Changing Arctic Ocean Seafloor JR18006 Cruise Report

Barnes DKA, Andrade L, Braun J, Broad E, Brunner L, Downes P, Dixon J, Ensor N, Evans J, Faust J, Godbold J, Henley S, Jones R, May R, McAfee C, Mesher T, Murdoch I, Owen R, Reed A, Rühl S, Sales de Freitas F, Stevenson M, Venables E, Vincent S, Walkinshaw C, Williams T, Wood C, Zaencker B & Zindorf M

RRS James Clark Ross Cruise JR18006
29th June – 2nd August 2019


Changing Arctic Ocean
Natural Environment Research Council

Acknowledgements - We are grateful to the captain, officers and crew of the RRS James Clark Ross for their efforts in making this cruise a success. We also thank our cruise manager Jeremy Evans for his support during the cruise planning and mobilization.

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1. Introduction and cruise summary

1.1 Background and scientific motivation

Arctic environments are amongst the most rapidly physically changing places on Earth. This is most visibly obvious in the decreasing concentrations and extent of sea ice. Atmospheric and oceanic temperatures are increasing strongly as are fresh water discharge and stratification. Mixing and circulation regimes are altering. Such changes impact the entire Arctic ecosystem, from sea surface to sea floor. For example, longer and more expansive open water periods influence the timing and longevity of phytoplankton blooms which are important for sustaining life at all trophic levels, from tiny zooplankton in the water column and microscopic benthic fauna, right up to the whales and seals at the top of the food chain. Changes in the light and nutrient regimes have consequences on quantity and quality of particulate and dissolved organic matter, nutrient cycling in water and sediments, and consequently biodiversity and its role in ecosystem functioning. The Changing Arctic Ocean Seafloor project focusses on seabed geochemical and biological changes, what drives them and why they matter.

In 2017 the Natural Environment Research Council (NERC) started an investment of £16 million in its 5-year Changing Arctic Ocean Programme (www.changing-arctic-ocean.ac.uk). The overarching aim of the programme is to better understand and quantify the impacts of climate change on Arctic ecosystems. The findings will ultimately inform our conservation and management strategies of polar regions. Four large projects were initially funded: ARISE (led by Claire Mahaffey, Uni. Liverpool), Arctic PRIZE (led by Finlo Cottier, SAMS), DIAPOD (led by David Pond, SAMS) and our one; ChAOS (led by Christian März, Uni. Leeds).

JR18006 was the third of three Changing Arctic Ocean Seafloor cruises to the Barents Sea. The overarching aim of the cruise was to collect a suite of pelagic and benthic samples across water mass (Atlantic to Arctic) and sea-ice gradients to enable:

- Determination of dissolved and particulate organic material and inorganic nutrient dynamics
- Estimation of water column primary production, phytoplankton community composition, photo-physiology and biomass
- Foodweb tracer analysis using stable isotopes techniques
- A mapping of the baseline ‘isoscape’
- Determination of the sediment and pore water geochemistry - organic material degradation and interactions with biological processes (e.g., bioturbation)
- Determination of the structure, function (e.g. nitrogen cycling, bioturbation), diversity and reproductive state of benthic communities (from epifauna to meiofauna)
- Determination of seabed microbial community production and diversity

In the third cruise we again attempted to visit the five core stations (B13-B17) along the 30 E meridian line in the Barents Sea. Our science objective was firstly to run CTDs to investigate; a) nutrient cycling, b) N and Si isotopes, c) uptake of inorganic and organic N compounds, d) dissolved oxygen, nutrients and chlorophyll, e) organic N and S cycling, f) microbial production, g) extracellular enzyme activity and h) bacterial and fungal communities. We then used a plankton net to look at; a) water column productivity, b) primary production, and c) species composition. We also collected sea ice for biochemical analyses. We used mega/multicore to collect short sediment cores to analyse sediment and porewater geochemistry and longer cores using a gravity corer. Box core collection enabled us to investigate sediment erodibility, exchange processes, nitrogen cycling, faunal biodiversity and provide sediment and specimens for investigation of bioirrigation and community functioning. Our underwater camera was used to image epifauna to estimate wider composition and densities of functional groups. Finally we collected mega and macro fauna on the larger scale for specimens for experimental work and to derive carbon content with Agassiz trawls.

1.2 Scientific and ships personnel

Scientific personnel

David Barnes	British Antarctic Survey	ChAOS (PSO)
Robyn Owen	British Oceanographic Data centre	CAO
Birthe Zaencker	Marine Biological Association of UK	MicroARC
Joanna Dixon	Plymouth Marine Laboratory	DMS
Patrick Downes	Plymouth Marine Laboratory	ChAOS
Rebecca May	Plymouth Marine Laboratory	ChAOS
Thomas Mesher	Plymouth Marine Laboratory	ChAOS
Saskia Ruhl	Plymouth Marine Laboratory	ChAOS
Chris Walkinshaw	Plymouth Marine Laboratory	ChAOS
Judith Braun	Scottish Association for Marine Science	PRIZE
Lars Brunner	Scottish Association for Marine Science	ChAOS
Emily Venables	Scottish Association for Marine Science	PRIZE
Johan Faust	University of Leeds	ChAOS
Felipe Sales de Freitas	University of Bristol	ChAOS
Rhiannon Jones	University of Bristol	ChAOS
Mark Stevenson	Newcastle University	ChAOS
Luiza Andrade	Newcastle University	ChAOS
Emmeline Broad	University of Southampton	ChAOS
Jasmin Godbold	University of Southampton	ChAOS
Adam Reed	University of Southampton	ChAOS
Thomas Williams	University of Southampton	ChAOS
Christina Wood	University of Southampton	ChAOS
Sian Henley	University of Edinburgh	ChAOS/PRIZE
Mark Zindorf	IFREMER	ChAOS

Engineering and IT personnel

Jez Evans	National Marine Facilities	NMF
Ian Murdoch	National Marine Facilities	NMF
Natalie Ensor	British Antarctic Survey	AME
Carsen McAfee	British Antarctic Survey	AME
Sean Vincent	British Antarctic Survey	IT

Ships compliment

Graham Chapman	Master
Simon Wallace	Chief officer
Pete Flynn	2nd officer
Scott Cramman	3rd officer
Gail McGregor	3rd officer
Patrick O'Hara	ETO Comms
Robert Gibson	Chief Engineer
Chris Donaldson	2nd Engineer
Aleksandr Hardy	3rd Engineer
Steve Eadie	4th Engineer

Robert Sutton	Deck Engineer
Douglas Stevens	ETO
Lloyd Sutton	Purser
Amber Chadwick	Doctor
Cliff Mullaney	Bosun/Sci'Ops
John O'Duffy	Bosun
Craig Lennon	Bosun's Mate
Steven Picton	Motorman
Carlos Vargas Leon	Motorman
Arnis Macans	Motorman
Samuel Bonsu	Seaman
Mark McMahon	Seaman
Colin McMaster	Seaman
Robert Leech	Seaman
Alan Howard	Seaman
Victoria Stone	Chief Cook
David Noble	2nd Cook
Derek Lee	Senior Steward
Russell Covey	Steward
David Williams	Steward
Oliver Burch	Steward

1.3 Cruise diary

Date	Weather/Ice	Activities
28/06/2019	Warm and sunny	Mobilization begins Harwich
30/06/2017	Warm and sunny	Leave Harwich for Transit to Tromsø
04/06/2017	Overcast, calm	Load test coring wire, organise labs
05/06/2017	Overcast, calm	Arrive off Tromsø, drop transit pax & pick up ChAOS pax & spare liquid N dewar
06/06/2017	Swell	Load test of CTD wire. CTD, SUCS and Plankton net tested at site south of B13,
07/07/2019	Sunny, calm	**B13**. Arrive and start science sequence. CTD (1), Plankton Net (1), SUCS (3), Multicore (3).
08/07/2019	Overcast, calm	**B13**. Continue science sequence. After last Multicore; Gravity Core (2), Multibeam swath, USNL box cores (14 [1 fail]), SMBA box cores (18).
09/07/2019	Overcast, calm	**B13**. Continue science sequence. After last SMBA box core; AGT tows (8), transit to B15
10/07/2019	Swell, rare drift ice	**B15**. Arrive and start science sequence. CTD (2), Plankton Net (1), SUCS (3), Multicore (3).
11/07/2019	Overcast, calm	**B15**. Continue science sequence. After last Multicore; Gravity Core (1), Multibeam swath, USNL box cores (14 [1 fail]), SMBA box cores (11), AGT (6).
12/07/2019	Sunny, calm	After AGTs finished transit south to B14
13/07/2019	Overcast, calm	**B14**. Arrive and start science sequence. CTD (2), Plankton Net (1), SUCS (4), Multicore (3), Gravity Core (1), Multibeam, SMBA box core (6) 7 USNL box core (14).
14/07/2019	Overcast, calm	**B14**. Continue science sequence. After last box core; AGT tows (7) then proceed to B16
15/07/2019	Overcast, swell, brash ice with small floes	Ice edge CTD
16/07/2019	9/10 broken 1st yr ice	**B16**. Arrive and start science sequence. CTD (2), Plankton Net (1), SUCS (2), Multicore (5), [no Gravity Core or multibeam], USNL box cores (13).
17/07/2019	9/10 broken 1st yr ice	**B16**. Continue science sequence. After last USNL box core; SMBA box cores (8), [no AGT tows], SUCS (2) and ice sampling. Then headed south for Longyearbyen
20/07/2019	re-enter open water, swell 25 knots then calm	Transit, drop 1 pax at Longyearbyen, then head north to Mooring site (west)
21/07/2019	5/10 to 10/10 ice, calm	Arrive Mooring site west. CTD.
22/07/2019	10/10 to 5/10 ice, calm	Plankton net, CTD, ice algae collection attempts then head south to B13
24/07/2019	Calm, open water	**B13**, Arrival and start AGT tows.
25/07/19	Calm, open water	**Y**, Arrival, SUCS, MUC and GC, then transit on to B3.

26/07/19	Swell, open water	**B3**, Arrival and start sequence of deployments; CTD, PN, CTD, SUCS (3), MUC (4), GC and box cores
27/07/19	Swell, open water	**B3**, Complete boxcores (13 + 7 fails) and trawls (6) and head for deep water transit to Aberdeen.
28/07/19	Swell, sunny	Transit. Packing, BOLs, post cruise assessment & cruise report
01/08/19	Calm	**Aberdeen**. Dock and begin demob

Table provides a summary of the events that took place each day on the ship.

Station locations

Table 1.4.1. Nominal station locations and depths (from IBACO bathymetry). Please refer to the cruise event log for the exact locations and depths of each activity at these stations.

Station	**Latitude**	**Longitude**	**Nominal depth (m)**	
B3	72° 38'N	19° 15' E	368	Opportunistic samples
B13	74° 30' N	30° E	363	Core ChAOS site
B14	76° 30' N	30° 30' E	294	Core ChAOS site
B15	78° 15' N	30° E	269	Core ChAOS site
B16	80° 6' N	30° E	287	Core ChAOS site
Y	73° 53'N	26° 34' E	456	Opportunistic samples
B50	72° 38' N	30° E	293	Practice site
Moor 1	81° 03 N	18° 42' E	270	PRIZE core site

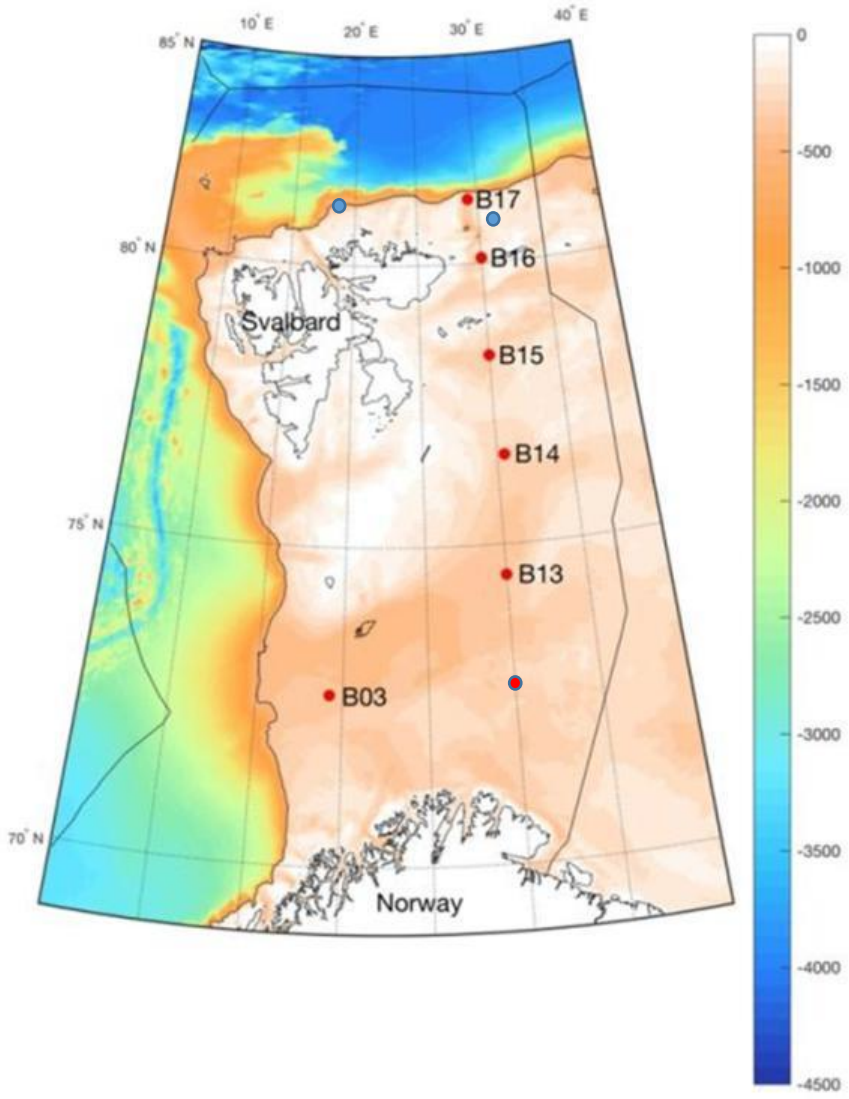


Figure 1.1 Map of planned JR18006 station locations

2. Data management, computing, hydrography & physics

2.1 Data Management

Robyn Owen, BODC - NOC

The British Oceanographic Data Centre (BODC) is the designated data centre for UK marine science along with the Polar Data Centre, BAS (PDC) when data are collected in the Arctic or Antarctica. The data collected from JR18006 will be divided between the two data centres. BODC will integrate all data into a documented, processed data set, ensuring that maximum and long-term use of the data is possible.

Event logging

A bridge log was created and maintained by the officers on watch with all events assigned a unique event number. Additional digital event logs were also created for the following deployments: CTD, SMBA box core, USNL box core, plankton net, mAGT, gravity core, multicore and SUCS. A digital log was also maintained for discrete underway salinity samples. To accompany the digital logs, paper logsheets were completed for every sampling activity using standard BODC templates.

All digital and paper logging, with the exception of the CTD casts, was completed between the PSO and data manager ensuring standard logging across all deployments. Events were also consistently cross checked against the bridge log with any discrepancies raised and resolved. Paper logsheets for the CTD deployments were completed by the AME technician.

Improvements could be made to the digital logging by ensuring that site, bridge event number and water depth are included in all logs. For coring activities, the time and position of when the core is taken should also be added as only the deployment and recovery points were recorded. This could be resolved by creating the logs with input from the scientist involved in the specific activity and not solely by the PSO and data manager.

Two opportunistic events for the sampling of sea ice algae were only recorded as paper logs and in the bridge log. Ideally all events should have been included in the digital logs. All deployments, with the exception of SUCS and mAGT, have been collated into one Event log in Appendix A using the digital logs. As metadata were not recorded in the digital logs for when corers were at the seabed, metadata were also taken from paper logs and the bridge log. Separate Event logs were created for mAGT and SUCS as a deployment and recovery time and position were not required, see Appendix A. Scanned copies of all paper logsheets are available from the legdata drive onboard or from BODC post cruise.

Cruise Data Storage

All data recorded by instrumentation linked to the ships network in the legdata K: Drive and additional folders created by cruise participants in legwork L: Drive will be backed up and transferred to the Storage Area Network (SAN) at BAS. All cruise participants will have access to this area and can contact PDC or BODC for copies of data or files.

Data Submission

Data are to be submitted to either BODC or PDC as soon as a dataset is completed as agreed in the Changing Arctic Ocean Data Management Plan. Biological and bathymetric data are to be submitted to PDC with all other data to be submitted to BODC. Guidelines on best practice for submitting data can be found on the BODC website, https://www.bodc.ac.uk/data/data_submission/. Data should also be accompanied by full metadata including methods; a metadata template can be found on the above BODC

website.

Data Discovery

Data held by BODC will be processed and made available online via the National Oceanographic Database (NODB), https://www.bodc.ac.uk/data/bodc_database/nodb/. Data will be embargoed for up to two years after dataset completion, not from data submission, and so only project participants will be able to access the data during this period. Metadata will be made publically available via the NODB when the data have been processed by BODC. Any requests for data within the embargo period by a non-project member will need to be agreed with the PI.

If a citation has been requested and agreed for a dataset, a Digital Object Identifier (DOI) will be minted and the dataset will be available for download, along with the citation, from https://www.bodc.ac.uk/data/published_data_library/. Any further data or metadata that is held by BODC can be requested by contacting Robyn Owen, rowen@bodc.ac.uk or enquiries@bodc.ac.uk.

Data held at PDC is discoverable using the Discovery Metadata System (www.bas.ac.uk/project/dms/) or by contacting Katy Buckland, Scientific Data Co-ordinator, polardatacentre@enquiries.ac.uk.

2.2 Computing

Sean Vincent British Antarctic Survey

2.2a timeline

30th June a new Leg was started for the transit to Tromsø, with the intention of starting another leg for the start of the science cruise (18006).
Terminated Ethernet cable to ISO lab.
1st July Ksync, ADCP and EK60 were started following the Cue Cards.
2nd July PSO requested that the Cruise Log be started before the ships' arrival at Tromsø. The new Cruise log was created, but the current leg was kept open for the cruise, and the IT cruise log amended to link the cruise leg, to JR18006.
3rd July SCS was not sending data to CTD PC. An error message was displayed when attempting to start 'SCS message send'. The SCS server was restarted and 'SCS message send' to CTD started successfully.
4th July Email from James France. He could not connect to the Picarro CF2220 PC via TeamViewer. A Google Remote Desktop was set up to connect to the CF220 PC. Details were recorded in the WiKi.
An Email alert was received from 'Cron Demon:' "*lockfile: Sorry, giving up on "/users/jcrdata/.em122"*. Em122 PC was rebooted; no further alerts have been received.
5th July Google Remote Desktop was set up to connect to the second Picarro PC.
6th July the EM122 SIS software started and tested. An email was received from Alice Fremand (via Jeremy Robst) with an attached GeoTiff image, to test if it would upload in SIS (Em122). The image was successfully uploaded to SIS and Helmsman.
NOTE: There is a bug in the SIS and Helmsman software. When the software is first started, the selector buttons in the Import/Export dialog are greyed-out, and so it is not possible to select the 'Background Image'. To resolve the issue briefly start then stop pinging, and the selector buttons will become useable.
Connected SUCS PC to the Data LAN. Split the SUCS video output, and routed it the CLAM display on the Bridge.
8th July EM122 Helmsman program was not displaying Swath scan lines, however they were displayed when logging was turned on.

11th July EM122 Sound Velocity profile updated. EM122 Helmsman program not displaying Swath scan lines, even when logging. SIS Geographic display moved to the bridge screen to aid crew in maintaining course/position during Swath surveys.
19th July the Plexus controller web interface was not accessible via the network switch; however it would connect when with a laptop directly connected to the Plexus PC. The router was shut down for 5 minutes which resolved the issue (a one minute shutdown had been tried previously but did not resolve the issue).
22 July the Team from the University of Southampton have an issue with the software they are using to process images. A PowerShell script were produced to move up to 1000 images into a folder and rename them, so that they could be processed by the software. A second script was produced to restore the files' original names and put them back into their original folder.

2.2b SWATH multibeam seabed mapping

Sean Vincent & David Barnes – BAS

The Em122 was started and SIS software set-up following the Em122 Start-up procedure in the JCR Wiki
All surveys were configured for opportunistic swathing using the default template:

- GridEngine Parameters
    - Depth Variable: z
    - Number of Cells in Processing Grid: 128x128
    - Cell Size (m): 125
    - Processing Parameters: Automatic
    - Advanced Options->Projections: 'Mercator_WGS84

The SVP profile was updated on 10th July using the data from the CTD cast at station B15
The following swath surveys were carried out. No survey was carried out whilst the JCR was in ice and therefore there is no survey for station B16.

18006_Test

- 6th July
- Transit to station B13

18006_a

- 8th July
- Station B13

18006_b

- 9th – 10th July
- Transit Station B13 to Station B15

18006_c

- 11th July
- Station B15

18006_d

- 11th July
- Not a survey was used as an attempt to get swath lines to display on Helmsman.

18006_e

- 12th July
- Transit Station B15 to Station B14

18006_f

- 13th July
- Station B14

18006_g

- 14th -15th July
- Transit Station B14 to Ice edge

18006_h

- 19th - 20th July
- Transit Ice edge to Longyearbyen
- Survey stopped when within 12 miles of Norwegian waters

18006_i

- 20th - 21st July
- Transit Longyearbyen to Ice edge
- Survey started outside Norwegian waters

18006_ j

- 13rd - 24th July
- Transit Ice edge to Station B13
- Survey stopped when within 12 miles of Norwegian waters

18006_k

- 25th July
- Transit Station Y to Station B3

18006_l

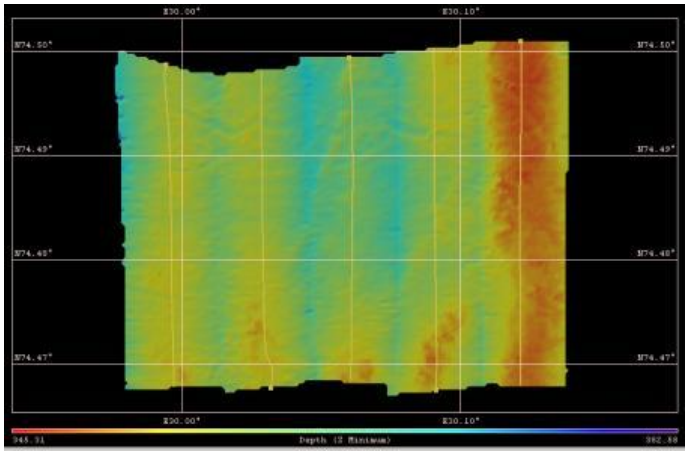
- 26th July
- Station B3

188006_ m (typing error when entering survey serial #)

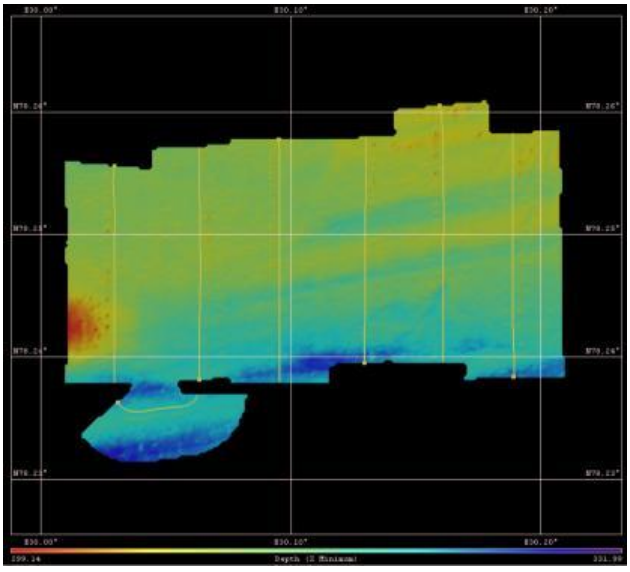
- 27rd - 28th July
- Transit Station B3 to end of trough

Screen grabs of SIS Geographical Display for surveys are shown of the areas mapped. These will later be cleaned by scientific party to give bathymetry derived seabed data.

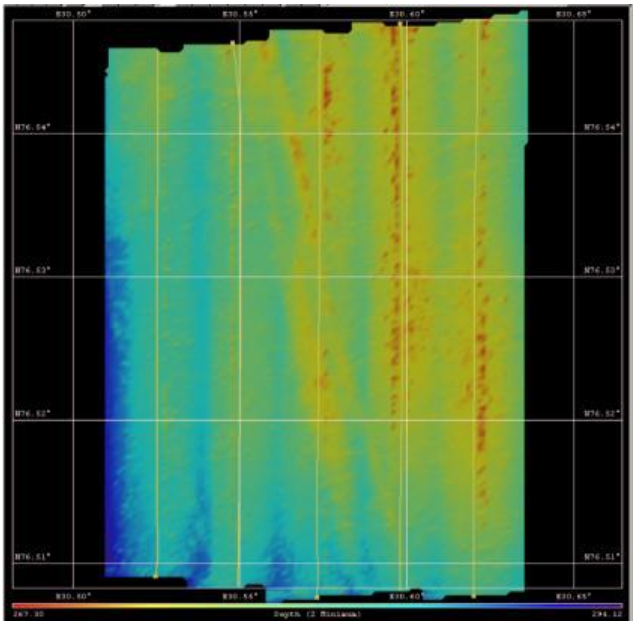
18006_a Station B13

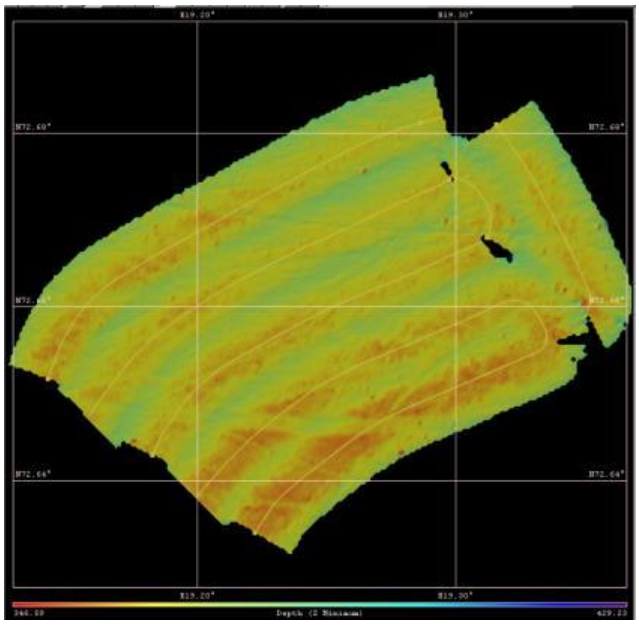


18006_c Station B15



18006_f Station B14





18006_l Station B3

2.2c ADCP

Saskia Ruhl

Ship-board underway Acoustic Doppler Current Profiler (SADCP)

SADCP data collection was almost continuous throughout the 2019 JR18006 cruise (see table below for dates and times on which it was switched on and off).

Table 2.3a SADCP timings

Start date	Start time	End date	End time	Includes measurements at stations
02.07.19	19:08	21.07.19	03:30	B13, B14, B15, B16
21.07.19	20:47	21.07.19	23:00	
21.07.19	23:08	25.07.19	08:02	B13
25.07.19	13:48	26.07.19	11:00	B3
26.07.19	19:10	27.07.19	00:00	B3
27.07.19	08:08	28.07.19	00:50	B3

2.3 Ship scientific equipment

Carson McAfee - BAS

2.3a Systems used on cruise

Instrument	#SN if Used	Make and Model	Comments
Lab Instruments			
AutoSal	63360	OSIL 8400B	
Scintillation counter	SGTC20150612	PERKINELMER TRI-CARB 2910TR	Used by external Scientist
XBT	NO		System Text Box Used
Acoustic			
ADCP	Yes		
EM122	Yes		
TOPAS	No		
EK60/80	Yes		
K-Sync	Yes		
SSU	No		
USBL	Yes	Sonardyne Ranger 2	New Beacons Added
10kHz IOS Pinger	No		
Benthos 12kHz Pinger	No		
Benthos 14kHz Pinger	No		
Mors 10kHz Transponder	No		
EA600	Yes		Bridge Equipment but logged
Oceanlogger			
Barometer1	V145002	VAISALA PTB210B1A2B	Inside the UIC
Barometer2	V145003	VAISALA PTB210B1A2B	Inside the UIC
Air humidity & temp1	61019333	Rotronic Hygroclip 2	On Foremast
Air humidity & temp2	61019251	Rotronic Hygroclip 2	On Foremast
TIR1 sensor (pyranometer)	172882	Kipp & Zonen Sp Lite2	On Foremast
TIR2 sensor (pyranometer)	172883	Kipp & Zonen Sp Lite2	On Foremast
PAR1 sensor	160959	Kipp & Zonen PQS-1	On Foremast
PAR2 sensor	160960	Kipp & Zonen PQS-1	On Foremast
Thermosalinograph	4524698-0018	SBE45	PrepLab
Transmissometer	1497DR	CST	PrepLab
Fluorometer	1498	WSCHL-1498	PrepLab

Flow meter	05/811950	LitreMeter F112-P-HC-AP-OR-PP	PrepLab
Seawater temp 1	0765	SBE38	Sea Inlet
Seawater temp 2	0771	SBE38	Sea Inlet

Instrument	#SN if Used	Make and Model	Comments
CTD			
Deck unit 1	0458	SBE11plus	
Underwater Comms/ Depth	0541	SBE9plus	
Temp1	5043	SBE3plus	
Temp2	4874	SBE3plus	
Cond1	1913	SBE 4C	
Cond2	3491	SBE 4C	
Pump1	1807	SBE5T	
Pump2	4458	SBE5T	
Standards Thermometer	0051	SBE35	
Transmissometer	CST-527DR	C-Star	
Oxygen sensor	0242	SBE43	Plumbed on T2&C2 line.
PAR sensor	70688	QCP2350	
Fluorometer	12-8513-001	CTG Aqua Tracker MkIII	
Altimeter	163162	Tritech S10127 232	
CTD swivel linkage	196115	Focal Technologies Group	
LADCP Master Down	14443	TeleDyne WHM300	
LADCP Slave Up	15060	TeleDyne WHM300	
Pylon	0636	SBE32	
Other ship's systems (non-AME)			
Anemometer	Yes		Bridge Equipment, logged
Ships Gyro	Yes		Bridge Equipment, logged
System(s) brought by science team (non-AME)			

2.3b Notes for Lab Instruments used

AutoSal

One Autosal was used near the end of the cruise. No problems were reported by the scientists.

Scintillation Counter

The Scintillation counter was used by Patrick Downes. He reported two events where the shuttle got caught, but noted that this was during rough sea conditions. Therefore no major issues to report.

2.3c Notes for Deck Systems

Winch Counter

The Winch counter system was not used on this cruise, but it was charged for the next cruise. During this process, I found that the system installed in a clear Perspex enclosure has a damaged battery, and will not take a charge.
I did manage to charge the second system (brown enclosure with handle) by using the bench top power supply. I set the voltage to 13.5V, and waited for the current draw to drop below 100 mA.
I also tested that the second system worked on both metering sheaves. You do have to switch between the two transmitters by following the instructions printed on the display.

SUCS

On the whole, the SUCS system worked well and was a success. However there are points to note;

Physical Installation

The initial installation followed the layout used in past installations. A ratchet strap was used as a framework for running cables (fibre, camera power, VGA feed) up to the UIC. The power cables for the monitor and winch were run along the floor in to the CTD annex and plugged in.

This was fine for the first cast and installation day as the deck was dry, however after the first CTD deployment and second SUCS cast it was pointed out by deck crew members that the power cables were lying on a wet deck due to CTD water sampling. This was then highlighted as a bigger issue, and taken to the 2nd Engineer who informed us that:

- No power cables should be run on deck.
- 240V cables should not be used out on deck at all. Only 110V is allowed under permit.

We managed to avoid the 240V issue, and settled the problem by running both power cables in to the CTD bottle annex through a route off the deck. The new route is up the ratchet strap, over the external light, around the top of the CTD annex door, over the crossbeam over the CTD annex door, and then through the lycab cable entry box on the RHS of the door. The route is shown in the attached pictures. This seemed to satisfy crew member concerns.

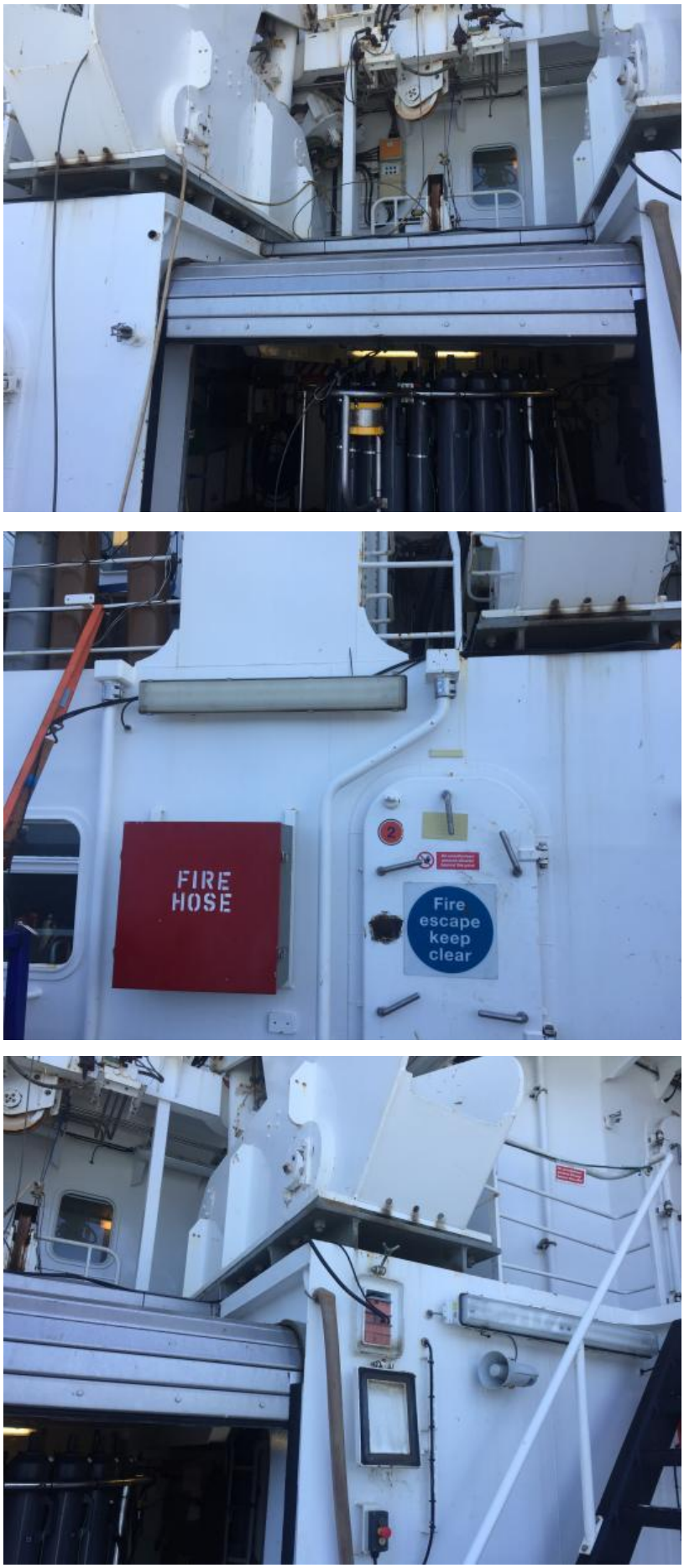


Figure 2.3c SUCS power setup in CTD annex

SUCS Depth Indicator

At the start of the cruise a decision was made not to install the cable sheave counter, and rely solely on the USBL beacon attached to the tripod. We encountered two situations where the USBL did not work.

During the first 50m the USBL is too close to the ship, and does not give an accurate depth reading, and therefore you don't know where the SUCS camera is. This rectifies itself once the tripod goes lower.

The second situation occurred after entering the ice. We suspect that there was a slushy ice layer on the bottom of the ship that coated the USBL transponder, and therefore could not send/receive properly. This resulted in no location information on the SUCS camera during deployment in the ice. This basically means lowering the SUCS camera blind and on one occasion resulted in a fairly heavy sea floor landing.

I would therefore recommend installing the cable counter system in future installations.

Spooling issue

This problem was first noticed when the winch would fail to respond to the manual request to spool right. This was initially solved by power cycling the unit, but got progressively worse. The problem was traced to the right hand side (when viewed from behind the drum, or left hand side when looking straight on to the spooler) proximity switch. The switch appears to be reading false positives quite rapidly. This makes the PLC think that the spooling mechanism has reached the RHS edge, and through relay logic physically stops the spooler from being able to move right. No spare was available on board, but one has been ordered for the cruise in December. It is a simple 3 wire installation. Additionally a new relay has been ordered for the system (labelled E2), in case the rapid switching states have worn out its contacts.

HMI/Cable Diameter Issue

During the installation stage with Gareth at the beginning of the cruise, it was noticed that after turning on the power the HMI attached to the PLC would indicate "1: Comm Err", and the cable diameter stays set to 0.00 mm. While this comm error is in place you cannot set the cable diameter to the required 14.00 mm.

Figure 2.3c2 cable diameter display

I made an assumption that the comm error was between the din mounted PLC and the HMI. So I powered off the system, removed the circular connector end of the red cable, and cleaned the contact pins. After this the system booted correctly with no comm error, and immediately showed 14.00 mm.

Later in the cruise we encountered a number of cases when the winch would stop auto spooling, and when inspecting the system I noted the same "1: Comm err" message. Under these cases cleaning the connector did not help, and I began to assume it may be a problem with the connector on the PLC. Since there was no spare PLC, I decided not to interfere with it in case I messed up the entire system. However after a number of power cycles, and connector cleans the system began to auto spool again, but I am not sure if the error message went away during this case as the door was closed.

Additionally I am beginning to suspect that the spooling issue was caused by the proximity switch, rather than the comm error. However I have not been able to test this theory.

At the end of the cruise I began testing on the system to fault find the proximity switch problem, and during this time I noticed a different behaviour on the HMI:

1. Power on system.
2. Reset pump emergency stop.
3. HMI would indicate "1: Comm err" and either blank or 0.00 mm cable diameter.
4. I would then use panel buttons to force spooling mechanism to move left/right.
5. The HMI would then indicate "1: Bad Reply"
6. After this the display would act a bit erratically. Most of the time it would appear to be working fine and display "Cable Dia. = 14.00mm" with no error messages. But occasionally it would cycle around and start displaying "1: Comm err" and clear the cable diameter. Sometimes it would jump from "Cable Dia. 0.00mm" up to "Cable Dia. 14.00mm" and back again without any error messages.

I have taken a video of this cycle. I am not sure what is causing this process. It may just be part of the natural boot process cycling between operational states under a fault case. It may be caused by trying to force spooling manually, or it may be an effect of the rapid oscillating states being fed to the PCL from the right hand side proximity sensor in its fault state. Regardless there is an issue to be fixed. What is unclear at this stage is whether the system will auto spool while this cycle is happening. This is a marginal concern for future use, however if the manual spooling issue is resolved with the replacement of the proximity sensor, then as a worst case we will be able to run the system on a fully manual basis.

XBT

No XBT's were used during the cruise, however the XBT system from the Shackleton was brought on to the JCR for testing. To test it we I used an old XBT test box from the cage (origins unknown). Its original documentation is found here:
"P:\AME\Ships\JCR\Instrumentation_&_Systems\XBT\Drawings\Test Box"

Note however that the schematic in the original documentation is wrong, as verified by testing the on board test box. I have corrected the mistake in a proteus design project, and designed a new BAS version of the PCB. The new project folder is located here:
"P:\AME\Ships\JCR\Instrumentation_&_Systems\XBT\Drawings\XBT_Test_Box_2019"

The current on board test box was wired up and connected directly to the 9 pin serial port on the back of the XBT deck unit. This test box is used to simulate the electrical signals received from a real XBT launch. This worked perfectly on the JCR XBT system, and the Shackleton's unit. This unit will now be kept in Cambridge for use on the SDA.

2.3d Notes for Acoustic Systems used

The Acoustic systems on the ship were started and maintained during the cruise by Sean Vincent (ICT). They were all configured to operate through the K-Sync unit.

ADCP

The Ships ADCP was started at the beginning of the cruise by Sean Vincent. Normally the ADCP is run and maintained by a dedicated member of the science staff. Unfortunately on this occasion this was not possible, and neither Sean nor I remembered to monitor the system throughout the cruise. The system did run, and did collect data, but it may not have been running on the optimal configuration.

Nearing the end of the cruise, around the West Mooring site, the ADCP was accidentally stopped. I restarted the system with the 500m, bottom tracking 8m bins, through SSU. This would have been applicable for the remainder of the cruise until the water got deeper after heading south towards the UK.

EM122

This system was run and operated by Sean Vincent and David Barnes. No issues were reported to me.

EK60/80

The system was run and operated by Sean Vincent. No issues were reported to me.

USBL

At the beginning of the cruise I was given a lesson on the system by Sean Quirk. This was very informative, and became apparent that I had been using the system wrong for a number of years. I can now add instruments and vessels correctly. Set the USBL transceiver with new settings (done wrong in previous years), and compensate for physical offsets. This was all achieved in the Fusion program.

During the cruise I added beacons 4 and 5. B4 and B5 are the same beacon types as B1 and B2 currently on the JCR. The configuration settings are documented in the USBL wiki. I then tested beacons B1, B2, B4 and B5 throughout the cruise and found that they all operated as expected. Primarily I had a beacon constantly attached to the CTD, and the SUCS camera. As far as possible, we would like to start putting beacons on all equipment that goes in to the water. If there is ever a situation where we lose equipment in the water, we would like to have some chance of retrieving it again (as was done on SUCs last year).

We only had one issue with the USBL system this cruise. After entering the ice we found that the system appeared to stop working. We have assumed that this was slushy ice covering the transducer, and preventing correct signal transmission and reception. In addition to this we found that the ice got caught in the USBL gate valve, and prevented us from closing the valve. This was a minor concern as there was a possibility that traveling through ice with the valve open could cause damage to the USBL head or the gate valve. Thankfully this was not the case.

EA600

The EA600 worked fine during the cruise, except for one occasion while in the ice. This was the same location where the USBL was not working, and we suspect that the same slushy ice must have covered the transducer preventing a correct ping and receive.

2.3e Notes about the Oceanlogger

After joining the ship I noticed that the underway water instrumentation (Transmissometer, Fluorometer, Thermosalinograph and flow meter) all showed signs of biological growth in their water feed pipes.

On the 06/07/2019 I removed all of the hose assembly, and scraped the inside clear using a bottle brush. This removed a significant amount of biological growth. I then washed the pipes with triton. I then flushed and cleaned the instruments. For the LADCP I wiped the lenses clean. I then plumbed the system, and started the water flow.

What is noteworthy is that in the past we used to run the system with a flow rate of 0.6 L/min. Last year it was pointed out that all the instruments would prefer running at a higher flow rate, however we decided that for consistency with past data we would continue with the 0.6 L/min flow rate. Since then an executive decision was made to run the system at a flow rate of 1.4 L/min, and should be run at this for the remainder of the ships life.

In general these systems operated well. There was the occasional case where the flow rate would drop while running external sea water hoses during mud sampling. This drop in pressure could not be fixed until after mud operations. The remainder of the ocean logger systems appear to have operated fine during the cruise.

2.3f Notes about the CTD

Basic Stats			
Number Of Casts	15	Number of Successful Casts	14
Max Depth	362	Min Depth	137
Cable Removed (m)	0	Number of Re-terminations (elect.)	1

2.3g CTD Deployment Procedure

Prior to deployment all bottles are cocked and the deionised water is vented from the T/C sensors. The lenses for Transmissometer, Fluorometer and PAR and wiped clean with milliQ and Kimtech, and then dried with Kimtech. Pre-deployment technical tests are carried out on the LADCP's and are logged. The LADCP is then activated and starts logging.

Once the Deck crew and winch operator are ready the CTD is lifted into the water and lowered to 10m, where power is started and logging begins. It is held here until the operator sees the difference between T1/T2 and C1/C2 stabilize. This can take some time, especially if the air temperature and sea temperature are far apart. In some circumstances such as turbulent surface waters or areas with large thermoclines, it can be necessary to lower the CTD to 20m or further to a depth where the temperature is more stable. Once stable, the CTD is lifted to as near to the surface as the winch operator deems safe then is lowered to the required depth or near bottom without stopping (attempting to maintain a constant velocity of 60m/min). The bottom depth is an approximation from the best echo sounder available, commonly the EM122. If bottom depth is required then the altimeter will start working from within 100m of the sea bed and is used to stop approximately 10m from the sea bed. From here some adjustment can be made to get closer, but is done at the operator's discretion. Once the down cast is complete bottles are fired at requested depths, in order of deepest first. After each bottle is fired at least 15 seconds are given to ensure that the independent standards thermometer has time to take a reading (The minimum is 8 seconds as defined in the manual).

Once on the surface the CTD is returned to the vessel, the C/T sensors are filled with deionised water to avoid damage. All data is backed up as soon as possible.

2.3h CTD Cast Summary Stats

Cast No	Ship Event No	Date	Start Time UTC	Lat	Lon	Max Depth	Distance to sea floor	Site Name
001	002	06/07/2019	23:36	72°37.765N	30°00.000 E	285	5	Test Site
002	003	07/07/2019	00:10	72°37.764N	29°59.971 E	296.01	3.6	Test Site
003	007	07/07/2019	16:19	74°30.017N	30°00.041 E	354	3	B13
004	058	10/07/2019	17:00	78°15.268N	29°59.977 E	306.9	3.2	B15
005	063	10/07/2019	21:33	78°15.294N	29°59.708 E	301.65	9.47	B15
006	093	12/07/2019	17:48	76°29.751N	30°00.010 E	282.38	9.6	B14
007	099	12/07/2019	23:18	76°30.394N	30°00.091 E	281.23	9.3	B14
008	100	13/07/2019	01:18	76°30.394N	30°00.090 E	287.1	3.7	B14
009	132	15/07/2019	07:25	79°14.841N	31°36.394 E	136.66	9.3	Ice Station 1
010	133	16/07/2019	03:51	80°02.580N	30°01.163 E	271.5	9.6	B16
011	135	16/07/2019	06:20	80°02.162N	29°58.314 E	290.6	3.49	B16
012	167	21/07/2019	21:42	81°02.502N	18°25.974 E	255.8	8.4	West Mooring
013	169	21/07/2019	23:49	81°02.369N	18°26.735 E	233.5	9.4	West Mooring
014	181	26/07/2019	02:26	72°37.879N	19°14.951 E	357	9.1	B3
015	183	26/07/2019	04:49	72°37.879N	19°14.950 E	362	3.2	B3

2.3i Information about CTD physical configuration

Name	Purpose	Distance from Base of Frame to Sensor (m)
Altimeter	Distance to sea bed (max 100m)	0.045
LADCP Master	Downward Facing LADCP	0.09
Temp1/Temp2	Temperature at 24Hz	0.3
Fluorimeter	Measures Florescence	0.165
9+	Communications and Pressure measurement	0.39
C1/C2	Conductivity Cells	0.345
Dissolved Oxygen	Oxygen in the Water	0.365
Bottles Bottom End Cap	Water collection (24)	0.56
Bottles Top End Cap	Water collection (24)	1.66
Transmissometer	Measure of light transmitted through water	0.27
SBE35 Top	Accurate Temperature sensor	1.43 (1.39)
SBE35 Bottom	Accurate Temperature sensor	0.75
Par	Radiation Sensor	1.61

2.3j Operational Log Summary

This is a shortened list of the CTD operational logs. The rest can be found on the JCR AME WIKI. The logs are listed from newest to oldest.

- **2018-07-31** CTD logsheets scanned for cruise data folder.
- **2019-07-26 04:49** Cast 015: 20L bottles were fine after cast. No leaks.
- **2019-07-26 02:26** Cast 014: 20L bottles were fine after cast. No leaks. This cast was further south and had warmer waters. This confirms my assumptions that the o-rings are a bit too stiff in cold temperatures, and dont form a proper seal.
- **2019-07-21 23:49** Cast 013: Ignore date and time of this log. It was later reported by scientists that the sample collected in niskin 17 was different from that expected, however the remaining samples were fine. This is assumed to be caused by the CTD pulling down water (due to its size) and therefore collecting water from a different depth than it would had if it had only moved up through the channel. Scientists are aware of this.
- **2019-07-21 23:49** Cast 013: During cast the CTD lead scientist went past a required depth, and requested that the CTD be lowered down the water channel with 12 closed niskins on the frame. We dropped from 19.3m to 20.6m to collect a sample with niskin 17. We are not sure what effect this will have on the sample integrity of precollected samples.
- **2019-07-21 21:42** Cast 012: Before cast bottle 24 (20L) was swapped for a 12L to ease access to niskin valve in bottle 1. Also, 16 polystyrene cups were added to the frame for pressure testing.
- **2019-07-21 14:53** Mega Tested the CTD Cable (Deck unit and Instrument disconnected). 250V=>53 MΩ, 500V=>56 MΩ, 1000V=~53 MΩ. Not brilliant, but acceptable values for use.
- **2019-07-13 01:18** Cast 008: After cast, bottle 12 fired, but cap/lid cot caught on rim of niskin, and did not close successfully.
- **2019-07-12 23:18** Cast 007: No faults, other than 20L niskin leaks.
- **2018-07-12 23:00** Mega Tested the CTD Cable (Deck unit and Instrument disconnected). 250V=>36 MΩ, 500V=>39 MΩ, 1000V=~35 MΩ. Not brilliant, but acceptable values for use. Values improving.
- **2018-07-12 22:00** Mega Tested the CTD Cable (Deck unit and Instrument disconnected). 250V=>25 MΩ, 500V=>26 MΩ, 1000V=~25 MΩ. Not brilliant, but acceptable values for use.
- **2019-07-12 18:30** Traced the CTD sea cable fault to the sea end cable termination. Pigtail fine, and cable fine. Reterminated using cable ends, and did not have to repeat a mechanical load test.
- **2019-07-12 17:48** Cast 006: Comm error on SBE11 Deck Unit immediately after reaching the bottom. Full short circuit, and sea cable fuse blown. Recovered to Deck.
- **2019-07-07 22:30** Decision is made to continue cruise with 50/50 mix of 12L and 20L and use 20L for water samples that are not affected by air contamination.
- **2019-07-07 22:10** Cast 005: After the cast the 12L bottles were fine with no leaks, however the 20L's all showed the same significant leak. Even with the new o-rings installed.
- **2019-07-10 21:33** Cast 005: Before the cast I changed Nottles 1->6 and 13->18 for 12L versions. I know that the 12L bottles have worked in the past. I also changed the top and bottom o-rings on the remaining 20L's (7->12 and 19->24).
- **2019-07-07 17:00** Cast 004: All bottles leaked after cast. All had a significant leak, with no discernable difference. I suspect a problem with the o-rings.
- **2019-07-07 16:19** Cast 003: No leaks reported. No problems with the bottles.
- **2019-07-07 00:10** Cast 002: After cast scientists reported that bottles 5, 8, 12, 18, 19 and 21 had small leaks. Bottle 5 was the worst. I replaced the top and bottom o-rings on bottle 5, and the top o-rings for 18 and 19. Will test performance on next cast.
- **2019-07-06 23:36** Cast 001: Test Cast. Used to evaluate the new 20L niskin lanyards/springs and test that there are no misfires or unintended bottle closes. After cast no bottles showed any unintended closes. New niskins are good for use.
- **2018-07-06** Test weight is deployed on new CTD cable with no significant problems. There were some minor slips, and minor grease collections, but nothing serious. Cable approved for use.

- **2018-07-06** The crew are nervous about the new CTD cable, and the possibility that it may leak grease and make CTD recovery difficult on the traction winch. They want to do a test deployment with a weight first.
- **2018-07-06** CTD is physically setup and complete. PC is now configured. New cruise specific XMLCON is created, and all instrument calibration constants are entered and checked.
- **2018-07-05** All niskin drain valves and o-rings are dryed and wiped clean. No more silicone contamination. Lead scientist happy.
- **2018-07-05** All niskin drain valves and o-rings are removed and left to soak in triton to help remove silicone. Niskin drain valve holes are brushed clean with triton, and then wiped dry.
- **2018-07-05** I immediately regret previously mentioned silicone application. Scientists are measuring for silicone concentrations in the niskin water samples. All silicone needs to be removed now.
- **2018-07-05** The niskin drain valves on 20L are quite stiff, and are difficult to pull out completely. I decide to apply a light quantity of silicone grease.
- **2019-07-05** Mechanical load test performed on the CTD cable. Bolted to deck matrix with a load cell. Held at 2.8 tons for 7 minutes. Cable and termination passed.
- **2019-07-05** The newly cleaned CTD cable is being used on this cruise. Previously the cable was delivered with too much grease to use, and had to be removed for cleaning.
- **2019-07-04** The space for the Par sensor is tight due to 20L niskin size. Sensor needs to be removed to fit niskin 9.
- **2019-07-04** 20L niskins removed from cage and installed on the frame.
- **2019-07-03** Note that DO sensor is plumbed on the T2&C2 line, as opposed to the normal configuration with T1&C1. This is due to an error made early in the season, and rather change the configuration now, a decision was made keep the layout, and just note the mistake for all JR18 cruises.
- **2019-07-03** T1, T2, C1 and Disolved Oxygen sensor were replaced with new sensors due to difficulty finding an up to date calibration document.
- **2019-07-03** Temperature, Conductivity and Disolved oxygen sensors removed and flushed with Triton, and then MilliQ. The plastic pipes used for their plumbing were also cleaned with a bottle brush to remove biological growth.
- **2019-07-02** Plastic/Brass cap removed from SBE35. This cap needs to be removed when sensor is used in the sea.
- **2019-07-02** Fluorometer moved and rotated to allow as much laminar flow of water past the sensor as possible.

2.3k CTD Points of Discussion

Dissolved Oxygen Sensor Placement

The Dissolved Oxygen (DO) Sensor is normally plumbed on the same pump as Conductivity Sensor 1 (C1) and Temperature Sensor 1 (T1). However early on in the JR18 season it was incorrectly plumbed on to the T2 and C2 pump. This mistake was not picked up until late in the JR18 season, and a decision was made to keep the configuration and just make it known for all JR18 season cruises. This will be rectified in the JR19 season.

20L Niskin Leaks

The new SDA 20L CTD niskins have been brought on to the JCR for testing. At the beginning of the cruise new springs were fitted to the newly modified niskin end caps. Instructions for making 20L bottle lanyards are located here: http://wiki.jcr.nerc-bas.ac.uk/AME:_How_to_make_lanyards

For the first 3 casts the 20L bottles appeared to operate well with no leaks, however from cast 4 all the 20L bottles began to leak quite badly. This was an immediate change, and did not come on gradually. I believe that this is caused by a drop in temperature, as the first 3 casts were in warmer water, and ambient temperature. This could also be seen after the CTD was recovered to its annex, and once the temperature increased the niskins would stop leaking. This was further verified by placing 20L o-rings, and 12L o-rings in a fridge, and comparing how malleable the material was after getting cold. There was a substantial different in the o-ring material.

The available spare o-rings were tested in the 20L niskins, but they were the same material and therefore did not stop the leak. New o-rings have been ordered for the next cruise, but there is nothing else available on the ship to use. Therefore in an effort to improve matters, a decision was made to supplement half of the CTD niskins for 12L bottles that would be used for Oxygen and DMS sampling, and the remaining 20L bottles would be used for bulk water collections. This was only a partial solution, because although the 12L bottles had a better seal, it did require us having to do two casts in order to collect sufficient water. This in turn meant that the samples from the different casts were not comparable with each other. This is unfortunate, but is the best solution available.

Nearing the end of the cruise, contact was made with Jeff Benson (NOC). He recommended testing the niskin spring tension, and from experience he adjusts the tension to 22 Kg. After testing the tension was found to be closer to 12.5 Kg. This was checked with the supplier of the 20L niskins and the new springs, who recommends 12.5 Kg in order to avoid damaging the niskin ends.

This was tested by cocking the top of the 20L niskins, and leaving the bottoms closed. The niskins were then filled to the brim with water, and left to sit. After two days there was no significant drop in water, and therefore no significant leak on the bottom niskin end cap. This means that the spring tension is enough to hold the full water head height pressure without the assistance of a fully sealed vessel. However this test was done under warm conditions in the CTD water bottle annex.

In addition to this the supplier verified that the supplied o-rings were “buna”, and become rigid under cold conditions. He has recommended Silicone or florosilicone materials, both of which have been ordered for the next cruise.

If the new o-rings are found to struggle on the next cruise then the only available option is to increase the spring tension. This can be done by using cable ties to compress a few coils on the springs.

Sea End Cable Termination

During cast 6 there was a complete failure in CTD communications after reaching the bottom of the deployment. The CTD was recovered to deck, and the fault was traced to the sea end cable termination. After dissecting the termination, it was found that there was a full short circuit between the feed and return lines. There was evidence of electrical burning. I suspect that this was a slowly developing problem that progressed over the previous casts, rather than a single event, and was most likely caused by salt water ingress.

The cable was reterminated, and has been operating fine for the remainder of the cruise. It is worth noting that the termination impedance of the new termination has been significantly lower than ones in previous years (~60 MΩ VS ~1000 MΩ), however this is still high enough for proper operation.

Optic Sensor Calibration

It is good practice to test the optic sensors at the beginning and end of the cruise to evaluate drift. More specifically for the Transmissometer and PAR sensors who require testing to define their calibration constants.

This is done by turning on the CTD and allowing everything to stabilise for 10 minutes. During this time it is important to clean the Transmissometer and PAR lenses. Wet kimtech with milliQ and wipe lenses clean, then dry with kimtech. After 10 minutes, completely cover the PAR sensor (so that no light can reach its lense), and then completely block the transmissiometer beam. Leave like this for 5 minutes. Then remove the covers and leave for a further 5 minutes.

After this you can shut off the CTD, and review the archived data in "seasave". Pull up a plot of voltage 0 (transmissometer voltage measurements) and voltage 6 (PAR voltage measurements). For the transmissometer zoom in to the plot to find the stable peak and trough voltages. The stable peak voltage is measured when there is no beam attenuation, and is defined as "A1". The stable trough voltage is measured when there is full beam attenuation (blocked), and is defined as "Y1". Similarly for PAR, plot the measured voltage and look for the trough stable voltage. This is defined as the "Voltage in Dark Value".

These measured values and the values provided in their calibration documents, are used to calculate the calibration constants needed in "Seasave" XMLCON. These are shown in the following tables.

Table 2.3k PAR and Transmissometer parameter details

PAR Parameter	Start of Cruise	End of Cruise
Date	06/07/2019	30/07/2019
Voltage in Dark	0.008547009	0.00854701
Calibration Constant	1.926782E+10	1.926782E+10
Offset	-5.29315E-2	-5.29315E-2

Transmissometer Parameter	Start of Cruise	End of Cruise
Date	06/07/2019	30/07/2019
Tw%	100%	100%
A1	4.797313V	4.7828V
Y1	0.003663V	0.003663V
M	21.23828	21.29832
B	-0.07779583	-0.07801575

2.4 CTD data

Emily Venables – Scottish Association for Marine Science

CTD data were collected at the stations summarised below, as described in the AME tech report.

Cast No	Event No	Date	Start Time UTC	Latitude	Longitude	Max Depth	Above sea bed	Site Name
001	002	06/07/2019	23:36	72°37.765N	30°00.000 E	285	5	Test Site
002	003	07/07/2019	00:10	72°37.764N	29°59.971 E	296.01	3.6	Test Site
003	007	07/07/2019	16:19	74°30.017N	30°00.041 E	354	3	B13
004	058	10/07/2019	17:00	78°15.268N	29°59.977 E	306.9	3.2	B14
005	062	10/07/2019	21:33	78°15.294N	29°59.708 E	301.65	9.47	B14
006	093	12/07/2019	17:48	76°29.751N	30°00.010 E	282.38	9.6	B15
007	099	12/07/2019	23:18	76°30.394N	30°00.091 E	281.23	9.3	B15
008	100	13/07/2019	01:18	76°30.394N	30°00.090 E	287.1	3.7	B15
009	132	15/07/2019	07:25	79°14.841N	31°36.394 E	136.66	9.3	Ice Station 1
010	133	16/07/2019	03:51	80°02.580N	30°01.163 E	271.5	9.6	B16
011	135	16/07/2019	06:20	80°02.162N	29°58.314 E	290.6	3.49	B16
012	167	21/07/2019	21:42	81°02.502N	18°25.974 E	255.8	8.4	West Mooring
013	169	21/07/2019	23:49	81°02.369N	18°26.735 E	233.5	9.4	West Mooring
014	181	26/07/2019	02:26	72°37.879N	19°14.951 E	357	9.1	B3
015	183	26/07/2019	04:49	72°37.879N	19°14.950 E	362	3.2	B3

Table 2.4 cast data

2.4a Data processing

This was kept as similar as possible to the processing on previous NERC Changing Arctic Ocean research cruises, specifically scripts developed by Jo Hopkins and Estelle Dumont on JR16006 and used for JR17006. Processing was carried out using Seabird Data Processing software version 7.26.7 and Matlab software version 2017b. Calibration against oxygen and salinity samples has not yet been applied.

Data were converted in Seabird initially to output pressure, oxygen, temperature, conductivity and depth. These data were run through Matlab routines to check what values to use for sensor alignment, then a batch file was set up to run the following modules through Seabird:

2.4b SBE Data conversion
Run: DatCnv

Input: JR18006_NNN.hex, JR18006_NNN.XMLCON, JR18006_NNN.bl, JR18006_NNN.hdr

Output: JR18006_NNN.cnv, JR18006_NNN.ros

Variables exported to binary *.cnv files:

- scan: Scan Count
- latitude: Latitude [deg]
- longitude: Longitude [deg]

- timeJ: Julian Days
- timeS: Time, Elapsed [seconds]
- pumps: Pump Status
- prDM: Pressure, Digiquartz [db]
- depSM: Depth [salt water, m]
- t090C: Temperature [ITS-90, deg C]
- t190C: Temperature, 2 [ITS-90, deg C]
- c0mS/cm: Conductivity [mS/cm]
- c1mS/cm: Conductivity, 2 [mS/cm]
- sbeox0V: Oxygen raw, SBE 43 [V]
- sbeox0Mm/L: Oxygen, SBE 43 [umol/l]
- flC: Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]
- CStarAt0: Beam Attenuation, WET Labs C-Star [1/m]
- CStarTr0: Beam Transmission, WET Labs C-Star [%]
- par: PAR/Irradiance, Biospherical/Licor [uE/m2/s]
- altM: Altimeter [m]

Default oxygen tau and hysteresis corrections were applied.
Created *.ros files from *.bl files using a 5s scan range and a scan range offset of -2.5s

2.4c SBE WildEdit
Input and output: JR18006_NNN.cnv

Flagging of major spikes: Pass 1 removed data points over 2 standard deviations of 100 scan average and pass 2 removed spikes over 20 standard deviations of 100 scan average.

2.4d SBE Filter
Input and output: JR18006_NNN.cnv

Low pass filter (0.15, as recommended by Seabird) applied to pressure and depth data.

2.4e SBE Align CTD
Input and output: JR18006_NNN.cnv

Conductivity: Conductivity sensor advances were applied to compensate for sensor time lag according to figure 2.4e1. The best alignment was produced by shifting the secondary sensor by +1 scan and leaving the primary sensor with no advance.

Temperature: No alignment was performed on either sensor as both seemed to be in good agreement.

Oxygen: The SBE43 Oxygen sensor typically has a time response of between 0 and 7 seconds according to SeaBird, generally increasing in colder temperatures. In this case, an advance of 6 seconds has been applied Figure 2.4e2.

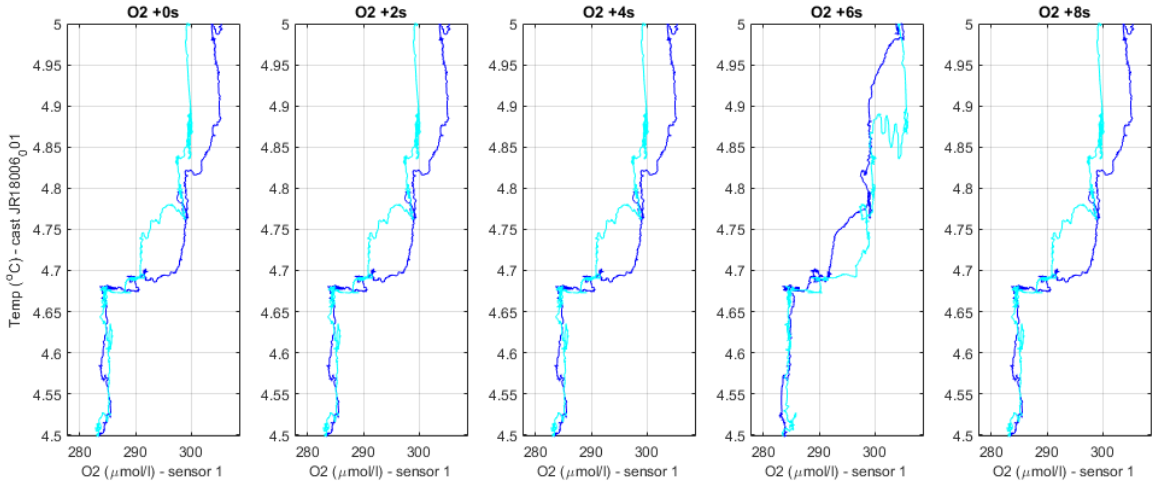


Figure 2.4e1 Oxygen measurements plotted against temperature to track water mass space rather than depth. Upcast and downcast data with advances from 0 to 8 seconds.

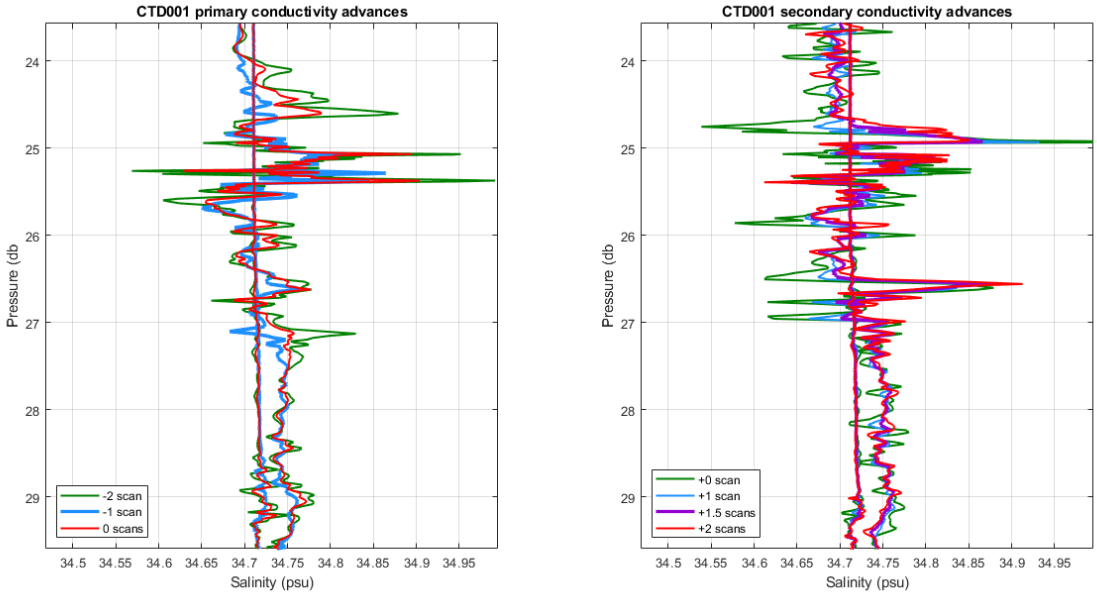


Figure 2.4e2 Conductivity sensor alignment test results.

2.4f SBE CellTM

Input and output: JR18006_NNN.cnv

A recursive filter run to remove conductivity cell thermal mass effects from measured conductivity.

Thermal anomaly amplitude, alpha was set to 0.03 and thermal anomaly time constant, tau was set to 7 as recommended by Seabird.

2.4g SBE Derive:

Input and output: JR18006_NNN.cnv

Variables derived from processed pressure, temperature and conductivity.

- depSM: Depth [salt water, m]
- sal00: Salinity, Practical [PSU]
- sal11: Salinity, Practical, 2 [PSU]
- sigma-é00: Density [sigma-theta, kg/m^3]
- sigma-é11: Density, 2 [sigma-theta, kg/m^3]
- svCM: Sound Velocity [Chen-Millero, m/s]
- svCM1: Sound Velocity, 2 [Chen-Millero, m/s]

2.4h SBE Translate
Input and output: JR18006_NNN.cnv

Conversion of binary data to asci. Data were kept in binary format up until this stage to avoid loss of precision.

2.4i SBE BottleSum
Input: JR18006_NNN.cnv, JR17006_NNN.bl

Output: JR18006_NNN.btl

Creation of *.btl bottle file using a 5s window centered around the bottle firing time. Final *.bl bottle files are produced in the Matlab processing stage.

2.4j SBE Strip
Input and output: JR18006_NNN.cnv

Removal of depth variable produced by DatCnv.

2.4k SBE Binavg
Input: JR18006_NNN.cnv

Output: JR18006_NNN_2hz.cnv

2.4l SBE Binavg
Input: JR18006_NNN.cnv

Output: JR18006_NNN_LADCP.cnv

1 second bins for LADCP

2.4m SBE AsciiOut
Input: JR18006_NNN_LADCP.cnv

Output: JR18006_NNN_LADCP.asc

Generate files for LADCP processing

Data will be processed further in Matlab using the CAO processing routines applied to JR16006 and JR17006 data. Calibrations for oxygen and salinity will be applied at this stage.

2.5 Underway data

Emily Venables – Scottish Association for Marine Science

2.5a Introduction

This section describes the underway data acquisition and processing during JR18006, bringing together navigation data with echo sounder depth, meteorological data and sea surface hydrographic parameters. Sea surface properties were sampled from the uncontaminated seawater supply when it was switched on. In sea ice it had to be turned off to avoid damaging the system. Flow rate was increased to 1.4 l/min from the usual 0.6 l/min required for the old fluorometer.

Table 2.5 Underway instrument channels processed and used in this report.

Instrument	**Parameter**	**Unit**
Oceanlogger	airtemp1	celsius
	humidity1	%RH
	par1	Umol/S.m2
	tir1	W/m2
	airtemp2	celsius
	humidity2	%RH
	par2	Umol/S.m2
	tir2	W/m2
	baro1	hPa
	baro2	hPa
	tstemp	celsius
	conductivity	S/ma
	salinity	psu
	sound velocity	m/sa
	transmittance	0<Tr<1
	flowrate	l/min
	sstemp1	celsius
	sstemp2	celsius
	fluorescence	ug/l
Anemometer	Wind direction	degrees
	Wind speed	m/s
	Wind speed	knots
Echosounder EA600	Depth	metres
Seatex GPS	Latitude	degrees
	Longitude	degrees

2.5b Instrument set-up

The oceanlogger system recorded the sea surface and most meteorological parameters. Anemometer, echosounder and position data came in from separate streams. Table 1 lists all those that have been extracted and processed. Serial numbers are documented in the instrumentation section. In all cases, data were received in csv format as *.ACO files. Column headings and units were listed in a corresponding .TPL file, each timestamped at time of recording in the format 'YYY DDD HH:MM:SS'.

Data have been processed for the entire science time of the cruise: Julian day 181, until day 210. Pumps were switched off in sea ice, so periods of no flow and a lag of 60 data points after restart have been removed from the data.

2.5c Navigation

The seatex navigation system worked smoothly and there was no need to process data from backup systems. Figure 2.5c shows the cruise track, with bathymetry from the echo sounder.

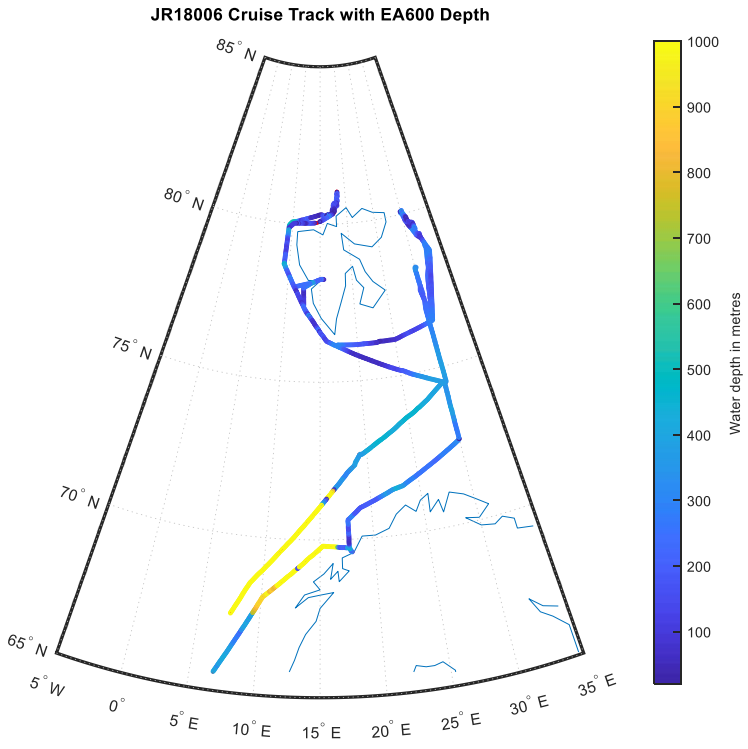


Figure 2.5c Cruise track showing EA600 echosounder bathymetry

2.5d Bathymetry - Echo sounder EA600

The Bathymetric data were often very noisy, with spurious dropouts and artefacts. No processing has been applied to these data.

2.5e Meteorological Data

Meteorological data were recorded throughout the cruise, saved as daily raw files and as a minute-average for the entire dataset. Figure 2.5e shows time series of some of the routinely measured parameters.

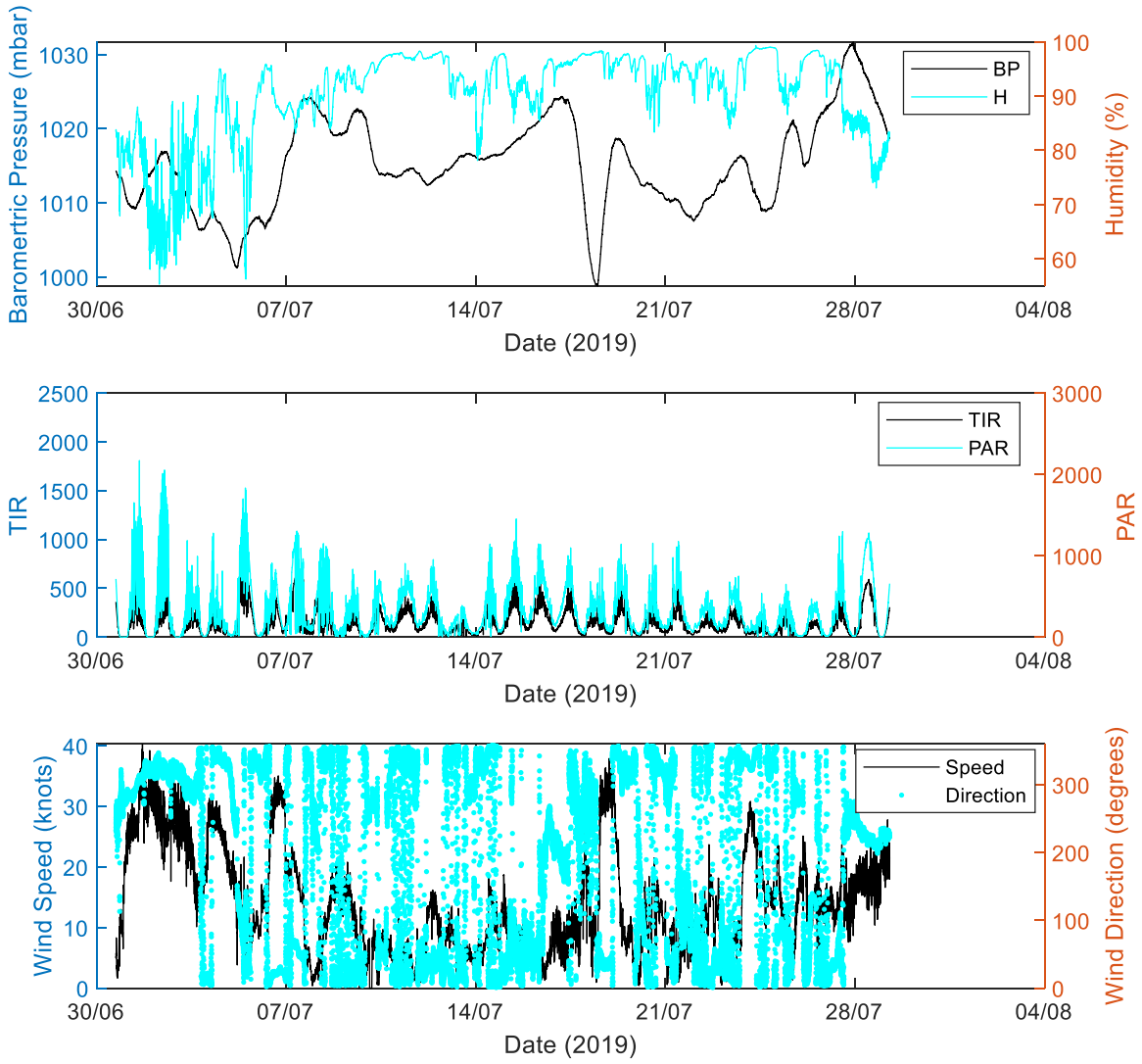


Figure 2.5e Meteorological data for the cruise duration.

2.5f Oceanlogger Data

Surface water parameters from the oceanlogger system were saved as daily raw files and as a minute-averaged time series. Data from times of no flow (when pumps were switched off), and from a lag time of 5 minutes (60 data points) afterwards were removed. No filtering was applied to these data, and the conductivity calibration from salinometer sample results has not yet been applied.

Figure 2.5f shows the hydrographic time series from the cruise along with chlorophyll and turbidity.

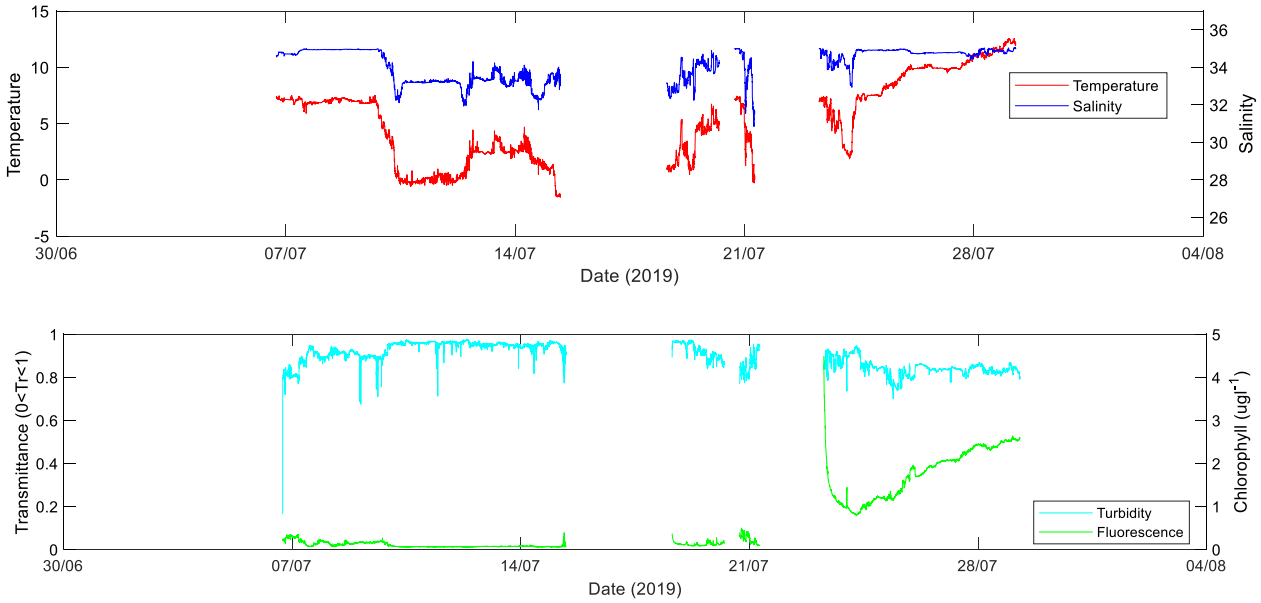


Figure 2.5f Surface Temperature, salinity, turbidity and fluorescence from the pumped underway surface water supply. Gaps where pumps were turned off in sea ice.

2.5g Underway conductivity calibration

42 discrete salinity samples were taken from the underway system during the cruise. When the pumps were running, these were taken at 0600, 1200, 1800 and 0000 each day. For each sample the bottle was rinsed 3 times with the running seawater, filled, dried, plastic insert fitted, bottle neck wiped, and lid put on.

Once a crate of 24 samples was full, it was placed in the Autosal laboratory to acclimatise to temperature for at least one day prior to analysis. At the start and end of each crate a standard seawater (SSW) sample was analysed, to monitor the drift of the instrument. Calibration from these results will be applied post-cruise.

2.6 Water mass definitions

Water mass classification considered throughout ChAOS work is:

Water mass	Description	Pot. temperature limits (°C)	Salinity limits (psu)
Arctic Deep Water (ADW)[1]	Cold and saline bottom waters of the Nansen Basin	~ -1.05	~ 34.91

Arctic Water (ArW)[2]	Cold and fresh water of Arctic origin	< 0	< 34.7
Atlantic Water (AtW) [2]	Warm and saline waters originating in the Atlantic	> 3	> 34.8
Barents Sea Water (BSW) [2]	Cold and saline bottom layer of the Barents Sea, formed by cooling and mixing of AtW, ArW and NCCW	< 2	> 34.8
Coastal Water (CW) / Surface Water (SW) [1]	Warm and fresh surface waters, coming from warming of the MW and / or coastal influences	> 3	< 34.5
Melt Water (MW) [2]	Fresh surface layer produced by sea ice melting	0 < T < 3	< 34.4
Norwegian Coastal Current Water (NCCW) [2]	Warm and fresh current near the Norwegian coast flowing to the Barents Sea through the Barents Sea Opening	> 3	< 34.4
Norwegian Sea Deep Water (NSDW)[3]	Cold and saline bottom waters of the Norwegian sea	-1 < T < 0	34.9 to 35.0

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Swift, J. H., Koltermann, K. P. (1988): The origin of Norwegian Sea Deep Water, Journal of Geophysical Research: Oceans (1978–2012), Vol. 93, No. C4, 3563-3569, https://doi.org/10.1029/JC093iC04p03563 .

3. Water column biogeochemistry

Water samples were collected over the full water column depth during CTD casts at 7 stations during the cruise (see event log for details). Full details on CTD procedures are included in the AME section of this report. Samples were taken from 12 L and 20 L Niskin bottles mounted on the ship's CTD rosette for a suite of biological, chemical and physical measurements, as summarised in Table 3.1

Table 3.1 biological, chemical and physical measurements made

Measurements	**Scientist(s) responsible**
Organic sulphur and nitrogen measurements and experiments	Jo Dixon, Plymouth Marine Laboratory
Inorganic macronutrient (nitrate+nitrite, nitrite, phosphate, silicate, ammonium) concentrations	Sian Henley, University of Edinburgh; Lars Brunner, SAMS
Stable nitrogen and oxygen isotope ($\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$) composition of nitrate	Sian Henley, University of Edinburgh; Rhiannon Jones, University of Bristol
Silicon isotope composition of silicic acid	Rhiannon Jones, University of Bristol
Dissolved organic carbon concentration	Judith Braun, SAMS; Mark Stevenson, Newcastle University
Primary production and bacterial production	Patrick Downes, Plymouth Marine Laboratory
Particle composition	Birthe Zäncke, Marine Biological Association
Nitrogen uptake experiments and nitrogen concentration measurements	Judith Braun, SAMS
Oxygen isotope composition of seawater	Felipe Salles de Freitas and Rhiannon Jones, University of Bristol
Bottom water samples taken for incubation experiments	Saskia Rühl and Chris Walkinshaw, Plymouth Marine Laboratory
For calibration of CTD sensors	
Dissolved oxygen concentration	Lars Brunner, SAMS
Chlorophyll concentration	Lars Brunner, SAMS
Salinity	Felipe Salles de Freitas and Rhiannon Jones, University of Bristol

Sampling order was according to sampling requirements for each parameter with samples for dissolved oxygen and DMS work taken first to minimise exchange with atmosphere. This was followed by samples for nutrient concentrations, nitrate and silicic acid isotopes, dissolved organic carbon, nitrogen uptake experiments and concentration measurements, and then chlorophyll, particles and primary and bacterial production. Sampling was completed with samples for oxygen isotopes of seawater and salinity. Bottom water samples for incubation experiments were taken from dedicated bottles. Samples were taken opportunistically for analysis of microplastics for Bhavani Narayanaswamy of SAMS when a spare surface water Niskin bottle was available.
At stations B14 and further north, 20 L Niskin bottles leaked substantially. This was most likely because the o-rings used with these bottles failed at cold temperatures. Twelve of these bottles were swapped for 12 L bottles, which had o-rings fit for purpose. Whilst this solved the leaking problem, the reduced water collection volume necessitated two casts being conducted at each station, which

increased CTD wire time by two hours per station. It is strongly recommended that new Niskin bottles be tested thoroughly and ensured fit for purpose prior to deployment.

3.1 Nutrient cycling in the water column, in sedimentary porewaters, and across the benthic interface; CTD and megacoring

Sian Henley, Rhiannon Jones, Lars Brunner, Johan Faust, Felipe Sales de Freitas, Mark Zindorf

3.1a Objectives

Nutrient chemical cycling within sediment porewaters and the overlying water column is central to the objectives of Module 3 of the ChAOS project and will provide a key dataset for interpretation of biological and chemical data collected across the project and CAO program. Cruise JR18006 is the third of three summer cruises occurring over three years of the ChAOS project. Measurements of inorganic macronutrient concentrations and isotopic signatures will inform our understanding of the processes by which nutrients are recycled in sedimentary systems, their fluxes across the sediment-water interface, and their role in benthic-pelagic coupling.

3.1b Water column nutrient concentration and nitrate and silicon isotope samples: CTD

Seawater samples collected during CTD deployments for nutrient concentration analysis were prefiltered directly from the Niskin bottle using clean nylon mesh of pore size 200 μm to exclude zooplankton. Two additional sets of samples were taken for nutrient analysis: one to be sent to the University of Liverpool for analysis as part of the NERC CAO program integration work; one to be kept as a back-up for analysis at SAMS. These samples were filtered through a 0.45 μm acropak filter, stored in acid-clean 120 ml HDPE bottles or 50 ml falcon tubes, and frozen at -20 °C for transport. Samples for nitrate and dissolved silicon (DSi) isotope analysis were filtered within four hours of collection using sterile acrodisc supor 0.2 μm pore size filters with a membrane prefilter and acid-clean plastic syringes. All sample storage bottles were acid-clean HDPE. Nitrate isotope samples were snap-frozen at -80 °C for ~12 hours and stored at -20 °C for transport to the University of Edinburgh for analysis. DSi samples were stored at +4 °C in the dark for transport to the University of Bristol. Inorganic nutrient samples were taken over the full water column depth at stations B3, B13, B14, B15, B16, Ice station 1 and Mooring west, and nitrate and silicon isotope samples were taken over the full water column depth at all stations except Mooring west.
Nutrient concentration data from the Mooring west station will be used to calibrate the SUNA V2 (submersible ultraviolet nitrate analyser) mounted at 21 m water depth on the Arctic PRIZE western mooring.

3.1c Sediment porewater sample collection: megacoring

Porewater samples were taken from sediment cores collected using the NMF megacorer and gravity corer using rhizone syringe filters. Samples were taken over the upper 30 cm of sediment using the megacorer and 110 cm using the gravity corer (see coring sections for full details). Porewater samples from four separate cores from each megacore deployment were combined, homogenised and split for analysis of various parameters, with splits for nitrate isotope analysis being snap frozen at -80 °C and stored at -20 °C in the same way as water column samples. Samples for silicon isotope analysis were stored at 4°C. Samples for nutrient analysis were stored at +4 °C in the dark and analysed at room temperature within 12 hours of collection.

3.1d Sample analysis: nutrient concentrations

Seawater and sediment porewater samples were analysed onboard for the concentration of nitrate+nitrite, nitrite, phosphate, silicate and ammonium using a Lachat Quikchem 8500 flow

injection analyser. Analyser performance and data quality for the suite of five nutrients were evaluated using international certified reference materials for nutrients in seawater (KANSO Limited, Japan, batch CI for seawater samples and CF for sediment porewaters). Two internal standards collected at the CTD test station south of station B13, filtered through a 0.45 µm acropak filter and stored frozen at -20 °C were also analysed with each seawater run and used in data quality control and evaluation of the analytical procedure.

Nutrient analysis was conducted on seawater samples from the water column and incubation experiments for nutrient flux calculations (Universities of Bristol and Edinburgh) and sediment resuspension (Plymouth Marine Laboratory), and on sediment porewater samples. Water column and incubation samples were analysed against standard solutions made up in a low-nutrient seawater (OSIL batch 27) standard matrix. Porewater samples for analysis of nitrate+nitrite, phosphate, silicate and ammonium were diluted in a 2:6 ratio of sample to milli-Q water (18.2 MΩ) – a 4x dilution, and analysed against standard solutions made up in a matrix of 2 parts low-nutrient seawater to 6 parts milli-Q water to match the analyte matrix. Porewater samples for nitrite analysis were undiluted and analysed against standard solutions made up in low-nutrient seawater. Megacore interface waters were analysed undiluted for nitrate+nitrite, nitrite, phosphate, silicate and ammonium.

3.1e Sample analysis: stable isotope composition of nitrate

Seawater and porewater samples will be analysed for their nitrate isotope composition at the University of Edinburgh using the denitrifier method and gas chromatography isotope ratio mass spectrometry (GC-IRMS) [Henley et al., 2018; Sigman et al., 2001; Casciotti et al., 2002].

3.1f Sample analysis: stable isotope composition of silicon

Seawater and porewater silicic acid and sedimentary silica phases will be analysed for their stable silicon isotope composition at the University of Bristol by Multi-Collector Inductively Coupled Plasma Mass Spectrometry [Hendry & Robinson, 2012; Cassarino et al., 2018].

References

Cassarino, L., Coath, C. D., Xavier, J. R., & Hendry, K. R. (2018). Silicon isotopes of deep sea sponges: new insights into biomineralisation and skeletal structure. Biogeosciences, vol. 15 (22), p. 6959-6977.

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Henley, S.F., Jones, E.J., Venables, H.J., Meredith, M.P., Firing, Y.L., Dittrich, R., Heiser, S., Stefels, J., Dougans, J. 2018. Macronutrient and carbon supply, uptake and cycling across the Antarctic Peninsula shelf during summer. Phil Trans Roy Soc A-Math Phys Engin Sci, 376, DOI: 10.1098/rsta.2017.0168.

Sigman DM, Casciotti KL, Andreani M, Barford C, Galanter M, Bohlke JK. A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. Anal Chem. 2001;73(17):4145-53.

Casciotti KL, Sigman DM, Hastings MG, Bohlke JK, Hilkert A. Measurement of the oxygen isotopic composition of nitrate in seawater and freshwater using the denitrifier method. Anal Chem. 2002;74(19):4905-12.

3.2 CTD sampling for N and Si isotopes (ChAOS/Arctic PRIZE)

Rhiannon Jones (University of Bristol)

3.2a Introduction

During uptake of essential nutrients such as nitrate and dissolved silicic acid, primary producers fractionate the isotopic composition of the nutrient between the residual composition in seawater and the uptake product, preferentially enriching the residual composition with a heavier isotopic composition as a process of mass-dependent fractionation. Analysis of the isotopic composition of nutrients in seawater across depth and between stations can help elucidate local patterns of nutrient utilisation; distribution of both preformed and regenerated nutrients through the water; as well as help indicate the roles of distinct water mass end members in regions of water mass mixing, such as the Barents Sea.

As part of the ChAOS and Arctic PRIZE projects, samples of full depth seawater at stations across the Barents Sea are collected for analysis of the natural abundance of nutrient isotopes. For cruise JR18006, silicon and nitrogen isotope samples were collected by Rhiannon Jones from the University of Bristol, for subsequent analysis by research groups led by Dr. Kate Hendry (University of Bristol) and Dr. Sian Henley (University of Edinburgh).

3.2b Methods

Samples for isotopic composition analysis of nitrate and silicic acid were obtained from the CTD rosette at stations B3, B13, B14, B15, B16, ICESTATION1, MWEST. A 1L acid-clean sample bottle was filled across a full depth profile at each station for both nitrate and silicic acid isotope samples. Sample bottles were stored in the dark at <+4 °C before processing within 6 hours. Seawater from sample bottles was hand-filtered using sterile and sample-rinsed acrodisc 0.2 μm filters and acid-clean mQ.H2O-rinsed Plastipak 60 ml syringes into acid-clean/sterile and mQ.H2O-rinsed 2 x 50 ml and 1 x 600 ml sample bottles for nitrate and silicic acid respectively. All apparatus were pre-rinsed thoroughly with sample before filtering and a new filter and clean syringe were used for each depth iteration. Nitrate isotope samples were frozen at -80 °C for < 24 hrs before storing at -20 °C before later analysis at the University of Edinburgh. Silicic acid isotope samples were stored at +4 °C in the dark parafilmed for subsequent analysis at the University of Bristol.

Table 3.2b1	Depth (m)	Niskin Bottle
	354	3
Event 7	349	4
Site B13	252	5
	182	6
	82	8
	42	9
	22	13
	15	15
	8	17
	3	21
	0	24

Table 3.2b2	Depth (m)	Niskin Bottle
	307	3
Event 58	302	4

Site B15	201	6
	131	8
	71	9
	50	12
	35	16
	3	18
	15	20
	1	24

Table 3.2b3	Depth (m)	Niskin Bottle
	287	1
Event 100	282	2
Site B14	242	3
	181	4
	152	5
	122	6
	65	8
	57	9
	40	14
	25	15
	12	16
	2	17

Table 3.2b4	Depth (m)	Niskin Bottle
	291	1
Event 135	285	2
Site B16	202	3
	152	4
	102	5
	61	6
	31	13
	15	15
	2	22

Table 3.2b5	Depth (m)	Niskin Bottle
	233	1
Event 169	192	2
Site B16	158	3
	127	4
	77	5
	37	6
	26	14
	11	24
	1.5	12

Table 3.2b6	Depth (m)	Niskin Bottle
	364	1
Event 183	359	2
Site B3	252	3
	152	4
	72	5
	40	6
	32	13
	24	14
	12	16
	3	19

3.3 Dissolved organic nutrient concentrations throughout the water column and uptake of inorganic and organic nitrogen compounds in the euphotic zone: CTD sampling

Judith Braun, SAMS
Sian Henley, University of Edinburgh
Mark Stevenson, Newcastle University

3.3a Objectives

The biogeochemistry of the water column is crucial for the regulation of primary production. Phytoplankton community composition and productivity determine quantity and quality of particulate organic matter exported to the sea floor shaping benthic communities. The benthic communities in turn provide nutrients to the water column coupling pelagic and benthic processes. The data on organic nutrient concentrations will complement the dataset on inorganic macronutrients provided by Module 3 of the ChAOS project. The determination of nitrogen uptake rates will add an insight into inorganic and organic nitrogen dynamics in the euphotic zone. Size fractionation work and the study of the phytoplankton community composition ties in with the studies on the carbon cycle, especially the export of carbon to the seafloor shaping benthic communities and biogeochemistry in sediments. The objective of this part in JR18006 is to examine these nutrient biogeochemical processes and their physical and biological controls adding to the overall understanding of the water column providing context to the benthic work in the marginal ice zone of the Arctic Ocean. This work is part of a PhD project under the Arctic PRIZE project, and participation in this cruise highlights and optimises the links and synergies between the PRIZE and ChAOS projects.

3.3b Sample collection

Water samples were taken from 20 L or 12 L niskin bottles mounted on the ship's CTD rosette over the full water column depth during CTD casts.

a. Dissolved organic nutrients

DOC, DON, urea and DFAA samples were taken over the full water column depth at the stations B13, B15, B14, B16, Mooring West and B3.

Samples for analysis of the concentration of dissolved organic carbon (DOC) and total nitrogen (TN) were filtered within four hours of collection using precombusted (450 °C for 6 hours) 25 mm GF/F filters (nominal pore size 0.7 µm) and an acid-washed glass syringe. Samples were

spiked with 50 µL 85 % orthophosphoric acid and stored in acid-cleaned and muffle-furnaced (450 °C for 6 hours) glass vials at +4 °C for transport to the home laboratory. To enable direct comparison with results from 2018, and explore differences between methodologies, samples were additionally taken for DOC & TN using a 0.45 µm membrane. Unfiltered water from the CTD Niskin bottles was used to fill acid washed (10% HCl), MilliQ rinsed (x3), sample rinsed (x3) 250 ml Nalgene bottles. Unfiltered seawater was then passed through a new 0.45 µm Whatman^{R} Puradisc AQUA Syringe Filter (cellulose acetate) for each sample, connected to a 20 ml syringe into 30 ml Nalgene bottles and frozen at −20°C. DOC & TN samples will be transported to SAMS on dry ice. Remaining unfiltered seawater will be transported to Newcastle University at −20°C and stored to enable additional future analyses.
All DOC and TN samples for JR18006 will be analysed at the Scottish Association for Marine Science using a Total Organic Carbon analyser (Shimadzu TOC-VCPH) coupled to an NDIR detector. Samples for analysis of urea and dissolved free amino acid concentrations were filtered within four hours of collection using sterile polyethersulfone 0.2 µm pore size filters and acid-cleaned plastic syringes. Urea and dissolved free amino acid samples were stored at -20 °C for transport to the home laboratory. Urea concentrations will be determined using spectrophotometry (520 nm) on an Evolution 300 UV-Vis Spectrophotometer (Thermo Scientific). Dissolved free amino acid concentrations will be analysed on a Trilogy laboratory fluorometer (Turner Designs) after o-phthalaldehyde reagent addition.

b. Uptake of inorganic and organic nitrogen in the euphotic zone

Nitrogen uptake experiments using ^{15}N-labelled potassium nitrate, ammonium chloride, urea and DFAA were conducted at stations B13, B15, B14, B16, Mooring West and B3 to quantify the uptake of organic and inorganic nitrogen sources and to calculate new and regenerated production. Samples from two to three depths (surface, chlorophyll maximum and bottom of the euphotic layer, corresponding to samplings depths of primary production experiments) were spiked immediately after collection and incubated for 6 hours in on-deck incubators modified to ambient light levels using neutral density filters. Incubations were terminated after 6 hours by filtration onto precombusted 25 mm GF/F filters, which were stored at -20 °C until analysis. Unspiked samples from each depth were filtered onto precombusted GF/F filters and stored at -20 °C to obtain the initial concentration and δ^{15}N of particulate organic material. At all stations, an extra set of samples from the chlorophyll maximum depth were spiked with the same ^{15}N-labelled potassium nitrate, ammonium chloride, urea and DFAA compounds, incubated and filtered using precombusted GF/A filters (nominal pore size 1.6 µm) to differentiate between autotrophic and heterotrophic uptake of nitrogen compounds. The N stable isotope composition of the samples will be analysed at SAMS using a PDZ Europa 20-20 Stable Isotope Analyser connected to an ANCA-NT preparation system. To test for successful separation of bacteria and phytoplankton, subsamples of the incubated samples were taken before and after filtration, fixed with 1 % final concentration Glutaraldehyde and stored at -80 °C for analysis at the home laboratory using flow cytometry.

To investigate phytoplankton community composition, sea water samples for phytoplankton counts were taken at stations B13, B15, B14, B16, Mooring West and B3 from two to three depths corresponding to ^{15}N uptake experiments. Cells were fixed with Lugol's iodine solution and stored in glass amber bottles with screw cap lids at + 4 °C in the dark until analysis at the home laboratory using light microscopy.

Acknowledgements: The Captain, Officers and Crew of RRS James Clark Ross were outstanding in their support of our work and their willingness and competence to address our requests. We would also like to thank the cruise leader David Barnes and all of our colleagues from the ChAOS project and various other teams, who were helpful, engaging and created a productive and enjoyable atmosphere throughout the cruise.

3.4 Dissolved Oxygen, nutrients and Chlorophyll

Lars Brunner – Scottish Association for Marine Science

3.4a Introduction

The work undertaken on this cruise consisted of three parts – **DO Analysis, Nutrient Sample** collection and **Chlorophyll** sample collection at each CTD cast/station (with some minor exceptions, see below). The nutrient samples and Chlorophyll samples were not analysed during the cruise, but are destined to be returned to SAMS for analysis in the near future.

For the Nutrient & Chlorophyll sampling I provide a short summary of the method used below, and the results will be added to the cruise report as soon as the samples are analysed. For the DO analysis I provide a short summary of the method, along with a summary of the results of the titrations. In each section I also note any abnormal samples or issues that were encountered, although thankfully these were minimal.

3.4b Stations and samples taken

Table 3.4b sampling timing and detail

Station and date	**DO**	**Nutrients**	**Chl A**
CTD test, 7th July	N	Y	N
B13, 7th July	Y	Y	Y
B15, 10th July	Y	Y	Y
B14, 13th July	Y	Y	Y
Ice edge station, 15th July	N	Y	N
B16, 16th July	Y	Y	Y
Mooring west, 21st July	Y	Y	Y
B3, 26th July	Y	Y	Y

3.4c DO Analysis

Analysis for dissolved oxygen levels was undertaken at each CTD site, with the exception of the ice edge station. Triplicate 150ml samples were taken using the CTD from three separate representative depths, usually near-bottom, mid-depth and surface, totalling 9 samples per station. The samples were immediately fixed using a standardised method, and transferred to the laboratory onboard and analysed using the Metrohm 848 Titrino plus analyser – this was carried out, at each station, within 2 hours of the samples being collected.
The results from the analysis are presented below for each station, with the mean and standard deviation of the three samples noted, along with the depth;

Table 3.4c B13 station details

Station B13 w. depth in metres	Mean O^2 level (µmol/l)	St. Dev (µmol/l)	Draw temp (Deg. C.)
354	329.7	6.177	4
182	323.9	2.903	5.4
surface	343.3	6.661	7.2

Table 3.4c2 B15 station details

Station B15 w. depth in metres	Mean O^2 level (µmol/l)	St. Dev (µmol/l)	Draw temp (Deg. C.)

301	373.4	0.784	2.8
201	359.8	0.979	0.8
surface	426.2	0.565	1

Table 3.4c3 B14 station details

Station B14 w. depth in metres	Mean O^2 level (µmol/l)	St. Dev (µmol/l)	Draw temp (Deg. C.)
281	328.9	9.198	3.7
92	363.5	0.907	3.8
2	384.3	0.561	5.5

Table 3.4c4 B16 station details

Station B16 w. depth in metres	Mean O^2 level (µmol/l)	St. Dev (µmol/l)	Draw temp (Deg. C.)
271	375.9	0.936	1.7
60	383.1	0.974	-0.6
2	423.3	0.799	-0.4

Table 3.4c5 Western Mooring details

Western mooring w. depth in metres	Mean O^2 level (µmol/l)	St. Dev (µmol/l)	Draw temp (Deg. C.)
256	319.0	3.839	3.5
125	319.9	1.283	2.5
surface	511.5	0.783	0.5

Table 3.4c6 B3 station details

Station B3 w. depth in metres	Mean O^2 level (µmol/l)	St. Dev (µmol/l)	Draw temp (Deg. C.)
358	297.1	2.919	8.1
72	301.8	0.525	6.3
3	301.1	1.368	10.1

3.4d Nutrient analysis

Analysis for nutrients was also undertaken at each CTD site. In conjunction with Sian Henley, a selection of sample depths was identified at each station depending on the CTD cast profile. The water draw from each depth was run through an Accropak 500 0.45µm filter, and frozen immediately after labelling in the ship's -20 Deg. C. freezer.

Two samples were taken at each required depth – one 125ml bottle, which will be analysed after the cruise by the University of Liverpool, and one 50ml falcon tube, which will be analysed at a later date by SAMS staff. In addition to the stations above, a set of sample standards were taken from a test CTD that was undertaken on the transit from Tromsø to the first station – these were also immediately stored in the -20 Deg. C. freezer.

3.4e Chlorophyll

Samples were taken for Chlorophyll A analysis at each station, except at the ice edge. Samples were taken from 5 depths from the top 50-60 metres, selected in accordance with the chlorophyll profile noted on the CTD cast. These were decanted from the appropriate niskin bottle using a hose with a fine mesh filter on the end to remove larger zooplankton from the sample. The samples were stored in the ship's walk-in fridge until analysis, although this was usually done within 30 minutes of sampling.

The samples were filtered using the SAMS vacuum pump rig, using glass microfiber filters. Two duplicate samples of 1 Litre from each depth was run through the rig, with the filters removed and stored in foil wrapped falcon tubes which were immediately placed in the walk-in freezer. These samples will be taken back to SAMS at the end of the cruise and analysed there.

3.5 Organic nitrogen and sulphur cycling in the Barents Sea

Joanna L Dixon & Rebecca S May, Plymouth Marine Laboratory

3.5a Introduction

Dimethylsulphide (DMS) is an organic sulphur compound produced by certain marine phytoplankton e.g. dinoflagellates from its precursor algal compound dimethylsulfoniopropionate (DMSP). Up to 84% of DMS produced is thought to be consumed by marine bacteria in situ; leaving on average 16% to flux across the sea surface interface into the atmosphere. When in the atmosphere DMS undergoes a series of reactions ultimately producing sulphate particles which contribute to the formation of cloud condensation nuclei (CCN). Thus DMS is often considered a climatically active gas, which can help offset the effects of warming though the production of clouds reflecting radiation from the sun. The main oxidation product of DMS in seawater is dimethylsulphoxide (DMSO). However, why DMSO is produced and what factors regulate its rate of formation is unclear. Recently a bacterial enzyme called trimethylamine mono-oxygenase (TMM), thought to occur in approximately 20% of all marine bacteria, has been found in culture to catalyse the formation of trimethylamine N-Oxide from trimethylamine (TMA) in a 1:1 stoichiometry with the formation of DMSO from DMS. This bacterial enzymatic process thus potentially links organic nitrogen and sulphur cycling. However, whether this reaction occurs in situ and the extent of regulation of the oxidation of DMS to DMSO by the TMM enzyme is currently unknown, and was the basis of a successfully funded NERC Discovery science proposal. The Polar Regions are known to be hot spots of DMS production; where arguably their contribution to the formation of CCN is most significant i.e. where anthropogenic sources of CCN are the lowest. Thus the main objective of this fieldwork campaign was to test the hypothesis that 'the availability of methylamines (organic nitrogen species) controls the rate of DMS loss through oxidation to DMSO in Arctic waters.'

3.5b Methodology & Approach

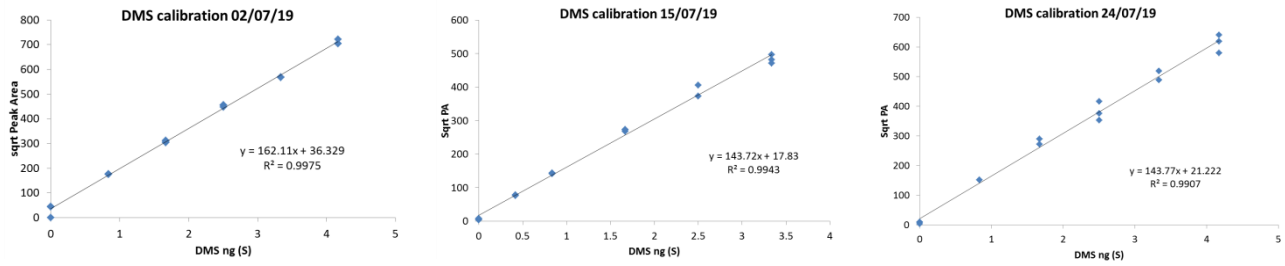
A series of 6 stations were sampled across a gradient of primary productivity (page 50) and DMS concentrations (Table 3.5b, Figure 3.5c). At each station waters were sampled at depths equivalent to approximately 100, 50, 25, 15, 3 and 1% of the photosynthetically active radiation at the sea surface. At each depth samples were taken to assess the concentration of DMS, dissolved and particulate DMSP, dissolved and particulate DMSO, dissolved and particulate methylamines and particulate N-osmolytes (pre-cursor compounds to methylamines). In addition, at the chlorophyll maximum 20L of water was sampled in order to set up methylamine addition experiments designed to test the above hypothesis.

Organic sulphur species

The concentration of DMS was determined in triplicate for each depth on the ship using a purge and trap system attached to a gas chromatograph (Varian 3800) fitted with a pulsed flame photometric detector (GC-PFPD). Weekly calibration curves (Figure 3.5b) were performed in addition to daily check standards. For a detailed description of the approach refer to Archer et al., (2009). Samples were additionally taken and stored for later analysis of dissolved and particulate DMSP and DMSO by sequential reduction to DMS followed by purge and trap into a proton transfer mass spectrometer (PTR-MS) back at Plymouth Marine Laboratory.

Figure 3.5b: DMS calibration curves

(a) (b) (c)



Organic nitrogen species

For particulate and dissolved methylamines, triplicate samples from four depths (see Table 3.5b) were gravity filtered through GF/F filters (47 mm diameter) into 10 ml of concentrated Hydrochloric acid (37%). Filters were stored frozen at -80^{0}C. Approximately 1L of acidified filtrate from each replicate was stored at 4^{0}C. Samples will be analysed using the approach of Cree et al (2018) by the University of Plymouth (PI: Dr Mark Fitzsimons).

Particulate samples for nitrogen osmolytes were syringe filtered in triplicate (50 and 2 ml samples) through methanol washed Nucleopore filters (0.2 um, 47 mm diameter) and stored frozen at -80^{o}C. Samples will be analysed as detailed in Beale et al., 2016 at Plymouth Marine Laboratory (PI: Dr Ruth Airs).

Methylamine addition incubation experiments

A series of 5 x 2L Tedlar bags were filled (using a peristaltic pump and 2L measuring cylinder) with water sampled at or close to the depth representing the chlorophyll maxima. Bags were stored in the dark at in situ temperature for approximately 12 hours prior to the start of the experiment. Stable sulphur tracers (d_3-DMS, d_6-DMSP, $^{13}C_2$-DMSO) were added to each bag at <10% in situ concentrations (the in situ concentrations of DMSP and DMSO were assumed based on the amount of DMS determined from the purge and trap GC-PFPD measurements). Two bags acted as controls, whilst 3 were additionally supplemented with trimethylamine and dimethylamine (at 50 nM final concentration). Bags were incubated for 24-48 hours and samples were taken at 4 time points during the incubation. At each time point the concentration of DMS was determined via purge and trap GC-PFPD, and samples collected for dissolved and particulate DMSP and DMSO. These samples will be analysed back at Plymouth Marine Laboratory via proton transfer mass spectrometry (PTR-MS) which will additionally determine the following rates;

1) Microbial consumption of DMSP and DMSO (from loss of d_6-DMSP and $^{13}C_2$-DMSO respectively)
2) Rate of microbial oxidation of DMS to DMSO (from appearance of d_3-DMSO from added d_3-DMS) with and without added methylamines i.e. control bags versus amended +methylamines bags
3) Rate of conversion of DMSP to DMSO (from appearance of d_6-DMSO from added d_6-DMSP)

At the end of the incubation 1 x 50 ml sample was taken from each bag for particulate N-osmolytes and the remaining seawater was filtered using a peristaltic pump through a sterivex and stored at -80^{0}C. These samples will be used to identify microbes containing the *tmm* gene (which encodes the TMM enzyme) and any upregulation in transcription due to the added methylamines (by the University of Warwick Pi: Dr Hendrik Schaefer)

Table 3.5b. Summary of stations sampled

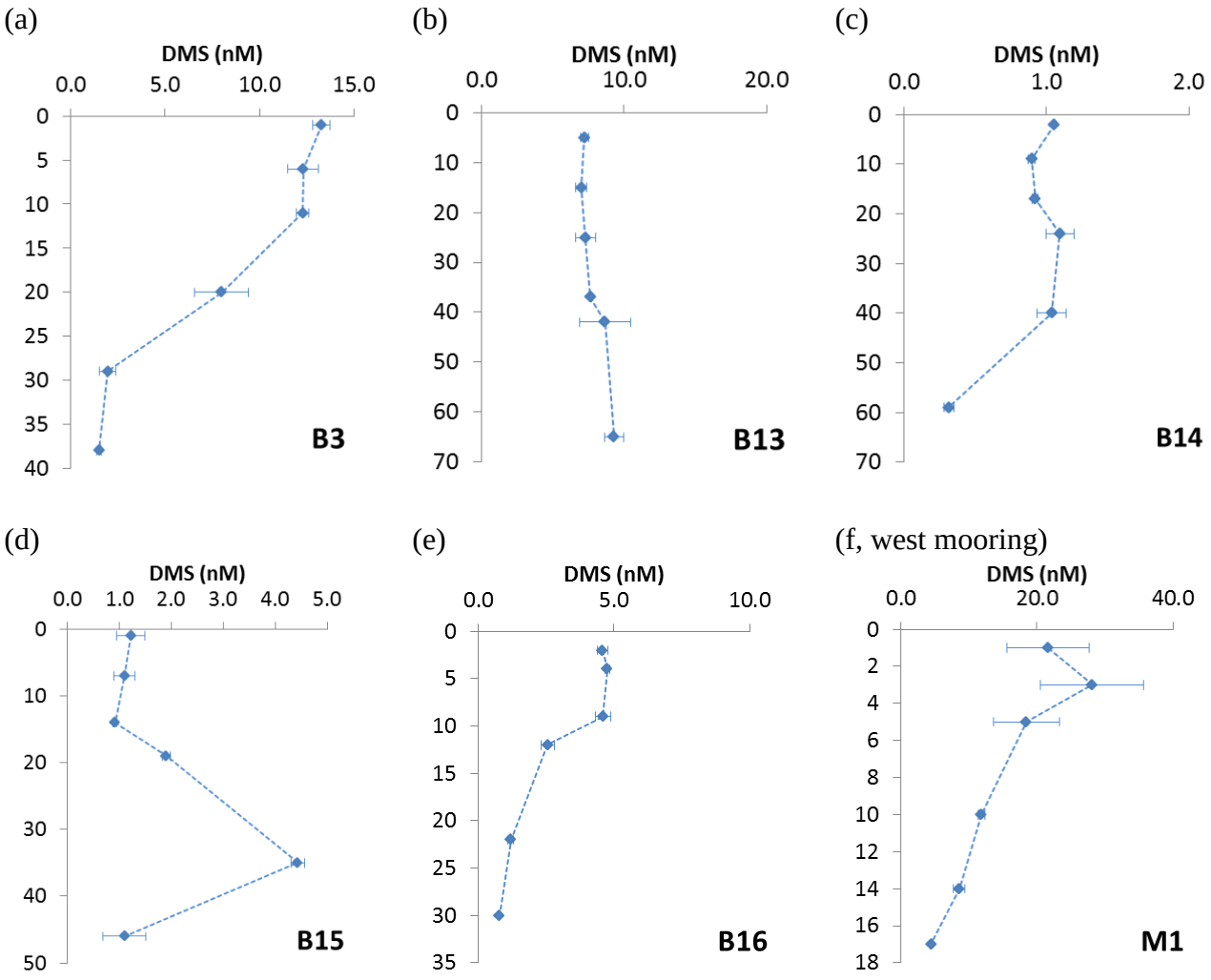
Station & log details	PAR (%) & Depth (m)	Samples taken
B13 (07/07/2019)		DMS, particulate and dissolved DMSP and
CTD003	100% - 1m*	DMSO, dissolved and particulate
Event no: 007	50% - 3m	methylamines*
	25% - 6m*	
	15% - 8m	At 1% Methylamine incubation experiment
	3% - 15m*	(DMS, dissolved and particulate
	1% - 20m*	DMSP/DMSO for 4 time points, particulate nitrogen osmolyte sample (50 ml) was taken at the end of the experiment. DNA sterivex sample with remaining seawater)
B15 (10/07/2019)		DMS, particulate and dissolved DMSP and
CTD005	100% - 1m*	DMSO, dissolved and particulate
Event no: 063	50% - 7m	methylamines*
	25% - 14m*	
	15% - 19m	At 3% Methylamine incubation experiment
	3% - 35m*	(DMS, dissolved and particulate
	1% - 46m*	DMSP/DMSO for 4 time points, particulate nitrogen osmolyte sample (50 ml) was taken at the end of the experiment. DNA sterivex sample with remaining seawater)
B14 (12/07/2019)		DMS, particulate and dissolved DMSP and
CTD006	100% - 1m*	DMSO, dissolved and particulate
Event no: 093	50% - 3m	methylamines*
	25% - 6m*	
	15% - 8m	At 1% Methylamine incubation experiment
	3% - 15m*	(DMS, dissolved and particulate
	1% - 20m*	DMSP/DMSO for 4 time points, particulate nitrogen osmolyte sample (50 ml) was taken at the end of the experiment. DNA sterivex sample with remaining seawater)
B16 (16/07/2019)		DMS, particulate and dissolved DMSP and
CTD010	100% - 2m*	DMSO, dissolved and particulate
Event no: 133	50% - 4m	methylamines*
	25% - 9m*	
	15% - 12m	At 15% Methylamine incubation
	3% - 22m*	experiment (DMS, dissolved and
	1% - 30m*	particulate DMSP/DMSO for 4 time points, particulate nitrogen osmolyte sample (50 ml) was taken at the end of the experiment. DNA sterivex sample with remaining seawater)
M1 (west Mooring),		DMS, particulate and dissolved DMSP and
21/07/2019	100% - 1m*	DMSO, dissolved and particulate
CTD012	50% - 3m	methylamines*
Event no: 167	25% - 5m	
	15% - 10m*	At 15% Methylamine incubation
	3% - 13m*	experiment (DMS, dissolved and
	1% - 17m*	particulate DMSP/DMSO for 4 time points,

		particulate nitrogen osmolyte sample (50 ml) was taken at the end of the experiment. DNA sterivex sample with remaining seawater)
B3 (26/07/2019) CTD Event no: 181	100% - 1m* 50% - 6m 25% - 11m 15% -20m* 3% - 29m* 1% - 38m*	DMS, particulate and dissolved DMSP and DMSO, dissolved and particulate methylamines* At 15% Methylamine incubation experiment (DMS, dissolved and particulate DMSP/DMSO for 4 time points, particulate nitrogen osmolyte sample (50 ml) was taken at the end of the experiment. DNA sterivex sample with remaining seawater)

3.5c Preliminary results

The concentration of DMS varied from a depth average of 0.9 ± 0.3 nM at station B14 to a maximum of 22.7 ± 4.9 nM in the top 5m at station M1 (west mooring, Figure 3.5b). A preliminary examination of a vertical phytoplankton net haul (refer to report by Patrick Downes) suggested that surface waters of station B14 hosted a grazer dominated community (end of phytoplankton bloom). In sharp contrast surface waters of M1 were characterised by numerous large chain forming diatoms. The depth average concentration of DMS at station B15 (excluding the peak of 4.4 ± 0.1 nM at 35 m, 3% PAR) was, similarly to station B14, relatively low at 1.3 ± 0.4 nM. The sharp peak in DMS at depth was suspected to be associated with a bloom of *Phaeocystis* plankton. The ice-edge was in between station B15 and B16; the latter station was in approximately 95% ice-cover and the ship had to 'clear ice' in order to safely deploy the CTD. The concentration of DMS at B16 was on average 4.6 ± 0.1 nM in the top 10m reducing to 0.8 ± 0.0 nM at 1% PAR (30m). At this station less numerous much smaller Diatoms (compared to M1) were observed in the vertical net sample. The concentration of DMS at station B13 was on average 7.9 ± 0.9 nM and showed relatively little variability with depth in the euphotic zone. A vertical net haul suggested a vibrant pigment rich dinoflagellate bloom. The average concentration of DMS in the top 11m was 12.6 ± 0.6 nM at the Atlantic influenced station B3. However, DMS reduced to 1.5 ± 0.2 nM at 38 m (1% PAR). ***[All data reported are provisional and subject to further verification prior to submission to BODC]***

Figure 3.5c: Depth profiles of the concentration of DMS (nM)



3.5d References

Archer SD, Cummings DG, Llewellyn CA, Fishwick JR (2009) Phytoplankton taxa, irradiance and nutrient availability determines the seasonal cycle of DMSP in temperate shelf seas. Mar Ecol Progr Ser 394, 111-124.

Beale R, Airs RL (2016) Quantification of glycine betaine, choline and TMAO in seawater particulates: minimisation of seawater associated ion suppression. Analytica Chemica Acta 938, 114.

Cree C, Airs RL, Archer SD, Fitzsimons MF (2018) Measurement of methylamines in seawater using solid phase microextraction and gas chromatography. Limnol Oceanogr 16, 411.

4. Phytoplankton and microbial production

4.1 Water column productivity

Patrick Downes - Plymouth Marine Laboratory

4.1a Introduction

Drastic changes in sea ice cover are predicted to impact the quality and quantity of dissolved organic matter (DOM). As well as changing the relative proportions of DOM sources; marine, sea-ice and terrestrial, which will in turn impact carbon cycling in the water column and sediment. The supply of organic carbon influences the activity of heterotrophic bacteria which utilise this carbon pool, recycling the DOM within the water column. Carbon entering this microbial loop is diverted away from higher trophic levels and export to the sea floor. Heterotrophic bacteria further compete with phytoplankton for inorganic nutrients consequently impacting phytoplankton community composition and rates of primary production. We aim to assess the dynamics between primary production and microbial production with emphasis on the utilisation of dissolved organic matter.

4.1b Sampling

4.1b1 CTD

Sampling depths were selected based on the PAR irradiance readings from the CTD at the surface of the water (approx. 2m) after being initially stabilised at 10m and bought back to the surface. Six set percentages of light 100%, 50%, 25%, 15%, 3% and 1% were calculated from the surface PAR(log) and the depths chosen accordingly. Additional samples were taken from below the euphotic zone. Once sampled from the CTD, the water was briefly stored in incubators at in-situ temperature before subsampling for the below methods.

Table 4.1b Sea water samples collected

Event number	CTD number	Station	Date	Lat	lon	Bottles sampled
007	CTD003	B13	07.07.19	74.50029	30.00064	23, 20, 18, 16, 14, 12, 8, 7, 5, 3
058	CTD004	B15	10.07.19	78.2549	29.99971	17, 16, 15, 14, 6, 5, 4, 3, 2, 1
099	CTD007	B14	12.07.19	76.50658	30.50156	24, 23, 22, 21, 20 , 19, 12, 11, 10, 9, 1
133	CTD010	B16	16.06.19	80.04295	30.00193	22, 20, 19, 12, 11, 10, 3, 2, 1
167	CTD012	W Moor	21.07.19	81.04173	18.43275	23, 22, 21, 20, 19, 12, 11, 10, 9, 8, 7
181	CTD014	B3	26.07.19	72.63132	19.24919	22, 21, 20, 19, 12, 11, 10, 9, 8, 7

4.1c Phytoplankton net

A bongo net with a 20µm mesh was deployed vertically to obtain live phytoplankton samples. The maximum depth varied between 40 – 50m depending on the chlorophyll maximum depth. Net samples were stored at in situ temperature before analysis.

Table 4.1c Phytoplankton net samples collected

Event number	ID	Station	Date	Lat	Lon
008	PN002	B13	07.07.19	74.50029	30.00064
059	PN003	B15	10.07.19	78.2549	29.99971
094	PN004	B14	12.07.19	76.49586	30.50017
134	PN005	B16	16.06.19	80.04295	30.00193
168	PN006	W Moor	21.07.19	81.04173	18.43275
182	PN007	B3	26.07.19	72.63132	19.24919

4.2 Primary Production

Summer primary production rates of 3 phytoplankton size classes were measured using 14C on deck incubations.

4.2a Methods

Sea water from each of the 6 PAR depths was dispensed into 70ml acid washed polycarbonate bottles, minimizing headspace. Each depth consisted of three replicates plus one fully blacked out and one used for a T0 measurement. Each bottle was spiked with 10µCi (370kBq) $NaH^{14}CO^3$. Dispensing and addition of the label was carried out swiftly before bottles were transferred to on-deck incubators, with corresponding light percentage density filters. Incubations were carried out for 24 hours with continuous day light and temperature maintained by a continuous supply of sea water from the non-toxic underway supply. To terminate the incubations, samples were transferred into a dark cool box for processing in the radiochemical lab. Before filtering, a subsample of 5ml from each bottle was aliquoted directly into a pony vial for measuring total organic carbon (TOC). Under low vacuum the samples were then sequentially filtered through 47mm polycarbonate membrane filters (20µm, 2µm, 0.2µm). Filters were then fumed for 2 hours with 37% HCL and desiccated for a minimum of 12 hours. Finally filters were placed in 8ml antistatic pony vials with the addition of ProSafe FC+ scintillation cocktail and stored in the dark for 24 hours before counting on a liquid scintillation analyzer with quench correction (PerkinElmer Tri-Carb 2900TR).

4.2b Community composition

To assess the phytoplankton and microbial communities a combination of techniques will be used. Taxonomic identification and enumeration of the phytoplankton assemblages will be coupled with biovolume estimates to support the primary production rates measured. Identification will be aided by photo documentation obtained from net samples. Flow-cytometry will be used to analyse the microbial community abundance of bacteria and nanoflagellates. Molecular samples were taken for next generation sequencing and qPCR to provide information on both microbial and phytoplankton taxonomy and relative abundances. Samples were obtained from each of the 6 PAR depths plus an additional deep sample at the salinity maximum defining the Atlantic bottom water.

Methods

Phytoplankton taxonomy

Lugol's fixation; for each depth a sample was aliquoted into a 500ml amber glass jar containing 5ml acid lugol's iodine solution. Formalin fixation; samples were preserved in neutral formalin buffered with Borax, by adding the sample directly to a 500ml amber glass jar containing 10ml buffered formalin. These samples will be used to analyse the calcifying members of the phytoplankton community. Light microscopy will be used at PML to analyse both the formalin and lugol's samples, for taxonomic identification and enumeration with additional biovolume estimates. Samples collected from the phytoplankton net were analyzed on board using light microscopy. Image libraries were created for each sampling site to aid in the identification of fixed samples (e.g. in figure 4.2b).

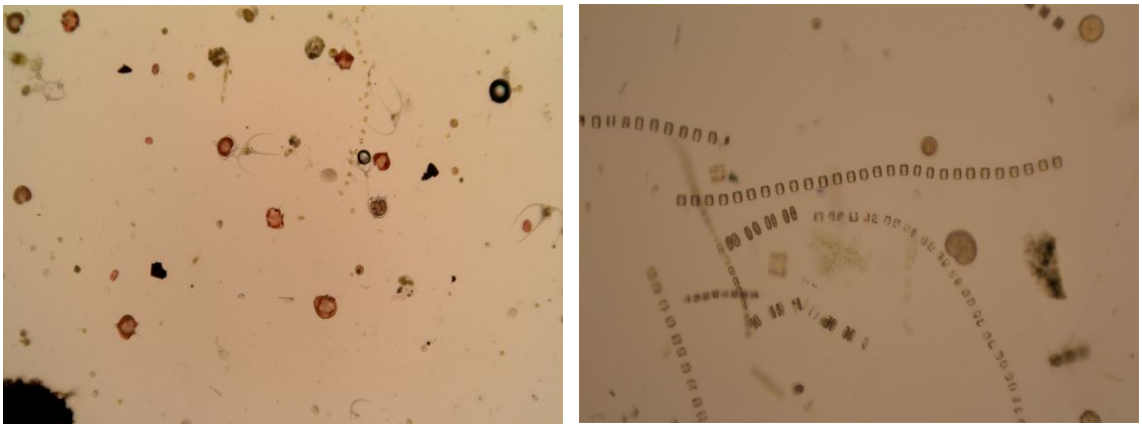


Figure 4.2b Phytoplankton net sample images. Dinoflagellate dominated community at B13 (left) and Diatom community at West M (right).

Flow-cytometry

Corresponding to the depths sampled for phytoplankton taxonomy, subsamples were preserved for flow-cytometry. Duplicates were taken for each depth; 1.8µl of sample was aliquoted into 2ml cryovials, prior to the addition of Pluronic F-68, final concentration 0.01% and Glutaraldehyde solution, final concentration 0.25%. cryovials were then kept at 4°C in the dark for 12 hours before storage at -80°C.

Molecular samples
For each depth sampled, 2 litres of sea water was filtered through a 0.22µm sterivex^{TM} filter unit using a peristaltic pump. The filter unit was then immediately stored at -80°C. Filters will be transported to PML for DNA and RNA extraction.

4.3 Microbial Production

Microbial production was estimated by measuring incorporation of radio labelled leucine. To gain a comparison of the relative contribution of archaeal and bacterial production to the whole community production, inhibitors were used in separate incubations.

4.3a Methods

Whole community production
Whole community production was measured at all depths sampled see table 4.1c. For each depth triplicates were used with one trichloroacetic acid (TCA) killed control, final concentration 5%. Micro-

centrifuge tubes containing 1.7ml sample were used for the incubations. Each was spiked with 3H-leucine at a final concentration of 20nmol L^{-1}. Incubations were conducted at in situ temperatures in the dark for three hours and terminated by the addition of TCA to a final concentration of 5%. The protocol described by Smith & Azam (1983) was used to process the samples before counting on a liquid scintillation analyzer with quench correction (PerkinElmer Tri-Carb 2900TR).

Bacterial vs Archaeal production
The same protocol was used as stated above with the addition of the following steps. For 1 depth, sample was aliquoted into 12 micro-centrifuge tubes. One set of triplicates were left untreated for total production. The archaeal inhibitor N1-guanyl-1,7-diaminoheptane (GC7) was added to a final concentration of 0.8mM to triplicates to estimate the bacterial contribution. To estimate the archaeal contribution, a set of triplicates was treated with Vancomycin (150µg/ml), Ampicillin(150µg/ml) and Fosfomycin (100µg/ml). All antibiotics plus the archaeal inhibitor GC7 were added to a final set of triplicates to assess resistant groups. Once the inhibitors were added, samples were kept in the dark at in-situ temperature for 24 hours, before the addition of 3H-leucine.

Smith DC, Azam F (1992) A simple, economical method for measuring bacterial protein synthesis rates in seawater using ^{3}H-leucine. Mar Microb Food Webs 6:107–114

4.4 Extracellular Enzyme Activity

Heterotrophic bacteria within the planktonic community play a key role in recycling organic matter and remineralising nutrients. The majority of this organic matter is too large for direct uptake; therefore it must be hydrolyzed by extracellular enzymes. The activity of these enzymes reflects the quantity and composition of the organic matter available. Enzyme activity was measured fluorometrically, using substrates which emit fluorescence after hydrolytic cleavage. The substrates and associated enzymes are outlined in the table below.

4.4a Methods

Previously (JR17007) saturating concentrations of the substrates were determined at B3, XSouth and B17, to represent Atlantic and Arctic waters. For each station four depths were used for enzyme assays, three surface plus one deep. Triplicates were used with a blank containing just seawater. The substrate was added to a 5ml cuvette, followed by the addition of 3ml sample. A T0 measurement was recorded directly after sample addition followed by 3-4 measurements over a 24hour period. The assays were kept in the dark at in situ temperatures. Standards for calibration curves were made using 7-amido-4-methylcoumarin and 4-Methylumbelliferone sodium salt dissolved in sterile filtered seawater.

Table 4.4a. Fluorogenic substrates and associated enzymes

Substrate	Enzyme
4-methylumbelliferyl phosphate	Alkaline phosphatase
4-methylumbelliferyl N-acetyl-β-D-glucosaminide	Chitobiases
4-methylumbelliferyl α-D-glucopyranoside	α-Glucosidase
4-methylumbelliferyl β-D-glucopyranoside	β - Glucosidase
L-Leucine-7-amido-4-methylcoumarin hydrochloride	Leucine- aminopeptidase

4.5 Bacterial and fungal communities on biogenic microgels

[1]Birthe Zäncker (Marine Biological Association of the UK) and [2]Michael Cunliffe
(Marine Biological Association of the UK)
1Author onboard, 2 Dataset PI
Micro-ARC

Background and objectives
Micro-ARC aims at understanding the links between pelagic microbial ecosystems and organic matter cycling in the changing Arctic Ocean. The production and degradation of organic matter by microbes are investigated. Therefore, samples for DNA/RNA in the water column and on microgels, fungal cultivation, phospholipid fatty acids (PLFA) and the abundance of microgels were taken in the Barents Sea.

4.5a Abundance and size distribution of microgels

Objectives
Determining the abundance and size distribution of microgels in the water column will give an idea of where the carbohydrate-rich and proteinaceous microgels are being produced and degraded.

Sampling strategy
Between 10ml and 100ml of seawater was subsampled from 10 litre plastic carboys. The seawater was filtered onto 0.45 µm, 25 mm Nuclepore filters. Two replicate filters were taken for all three microscopic methods. Filters for analysis of Transparent Exopolymer Particles (TEP) were stained with 1 ml 0.2 µm filtered Alcian Blue for 3 s. Filters for analysis of Coomassie Stainable Particles (CSP) were stained with 1 ml 0.2 µm filtered Coomassie Brilliant blue for 30 s. Filters for fluorescent analysis were not stained on the ship.
All filters were transferred onto a petri dish and were subsequently frozen at -20°C.

4.5b Methods
Frozen samples will be transported back to the Marine Biological Association of the UK (MBA). There the samples will be analysed microscopically using established methods.

Samples collected
At each station, six depths were sampled from the CTD. A complete list of all collected samples is presented in Table 4.5b.

Table 4.5b List of all samples collected during JR18006 in July 2019

JR18006 event n°	station	date	latitude	longitude	depths sampled [m]
007	B13	07.07.2019	74.50029	30.00064	3, 15, 22, 82, 182, 349
058	B15	10.07.2019	78.254	29.99971	1, 15, 35, 50, 201, 302
099	B14	12.07.2019	76.50658	30.50156	2, 40, 92, 152, 242, 281

132	ice edge	15.07.2019	79.24753	31.60556	
133	B16	16.07.2019	80.04295	30.0193	3.6, 8, 21, 32, 77, 137
167	W Moor	21.07.2019	81.04173	18.43275	2, 12, 30, 60, 152, 271
181	B3	26.07.2019	72.63132	19.24919	1, 11, 36, 76, 176, 256
					3, 21, 72, 152, 252, 358

4.5c DNA and RNA of the water column and on microgels

Objectives
The analysis of the total and active community of both bacteria and fungi in the water column will be compared to the communities on carbohydrate-rich microgels in order to identify community differences, main degraders of the microgels and other microbes benefiting from the phytoplankton-derived microgels.

Sampling strategy
For the water column DNA/RNA samples, 1L of seawater was subsampled from a 10 litre plastic carboy. For the microgel samples, the same volume as for the microscopy samples from section 7.1 was subsampled from a 10 litre plastic carboy. For water column DNA/RNA, the seawater was filtered onto 0.2 µm, 47 mm cellulose nitrate filters. For microgel DNA/RNA, the seawater was filtered onto two 0.45 µm, 25 mm Nuclepore filters for each sample. One Nuclepore filter was stained with 1 ml 0.2 µm filtered Alcian Blue for 3 s per sample. None of the other filters were stained. All filters were frozen immediately at -80°C after filtration.

Methods
Frozen samples will be transported back to the Marine Biological Association of the UK (MBA). DNA/RNA will be extracted and sequenced using next generation sequencing methods.

Samples collected
At each station, six depths were sampled from the CTD. A complete list of all collected samples is presented in Table 4.5b.

4.5d Sampling for fungi cultivation in the water column

Objectives
Cultivation and isolation of Arctic fungi will allow laboratory studies to investigate their physiology e.g. their potential to degrade different food sources.

Sampling strategy
500 ml of seawater was subsampled from a 10 litre plastic carboy. The seawater was filtered through a 0.45 µm, 47 mm MCE membrane. Simultaneously, 18 ml of sample were mixed with 6 ml 100 % glycerol to obtain a 25 % glycerol solution which was subsequently filtered through a 0.2 µm syringe filter. The filter was placed in a 30 ml plastic tube containing the sterile glycerol solution and frozen at -80°C.

Methods
Frozen samples will be transported back to the Marine Biological Association of the UK (MBA).

Filters will be thawed and cultivated on different media at *in situ* temperature.

Samples collected
At each station, six depths were sampled from the CTD. A complete list of all collected samples is presented in Table 4.5b.

4.5e Phospholipid fatty acid (PLFA) sampling

Objectives
The analysis of PLFA will enable the analysis of the microbial food web structure in the Barents Sea.

Sampling strategy
4 L of seawater was subsampled from a 10 litre plastic carboy. The seawater was filtered through a 47 mm GF/F filter. The filter was stored in ashed aluminium foil and stored at -20°C.

Methods
Frozen samples will be transported back to the Marine Biological Association of the UK (MBA). The PLFA will be extracted and subsequently analysed using gas chromatography.

Samples collected
At each station, six depths were sampled from the CTD. A complete list of all collected samples is presented in Table 4.5b.

4.6 Arctic Sea Ice samples

Mark Stevenson (Newcastle), Sian Henley (Edinburgh), Jasmin Godbold (Southampton), Adam Reed (Southampton), Jo Dixon (PML)

Sea ice and algal samples were collected from two stations (B16, E166) and (West Mooring, E170), to enable potential future analysis of DOC, lipid biomarkers, particulate $\delta^{13}C$/ $\delta^{15}N$, $\delta^{18}O$, particulate nitrogen osmolites and pigments.

4.6a Rationale

Arctic sea ice provides a key ecosystem for algal production, fixing carbon due to the presence of algae attached on, under and within the ice. During the summer melt period warmer temperatures and a variety of habitats (pools, meltwater cracks, under ice) facilitate the growth of diverse algal communities. Sinking algae during ice out is one potential source of organic matter supply to the benthos and subsequent sedimentation and burial of organic matter. Variations between stations at the ice edge are possible due to the unique sea ice flow patterns north of Svalbard, influenced by weather patterns, ocean current flows and the presence of land.

Figure 4.6a Sea ice broken during the ships movement, collected, melted and filtered (Photo A.Reed).

Sea ice can be a key location for organic carbon fixation, especially during melt where algae and microbes colonise freshwater melt pools, or become attached to melting ice in contact with seawater. Key controls on algal community composition include availability of nutrients and presence of particulate/dissolved organic matter on the ice, which is linked to the presence of multi-year ice, atmospheric deposition and the initial source of the transported ice. Algae are predominantly fixers of carbon through primary production. However, when nutrients are limited they may adopt mixotrophic strategies, either directly consuming organic matter or by utilising energy released from bacterial colonies to supplement growth.

Aim

Characterise algal community composition and the isotopic composition of filtered melted sea ice to identify distinct sources which may be incorporated into benthic sediments.

4.6b Methods

At B16 (E166) a 10 litre plastic bucket attached to a rope was used collect pieces of broken sea ice, after movement through the ice by the JCR. Ice chunks were placed into a 10 litre bucket and stored at 4 °C until fully melted prior to filtration for the proposed analyses (see below). At the West Mooring (E170) the NMF ice catcher was deployed and ice chunks similar placed into a 10 litre bucket and melted. Nitrile gloves were worn when handling ice to avoid contamination. Filtration and preparation of samples for specific analyses followed the standard methodology detailed in the relevant sections of this report.

Sample types collected

Figure 4.6b – Collection of sea ice using NMF ice catcher attached to the JCR's hydraulic crane (Photo A.Reed).

From water filtrates

Pigment analysis – determine algal community composition.

DOC – quantify the generally more labile 'dissolved' fraction of sea ice.

Lipid analysis – *n*-alkane/*n*-alkanoic acid analysis could be used to determine if the organic matter present is labile or recalcitrant and also indicate if any is terrestrially sourced.

Bulk POM/$\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ – to help determine the sources of organic matter, its reactivity and position of sea ice algae in the arctic food-web.

Deployment of the NMF ice catcher (AKA: 'Murdoch Scoop')

Deployment of the NMF-NOC-Southampton Murdoch Scoop was trialled at the West Mooring station (E170).

Challenges

Compared with JR17007 (2018) visible patches of sea ice algae during sampling of JR18006 (2019) were less abundant and more patchy making the collection of filamentous algae not possible. Instead, lumps of ice were collected, melted in buckets at 4°C and the resulting water filtered through ashed 0.7 µm GF-F filters supplied by Newcastle University. Deposits on the filter had a slight yellow-greenish tinge, with some small black particulates also visible.

It was agreed that the NMF ice catcher is fit for purpose but that a range of finer mesh sizes might be recommended for future cruises. Replacement mesh would also be recommended in case of damage by ice. Also it is worth noting that aperture of the ice catcher is fairly small in the context of crushed floating ice which surrounds the ship, making operation of the crane by the winch driver fairly challenging, especially in cold conditions.

4.6c Samples collected

Station	Event	Samples collected	Time	Date	Lat	Long
B16	E166	Algal/biomarker samples for −80 °C x3 (Stevenson). DOC x1 (Stevenson). Bulk POM/$\delta^{13}C$ & $\delta^{15}N$ x3 (Henley). Particulate Nitrogen Osmolites x 3 (Dixon).	09:56:00	17/07/2019	80° 7.198	30° 10.065
West Mooring	E170	Algal/biomarker samples for −80 °C x3 (Stevenson). DOC x1 (Stevenson). Bulk POM/$\delta^{13}C$ & $\delta^{15}N$ x3 (Henley).	02:09:00	22/07/2019	81° 1.488	18° 27.727

5 Sediment and pore water geochemistry

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[1]Author, ChAOS

5.1 Sampling strategy and procedures

5.1a Background and objectives

Samples for sediment and pore water geochemistry were taken to study the amounts and types of; organic material at the seafloor of the Barents Sea, the availability of electron acceptors (e.g., nitrate, Fe and Mn oxides, sulphate) for organic matter degradation, the recycling versus burial of nutrients released by organic matter degradation, and the interactions of sediment and pore water geochemistry with biological processes (e.g., bioturbation, microbial community structures).

5.1b Sampling strategy/instrument description

Sampling were initially selected for the ChAOS JR16006 cruise in 2017 based on available sediment distribution maps of the Barents Sea, with the aim to sample settings with mainly muddy sediment for optimal recovery. In the Barents Sea, muddy sediments are prevalent within the deeper (~300 m) troughs carved by ice streams of the Eurasian ice sheet following the Last Glacial Maximum, while the shallower banks are often covered by coarse-grained material due to stronger currents.

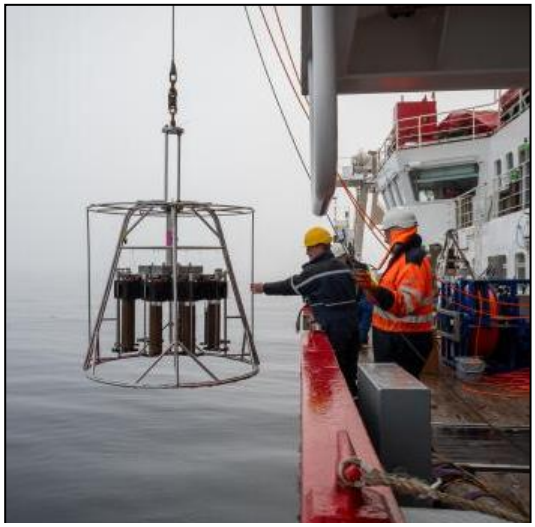

Figure 5.1b: Recovery of Megacorer (Photo: J.Faust)

Sampling for sediment and pore water geochemistry was conducted with the Megacorer (a multicoring device with up to 12 core tubes) (Fig. 5.1b), which is the most appropriate instrument to sample the top ~30-40 cm of sediment with the overlying bottom water and an intact sediment-surface (Figs. 5.1b2 & 5.1b3). The Megacorer and accessories (110 mm wide Perspex tubes, rubber bungs, core extruder etc.) were provided by National Marine Facilities.

Prior to deployment, the Megacorer was set up with 8 tubes at each station and was deployed at least 3 times at each station, with ~50 m distance between individual deployments to account for spatial variability. The actual number of deployments at each station was dependent on the recovery of intact sediment cores. At each deployment location, 4 intact cores were required for pore water sampling and 3 intact cores were required for sediment sampling. If less than seven intact cores were collected at a single deployment, a second deployment was done without moving the ship.

Figure 5.1b2: Intact sediment surface with benthic fauna in a Megacorer tube. Photo: M. Zindorf

Figure 5.1b3: Pore water extraction with Rhizone samplers and 30 mL syringes in the sink of the wet lab. Photo: M. Zindorf

For pore water sampling, pre-drilled cores were transferred into the sinks in the wet lab and fixed with bungee cords. Pore water samples were taken with Rhizone samplers attached to 30 mL plastic syringes with spacers to create a vacuum. At the appropriate depths, the tape was perforated using a pipette tip, and Rhizones were inserted quickly and carefully. If Rhizones could not be inserted into certain sediment horizons without force (due to the occurrence of rocks), these intervals were not sampled. The pore water sampling order was as follows: Bottom water samples were extracted first (~500 mL). While bottom water was being extracted, the Cellotape was perforated at the appropriate depths from the deepest horizon to 4.5 cm depth, Rhizones were inserted, and syringes were attached. Once sufficient bottom water had been sampled, the remaining overlying water was drained by perforating the holes right above the sediment-water interface. Then the holes at 2.5, 1.5 and 0.5 cm depth were opened, and Rhizones were inserted very quickly to avoid the loss of pore water from the very water-rich uppermost sediment horizons. Rhizones were left in the core tubes for up to ~2 hours, depending on the efficiency of pore water extraction (very fast in the top layers, much slower in deeper layers). Pore water volumes ranged from 1 to 30 mL per syringe. Following sampling, pore water samples from the four core tubes from each Megacorer deployment were combined into acid-washed and MilliQ-rinsed vials to reach maximum pore water volumes for individual sediment layers. From these combined pore water samples, splits were taken for the following analyses: Nutrient analysis (Henley) – 12 mL; dissolved metal analysis (Faust) – 3 mL; and cation/anion analysis (Faust) – 3-4 mL. If enough pore water was available 50 mL from 0.5-4.5 cm and 6.5-12.5 cm was taken for ^{14}C-DIC measurements. Samples for nutrient analysis were stored untreated for less than 1 day at 4°C prior to shipboard analysis (silicate, phosphate, nitrite, nitrate+nitrite, ammonium). Samples for cation analysis were acidified with HCl and stored together with untreated samples for anion analysis at 4°C. Samples for nitrate isotope analysis were flash-frozen untreated at -80°C, then transferred to -20°C for storage within ~ 24 hours. Samples for ^{14}C-DIC were frozen immediately after sampling at -20°C. Samples for δ^{30}Si were stored at 4°C. Equivalent splits were also taken from bottom water samples and treated and stored in the same way as for pore waters.

Figure 5.1b4: Sediment coring team. Photo: R. Owen

5.2 Gravity Coring

At most of the stations a gravity core was taken at the same position as the final Megacorer deployment. The gravity corer used allowed a maximum recovery of 3 m and the liner used was 6.6 cm in diameter. After the gravity core arrived on deck the barrel was removed from the bomb and transferred to trestles to remove the liner. The core liner was pulled out of the barrel and the empty top part was cut off. Both endings of the core were sealed with caps and tape. The core was immediately transferred to the cold room (4°C) where 3.5 mm holes were drilled into the core liner every 10 cm for pore water sampling. Pore water samples were taken with Rhizone samplers attached to 30 mL plastic syringes with spacers to create a vacuum. Rhizones were left in the core tubes for up to ~6 hours, depending on the efficiency of pore water extraction. Pore water volumes ranged from 1 to 6 mL per syringe. Depending on the volume of pore water retrieved splits were taken for the following analyses: Nutrient analysis (Henley) – 2 mL; dissolved metal analysis (Faust) – 2 mL; and cation/anion analysis (Faust) – 1 mL. After pore water sampling was finished gravity cores were taped to seal the holes and stored at 4°C in the cold room.

Figure 5.2a: Pore water extraction with Rhizone samplers and 30 mL syringes in the cold room. Photo: J. Faust

5.2b Oxygen levels in bottom waters and surface sediments

Background and objectives

Oxygen plays a crucial role in biogeochemical processes as a powerful terminal electron acceptor for heterotrophic organic matter degradation and for the re-oxidation of reduced species (e.g., NH_4^+, Mn^{2+}, Fe^{2+}, H_2S) produced during organic matter respiration. Oxygen concentrations at the sediment-water interface and its penetration depth in the uppermost sediment layers have a strong impact on organic matter burial and nutrient cycling. Alongside porewater and solid-phase geochemical depth-profiles, oxygen profiles help to better constrain diagenetic models, which aim to improve our quantitative understanding of benthic-pelagic coupling. We determined oxygen levels in bottom waters and surface sediments aiming to (i) estimate concentrations and penetration depths; and (ii) inform Reaction-Transport models designed for assessing organic matter dynamics.

Methods

A Pyro Science FireSting O_2 Mini (OEM) sensor was used for oxygen determination. Prior to analyses, the probe was calibrated with the *one-point calibration – air saturated water* mode. After calibration, the sensor was kept in Milli-Q water. After each multicore deployment, an intact core, with no disturbance in the overlying water and surface sediments, was selected for oxygen measurements. Given the non-destructive nature of such assessment, the same core was used for further sampling (e.g., pigments or inorganics) when necessary.

Shortly after retrieval, the selected core was transferred to a room at constant temperature (4 °C) and attached to a core rack for oxygen probing. The probe was attached to a mobile plastic tube, which was connected to a plastic cap sitting on top of the core (Fig. 5.2b).

As such, oxygen profiling at the bottom water (~ 10 – 5 cm) and surface sediment (~ 4 cmbsf) was possible. At the bottom water, three consecutive points were measured at every cm in the bottom water, whereas in the sediments 10 consecutive points were determined at every 0.25 – 0.5 cm, from the sediment-water interface to near-zero oxygen levels.

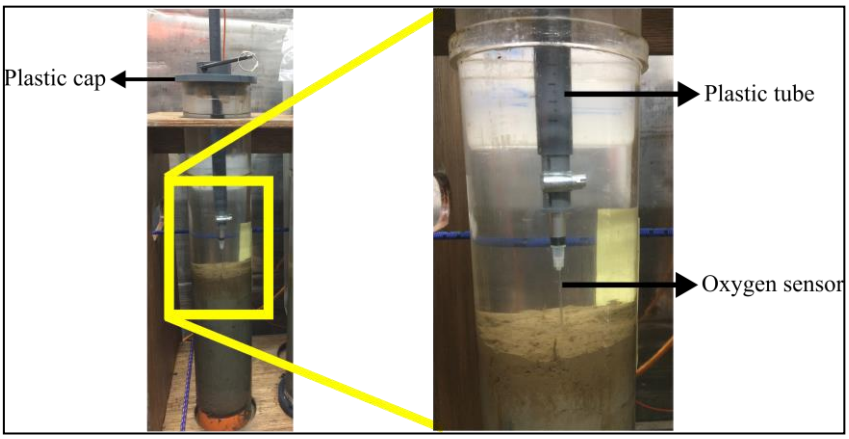

Figure 5.2b: Oxygen measurements set-up. Entire core and sensor plastic support on the left-hand side and oxygen sensor at the sediment-water interface on the right-hand side. Photo: F.S. Freitas

5.2c Preliminary results

Overall, bottom water oxygen levels showed similar patterns at all stations (~ 270 – 300 µM). At the interface a large drop in oxygen levels was recorded in all sites. The oxygen penetration depth varied from ~ 0.5 cmbsf at B14 to ~ 3 cmbsf at B15. We noticed that using partially disturbed cores, with evidence of resuspension during sampling, is unsuitable for oxygen determination. An evident shift in the oxygen profile was noticeable when compared to replica cores from the same station.

5.2d Core incubations

Background and objectives

Nutrient benthic fluxes are key mechanisms returning to the water column macronutrients released during organic matter heterotrophic degradation. Such fluxes can be determined via nutrient porewater depth profiles, which integrate longer-term processes associated to organic matter respiration and nutrient cycling. However, short-term processes (e.g., seasonal blooms) can be underrepresented with such approach. Directly assessing benthic fluxes through field experiments are an alternative to investigate nutrients release and uptake. Thus, we developed sediment core incubations aiming to (i) quantify macronutrients concentration evolution over a short time period due to organic matter respiration; and (ii) determine silicon isotopic composition ($\delta^{30}Si$) associated with diatom frustule sinking and dissolution.

Methods

An intact sediment core (100 mm i.d.) containing undisturbed surface sediments and overlying water from each station was selected for core incubation experiments. Shortly after retrieval the core was transported to a room with constant temperature (4 °C), attached to a core rack and kept in the dark for the course of the incubation. A plastic cap fitted with a magnetic stirrer bar for gently homogenising the overlying water, and a plastic tube for sampling collection was fitted on the top of the core. The cap was then lowered until it reached the top of the overlying water. A magnetic motor was fitter on the top of the cap to power the stirrer bar (Fig. 5.2d). The water height was measure with a measuring tape to estimate the water volume at the beginning of the incubation.

At each site, the incubation was run for 24 hours. A bottom water sample was taken at the beginning of the incubation, and then at every three hours. In total 9 water samples per experiment were taken. A 60 mL plastic syringe attached to the plastic tubing was used to withdraw samples. Each sample was approx. 50 mL, which were filtered through a syringe filter (Acrodisc PF Syringe filter with 0.8/0.2 µm supor membrane) and split into two aliquots: 25 mL for macronutrients (S. Henly) and 25 mL for δ^{30}Si (K. Hendry). Nutrient samples were kept at 4 °C and analysed shortly after the end of each experiment. The δ^{30}Si samples were kept at 4 °C for future analysis at the University of Bristol.

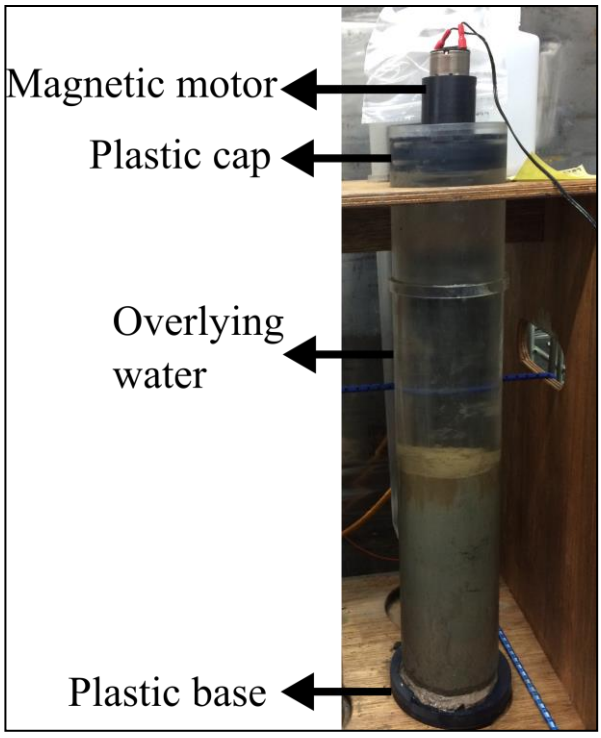

Figure 5.2d: Sediment core incubation set-up. Photo: F.S. Freitas

5.2e Data quality notes/ problems

- Instrument and material problems: The pre-drilled tubes for pore water sampling had to be modified by members of the ChAOS team onboard, as the holes to insert the Rhizone samplers into some of the tubes were too small. The pre-drilled tubes were therefore drilled again using a manual drill with a 3.5 mm steel bit. The pre-drilled tubes from JR16006 also caused problems due to holes drilled on the rings. These holes often leaked or caused issues when the tubes were installed on the Megacorer.

- Due to failed syringes and/or sediment characteristics, the amounts of pore water were not uniform, and in some intervals were not sufficient to provide sufficient volume for all planned analyses.

- Due to limitations in the volume of Qiagen LifeGuard Soil Preservation Solution available on the ship (1000 ml) it was not possible to preserve the entire depth range of cores from B14 and B15.

- It was not possible to sample at station B17 as during 2017 and 2018 due to ice cover and logistical reasons.

Table 5.2e Megacore (Multicore) samples collected

Station	Event	Latitude	Longitude	Water depth (m)
B50	E06	72°6293N	30°0044E	293
Tube #	**Samples taken**			
1	Sediment samples (34 cm; n=36) for inorganic geochemistry for J.Faust (Leeds)			

Station	Event	Latitude	Longitude	Water depth (m)
B13	E12	74°29.955N	29°59.470E	361

Tube #	Samples taken
3	Sediment samples (32 cm; n=34) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)
2,5,7,8	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds)
4	Incubation (Bristol)
3	Oxygen (Bristol)
6	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)

Station	Event	Latitude	Longitude	Water depth (m)
B13	E13	74°29.954N	29°59.572E	362

Tube #	Samples taken
1	Sediment samples (34 cm; n=36) for inorganic geochemistry for J.Faust (Leeds)
2,3,4,8	Pore water samples (n=13) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Nitrate isotope samples (~12 mL) for S. Henley (Edinburgh)
6	Sediment samples (34 cm; n=36) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)
7	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)
5	Oxygen (Bristol)

Station	Event	Latitude	Longitude	Water depth (m)
B13	E14	74.4997°N	29.9929°E	359

Tube #	Samples taken
7	Sediment samples (35 cm; n=37) for inorganic geochemistry for J.Faust (Leeds)
2,3,6,8	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Silica isotope samples (~5 mL) for K. Hendry (Bristol)
4	Sediment samples (41 cm; n=43) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)
5	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)
1	Oxygen (Bristol)

Station	Event	Latitude	Longitude	Water depth (m)
B15	E64	78°15.294N	29°59.704E	318

Tube #	Samples taken
3	Sediment samples (32 cm; n=34) for inorganic geochemistry for J.Faust (Leeds)
2,5,6,7	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Nitrate isotope samples (~12 mL) for S. Henley (Edinburgh)
3	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML) and oxygen (Bristol)
4	Sediment samples (42 cm; n=44) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)
1	Sediment samples (34 cm; n=36) for RNA analysis for L. Andrade (Newcastle)

Station	Event	Latitude	Longitude	Water depth (m)
B15	E65	78°15.293N	29°59.845E	319
Tube #	**Samples taken**			
5	Sediment samples (41 cm; n=43) for inorganic geochemistry for J.Faust (Leeds) and Oxygen (Bristol)			
1,4,6,7	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Silica isotope samples (~5 mL) for K. Hendry (Bristol)			
2	Sediment samples (43 cm; n=45) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			
8	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)			
3	Incubation (F. Sales de Freitas)			

Station	Event	Latitude	Longitude	Water depth (m)
B15	E66	78°15.321N	29°59.839E	318
Tube #	**Samples taken**			
7	Sediment samples (40 cm; n=42) for inorganic geochemistry for J.Faust (Leeds)			
1,2,6,8	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. DIC samples for C14 analysis (1.5 - 4.5 cm 50 mL and 6.5 - 12.5 cm 50 ml) for R. Hilton (Durham)			
5	Sediment samples (42 cm; n=44) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			
4	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)			
3	Oxygen (Bristol)			

Station	Event	Latitude	Longitude	Water depth (m)
B14	101	76.50660°N	30.50159°E	294
Tube #	**Samples taken**			
2	Sediment samples (32 cm; n=34) for inorganic geochemistry for J.Faust (Leeds) and Oxygen (Bristol)			
1,4,5,6	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Silica isotope samples (~5 mL) for K. Hendry (Bristol)			
7	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)			
3	Sediment samples (37 cm; n=39) for organic geochemistry and DNA for M. Stevenson and L. Andrade (Newcastle) and sediment samples (30 cm; n=32) for RNA analysis for L. Andrade (Newcastle)			
8	Incubation (F. Sales de Freitas)			

Station	Event	Latitude	Longitude	Water depth (m)
B14	E101	76.50704°N	30.50212°E	294
Tube #	**Samples taken**			
5	Sediment samples (36 cm; n=38) for inorganic geochemistry for J.Faust (Leeds) and Oxygen (Bristol)			
1,2,3,7	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Nitrate isotope samples (~12 mL) for S. Henley (Edinburgh)			
6	Sediment samples (38 cm; n=40) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			
4	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML) and oxygen (Bristol)			

Station	Event	Latitude	Longitude	Water depth (m)
B14	E103	76.50692°N	30.50398°E	294
Tube #	**Samples taken**			
1	Oxygen (Bristol)			
2,3,5,6	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. DIC samples for C14 analysis (1.5 - 4.5 cm 50mL) for R. Hilton (Durham)			
4	Sediment samples (32 cm; n=34) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			
7	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)			

Station	Event	Latitude	Longitude	Water depth (m)
B16	138	80.07092°N	29.94201°E	298
Tube #	**Samples taken**			
4	Pigments			
1,2,3	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds)			

Station	Event	Latitude	Longitude	Water depth (m)
B16	E139	80.06711°N	29.94487°E	299
Tube #	**Samples taken**			
2	Sediment samples (30 cm; n=32) for inorganic geochemistry for J.Faust (Leeds) and Oxygen (Bristol)			
6	Pore water samples (n=15) Combined with PW from E138			
1	Sediment samples (32 cm; n=34) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			
4	Oxygen (Bristol)			
3	Incubation (F. Sales de Freitas)			

Station	Event	Latitude	Longitude	Water depth (m)
B14	E140	80.06293°N	29.94457°E	296

Tube #	Samples taken
1	Pore water samples (n=15) 1. DIC samples for C14 analysis (1.5 - 4.5 cm 50mL and 6.5 - 12.5 cm 10mL) for R. Hilton (Durham)

Station	Event	Latitude	Longitude	Water depth (m)
B16	E141	80.05943°N	29.94256°E	296

Tube #	Samples taken
1	Oxygen (Bristol)
1,2,4,7	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Nitrate isotope samples (~12 mL) for S. Henley (Edinburgh)
5	Sediment samples (27 cm; n=29) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)
6	Oxygen and sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)

Station	Event	Latitude	Longitude	Water depth (m)
B16	E142	80.05653°N	29.93943°E	299

Tube #	Samples taken
2,3,4,5	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Silica isotope samples (~5 mL) for K. Hendry (Bristol)
1	Sediment samples (33 cm; n=35) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)
6	Oxygen and sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)

Station	Event	Latitude	Longitude	Water depth (m)
BY	179	73°53.358N	26°20.195E	457

Tube #	Samples taken
5	Pigments and Oxygen (Bristol)
1,2,3,8	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Nitrate isotope samples (~12 mL) for S. Henley (Edinburgh)
7	Frozen

4	Sediment samples (34 cm; n=36) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)

Station	Event	Latitude	Longitude	Water depth (m)
B3	188	72°38.184N	19°15.859E	364
Tube #	**Samples taken**			
4	Pigments and Oxygen (Bristol)			
1,5,6	Pore water samples (n=12) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Nitrate isotope samples (~12 mL) for S. Henley (Edinburgh)			
2	Sediment samples (20 cm; n=22) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			

Station	Event	Latitude	Longitude	Water depth (m)
B3	E189	72°38.184N	19°15.947E	366
Tube #	**Samples taken**			
8	Sediment samples (25 cm; n=27) for inorganic geochemistry for J.Faust (Leeds)			
1,2,5,6	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. Silica isotope samples (~5 mL) for K. Hendry (Bristol)			
3	Sediment samples (40 cm; n=42) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			
7	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML) and oxygen (Bristol)			
4	Incubation (F. Sales de Freitas)			

Station	Event	Latitude	Longitude	Water depth (m)
B3	E190	72°38.211N	19°15.941E	366
Tube #	**Samples taken**			
3	Sediment samples (35 cm; n=37) for inorganic geochemistry for J.Faust (Leeds)			
1,5,7,8	Pore water samples (n=15) 1. Nutrient samples (~12 mL)- analyzed shipboard 2. Acidified split for elemental analysis (~3 mL) for J. Faust (Leeds) 3. Unacidified split for major ion analysis (~1-2 mL) for J. Faust (Leeds) 4. DIC samples for C14 analysis (1.5 - 4.5 cm 50mL) for R. Hilton (Durham)			
2	Sediment samples (39 cm; n=41) for organic geochemistry & DNA for M. Stevenson & L.Andrade (Newcastle)			
6	Sediment samples (top 0-0.5 cm) for pigment analysis for R. Airs (PML)			
4	Oxygen (Bristol) and Freeze			

Table 5.2f Gravity core samples collected

Station	Event	Latitude	Longitude	Water depth (m)	Core Length (cm)	Samples Taken
B13	E16	74°29.981N	29°59.572E	362	70	None
B15	E67	78°15.320N	29°59.837E	318	130	PW samples (n=12), ICP Leeds, Nutrients Sian, IC Leeds
B14	E104	76.50698°N	30.50416°E	298	60	PW samples (n=5), ICP Leeds, Nutrients Sian, IC Leeds
BY	E180	73°53.357N	26°20.191E	456	190	PW samples (n=18), ICP Leeds, IC Leeds
B13	E191	72°38.210N	19°15.945E	369	130	PW samples (n=12), ICP Leeds, IC Leeds

6.0 Sediment erodibility, exchange processes and Nitrogen cycling

6.1 Sediment erodibility and exchange processes at the benthic/pelagic boundary driven by advective pressure

Saskia Ruhl (Plymouth Marine Laboratory)

6.1a Background

The objective was to measure factors impacting benthic/pelagic exchange processes along an environmental gradient of water mass distribution and typical seasonal sea ice cover levels, in order to understand differences between areas and how a shift of the polar front and climate-related changes in sea ice cover may affect local exchange processes. Critical sediment shear stresses and biologically important compounds, typically affected by benthic-pelagic exchange processes, were quantified. A measure of bioirrigative and advective transport across the benthic/pelagic boundary was included.

For future analyses these data could be combined with information on local macrofaunal abundance and biomass to quantify the extent of biologically mediated exchange processes. Additionally, by combining the benthic/pelagic boundary data with measurements of nutrients, organic carbon and pigment presence throughout the water column, sources and sinks of each of them may be identified. Granulometry data from stations will provide additional information on sediment properties across sites.

6.1b Methods

Sediment cores were taken from stations B13, B14, B15 and B16 with a 30 x 30 cm USNL box corer. Re-sampling of any single point was avoided and the distance between cores was between five and ten metres. From each box corer box, five replicate 30 cm diameter sub-cores were used to extract an intact

sediment core and the overlying water (see figure 6.1b1), and sealed on the bottom using a marine plywood base and neoprene seal.

Figure 6.1b1 Removal of one of the sediment cores from the box corer box, while keeping the sediment matrix and overlying water intact. The box cores with removable side panels were in part funded through the Charles Boyden Award and allowed the sampling process to be faster and less labour intensive than it would otherwise have been.

Cores were then transported into a temperature controlled laboratory that was kept at roughly 2 °C. This was as close to the bottom temperature of each station as the room could be cooled down to; the true bottom temperature as determined by the CTD drops preceding the sediment sampling varied between 2 °C and – 1.5 °C. Disruption of the sediment matrix and accidental resuspension during core transport where avoided as far as possible by using a carrying frame and rolling platform (see figure 6.1b2).

Figure 6.1b2 Transport of a core using the carrying frame and rolling platform across the deck

Where the water level upon taking the sub-cores was of insufficient height, bottom water from the CTD was used to top it up using bubble wrap and airline tubing as described by Widdows *et al*. (1998). Each core was given a 24 hour period between sampling and processing to settle, during which the water was aerated gently near its surface using air stones. Non-airtight neoprene lids were used to protect the cores from light. Weather conditions during the cruise were calm enough to eliminate the risk of accidental resuspension due to wave action during the settling period.

Sample processing methods were based on the Core Mini Flume (CMF) methods described in Thompson *et al.* (2013). Throughout the flume runs, optical backscatter was recorded continuously and Suspended Particulate Matter (SPM) was collected from a port mid-way through the water column and filtered through pre-weighed 25 μm glass fibre filters (GF/F; Whatmann). These samples will be re-weighed after drying at 60 °C for 24 hours then again after ashing at 450 °C for 24 hours to determine total organic carbon content in the suspended matter. In addition to the optical back scatter and SPM measurements undertaken to monitor the erosion, resuspension and settling processes throughout the flume run, the overlying water was sampled for nutrients (nitrite, nitrate, ammonia, silicate and phosphate). Nutrient samples were collected at the same intervals as SPM samples and filtered through 0.2 μm membrane filters. They were stored in a dark refrigerated environment and analysed within 48 hours using the methods described in section 3.1.

To calculate rates of bioirrigative and advective transport, Sodium Bromide (NaBr) was added to flumes at a concentration of 10 uM prior to each run, sampled 15 minutes after the initial addition, after four hours of incubation, immediately prior to running the flume, and immediately after the end of the experiment. *In-situ* samples of the bottom water collected in the CTD at each station were also collected to provide a local base line bromide concentration to which samples taken during a flume run could be compared. All samples were filtered using 25 μm GF/F and stored in the dark and frozen at -20°C prior to analysis. Bromide concentration will be determined from the samples using the materials and methods as detailed in Queiros *et al.* (2019).

In addition to the water samples detailed above, sediment samples were taken before and after application of the flume by syringe-coring areas of the sediment core from within the flume channel and other areas which had remained untouched by the simulated resuspension (see figure 6.1b3).

Figure 6.1b3 View from the top of the flume immediately after the end of the flume run, before syringe cores are taken. The flow channel around the outside exhibits elevated levels of suspended matter while the central section is unaffected by the resuspension experiment and can be used as a control sampling area.

Wet bulk density, water content and organic content loss on ignition will be determined from the syringe cores by separating them into depth sections corresponding to 0-1, 1-2, 2-3, and 3-5 cm depth from the sediment

surface, then weighing each section wet, dry (after 60 °C for 24 hours) and ashed (after 450 °C for 24 hours). Additional syringe cores collected in the same manner will be analysed for sedimentary pigment composition. The analysis of these cores will be executed using the methods detailed in Tait *et al.* (2015).

6.1c Parameters measured at stations B13, B14, B15 and B16

Optical backscatter (OBS)	Before and throughout flume runs as well as during the settling process
SPM concentration	Before and throughout flume runs
Total organic carbon in SPM	Before and throughout flume runs
Pigment composition at the sediment surface	Before and after critical shear stress application
Sediment density and porosity in four different depth layers	Before and after critical shear stress application
Sedimentary levels of total organic carbon in four different depth layers	Before and after critical shear stress application
Bioirrigation rates	Base rate of bioirrigative solute exchange
Rate of advective flux	Throughout flume runs
Critical erosion thresholds	Calculated from the OBS and SPM data using the methods detailed in Thomson *et al.* (2013).

6.1d References

Queiros, A.M., Stephens, N., Widdicombe, S., Tait, K., McCoy, S.J., Ingels, J., Ruhl, S., Airs, R., Besley, A., Carnovale, G., Cazenave, P., Dashfield, S., Hua, E., Jones, M., Lindeque, P., McNeill, C., Nunes, J., Parry, H., Pascoe, C., Widdicombe, C., Smyth, T., Atkinson, A., Krause,-Jensen, D., Somerfield, P. (2019). Connected macroalgal-sediment systems: blue carbon and food webs in the deep coastal ocean, Ecol Monogr In press

Tait, K., Airs, R.L., Widicombe, C.E., Tarran, G.A., Jones, M.R., Widdicombe, S. (2015). Dynamic responses of the benthic bacterial community at the Western English Channel observatory site L4 are driven by deposition of fresh phytodetritus. Progr Oceanogr, 137, 546-558.

Thompson, C.E.L., Couceiro, F., Fones, G.R., Amos, C.L. (2013). Shipboard measurements of sediment stability using a small annular flume – Core Mini Flume (CMF), *Limnology and Oceanography*, 11, 604-615.

Widdows, J., Brinsley, M., Elliott, M. (1998). Use of *in situ* flume to quantify particle flux. *In: Black, K.S., Paterson, D.M., Cramp, A.* (eds) *Sedimentary Processes in the Intertidal Zone.* Geological Society, London, Special Publications, 139, 85-97.

6.2 Sediment nitrogen cycling

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[1]Author, [2]Dataset PI

6.2a Background and objectives

To understand the effects of differing organic matter (OM) supply, due to various states of ice cover, on the dominant pathways of nitrogen transformation, isotopes ($\delta^{15}N$) will be used to assess processes of N immobilization and microbial processes at each of the ChAOS benthic stations.

6.2b Sampling strategy/instrument description

To determine rate measurements for important N-cycling sediment processes (***nitrification***, ***denitrification*** and ***anammox***), bottled sediment samples and sediment cores spiked with 15N were collected and incubated for 24 hours. Incubations were conducted at 5 of the 6 ChAOS benthic stations (B3, B13, B14, B15, B16) with all N-cycling cores being collected from the USNL corer.

6.2c Methods/Processing/Calibrations

Nitrification rates: At each ChAOS benthic station, 12 replicate samples of surface sediment were collected in pre-weighed, 14 mL glass vials (using a 50mL syringe to take up the surface layer down to 0.5 cm depth). Approximately 4-5 mL of sediment was collected in each vial and filled with bottom water to create a slurry. Subsets of the slurries were amended with 0.14 mL of 1M zinc chloride ($ZnCl_2$; n=3), 0.14 mL of 1M allylthiourea (ATU; n=3) and 0.14 mL of 1M sodium chlorate ($NaClO_3$; n=3) and incubated in the CT-room at bottom temperature for ca. 24-36 hours. A parallel incubation without sediment (bottom water + treatments) was conducted at the same time. At the end of the incubation period, 0.5 mL of 1M $ZnCl_2$ was added to all the bottles for preservation. Ammonium oxidation rates will be measured as rates of nitrite accumulation in the $NaClO_3$-treated samples compared to the ATU-treated samples. The initial $ZnCl_2$ treatment acts as the starting point. Sediment rates will be corrected for ammonium oxidation in bottom water.

Denitrification and Anammox rates: At each ChAOS benthic station, 12 replicate cores were collected (i.d. 7 cm) from 3-4 separate USNL cores. Each core-tube had approximately 15 cm of sediment and 15 cm of overlying water. Overlying water was discarded from each core and replaced with bottom water amended with $^{15}NO_3^-$ (Three treatments: +0 μM, +50 μM, +200 μM $^{15}NO_3^-$). The +0 treatment was immediately homogenized with a power tool and the slurry decanted into 125 mL glass bottles. 1 mL of 1M $ZnCl_2$ was added for preservation and the bottles were sealed with Teflon-lined rubber septa and Al-crimps. The remaining two treatments were incubated in the CT-room, at bottom water temperature for ca. 24-36 hours. Magnetic fleas were suspended in the core tubes and agitated by an external electromagnetic circuit. After the incubation period, the cores were homogenized and preserved as above. Denitrification and Anammox rates will be determined post-cruise by membrane inlet mass spectrometry.

6.2d Data quality notes/ problems

Site B17 was unavailable for sampling due to sea ice cover, therefore only five of the six ChAOS stations could be sampled. There were no significant data quality issues to note. Incubation temperature in the cool room was set as low as possible (approx. 1°C), however temperatures reached lower than this at stations B14, B15 and B16 (0.87°C, -1.82°C and -1.83°C, respectively).

6.2e Samples collected

Stn.	Location	Date	Depth (m)	Bottom water (T°C)	Cool lab (T°C)	Event #
B3	72 66 N 19 35 E	26 Jul 2019	370	4.32	2.2	193, 194, 195
B13	74 47 N 30 12 E	08 Jul 2019	384	1.48	2.0	18, 24, 26
B14	76 55 N 30 62 E	13 Jul 2019	282	0.87	2.4	112, 116, 120
B15	78 26 N 30 20 E	11 Jul 2019	312	-1.82	2.0	70, 72, 78
B16	80 06 N 29 93 E	16 Jul 2019	294	-1.83	1.9	143, 144, 149

Table 6.2e Sampling details for nitrification and denitrification incubations.

Results

All the samples will be analysed once returned to Plymouth Marine Laboratory. Consequently, there are no preliminary data available for this section.

7 Benthic fauna

Tom Mesher. Jasmin Godbold, Adam Reed, Christina Wood, Emme Broad, David Barnes

Rates of warming in the high northern latitudes are amongst the highest globally. One of the most obvious manifestations is the dramatic reduction in summer sea ice extent and thickness over the past few decades. These changes in ice cover exert cascading effects on Arctic Ocean carbon and nutrient dynamics, causing important feedbacks on the local benthic ecosystems, regional processes and the global climate system. The Arctic Ocean accounts for up to 14% of the global atmospheric CO_2 uptake and is therefore of fundamental importance to the global carbon cycle. However, changes to certain key components of Arctic ecosystems, such as benthic faunal assemblages or the extent of carbon and nutrient burial are often ignored in political and scientific discussions of a changing Arctic Ocean. However, the Arctic Ocean seafloor hosts a diverse and productive benthic ecosystem that is a crucial component of an intimately coupled benthic-pelagic system. The relative importance of benthic organisms in modulating sequestration, transformation and storage of bio-essential nutrients and carbon across the Arctic Ocean is still poorly constrained.

7.1 Community structure and biodiversity

7.1a Background and objectives

Benthic organisms residing on and within Arctic shelf sediments rely primarily on the supply of organic matter (OM) from the overlying water column. Consequently, seasonal and inter-annual patterns in pelagic primary production strongly influence the temporal patterns seen in the structure and function of benthic communities. In Arctic systems the quantity, quality and timing of this OM supply depends on the presence or absence of sea ice cover. Seasonal and inter-annual variation in the duration and intensity of ice cover will set the availability of light and nutrients for primary production, as well as providing additional pulses of OM from specific under-ice algae. Therefore, benthic assemblage composition, organism activity and standing stock are likely to differ considerably along the continuum of sea ice-covered to open water, with inevitable effects on the key ecosystem functions provided by benthic organisms and the biogeochemical processes they support. Specifically, ecosystem functions

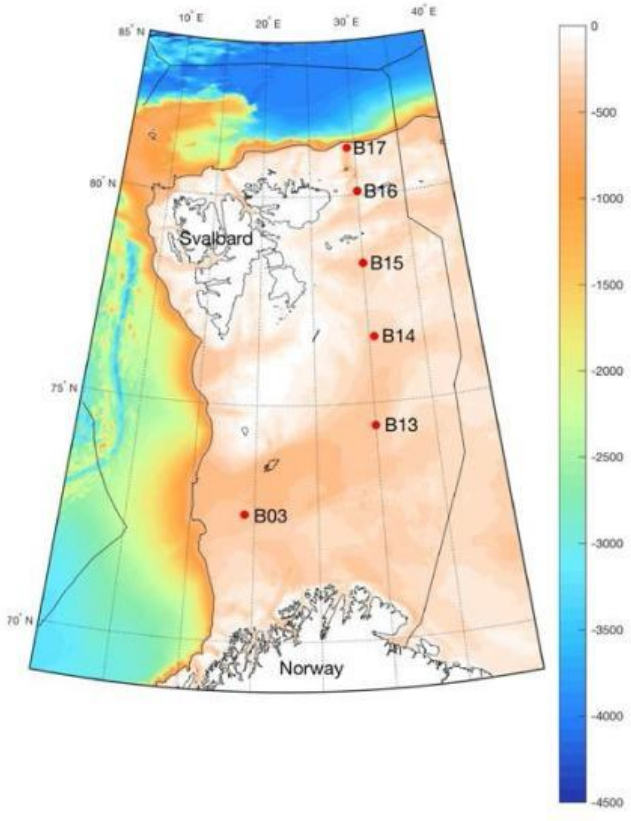


Figure 7.1a Location of the 6 full ChAOS project benthic sampling stations

such as carbon accumulation and storage, secondary production and energy transfer to higher trophic levels, and nutrient cycling (transformations and fluxes) depend heavily on all aspects of the biological system, from microbes to megafauna. To begin to understand the importance of sea ice conditions on the structure, function and diversity of benthic communities inhabiting shelf sediment habitats, a transect of 5 Stations (B3, B13, B14, B15 and B16) was sampled that ran from ice free NE Atlantic dominated communities in the south (B3) to predominately ice covered Arctic dominated communities in the north (B16) (Figure 7.1a).

7.2 Biota composition & sampling

7.2a Sampling methodology/instrument description

To collect organisms across the full range of benthic invertebrates, a range of sampling equipment as deployed at 5 of the full ChAOS benthic stations (B3, B13, B14, B15, B16). Sampling was replicated from the previous cruises, JR16006, and JR17007, as follows. Four specific animal groups were sampled. The smallest organism group collected was the ***meiofauna***. These organisms are defined as those animals that live within the interstices between the sediment grains and are generally retained on a 63μm mesh. Larger than the meiofauna are the ***macrofauna*** and these organisms are large enough to move sediment particles and construct sediment features, such as tubes and burrows. This group is defined as those organisms large enough to be retained on a 0.5mm mesh. The next group is the ***mega-infauna*** and these are the large bodied, sparsely distributed organisms living within the sediment and are retained on a 1cm mesh. Finally there are the large bodied organisms that live on or near the sediment surface known as the ***epifauna***. These were collected using a trawl. Depending on the size of sample required for each of specific organism groups, two types of boxcorer were deployed; the USNL corer (surface area 0.1m^2) and the larger SMBA corer (surface area 0.5m^2). Samples for meiofauna and macrofauna were collected using the UNSL corer, whilst samples for mega-infauna were collected from the SMBA corer. In addition to the faunal samples, sediment samples were collected for sediment particle size analysis (PSA) to characterize the sediment type at each station.

Figure 7.2b Image showing the manual inspection of the sample for infauna >1cm.

7.2b SMBA Large box-corer

<u>Megafauna</u>

At all full ChAOS benthic stations, 5 replicate 0.5m^2 sediment cores were collected using the SMBA box corer. The top, loose section of each sample was sieved through a 1cm mesh and the bottom, clay-like sediment was manually inspected for any infaunal organisms >1cm. All sieved residue and clay dwelling organisms were placed into a 0.5L pot and preserved with 10% formaldehyde solution.

Station	Location	Date	Depth	Event No's.
B3	72.65N 19.34E	27/7/2019	374m	203,205,206,207,210
B13	74.46N 30.12E	09/7/2019	353m	045,046.047,048,049
B14	76.55N 30.62E	13/7/2019	281m	106,107,108,109,110
B15	78.26N 30.20E	11/7/2019	313m	082,083,084,085,086
B16	80.09N 30.15E	17/7/2019	264m	156,157,158,159,160

Table 7.2b Samples taken to collect megafauna and describe benthic community abundance, diversity and structure.

Results
The sample residue will be returned to PML where the mega-infauna (organisms >1cm) will be extracted, identified and biomass obtained.

Data quality notes/ problems
There were no significant sample collection or data quality issues to note. However, it should be noted that site B16 had many large rocks. At station B3, there were 7 failed deployments of the box corer due to it not firing, the collection of a very small sample, or the wire getting caught and tangled.

7.2c UNSL Small box-corer

Figure 7.2c Image showing the residues collected from a sample at station B3.

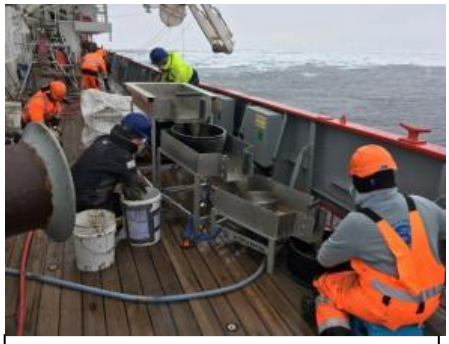


Figure 7.2c2 Image showing the sieve table set-up and the staged sieves.

7.2a Meiofauna and Macrofauna
At all full ChAOS benthic stations, 5 replicate 0.1m^2 sediment cores were collected using the UNSL box-corer. The overlying water was drained off to reveal the sediment surface. In each core, three 50ml syringe corers were then pushed into the sediment to a depth of approximately 8 cm. The sediment from these 3 x 50ml cores was pooled into a pot and preserved with 10% formaldehyde solution. The remaining sediment in the core was sieved over 2mm, 1mm, and 0.5mm sieves and the residues were combined into the 0.5mm sieve before being placed into a pot and preserved with 10% formaldehyde solution.

Station	Location	Date	Depth	Event No.
B3	72.65N 19.34E	26/7/2018	373m	196,198,199,200,202
B13	74.46N 30.11E	08/7/3018	353m	Meiofauna: 023,024,026,028,030 Macrofauna: 019,021,023,028,030
B14	76.55N 30.61E	13/7/2018	281m	114,118,122,123,124
B15	78.26N 30.20E	11/7/2018	313m	069,071,074,075,076
B16	80.10N 29.99E	16/7/2018	291m	151,152,153,154,155

Table 7.2c Samples taken to collect meiofauna and macrofauna to describe benthic community abundance, diversity and structure.

Results
These samples will be returned to Plymouth Marine Laboratory (PML) where the meiofauna

(organisms <63µm) and macrofauna (organisms >0.5mm) will be extracted, identified, measured and their biomass calculated.

Data quality notes/ problems
There were no significant sample collection or data quality issues to note. However, it should be noted that at site B3, one of the UNSL box corer scoops got damaged by a rock. Only two samples retrieved from station B3 were rejected due to them not containing sufficient sediment, all other samples collected at each of the stations were of 'good' quality.

Figure 7.2c3 Image showing a rock and the damage it caused to the scoop.

7.3 Particle Size Analysis

At each of the ChAOS benthic stations, 3 USNL cores were subsampled for Particle Size Analysis (PSA). In each core, three 50ml syringe corers were pushed into the sediment to a depth of approximately 8 cm. The sediment from these 3 x 50ml cores was pooled and placed into a Ziploc plastic bag which was sealed and then placed into a -20 ºC freezer.

Station	Location	Date	Depth	Event No.
B3	72.65N 19.34E	26/7/2018	370m	193,194,195
B13	74.46N 30.11E	08/7/2018	355m	018,045,046
B14	76.55N 30.61E	13/7/2018	281m	112,116,120
B15	78.26N 30.20E	11/7/2018	312m	070,072,078
B16	80.05N 29.93E	16/7/2018	296m	143,144,149

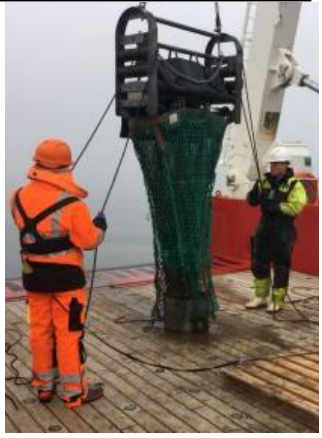
Table 7.3 Samples taken to characterise sediment at each station

Results
These samples will be returned to PML and analysed.

Data quality notes/ problems
There were no significant sample collection or data quality issues to note.

7.4 Agassiz Trawls

7.4 Image showing the trawl contents being emptied into a 1cm mesh sieve.



7.4a Epifauna

At each of the ChAOS benthic stations, epifauna were collected from 3 separate 1.25m wide Agassiz trawl tows. The trawl was paid out at a winch speed that kept the tension off the wire until a length of cable had been deployed that was between 1.5 and 2 times the water depth. The pay-out was then halted and the timing for the trawl was started at this time. After 15 minutes the trawl recovery started and this point constituted the end of the trawl time. At the start and end of the trawl period both location and time were recorded. The 3 trawl tows were conducted for 15 minutes each at a ship speed of 1 knot. On recovery the sediment from the trawl cod end was sieved over a 1cm mesh and the fauna recovered were placed in a 5 litre bucket and preserved with 10% buffered formaldehyde solution.

Station	Location	Date	Depth	Event No.
B3	72.66N 19.26E	27/7/2018	377m	214,215,216
B13	74.49N 30.03E	09/7/3018	360m	050,051,052
B14	76.53N 30.54E	14/7/2018	280m	129,130,131
B15	78.26N 30.20E	12/7/2018	320m	090,091,092

Table 7.4a. Samples will be used to quantify the community structure and biomass of large epifaunal organisms at each of the benthic stations.

7.4b Results

These fauna will be returned to Plymouth Marine Laboratory where they will be identified to species (where possible) and weighed (blotted wet weight and decalcified wet weight). This material will then be supplied to Dr Laura Grange (University of Bangor) for histological analysis.

7.4c Data quality notes/ problems

Trawling for samples at station B16 was not considered possible due to the ice conditions, and therefore, could not be collected; however, there were no significant sample collection or data quality issues to note for the samples collected.

Sampling details for Benthic Community Structure and Biodiversity			**Stations**					
			B3	**B13**	**B14**	**B15**	**B16**	**B17**
			26/27 July	8 / 9 July	13 / 14 July	10 / 11 July	16/17 July	Not reached
			72 38 N 19 15 E	74 30 N 30 00 E	76 30 N 30 30 E	78 15 N 30 01 E	80 06 N 30 06 E	81 18 N 29 10 E
			370m	359m	290m	316m	290m	310m
Sample	**Kit**	**# Reps**	**Event numbers**					
Macrofauna	USNL	5	14	14	14	14	13	
Mega-Infauna	SMBA	5	6	18	6	11	6	
Epifauna	1.25m Agassiz (15 mins)	3	6		7	6	0	
Epifauna	SUCS	20 photos site^{-1} 1-4 sites station^{-1}	3	3	4	4	3	

Table 7.4b Samples taken to describe benthic community abundance, diversity and structure.

7.5 Shelf Underwater Camera System

David Barnes - British Antarctic Survey

Twenty SUCS images were attempted at each of 2-4 locations within each major ChAOS site (see Table 4.3a) to characterise the surface living mega and macrofauna. Some images at each site were performed over 2017 and 2018 (JR16006 and JR17007) trawl tracks to investigate faunal recovery and to explore composition signals of disturbed Arctic benthos. In addition to the samples described above, addition SUCS deployments were conducted at two other stations (Table 7.5a).

Stn	Date	Approx location	Depth	Replicates	Event Numbers
B50	25/07/2019	72.6 N, 30 E	290	3	5
Y	07/07/2019	73.5 N, 26.3 E	445	1	178

Table 7.5 Additional SUCS deployments conducted at two auxiliary ChAOS stations.

7.5b Results

Images will be analysed at BAS. Exemplar images from the SUCS are shown below illustrating the type of epifauna observed at the ChAOS benthic stations. Fauna present in images are recorded as density, by both morphotype and functional groups. These data are linked to BAS carbon content from trawl specimens. Standing stock of epifaunal carbon is estimated for each image by substituting carbon content of individual of each morphotype of each size (from lab work on trawl specimens at BAS). Epifaunal carbon variability within and between sites is then analysed with respect to environmental variables (from corresponding CTD & multibeam data).

Figure 7.5b Station B3: Typical images of the seabed

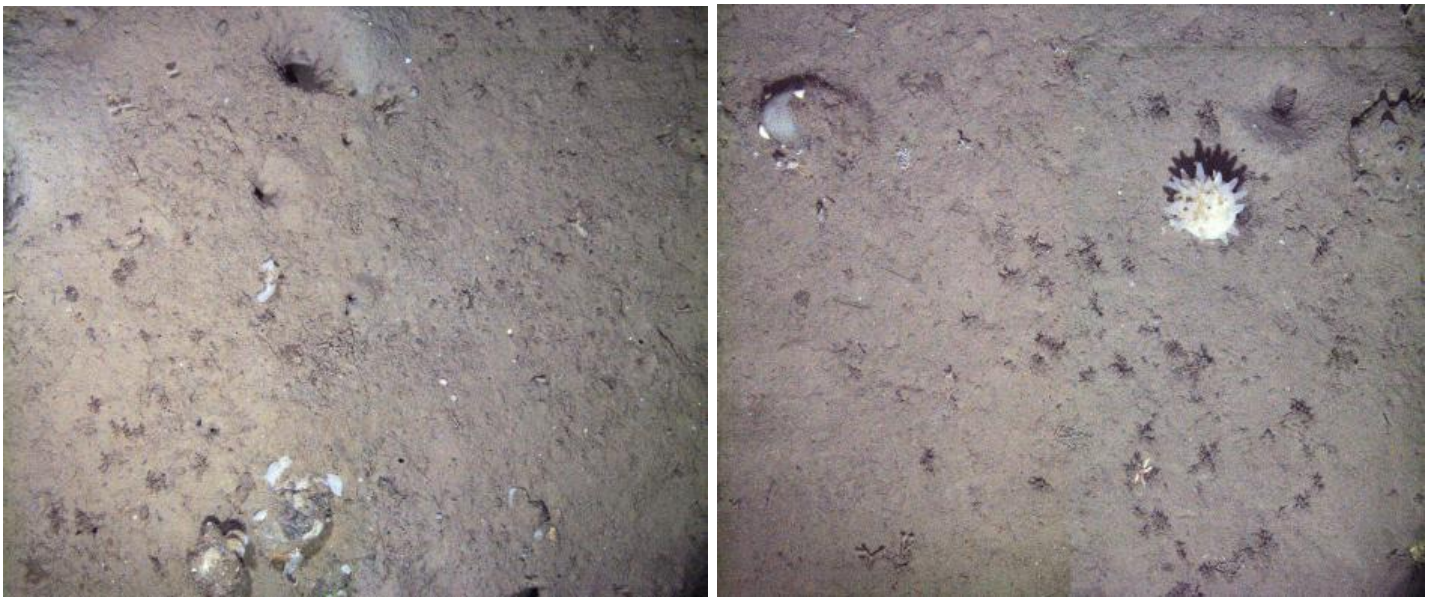


Figure 7.5b Station B13 Typical images of the seabed

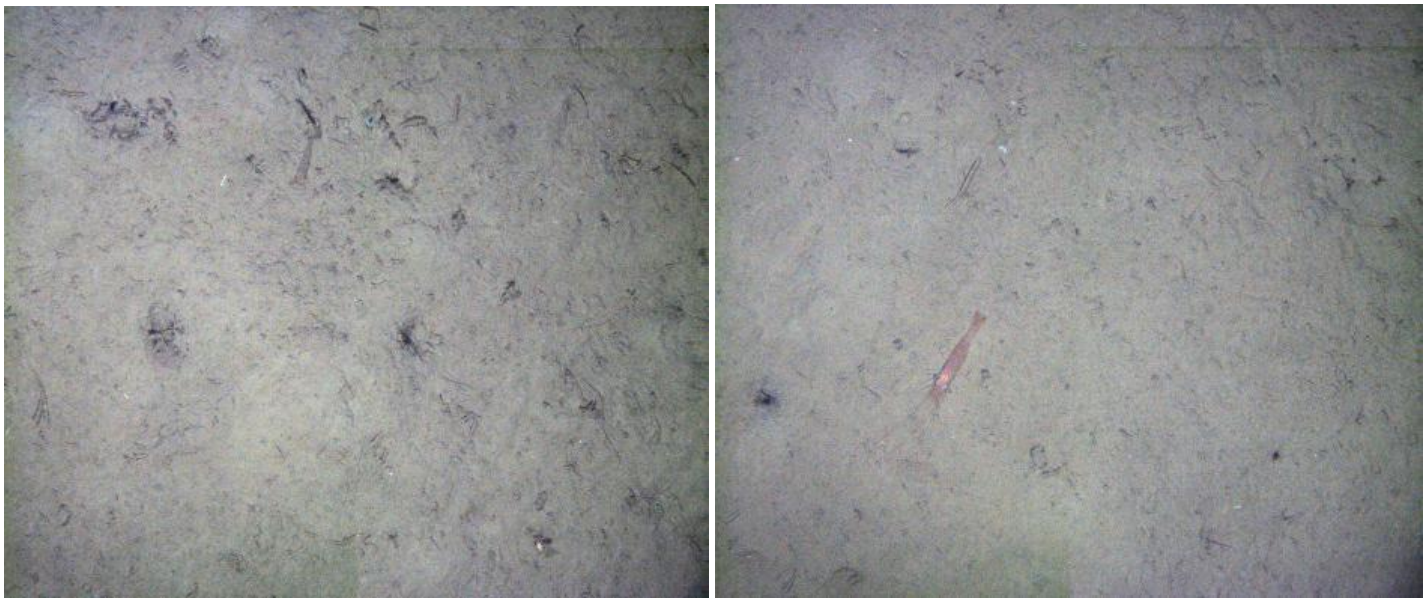


Figure 7.5c Station B14 Typical images of the seabed

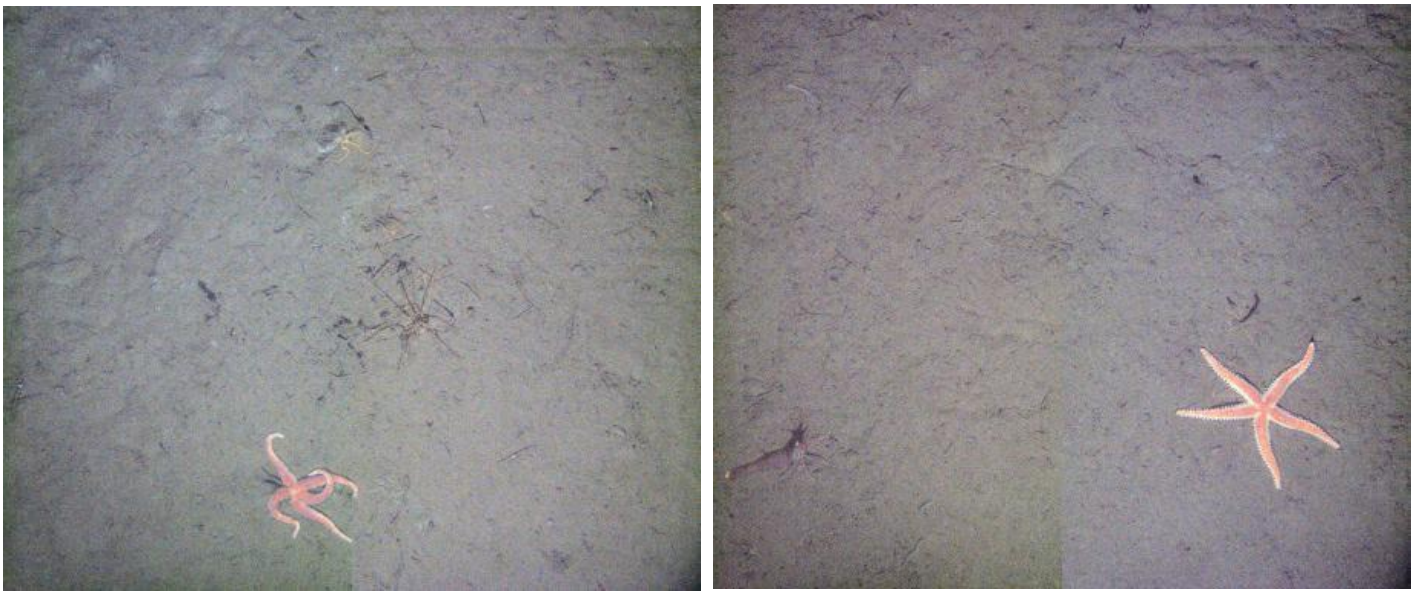


Figure 7.5d Station B15 Typical images of the seabed

Figure 7.5e Station B16 Typical images of the seabed

7.6 Benthic community function

Jasmin Godbold, Adam Reed, Tom Williams, Emmeline Broad and Christina Wood
(University of Southampton)

At the seafloor, a significant proportion of organic matter (OM) from marine, terrestrial, or sea ice sources is remineralised *via* microbially mediated processes (e.g., denitrification, ammonification, Fe/Mn or sulphate reduction) that are coupled to the activity of benthic meio-, macro- and mega-fauna (e.g., *via* bioturbation, bioirrigation). These coupled biological and biogeochemical processes lead to a partition of the carbon and nutrient pools into a fraction that is recycled to drive a benthic-pelagic feedback loop, and a fraction that is buried in sediments. The resulting feedback with water column processes (physical mixing, primary productivity) are more pronounced than in the open ocean and, on the Arctic shelf, plays a crucial role for benthic-pelagic coupling and ecosystem productivity, as well as the long-term removal of carbon from the ocean-atmosphere system. Key uncertainties exist, however, in how changes in sea ice cover, with a trend to thinner and reduced ice cover that exhibits significant inter-annual variability, will alter existing biological community composition and structure, biogeochemical processes, and associated ecosystem functioning. Understanding these changes to the benthic environment is of critical importance to understanding the Arctic Ocean ecosystem as a whole.

7.6a Background and Objectives

The functional role of epi- and infauna is critical to understanding biogeochemical cycling at the sediment water interface, and the potential for organic matter to be recycled, or stored, in ocean floor sediments. The behaviour of sediment invertebrate species in terms of how they mix sediments (bioturbation) and move water through their burrows (bioirrigation) enhance the movement of oxygenated seawater into the sediment, driving a feed-back loop for nutrient cycling, and exerting a strong influence on the rate and degree of organic matter degradation. Currently there is little understanding of how future climate conditions or changes in local environmental conditions affect organism behaviour and the associated cycling of nutrients in Arctic soft sediment habitats. To gain a better understanding of these processes we collected sediment and fauna for three independent studies:

1) Understanding how individual organisms move oxygenated and de-oxygenated water within their burrows
2) Quantifying the effect that changes in food supply in the form of sea ice algae have on benthic invertebrate behaviour and ecosystem functioning
3) Quantifying the effect of future climate conditions on species behaviour and ecosystem functioning

7.6b Sampling strategy/instrument description

At station B13 and B14 we collected surficial sediment (oxygenated sediment layer only ~ top 10 cm) from replicate SMBA (13 at station B13 and 2 at B14) deployments and sieved it through a 500 µm sieve in shallow water. The sediment was left to settle for 48 hours, then the overlying water was removed, and the sediment homogenised before being distributed (~15cm depth) between 45 small aquaria (internal LWH: 12 x 12 x 33cm, wall thickness: 0.5cm). The

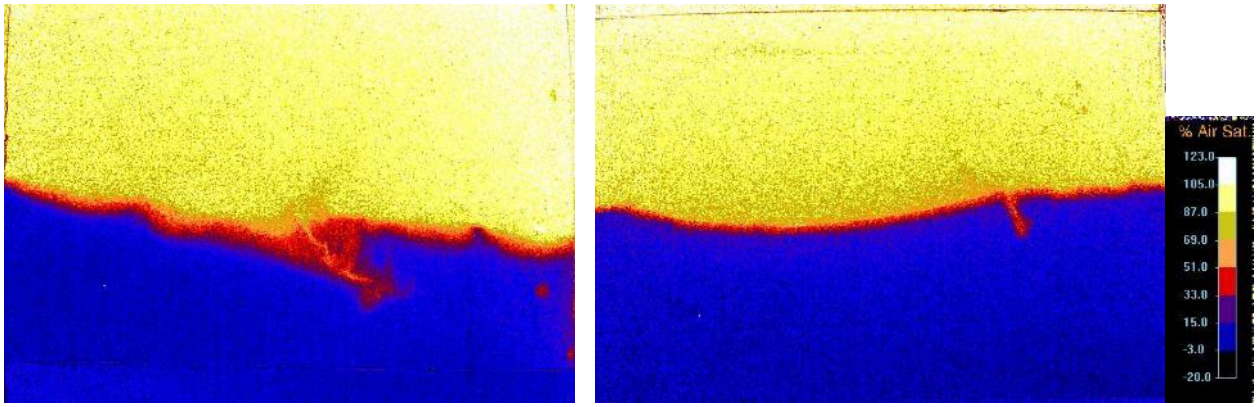
remaining sediment was retained in a large tub and supplemented with further sieved, surficial sediment from three replicate SMBA box cores at Station B16. All sediment was homogenised, regularly aerated by mixing and stored at 4°C for transport back to the University of Southampton. This sediment was also used for the on-board oxygen experiments (Obj. 1).

Figure 7.4b Temperature controlled water baths and mesocosms containing sieved sediment and benthic invertebrates.

From station B13 and B14 we used 10 replicate 5 minute Agassiz trawls (see later section of report) for the collection of *Ctenodiscus crispatus, Bathyarca glacialis* and *Astarte crenata.* Due to their high abundances the opportunity arose to collect Pectinariidae and Scaphopods for use in the oxygen (Obj.1) and climate change (Obj. 3) experiments. Any additional individuals of the target species recovered in the SMBA cores were also retained. All animals were evenly distributed into large aquaria (internal LWH: 20 x 20 x 34 cm, wall thickness: 0.5cm), continually aerated and held at ambient bottom water temperature (0 ± 1 ˚C) in our onboard mesocosm system consisting of temperature controlled tanks maintained by a chiller system (independent from ship services).

7.6c Objective 1: Oxygen experiments

Little is known regarding the individual roles of species bioirrigation behaviour and the associated oxygenation of sediments in polar environments, nor how projected climate change will affect these processes. The aim of the oxygen camera experiments was to characterise the role of burrowing and feeding activity on oxygen transfer and mixing within the sediments and at the sediment-water interface during 24 hour incubations. Using planar optodes attached to specially designed sediment cores and a VisiSens TD oxygen camera (PreSens, Germany), the oxygen camera set-up is capable of tracking changes in oxygen concentrations in near real time as animals are feeding or burrowing. Our key aim was to characterise the behaviour of a range



a **b**

of benthic invertebrate species across 24 hour timelapse videos. Individual species were collected from SMBA box cores and Agassiz trawls across the Barents Sea transect. One individual of each species was added to an oxygen-camera core (290 x 180 mm, with either 12mm, 15mm, 17mm or 32mm thickness depending on the species) that contained ~10cm of sediment and 5 cm of seawater approximately 12 hours before the start of the timelapse. This allowed the animals to settle and build their burrows. The 24-hour incubations took place in the cold room at 1° C within a darkened box and all cores were gently oxygenated for the duration of the experiment. Images from all experiments have been processed on board, and will be analysed at the University of Southampton. It is expected that these data will provide a better understanding of the roles of individual species in sediment and from across their range over the polar front.

Figure 7.6c Images from oxygen camera timelaspe a) Pectinarid polychaete (B13) burrowing activity; b) Scaphopod (B13) bioirrigation.

Table 7.6c Species List for Oxygen Camera (to be identified at U. Southampton)

Date	Species Code	Description	Station
12th July 2019	Sp1	Long polychaete	B13
12th July 2019	Sp2	Pectinarid	B13
13th July 2019	Sp3	*Ctenodiscus crispatus*	B13
15th July 2019	Sp4	Large Polychaete (escaped)	B13
16th July 2019	Sp5	Scaphopod	B13
17th July 2019	Sp6	Pectinarid	B13
18th July 2019	Sp7	*Ctenodiscus crispatus*	B13
19th July 2019	Sp8	*Bathyarca glacialis*	B13
20th July 2019	Sp9	*Astarte crenata*	B16
21st July 2019	Sp10	Bamboo Worm	B16
22nd July 2019	Sp11	*Nephtys sp.*	B16
23rd July 2019	Sp12	Isopod (small)	B14
24th July 2019	Sp13	Scalibrigmatidae	B16
25th July 2019	Sp14	Sipunculid	B16
26th July 2019	Sp15	Flatworm	B16
27th July 2019	Sp16	Caprellidae?	B13
28th July 2019	Sp17	*Molpadia* sp	B3
29th July 2019	Sp18	*Ctenodiscus* burrowing	B16
30th July 2019	Sp19	sp.	B13

7.6d Objective 2: Ice-algal experiments

The *C. crispatus*, *B. glacialis* and *A. crenata* collected at station B13 and B14 were separated between 45 small cores as follows: *Ctenodiscus crispatus* – 15 replicate cores of 2 individuals, *B. glacialis* – 15 replicate cores with 2 individuals each, *A. crenata* – 15 replicate cores with 2 individuals each. We measured the shell dimensions (length × height × timidity, mm) of all *B. glacialis* and *A. crenata*, as well as the dimensions of all *C. crispatus* (arm length and pit length, mm) individuals. These cores were maintained and the overlying water exchanged for uncontaminated surface seawater every 7 days. Fish food was provided 1-2 per week. Controlled experiments looking at the effects of variation in food quality (phytoplankton versus

sea ice algae) on the behaviour and associated nutrient generation in sediments, will be undertaken for a period of 4 months once the cores are returned to the University of Southampton.

7.6e Objective 3: Climate change experiments

The Pectinarid individuals that were collected opportunistically due to their high presence in the trawls, and the remaining target species (*C. crispatus*, *B. glacialis* and *A. crenata*) that were all collected at B13 and B14 were maintained in large cores containing sediment and maintained at ambient bottom water temperatures. The overlying water was exchanged for uncontaminated surface seawater every 7 days throughout the cruise. Fish food was provided 1-2 times per week. Controlled climate experiments under present and future (year 2050) environmental conditions will be undertaken for a period of 6 months once the cores are returned to the University of Southampton.

Data quality notes/ problems

For the incubation cores, there were no significant concerns with sample collection or with the maintenance of the cores at bottom water temperature. Two individuals of *A. crenata* that had been distributed into small cores for Objective 2 had not buried after 2 days and were replaced with two new individuals.

Samples collected

Table 7.6e1 Sampling details for the collection of sediment from the SMBA corer

Station	Event #	Date	Latitude	Longitude	Time	Depth (m)
B13	32	08/07/2019	74.46607	30.11835	18:14:45	354.59
	33	08/07/2019	74.46613	30.11831	18:52:08	354.21
	34	08/07/2019	74.46614	30.1184	19:23:06	354.19
	35	08/07/2019	74.46621	30.1184	20:02:01	357.1
	36	08/07/2019	74.46618	30.11864	20:32:64	354.41
	37	08/07/2019	74.46623	30.11868	21:05:04	354.38
	38	08/07/2019	74.46619	30.119	21:50:21	353.99
	39	08/07/2019	74.46626	30.11901	22:29:06	254.18
	40	08/07/2019	74.46625	30.1191	23:05:50	353.91
	41	08/07/2019	74.46627	30.11932	23:36:46	353.82
	42	09/07/2019	74.46632	30.1194	00:18:57	353.97
	43	09/07/2019	74.46632	30.11948	00:53:47	353.5
	44	09/07/2019	74.46631	30.11958	01:30:14	354.32
B14	105	13/07/2019	76.55291	30.61992	09:00:16	281.47
	106	13/07/2019	76.55282	30.61963	09:38:10	281.41
B16	161	17/07/2019	80.08478	30.15126	06:00:25	263
	162	17/07/2019	80.08561	30.14997	06:28:22	264
	163	17/07/2019	80.08785	30.1499	07:04:36	264

Table 7.6e2 Sampling details for the collection of organisms from the Agassiz trawl

Station	Event	Date	Latitude			Longitude			Bottom time	Start time	End time	Trawl time (mins)	Depth (m)
			Bottom	Start	End	Bottom	Start	End					
	53	09/07/2019	74.50386	74.50431	74.50488	30.16057	30.16697	30.175	15:00	15:13	15:29	16	354.38
	54	09/07/2019	74.50569	74.50609	74.50678	30.18605	30.19163	30.20171	16:08	16:20	16:40	20	354.18
	171	24/07/2019	74.49889	74.4973	74.4963	29.99775	29.98403	29.97519	16:43	17:12	17:31	19	366.23
	172	24/07/2019	74.49567	74.49566	74.49568	29.9643	29.95472	29.94587	18:11	18:29	18:46	17	371.62
B13	173	24/07/2019	74.4964	74.49767	74.49861	29.93578	29.92737	29.92129	19:30	19:49	20:03	24	370.91
	174	24/07/2019	74.50068	74.50213	74.50327	29.90772	29.89843	29.89113	21:02	21:22	21:38	26	373.7
	175	24/07/2019	74.50524	74.50657	74.50765	29.87843	29.86988	29.86281	22:26	22:45	23:01	16	372.53
	176	24/07/2019	74.51009	74.5109	74.51229	29.84718	29.84188	29.83291	23:47	00:04	00:21	17	371.8
	177	25/07/2019	74.51637	74.51866	74.52021	29.81048	29.80509	29.80134	01:14	01:33	01:47	14	368.95
B14	125	14/07/2019	76.50093	76.5033	76.50506	30.4772	30.48307	30.48734	23:51	00:10	00:25	15	295.7

Table 7.6e3 Body dimensions of the cushion star *Ctenodiscus crispatus* for Objective 2

Core ID	Individual ID	Radial length (mm)	Inter-radial length (mm)
1	1	17.92	11.55
1	2	15.75	11.00
2	3	16.85	9.20
2	4	17.40	10.15
3	5	17.38	10.40
3	6	21.29	11.25
4	7	19.53	12.77
4	8	18.06	10.11
5	9	20.23	12.98
5	10	19.03	11.38
6	11	18.72	12.18
6	12	21.66	11.42
7	13	17.40	11.32
7	14	22.32	12.19
8	15	21.08	12.44
8	16	20.05	12.13
9	17	20.38	11.26
9	18	21.18	11.18
10	19	20.38	12.46
10	20	22.18	14.48
11	21	22.50	13.47
11	22	22.45	13.49
12	23	18.52	10.88
12	24	18.86	13.83
13	25	19.60	10.88
13	26	23.09	12.63
14	27	19.86	11.56
14	28	21.92	13.23
15	29	22.56	13.06

Table 7.6e4 Shell dimensions for *Bathyarca glacialis* for Objective 2

Core ID	Individual ID	Shell length (mm)	Shell height (mm)	Tumidity (mm)
16	1	21.54	13.99	9.01
16	2	22.68	14.98	10.70
16	3	21.43	15.02	10.38
17	4	23.48	15.13	10.38
17	5	22.73	15.19	10.48
17	6	22.58	14.18	10.56
18	7	19.74	14.58	9.07
18	8	24.18	16.72	12.17
18	9	22.40	16.54	9.83
19	10	21.54	15.66	10.76
19	11	20.53	15.05	9.79
19	12	20.98	16.11	9.81
20	13	22.07	15.43	10.12
20	14	20.78	15.06	9.48
20	15	22.68	16.98	10.88
21	16	19.95	13.68	8.00
21	17	22.44	16.68	10.18
21	18	22.96	17.48	11.18
22	19	21.18	15.71	10.10
22	20	21.68	16.98	11.68
22	21	22.96	17.33	9.93
23	22	20.28	15.72	9.23
23	23	20.48	14.63	9.54
23	24	20.83	14.48	9.35
24	25	21.59	15.34	10.48
24	26	22.46	16.13	10.64
24	27	23.19	17.68	10.98
25	28	21.18	14.94	9.45
25	29	24.91	18.31	11.50
25	30	19.81	14.70	8.57
26	31	22.55	16.34	10.61
26	32	20.58	15.70	8.82
26	33	22.19	15.46	10.00
27	34	23.15	17.68	10.62
27	35	20.98	15.37	9.79
27	36	22.29	16.78	10.57
28	37	21.42	14.86	9.40
28	38	22.21	15.71	8.85
28	39	21.08	15.42	10.07
29	40	20.62	14.85	9.55
29	41	20.69	15.53	9.79
29	42	22.10	15.89	10.16
30	43	21.18	16.00	10.88
30	44	21.94	16.20	10.28
30	45	21.18	15.99	9.04

Table 7.6e4 Shell dimensions for *Astarte crenata* for Objective 2

Core ID	Individual ID	Shell length (mm)	Shell height (mm)	Tumidity (mm)
31	1	23.84	19.97	10.50
31	2	25.61	22.24	10.77
32	3	24.26	21.63	9.81
32	4	21.28	18.39	8.05
33	5	24.75	20.29	10.36
33	6	24.46	19.19	9.97
34	7	27.59	22.09	11.06
34	8	22.80	18.36	8.78
35	9	23.68	20.38	10.11
35	10	22.54	18.77	9.98
36	11	25.45	22.02	10.28
36	12	22.90	19.92	10.28
37	13	19.15	23.96	12.07
37	14	21.08	16.47	9.81
38	15	19.18	16.34	8.07
38	16	24.38	20.88	11.18
39	17	27.25	22.23	12.17
39	18	20.48	16.33	8.35
40	19	23.45	18.75	9.91
40	20	22.04	17.58	9.26
41	21	25.80	22.68	11.82
41	22	20.66	17.41	9.13
42	23	21.27	17.31	8.39
42	24	21.40	16.98	8.18
43	25	23.85	20.14	10.14
43	26	23.64	19.50	10.04
44	27	25.19	20.14	11.90
44	28	20.38	17.09	8.38
45	29	21.32	17.19	8.81
45	30	20.05	16.68	8.99

8 Moorings

It had been planned to recover two moorings to the north of Svalbard, but the amount of ice cover made this impossible. Moorings were deployed on JR17006 and are described in that cruise report, the eastern one at 81°18.144’N, 31°20.494’E and the western one at 81°02.040’N, 18°24.840’E.

Access was made to the western site on 21st July 2019 and communication established with the acoustic release on the mooring, but ice cover was too thick to justify attempting recovery. A CTD profile was conducted to provide a calibration profile for when the instruments are eventually recovered. Ice cover prevented us from reaching the eastern mooring site at all, and discussions are underway with Norwegian colleagues to find alternative options for recovery later in the season.

Appendix A - Cruise Event Log

1. CTD

Time	Latitude	Longitude	Depth (m)	Event	In	Max Depth	Out	Deck	Comment
06/07/2019 23:36	72.62942	29.99949	293.9	2	X				
06/07/2019 23:51	72.62942	29.9995	294.4	2		X			Test to 294 m
06/07/2019 23:59	72.62942	29.99949	293.6	2			X		
07/07/2019 00:14	72.62907	29.99973	295.9	3	X				
07/07/2019 00:23	72.62941	29.99949	295	3		X			Test to 285 m
07/07/2019 00:38	72.62945	29.99939	293.6	3			X		
07/07/2019 00:42	72.62943	29.99946	294.3	3				X	
07/07/2019 16:18	74.50029	30.00064	358.6	7	X				
07/07/2019 16:32	74.50028	30.00062	359.1	7		X			**B13** CTD to 350 m
07/07/2019 16:48	74.50028	30.00066	358.7	7			X		
07/07/2019 17:00	74.50027	30.00072	359	7				X	
10/07/2019 16:59	78.254	29.99971	318.7	58	X				
10/07/2019 17:11	78.25402	29.99959	318.4	58		X			**B15** CTD to 305 m,
10/07/2019 17:35	78.25401	29.99957	317.8	58			X		
10/07/2019 17:38	78.25401	29.99958	319.9	58				X	
10/07/2019 21:31	78.2549	29.99508	349.1	63	X				**B15** to 300m
10/07/2019 21:43	78.2549	29.99512	318.2	63		X			
10/07/2019 22:08	78.2549	29.99513	318.3	63			X		
10/07/2019 22:12	78.25491	29.99516	318.5	63				X	
12/07/2019 17:49	76.49586	30.50017	295.6	93	X				**B14** CTD to 280 m
12/07/2019 17:59	76.49586	30.50017	295.4	93		X			
12/07/2019 18:07	76.49587	30.50021	295.4	93			X		
12/07/2019 18:10	76.49587	30.50021	295.3	93				X	
12/07/2019 23:18	76.50658	30.50156	294.2	99	X				**B14** CTD to 280m
12/07/2019 23:27	76.50657	30.50154	293.9	99		X			
12/07/2019 23:52	76.50656	30.50156	294.2	99			X		
12/07/2019 23:54	76.50656	30.50157	294.3	99				X	
13/07/2019 01:19	76.50656	30.5015	294.2	100	X				
13/07/2019 01:28	76.50658	30.50156	294.4	100		X			Stopped at 287m
13/07/2019 01:55	76.50657	30.50152	294.2	100			X		
13/07/2019 01:57	76.50657	30.50151	294.4	100				X	
15/07/2019 07:26	79.24753	31.60556	143.5	132	X				
15/07/2019 07:36	79.24834	31.60066	146.1	132		X			ice edge to 134 m
15/07/2019 07:59	79.25116	31.58787	155	132			X		
15/07/2019 08:01	79.25139	31.58713	155	132				X	
16/07/2019 03:51	80.04295	30.0193	287.7	133	X				**B16** CTD to 269m
16/07/2019 04:04	80.0416	30.01567	288.4	133		X			
16/07/2019 04:35	80.03869	30.00618	292.9	133			X		
16/07/2019 04:37	80.03867	30.00579	318.7	133				X	
16/07/2019 06:20	80.03612	29.97128	301.7	135	X				**B16** CTD to 288m
16/07/2019 06:32	80.03661	29.96757	301.8	135		X			
16/07/2019 07:07	80.03886	29.95815	301.8	135			X		
16/07/2019 07:09	80.0394	29.95659	301	135				X	
21/07/2019 21:40	81.04173	18.43275	269.7	167	X				at West Mooring
21/07/2019 21:59	81.04133	18.43441	264.6	167		X			Stopped at 256m
21/07/2019 22:20	81.04092	18.4363	258.4	167			X		

21/07/2019 22:22	81.04089	18.43648	289.2	167				X	
21/07/2019 23:47	81.0395	18.44541	244.7	169	X				
21/07/2019 23:57	81.03943	18.44677	274.4	169		X			Stopped at 232m
22/07/2019 00:35	81.03933	18.45278	272.4	169			X		
22/07/2019 00:37	81.03933	18.45324	273.9	169				X	
26/07/2019 02:25	72.63132	19.24919	369.8	181	X				**B3** CTD to 356 m
26/07/2019 02:38	72.63132	19.24919	367.5	181		X			
26/07/2019 03:04	72.63132	19.24918	370	181			X		
26/07/2019 03:06	72.63132	19.24916	368.1	181				X	
26/07/2019 04:38	72.63133	19.24909	367.3	183	X				**B3** CTD to 360 m
26/07/2019 05:02	72.63129	19.24919	397.9	183		X			
26/07/2019 05:40	72.6313	19.24914	368	183			X		
26/07/2019 05:42	72.6313	19.24918	368.6	183				X	

2. PN

Time	Event	Latitude	Longitude	Depth	SST	Site	Comment
07/07/2019 00:25	4	72.62942	29.99953	294.25	7.1479	B50	Test
07/07/2019 00:37	4	72.62944	29.99936	294.05	7.1494	B50	Recovered
07/07/2019 17:12	8	74.50028	30.00072	358.72	6.8807	B13	Plankton net in
07/07/2019 17:24	8	74.5003	30.00068	359.42	6.9081	B13	Recovered
10/07/2019 17:56	59	78.254	29.99958	321.64	-0.1921	B15	Plankton net in
10/07/2019 18:02	59	78.25399	29.99958	318.52	-0.1827	B15	Recovered
12/07/2019 18:21	94	76.49588	30.50023	295.23	2.5442	B14	PN in for B14
12/07/2019 18:31	94	76.49588	30.50019	295.35	2.5393	B14	Recovered
16/07/2019 04:50	134	80.03761	30.00194	292.4	9.6528	B16	Plankton net in
16/07/2019 04:58	134	80.03713	29.99919	293.15	9.6525	B16	Recovered
21/07/2019 22:34	168	81.04065	18.4377	256.6	10.7304	Mooring W	Plankton net in
21/07/2019 22:43	168	81.04046	18.43848	255.53	10.7274	Mooring W	Recovered
26/07/2019 03:07	182	72.63132	19.24914	368.16	9.9094	B3	Plankton net in
26/07/2019 03:31	182	72.6313	19.24917	368	9.879	B3	Recovered

3. SUCS

Time	Event	Latitude	Longitude	Depth	USBL Lat	USBL long	Site	Pic	Depth USBL
07/07/2019 01:52	5	72.62943	29.99946	293.81	72.62949	29.99814	B50	1	
07/07/2019 01:57	5	72.62938	30.00077	292.87	72.62952	29.99832	B50	2	
07/07/2019 01:58	5	72.62937	30.00103	292.6	72.62952	29.99849	B50	3	
07/07/2019 01:59	5	72.62935	30.00132	324.71	72.62953	29.99866	B50	4	
07/07/2019 02:01	5	72.62933	30.0018	292.53	72.62952	29.99901	B50	5	
07/07/2019 02:04	5	72.62928	30.0026	292.26	72.6295	29.99967	B50	6	
07/07/2019 02:05	5	72.62926	30.00289	293.15	72.62949	29.99989	B50	7	
07/07/2019 02:06	5	72.62926	30.00331	293.99	72.62947	30.00017	B50	8	
07/07/2019 02:07	5	72.62926	30.00366	292.92	72.62947	30.00046	B50	9	
07/07/2019 02:09	5	72.62924	30.00408	292.4	72.62946	30.00076	B50	10	
07/07/2019 17:57	9	74.50026	30.00087	359.19	74.50026	30.00117	B13_1	1	
07/07/2019 18:01	9	74.50023	30.00156	359.52	74.50029	30.00151	B13_1	2	
07/07/2019 18:03	9	74.50022	30.0021	358.53	74.50028	30.00179	B13_1	3	
07/07/2019 18:04	9	74.50021	30.00262	359.76	74.50028	30.00217	B13_1	4	
07/07/2019 18:10	9	74.50016	30.00342	361.15	74.50023	30.00279	B13_1	5	

07/07/2019 18:12	9	74.50013	30.00387	358.81	74.50024	30.00372	B13_1	6	
07/07/2019 18:14	9	74.50007	30.00456	359.11	74.50019	30.00425	B13_1	7	
07/07/2019 18:16	9	74.50005	30.00498	359.36	74.50016	30.00456	B13_1	8	
07/07/2019 18:17	9	74.50001	30.00543	359.49	74.50012	30.00494	B13_1	9	
07/07/2019 18:18	9	74.5	30.00567	359.72	74.5001	30.00519	B13_1	10	
07/07/2019 18:20	9	74.49998	30.0059	359.52	74.50008	30.00545	B13_1	11	
07/07/2019 18:21	9	74.49995	30.00617	359.15	74.50005	30.00571	B13_1	12	
07/07/2019 18:24	9	74.4999	30.00697	359.73	74.50004	30.00616	B13_1	13	
07/07/2019 18:24	9	74.49989	30.00707	359.16	74.50003	30.00644	B13_1	14	
07/07/2019 18:25	9	74.49987	30.00732	359.2	74.50001	30.00675	B13_1	15	
07/07/2019 18:26	9	74.49986	30.00765	359.13	74.49998	30.00706	B13_1	16	
07/07/2019 18:28	9	74.49984	30.00789	359.13	74.49995	30.00735	B13_1	17	
07/07/2019 18:28	9	74.49983	30.0081	359	74.49994	30.00757	B13_1	18	
07/07/2019 18:30	9	74.49979	30.00855	359.87	74.4999	30.00798	B13_1	19	
07/07/2019 18:31	9	74.49976	30.00882	359.71	74.49987	30.00825	B13_1	20	
07/07/2019 19:18	10	74.49989	29.99242	362.24	74.5	29.99213	B13_2	1	
07/07/2019 19:20	10	74.49986	29.99285	360.53	74.49997	29.99244	B13_2	2	
07/07/2019 19:21	10	74.49983	29.99314	361.14	74.49995	29.99261	B13_2	3	
07/07/2019 19:23	10	74.49978	29.99366	360.84	74.49989	29.993	B13_2	4	
07/07/2019 19:24	10	74.49975	29.99402	360.79	74.49986	29.99335	B13_2	5	
07/07/2019 19:25	10	74.49973	29.99435	360.58	74.49983	29.99358	B13_2	6	
07/07/2019 19:26	10	74.49969	29.9947	360.7	74.4998	29.9939	B13_2	7	
07/07/2019 19:27	10	74.49967	29.99494	361.05	74.49978	29.99414	B13_2	8	
07/07/2019 19:28	10	74.49964	29.99509	362.04	74.49976	29.9943	B13_2	9	
07/07/2019 19:28	10	74.49963	29.99528	360.7	74.49975	29.99447	B13_2	10	
07/07/2019 19:29	10	74.4996	29.99555	360.69	74.49973	29.99472	B13_2	11	
07/07/2019 19:30	10	74.49957	29.99581	360.72	74.49971	29.99495	B13_2	12	
07/07/2019 19:31	10	74.49953	29.99618	361.51	74.49966	29.99534	B13_2	13	
07/07/2019 19:32	10	74.49952	29.99648	360.93	74.49964	29.99559	B13_2	14	
07/07/2019 19:33	10	74.49948	29.99677	362.06	74.49962	29.99586	B13_2	15	
07/07/2019 19:34	10	74.49946	29.9971	361.78	74.49959	29.99616	B13_2	16	
07/07/2019 19:35	10	74.49944	29.9973	361.16	74.49958	29.99635	B13_2	17	
07/07/2019 19:36	10	74.49942	29.99757	360.29	74.49955	29.99666	B13_2	18	
07/07/2019 19:37	10	74.4994	29.99784	360.18	74.49952	29.99694	B13_2	19	
07/07/2019 19:40	10	74.49933	29.99861	359.95	74.49945	29.99771	B13_2	20	
07/07/2019 20:10	11	74.50008	29.98305	364.92	74.50001	29.98298	B13_3	1	
07/07/2019 20:13	11	74.5	29.98367	364.61	74.50005	29.98317	B13_3	2	
07/07/2019 20:14	11	74.49996	29.98407	364.02	74.50003	29.98335	B13_3	3	
07/07/2019 20:16	11	74.49992	29.9845	364.04	74.50001	29.9836	B13_3	4	
07/07/2019 20:17	11	74.49987	29.98502	364.43	74.49997	29.98401	B13_3	5	
07/07/2019 20:19	11	74.49983	29.98561	364.11	74.49992	29.98457	B13_3	6	
07/07/2019 20:20	11	74.49979	29.98592	363.57	74.49989	29.98488	B13_3	7	
07/07/2019 20:22	11	74.49974	29.98629	363.49	74.49987	29.98526	B13_3	8	
07/07/2019 20:23	11	74.4997	29.98665	363.26	74.49982	29.98566	B13_3	9	
07/07/2019 20:25	11	74.49964	29.98723	363.18	74.49975	29.98626	B13_3	10	
07/07/2019 20:26	11	74.49959	29.98769	363.06	74.49971	29.98667	B13_3	11	
07/07/2019 20:28	11	74.49956	29.98805	363.25	74.49969	29.987	B13_3	12	
07/07/2019 20:29	11	74.49952	29.98841	387.36	74.49965	29.98733	B13_3	13	
07/07/2019 20:30	11	74.49948	29.98875	362.51	74.49961	29.9877	B13_3	14	
07/07/2019 20:33	11	74.49942	29.98948	362.42	74.49954	29.98838	B13_3	15	
07/07/2019 20:33	11	74.4994	29.98968	362.69	74.49951	29.9886	B13_3	16	

07/07/2019 20:34	11	74.49936	29.98996	361.61	74.49949	29.98886	B13_3	17	
07/07/2019 20:36	11	74.49932	29.99041	361.93	74.49945	29.98925	B13_3	18	
07/07/2019 20:37	11	74.49929	29.99078	362.35	74.49942	29.98963	B13_3	19	
07/07/2019 20:38	11	74.49926	29.99106	362.02	74.49939	29.98996	B13_3	20	
10/07/2019 18:24	60	78.25401	29.99958	317.8	78.25433	29.99934	B15	1	317
10/07/2019 18:26	60	78.25381	29.99928	317.79	78.2543	29.99934	B15	2	317
10/07/2019 18:29	60	78.2536	29.999	317.18	78.2542	29.99926	B15	3	317
10/07/2019 18:32	60	78.25336	29.99868	315.76	78.25405	29.99904	B15	4	317
10/07/2019 18:34	60	78.25324	29.99851	316.02	78.25397	29.99895	B15	5	317
10/07/2019 18:36	60	78.25308	29.9983	316.73	78.25384	29.9988	B15	6	317
10/07/2019 18:37	60	78.25296	29.99817	316.85	78.25376	29.99868	B15	7	316
10/07/2019 18:38	60	78.25286	29.99799	316.82	78.25366	29.99859	B15	8	316
10/07/2019 18:40	60	78.25269	29.99784	346.48	78.25353	29.99845	B15	9	315
10/07/2019 18:42	60	78.25261	29.99774	317.17	78.25346	29.99837	B15	10	315
10/07/2019 18:43	60	78.25252	29.99761	316.74	78.25338	29.99826	B15	11	315
10/07/2019 18:44	60	78.25244	29.99752	316.14	78.25333	29.99819	B15	12	315
10/07/2019 18:45	60	78.25234	29.99736	316.8	78.25322	29.99805	B15	13	315
10/07/2019 18:46	60	78.25224	29.99724	316.84	78.25313	29.99795	B15	14	315
10/07/2019 18:47	60	78.25217	29.99716	316.18	78.25307	29.99788	B15	15	316
10/07/2019 18:48	60	78.25209	29.99705	317.28	78.25301	29.99782	B15	16	315
10/07/2019 18:49	60	78.25201	29.99695	316.59	78.25292	29.99773	B15	17	316
10/07/2019 18:50	60	78.25194	29.99687	317.26	78.25286	29.99764	B15	18	315
10/07/2019 18:51	60	78.25188	29.99679	317.24	78.25281	29.99758	B15	19	316
10/07/2019 18:51	60	78.25183	29.99671	316.56	78.25276	29.99751	B15	20	316
10/07/2019 19:22	61	78.25022	30.00006	316.8	78.25042	29.99936	B15_2	1	316
10/07/2019 19:26	61	78.24995	30.00057	316.88	78.25036	29.99964	B15_2	2	315
10/07/2019 19:28	61	78.24981	30.00088	317.08	78.25027	29.99988	B15_2	3	316
10/07/2019 19:29	61	78.2497	30.00111	347.5	78.25021	30.00003	B15_2	4	315
10/07/2019 19:31	61	78.24955	30.00149	317.21	78.25009	30.00039	B15_2	5	316
10/07/2019 19:32	61	78.24946	30.00165	317.37	78.25003	30.00053	B15_2	6	316
10/07/2019 19:33	61	78.2494	30.00178	317.21	78.24999	30.00068	B15_2	7	316
10/07/2019 19:34	61	78.24931	30.00197	317.5	78.2499	30.00089	B15_2	8	316
10/07/2019 19:35	61	78.24924	30.00212	317.4	78.24985	30.00102	B15_2	9	316
10/07/2019 19:36	61	78.24918	30.00226	317.24	78.24979	30.00116	B15_2	10	316
10/07/2019 19:37	61	78.24912	30.00239	317.23	78.24974	30.00127	B15_2	11	316
10/07/2019 19:38	61	78.24904	30.00254	316.94	78.24966	30.00144	B15_2	12	316
10/07/2019 19:40	61	78.24891	30.0028	316.88	78.24954	30.00171	B15_2	13	316
10/07/2019 19:41	61	78.24882	30.00293	317.23	78.24946	30.00187	B15_2	14	315
10/07/2019 19:42	61	78.24873	30.00313	317.1	78.24939	30.00202	B15_2	15	317
10/07/2019 19:43	61	78.24861	30.00338	317.58	78.24926	30.00227	B15_2	16	316
10/07/2019 19:44	61	78.24853	30.00357	317.4	78.24918	30.00246	B15_2	17	316
10/07/2019 19:46	61	78.24841	30.0038	317.52	78.24906	30.00269	B15_2	18	316
10/07/2019 19:47	61	78.24835	30.00389	317.21	78.24903	30.00275	B15_2	19	316
10/07/2019 19:48	61	78.24829	30.00401	316.45	78.24896	30.0029	B15_2	20	316
10/07/2019 20:26	62	78.25662	29.99237	319.38	78.25682	29.99166	B15_3	1	317
10/07/2019 20:28	62	78.25654	29.99249	318.05	78.2568	29.99164	B15_3	2	317
10/07/2019 20:29	62	78.25646	29.9926	317.94	78.25676	29.99172	B15_3	3	317
10/07/2019 20:31	62	78.25639	29.99269	317.94	78.25671	29.99181	B15_3	4	317
10/07/2019 20:33	62	78.25628	29.99288	318.08	78.25663	29.99196	B15_3	5	317
10/07/2019 20:34	62	78.25621	29.993	318.14	78.25657	29.99208	B15_3	6	317
10/07/2019 20:35	62	78.25615	29.99316	321.82	78.25653	29.99219	B15_3	7	317

10/07/2019 20:36	62	78.25611	29.9932	318.7	78.25649	29.99227	B15_3	8	317
10/07/2019 20:37	62	78.25605	29.99326	318.08	78.25644	29.99236	B15_3	9	317
10/07/2019 20:39	62	78.25597	29.99339	318.08	78.25635	29.99249	B15_3	10	317
10/07/2019 20:40	62	78.25591	29.99348	318.27	78.25629	29.99259	B15_3	11	317
10/07/2019 20:42	62	78.25582	29.99363	318.01	78.2562	29.99272	B15_3	12	317
10/07/2019 20:43	62	78.25572	29.99378	318.41	78.25609	29.99289	B15_3	13	318
10/07/2019 20:45	62	78.25561	29.99394	318.58	78.25599	29.99304	B15_3	14	317
10/07/2019 20:47	62	78.25554	29.994	318.66	78.25591	29.99313	B15_3	15	318
10/07/2019 20:49	62	78.25544	29.99416	318.1	78.2558	29.99326	B15_3	16	318
10/07/2019 20:51	62	78.25526	29.99442	318.58	78.25568	29.99343	B15_3	17	317
10/07/2019 20:52	62	78.25516	29.99454	318.08	78.25561	29.99355	B15_3	18	317
10/07/2019 20:54	62	78.25505	29.9947	318.01	78.25552	29.99368	B15_3	19	317
10/07/2019 20:55	62	78.25495	29.99484	318.77	78.25545	29.99379	B15_3	20	317
12/07/2019 19:18	95	76.49588	30.50016	295.21	76.49586	30.50112	B14_1	1	
12/07/2019 19:20	95	76.49595	30.49976	295.09	76.49588	30.50097	B14_1	2	
12/07/2019 19:22	95	76.49603	30.49928	295.49	76.49593	30.50067	B14_1	3	
12/07/2019 19:23	95	76.49611	30.49882	296.2	76.49596	30.50043	B14_1	4	
12/07/2019 19:25	95	76.49622	30.49837	296.82	76.49604	30.50006	B14_1	5	
12/07/2019 19:29	95	76.49639	30.49743	296.8	76.49613	30.49959	B14_1	6	
12/07/2019 19:30	95	76.49646	30.49701	296.38	76.49619	30.49928	B14_1	7	
12/07/2019 19:31	95	76.4965	30.49682	296.21	76.49623	30.49911	B14_1	8	289
12/07/2019 19:31	95	76.49654	30.49663	294.91	76.49627	30.49885	B14_1	9	289
12/07/2019 19:32	95	76.49659	30.49635	295.64	76.49633	30.49852	B14_1	10	290
12/07/2019 19:33	95	76.49663	30.49612	295.69	76.49637	30.4983	B14_1	11	291
12/07/2019 19:34	95	76.49667	30.49585	295.5	76.49643	30.49801	B14_1	12	291
12/07/2019 19:36	95	76.49674	30.49544	295.34	76.4965	30.49758	B14_1	13	291
12/07/2019 19:37	95	76.4968	30.49516	295.5	76.49656	30.49728	B14_1	14	291
12/07/2019 19:38	95	76.49686	30.49488	295.39	76.49661	30.49705	B14_1	15	291
12/07/2019 19:39	95	76.49695	30.49445	295.34	76.49668	30.49661	B14_1	16	291
12/07/2019 20:19	96	76.49746	30.5054	295.23	76.49738	30.50648	B14_2	1	289
12/07/2019 20:21	96	76.49755	30.50511	295.5	76.49739	30.50629	B14_2	2	290
12/07/2019 20:22	96	76.49765	30.50492	295.11	76.49743	30.50616	B14_2	3	289
12/07/2019 20:23	96	76.49774	30.50472	295.39	76.4975	30.50601	B14_2	4	290
12/07/2019 20:24	96	76.49782	30.50457	295.37	76.49755	30.50591	B14_2	5	290
12/07/2019 20:26	96	76.49793	30.50442	299.45	76.49764	30.50573	B14_2	6	290
12/07/2019 20:27	96	76.49803	30.50441	294.92	76.49764	30.50571	B14_2	7	289
12/07/2019 20:29	96	76.49818	30.50442	295.12	76.49784	30.50549	B14_2	8	289
12/07/2019 20:31	96	76.49834	30.50444	295.14	76.49799	30.50547	B14_2	9	290
12/07/2019 20:32	96	76.49847	30.50444	295.15	76.49803	30.50546	B14_2	10	289
12/07/2019 20:34	96	76.49862	30.50443	295.15	76.49826	30.50546	B14_2	11	290
12/07/2019 20:35	96	76.49872	30.5044	295.05	76.49835	30.50544	B14_2	12	290
12/07/2019 20:37	96	76.49885	30.50438	295.07	76.49848	30.50543	B14_2	13	289
12/07/2019 20:38	96	76.49897	30.50437	295.2	76.4986	30.50542	B14_2	14	290
12/07/2019 20:40	96	76.49906	30.50435	295.12	76.49869	30.5054	B14_2	15	289
12/07/2019 20:41	96	76.49915	30.5043	295.16	76.4988	30.5054	B14_2	16	291
12/07/2019 20:42	96	76.49926	30.50433	295.08	76.49887	30.50536	B14_2	17	289
12/07/2019 20:44	96	76.49938	30.50434	295.08	76.49898	30.50536	B14_2	18	288
12/07/2019 20:45	96	76.49947	30.50433	295.19	76.49907	30.50537	B14_2	19	289
12/07/2019 20:46	96	76.49961	30.50436	295.02	76.49923	30.50538	B14_2	20	290
12/07/2019 21:16	97	76.5024	30.50669	295.05	76.50248	30.50766	B14_3	1	289
12/07/2019 21:18	97	76.5024	30.50629	294.8	76.50248	30.50758	B14_3	2	289

12/07/2019 21:20	97	76.5024	30.50559	294.95	76.50248	30.50725	B14_3	3	289
12/07/2019 21:21	97	76.5024	30.50491	294.5	76.50248	30.5068	B14_3	4	289
12/07/2019 21:23	97	76.5024	30.5042	294.73	76.50247	30.50644	B14_3	5	289
12/07/2019 21:25	97	76.5024	30.50364	294.85	76.50247	30.50593	B14_3	6	289
12/07/2019 21:27	97	76.50241	30.50295	295.03	76.50248	30.50532	B14_3	7	289
12/07/2019 21:28	97	76.50241	30.50244	294.57	76.50248	30.50482	B14_3	8	289
12/07/2019 21:30	97	76.50241	30.50201	294.72	76.50248	30.50446	B14_3	9	289
12/07/2019 21:31	97	76.50241	30.50136	293.94	76.50248	30.50384	B14_3	10	289
12/07/2019 21:33	97	76.50241	30.5009	294.68	76.50248	30.50343	B14_3	11	289
12/07/2019 21:34	97	76.50241	30.50042	294.39	76.50248	30.50297	B14_3	12	289
12/07/2019 21:36	97	76.50241	30.49989	295.08	76.50248	30.50246	B14_3	13	289
12/07/2019 21:38	97	76.5024	30.49922	294.66	76.50247	30.50194	B14_3	14	290
12/07/2019 21:41	97	76.5024	30.49799	294.84	76.50248	30.50057	B14_3	15	289
12/07/2019 21:42	97	76.5024	30.49749	295.01	76.50248	30.50019	B14_3	16	289
12/07/2019 21:44	97	76.50241	30.49701	295.71	76.50248	30.49966	B14_3	17	289
12/07/2019 21:45	97	76.50241	30.49642	295.01	76.50248	30.49912	B14_3	18	289
12/07/2019 21:47	97	76.50241	30.49598	295.39	76.50248	30.49865	B14_3	19	289
12/07/2019 21:48	97	76.50241	30.49543	295.35	76.50247	30.49809	B14_3	20	289
12/07/2019 22:28	98	76.50583	30.50692	293.87	76.50589	30.5079	B14_4	1	289
12/07/2019 22:30	98	76.50589	30.50648	294.2	76.50586	30.50782	B14_4	2	289
12/07/2019 22:33	98	76.50595	30.50599	294.09	76.5059	30.50755	B14_4	3	289
12/07/2019 22:35	98	76.506	30.50561	294.29	76.50594	30.50723	B14_4	4	289
12/07/2019 22:36	98	76.50604	30.50538	294.12	76.50597	30.50702	B14_4	5	289
12/07/2019 22:37	98	76.50607	30.50514	294.88	76.50599	30.50683	B14_4	6	289
12/07/2019 22:39	98	76.50612	30.50477	294.23	76.50604	30.50652	B14_4	7	289
12/07/2019 22:40	98	76.50614	30.50448	294.18	76.50607	30.50627	B14_4	8	289
12/07/2019 22:41	98	76.50618	30.5042	294.17	76.5061	30.506	B14_4	9	289
12/07/2019 22:43	98	76.50623	30.50386	294.5	76.50614	30.50565	B14_4	10	289
12/07/2019 22:44	98	76.50626	30.50363	294.28	76.50617	30.50544	B14_4	11	289
12/07/2019 22:45	98	76.5063	30.50339	294.39	76.50619	30.5053	B14_4	12	288
12/07/2019 22:46	98	76.50633	30.50322	294.41	76.50619	30.5053	B14_4	13	288
12/07/2019 22:48	98	76.50637	30.5029	294.2	76.50627	30.50473	B14_4	14	288
12/07/2019 22:49	98	76.50641	30.50256	294.42	76.50631	30.50447	B14_4	15	289
12/07/2019 22:50	98	76.50644	30.50235	294.06	76.50634	30.50424	B14_4	16	289
12/07/2019 22:51	98	76.50647	30.50214	294.16	76.50637	30.50401	B14_4	17	288
12/07/2019 22:52	98	76.5065	30.5019	294.1	76.5064	30.50378	B14_4	18	289
12/07/2019 22:53	98	76.50653	30.50178	294.54	76.50642	30.50362	B14_4	19	289
12/07/2019 22:54	98	76.50656	30.50159	294.71	76.50645	30.50345	B14_4	20	289
16/07/2019 11:57	136	80.07498	29.92202	300			B16_1	1	300
16/07/2019 12:00	136	80.07501	29.92268	300			B16_1	2	300
16/07/2019 12:36	137	80.07474	29.92984	298			B16_1	3	
16/07/2019 12:37	137	80.0747	29.93035	299			B16_1	4	
16/07/2019 12:38	137	80.07469	29.93061	298			B16_1	5	
16/07/2019 12:39	137	80.07467	29.93101	298			B16_1	6	
16/07/2019 12:40	137	80.07465	29.93129	297			B16_1	7	
16/07/2019 12:41	137	80.07463	29.93156	299			B16_1	8	
16/07/2019 12:42	137	80.07461	29.93183	298			B16_1	9	
16/07/2019 12:43	137	80.0746	29.93205	297			B16_1	10	
16/07/2019 12:44	137	80.07458	29.93239	297			B16_1	11	
16/07/2019 12:45	137	80.07453	29.93273	302			B16_1	12	
16/07/2019 12:46	137	80.07449	29.93289	300			B16_1	13	

16/07/2019 12:47	137	80.07446	29.93307	298	80.07448	29.93297	B16_1	14	
16/07/2019 12:49	137	80.07438	29.93341	298			B16_1	15	
16/07/2019 12:49	137	80.07435	29.93354	300			B16_1	16	
16/07/2019 12:51	137	80.07427	29.9339	295			B16_1	17	
16/07/2019 12:52	137	80.07421	29.93413	301			B16_1	18	
16/07/2019 12:53	137	80.07416	29.93433	0			B16_1	19	
16/07/2019 12:54	137	80.07411	29.93468	297			B16_1	20	
17/07/2019 08:16	164	80.09726	30.1549	262			B16_2	1	
17/07/2019 08:17	164	80.09737	30.15457	263			B16_2	2	
17/07/2019 08:18	164	80.09752	30.15468	264			B16_2	3	
17/07/2019 08:19	164	80.09767	30.15486	268			B16_2	4	
17/07/2019 08:20	164	80.0978	30.15515	264			B16_2	5	
17/07/2019 08:20	164	80.09796	30.15559	263			B16_2	6	
17/07/2019 08:21	164	80.09804	30.15592	263			B16_2	7	
17/07/2019 08:21	164	80.09814	30.15613	263			B16_2	8	
17/07/2019 08:22	164	80.09824	30.15612	263			B16_2	9	
17/07/2019 08:22	164	80.09836	30.15602	264			B16_2	10	
17/07/2019 08:23	164	80.09846	30.15602	263			B16_2	11	
17/07/2019 08:24	164	80.09862	30.15587	264			B16_2	12	
17/07/2019 08:24	164	80.0987	30.1558	264			B16_2	13	
17/07/2019 08:25	164	80.0988	30.15584	263			B16_2	14	
17/07/2019 08:26	164	80.09891	30.15591	263			B16_2	15	
17/07/2019 08:26	164	80.099	30.15596	264			B16_2	16	
17/07/2019 08:27	164	80.09908	30.15599	263			B16_2	17	
17/07/2019 08:27	164	80.09917	30.15604	263			B16_2	18	
17/07/2019 08:28	164	80.09924	30.15608	263			B16_2	19	
17/07/2019 08:28	164	80.09933	30.15617	263			B16_2	20	
17/07/2019 09:13	166	80.10794	30.16286	262			B16_3	1	
17/07/2019 09:14	166	80.1081	30.16336	266	80.10808	30.16327	B16_3	2	
17/07/2019 09:15	166	80.10823	30.16375	260	80.10808	30.16327	B16_3	3	
17/07/2019 09:15	166	80.10836	30.16397	262			B16_3	4	
17/07/2019 09:16	166	80.1085	30.16394	261			B16_3	5	
17/07/2019 09:16	166	80.1086	30.16383	262	80.10803	30.15605	B16_3	6	
17/07/2019 09:17	166	80.10874	30.16371	260	80.10803	30.15605	B16_3	7	
17/07/2019 09:17	166	80.10886	30.16351	260			B16_3	8	
17/07/2019 09:18	166	80.10899	30.16323	260			B16_3	9	
17/07/2019 09:18	166	80.10914	30.16306	260			B16_3	10	
17/07/2019 09:19	166	80.10936	30.16306	261			B16_3	11	
17/07/2019 09:20	166	80.10948	30.16323	264	80.10855	30.16336	B16_3	12	
17/07/2019 09:21	166	80.10958	30.16344	265	80.11097	30.16037	B16_3	13	
17/07/2019 09:21	166	80.10966	30.16373	260	80.11043	30.16863	B16_3	14	
17/07/2019 09:22	166	80.10977	30.16425	262			B16_3	15	
17/07/2019 09:22	166	80.10985	30.16457	261	80.10992	30.16239	B16_3	16	
17/07/2019 09:23	166	80.11001	30.16495	261	80.10998	30.16221	B16_3	17	
17/07/2019 09:24	166	80.11014	30.16523	264			B16_3	18	
17/07/2019 09:24	166	80.11027	30.16517	261			B16_3	19	
17/07/2019 09:25	166	80.11037	30.16501	263			B16_3	20	
25/07/2019 10:13	178	73.88645	26.33331	452.25	73.88615	26.33368	Y	1	439
25/07/2019 10:20	178	73.88692	26.33389	453.98	73.88627	26.33361	Y	2	438
25/07/2019 10:22	178	73.88705	26.33403	454.47	73.88635	26.33371	Y	3	438
25/07/2019 10:24	178	73.88718	26.33419	454.82	73.88643	26.3338	Y	4	438

25/07/2019 10:25	178	73.8873	26.33433	457.95	73.88647	26.33394	Y	5	438
25/07/2019 10:27	178	73.88744	26.33447	457.73	73.88657	26.33399	Y	6	439
25/07/2019 10:28	178	73.88755	26.33464	458.86	73.88662	26.3341	Y	7	438
25/07/2019 10:30	178	73.88765	26.33471	458.66	73.88673	26.33414	Y	8	440
25/07/2019 10:31	178	73.8878	26.33488	457.08	73.88683	26.33429	Y	9	439
25/07/2019 10:34	178	73.888	26.33511	458.04	73.887	26.33445	Y	10	440
25/07/2019 10:36	178	73.88813	26.33529	457.66	73.8871	26.33454	Y	11	440
25/07/2019 10:37	178	73.88824	26.33541	457.82	73.88721	26.33459	Y	12	442
25/07/2019 10:40	178	73.88845	26.33564	457.5	73.88738	26.33478	Y	13	443
25/07/2019 10:41	178	73.88855	26.33577	458.24	73.88747	26.33488	Y	14	443
25/07/2019 10:43	178	73.8887	26.33597	457.57	73.88761	26.33503	Y	15	445
25/07/2019 10:44	178	73.8888	26.33611	461.32	73.88769	26.33513	Y	16	446
25/07/2019 10:45	178	73.8889	26.33623	457.22	73.88778	26.33524	Y	17	446
25/07/2019 10:48	178	73.88908	26.33642	457.1	73.88793	26.33536	Y	18	446
25/07/2019 10:49	178	73.88917	26.33649	456.64	73.88803	26.33548	Y	19	445
25/07/2019 10:50	178	73.88925	26.33659	455.99	73.88812	26.33555	Y	20	444
26/07/2019 06:20	184	72.63129	19.24906	368.3	72.63136	19.2492	B3_1	1	359
26/07/2019 06:27	184	72.63205	19.24904	377.32	72.63145	19.24964	B3_1	2	359
26/07/2019 06:28	184	72.63218	19.24904	370.87	72.63152	19.24972	B3_1	3	358
26/07/2019 06:31	184	72.63261	19.24914	367.04	72.63175	19.24989	B3_1	4	359
26/07/2019 06:32	184	72.63276	19.24909	368.05	72.63186	19.24983	B3_1	5	360
26/07/2019 06:33	184	72.63289	19.24911	367.85	72.63195	19.24995	B3_1	6	360
26/07/2019 06:34	184	72.63309	19.24914	367.51	72.6321	19.24997	B3_1	7	361
26/07/2019 06:36	184	72.6333	19.24908	367.84	72.63229	19.24999	B3_1	8	360
26/07/2019 06:37	184	72.63343	19.24908	366.69	72.6324	19.25003	B3_1	9	359
26/07/2019 06:38	184	72.6336	19.24915	366.14	72.63255	19.25003	B3_1	10	358
26/07/2019 06:39	184	72.63373	19.2491	364.77	72.63267	19.25006	B3_1	11	358
26/07/2019 06:41	184	72.63391	19.2491	364.26	72.6328	19.25003	B3_1	12	358
26/07/2019 06:42	184	72.63409	19.24907	393.85	72.63289	19.25008	B3_1	13	350
26/07/2019 06:45	184	72.63449	19.24909	368.65	72.6333	19.25014	B3_1	14	357
26/07/2019 06:46	184	72.63467	19.24914	399.7	72.63345	19.25022	B3_1	15	358
26/07/2019 06:47	184	72.63486	19.24911	396.38	72.6336	19.25016	B3_1	16	354
26/07/2019 06:49	184	72.63506	19.24908	396.34	72.63379	19.25027	B3_1	17	357
26/07/2019 06:49	184	72.63515	19.24911	363.75	72.63385	19.25028	B3_1	18	356
26/07/2019 06:50	184	72.63525	19.24914	363.48	72.63394	19.25028	B3_1	19	355
26/07/2019 06:51	184	72.63536	19.24912	364.39	72.63407	19.25031	B3_1	20	355
26/07/2019 07:25	185	72.63108	19.25771	368.97	72.63112	19.2575	B3_2	1	358
26/07/2019 07:27	185	72.63132	19.25769	369.42	72.63116	19.2576	B3_2	2	358
26/07/2019 07:28	185	72.63147	19.25764	370.41	72.63123	19.25761	B3_2	3	359
26/07/2019 07:30	185	72.63173	19.25766	368.9	72.63137	19.25767	B3_2	4	360
26/07/2019 07:31	185	72.63191	19.25761	367.67	72.63148	19.25773	B3_2	5	360
26/07/2019 07:33	185	72.6321	19.25766	366.28	72.63161	19.25777	B3_2	6	360
26/07/2019 07:34	185	72.63233	19.25776	365.38	72.63175	19.25782	B3_2	7	359
26/07/2019 07:36	185	72.63253	19.2577	366.22	72.63194	19.25791	B3_2	8	357
26/07/2019 07:37	185	72.63276	19.25774	368.26	72.63214	19.25797	B3_2	9	355
26/07/2019 07:38	185	72.63288	19.25773	368.14	72.63227	19.25798	B3_2	10	356
26/07/2019 07:39	185	72.63301	19.25777	367.46	72.63238	19.258	B3_2	11	356
26/07/2019 07:40	185	72.63318	19.25769	366.92	72.63255	19.25803	B3_2	12	357
26/07/2019 07:42	185	72.63335	19.25772	366.01	72.6332	19.25768	B3_2	13	361
26/07/2019 07:42	185	72.6334	19.25772	365.63	72.63271	19.25807	B3_2	14	357
26/07/2019 07:45	185	72.63374	19.25769	367.54	72.63302	19.25815	B3_2	15	358

26/07/2019 07:47	185	72.63405	19.25775	363.4	72.63327	19.2582	B3_2	16	358
26/07/2019 07:48	185	72.63417	19.25769	363.59	72.63338	19.25823	B3_2	17	356
26/07/2019 07:48	185	72.63427	19.25769	395.01	72.63349	19.25821	B3_2	18	355
26/07/2019 07:49	185	72.6344	19.25775	368.92	72.6336	19.25823	B3_2	19	356
26/07/2019 07:51	185	72.63462	19.2577	369.06	72.63376	19.25823	B3_2	20	357
26/07/2019 08:18	186	72.63145	19.26423	363.63	72.63149	19.264	B3_3	1	354
26/07/2019 08:20	186	72.63167	19.26418	382.18	72.63152	19.26405	B3_3	2	354
26/07/2019 08:23	186	72.63205	19.26426	392.24	72.63171	19.26419	B3_3	3	354
26/07/2019 08:24	186	72.63226	19.26424	363.5	72.63185	19.26425	B3_3	4	354
26/07/2019 08:27	186	72.63257	19.26422	366.02	72.63209	19.26431	B3_3	5	355
26/07/2019 08:28	186	72.6328	19.26421	368.16	72.63226	19.26436	B3_3	6	354
26/07/2019 08:30	186	72.63304	19.26424	367.69	72.63246	19.2644	B3_3	7	357
26/07/2019 08:32	186	72.63326	19.26421	369.25	72.63263	19.26446	B3_3	8	357
26/07/2019 08:33	186	72.63349	19.26422	367.83	72.63286	19.26455	B3_3	9	357
26/07/2019 08:35	186	72.63368	19.26423	366.42	72.63301	19.26454	B3_3	10	356
26/07/2019 08:36	186	72.63385	19.26416	364.43	72.63393	19.26348	B3_3	11	354
26/07/2019 08:38	186	72.63419	19.26419	363.45	72.63353	19.26459	B3_3	12	358
26/07/2019 08:40	186	72.63444	19.26423	369.22	72.63375	19.26452	B3_3	13	356
26/07/2019 08:41	186	72.63457	19.26423	367.63	72.63386	19.26451	B3_3	14	354
26/07/2019 08:42	186	72.63465	19.26421	367.8	72.63394	19.26452	B3_3	15	355
26/07/2019 08:43	186	72.63492	19.26425	365.93	72.63417	19.26451	B3_3	16	353
26/07/2019 08:44	186	72.63505	19.26424	364.53	72.63434	19.26455	B3_3	17	358
26/07/2019 08:47	186	72.63539	19.26422	374.24	72.63461	19.26457	B3_3	18	359
26/07/2019 08:48	186	72.63558	19.26422	370.1	72.63484	19.26454	B3_3	19	357

4. MUC

Date (UTC)	Event	Station	ID	Latitude (°N)	Longitude (°E)	Water depth (m)	Cores successful
07/07/2019 03:57	006	B50	MUC001	72.62928	30.00435	292.42	4/4
07/07/2019 21:56	012	B13	MUC002	74.49927	29.9912	361.15	8/8
07/07/2019 23:04	013	B13	MUC003	74.49926	29.99286	362.3	7/8
08/07/2019 00:13	014	B13	MUC004	74.49969	29.99288	361.81	8/8
10/07/2019 23:05	064	B15	MUC005	78.25491	29.99508	318.28	7/8
11/07/2019 00:07	065	B15	MUC006	78.25489	29.9974	318.59	8/8
11/07/2019 01:06	066	B15	MUC007	78.25535	29.99732	317.9	8/8
13/07/2019 02:50	101	B14	MUC008	76.5066	30.50159	294.19	7/8
13/07/2019 03:36	102	B14	MUC009	76.50704	30.50212	294.2	7/8
13/07/2019 04:22	103	B14	MUC010	76.50692	30.50398	293.85	7/8
16/07/2019 13:49	138	B16	MUC011	80.07092	29.94201	298	5/8
16/07/2019 14:32	139	B16	MUC012	80.06711	29.94487	299	6/8
16/07/2019 15:15	140	B16	MUC013	80.06293	29.94457	304	2/8
16/07/2019 15:54	141	B16	MUC014	80.05943	29.94256	297	7/8
16/07/2019 16:35	142	B16	MUC015	80.05653	29.93943	298	6/8
25/07/2019 11:49	179	Y	MUC016	73.8893	26.33659	460.47	8/8
26/07/2019 09:42	187	B3	MUC017	72.63593	19.26419	366.1	0/8
26/07/2019 10:26	188	B3	MUC018	72.63593	19.26417	364.91	6/8
26/07/2019 11:09	189	B3	MUC019	72.63641	19.2658	365.04	8/8
26/07/2019 11:56	190	B3	MUC020	72.63684	19.26571	367.61	8/8

5. GC

Time	Event	Latitude	Longitude	Depth	Site	success	Comment
08/07/2019 02:24	15	74.49971	29.99292	361.5	B13	No	Time is at bottom
08/07/2019 03:30	16	74.49971	29.99289	362.3	B13	Yes	Time is at bottom
11/07/2019 02:14	67	78.23686	30.02995	362	B15	Yes	Time is at bottom
13/07/2019 05:17	104	76.50698	30.50416	298.2	B14	Yes	Time is at bottom
25/07/2019 12:51	180	73.88931	26.33654	457	Y	Yes	Time is at bottom
26/07/2019 12:52	191	72.63684	19.26574	366.4	B3	Yes	Time is at bottom

6. USNL

Time	Event	latitude	longitude	Depth	Site	water	deck	Comment
08/07/2019 07:26	18	74.46566	30.11825	354.64	B13	X		
08/07/2019 07:56	18	74.46566	30.11824	354.63	B13		X	
08/07/2019 08:20	19	74.46568	30.11818	353.41	B13	X		2nd Core
08/07/2019 08:57	19	74.46574	30.11806	353.26	B13		X	
08/07/2019 09:13	20	74.46575	30.11818	354.21	B13	X		
08/07/2019 10:18	20	74.46575	30.11817	353.93	B13		X	
08/07/2019 10:39	21	74.46579	30.11804	353.43	B13	X		
08/07/2019 10:56	21	74.4658	30.11807	353.79	B13		X	3rd Tom core
08/07/2019 11:08	22	74.46583	30.11797	353.81	B13	X		
08/07/2019 11:32	22	74.46584	30.11806	354.04	B13		X	Fail
08/07/2019 11:38	23	74.46584	30.11805	354.03	B13	X		Fail
08/07/2019 11:59	23	74.46583	30.11803	353.83	B13		X	Fail
08/07/2019 12:14	24	74.46586	30.11819	353.67	B13	X		
08/07/2019 12:40	24	74.46584	30.11812	384.07	B13		X	2nd Chris
08/07/2019 12:51	25	74.4659	30.11809	353.36	B13	X		
08/07/2019 13:15	25	74.46589	30.11805	353.89	B13		X	2nd Saskia
08/07/2019 13:25	26	74.4659	30.1182	353.81	B13	X		
08/07/2019 13:58	26	74.46594	30.1182	384.4	B13		X	3rd Chris
08/07/2019 14:08	27	74.46595	30.11815	353.77	B13	X		
08/07/2019 14:36	27	74.46596	30.11818	353.74	B13		X	3rd Saskia
08/07/2019 14:50	28	74.46597	30.11834	353.95	B13	X		
08/07/2019 15:14	28	74.46598	30.1183	353.49	B13		X	4th Core Tom
08/07/2019 15:24	29	74.46602	30.11824	353.33	B13	X		
08/07/2019 15:49	29	74.46602	30.11822	355.72	B13		X	4th Saskia
08/07/2019 16:01	30	74.46605	30.11836	382.7	B13	X		
08/07/2019 16:28	30	74.46602	30.11834	353.84	B13		X	5th Core Tom
08/07/2019 16:43	31	74.46609	30.11827	354.3	B13	X		
08/07/2019 17:10	31	74.46609	30.11837	354.36	B13		X	5th Saskia
11/07/2019 05:49	68	78.26152	30.20282	312.8	B15	X		
11/07/2019 06:17	68	78.26153	30.20271	312.36	B15		X	core Saskia
11/07/2019 06:25	69	78.26147	30.20239	312.41	B15	X		
11/07/2019 06:56	69	78.26149	30.20241	312.8	B15		X	1st Tom
11/07/2019 07:04	70	78.26145	30.20222	312.64	B15	X		
11/07/2019 07:30	70	78.26146	30.20224	311.96	B15		X	1st Chris
11/07/2019 07:39	71	78.26144	30.20193	313.08	B15	X		
11/07/2019 08:08	71	78.26142	30.20203	312.92	B15		X	2nd Tom
11/07/2019 08:17	72	78.26139	30.20189	312.81	B15	X		
11/07/2019 08:47	72	78.26139	30.20186	312.95	B15		X	2nd Chris

11/07/2019 08:54	73	78.26139	30.2017	312.89	B15	X		
11/07/2019 09:26	73	78.26137	30.20164	313.33	B15		X	2nd Saskia
11/07/2019 09:30	74	78.26134	30.20148	313.24	B15	X		
11/07/2019 09:53	74	78.26134	30.20148	313.26	B15		X	3rd core Tom
11/07/2019 10:12	75	78.26133	30.2013	313.44	B15	X		
11/07/2019 10:58	75	78.26133	30.20128	313.39	B15		X	4th core Tom
11/07/2019 11:07	76	78.26133	30.20105	314	B15	X		
11/07/2019 11:31	76	78.2613	30.2011	313.37	B15		X	5th core Tom
11/07/2019 11:45	77	78.2613	30.20113	313.24	B15	X		
11/07/2019 12:10	77	78.26126	30.20075	313.17	B15		X	3rd Saskia
11/07/2019 12:19	78	78.26126	30.2007	313.41	B15	X		
11/07/2019 12:44	78	78.26126	30.20064	313.2	B15		X	3rd Chris
11/07/2019 12:52	79	78.26125	30.20045	343.59	B15	X		
11/07/2019 13:14	79	78.26125	30.20045	343.59	B15		X	4th Saskia
11/07/2019 13:25	80	78.2612	30.20026	313.4	B15	X		
11/07/2019 13:47	80	78.26122	30.20032	313.3	B15		X	Fail
11/07/2019 13:59	81	78.26117	30.20001	318.73	B15	X		
11/07/2019 14:21	81	78.26117	30.19994	313.19	B15		X	5th Saskia
13/07/2019 12:49	111	76.55237	30.61852	281.57	B14	X		
13/07/2019 13:10	111	76.55236	30.61845	281.32	B14		X	1st Saskia
13/07/2019 13:22	112	76.55232	30.61819	281.93	B14	X		
13/07/2019 13:45	112	76.55232	30.61825	281.6	B14		X	1st Chris
13/07/2019 13:50	113	76.55227	30.61812	281.46	B14	X		
13/07/2019 14:41	113	76.55226	30.61813	281.56	B14		X	Fail
13/07/2019 14:49	114	76.55226	30.61814	281.68	B14	X		
13/07/2019 15:11	114	76.55227	30.61811	281.44	B14		X	1st Tom
13/07/2019 15:21	115	76.5522	30.61797	281.37	B14	X		
13/07/2019 15:42	115	76.55217	30.61811	281.53	B14		X	2nd Saskia
13/07/2019 15:55	116	76.55207	30.6178	281.66	B14	X		
13/07/2019 16:17	116	76.55209	30.6179	281.51	B14		X	2nd Chris
13/07/2019 16:35	117	76.552	30.61769	281.12	B14	X		
13/07/2019 16:57	117	76.552	30.61769	281.39	B14		X	3rd Saskia
13/07/2019 17:11	118	76.55192	30.61749	281.39	B14	X		
13/07/2019 17:34	118	76.55191	30.61749	281.31	B14		X	2nd Tom
13/07/2019 17:48	119	76.55183	30.61728	281.24	B14	X		
13/07/2019 18:03	119	76.55183	30.6173	281.74	B14		X	4th Saskia
13/07/2019 18:24	120	76.55184	30.61731	281.15	B14	X		
13/07/2019 18:46	120	76.55183	30.61732	281.22	B14		X	3rd Chris
13/07/2019 19:01	121	76.55177	30.61707	281.38	B14	X		
13/07/2019 19:22	121	76.55177	30.61711	281.11	B14		X	5th Saskia
13/07/2019 19:31	122	76.55169	30.61685	280.87	B14	X		
13/07/2019 20:19	122	76.5517	30.6169	280.78	B14		X	Fail
13/07/2019 20:46	123	76.55153	30.61648	281.3	B14	X		
13/07/2019 21:07	123	76.55155	30.61651	281.08	B14		X	4th Tom
13/07/2019 21:20	124	76.55147	30.61627	280.89	B14	X		
13/07/2019 22:05	124	76.55148	30.61631	280.83	B14		X	Fail
16/07/2019 17:34	143	80.055	29.93372	296	B16	X		
16/07/2019 18:05	143	80.05595	29.93043	294	B16		X	Core Chris
16/07/2019 18:18	144	80.05673	29.92926	293	B16	X		
16/07/2019 18:40	144	80.05832	29.9262	296	B16		X	2nd Chris
16/07/2019 18:57	145	80.06001	29.92376	296	B16	X		

16/07/2019 19:22	145	80.06242	29.92257	296	B16		X	1st Saskia
16/07/2019 20:08	146	80.07056	29.92567	293	B16	X		
16/07/2019 20:31	146	80.07458	29.92959	293	B16		X	2nd Saskia
16/07/2019 20:48	147	80.07826	29.93194	300	B16	X		
16/07/2019 21:12	147	80.08279	29.93968	300	B16		X	3rd Saskia
16/07/2019 21:22	148	80.08495	29.94314	300	B16	X		
16/07/2019 21:46	148	80.08899	29.95215	299	B16		X	4th Saskia
16/07/2019 21:57	149	80.09157	29.9567	300	B16	X		
16/07/2019 22:21	149	80.09586	29.9669	300	B16		X	3rd Chris
16/07/2019 22:32	150	80.09773	29.97427	296	B16	X		
16/07/2019 22:54	150	80.10068	29.98869	296	B16		X	5th Saskia
16/07/2019 23:04	151	80.10229	29.99438	291	B16	X		
16/07/2019 23:26	151	80.10481	30.00817	291	B16		X	1st core Tom
16/07/2019 23:35	152	80.10558	30.01396	295	B16	X		
16/07/2019 23:58	152	80.10706	30.03227	295	B16		X	2nd Tom
17/07/2019 00:08	153	80.1075	30.03885	285	B16	X		
17/07/2019 00:29	153	80.10768	30.05347	285	B16		X	3rd core Tom
17/07/2019 00:38	154	80.10783	30.06036	276	B16	X		
17/07/2019 01:00	154	80.10735	30.07382	276	B16		X	4th core Tom
17/07/2019 01:10	155	80.10682	30.08064	269	B16	X		
17/07/2019 01:35	155	80.10576	30.09415	269	B16		X	5th core Tom
26/07/2019 17:36	192	72.65933	19.3474	397.07	B3	X		
26/07/2019 18:06	192	72.65932	19.3474	370.26	B3		X	Fail
26/07/2019 18:18	193	72.6593	19.3471	370.38	B3	X		
26/07/2019 18:48	193	72.6593	19.34713	370.43	B3		X	1st core Chris
26/07/2019 19:00	194	72.65927	19.34679	370.7	B3	X		
26/07/2019 19:28	194	72.65928	19.34686	372.29	B3		X	2nd Chris
26/07/2019 19:38	195	72.65922	19.3462	372.2	B3	X		
26/07/2019 20:03	195	72.65923	19.34621	370.61	B3		X	3rd Chris
26/07/2019 20:15	196	72.6592	19.34557	371.88	B3	X		
26/07/2019 20:39	196	72.65917	19.34555	373.5	B3		X	1st core Tom
26/07/2019 20:48	197	72.65914	19.34499	373.27	B3	X		
26/07/2019 21:12	197	72.65915	19.34495	373.62	B3		X	S'ampton top
26/07/2019 21:21	198	72.65913	19.34446	373.51	B3	X		
26/07/2019 21:46	198	72.65913	19.34438	374.41	B3		X	2nd Tom
26/07/2019 21:54	199	72.65909	19.34375	373.44	B3	X		
26/07/2019 22:16	199	72.65911	19.3438	373.8	B3		X	3rd core Tom
26/07/2019 22:28	200	72.65912	19.3432	373.09	B3	X		
26/07/2019 22:51	200	72.65909	19.34319	373.59	B3		X	4th core Tom
26/07/2019 23:01	201	72.65909	19.34259	372.28	B3	X		
26/07/2019 23:27	201	72.6591	19.34256	373.17	B3		X	Southampton
26/07/2019 23:39	202	72.6591	19.34197	373.02	B3	X		
27/07/2019 00:28	202	72.65905	19.34192	373.73	B3		X	Fail

7. SMBA

Time	Event	Latitude	Longitude	Depth	Site	water	deck	Comment
08/07/2019 18:14	32	74.46607	30.11835	354.6	B13	X		
08/07/2019 18:42	32	74.46608	30.11834	354.4	B13		X	South 1
08/07/2019 18:52	33	74.46613	30.11831	354.2	B13	X		
08/07/2019 19:20	33	74.46613	30.11831	354	B13		X	South 2nd

08/07/2019 19:23	34	74.46614	30.1184	354.2	B13	X		
08/07/2019 19:52	34	74.46615	30.11837	354.5	B13		X	South 3rd
08/07/2019 20:02	35	74.46621	30.1184	357.1	B13	X		
08/07/2019 20:28	35	74.4662	30.11849	354.4	B13		X	core No 4
08/07/2019 20:32	36	74.46618	30.11864	354.4	B13	X		
08/07/2019 20:57	36	74.46617	30.11861	354.2	B13		X	South
08/07/2019 21:05	37	74.46623	30.11868	354.4	B13	X		
08/07/2019 21:33	37	74.46623	30.11864	354.4	B13		X	South
08/07/2019 21:50	38	74.46619	30.119	354	B13	X		
08/07/2019 22:18	38	74.46621	30.11902	354.3	B13		X	South
08/07/2019 22:29	39	74.46626	30.11901	354.2	B13	X		
08/07/2019 22:56	39	74.46626	30.11903	353.9	B13		X	South
08/07/2019 23:05	40	74.46625	30.1191	353.9	B13	X		
08/07/2019 23:29	40	74.46626	30.1192	354.1	B13		X	South
08/07/2019 23:36	41	74.46627	30.11932	353.8	B13	X		
09/07/2019 00:04	41	74.46629	30.11933	354	B13		X	South
09/07/2019 00:18	42	74.46632	30.1194	354	B13	X		
09/07/2019 00:44	42	74.46634	30.11936	353.4	B13		X	South
09/07/2019 00:53	43	74.46632	30.11948	353.5	B13	X		
09/07/2019 01:20	43	74.4663	30.11947	354.4	B13		X	South
09/07/2019 01:30	44	74.46631	30.11958	354.3	B13	X		
09/07/2019 01:58	44	74.46634	30.1195	353.8	B13		X	South
09/07/2019 02:09	45	74.46632	30.1197	352.9	B13	X		
09/07/2019 02:38	45	74.46631	30.11982	353.8	B13		X	1st Tom
09/07/2019 02:45	46	74.46632	30.11978	353.9	B13	X		
09/07/2019 03:14	46	74.46635	30.11987	353.7	B13		X	2nd Tom
09/07/2019 03:22	47	74.46633	30.12002	353.6	B13	X		
09/07/2019 03:52	47	74.46632	30.11995	353.4	B13		X	3rd Tom
09/07/2019 03:58	48	74.46635	30.12009	353.6	B13	X		
09/07/2019 04:27	48	74.46634	30.12015	353.4	B13		X	4th Tom
09/07/2019 04:38	49	74.46632	30.12027	353.5	B13	X		
09/07/2019 05:06	49	74.46629	30.12027	354.2	B13		X	5th Tom
11/07/2019 14:55	82	78.26114	30.19973	313	B15	X		
11/07/2019 15:19	82	78.26114	30.19971	313.1	B15		X	1st Tom
11/07/2019 15:31	83	78.26112	30.19951	313.5	B15	X		
11/07/2019 15:54	83	78.26112	30.1996	313.4	B15		X	2nd Tom
11/07/2019 16:06	84	78.26109	30.19937	313.3	B15	X		
11/07/2019 16:33	84	78.26108	30.19945	312.9	B15		X	3rd Tom
11/07/2019 16:43	85	78.26106	30.19931	343.1	B15	X		
11/07/2019 17:08	85	78.26107	30.19923	313.2	B15		X	4th Tom
11/07/2019 17:18	86	78.26104	30.19914	313.5	B15	X		
11/07/2019 17:42	86	78.26104	30.19905	313.1	B15		X	5th Tom
13/07/2019 09:00	105	76.55291	30.61992	281.5	B14	X		
13/07/2019 09:23	105	76.55288	30.6198	281.5	B14		X	PML & South
13/07/2019 09:38	106	76.55282	30.61963	281.4	B14	X		
13/07/2019 09:59	106	76.55282	30.6197	281.4	B14		X	South
13/07/2019 10:17	107	76.55273	30.61948	312.3	B14	X		
13/07/2019 10:39	107	76.55274	30.61946	281.4	B14		X	
13/07/2019 10:48	108	76.55267	30.61925	312.4	B14	X		
13/07/2019 11:12	108	76.55266	30.61933	281.2	B14		X	
13/07/2019 11:25	109	76.5525	30.61904	281.4	B14	X		

13/07/2019 11:48	109	76.55251	30.61903	281.9	B14		X	
13/07/2019 11:57	110	76.55242	30.61887	282.5	B14	X		
13/07/2019 12:17	110	76.55242	30.61887	281.5	B14		X	
17/07/2019 03:14	156	80.0958	30.13844	265	B16	X		
17/07/2019 03:37	156	80.09345	30.14409	266	B16		X	1st Tom
17/07/2019 03:51	157	80.09187	30.14755	264	B16	X		
17/07/2019 04:14	263	80.08927	30.15017	263	B16		X	2nd Tom
17/07/2019 04:24	158	80.08858	30.15095	265	B16	X		
17/07/2019 04:43	158	80.08699	30.15137	263	B16		X	3rd Tom
17/07/2019 04:53	159	80.08603	30.15183	264	B16	X		
17/07/2019 05:15	159	80.0851	30.15193	263	B16		X	4th Tom
17/07/2019 05:32	160	80.08503	30.15117	265	B16	X		
17/07/2019 05:51	160	80.08478	30.15118	264	B16		X	5th Tom
17/07/2019 06:00	161	80.08478	30.15126	263	B16	X		
17/07/2019 06:21	161	80.08547	30.15018	265	B16		X	South Core
17/07/2019 06:28	162	80.08561	30.14997	264	B16	X		
17/07/2019 06:50	162	80.08662	30.14989	265	B16		X	South 2nd
17/07/2019 07:04	163	80.08785	30.1499	264	B16	X		
17/07/2019 07:29	163	80.09042	30.151	264	B16		X	South 3rd
27/07/2019 01:24	203	72.65907	19.3414	374.7	B3	X		
27/07/2019 01:54	203	72.65907	19.3414	374.7	B3		X	1st Tom
27/07/2019 02:17	204	72.65908	19.34075	375.4	B3	X		
27/07/2019 02:44	204	72.65909	19.34078	376.1	B3		X	Fail
27/07/2019 02:50	205	72.6591	19.34044	374.2	B3	X		
27/07/2019 03:14	205	72.65909	19.3405	374.3	B3		X	2nd Tom
27/07/2019 03:21	206	72.65909	19.34023	374.6	B3	X		
27/07/2019 03:47	206	72.65906	19.34022	373	B3		X	3rd Tom
27/07/2019 03:51	207	72.65909	19.33993	373.1	B3	X		
27/07/2019 04:26	207	72.65912	19.33956	373	B3		X	4th Tom
27/07/2019 04:30	208	72.65912	19.33959	371.8	B3	X		
27/07/2019 04:59	208	72.65913	19.33961	372.2	B3		X	Failed
27/07/2019 05:01	209	72.65912	19.33959	372.4	B3	X		
27/07/2019 05:30	209	72.65911	19.33959	372.8	B3		X	Failed
27/07/2019 05:35	210	72.65912	19.33929	372.3	B3	X		
27/07/2019 06:07	210	72.65913	19.33924	372.7	B3		X	5th Tom

8. mAGT

Time	Event	Latitude	Longitude	Depth	Site	On bed	Start	off bed	Comment
09/07/2019 06:56	50	74.49191	30.00401	359.03	B13	X			
09/07/2019 06:56	50	74.49191	30.00407	359.48	B13		X		winch issues
09/07/2019 07:18	50	74.49296	30.01482	360.51	B13			X	South
09/07/2019 08:35	51	74.49388	30.02666	360.12	B13	X			
09/07/2019 08:35	51	74.49389	30.02679	359.93	B13		X		
09/07/2019 08:53	51	74.49445	30.03548	363.57	B13			X	South
09/07/2019 09:43	52	74.49555	30.05156	367.28	B13	X			
09/07/2019 09:44	52	74.49555	30.05188	367.78	B13		X		
09/07/2019 10:00	52	74.4963	30.06199	365.79	B13			X	1st Tom
09/07/2019 10:39	53	74.4972	30.0744	361.86	B13	X			
09/07/2019 10:49	53	74.49767	30.07926	362.91	B13		X		winch issues
09/07/2019 11:09	53	74.49857	30.08872	359.86	B13			X	2nd Tom

09/07/2019 12:24	54	74.50071	30.11158	351.78	B13	X			
09/07/2019 12:36	54	74.50109	30.11768	351.66	B13		X		
09/07/2019 12:53	54	74.50149	30.12638	351.67	B13			X	3rd Tom
09/07/2019 13:56	55	74.50213	30.13646	352.62	B13	X			
09/07/2019 14:08	55	74.50254	30.14255	353.06	B13		X		
09/07/2019 14:27	55	74.50321	30.1518	353.21	B13			X	1st BAS
09/07/2019 15:00	56	74.50386	30.16057	353.74	B13	X			
09/07/2019 15:13	56	74.50431	30.16697	354.38	B13		X		
09/07/2019 15:29	56	74.50488	30.175	353.87	B13			X	2nd BAS
09/07/2019 16:08	57	74.50569	30.18605	353.32	B13	X			
09/07/2019 16:20	57	74.50609	30.19163	354.18	B13		X		
09/07/2019 16:40	57	74.50678	30.20171	352.69	B13			X	3rd BAS
11/07/2019 18:55	87	78.26039	30.19459	314.59	B15	X			
11/07/2019 19:06	87	78.25958	30.18889	313.53	B15		X		
11/07/2019 19:23	87	78.25817	30.17908	313.36	B15			X	1st BAS
11/07/2019 20:27	88	78.27459	30.02158	312.35	B15	X			
11/07/2019 20:47	88	78.27239	30.01348	319.84	B15		X		
11/07/2019 21:10	88	78.26975	30.00447	324.09	B15			X	2nd BAS
11/07/2019 21:54	89	78.26976	30.01996	322.91	B15	X			
11/07/2019 22:16	89	78.26789	30.01093	322.25	B15		X		
11/07/2019 22:33	89	78.26517	30.01781	320.43	B15			X	3rd BAS
11/07/2019 23:28	90	78.26511	30.0175	320.52	B15	X			
11/07/2019 23:52	90	78.2636	30.01002	321.68	B15		X		
12/07/2019 00:08	90	78.26198	30.00222	322.04	B15			X	1st Tom
12/07/2019 00:56	91	78.26199	30.02258	322.41	B15	X			
12/07/2019 01:22	91	78.25949	30.01042	322.29	B15		X		
12/07/2019 01:35	91	78.25795	30.00294	321.41	B15			X	2nd Tom
12/07/2019 02:37	92	78.25743	30.02071	320.22	B15	X			
12/07/2019 02:57	92	78.25547	30.0111	319.16	B15		X		
12/07/2019 03:13	92	78.25399	30.00385	318.5	B15			X	3rd Tom
13/07/2019 23:51	125	76.50093	30.4772	295.78	B14	X			
14/07/2019 00:10	125	76.5033	30.48307	295.7	B14		X		
14/07/2019 00:25	125	76.50506	30.48734	297.51	B14			X	South
14/07/2019 03:20	126	76.51252	30.50418	292.93	B14	X			
14/07/2019 03:34	126	76.51428	30.50694	291.07	B14		X		
14/07/2019 03:48	126	76.51613	30.50998	291.76	B14			X	BAS
14/07/2019 04:35	127	76.52007	30.51617	290.53	B14	X			
14/07/2019 04:50	127	76.51942	30.51517	290.45	B14		X		
14/07/2019 05:04	127	76.52384	30.52182	289.05	B14			X	BAS
14/07/2019 05:48	128	76.52876	30.52928	288.1	B14	X			
14/07/2019 06:04	128	76.52978	30.53085	287.55	B14		X		
14/07/2019 06:20	128	76.53193	30.53421	286.62	B14			X	BAS
14/07/2019 06:56	129	76.53438	30.53789	286.31	B14	X			
14/07/2019 07:13	129	76.53659	30.54132	285.54	B14		X		
14/07/2019 07:28	129	76.53853	30.54431	285.77	B14			X	1st Tom
14/07/2019 08:08	130	76.5415	30.54897	284.12	B14	X			
14/07/2019 08:28	130	76.54412	30.55302	280.88	B14		X		
14/07/2019 08:55	130	76.54682	30.55717	275.88	B14			X	2nd tom
14/07/2019 09:39	131	76.54957	30.56011	281.21	B14	X			
14/07/2019 09:58	131	76.55213	30.56149	279.91	B14		X		
14/07/2019 10:14	131	76.55454	30.56279	279.47	B14			x	3rd Tom

24/07/2019 16:43	171	74.49889	29.99775	362.15	B13	X			
24/07/2019 17:12	171	74.4973	29.98403	366.23	B13		X		
24/07/2019 17:30	171	74.4963	29.97519	366.69	B13			X	South
24/07/2019 18:11	172	74.49567	29.9643	367.31	B13	X			
24/07/2019 18:29	172	74.49566	29.95472	367.56	B13		X		
24/07/2019 18:46	172	74.49568	29.94587	371.62	B13			X	South
24/07/2019 19:30	173	74.4964	29.93578	371.81	B13	X			
24/07/2019 19:49	173	74.49767	29.92737	370.91	B13		X		
24/07/2019 20:02	173	74.49861	29.92129	372.32	B13			X	South
24/07/2019 21:02	174	74.50068	29.90772	374.83	B13	X			
24/07/2019 21:22	174	74.50213	29.89843	373.7	B13		X		
24/07/2019 21:38	174	74.50327	29.89113	375.27	B13			X	South
24/07/2019 22:25	175	74.50524	29.87843	372.55	B13	X			
24/07/2019 22:44	175	74.50657	29.86988	372.53	B13		X		
24/07/2019 23:00	175	74.50765	29.86281	373.29	B13			X	South
24/07/2019 23:46	176	74.51009	29.84718	372.81	B13	X			
25/07/2019 00:03	176	74.5109	29.84188	371.8	B13		X		
25/07/2019 00:20	176	74.51229	29.83291	369.36	B13			X	South
25/07/2019 01:13	177	74.51637	29.81048	369.16	B13	X			
25/07/2019 01:33	177	74.51866	29.80509	368.95	B13		X		
25/07/2019 01:46	177	74.52021	29.80134	369.05	B13			X	South
27/07/2019 07:00	211	72.6594	19.33377	372.85	B3	X			
27/07/2019 07:10	211	72.65963	19.32942	372.36	B3		X		
27/07/2019 07:27	211	72.66005	19.32152	372.65	B3			X	1st BAS
27/07/2019 07:58	212	72.66058	19.31125	372.43	B3	X			
27/07/2019 08:20	212	72.66068	19.3091	373.4	B3		X		
27/07/2019 08:37	212	72.66106	19.30156	371.68	B3			X	2nd BAS
27/07/2019 09:25	213	72.66155	19.29208	371.7	B3	X			
27/07/2019 09:36	213	72.66185	19.28583	372.62	B3		X		
27/07/2019 09:51	213	72.66214	19.28032	373.23	B3			X	3rd BAS
27/07/2019 10:29	214	72.66262	19.27071	377.13	B3	X			
27/07/2019 10:40	214	72.66287	19.26561	374.04	B3		X		
27/07/2019 10:56	214	72.66323	19.25825	378.52	B3			X	1st Tom
27/07/2019 11:51	215	72.66385	19.25077	375.1	B3	X			
27/07/2019 12:03	215	72.66531	19.25252	405.71	B3		X		
27/07/2019 12:21	215	72.66766	19.25524	374.73	B3			X	2nd Tom
27/07/2019 13:04	216	72.67033	19.26126	374.02	B3	X			
27/07/2019 13:15	216	72.6709	19.26592	376.92	B3		X		
27/07/2019 13:32	216	72.6718	19.27332	375.17	B3			X	3rd Tom