 20). The long-chain FA's of appendicularians are dominated by C_{25} and C_{26} compounds tentatively identified as monoeneoic FA's. Two long-chain sterols (tentiatively identified as C_{29} and C_{30} sterols) were also present in addition to C_{27} sterol, (undoubtedly cholesterol). These long-chain FA's and sterols are likely to be markers of terrestrial-source materials. We are at this moment acquiring the standards necessary to identify these compounds conclusively. These very early results suport our hypothesis that copepods select for marine-source materials (i.e. phytoplankton) and against terrestrial-based SPM, while the appendicularians, which filter feed non-selectively using a fine-mesh, mucous filter, ingest particles in proportion to their abundance, including terrestrial material delivered to the shelf via the Mackenzie River. Our intended further lipid and FA analyses, and mineralogical studies, will allow us to test the robustness of this conclusion for the time period covered by the pilot expedition.

The lipid class analysis of the appendicularians also revealed an unanticipated result which we intend to pursue, which was the presence of a surprisingly high proportion of wax esters, generally believed to be an over-wintering energy store exclusive to high latitude copepods and their predators. The wax ester levels ranged from 4-7 % of total lipids as determined by Iatroscan-TLC/FID and confirmed by short-column GC. This is all the more surprising considering that the appendicularians we have analyzed up to now has been the species without the orange droplets surrounding the gut complex. We are looking forward to determining if the species with the orange droplets has even a higer percentage of wax esters, or some other unexpected, storage-lipid class. If supported by the analysis of further samples, this will be the first report of depo-lipid storage by a pelagic tunicate, and may provide an answer to a long-standing mystery of how appendicularians survive the long, polar winter.

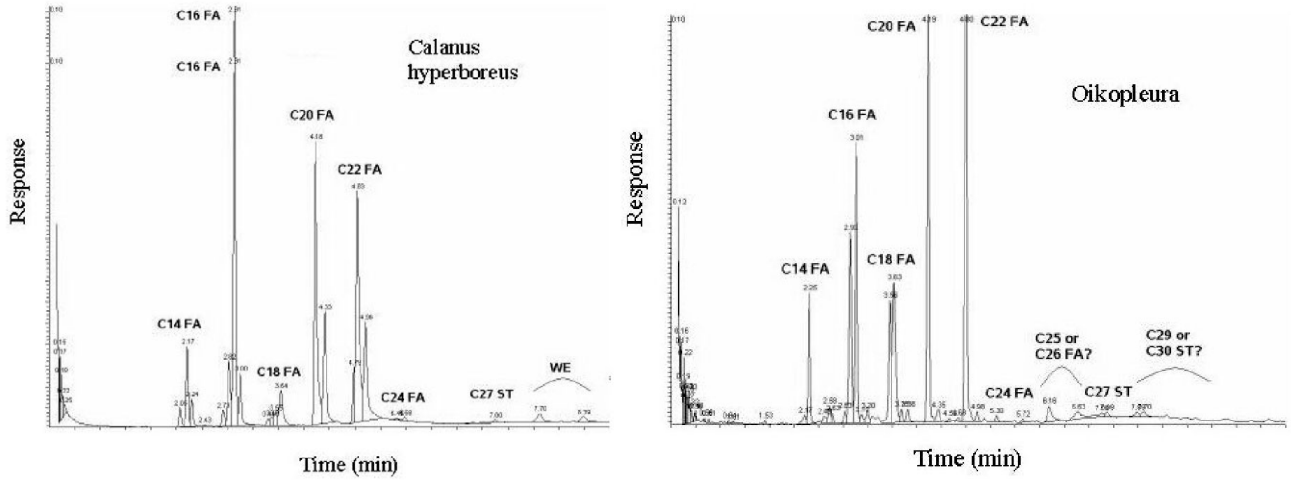


Figure 20. Partial chromatograms showing a) the chain length of somatic fatty acids and sterols of *Oikopleura* spp. (upper) and b) *Calanus hyperboreus* C6 females (lower) from the Beaufort Sea Shelf in September-October 2002. 'FA' = fatty acid. 'ST' = sterol. 'WE' = wax ester. 'C14' = 14-carbon chain, and etc. Transmethylated extracts of the compounds were analyzed by short-column, gas chromatography.

Future Plans

In addition to completing the analyses of our samples outlined above, we have just submitted a DFO-Subvention Grant proposal in collaboration with Dr. Cynthia McKenzie, DFO Newfoundland, to conduct electron microscope, energy dispersive X-ray spectrometry (EM/EDX, i.e. electron microprobe analyses) of the faecal pellets of copepods and appendicularians from the year-long CASES expedition. If successful, this will allow us to obtain an elemental fingerprint of individual particles (i.e. phytoplantkon, protists, clay minerals and organic and inorganic detritus) within the faecal pellets of these two types of grazers, and to further fine-tune our determination of their degree of ingestion of terrestrial-based vs. marine-based particles.

References

Dagg, M.J., E.P. Green, B.A McKee, P.B. Ortner. 1996. Biological removal of fine-grained lithogenic particles from a large river plume. *J. Mar. Res.* 54: 149-160.

Hamm, C.E. 2002. Interactive aggregation and sedimentation of diatoms and clay-sized lithogenic material. *Limnol. Oceanogr.* 47: 1790-1795.

Parsons, T.R, D.G. Webb, B.E. Rokeby, M. Lawrence, G. Hopky. 1989. Autotrophic and heterotrophic production in the Mackenzie River/Beaufort Sea Estuary. *Polar Biol.* 9: 261-266.

Troedsson, C., J.-M. Bouquet, D.L. Aksnes, E.M. Thompson. 2002. Resource allocation between somatic growth and reproductive output in the pelagic chordate *Oikopleura dioica* allows opportunistic response to nutritional variation. *Mar. Ecol. Prog. Ser.* 243: 83-91.

Viitasalo, M.M, A.-S. Rosenberg, M. Heiskanen, M. Koski. 1999. Sedimentation of copepod fecal material in the coastal northern Baltic Sea: Where did all the pellets go? *Limnol. Oceanogr.* 44: 1388-1399.

Table 17. Summary of stations visited and samples collected during the CASES 2002 cruise to the Beaufort Sea. Note that times are local, not GMT. For GMT, add 6h through Station 6, and add 5h thereafter.

Stn	Date	Time	Lat	Long	Tow Depth (m)	Samples Collected
24A	240902	0911	70.78	232.42	170	total zooplankton community
24A	240902	1007	70.78	232.42	40	total zooplankton community
30	250902	0810	71.33	231.33	60	26 appendicularian bodies
33	250902	1600	71.58	230.81	260	37 appendicularian bodies
36	250902	2230	71.62	230.03	240	26 appendicularian bodies
39	260902	0530	71.44	229.08	321	32 appendicularian bodies
42	260902	1615	71.54	228.14	300	34 appendicularian bodies
45	270902	0615	71.59	227.10	700	114 appendicularian bodies
49B	290902	2349	71.45	226.22	932	total zooplankton community
49B	290902	0111	71.45	226.22	80	total zooplankton community
53	290902	1830	71.11	226.29	426	34 appendicularian bodies
56	300902	0031	70.85	226.34	76	73 appendicularian bodies, 17 faecal pellets
62	300902	1127	70.34	226.46	58	104 appendicularian bodies, 23 faecal pellets
65B	021002	0103	70.15	226.49	36	total zooplankton community, oblique tow
65C	021002	2308	70.15	226.49	15	total zooplankton community
66A	041002	0155	70.85	226.35	71	total zooplankton community, 2 codends
66A	041002	0242	70.85	226.35	20	total zooplankton community
72	051002	1507	70.98	228.19	56	129 appendicularian bodies, 49 faecal pellets
75	051002	0058	71.06	229.08	50	119 appendicularian bodies, 74 faecal pellets
78	061002	0301	71.14	229.97	40	63 appendicularian bodies, 61 faecal pellets
83A	061002	2056	71.26	231.54	50	total zooplankton community
83A	061002	2149	71.26	231.54	20	total zooplankton community
86	071002	2144	71.37	232.50	215	4 appendicularian bodies
89	081002	0808	71.40	233.25	308	20 appendicularian bodies
92	081002	1759	71.24	234.03	400	39 appendicularian bodies
95	091002	0205	71.07	234.56	330	79 appendicularian bodies, 25 faecal pellets
98	091002	1005	70.89	235.18	369	75 appendicularian bodies, 26 faecal pellets
101A	091002	2258	70.73	235.79	454	total zooplankton community
101A	101002	0001	70.73	235.79	30	total zooplankton community
12B	111002	2200	69.83	233.87	143	total zooplankton community
12B	111002	2225	69.83	233.87	30	total zooplankton community
9	121002	1532	70.09	234.14	127	18 appendicularian bodies, 3 faecal pellets
6	121002	2105	70.35	234.50	191	20 appendicularian bodies, 22 faecal pellets
3	131002	0407	70.43	235.48	166	10 appendicularian bodies, 2 faecal pellets
104	131002	1210	70.66	236.55	422	30 appendicularian bodies, 14 faecal pellets
107	131002	1924	70.64	237.36	340	16 appendicularian bodies
110	141002	0105	70.59	238.16	542	11 appendicularian bodies

5.3 Contaminants

Principal investigators: Gary Stern & Robie Macdonald
Cruise participants: Paul Helm & Eric Braekevelt

The preliminary CASES cruise in September-October 2002 proved successful for the Contaminants group from the Freshwater Institute, DFO, in Winnipeg. Air, water, sediment, and zooplankton samples were collected predominantly at full 24-hour stations. With the exception of the loss of our floating pump array, we were very happy with the outcome of this preliminary trip. Samples collected, especially air and water samples, will allow us to evaluate background contamination from the ship, which is often a major issue when analysing for our compounds of interest (especially PCBs and metals) in the arctic environment. This work is needed to determine if samples collected next year will be of value. Unlike many aboard the ship, our samples are not analyzed on board and will be processed in our lab in the coming months.

A total of 20 air samples were collected from two high-volume air samplers, one located at the bow on the foredeck, the other above the bridge. Some samples were collected for a short period of time and sampling media from the two samplers used in parallel will have to be combined for analysis. The locations of the air samplers were chosen to minimize background contamination from the ship itself and the stack plume. The air samplers were turned off when prevailing winds came from the stern, as was the case during deployment of the plankton nets. This was inconvenient and analytically undesirable as contaminants can be passively sampled while the pumps are not running or may back-diffuse out of the collection media. Air samplers may be more effectively deployed at ice camps or semi-permanent stations rather than sampling aboard the ship itself.

In collaboration with the zooplankton researchers (Fortier's and Deibel's groups), bulk zooplankton samples were collected periodically at full stations and some basic stations. Size fractions (>200 μm and >500 μm) were combined in many cases to ensure adequate biomass for analysis. Our group did not have the expertise to separate organisms by species, but we intend to do this in the field next year. At two locations *Themisto libellula* were separated from other zooplankton species to determine the mass necessary for individual species analysis. For species-separated samples, extra tows dedicated to contaminants will be necessary given the demands of other researchers for specific species (eg. *T. libellula*) and our biomass requirements.

Four water samples of approximately 200 L were collected in two deployments of the floating array before it was lost at the third full station near the Mackenzie Delta. Although the reasons for the loss are unknown, possibilities include loss of power in the radio beacon and drifting out of range possibly reaching currents taking them away from the search area. Our inexperience in deploying the drifting arrays may also have been a factor. Despite the loss, we are eager to continue sampling in this fashion as it increases the volume of water pumped for analysis and minimizes contamination from the ship. This loss did not force suspension of our operations however, as we were able to obtain 26 samples of approximately 90 L from various depths at or near full stations. These samples were processed through resin columns in Shantytown, which may lead to contamination issues due to the time taken to process this water (up to 5 hours). All water samples will be extracted in our lab and analysed over the coming months. In addition to the high volume water samples for organic contaminant analysis, 43 water samples of 250 or 500 mL were collected for mercury analysis from

the Rosette and also from go-flows for inshore (from the zodiac) and Mackenzie River (courtesy of W. Vincent) samples. Again, the effects of possible contamination, either background from the ship or resulting from $HgCl_2$ use as a preservative by another scientist on board, will have to be evaluated.

Ten-centimetre diameter push cores were collected from six of the seven full stations from box cores. In addition, as much surface sediment (top 0.5 cm) was collected as possible. Cores were sliced on site in Shantytown. These will be dried and dated by Pb-210 and Cs-137, and extracted and analysed for organochlorine contaminants and heavy metals. At station 83, the box core did not close properly, possibly due to the amount of clams and barnacles, etc. in the sediment and we did not obtain a push core. A sediment-water interface as undisturbed as possible is critical for accurately dating cores. We recommend some maintenance on the box coring apparatus including repair/replacement of the plastic lining on the closing foot and possibly installing gaskets along the screw-edges of the box to ensure good seals to prevent water from leaking from the box and disturbing the interface. Although we took only one core from each box (generally 1 box per station), a duplicate core would be preferred. Given the demands for sediment by various groups, and our need for more surface sediment, we recommend obtaining two acceptable box cores per station. In addition, processing the box core, especially obtaining surface sediment, may need to be conducted in a warmer area than the foredeck. The surface sediment freezes rapidly at the -15°C conditions experienced later in the cruise.

This preliminary cruise was crucial to us in tailoring our sampling plans and needs for next year and training of those who will be involved (Paul and Eric). In addition, meeting and working with other scientists involved in the project will undoubtedly lead to fruitful collaborations. Our thanks to the crew of the Pierre Radisson for expertly manoeuvring the ship and for assistance in sample collection.

6. Organic and Inorganic Fluxes

Subproject leaders: Phil Hill, Robie Macdonald

6.1 Long-term sediment traps deployment

Principal investigators: Hiroshi Sasaki, Paul Wassmann & Martin Fortier
Cruise participants: Makoto Sampei, Humphrey Melling, Doug Sieberg

Four long-term sediment traps were deployed by our Japanese colleagues on moorings CA-07 & CA-08 during the CASES 2002 expedition onboard the CCGS *Sir Wilfrid Laurier* (see Figure 4). The 4 traps will be recovered and redeployed in the Fall 2003, along with over 20 new sediment traps, as part of the main overwintering expedition of CASES.

6.2 Free-drifting sediment traps

Principal investigators: Christine Michel, Jody Deming
Cruise participants: Christine Michel, Bernard Leblanc & Jody Deming

This program directly relates to the overall CASES bio-geochemical approach to studying biogenic (including carbon and other bio-geochemical constituents) fluxes and shelf-basin interactions. Regular deployments of Free-drifting Sediment Traps (FSTs) constitute an important component of the CASES Program as a means to investigate pelagic-benthic coupling processes and link primary production and surface exchange processes with export at depth. The FST Program is thus tightly related to other components of CASES, for example with aspects of primary production, carbon and nutrient fluxes to grazers and recycling, sedimentation and accumulation at depth.

The general objectives of the FST Program were to:

- Evaluate the sinking export of organic and inorganic material from the euphotic zone (at full stations of the CASES expedition plan),
- Assess vertical changes in sedimentation of organic and inorganic material within and below the euphotic zone, and
- Characterize the type of material sinking at each depth and exported from and below the euphotic zone.

The sampling was carried out according to original plans. At each of the six full stations of the CASES expedition plan, we deployed and successfully recovered free-drifting trap arrays.

In order to account for potential physical and bio-geochemical features and to capture changes along the depth axis, our sampling approach was to install traps at multiple depths within and below the euphotic zone. Whenever possible, i.e. depending on station depth, the traps were installed at 8 depths ranging from 10 to 150 m (Table 18). The moorings were deployed for ca. 24 h (Table 18). The traps were PVC cylinders 10 cm diam., with an aspect ratio of 7. Upon deployment, the traps were filled with deep seawater collected at a previous station and filtered through 0.22 μm filter; two traps were installed at each depth. The traps did not contain any poison or preservative, which allowed for the determination of extracellular enzymatic activities (J. Deming). Upon recovery, the traps were placed in a dark cold room (-1.0°C) and the material was allowed to sediment during 8 h. After that period, the bottom fraction of each trap was collected and pre-screened using a 450μm nitex mesh. Trap bottom fractions from the same depth (from two traps) were combined in order to obtain only one sample from which all subsamples were taken for further analysis. One subsample was given to J. Deming for determination of enzymatic activities and another subsample was given to D. Amiel (C. Cochran) for ^{234}Th

analysis. The rest of the trap sample was processed as follows.

Duplicate subsamples were filtered on Whatman GF/F filters for the fluorometric determination of chlorophyll *a* (chl *a*) and phaeopigments (Turner Designs 10AU fluorometer), after 24 h extraction in 90% acetone (Parsons et al., 1984). Additional subsamples were filtered on pre-combusted Whatman GF/F filters for particulate organic and inorganic carbon, and nitrogen, analysis. The samples were dessicated at 60°C during 24 h and brought back to our laboratory for analysis. Subsamples were filtered on Nuclepore polycarbonate 0.8 µm filters, on an all-plastic system, for the determination of biogenic silica. The filters were frozen at -80°C and brought back to our laboratory for later analysis. Subsamples were also preserved in acidic lugol's solution for cell identification and counts, and in borate-buffered formalin for faeces counts. In general, the small amount of material collected did not allow for additional analyses. However, for traps that collected the most material, we filtered the remaining volume on pre-weighted 47mm Nuclepore 0.2 µm filters, for dry weight determination on a balance Metler Toledo AG285 after passing the filters through a Sartorius ionizer blower.

Preliminary results show very low fluxes of chl *a* and total pigments at all the stations visited during the fall (< 0.5 mg m^{-2} d^{-1}, Figure 21). Sinking fluxes of chl *a* were slightly higher at stations 66 (shelf break) and 101 (polynya), although they still remained low, as expected for the fall period. At shallow stations on the shelf, higher fluxes close to the bottom suggest resuspension of bottom sediments. Detailed analysis of the complete suite of parameters from the sediment trap material, including bacterial abundance and extracellular enzyme activity, will provide insights into processes of sedimentation, resuspension and recycling of material within and below the euphotic zone.

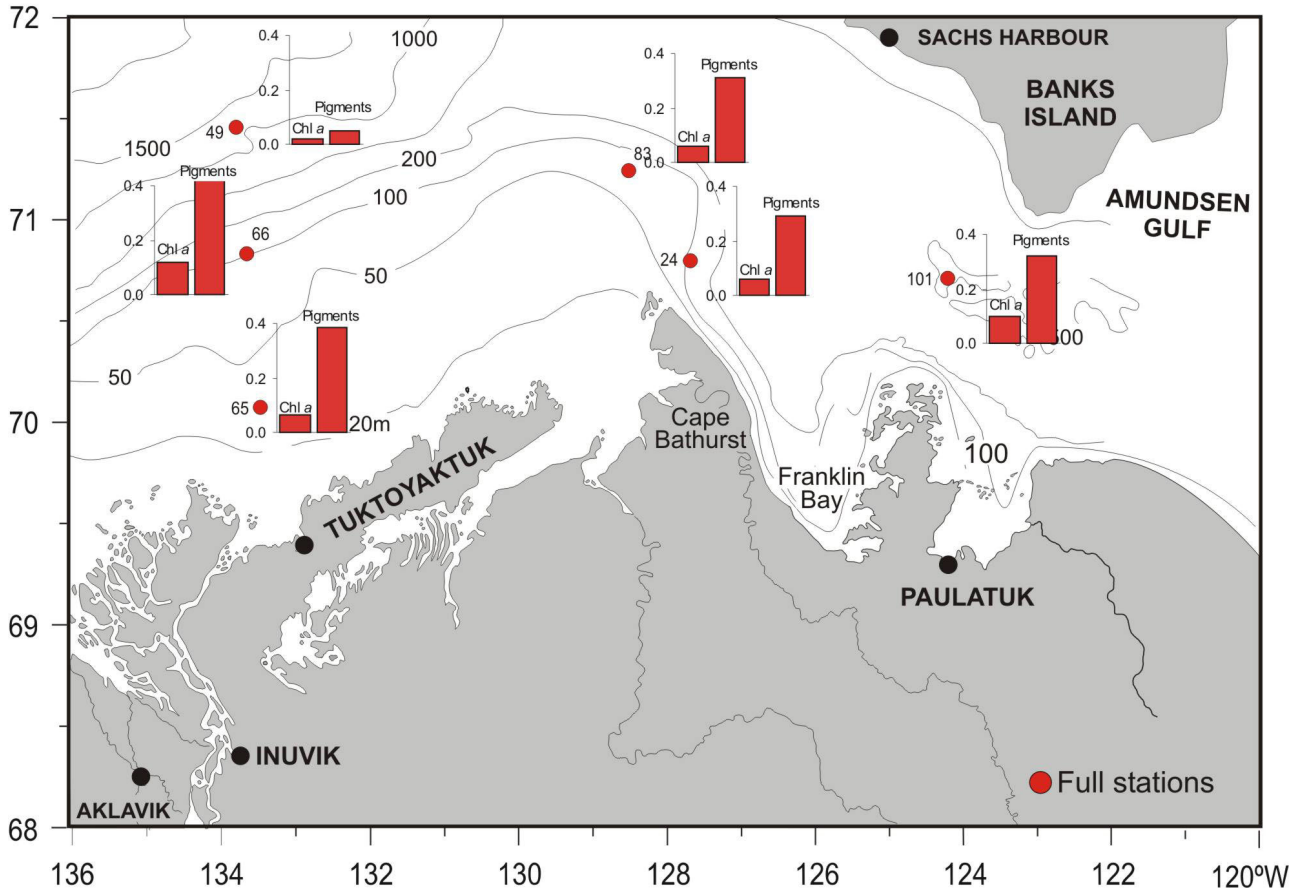


Figure 21. Sinking fluxes of chlorophyll a and total pigments at 25 m (in mg m-2 d-1), from short-term drifting trap deployments at full stations during the CASES 2002 fall expedition.

Table 18. Details of free-drifting sediment trap deployments during the CASES 2002 fall expedition.

Station	Trap depths (m)	Date in	Duration (d)	Position in		Position out	
				Lat (N)	Long (W)	Lat (N)	Long (W)
24	10, 15, 25, 50, 75, 100	9/23/02	1.16	70° 47.5'	127° 37.2'	70° 44.0	127° 45.0
49	10, 15, 25, 50, 75, 100, 125, 150	9/28/02	1.01	71° 27.6'	133° 43.9'	71° 32.15'	133° 40.4'
65	20, 25, 35	10/1/02	1.03	70° 06.75'	133° 28.03'	70° 05.05'	133° 32.3'
66	10, 15, 25, 50	10/5/02	0.91	70° 50.45'	133° 38.45'	70° 50.2'	133° 32.0'
83	10, 15, 25, 50	10/6/02	1.09	71° 15.8'	128° 31.7'	71° 12.24'	128° 11.95'
101	10, 15, 25, 50, 75, 100, 125, 150	10/9/02	0.80	70° 44.1'	124°14.3'	70° 42.10'	124° 14.3'

6.3 Dissolved Water Properties: Carbon and Oxygen

Principal investigator & cruise participant: *Lisa Miller*

Dissolved oxygen (O_2), total inorganic carbon (DIC), and total organic carbon (TOC) samples were collected at all depths at nearly all basic and full stations. Altogether, 395 oxygen samples, 431 DIC samples (through station 3, cast 127), and 462 TOC samples (through station 6, cast 124) were collected. In addition to regular rosette work, DIC and TOC were collected on the zodiac/helicopter transect (stations Z1, Z2, Z5, Z7), and TOC was collected at both of the Mackenzie River sites (R1 & R2). At all full stations where Tim Papakyriakou's sonic anemometer was mounted, surface DIC was also collected from all rosette casts, in order to correlate his measured CO_2 fluxes with changes in the air-sea pCO_2 gradient.

The DIC and TOC samples will be analyzed over the next year at IOS, but the oxygen samples have been measured on board, generally within 3 days of collection. I used an automated Winkler titration system developed at IOS and based on colorimetric detection. The analyses were calibrated using the calculated normality of a potassium iodate (KIO_3) standard solution prepared by Warwick Vincent's lab (as were all the reagents). Precision of the analyses, based on multiple samples tapped from the same niskin bottles, was 0.028 mL/L.

In addition to the systematic observational sampling, I conducted a number of 5-day respiration experiments with Warwick Vincent. At station 49, we incubated O_2 samples from 0, 90, and 150 m, while at station 60, we used the 0 and 16 m depths. In the deep samples, we saw increases in O_2 concentrations, despite having conducted the incubations in the dark, and we saw no significant change in any of the other samples. However, we took no special precautions to prevent gas exchange in the samples over the extended incubation period, and the changes we could have expected are close to the precision limit of the method. Therefore, we are considering improvements to the method for next year's expedition.

6.4 Natural Radionuclides

Principal investigator: Kirk Cochran
Crusie participants: David Amiel & Alex Kolker

Water column

Objectives

The ^{234}Th approach uses the disequilibrium that exists in seawater between ^{234}Th and its conservatively behaved parent ^{238}U to estimate fluxes of particles and POC. Upon integration of vertical profiles (0-100m) this disequilibrium produces a ^{234}Th deficit that is directly related to ambient particle concentrations and fluxes. Furthermore, if such particles are of biological origin, use of the C:Th ratio can be used to transform ^{234}Th fluxes into carbon fluxes, thus providing independent confirmation of fluxes obtained from sediment traps. Application of ^{234}Th has gained in recent years and its use has extended to high latitude systems. Sampling depths were chosen to provide overlap with depths of floating sediment traps.

Methods

1.Large volume

In the recent past, large volumes (> 100 l) of seawater were required to concentrate Th in order to obtain good count rates and statistics. In this method, in situ pumps powered by battery or ship power are used to collect samples. The samples thus obtained are counted at sea using non-destructive beta and gamma counting. On this expedition however, the battery-powered pumps did not work and a backup radiochemical method was employed.

2. Small volume

This method requires only 2L of seawater that can be obtained from Niskin bottles. In 4L Nalgene beakers, a precipitation reaction is set up using potassium permanganate and manganese chloride reagents. Th is scavenged onto the manganese oxide precipitate, the suspension containing total Th (particulate + dissolved) is filtered, mounted onto planchets, and beta counted. We used this method at 7 full stations (see below).

Preliminary results

At the deep station 49 (1600m), small volume samples were priority mailed back to our lab to be counted. Preliminary reduction of the data showed ^{234}Th to be in equilibrium with ^{238}U, thus indicating low particle and POC fluxes.

Suggestions

The Thorium method assumes particles in the water column to be of biological origin. At stations close to the Mackenzie River this assumption is clearly violated and Th is not an appropriate tracer of biologically derived fluxes. 234Thh sampling in next year's CASES cruises will focus on the Cape Bathurst Polynya, Amundsen Gulf and outer shelf regions. This last area was under-explored this year and we suggest an outer shelf transect be added to future expeditions that will roughly follow the northern ice-edge.

Table 19: Water column ^{234}Th sampling

Station	Depth (m)	Pump	Small Volume
49	1000	0-30 m	0-100 m
65	30	0-30 m	0-100 m
66	65	0-30 m	0-100 m
83	145	0-30 m	0-100 m
12	48	0-30 m	0-100 m
104	580	0-30 m	0-100 m

Sediments

Objectives

We collected sediment from box cores at each of the full stations using a 7.5 x 21 x 30 cm plexiglas subcorer. One duplicate core was taken at station 65 while the core taken from station 83 was highly disturbed and will not be used for our analyses. Cores were sectioned into 1-2 cm intervals. During sectioning, general observations were noted, with particular interest in diagenetic horizons i.e. redox boundries. We also noted any organisms present that can later be used to correlate with bioturbation rates. In the lab, we will analyze the cores for numerous geochemical properties. These analyses are likely to include: estimating particles fluxes using excess ^{234}Th, establishing geochronologies using ^{210}Pb, sourcing sedimentary organic carbon using ^{13}C and determining grain size distributions using a sedigraph and settling column.

Table 20: Sediment cores sampling details

Station	Depth (m)	Diagenetic Horizons	Remarks
24	147	Brown to grey (5-7cm)	
49	1000	Brown to grey (3-5cm)	Large grain sizes in top sediments. This may be a turbidite.
65	30	Black streaks (FeS) at 10-20cm.	Duplicate core taken at this site.
66	65	Brown to grey @ 3cm Grey to black@ 8cm	Core was very mucky. Indicative of high organic load.
83	145	N.A.	Core slumped. Will use for grain size only.
12	48	Brown to Grey @7cm. Yellow streaks below 7cm.	
104	580	Numerous color changes. 0-5cm brown. 5-10cm brown + grey. 10-16 cm grey w/ brown streaks. 16-20 cm brown. 21-24.5 cm grey.	Color changes may indicate a dynamic sedimentary and geochemical environment.

Notes: Diagenetic horizons should be read with the overlying section being the first section (ie brown- grey).

7. Benthic Processes and Carbon Cycling/8. Millenial-Decadal Variability in Sea Ice and Carbon Fluxes

Suproject leaders: Alec Aitken & David B. Scott

7 & 8.1 Box coring: Benthic ecology, contaminants & paleoenvironement

Principal investigators: Alec Aitken, David B. Scott, André Rochon, Peta Mudie, Kathy Conlan, Jean-Marc Gagnon, Dennis Darby, Steve Blasco
Cruise participant: Mélanie Simard

Introduction

The main objectives of CASES are to document the oceanographical, physical, chemical and biological processes on the Mackenzie Shelf and in the Amundsen Gulf polynya. In particular, the "benthic" component of CASES is composed of two separate projects that focus on the benthos and on marine sediments. Subroject 7 is composed of 4 interrelated components: a) documenting the response of benthic communities to seasonal variations in sedimentation; b) documenting the response of benthic community structures due to ice scouring; c) the impact on a) and b) on the rate of carbon mineralization in Arctic shelf sediments; d) document biogeochemical markers as proxies for the various sources of organic materials consumed by Arctic Shelf benthos. Subproject 8 will focus on the use of proxy data to quantify and document the Holocene variations in sea ice and other sea surface parameters (temperature, salinity) and paleoenvironments (dinocysts and benthic foraminifers), the transport and origin of ice rafted debris and the variations in the direction of the Arctic ice drift, the export of particulate organic matter from the inner shelf to the outer shelf and slope, and the variations of the Mackenzie river discharge (diatoms). The two "benthic" components will allow to document the organic carbon production and transport from the shelf to the slope, and to link the benthic and pelagic processes.

Objectives

The study of surface and/or sub-bottom sediments requires to perform multibeam and sub-bottom profiler surveys in order to select the most appropriate sampling locations for both subprojects 7 and 8. Because these tools were not available onboard the Radisson, the objectives of the cruise were of an exploratory nature, rather than to target specific sampling locations. Boxcore were collected at 8 long (full) stations in order to provide surface sediment samples for various analyses, and as a guide to prepare the 2003-2004 sampling strategy. In addition, the samples collected during the 2002 will be used to assess the sediment content in macro and microfauna/flora, and to test the sediment sieving procedure in order to maximize its efficiency.

In particular, surface sediment samples will be used to determine the dinoflagellate cyst assemblages, and increase the geographical coverage of the arctic coretop database, which is a prerequisite for accurate reconstruction of sea ice history that will be carried on as part of the main objective of project 8. Similar samples will also be analysed for their content in ice rafted debris, and incorporated in a database that aims at documenting the different sources and provenance of the debris for the reconstruction of paleo-ice flow. The benthic foraminifer assemblages will also be analyzed in order to assess their distribution in relation with temperature and salinity conditions.

Onboard and onshore participants

Most of the PIs involved with subprojects 7 and 8 had other commitments, and could not participate to the cruise CASES 2002. Therefore, a student was hired to collect the boxcore, and conduct the sediment sub sampling and onboard processing. Other CASES participants showed interest in

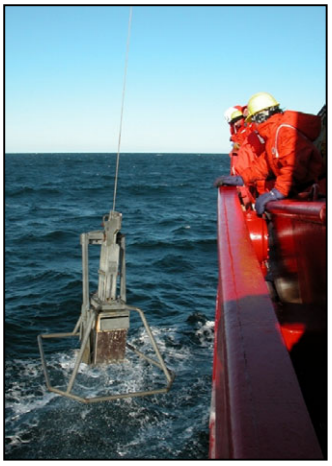
sediment samples, and hiring a student to meet the sample requirements of everyone proved to be a good investment. Melanie Simard, from the Université du Québec à Rimouski, was in charge of collecting boxcores at the long (full) stations, and to collect surface sediments samples, push cores and process bulk sediment samples in order to isolate and preserve the benthic macrofauna.

Table 21. List of participants from the various projects that required sediment sampling, as well as the type of analysis to be performed on the samples.

Participants	Affiliation	Project	Type of sample	Type of analysis
A. Rochon/	GSC Atlantic	8	Surface &	Palynology
D.B. Scott	Dalhousie	8	Surface	Foraminifers
D. Darby/	Old Dominion	8	Surface	Ice rafted debris
A. Mucci	McGill	6	Surface &	C_{inorg}, C_{tot}, N_{tot}, ^{13}C, ^{15}N
S. Demers/	ISMER	3	Surface &	Grain size, biomass, meiofauna,
D. Amiel		6	Push cores	^{210}Pb, ^{13}C, ^{234}Th
G. Stern/	DFO	5	Push cores	Contaminants
K. Conlan	CMN	7	Surface/bulk	Macrofauna
A. Aitken	U. Saskatchewan	7	Surface/bulk	Macrofauna
J.-M. Gagnon	CMN	7	Surface/bulk	Macrofauna
K. Azetsu-Scott	DFO		Water sampling	$\delta^{18}O$

In addition to the CASES participants, Kumiko Azetsu-Scott (DFO) requested water samples to analyse its $\delta^{18}O$ composition. These analyses will complement those performed by Lisa Miller (subprojects 1, 4 and 6).

Boxcore location and subsamples



Boxcores were collected from 6 long (full), and 1 basic stations. All the sediment subsamples were processed and stored according to the instructions provided by the different participants. The boxcore used during the cruise was on-loan from the Institut Maurice Lamontagne (Mont-Joli, QC), and consisted of a 0.125m^3 aluminium box enclosed in a steel frame. A shovel and lid closed the bottom and top of the boxcore while it is brought back onboard. Push core subsamples were collected using PVC or Plexiglas tubes. Three different sizes were used: a 10 cm diameter Plexiglas tube, a 12 cm diameter PVC tube and a rectangular 9.5cm x 21cm x 40cm PVC box. Most of the surface samples were collected using a 2.5 cm diameter syringe. A few samples were collected using a simple spoon. Participants requested the following subsamples:

- sediment sub-core (push core of 12 cm diam.) for contaminant analyses for Stern's group;
- sediment sub-core (rectangular push core of 21 x 7 cm) for radio isotope analyses (^{13}C, ^{210}Pb, ^{234}Th) (Amiel);
- sediment sub-core for micropaleontological analysis:
    a) dinocysts + C_{tot} + C_{inorg} (push core of 10 cm diam.) for Rochon
    b) palynology (10 cc of the top 0.5 cm of surface sediment) for Rochon/ Mudie
    c) foraminifers (2 syringes of 2.5 cm diameters x 1 cm depth) for Rochon/Scott

- sediment sub-core (2 syringes of 2.5 cm diam. x 1 cm depth) for ice rafted debris for Rochon/Darby;
- sediment sub-core (2 syringes of 2.5 cm diam. x 1 cm depth) for mineralogy (C_{inorg},C_{tot}, N_{tot}, N_{15}) for Rochon/Mucci
- sediment sub-core (7 syringes of 2.5 cm diam. x 1 cm depth) for phytoplankton fluxes analyses for Demers/Nozais;
- sediment sub-core for meiofauna (3 syringes of 2.5 cm diam. x 1 cm depth for Demers/Nozais
- sediment sample (35 x 35 x 15 cm depth) and sieving (4mm, 1 mm and 0.5 mm) for macrofauna for Gagnon/Aitken/Conlan

Table 22. Geographical location of the boxcore stations.

Station (Type)	Date	Latitude	Longitude	Depth (m)	Box number	Samples collected
Station 24 (Full)	24/09/2002	70° 48.4' N	127° 38.4' W	147	box 1A	1; 3a; 3c; 4-8
	24/09/2002	70° 48.4' N	127° 38.4' W	140	box 1B	1 (duplicate); 2; 3b
Station 49 (Full)	29/09/2002	71° 27.1' N	133° 48.6' W	1000	box 2	1-8
Station 65 (Full)	02/10/2002	70° 08.7' N	133° 30.9' W	30	box 3A	2-8
	02/10/2002	70° 08.7' N	133° 30.9' W	30	box 3B	1, 2
	03/10/2002	70° 08.7' N	133° 30.9' W	42	box 3C	1, 3-5, 8
Station 66 (Full)	04/10/2002	70° 50.3' N	133° 38.0' W	65	box 4	1-8
Station 83 (Full)	07/10/2002	71° 16.0' N	128° 31.0' W	48	box 5	2-8
Station 101 (Full)	No boxcore due to storm. Replaced with station 104 (basic)					
Station 12 (Full)	12/10/2002	69° 50.3' N	126° 09.3' W	145	box 6	1-8
Station 104 (Basic)	13/10/2002	70° 39.0' N	123° 30.0' W	580	box 7	1-8

Table 23. Size and volume of the sieved sediment samples.

Box number	Size of sieved sample (cm)	Volume of sediment sieved (litre)
box 1A	50 x 35 x 15 (depth)	2.63
box 2	38 x 34 x 15	1.94
box 3A	35 x 35 x 15	1.84
box 3C	35 x 35 x 15	1.84
box 4	35 x 35 x 15	1.84
box 5	25 x 35 x 15 (approx.)	1.31
box 6	35 x 35 x 15	1.84
box 7	35 x 35 x 15	1.84

Recommendations

- The bulk sediment samples were processed through 4, 1, and 0.5 mm mesh, and this task proved to be time-consuming for one person.
- The following material would be useful for the 2003-2004 campaign: shovels and buckets to collect the sediment to be sieved, high quality hose; high quality Ziploc bags, dissection kit to collect delicate organisms from sieves.
- Collecting the numerous surface samples using syringes also proved to be time consuming. A simple spoon or stainless steel spatula will do the same job in less than half the time.
- Other items to consider: bungee cords to secure cores and other items in the cold room. A well garnished tool box (hammer, ratchet wrench (1 large, 2 smaller ones) good screwdrivers, spare bolts, nuts for the boxcore, shackles and electric wire to secure them).

Appendix 1. Cruise log of the CASES2002 expedition

Note: This is a copy of the schedules posted by the Chief Scientist during the cruise. Although it was updated with the detailed ship logbook, this log should only be used for general reference. Please refer to the CTD logsheets (Appendix 2) for exact position, time and depths of sampling stations. Note that time is given as local time, as used on the ship. Depth is given as sounder depth under the keel (add ~7m for the draft of the ship).

Wed, 18 September (UTC-4h)	
11:00 to 17:30	Boarding the Pierre Radisson in Allen Bay, Resolute
17:30	Ship leaves Allen Bay en route for Amundsen Gulf
Thu, 19 September (UTC-4h)	Set-up
Fri, 20 September (UTC-6h)	Set-up
	Bring clocks back 2 hours (UTC-6h)
Sat, 21 September (UTC-6h)	Set-up
13:00	Fire drill
Sun, 22 September (UTC-6h)	**Station 01-CTD (~300m)**
09:00 to 10:20	CTD-rosette trials
10:20 to 10:40	CTD
08:00 to 12:00	Set-up of monster net/Turn winch
12:30	Sail to Station 02
13:15	**Station 02-CTD (~250m)**
13:35 to 14:00	CTD
14:20 to 14:30	Optical profile (Nozais)
15:00	Sail to Station 03
16:20	**Station 03-BASIC (~200m)**
16:55 to 17:07	Vertical net
17:00 to 18:00	Horizontal tow (cancelled, 40+knots winds)
18:00 to 19:00	Rosette (cancelled because of sea state)
19:00	Steering committee meeting
20:00	Steam west to Station 18-Away from Monster Low
Mon, 23 September (UTC-6h)	
00:15	**Station 18-BASIC (~180m)**
00:30 to 01:06	Rosette
01:42 to 02:06	Vertical net tow
02:36 to 03:00	Horizontal tow
03:00	Sail to Station 19
04:20	**Station 19-CTD (~150m)**
04:23 to 04:48	CTD
04:50	Sail to Station 20
05:20	**Station 20- CTD (~150m)**
05:26 to 05:44	CTD
05:45	Sail to Station 21
06:18	**Station 21-BASIC (~120m)**
07:55 to 08:18	Rosette
08:40 to 09:10	Vertical net tow
09:35	Helicopter departs for Baillie Island reconnaissance
09:44 to 10:03	Horizontal tow
10:10	Sail to Station 22
10:55	**Station 22-CTD (~150m)**
11:06 to 11:24	CTD
11:25	Sail to Station 23
11:51	Helicopter returns
13:00	**Station 23- CTD (~170m)**
13:00 to 13:15	CTD
13:20	Sail to Station 24

14:10 to 14:40	FSTs deployment (Michel)
14:45 to 16:00	Resume sailing to Station 24
16:00	**Station 24-FULL (166m)**
16:00 to 17:00	Pump line deployment (Helm)
17:10 to 18:00	Vertical net tows
18:15 to 19:40	Horizontal net tows (Michaud)
20:00 to 02:20	Thorium pumping (Amiel)
Tue, 24 September (UTC-6h)	
03:50 to 04:10	Rosette (deep + special)
06:35 to 06:45	Rosette (microbes)
07:55 to 08:22	Rosette (primary production)
08:46 to 10:13	Vertical net tows
10:30 to 11:05	Horizontal net tows
11:20 to 11:44	Rosette (contaminants)
13:44 to 16:10	Box coring
16:35 to 17:00	Optical profile
17:00 to 19:30	Move to and recover FSTs/Pumps
19:30	En route to 25
21:00	**Station 25-CTD (109m)**
21:12 to 21:22	CTD
21:25	Sail to Station 26
22:35	**Station 26- CTD (61m)**
23:00 to 23:15	CTD
23:20	Sail to Station 27
Wed, 25 September (UTC-6h)	
00:30	**Station 27-BASIC (~90m)**
00:36 to 00:50	Rosette
01:20 to 01:30	Vertical net tow
01:50 to 02:20	Horizontal tow
02:30	Sail to Station 28
03:45	**Station 28-CTD (~60m)**
03:55 to 04:10	CTD
04:15	Sail to Station 29
05:10	**Station 29- CTD (50m)**
05:34 to 05:40	CTD
05:40	Sail to Station 30
06:20	**Station 30-BASIC (60m)**
07:20 to 07:35	Rosette
08:00 to 08:15	Vertical net tow
08:30 to 09:00	Horizontal tow
09:05	Sail to Station 31
10:05	**Station 31-CTD (77m)**
10:22 to 10:32	CTD
10:38	Sail to Station 32
12:00	**Station 32- CTD (~150m)**
12:05 to 12:20	CTD
12:25	Sail to Station 33
13:30	**Station 33-BASIC (255m)**
13:45 to 14:05	Optical profile
14:15	Helicopter departs (Barber)
14:25 to 14:56	Rosette
15:45	Helicopter returns
16:05 to 16:25	Vertical net tow
16:50 to 17:25	Horizontal tow
17:30	Sail to Station 34
18:00	**Station 34-CTD (285m)**
18:30 to 18:48	CTD
18:50	Sail to Station 35
19:30	**Station 35- CTD (287m)**

19:45 to 20:15	CTD
20:30	Sail to Station 36
21:25	**Station 36-BASIC (243m)**
21:30 to 21:57	Rosette
22:38 to 23:04	Vertical net tow
23:18 to 23:54	Horizontal tow (if no ice or slush)
Thursday, 26 September (UTC-6h)	
00:00	Sail to Station 37
01:10	**Station 37-CTD (237m)**
01:20 to 01:40	CTD
01:45	Sail to Station 38
02:45	**Station 38- CTD (207m)**
03:00 to 03:15	CTD
03:30	Sail to Station 39
04:35	**Station 39-BASIC (305m)**
04:45 to 05:05	Rosette
05:30 to 05:55	Vertical net tow
06:05 to 06:50	Horizontal tow (if no ice or slush)
07:15	Sail to Station 40
08:55	**Station 40-CTD (~500m) (back in the ice pack)**
09:15	Helicopter raid (Michel)
09:28	Zodiac launch (Barber)
09:42 to 10:05	CTD
11:15	Zodiac onboard
11:15	Sail to Station 41
11:30	Helicopter onboard
12:30	**Station 41- CTD (560m)**
12:36 to 13:00	CTD
13:05	Sail to Station 42
14:30	**Station 42-BASIC (560m)**
14:33 to 14:55	Optical profile
15:00 to 15:57	Rosette
16:20 to 16:55	Vertical net tow
16:15	Helicopter returns (2^{nd} run)
17:05 to 17:50	Horizontal tow
18:30 to 20:43	Thorium pumping trials
20:45	Sail to Station 43
21:30	Enter Arctic Ice pack
23:00	**Station 43-CTD (575m)**
23:06 to 23:35	CTD
23:40	Sail to Station 44
Friday, 27 September (UTC-6h)	
01:00	**Station 44- CTD (570m)**
01:30 to 02:00	CTD
02:00	Sail to Station 45
03:30	**Station 45-BASIC (1036m)**
03:40 to 04:35	Rosette 1
04:45 to 06:00	Vertical net tow
06:15 to 06:30	Rosette 2 (if needed)
07:30	Sail to Station 46
08:30	**Station 46-CTD (~900m)**
08:44 to 09:15	CTD1
09:25	Helicopter raid
10:11 to 10:57	CTD2
11:05	Sail to Station 47
12:50	**Station 47- CTD (1300m)**
13:03 to 14:05	CTD
14:25	Sail to Station 48
15:30	**Station 48-CTD (1600m)**

16:15 to 16:38	Optical profile
16:40 to 17:20	Sail to mooring deployment site in open water
17:20 to 17:53	Sediment trap deployment
18:05 to 18:30	Pump line deployment (cancelled)
19:00 to 19:20	Recover traps stuck in ice
19:45 to 21:09	Rosette (contaminants + trap water)
21:15	Sail south to open water
21:30 to 22:00	Pump line & Sediment trap deployments (cancelled)
22:15 to 00:00	**Sail south to 49-FULL**
Saturday, 28 September (UTC-6h)	
00:00	**Station 49 –FULL (1438m)**
00:30 to 09:30	Delay because of sea state
09:45 to 10:15	Sediment trap & Pump line deployments
10:39 to 12:40	Vertical net tows
13:05 to 13:40	Horizontal tow
14:03 to 15:30	Rosette (deep + special)
15:38 to 16:00	Optical profile
16:00 to 19:45	Thorium pumping
20:24 to 20:54	Rosette (deep + special)
22:34 to 23:15	Horizontal tow
23:48 to 01:30	Vertical net tow
Sunday, 29 September (UTC-6h)	
03:43 to 04:05	Rosette (microbes)
05:05 to 05:25	Rosette (primary production)
06:30 to 08:21	Box coring
08:30	Clean front deck, remove mud….
09:30 to 11:05	Locate & retrieve drifting arrays
11:10	Sail to station 50 (south to Tuk)
12:30	**Station 50- CTD (1060m)**
12:40 to 13:30	CTD
13:30	Sail to Station 51
14:15	**Station 51-CTD (~800m)**
14:15 to 14:37	Optical profile
14:55 to 15:30	CTD
15:30	Sail to Station 52
16:15	**Station 52- CTD (~500m)**
16:23 to 16:53	CTD
16:55	Sail to Station 53
17:30	**Station 53-BASIC (~400m)**
17:35 to 18:10	Rosette
18:25 to 19:00	Vertical net tow
19:20 to 19:50	Horizontal tow
19:50 to 20:13	Reposition
20:17 to 20:35	Rosette
20:35	Sail to Station 54
21:24	**Station 54-CTD (150m)**
21:26 to 21:40	CTD
21:45	Sail to Station 55
22:25	**Station 55- CTD (~80m)**
22:28 to 23:00	CTD
23:00	Sail to Station 56
23:42	**Station 56-BASIC (~70m)**
23:49 to 00:08	Rosette
Monday, 30 September (UTC-6h)	
00:30 to 00:45	Vertical net tow
00:56 to 01:35	Horizontal tow
01:45	En route to Station 57
02:30	**Station 57-CTD (~70m)**
02:35 to 02:48	CTD

02:52	Sail to Station 58
03:40	**Station 58- CTD (70m)**
03:47 to 03:56	CTD
04:00	Sail to Station 59
04:30	**Station 59-BASIC (64m)**
05:25 to 05:35	Vertical net tow
05:50 to 06:25	Horizontal tow
07:10 to 07:25	Rosette
07:30	En route for station 60
08:20	**Station 60-CTD (63m)**
08:49 to 08:57	CTD
09:00	Sail to Station 61
09:40	**Station 61- CTD (55m)**
10:00 to 10:08	CTD
10:20	Sail to Station 62
11:00	**Station 62-BASIC (55m)**
11:10 to 11:40	Vertical net tow
11:50 to 12:05	Reposition
12:10 to 12:40	Horizontal tow
12:40 to13:20	Lower met tower on foredeck
13:43 to 14:00	Rosette
14:00	En route to Station 63
14:50	**Station 63-CTD**
15:00 to 16:40	Helicopter from Sir Wilfrid Laurier on board
15:45 to 15:53	CTD
16:00	Sail to Station 64
16:30	**Station 64- CTD (38 m)**
16:48 to 16:55	CTD
17:00 to 17:30	Drop anchor
18:00 to 08:00	**MID-CRUISE BREAK & PARTY**
Tuesday, 01 October (UTC-6h)	
08:45 to 09:00	Raise anchor
09:00	Sail to Station 65
09:50	**Station 65-Full (33m)**
09:57 to 10:05	Trap deployment
10:10 to 10:57	Pump line deployment
11:00 to 11:20	Reposition
11:30 to 11:50	Vertical net tow
12:05 to 13:00	Horizontal net tows
13:30	Helicopter departs for Tuk to debark scientists & pick up media
14:00 to 14:30	Optical profile (cancelled because of sea state)
14:30 to 15:00	Optical & contaminants rosette (cancelled because of sea state)
15:15 to 18:20	Thorium pumping
16:45	Helicopter back from Tuk with media crew (3)
19:00 to 23:30	Break in operations due to sea state (> 30knts)
23:30 to 23:33	CTD19 profile on front deck
23:44 to 00:10	Collect surface water with Go-Flow bottles
Wednesday, 02 October (UTC-6h)	
00:30 to 00:45	Vertical net tow
01:00 to 02:00	Horizontal net tows
02:00 to 05:00	Break in operations due to sea state (> 30knts)
05:30 to 05:50	Rosette
06:35 to 06:50	Rosette
07:00 to 08:45	Box coring
09:20 to 11:00	Move to and recover Traps
11:00 to 16:30	Search for drifting pump array (no success)
14:10 to 16:05	Helicopter search for pump array
16:40	Reposition to Station 65
17:00 to 17:20	Rosette

18:00 to 22:00	Search for drifting pump array (no success)
22:00 to 22:30	Reposition
22:44 to 22:55	Rosette
23:14 to 23:22	Vertical net tow
23:35 to 00:10	Horizontal net tow
Thursday, 03 October (UTC-6h)	
05:45 to 08:00	Thorium pump (cancelled malfunction)
09:30	Zodiac departs for inshore sampling transect
10:00	Reposition
11:00 to 12:00	Box core
14:00 to 14:08	Rosette
14:25	Helicopter depart for radiometer survey
14:33 to 14:45	Optical profile
15:00	Move south towards Zodiac
18:30	Zodiac onboard
19:00 to 23:30	Sail to Station 66
22:20 to 22:30	Fix met tower
23:30	**Station 66-Full (77m)**
23:55 to 00:35	Deploy drifting traps
Friday, 04 October (UTC-6h)	
00:55 to 01:10	Rosette contaminants 1
01:30 to 02:50	Horizontal tow
03:07 to 03:40	Vertical net tows
05:05 to 05:25	Rosette (microbes)
07:00 to 07:17	Rosette (primary production)
08:30 to 11:00	Thorium pumping (cancelled)
Around 10:30	Helicopter departs for Inuvik (cancelled)
11:15 to 12:13	Vertical net tows
12:25 to 13:12	Horizontal tow
13:33 to 13:52	Rosette (deep + special) & contaminants
14:02 to 14:17	Optical profile
14:35 to 15:00	Box coring
19:00	Steering committee
21:30 to 22:40	Search for & retrieve drifting traps
23:00	Sail to station 67-CTD
23:45	**Station 67-CTD (63m)**
23:52 to 00:00	CTD
Saturday, 05 October (UTC-6h)	
00:00	Sail to Station 68
01:00	**Station 68- CTD (62m)**
01:04 to 01:12	CTD
01:15	Sail to Station 69
02:15	**Station 69-BASIC (61m)**
02:25 to 02:40	Vertical net tow
03:00 to 04:00	Horizontal tow (cancelled)
04:10 to 04:20	Rosette
04:25	En route to Station 70
07:00	**Station 70-CTD (57m)**
07:15 to 07:28	CTD
07:30	Sail to Station 71
08:25	Enter pancake ice field
08:30	**Station 71- CTD (57m)**
09:00 to 11:00	CTD repair
10:47 to 11:02	Ice sampling basket
11:34 to 11:44	CTD
11:46	Sail to Station 72
12:15	**Station 72-BASIC (55m)**
12:53 to 13:12	Rosette
13:36 to 13:55	Optical profile

14:28 to 15:23	Helicopter survey for media
14:43 to 15:16	Vertical net tow
15:15 to 16:00	Horizontal tow (cancelled because of ice)
15:25	En route to Station 73
16:20	**Station 73-CTD (57m)**
16:40 to 17:00	Deploy basket for radiometer measurements
17:25 to 17:35	CTD
17:40	Sail to Station 74
18:20	**Station 74- CTD**
18:35 to 18:45	CTD
18:50	Sail to Station 75
20:00	**Station 75-BASIC (50m)**
20:03 to 20:22	Rosette
20:45 to 21:10	Vertical net tow
21:24 to 21:54	Horizontal tow
22:10	En route to Station 76
23:20	**Station 76-CTD (43m)**
23:21 to 23:40	CTD
23:40	Sail to Station 77
Sunday, 06 October (UTC-6h)	
00:45	**Station 77- CTD (42m)**
00:56 to 01:05	CTD
01:20	Sail to Station 78
03:00	**Station 78-BASIC (40m)**
03:00 to 03:10	Vertical net tow
03:45 to 4:30	Horizontal tow (cancelled, ice cover)
04:30 to 04:45	Rosette
04:50	En route to Station 79
05:50	**Station 79-CTD**
05:55 to 06:05	CTD
06:10	Sail to Station 80
07:30	**Station 80-CTD (41m)**
08:08 to 08:12	CTD
08:15	Sail to Station 81
10:10	**Station 81-BASIC (42m)**
10:12 to 10:25	Vertical net tow
10:45 to 10:55	Ice basket
11:38 to 11:54	Rosette
11:55	En route to Station 82
12:50	**Station 82-CTD (48m)**
13:08 to 13:20	CTD
13:25	Sail to Station 83
14:00	**Station 83- Full (50m)**
14:00 to 14:20	Trap deployment
14:37 to 15:00	Basket sampling (radiation)
15:03 to 15:12	Basket sampling (ice)
15:10 to 15:20	Move back to check on traps- traps OK
15:20 to 15:30	Move back to station 83
15:33 to 15:45	Launch Zodiac for film crew
15:57 to 16:10	Rosette contaminants 1
16:15 to 16:30	Zodiac returns onboard
17:00 to 19:40	Thorium pumping
20:04 to 20:24	Horizontal tow (if no ice)
20:54 to 21:57	Vertical net tows
Monday, 07 October (UTC-6h)	
02:12 to 02:25	Rosette contaminants 2
05:05 to 05:20	Rosette (microbes)
07:00 to 07:15	Rosette (primary production)
08:00 to 10:00	Box coring & cleaning deck

10:45 to 12:45	Debark film crew in Sachs harbour
11:20 to 11:54	Vertical net tows
12:05 to 13:20	Horizontal tow (if no ice)
13:23 to 13:27	Surface water collection (Go-Flow)
13:38 to 13:50	Optical profile
13:57 to 14:11	Basket sampling (ice)
14:15 to 16:30	Search for & retrieve drifting traps
16:30	Sail to Station 84
17:15	**Station 84-CTD (75m)**
17:20 to 17:30	CTD
17:35	Sail to Station 85
18:30	**Station 85-CTD (153m)**
19:00 to 19:25	CTD
19:30	Sail to Station 86
20:40	**Station 86-BASIC (215m)**
21:00 to 21:21	Rosette 1
21:44 to 22:06	Vertical net tow
22:10 to 00:30	Search for sampling spot in ice
Tuesday, 08 October (UTC-6h)	
00:30 to 01:00	Rosette (aborted-pump failure)
01:00 to 02:00	CTD Pump Repair
02:00 to 02:37	Rosette
02:40	En route to Station 87
03:50	**Station 87-CTD (323m)**
04:05 to 04:30	CTD
04:35	Sail to Station 88
06:00	**Station 88-CTD (372m)**
06:00 to 6:20	CTD
06:25	Sail to Station 89
07:30	**Station 89-BASIC (445m)**
08:07 to 08:40	Vertical net tow
09:00 to 10:00	Horizontal tow (cancelled because of ice)
10:20	Helicopter departs for Inuvik
10:41 to 11:00	Rosette (pulley problems)
11:00 to 11:40	Fix pulley
11:48 to12:34	Rosette
12:40 to 13:15	Basket sampling (radiation)
13:20 to 13:35	Basket sampling (ice)
13:40	En route to Station 90
13:50	± 10 seals + 3 bears seen on new ice pack
14:40	**Station 90-CTD (440m)**
14:43 to 15:12	CTD
15:15	Sail to Station 91-CTD
16:00	**Station 91-CTD (450m)**
16:15 to 16:35	CTD
16:40	Sail to Station 92
17:30	**Station 92-BASIC (400m)**
17:55 to 18:25	Vertical net tow
19:25	Helicopter returns from Inuvik
20:30 to 21:12	Rosette
21:20	En route to Station 93
22:07	**Station 93-CTD (380m)**
22:09 to 22:30	CTD
22:35	Sail to Station 94, exit pack ice field
Wednesday, 09 October (UTC-6h)	
00:00	**Station 94-CTD**
00:12 to 00:27	CTD
00:30	Sail to Station 95
01:30	**Station 95-BASIC (340m)**

02:06 to 02:50	Vertical net tow
02:57 to 03:36	Horizontal tow (if no ice)
04:00 to 04:35	Rosette
04:40	En route to Station 96
05:45	**Station 96-CTD (341m)**
06:00 to 06:15	CTD
06:20	Sail to Station 97
08:00	**Station 97-CTD (383m)**
08:07 to 08:30	CTD
08:30 to 9:15	Satellite communication trials
09:16	Sail to Station 98
10:00	**Station 98-BASIC (367m)**
10:05 to 10:42	Vertical net tow
10:53 to 11:18	Horizontal tow (if no ice)
12:13 to 12:48	Rosette
13:05 to 13:20	Optical profile
13:28 to 13:35	Surface water sampling (Go-Flow)
13:35	Sailt to Station 99
14:45	**Station 99-CTD (410m)**
15:10 to 15:34	CTD
15:40	Sail to Station 100
16:45	**Station 100-CTD (450m)**
17:00 to 17:25	CTD
17:30	Sail to Station 101
18:10	**Station 101-FULL (500m)**
18:45 to 19:00	Sediment trap deployment
20:06 to 20:40	Rosette Contaminants 1
21:00 to 21:30	Horizontal tows (if no ice)
21:45 to 00:20	Vertical net tows
Thursday, 10 October (UTC-6h)	
00:34 to 03:55	Thorium pumping
04:10 to 04:40	Rosette (deep + special)
05:30 to 06:00	Rosette (microbes)
07:00 to 07:15	Rosette (primary production)
08:00	Wind increasing to 40knts (gusting 50knts)
09:30 to 10:30	Rosette Contaminants 2 (cancelled because of sea state)
11:30 to 12:15	Horizontal tow (aborted because of sea state)
12:38 to 13:55	Locate & retrieve drifting traps (45/50knts winds)
13:55	Postpone Full station and move to sheltered Franklin Bay
14:00 to 00:00	Sail to Station 17 in Franklin Bay
Friday, 11 October (UTC-6h)	
00:00	**Station 17-CTD (207m)**
00:00 to 00:14	CTD
00:16	Sail to Station 16
01:00	**Station 16-CTD (216m)**
01:13 to 01:28	CTD
01:32	Sail to Station 15
02:15	**Station 15-BASIC (230m)**
03:03 to 03:28	Rosette (heavy current & drift)
04:40 to 04:55	Vertical net tow
05:00	En route to Station 14
07:00	**Station 14-CTD**
07:05 to 07:20	CTD
07:25	Sail to Station 13
08:55	**Station 13-CTD (187m)**
09:02 to 09:18	CTD
09:20	Sail to Station 12
10:05	**Station 12-FULL (140m)**
10:35 to 11:05	Basket sampling (ice)

11:45 to 12:20	Vertical net tows
13:05 to 13:10	Surface water sampling (Go-Flow)
13:40 to 13:50	Optical profile
14:46 to 15:15	Basket sampling (Irradiance & Ice)
15:53 to 18:20	Thorium pumping
19:00 to 19:15	Rosette 1
22:02 to 22:34	Vertical net tows
Saturday, 12 October (UTC-6h)	
03:00 to 03:35	Rosette 2
05:00 to 05:25	Rosette 3
06:55 to 07:05	Rosette 4
08:45 to 09:45	Box core & clean decks
09:45	Sail to Station 11
10:25 to 10:50	Basket sampling (ice)
12:15	**Station 11-CTD (150m)**
12:20 to 12:43	CTD
12:45	Sail to Station 10
13:45	**Station 10-CTD (175m)**
14:00 to 14:12	CTD
14:15	Sail to Station 09
14:54	Radiosonde launch
15:15	**Station 09-BASIC (130m)**
15:30 to 15:45	Vertical net tow
16:10 to 16:30	Rosette
16:35	En route to Station 08
18:00	**Station 08-CTD (142m)**
18:00 to 18:15	CTD
18:20	Sail to Station 07
19:30	**Station 07-CTD (233m)**
19:35 to 19:45	CTD
19:50	Sail to Station 06
20:45	**Station 06-BASIC (191m)**
21:15 to 21:40	Vertical net tow
22:03 to 22:25	Rosette
22:30	En route to Station 05
23:40	**Station 05-CTD**
23:45 to 23:53	CTD (pulley failure)
Sunday, 13 October (UTC-5h)	
00:01	**Bring clocks forward by 1 hour**
01:17to 01:28	CTD (2nd try)
01:35	Sail to Station 4
02:45	**Station 04-CTD (125m)**
02:46 to 02:54	CTD
03:00	Sail to Station 03
03:50	**Station 03-BASIC (172m)**
04:00 to 04:20	Vertical net tow
05:00 to 05:30	Rosette
05:35	En route to Station 102
06:50	Radiosonde launch
07:50	**Station 102-CTD (471m)**
08:04 to 08:30	CTD
08:35	Sail to Station 103
09:00	**Station 103-CTD (496m)**
09:32 to 10:54	CTD
10:55	Sail to Station 104
11:05	**Station 104-BASIC (409m)**
11:09 to 11:46	Rosette
12:09 to 12:50	Vertical net tow
13:00 to 13:05	Surface water sampling (Go-Flow)

13:15 to 13:30	Optical profile
13:45 to 15:30	Box coring & clean decks
15:40	En route to Station 105
16:30	**Station 105-CTD (540m)**
16:35 to 17:00	CTD
17:05	Sail to Station 106
18:00	**Station 106-CTD (545m)**
18:10 to 18:35	CTD
18:40	Sail to Station 107
19:10	**Station 107-BASIC (514m)**
19:20 to 20:00	Vertical net tow (high winds & ice)
20:18 to 20:42	Rosette
20:45	En route to Station 108
22:15	**Station 108-CTD (529m)**
22:18 to 22:42	CTD
22:50	Sail to Station 109
23:28	**Station 109-CTD (564m)**
23:30 to 23:54	CTD
00:00	Sail to Station 110
Monday, 14 October (UTC-5h)	
00:40	**Station 110-BASIC (540m)**
01:00 to 01:50	Vertical net tow
02:07 to 02:48	Rosette
03:00	End of CASES2002 sampling
03:30	Sail to Coppermine
Evening	End of cruise party
Tuesday, 15 October (UTC-5h)	**Coronation Gulf to Queen Maud Gulf**
10:00 to 12:00	**Debark 5 scientists in Kugluktuk**
12:00	Home Sweet Home by ship for the rest of us!!!!!!!!!!!
15:50	Rosette (Coronation Gulf)
Wednesday, 16 October (UTC-5h)	**Queen Maud Gulf to Larsen Sound**
	Sail through ice infested Victoria Strait & Larsen Sound
Thursday, 17 October (UTC-5h)	**Larsen Sound to Barrow Strait**
10:54 to 11:35	Rosette (Franklin Strait)
Friday, 18 October (UTC-5h)	**Barrow Strait to Pond Inlet**
Saturday, 19 October (UTC-5h)	**Pond Inlet to Baffin Bay**
Sunday, 20 October (UTC-4h)	**Baffin Bay to Davis Strait**
	Bring clocks forward by 1 hour
Monday, 21 October (UTC-4h)	**Davis Strait to Killinek**
15:57 to 16:57	Transfer fuel drums to Killinek
Tuesday, 22 October (UTC-4h)	**Hudson Strait to Labrador Sea**
Wednesday, 23 October (UTC-4h)	**Labrador Sea to Strait of Belle Isle**
Thursday, 24 October (UTC-4h)	**Strait of Belle Isle to Anticosti**
Friday, 25 October (UTC-4h)	**Anticosti to Tadoussac**
Saturday, 26 October (UTC-4h)	**Tadoussac to Quebec City**
09:30	Coast Guard base Quebec City
10:00	End of expedition, scientists debark ship

Appendix 2. CTD cast log sheet of the CASES2002 expedition

CAST#	STATION #	STATION TYPE	START DATE UTC	START TIME UTC	LAT. (N)	LONG. (W)	BOTTOM (M)	CAST (M)
001 D	001	CTD	22/9/02	1610	70 21.01	123 53.88	318	312
001 U	001		22/9/02	1631	70 21.12	123 53.88		312
002 D	002	CTD	22/9/02	1930	70 23.17	124 12.26	260	258
002 U	002		22/9/02	1945	70 23.22	124 12.10		252
003 D	018	BASIC	23/9/02	0626	70 19.20	126 51.42	237	229
003 U	018		23/9/02	0638	70 19.04	126 50.92		227
004 D	019	CTD	23/9/02	1032	70 24.30	126 59.06	256	249
004 U	019		23/9/02	1043	70 24.32	126 58.88	256	251
005 D	020	CTD	23/9/02	1132	70 29.33	127 05.99	213	204
005 U	020		23/9/02	1141	70 29.33	127 05.86	213	204
006 D	021	BASIC	23/9/02	1353	70 34.21	127 13.03	267	249
006 U	021		23/9/02	1402	70 34.22	127 12.96	267	249
007 D	022	CTD	23/9/02	1705	70 38.96	127 19.87	246	239
007 U	022		23/9/02	1714	70 38.90	127 19.65	246	239
008 D	023	CTD	23/9/02	1857	70 44.21	127 29.91	192	175
008 U	023		23/9/02	1904	70 44.23	127 29.91	192	175
009 D	024	FULL	24/9/02	0951	70 49.30	127 40.39	151	136
009 U	024		24/9/02	1007	70 49.27	127 40.67	151	139
010 D	024	FULL	24/9/02	1230	70 45.89	127 36.55	168	54
010 U	024		24/9/02	1237	70 45.90	127 36.51	168	54
011 D	024	FULL	24/9/02	1353	70 46.83	127 35.02	165	49
011 U	024		24/9/02	1401	70 46.80	127 34.75	165	49
012 D	024	FULL	24/9/02	1700	70 44.70	127 29.26	190	174
012 U	024		24/9/02	1728	70 44.74	127 29.19	190	174
013 D	025	CTD	25/9/02	0309	70 54.23	127 49.61	116	110
013 U	025		25/9/02	0318	70 54.14	127 49.44		111
014 D	026	CTD	25/9/02	0503	70 59.44	128 00.01	66	63
014 U	026		25/9/02	0509	70 59.38	128 00.03		64
015 D	027	BASIC	25/9/02	0632	71 04.41	128 10.07	60	49
015 U	027		25/9/02	0639	71 04.41	128 10.01	60	49
016 D	028	CTD	25/9/02	0954	71 09.81	128 20.65	62	50
016 U	028		25/9/02	1001	71 09.89	128 20.83	62	50
017 D	029	CTD	25/9/02	1132	71 14.90	128 30.30	56	44
017 U	029		25/9/02	1138	71 14.95	128 30.29	56	44
018 D	030	BASIC	25/9/02	1318	71 19.83	128 40.13	59	49
018 U	030		25/9/02	1326	71 19.87	128 40.33	59	50
019 D	031	CTD	25/09/02	1620	71 24.83	128 49.45	84	78
019 U	031		25/09/02	1627	71 24.79	128 49.45	84	78
020 D	032	CTD	25/09/02	1801	71 29.79	129 00.05	183	192
020 U	032		25/09/02	1812	71 29.71	129 00.07	183	192
021 D	033	BASIC	25/9/02	2023	71 34.88	129 11.02	258	242
021 U	033		25/9/02	2035	71 34.88	129 11.34	258	242
022 D	034	CTD	26/9/02	0027	71 40.18	129 19.92	292	273
022 U	034		26/9/02	0037	71 40.23	129 19.94		273
023 D	035	CTD	26/9/02	0146	71 38.69	129 38.98	294	277
023 U	035		26/9/02	0200	71 38.66	129 38.83		
024 D	036	BASIC	26/9/02	0328	71 37.38	129 58.02	250	230
024 U	036		26/9/02	0337	71 37.38	129 58.15		
025 D	037	CTD	26/9/02	0721	71 35.99	130 16.49	245	228

025 U	037		26/9/02	0730	71 35.92	130 16.71	245	230
026 D	038	CTD	26/9/02	0858	71 31.47	130 34.45	214	196
026 U	038		26/9/02	0905	71 31.40	130 34.53	214	202
027 D	039	BASIC	26/9/02	1031	71 26.17	130 54.71	309	295
027 U	039		26/9/02	1042	71 26.10	130 55.04	309	298
028 D	040	CTD	26/9/02	1540	71 31.81	131 12.44	389	380
028 U	040		26/9/02	1550	71 31.80	131 12.55	389	380
029D	041	CTD	26/09/02	1833	71 30.59	131 32.52	582	560
029U	041		26/09/02	1849	71 30.51	131 32.78	569	
030D	042	BASIC	26/09/02	2102	71 32.2	131 51.48	571	572
030U	042		26/09/02	2118	71 32.16	131 51.76	590	
031 D	043	CTD	27/9/02	0503	71 37.32	132 11.26	572	570
031 U	043		27/9/02	0517	71 37.37	132 11.55	572	570
032 D	044	CTD	27/9/02	0730	71 36.20	132 31.89	562	555
032 U	044		27/9/02	0743	71 36.28	132 32.33	562	555
033 D	045 a	BASIC	27/9/02	0938	71 36.09	132 49.93	1000	961
033 U	045 a		27/9/02	0959	71 34.20	132 50.46	1000	965
034 D	045 b	BASIC	27/9/02	1215	71 35.24	132 53.79	1036	71
034 U	045 b		27/9/02	1223	71 35.32	132 53.96	1036	71
035 D	046	CTD	27/09/02	1443	71 37.76	133 06.19	662	657
035 U	046		27/09/02	1500	71 37.81	133 05.94	662	657
036 D	046	CTD	27/09/02	1608	71 39.16	133 03.76	1386?	1162
036 U	046		27/09/02	1635	71 39.27	133 03.55	1172	1162
037 D	047	CTD	27/09/02	1900	71 40.69	133 33.86	1260?	1419
037 U	047		27/09/02	1935	71 40.69	133 34.23	1429	1419
038 D	048	FULL	28/9/02	0141	71 43.87	133 58.68	1372	1605
038 U	048		28/9/02	0233	71 43.87	133 58.18		1600
039 D	049		28/09/02	1956	71 27.12	133 46.52	1000	961
039 U	049		28/09/02	2023	71 26.97	133 46.73	968	
039 V	049		28/09/02	2104	71 26.84	133 46.52	968	
040 D	049	FULL	29/9/02	0223	71 27.07	133 47.20	989	401
040 U	049		29/9/02	0234	71 27.03	133 47.21		406
041 D	049	FULL	29/9/02	0940	71 27.01	133 46.92	987	92
041 U	049		29/9/02	0949	71 27.01	133 46.93	987	92
042 D	049	FULL	29/9/02	1103	71 26.82	133 46.97	1022	91
042 U	049		29/9/02	1110	71 26.78	133 46.97	1022	92
043 D	050	CTD	29/09/02	1838	71 22.14	133 44.98	1060	1040
043 U	050		29/09/02	1902	71 22.12	133 45.28	1060	
044 D	051	CTD	29/09/02	2048	71 17.02	133 43.81	907	878
044 U	051		29/09/02	2111	71 16.93	133 44.15	888	878
045 D	52	CTD	29/9/02	2220	71 11.64	133 43.03	689	662
045 U	52		29/9/02	2239	71 11.55	133 43.41		665
046 D	53	BASIC	29/9/02	2336	71 06.58	133 42.09	415	388
046 U	53		29/9/02	2350	71 06.51	133 42.48		389
047 D	53	BASIC	30/9/02	0215	71 06.48	133 42.16	407	78
047 U	53		30/9/02	0222	71 06.43	133 42.52		78
048 D	54	CTD	30/9/02	0325	71 01.51	133 41.58	154	153
048 U	54		30/9/02	0333	71 01.46	133 41.54	163	153
049 D	55	CTD	30/9/02	0427	70 56.30	133 40.10	87	73
049 U	55		30/9/02	0433	70 56.31	133 40.26		
050 D	56	BASIC	30/9/02	0542	70 51.20	133 39.24	77	66
050 U	56		30/9/02	0554	70 51.26	133 39.59	77	68
051 D	57	CTD	30/9/02	0837	70 46.16	133 37.72	66	60
051 U	57		30/9/02	0843	70 46.17	133 37.74	66	60
052 D	58	CTD	30/9/02	0944	70 40.94	133 36.83	64	58

052 U	58		30/9/02	0950	70 40.93	133 36.82	64	58
053 D	59	BASIC	30/9/02	1305	70 35.56	133 35.13	69	60
053 U	59		30/9/02	1313	70 35.53	133 35.23	69	60
054 D	60	CTD	30/09/02	1444	70 30.76	133 34.99	70	57
054 U	60		30/09/02	1453	70 30.75	133 35.30	70	57
055 D	61	CTD	30/09/02	1556	70 25.50	133 34.04	61	51
055 U	61		30/09/02	1603	70 25.40	133 34.20	61	51
056 D	62	BASIC	30/09/02	1940	70 20.39	133 33.26	62	51
056 U	62		30/09/02	1947	70 20.31	133 32.41	62	51
057 D	63	CTD	30/09/02	2140	70 15.37	133 32.08	52	41
057 U	63		30/09/02	2148	70 15.36	133 32.11	52	41
058 D	64	CTD	30/9/02	2244	70 10.08	133 30.91	45	33
058 U	64		30/9/02	2251	70 10.08	133 30.97	45	33
059 D	65	FULL	02/10/02	1133	70 08.75	133 30.69	43	31
059 U	65		02/10/02	1137	70 08.75	133 30.81	43	31
060 D	65	FULL	02/10/02	1236	70 08.68	133 30.91	42	31
060 U	65		02/10/02	1241	70 08.70	133 31.03	42	31
061 D	65	FULL	2/10/02	2306	70 08.81	133 31.31	44	31
061 U	65		2/10/02	2311	70 08.77	133 31.31		31
062 D	65	FULL	3/10/02	0444	70 08.74	133 30.87	43	30
062 U	65		3/10/02	0448	70 08.75	133 30.86		
063 D	65	FULL	3/10/02	1955	70 08.79	133 30.62	43	31
063 U	65		3/10/02	2002	70 08.79	133 30.65	43	
064 D	66	FULL	4/10/02	0653	70 51.23	133 39.00	78	65
064 U	66		4/10/02	0659	70 51.26	133 38.94	78	65
065 D	66	FULL	4/10/02	1103	70 51.16	133 38.99	78	50
065 U	66		4/10/02	1109	70 51.10	133 38.98	78	50
066 D	66	FULL	4/10/02	1301	70 51.22	133 38.93	78	41
066 U	66		4/10/02	1306	70 51.20	133 38.97	78	41
067D	66	FULL	4/10/02	1929	70 51.05	133 39.18	78	65
067U	66		4/10/02	1936	70 51.08	133 39.11	78	65
068 D	67	CTD	5/10/02	0549	70 51.59	133 21.68	70	57
068 U	67		5/10/02	0555	70 51.54	133 21.57		
069 D	68	CTD	5/10/02	0703	70 53.12	133 04.11	69	56
069 U	68		5/10/02	0707	70 53.13	133 04.14	69	56
070 D	69	BASIC	5/10/02	1008	70 54.78	132 45.54	68	56
070 U	69		5/10/02	1013	70 54.81	132 45.58	68	56
071 D	70	CTD	5/10/02	1315	70 56.21	132 26.66	65	52
071 U	70		5/10/02	1323	70 56.29	132 26.36	65	53
072 D	71	CTD	5/10/02	1732	70 57.59	132 06.21	64	54
072 U	71		5/10/02	1738	70 57.62	132 06.14	64	54
073 D	72	BASIC	5/10/02	1852	70 59.10	131 48.97	62	56
073 U	72		5/10/02	1859	70 59.05	131 48.64	62	56
074 D	73	CTD	5/10/02	2325	71 01.24	131 33.33	64	60
074 U	73		5/10/02	2331	71 01.32	131 33.32		59
075 D	74	CTD	6/10/02	0031	71 02.34	131 13.83	63	50
075 U	74		6/10/02	0038	71 02.35	131 14.00	63	50
076 D	75	BASIC	6/10/02	0202	71 03.76	130 55.39	57	54
076 U	75		6/10/02	0211	71 03.80	130 55.03		53
077 D	76	CTD	6/10/02	0520	71 05.27	130 38.74	50	39
077 U	76		6/10/02	0526	71 05.21	130 38.23		
078 D	77	CTD	6/10/02	0654	71 07.09	130 18.44	49	37
078 U	77		6/10/02	0658	71 07.11	130 18.37	49	37
079 D	78	BASIC	6/10/02	1028	71 08.42	130 01.95	46	34
079 U	78		6/10/02	1035	71 08.37	130 01.59	46	34

080 D	79	CTD	6/10/02	1155	71 09.75	129 42.58	46	34
080 U	79		6/10/02	1201	71 09.67	129 42.28	46	34
081 D	80	CTD	6/10/02	1403	71 11.36	129 23.84	47	36
081 U	80		6/10/02	1411	71 11.38	129 23.52	47	36
082 D	81	BASIC	6/10/02	1735	71 12.38	129 09.31	48	36
082 U	81		6/10/02	1741	71 12.39	129 08.91	48	36
083 D	82	CTD	6/10/02	1905	71 14.64	128 47.08	55	43
083 U	82		6/10/02	1911	71 14.64	128 47.02	55	43
084 D	83	FULL	6/10/02	2155	71 15.52	128 27.76	55	43
084 U	83		6/10/02	2201	71 15.54	128 27.59		44
085 D	83	FULL	7/10/02	0812	71 15.89	128 28.83	55	10.2
085 U	83		7/10/02	0815	71 15.90	128 28.71	55	10.2
086 D	83	FULL	7/10/02	1103	71 15.82	128 30.86	54	43
086 U	83		7/10/02	1108	71 15.76	128 30.57	54	43
087 D	83	FULL	7/10/02	1259	71 15.73	128 30.51	55	29.5
087 U	83		7/10/02	1303	71 15.68	128 30.48	55	29.5
088 D	84	CTD	7/10/02	2321	71 17.44	128 11.33	82	68
088 U	84		7/10/02	2326	71 17.43	128 11.14		68
089 D	85	CTD	8/10/02	0100	71 18.92	127 53.42	160	150
089 U	85		8/10/02	0118	71 18.52	127 52.96		151
090 D	86	BASIC	8/10/02	0754	71 22.04	127 29.31	270	252
090 U	86		8/10/02	0808	71 22.20	127 29.74	270	256
091 D	87	CTD	8/10/02	1003	71 22.17	127 13.21	340	305
091 U	87		8/10/02	1015	71 22.29	127 12.70	340	310
092 D	88	CTD	8/10/02	1201	71 23.74	127 01.11	379	368
092 U	88		8/10/02	1211	71 23.76	127 11.74	379	362
093 D	89	BASIC	8/10/02	1634	71 24.82	126 40.68	458	150
094 D	89	BASIC	8/10/02	1745	71 24.55	126 44.52	455	429
094 U	89		8/10/02	1806	71 24.11	126 45.15	455	430
095 D	90	CTD	8/10/02	2039	71 21.63	126 28.26	472	450
095 U	90		8/10/02	2054	71 21.77	126 28.42	472	451
096 D	91	CTD	8/10/02	2210	71 18.06	126 15.18	457	435
096 U	91		8/10/02	2224	71 18.21	126 15.08		
097 D	92	BASIC	9/10/02	0227	71 14.07	125 58.77	395	386
097 U	92		9/10/02	0243	71 14.26	125 58.32		379
098 D	93	CTD	9/10/02	0406	71 11.31	125 49.96	403	381
098 U	93		9/10/02	0419	71 11.51	125 49.38		384
099 D	94	CTD	9/10/02	0605	71 07.76	125 38.40	415	400
099 U	94		9/10/02	0616	71 07.82	125 38.48	415	400
100 D	95	BASIC	9/10/02	1000	71 04.24	125 26.13	347	329
100 U	95		9/10/02	1011	71 04.28	125 26.26	347	330
101 D	96	CTD	9/10/02	1157	71 00.85	125 13.60	348	328
101 U	96		9/10/02	1205	71 00.83	125 13.55	348	329
102 D	97	CTD	9/10/02	1403	70 57.30	125 01.50	390	372
102 U	97		9/10/02	1416	70 57.32	125 01.54	390	372
103 D	98	BASIC	9/10/02	1803	70 53.73	124 49.00	367	351
103 U	98		9/10/02	1823	70 53.54	124 48.95	367	352
104 D	99	BASIC	9/10/02	2107	70 50.36	124 37.71	417	411
104 U	99		9/10/02	2120	70 50.32	124 37.92	442	411
105 D	100	CTD	9/10/02	2257	70 46.77	124 25.14	459	437
105 U	100		9/10/02	2310	70 46.83	124 25.23		439
106 D	101	FULL	10/10/02	0202	70 43.59	124 12.47	529	510
106 U	101		10/10/02	0216	70 43.68	124 12.51		
107 D	101	FULL	10/10/02	1009	70 43.70	124 11.73	502	479
107 D	101		10/10/02	1020	70 43.70	124 11.64	502	480

108 D	101	FULL	10/10/02	1128	70 43.39	124 11.05	446	429
108 D	101		10/10/02	1141	70 43.35	124 10.96	446	429
109 D	101	FULL	10/10/02	1257	70 43.48	124 11.19	449	41
109 U	101		10/10/02	1302	70 43.48	124 11.13	449	41
110 D	17	CTD	11/10/02	0557	70 13.32	126 41.32	214	193
110 U	17		11/10/02	0605	70 13.20	126 41.12	214	193
111 D	16	CTD	11/10/02	0710	70 09.04	126 37.14	223	209
111 U	16		11/10/02	0720	70 08.85	126 36.78	223	209
112 D	15	BASIC	11/10/02	0858	70 05.18	126 31.78	237	219
112 U	15		11/10/02	0909	70 04.98	126 31.44	237	219
113 D	14	CTD	11/10/02	1304	70 00.42	126 22.60	212	196
113 U	14		11/10/02	1313	70 00.31	126 22.27	212	196
114 D	13	CTD	11/10/02	1458	69 55.72	126 15.37	194	178
114 U	13		11/10/02	1508	69 55.71	126 15.07	194	178
115 D	12	FULL	12/10/02	0056	69 49.68	126 08.47	150	140
115 U	12		12/10/02	0104	69 49.54	126 08.08		
116 D	12	FULL	12/10/02	0858	69 50.16	126 09.15	153	138
116 U	12		12/10/02	0917	69 50.17	126 08.76	153	141
117 D	12	FULL	12/10/02	1056	69 49.89	126 09.89	149	133
117 U	12		12/10/02	1107	69 49.85	126 08.71	149	133
118 D	12	FULL	12/10/02	1254	69 50.20	126 09.77	154	10
118 U	12		12/10/02				154	10
119 D	11	CTD	12/10/02	1819	69 54.70	126 00.32	157	146
119 U	11		12/10/02	1835	69 54.60	126 59.52	153	146
120 D	10	CTD	12/10/02	1957	70 00.11	125 58.62	182	166
FROM	**NOW**		**ON:**	**ONLY**	**ONE**	**CAST**	**PER**	
121 D	9	BASIC	12/10/02	2207	70 05.68	125 51.49	140	124
122	8	CTD	12/10/02	2359	70 10.50	125 43.40	149	131
123	7	CTD	13/10/02	0133	70 16.45	125 38.49	240 ?	219
124	6	BASIC	13/10/02	0401	70 20.75	125 30.00	200	188
125	5	CTD	13/10/02	0615	70 25.17	125 12.17	170	155
126	4	CTD	13/10/02	0744	70 25.46	125 50.40	132	112
127	3	BASIC	13/10/02	1000	70 25.55	124 31.28	182	164
128	102	CTD	13/10/02	1259	70 39.98	123 59.76	432	450
129	103	CTD	13/10/02	1428	70 39.60	123 43.93	503	477
130	104	BASIC	13/10/02	1606	70 39.50	123 27.14	407	396
131	105	CTD	13/10/02	2136	70 39.40	123 11.66	540	526
132	106	CTD	13/10/02	2306	70 39.40	122 51.87	552	528
133	107	BASIC	14/10/02	0138	70 38.20	122 38.18	516	484
134	108	CTD	14/10/02	0316	70 38.98	122 21.60	536	520
135	109	CTD	14/10/02	0429	70 37.62	122 04.70	571?	482
136	110	BASIC	14/10/02	0706	70 35.58	121 50.17	537	502

Appendix 3. CASES2002 science party

1. Amiel, David	davidamiel86@hotmail.com
2. Barber, David	dbarber@Ms.UManitoba.CA
3. Buzinski, Tara	tarab@mun.ca
4. Braekevelt, Eric	BraekeveltE@dfo-mpo.gc.ca
5. Caron, Gitane	gitanecaron@hotmail.com
6. Deibel, Don	ddeibel@morgan.ucs.mun.ca
7. Deming, Jody	jdeming@u.washington.edu
8. Desmeules, Gilles	Gilles_Desmeules@uqar.qc.ca
9. Fortier, Martin	martin.fortier@giroq.ulaval.ca
10. Francey, Mary-Ann	
11. Helm, Paul	HelmPA@DFO-MPO.GC.CA
12. Kolker, Alex	kolker@msrc.sunysb.edu
13. Konig, Chris	konigc@CIMS.nyu.edu
14. Lacoste, Karine	karine_lacoste@uqar.qc.ca
15. Leblanc, Bernard	Leblancbe@dfo-mpo.gc.ca
16. Létourneau, Louis	louis.letourneau@giroq.ulaval.ca
17. Martineau, Christine	christine.martineau@giroq.ulaval.ca
18. Michaud, Luc	luc.michaud@giroq.ulaval.ca
19. Michel, Christine	Michelc@dfo-mpo.gc.ca
20. Miller, Lisa A.	millerli@pac.dfo-mpo.gc.ca
21. Minnett, Peter	pminnett@rrsl.rsmas.miami.edu
22. Nozais, Christian	christian_nozais@uqar.uquebec.ca
23. Ortmann, Alice	ortmann@interchange.ubc.ca
24. Owens, Owen	oowens@shaw.ca
25. Papakyriakou, Tim	Tim_Papakyriakou@umanitoba.ca
26. Prokopowicz, Anna	anna.prokopowicz@giroq.ulaval.ca
27. Rail, Marie-Emmanuelle	marie-emmanuelle_rail@inrs-ete.uquebec.ca
28. Robert, Marie	RobertM@pac.dfo-mpo.gc.ca
29. Rolland, Nicolas	nicolas.rolland@giroq.ulaval.ca
30. Simard, Melanie	melsimard16@yahoo.ca
31. Tremblay, Jean-Eric	jett@globetrotter.qc.ca
32. Vincent, Warwick F.	warwick.vincent@bio.ulaval.ca
33. Wells, Llyd	chimera1@ocean.washington.edu