HEINCKE Report

CARBOSTORE
Carbon Storage in German Coastal Seas – Stability, Vulnerability and Perspectives for Manageability

Cruise No. HE611

NOVEMBER 07 – December 01, 2022

Bremerhaven (Germany) – Bremerhaven (Germany)

CARBOSTORE

D Baiko, L Cotovicz Jr., E Husmann, A Lübben, C Mears, A Neumann, C Petrauskas, A-C Rohrweber, L M Ruth, L Schmidt, H Thomas, B van Dam

Prof. Dr. Helmuth Thomas

Helmholtz-Zentrum Hereon GmbH

2023

Table of Contents

1 Cruise Summary

The cruise HE611, which took place from November 4 to December 1, 2022, investigated in greater depth, the relationships and exchanges between atmospheric, oceanic, and sedimentary carbon reservoirs within coastal shelf systems, here the North Sea and the Baltic Sea. Two of the major aims were to achieve this during winter and synoptically for both seas. To do this, in depth sampling of the North and Baltic Seas was projected. Within the North Sea, a 1 degree x 1 degree grid was originally planned, spanning the latitudinal extent of the North Sea. Within the Baltic Sea, efforts were focused on gaining better understanding of the link between the two coastal seas, as the Baltic outflow plays an important role in carbonate system of the North Sea. Therefore, in addition to sampling the northern deep section of the Baltic Proper, in particular the Gotland, Arkona and Bornholm Basins, emphasis was placed on sampling along the German coastline following Baltic outflow through the Kattegat and Skagerrak to the North Sea system. This overall strategy helps glean information of the carbon cycling within the Baltic and the winter influence these processes have on the North Sea system as a whole. Water column sampling (see figure 3.1) was performed at all stations. These activities were complemented by sediment sampling at selected stations as well as underway measurements using radar and eddy covariance systems.

The cruise unfortunately was dominated by bad, in particular persistent stormy weather conditions. As winds mainly came from southerly direction, our planned sampling was hindered substantially. We decided to not begin our program in the North Sea as planned; rather we headed from Bremerhaven first via the Nord-Ostsee-Kanal into the Baltic Sea, where initially weather conditions were appropriate to carry out work. During sampling near the Gotland Deep, weather conditions forced us to seek shelter in Warnemünde. We then continued via Kattegatt and Skagerrak into the southeastern North Sea, where, again weather conditions required us to go into the port of Bremerhaven. We then managed to sample the southern and central North Sea, with a further interruption in Hirtshals. In contradiction to our plans, it was not possible to sample the northernmost regions of the North Sea. While the expedition was affected by a tangible loss of sampling activities, still the major aim to record winter conditions in the North Sea and the Baltic Sea synoptically was met.

2 Participants

2.1 Principal Investigators

Name	Institution
Thomas, Helmuth, Prof. Dr.	HEREON

2.2 Scientific Party

Name	Discipline	Institution
Thomas, Helmuth, Prof. Dr.	Chief Scientist	HEREON
Van Dam, Bryce, Dr.	Deputy Scientist	HEREON
Mears, Chantal		HEREON
Petrauskas, Catharina		HEREON
Schröder, Lea		HEREON
Rohrweber, Ann-Cathrin		HEREON
Husmann, Eva		HEREON
Schmidt, Leon		HEREON
Neumann, Andreas, Dr.		HEREON
Cotovicz Jr., Luiz, Dr.		IOW
Nantke, Carla, Dr.		IOW
Ruth, Linda Michelle		IOW
Scheidereit, Leonie		GEOMAR
Baiko, Dariya		ICBM
Lübben, Andrea		ICBM
Albinus, Michelle		ICBM

2.3 Participating Institutions

HEREON	Helmholtz-Zentrum Hereon GmbH
IOW	Leibniz Institute for Baltic Sea Research Warnemünde
GEOMAR	Helmholtz Centre for Ocean Research Kiel
ICBM	Institute for Chemistry and Biology of the Marine Environment, University of Oldenburg

3 Research Program

3.1 Description of the Work Area

Figure 3.1 shows the cruise track and stations of the cruise. The figure maps also the type of sampling – water and sediment samples.

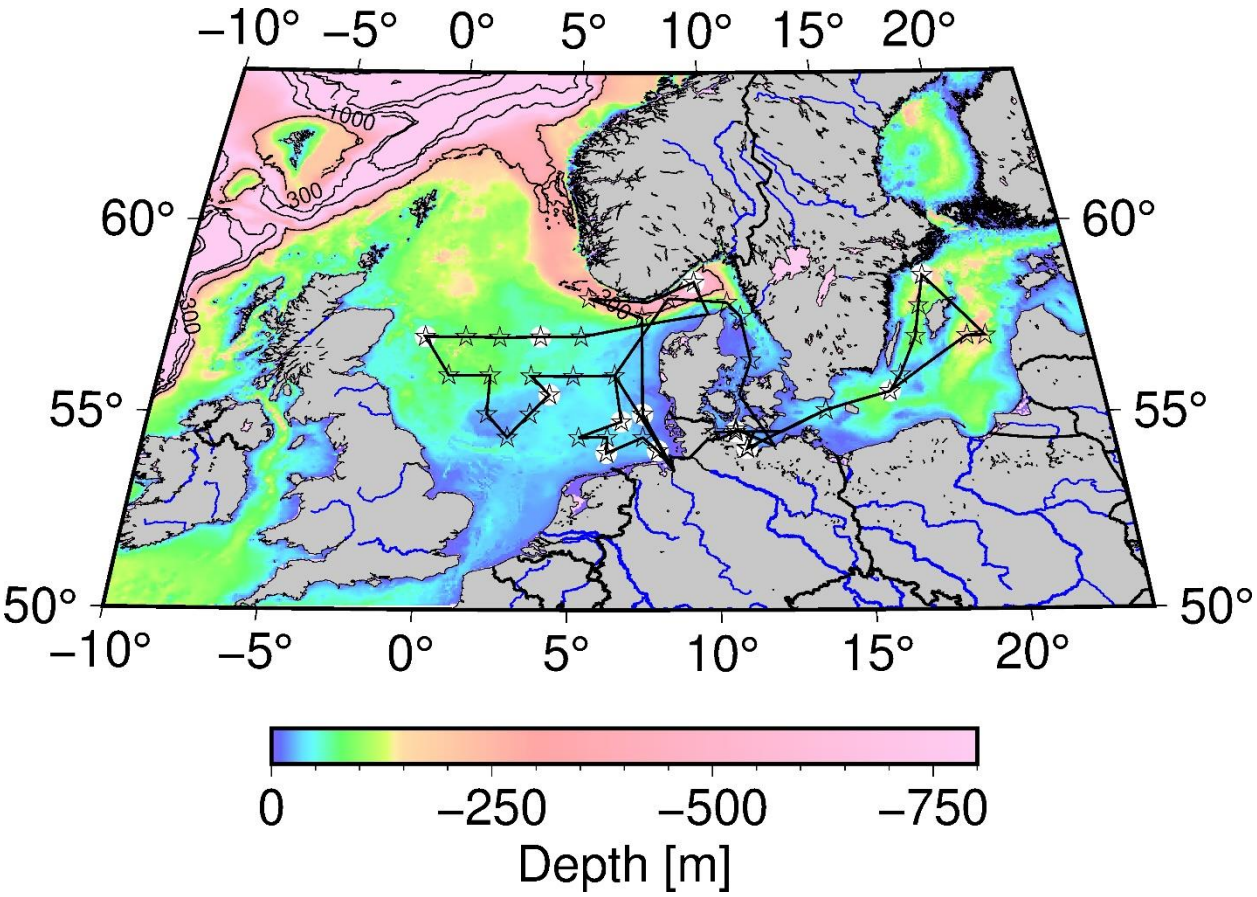

Figure 3.1: Cruise track and stations occupied during HE611. White circles indicate stations with sediment sampling.

3.2 Aims of the Cruise

Carbon cycling in the coastal ocean is not homogeneous, and air-sea carbon dioxide (CO_2) exchange is highly variable with location and season. In addition, there is a relative lack of winter-time studies that hampers a complete understanding of coastal C cycling. This is an especially pressing issue for North Sea and Baltic Sea science, as the factors making winter research so challenging are the same ones that enhance biogeochemical processes like air-sea CO_2 exchange and benthic-pelagic mixing. This winter-time expedition aims to close this research gap across the North and Baltic Seas, focusing on the pelagic and benthic processes which control the coastal C sink.

3.3 Agenda of the Cruise

The cruise, unfortunately was dominated by bad, in particular persistent stormy weather conditions. As winds mainly came from southerly direction, our planned sampling was hindered substantially. We decided to begin our program not as planned in the North Sea, rather we headed from Bremerhaven first via the Nord-Ostsee-Kanal into the Baltic Sea, where initially weather conditions were appropriate to carry out work. During sampling near the Gotland Deep, weather conditions forced us to seek shelter in Warnemünde. We then continued via Kattegatt and Skagerrak into the southeastern North Sea, where, again weather conditions required us to go into the port of Bremerhaven. We then managed to sample the southern and central North Sea, with a further interruption in Hirtshals. In contrast to our plans, it was not possible to sample the northernmost regions of the North Sea. While the expedition was affected by a tangible loss of sampling activities, still the major aim to record winter conditions in the North Sea and the Baltic Sea synoptically was met.

4 Narrative of the Cruise

The cruise HE611, which took place between November 4 to December 1, 2022, investigated in greater depth, the relationships and exchanges between atmospheric, oceanic, and sedimentary carbon reservoirs within coastal shelf systems, here the North Sea and the Baltic Sea. Two of the major aims were to achieve this during winter and synoptically for both seas. To do this, in depth sampling of the North and Baltic Seas were projected. Within the North Sea, a 1 degree x 1 degree grid was originally planned, spanning the latitudinal extent of the North Sea. Within the Baltic Sea, efforts were focused on gaining better understanding of the link between the two coastal seas, as the Baltic outflow plays an important role in carbonate system of the North Sea. Therefore, in addition to sampling the Northern deep section of the Baltic Proper, in particular the Gotland, Arkona and Bornholm Basins, emphasis was placed on sampling along the German coastline following Baltic outflow through the Kattegat and Skagerrak to the North Sea system. This overall strategy helps glean information of the carbon cycling within the Baltic and the winter influence these processes have on the North Sea system as a whole. Water column sampling (Fig.1) was performed at all stations. These activities were complemented by sediment sampling at selected stations as well as underway measurements using radar and eddy covariance systems.

5 Preliminary Results

5.1 Underway Measurements

This chapter summarizes a set of various underway measurements that were continuously been carried out during the cruise HE611.

5.1.1 Ferrybox Measurements

(A. Lübben[1])

[1] ICBM / University of Oldenburg

With a Ferrybox continuous underway measurements of the surface layer have been carried out. This device is a flow-through system connected to the ship's continuous pump system to monitor continuously temperature, salinity, chlorophyll fluorescence, turbidity and dissolved oxygen. Additionally, a pCO_2 sensor was connected to the system.

As one of the projects goal is to investigate the circulation and exchange of water masses in the Skagerrak, figure 5.1 shows salinity (lower plot right) and temperature (lower plot left) data when crossing the Skagerrak with strong gradients in both parameters. In comparison, figure 5.1 (bottom plots) shows similar measurements taken during cruise HE586 obtained about one year before (October 7-8, 2021). The opposite pattern of both parameters demonstrates the possible variability of the exchange regarding to the meteorological situation. As in October 2021 moderate winds from west/southwest were observed, November 2022 was dominated by storm from southernly direction.

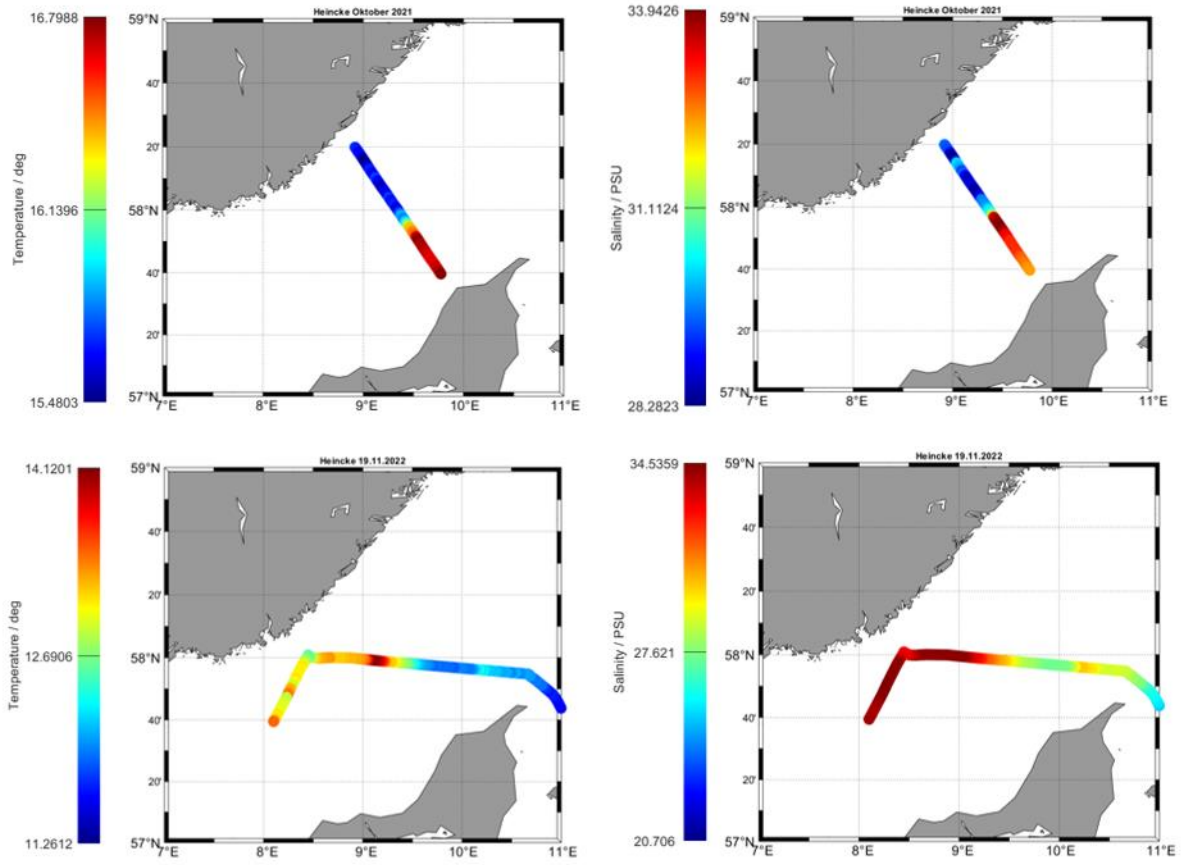

Figure 5.1: Temperature and salinity gradients in the Skagerrak. The plots at the top show data from the Heincke cruise in October 2021 (HE586), the bottom plots are from the current Heincke cruise HE611.

5.1.2 Acoustic Doppler Current Profiler (ADCP)

(A. Lübben[1])

[1] ICBM / University of Oldenburg

A 600-kHz acoustic Doppler current profiler (ADCP) was attached to the RV Heincke's moon pool. Current velocity and direction data were measured continuously during the whole cruise. Among other things these data provide information on water discharge through the Skagerrak and underline the analyses of mixing processes.

5.1.3 Eddy Covariance and Radar

(B. van Dam[1]; L. Scheidereit[2])

[1] Helmholtz-Zentrum Hereon

[2] GEOMAR

While at dock in Bremerhaven, eddy covariance (EC) instrumentation was installed on the ship's fore deck, for the purpose of continuously measuring air-water CO_2 exchange. This

instrumentation was mounted on the meteorology superstructure, and included: one Campbell CSAT-3 sonic anemometer (3D wind speed), a Landmark 10 internal motion unit (to correct winds for 3D ship motion), compass and GPS (ship heading and drift). The inlets for CO_2 measurements were also mounted on the mast and connected via Dekabon tubing to the infrared gas analyzer (LI-COR 7200). A logged valve switch was used to determine the time delay between wind speed and CO_2 measurements (which were physically de-coupled), by injecting a "puff" of N_2 into the CO_2 inlet. This N_2 source was also used to check the zero stability of the CO_2 analyzer on a daily basis. The instruments ran continuously with very few issues for the duration of the cruise, and data were downloaded daily and saved redundantly on hard drives. In early 2023, Hereon and GEOMAR will work together to process this dataset, which includes motion correction, calibration of the CO_2 record, and combination with water-side measurements. This will be a lengthy process, but we hope to have final CO_2 fluxes calculated by the end of 2024.

In addition to the EC instruments, a marine X-Band radar system was installed on the deck above the ship's bridge. This radar operated continuously, without any major issues throughout the cruise, and will provide data regarding sea state conditions, which will help to interpret EC-based CO_2 flux measurements. The radar system was turned off when we were in, entering, or leaving port, but was otherwise in continuous operation.

5.2 Water Sampling

During the cruise a great number of water samples were taken. Besides dissolved green house gases and dissolved organic matter, there were also radium isotopes, carbonates and trace metals sampled and analyzed.

5.2.1 Water Sampling for Dissolved Greenhouse Gases (CH_4, N_2O)

(L. C. Cotovicz[1]; G. Rehder[1]; B. van Dam[2])

[1] Leibniz-Institut für Ostseeforschung Warnemünde

[2] Helmholtz-Zentrum Hereon

Water samples for dissolved methane (CH_4) and nitrous oxide (N_2O) were taken at various depths from 49 stations using the Niskin bottles of the CTD rosette. The complete list of samples for CH_4 and N_2O is presented in the table 11.1.1 (attached in the appendices). The samples were bottled from the same cast as the nutrient-samples (nutrients are essential for data interpretation). Additionally, water overlaying the sediment cores (MUC) was sampled with a syringe directly from the sediment core incubations in 9 stations. The 200 mL crimp bottles used for CH_4 and N_2O analysis were filled with seawater (ideally with bottle overflow). The bottles were crimped immediately after sampling using rubber stoppers, aluminum caps and a crimper. After crimping, the samples were poisoned with 200 µL $HgCl_2$. The samples were stored upside down in the cooling room (4°C) and in the dark until further analysis in laboratory.

The dissolved CH_4 concentration will be determined at the IOW by gas chromatography (GC) on an Agilent 7890B instrument (Agilent Technologies, Santa Clara, USA) coupled to a flame ionization detector (FID). The dissolved N_2O concentration will be determined by gas

chromatography (GC) coupled to an electron capture detector (ECD). A purge-and-trap technique will be applied. A calibration standard (gas composition of 9.9379 ± 0.015 ppm CH_4 and 1982.07 ± 3.77 ppb N_2O) will be measured daily before and after the sample measurements for quality control. The standards are recalibrated according to high-precision standards (ICOS-CAL, Max Planck Institute, Jena, Germany).

Diffusive fluxes of CH_4 and N_2O at the air-water interface will be computed according to the following equation:

$$F\ (GHG) = k\ (\Delta GHG)$$

where F (GHG) represents the diffusive fluxes of CH_4 and N_2O, k represents the gas transfer velocity of a given gas at a given temperature, and ΔGHG represents the concentration gradient between the water and the water at equilibrium with the overlying atmosphere. To calculate the gas transfer velocity, we first normalized a Schmidt number. Afterwards, diverse empirical equations will be applied to derive k600 values, particularly parameterizations stablished for estuarine and coastal waters. The fluxes of CH_4 and N_2O will be converted to CO_2-equivalent emissions (CO_2eq) in order to compare the fluxes of these greenhouse gases in terms of global warming potential. In the first semester of 2023, IOW will process the measurements of CH_4 and N_2O. We hope to have CH_4 and N_2O concentrations and air-water diffusive fluxes by the end of 2023.

5.2.2 Water Sampling for Dissolved Organic Matter Analyses

(D. Baiko[1], W. Freund[1], C. Nantke[2], T. Dittmar[1], M. Seidel[1])

[1] ICBM / University of Oldenburg

[2] Leibniz-Institut für Ostseeforschung Warnemünde

Water for dissolved organic matter (DOM) analyses was collected at various depths from 46 stations using Niskin bottles of the CTD rosette (see table 11.1.2 in the appendices). Approximately 5 L of seawater was collected into pre-rinsed HDPE canisters. Additionally, water overlaying the sediment (denoted as “bottom water”) was sampled with a syringe directly from sediment core liners at 10 stations. Moreover, porewater was collected at four selected stations by Carla Nantke and Linda Ruth using pre-rinsed rhizons.

All water samples were filtered through combusted GF/F (0.7 µm) filters with a GMF pre-filter (2 µm) by means of peristaltic pump (Masterflex) or manually with a syringe in case of small volumes (sediment core samples). Total humic-like fluorescence was measured in filtered water with an Aquafluor handheld fluorimeter (Turner Designs, wavelength 350 nm excitation, 420 nm detection) immediately after filtration. DOM samples were acidified to pH 2 with 25% HCl p.a. Aliquots of each sample for the quantification of dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) were transferred to HDPE vials in triplicates. All samples were stored frozen on board and upon arrival transported cooled to the University of Oldenburg.

Bulk seawater DOC and TDN concentrations were measured at the ICBM (University of Oldenburg) via high-temperature catalytic oxidation (Shimadzu TOC Analyzer). The molecular composition of solid-phase extracted DOM (SPE-DOM) will be analyzed via Fourier-transform ion cyclotron resonance mass spectrometry (FT-ICR-MS) and dissolved organic sulfur (DOS) concentrations of SPE-DOM will be measured on an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) at the ICBM (University of Oldenburg).

5.2.3 Water Sampling Radium Isotopes

(C. Mears[1], L. Schroeder[1], C. Petrauskas[1], H. Thomas[1])

[1]Helmholtz-Zentrum Hereon

The natural radioactive Radium isotopes ^{223}Ra, ^{224}Ra, ^{228}Ra, and ^{226}Ra, were collected at varying depths throughout the water column for 49 stations sampled during the HE611 campaign. For each station, approximately 200L of surface water was collected via the shipside pump and then later pumped via Gardena pump from the ships moon pool. Alternatively, subsurface samples were collected via the rosette of Niskin bottles attached to the onboard CTD, which allowed for approximately 100-120 liters of seawater to be collected (see table 11.1.3 in the appendices).

All water samples were filtered first through a 10 µm filter, followed by a 1µm filter in series. For both the surface samples from the moon pool, as well as the subsurface samples, a Gardena garden pump was used. Once filtered, the sample water was pumped by means of peristaltic pump at a rate of 1L/minute over MnO_2 fibers. After the entire sample volume was pumped across the MnO_2 fibers, each fiber was rinsed with MilliQ water and then dried with forced air. The short-lived radium isotopes (^{223}Ra and ^{224}Ra) were measured onboard via a Radium Delayed Coincidence Counter (RaDeCC). Each sample was ideally counted immediately after sampling, at approximately one week post sampling, and finally at approximately 3 weeks after sampling. All samples were stored individually in Ziploc bags, and shipped back to Helmholtz-Zentrum Hereon after the cruise, where they will be processed in the laboratory for the long-lived radium isotopes (Moore & Reid, 1983).

5.2.4 Carbonate Water Sampling

(C. Mears[1], L. Schroeder[1], C. Petrauskas[1], H. Thomas[1], B. van Dam[1])

[1]Helmholtz-Zentrum Hereon

Discrete carbonate samples, analyzing the Dissolved Inorganic Carbon (DIC) and Alkalinity (AT) concentrations at varying depths per station, were taken (see table 11.1.4 in the appendices). For each sample, approximately 330 mL of water was collected directly from the associated Niskin bottle from the CTD rosette into a plastic BOD bottle, leaving no headspace for gas exchange. Directly after being filled, the bottles were sealed with a glass stopper coated in silicon grease, ensuring no gas transfer. Once sealed, the samples were stored in a cool and dark place until they could be processed. In the event that the sample could not be processed directly (<24 hours), the samples were spiked with 100 µL of $HgCl_2$ to ensure not change in the DIC and AT concentrations associated with biological respiration.

The samples were processed onboard the vessel by a VINDTA (Versatile INstrument for the Determination of Total inorganic carbon and titration Alkalinity) 3C Marianda, which analyzes DIC and AT concentrations via coulometric and potentiometric titration, respectively.

5.2.5 Water Sampling for Trace Metal Analysis

(A.-C. Rohrweber[1])

[1] Helmholtz-Zentrum Hereon

Three different types of samples were taken for trace metal analysis via ICP-MS/MS, namely water from the water rosette, pore water from one MUC core and sediment from a separate MUC core (see 5.4 for pore water and sediment analysis). The stations sampled for trace metal analysis are listed in table 11.1.5 in the appendices.

Water samples for trace metal analysis were taken at every CTD station by tapping up to 400 mL from the Niskin bottles of the CTD rosette directly into acid-leached PFA bottles without the use of adapters or tubes. All subsequent sample processing onboard took place inside of a tabletop clean bench (Captair 700). From each PFA bottle, water was filtered in a triplicate using individual DigiTubes (50 mL graded, acid-leached, SCP Science) and also three separate DigiFilters (0.45 µm, acid-leached, SCP Science). The first 5-10 mL of sample that passed through each filter were discarded. The collected samples were then acidified with 0.1 mL concentrated HNO_3 and frozen due to lack of cold storage space. PFA bottles were rinsed with MilliQ water between uses and blank samples taken at the end of the voyage.

At Hereon, samples will be thawed and kept in a fridge until analysis using a coupling of a seaFAST (Elemental Scientific) automated preconcentration system and an ICP-MS/MS (Agilent 8900). A total of 37 elements will be measured and results will be validated using NASS-7 as certified reference material.

5.3 Sediment Sampling and Experimental Work

(A. Neumann[1], E. Husmann[1], T. Sanders[1], B. van Dam[1], L. C. Cotovicz[2], A.-C. Rohrweber[1])

[1] Helmholtz-Zentrum Hereon

[2] Leibniz-Institut für Ostseeforschung Warnemünde

5.3.1 Overview

During the HE611, we obtained virtually undisturbed sediment samples of the surface sediment by means of a Multicorer (Oktopus Kiel, Germany). Several undisturbed sediment cores with intact pore water were retrieved at the sites (summarized in table 5.3.1) and were provided to several experiments. Specifically prepared core liners were sampled for pore water for later measurement of nutrients and dissolved metals (see 5.3.2). A second set of cores was sliced for the posterior analysis of the solids for particle-bound metals, C/N analysis, TEP analysis (see 5.4), and chlorophyll content (see 5.4.3). A third set of cores was subject to a whole-core incubation

experiment for the direct measurement of benthic fluxes of oxygen, nutrients, metals, DIC / AT, and GHG (see 5.3.4).

Table 5.3.1: Sediment samples retrieved during HE611. Abbreviations: pore water sampling (PW), sliced core (Slice), whole-core incubation (WCI).

Site	Latitude (deg)	Longitude (deg)	Samples
2	54.119233	11.133329	Slice, WCI, PW
4	55.569837	16.370832	Slice, WCI, PW
8	58.541716	18.232061	Slice, WCI, PW
12	54.550397	10.768902	Slice, WCI, PW
19	54.455419	11.51976	Slice, WCI, PW
26	54.808923	6.74347	Slice, WCI, PW
29	53.998876	6.229644	Slice, WCI, PW
31	54.06128	8.01735	Slice, WCI, PW
32	54.999034	7.503523	Slice, WCI
35	58.430034	9.479546	Slice, WCI, PW
37	56.999279	3.748644	Slice, WCI
40	56.999671	-0.50049	Slice
46	55.49983	4.167807	Slice, WCI

5.3.2 Pore Water Sampling for Trace Metal Analysis

(A.-C. Rohrweber[1])

[1] Helmholtz-Zentrum Hereon

Pore water samples for trace metal analysis were obtained from a multicorer (Oktopus Kiel, Germany) core by inserting rhizons (CSS 5 cm, female luer) into pre-drilled holes in the core liner and pulling a vacuum with 15 mL syringes. Sampling intervals measured 1 cm for the topmost 10 cm, 2 cm at approximately 10 - 25 cm depth and 4 cm for the remainder of the core. Samples were transferred to acid-leached vials (2 mL Cryovials, 2 mL Eppendorf vials, 1.5 mL Eppendorf vials) in duplicates and frozen. Whenever additional pore water was available, it was transferred to 15 mL plastic tubes and frozen for analysis of nutrients in the laboratory of Dr. Tina Sanders at Hereon. The stations sampled for trace metal analysis are listed in table 11.1.5 in the appendices.

5.3.3 Sediment from MUC Cores

(A. Neumann[1], A.-C. Rohrweber[1])

[1] Helmholtz-Zentrum Hereon

A multicorer (MUC) with 60 cm long core liners was used to retrieve undisturbed sediment cores. Multicores with a typical length of the sediment column in the range of 20 cm (sand) to 50 cm (mud) were sliced with the help of a core extruder.on board in 1 cm intervals for analyses of the solids and trace metals. At stations 12 and 19, sediment was sampled for trace metal analysis in 2 cm intervals between 10 cm sediment depth and the bottom end of the core. All samples were collected in acid-leached plastic beakers and frozen immediately.

At Hereon, samples will be stored in a freezer at -80°C prior to freeze-drying. The samples can then be stored at room temperature until they will be further processed via microwave-assisted strong acid leaching. The analysis of the leachate will comprise of a multi-element fingerprint measured with ICP-MS/MS (Agilent 8800). Additional cores were sampled for TEP (see 5.4) and chlorophyll directly after core retrieval by slicing in 1 cm intervals. The samples were stored frozen at -20 °C until analysis at Hereon.

A noteworthy find is the massive occurrence of centimeter-sized, fast-growing manganese nodules (Fig. 5.3.1) in the surface sediment of the Landsort Deep in the Baltic Sea (station HE611-8).

Fig. 5.3.1: Manganese nodules form the surface sediment at Landsort Deep (A. Neumann).

5.3.4 Whole-Core Incubations

Whole-core incubations were employed to measure the fauna-mediated fluxes of oxygen, nutrients, metals, DIC / AT, and the greenhouse gases (GHG) CH_4, N_2O. The method is described in detail in Neumann et al. (2021). Typically, four suitable cores were selected and the incubation was set up within 1 hour after retrieval (Fig. 5.3.2). Oxygen was measured online with fibre-optical optodes and was used to assess the progress of the incubation. After initial samples for dissolved metals and nutrients, a tracer for bioirrigation (NaBr) was injected into the supernatant. During the incubation, subsamples from the supernatant were collected at multiple times throughout the incubation, filtered through 0.45 µm CA filters. Samples for nutrient analysis were stored frozen, and stored refrigerated for Bromide measurement, respectively. After the termination of the incubation after 24-36 hours and at typically > 80 % oxygen saturation, additional endpoint samples for metal analysis, DIC / AT, and GHG were taken. Finally, additional samples from the surface sediment of each incubated core were collected, and the macrofauna of each core was obtained by sieving the cores through a 1 mm sieve and preserving the collected for later analysis. The results of the incubations were not yet available at the time this report was prepared. The

bottom water was oxygen depleted at sites 4 & 8, and thus the incubation method was altered to preserve the anoxic conditions in the supernatant. Here, cores were capped immediately after retrieval without bubbles / headspace and incubated without any further interference. Consequently, there are no oxygen measurements available, no bromide tracer was injected, and nutrient samples were taken only once at the end of the incubation directly after sampling for DIC, AT, GHG.

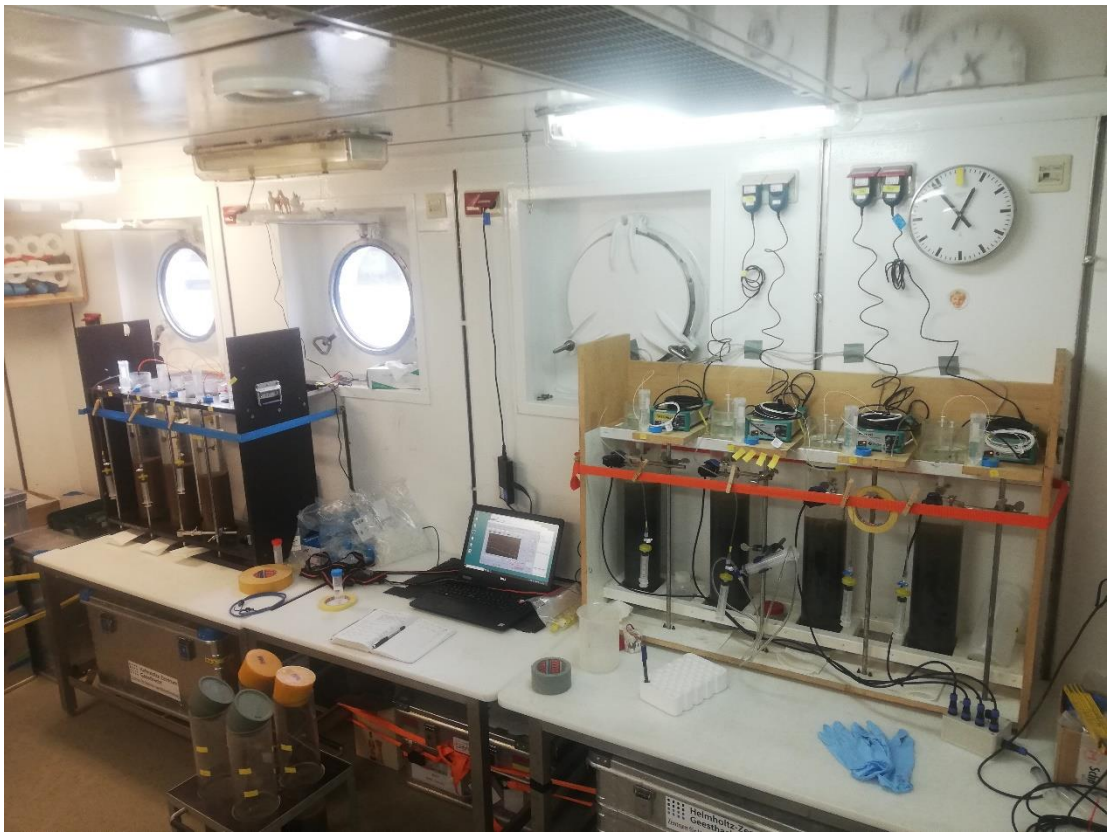

Fig. 5.3.2: Incubation setup in the ship's temperature controlled laboratory. (A. Neumann)

5.4 Bentho-Pelagic Particle Fluxes – CPICS Deployment and TEP Sampling

(A. Neumann[1], E. Husmann[1], L. Schmidt[1])

[1] Helmholtz-Zentrum Hereon

Transparent exopolymer particles (TEP) are well studied in the water column. They play a major role in particle aggregation processes and marine snow formation and therefore contribute to carbon transport to deep water layers. These observations were also made in shallow epeiric basins and seas, where the average depth is above 100 m. Riverine nutrient inflow and nutrient recycling within the water column promote phytoplankton blooms. Through different processes, TEP is released during and shortly after the bloom. Free floating particles stick to TEP, which in turn increases the overall floc weight and therefore its probability to sink and transport attached organic matter to deeper water layers and the sediment.

To investigate the dynamics of particles from the water column to the sediment and hence the coupling of the bentho-pelagic in a winter scenario, we sampled the water column for TEP and

adjacent biogeochemical parameters, complemented the water sampling with particle image profiles and developed a method to further investigate TEP and particle properties at the sediment surface and the topmost layers of the sediment.

5.4.1 Water Sampling

CTD water samples were taken for suspended particulate matter (SPM), Chlorophyll a (Chl a), particulate organic matter (POC) and TEP. At the stations listed below surface and bottom water was sampled, respectively. Additionally, we sampled at chlorophyll max in stratified water bodies, adding a third depth to the parameter profile. For SPM, at least 4000 mL water was filtered on precombusted (450°C for 4 hours) and MilliQ-rinsed GF/F (0.7 µm) filters. Before storage, the filter was MilliQ- rinsed once more to reduce the salt-induced weight off-set. For each Chl a sample, 1000 mL water was filtered GF/F filters (47 mm, 0.7 µm). Three replicate samples were taken for POC and 100 mL, 150 mL, and 200 mL, respectively, was filtered onto pre-combusted (450°C for 4 hours) GF/F filters (26 mm, 0.7µm). Water samples for TEP were filtered onto polycarbonate filters (47 mm, 0.4 µm) and stained with 0.02% aqueous solution of alcian blue (8GX) in 0.06% acetic acid according to Passow & Alldredge (1995). However, due to the larger filter size of 47 mm, the original protocol was altered and the added volume was increased to 1000 µL to cover and stain all TEP on the filter's surface.

All water samples were vacuum filtered (constant vacuum of 150 mm of Hg) according to their respective method and stored frozen at -20°C on board RV Heincke until further analysis on land.

5.4.2 CPICS Deployment

The in situ dark field microscopy camera system CPICS (Continuous Particle Imaging and Classification System) was deployed in conjunction with the MUC (multicorer). To estimating particle distribution, characterize and estimate their volume, a water column profile was run at max winch speed of 0.3 ms^{-1}. At the surface, chlorophyll max (if stratified) and the bottom, the CPICS was stopped for 3 minutes, which increased the picture density and therefore the probability to answer aforementioned estimates during winter.

5.4.3 Sediment Sampling for Chlorophyll and TEP Analysis

Sediment samples were taken from sediment cores recovered by a multicorer (MUC) equipped with transparent acrylic core liners. Cores were selected for analysis if the surface's particle deposition was undisturbed. Two replicate cores were sampled for Chl a and TEP analysis. On board, the core was sliced in 1 cm intervals while being manually extruded. For Chlorophyll a, 10 mL sediment was sampled in 1 cm intervals from the top 10 cm in mud areas and top 15 cm in areas with greater grain size. Additionally, 10 mL of the surface particle deposition was collected with a syringe. All Chlorophyll samples were stored frozen at -20°C on board the ship.
The top 5 cm and the fluffy particle deposition of the sediment cores were also sampled for TEP. 250 µL sample was collected from fine sediments, whereas 500 µL was collected from sediment cores with greater grain size. The sample was then suspended in 0.2 µm filtered sea water. The suspension was poured onto polycarbonate filters (47 mm, 0.4 µm) and vacuum-filtered at constant vacuum of 150 mm of Hg. TEP was stained with 0.02% aqueous solution of alcian blue (8GX) in 0.06% acetic acid following the protocol by Passow & Alldredge (1995) with the

volumetric adjustment described above. Filters were retrieved soon after and stored frozen at -20°C on board the ship.

5.5 Process Study

(B. van Dam[1], H. Thomas[1])

[1] Helmholtz-Zentrum Hereon

The process study describes a pause of the primary cruise plan due to bad weather conditions and no access to the open sea in the second week of the cruise. In order to make the most of the time, the crew visited some near-shore stations at greater density. More information on the stations visited during this process study see table 11.1.6 in the appendices.

6 Station List HE611

The station lists can be found in the appendix under 11.1 as well as in the attached excel spreadsheet to this cruise report.

7 Data and Sample Storage and Availability

Data will be stored to hereon's data center HCDC and will be made accessible after finalization of involved PhD theses work.

8 Acknowledgements

The expedition contributes to the project "The Ocean's Alkalinity: connecting geological and metabolic processes and time-scales", BMBF under "Make our Planet Great Again—German Research Initiative", grant number 57429828, implemented by the German Academic Exchange Service (DAAD).

9 References

Moore, W. S., & Reid, D. F. (1973). Extraction of radium from natural waters using manganese impregnated acrylic fibers. *Journal of Geophysical Research*, 78 (36), 8880–8886. https://doi.org/10.1029/jc078i036p08880.

Neumann, A.; Beusekom, J.; Eisele, A.; Emeis, K.; Friedrich, J.; Kröncke, I.; Logemann, E.; Meyer, J.; Naderipour, C.; Schückel, U.; Wrede, A.; Zettler, M. (2021). Macrofauna as a major driver of bentho-pelagic exchange in the southern North Sea. *Limnology and Oceanography*, Vol. 66, (2021) 6, 2203 - 2217. https://doi.org/10.1002/lno.11748

Passow, U., & Alldredge, A. L. (1995). A dye-binding assay for the spectrophotometric measurement of transparent exopolymer particles (TEP). Limnology and Oceanography, 40 (7), 1326-1335. https://doi.org/10.4319/lo.1995.40.7.1326.

10 Abbreviations

AT	Total alkalinity
BW	Bottom water
CPICS	Continuous Particle Imaging Classification System, underwater microscope
CTD	Rosette for water sampling; *conductivity, temperature, depth*
DIC	Dissolved inorganic carbon
DOC	Dissolved organic carbon
DOM	Dissolved organic matter
DOS	Dissolved organic suphur
EC	Eddy Covariance
ECD	Electron Capture Detector
FID	Flame Ionization Detector
FT-ICR-MS	Fourier-transform ion cyclotron resonance mass spectrometry
GC	Gas Chromatography
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometer
MUC	Multicorer, sediment corer
PW	Pore water
RaDeCC	Radium Delayed Coincidence Counter
SPE	Solid-phase extracted; solid phase extraction
SW	Surface water
TDN	Total dissolved nitrogen
VINDTA	Versatile instrument for the determination of total inorganic carbon and titration alkalinity

11 Appendices

11.1 Tables from Preliminary Results

Table 11.1.1: Discrete sampling stations, including location (latitude, longitude), sampling depth (m), CTD cast number, and station label for CH_4 and N_2O.

Sample ID	Latitude	Longitude	Depth (m)	CTD btl Nr.	Station Label
HE611 1-1-2	54°33.348	10°45.096	21.8	2	HE611 1-1-2
HE611 1-1-6	54°33.348	10°45.096	10.8	6	HE611 1-1-6
HE611 1-1-10	54°33.348	10°45.096	2.6	10	HE611 1-1-10
HE611 2-1-10	54°7.170	11°7.967	2.2	10	HE611 2-1-10
HE611 2-1-6	54°7.170	11°7.967	10.6	6	HE611 2-1-6
HE611 2-1-2	54°7.170	11°7.967	21.2	2	HE611 2-1-2
HE611 3-1-2	55°6.024	14°0.020	43.3	2	HE611 3-1-2
HE611 3-1-6	55°6.024	14°0.020	33	6	HE611 3-1-6
HE611 3-1-10	55°6.024	14°0.020	2.9	10	HE611 3-1-10
HE611 4-1-4	55°34.198	16°22.246	66.1	4	HE611 4-1-4
HE611 4-1-6	55°34.198	16°22.246	50.5	6	HE611 4-1-6
HE611 4-1-10	55°34.198	16°22.246	40.2	10	HE611 4-1-10
HE611 4-1-12	55°34.198	16°22.246	24.9	12	HE611 4-1-12
HE611 4-3-5	55°34.198	16°22.246	3.2	5	HE611 4-3-5
HE611 4-5 Inku1	55°34.198	16°22.246	72.1	MUC	HE611 4-5 Inku1
HE611 4-5 Inku2	55°34.198	16°22.246	72.1	MUC	HE611 4-5 Inku2
HE611 4-5 Inku3	55°34.198	16°22.246	72.1	MUC	HE611 4-5 Inku3
HE611 4-5 Inku4	55°34.198	16°22.246	72.1	MUC	HE611 4-5 Inku4
HE611 5-1-2	56°0.16	16°49.825	34.1	2	HE611 5-1-2
HE611 5-1-6	56°0.16	16°49.825	18.1	6	HE611 5-1-6
HE611 5-1-10	56°0.16	16°49.825	3.1	10	HE611 5-1-10
HE611 6-1-2	56°59.989	17°36.016	99.9	2	HE611 6-1-2
HE611 6-1-4	56°59.989	17°36.016	70.1	4	HE611 6-1-4
HE611 6-1-6	56°59.989	17°36.016	49.8	6	HE611 6-1-6
HE611 6-1-10	56°59.989	17°36.016	25.5	10	HE611 6-1-10
HE611 6-1-12	56°59.989	17°36.016	3.6	12	HE611 6-1-12
HE611 7-1-2	57°48.016	17°54.013	87.8	2	HE611 7-1-2
HE611 7-1-4	57°48.016	17°54.013	74.8	4	HE611 7-1-4
HE611 7-1-6	57°48.016	17°54.013	60	6	HE611 7-1-6
HE611 7-1-10	57°48.016	17°54.013	34.8	10	HE611 7-1-10
HE611 7-1-12	57°48.016	17°54.013	2.5	12	HE611 7-1-12
HE611 8-1-4	58°32.508	18°13.963	352	4	HE611 8-1-4
HE611 8-1-6	58°32.508	18°13.963	250.4	6	HE611 8-1-6

HE611 8-1-7	58°32.508	18°13.963	99.4	7	HE611 8-1-7
HE611 8-1-12	58°32.508	18°13.963	39.8	12	HE611 8-1-12
HE611 8-2-4	58°32.508	18°13.963	2.3	4	HE611 8-2-4
HE611 8-10 Inku1	58°32.508	18°13.963	375.4	MUC	HE611 8-10 Inku1
HE611 8-10 Inku2	58°32.508	18°13.963	375.4	MUC	HE611 8-10 Inku2
HE611 8-10 Inku3	58°32.508	18°13.963	375.4	MUC	HE611 8-10 Inku3
HE611 8-10 Inku4	58°32.508	18°13.963	375.4	MUC	HE611 8-10 Inku4
HE 611 9-1-2	56°59.934	20°10.884	160.8	2	HE 611 9-1-2
HE 611 9-1-4	56°59.934	20°10.884	119.3	4	HE 611 9-1-4
HE 611 9-1-6	56°59.934	20°10.884	75.7	6	HE 611 9-1-6
HE 611 9-1-10	56°59.934	20°10.884	61	10	HE 611 9-1-10
HE611 9-1-12	56°59.934	20°10.884	34.8	12	HE611 9-1-12
HE611 9-2-3	56°59.934	20°10.884	5.3	3	HE611 9-2-3
HE611 10-1-4	56°59.786	19°30.805	170	4	HE611 10-1-4
HE611 10-1-6	56°59.786	19°30.805	120.4	6	HE611 10-1-6
HE611 10-1-7	56°59.786	19°30.805	79.9	7	HE611 10-1-7
HE611 10-1-12	56°59.786	19°30.805	50.2	12	HE611 10-1-12
HE611 10-2-4	56°59.786	19°30.805	3.4	4	HE611 10-2-4
HE611 11-1-2	54°31.831	10°02.412	23.6	2	HE611 11-1-2
HE611 11-1-7	54°31.831	10°02.412	3.9	7	HE611 11-1-7
HE611 12-1-4	54°33.016	10°46.080	19.3	4	HE611 12-1-4
HE611 12-1-12	54°33.016	10°46.080	3.8	12	HE611 12-1-12
HE611 12-5- Inku1	54°33.016	10°46.080	19.6	MUC	HE611 12-5- Inku1
HE611 12-5 Inku2	54°33.016	10°46.080	19.6	MUC	HE611 12-5 Inku2
HE611 12-5 Inku3	54°33.016	10°46.080	19.6	MUC	HE611 12-5 Inku3
HE611 12-5 Inku4	54°33.016	10°46.080	19.6	MUC	HE611 12-5 Inku4
HE611 13-1-2	54°36.576	10°46.122	16.8	2	HE611 13-1-2
HE611 13-1-6	54°36.576	10°46.122	3.8	6	HE611 13-1-6
HE611 14-1-3	54°39.175	10°45.997	19.1	3	HE611 14-1-3
HE611 14-1-4	54°39.175	10°45.997	3.1	4	HE611 14-1-4
HE611 15-1-2	54°35.678	11°3.284	28.2	2	HE611 15-1-2
HE611 15-1-6	54°35.678	11°3.284	7	6	HE611 15-1-6
HE611 15-1-7	54°35.678	11°3.284	3.2	7	HE611 15-1-7
HE611 16	54°34.200	11°10.829			HE611 16
HE611 16	54°34.200	11°10.829			HE611 16
HE611 17-1-3	54°32.518	11°18.194	25.4	3	HE611 17-1-3
HE611 17-1-4	54°32.518	11°18.194	2.5	4	HE611 17-1-4
HE611 18	54°29.818	11°25.620			HE611 18
HE611 18	54°29.818	11°25.620			HE611 18
HE611 19-1-3	54°27.311	11°31.187	22.1	3	HE611 19-1-3
HE611 19-1-4	54°27.311	11°31.187	3	4	HE611 19-1-4
HE611 19-5 Inku1	54°27.311	11°31.187	22.2	MUC	HE611 19-5 Inku1
HE611 19-5 Inku2	54°27.311	11°31.187	22.2	MUC	HE611 19-5 Inku2
HE611 19-5 Inku3	54°27.311	11°31.187	22.2	MUC	HE611 19-5 Inku3
HE611 19-5 Inku4	54°27.311	11°31.187	22.2	MUC	HE611 19-5 Inku4
HE611 20-1-3	55°29.998	10°57.488	13	3	HE611 20-1-3

HE611 20-1-4	55°29.998	10°57.488	3.1	4	HE611 20-1-4
HE611 21-1-3	56°23.476	11°26.281	14	3	HE611 21-1-3
HE611 21-1-4	56°23.476	11°26.281	3.7	4	HE611 21-1-4
HE611 22-1-2	57°31.918	11°10.416	36.2	2	HE611 22-1-2
HE611 22-1-6	57°31.918	11°10.416	15.5	6	HE611 22-1-6
HE611 22-1-7	57°31.918	11°10.416	3.8	7	HE611 22-1-7
HE611 23-1-4	57°54.005	10°41.555	137	4	HE611 23-1-4
HE611 23-1-6	57°54.005	10°41.555	99.9	6	HE611 23-1-6
HE611 23-1-7	57°54.005	10°41.555	70.6	7	HE611 23-1-7
HE611 23-12	57°54.005	10°41.555	30.5	12	HE611 23-12
HE611 23-4-2	57°54.005	10°41.555	3	4	HE611 23-4-2
HE611 24-1-2	58°0.000	8°29.748	513.1	2	HE611 24-1-2
HE611 24-1-4	58°0.000	8°29.748	449.6	4	HE611 24-1-4
HE611 24-1-5	58°0.000	8°29.748	300	5	HE611 24-1-5
HE611 24-1-6	58°0.000	8°29.748	200	6	HE611 24-1-6
HE611 24-1-7	58°0.000	8°29.748	100	7	HE611 24-1-7
HE611 24-1-8	58°0.000	8°29.748	60.6	8	HE611 24-1-8
HE611 24-1-9	58°0.000	8°29.748	50	9	HE611 24-1-9
HE611 24-1-11	58°0.000	8°29.748	4.2	11	HE611 24-1-11
HE611 25-1-1	56°59.989	6°29.954	39.8	1	HE611 25-1-1
HE611 25-1-4	56°59.990	6°29.955	3.9	4	HE611 25-1-4
HE611 26-1-3	54°48.496	6°44.604	36.8	3	HE611 26-1-3
HE611 26-1-4	54°48.497	6°44.605	3.8	4	HE611 26-1-4
HE611 26-5 Inku1	54°48.498	6°44.606	39.3	MUC	HE611 26-5 Inku1
HE611 26-5 Inku2	54°48.499	6°44.607	39.3	MUC	HE611 26-5 Inku2
HE611 26-5 Inku3	54°48.500	6°44.608	39.3	MUC	HE611 26-5 Inku3
HE611 26-5 Inku4	54°48.501	6°44.609	39.3	MUC	HE611 26-5 Inku4
HE611 27-1-3	54°24.004	5°15.001	38.4	3	HE611 27-1-3
HE611 27-1-4	54°24.004	5°15.001	2.8	4	HE611 27-1-4
HE611 28-1-1	54°24.01	6°15.04	31	1	HE611 28-1-1
HE611 28-1-7	54°24.02	6°15.05	4	7	HE611 28-1-7
HE611 29-1-3	53°59.940	6°13.756	29	3	HE611 29-1-3
HE611 29-1-4	53°59.940	6°13.756	3.8	4	HE611 29-1-4
HE611 30-4	54°23.999	7°30.004	21.2	4	HE611 30-4
HE611 30-6	54°23.999	7°30.004	4.7	6	HE611 30-6
HE611 31-1-4	54°3.697	8°0.919	24.2	5	HE611 31-1-4
HE611 31-1-7	54°3.697	8°0.919	2.8	7	HE611 31-1-7
HE611 31-3 Inku1	54°3.697	8°0.919	25.7	MUC	HE611 31-3 Inku1
HE611 31-3 Inku2	54°3.697	8°0.919	25.7	MUC	HE611 31-3 Inku2
HE611 31-3 Inku3	54°3.697	8°0.919	25.7	MUC	HE611 31-3 Inku3
HE611 31-3 Inku4	54°3.697	8°0.919	25.7	MUC	HE611 31-3 Inku4
HE611 32-bottom	55°0.013	7°30.040	22.7	4	HE611 32-bottom
HE611 32-surface	55°0.013	7°30.040	4.9	7	HE611 32-surface
HE611 32-Inku1	55°0.013	7°30.040	26	MUC	HE611 32-Inku1
HE611 32-Inku2	55°0.013	7°30.040	26	MUC	HE611 32-Inku2
HE611 32-Inku3	55°0.013	7°30.040	26	MUC	HE611 32-Inku3

HE611 32-Inku4	55°0.013	7°30.040	26	MUC	HE611 32-Inku4
HE611 33-1	57°29.963	7°29.801	196.4	1	HE611 33-1
HE611 33-3	57°29.963	7°29.801	149.3	3	HE611 33-3
HE611 33-5	57°29.963	7°29.801	116	5	HE611 33-5
HE611 33-7	57°29.963	7°29.801	75.8	7	HE611 33-7
HE611 33-8	57°29.963	7°29.801	60.1	8	HE611 33-8
HE611 33-10	57°29.963	7°29.801	49.4	10	HE611 33-10
HE611 33-11	57°29.963	7°29.801	40.7	11	HE611 33-11
HE611 33-12	57°29.963	7°29.801	9.8	12	HE611 33-12
HE611 34-3	57°59.999	5°30.035	216.7	3	HE611 34-3
HE611 34-4	57°59.999	5°30.035	152.2	4	HE611 34-4
HE611 34-5	57°59.999	5°30.035	124.9	5	HE611 34-5
HE611 34-6	57°59.999	5°30.035	100.7	6	HE611 34-6
HE611 34-7	57°59.999	5°30.035	74.8	7	HE611 34-7
HE611 34-8	57°59.999	5°30.035	50.6	8	HE611 34-8
HE611 34-11	57°59.999	5°30.035	8.3	11	HE611 34-11
HE611 35-1	58°25.780	9°28.783	501.6	1	HE611 35-1
HE611 35-3	58°25.780	9°28.783	399.4	3	HE611 35-3
HE611 35-4	58°25.780	9°28.783	349.3	4	HE611 35-4
HE611 35-5	58°25.780	9°28.783	250.2	5	HE611 35-5
HE611 35-6	58°25.780	9°28.783	200.3	6	HE611 35-6
HE611 35-7	58°25.780	9°28.783	150.3	7	HE611 35-7
HE611 35-8	58°25.780	9°28.783	99.6	8	HE611 35-8
HE611 35-9	58°25.780	9°28.783	59.2	9	HE611 35-9
HE611 35-11	58°25.780	9°28.783	4.6	11	HE611 35-11
HE611 35-Inku1	58°25.780	9°28.783	525	MUC	HE611 35-Inku1
HE611 35-Inku2	58°25.780	9°28.783	525	MUC	HE611 35-Inku2
HE611 35-Inku3	58°25.780	9°28.783	525	MUC	HE611 35-Inku3
HE611 35-Inku4	58°25.780	9°28.783	525	MUC	HE611 35-Inku4
HE611 36-1	57°0.016	5°14.940	51.3	1	HE611 36-1
HE611 36-7	57°0.016	5°14.940	5.2	7	HE611 36-7
HE611 37-1	56°59.964	3°44.917	61.4	1	HE611 37-1
HE611 37-7	56°59.965	3°44.918	5	7	HE611 37-7
HE611 38-1	57°0.048	2°14.599	75.8	1	HE611 38-1
HE611 38-6	57°0.048	2°14.599	50.1	6	HE611 38-6
HE611 38-11	57°0.048	2°14.599	3.8	11	HE611 38-11
HE611 39-5	56°59.977	0°59.995	86.6	5	HE611 39-5
HE611 39-11	56°59.977	0°59.995	5.3	11	HE611 39-11
HE611 40-4	56°59.994	0°29.998	74.6	4	HE611 40-4
HE611 40-10	56°59.994	0°29.998	3.4	10	HE611 40-10
HE611 41-1	56°0.019	0°29.981	80.4	1	HE611 41-1
HE611 41-3	56°0.019	0°29.981	70.1	3	HE611 41-3
HE611 41-5	56°0.019	0°29.981	50	5	HE611 41-5
HE611 41-8	56°0.019	0°29.981	30.3	8	HE611 41-8
HE611 41-9	56°0.019	0°29.981	20.1	9	HE611 41-9
HE611 41-11	56°0.019	0°29.981	4.2	11	HE611 41-11

HE611 42-2	55°59.996	1°59.999	82	2	HE611 42-2
HE611 42-4	55°59.996	1°59.999	70.1	4	HE611 42-4
HE611 42-6	55°59.996	1°59.999	58	6	HE611 42-6
HE611 42-8	55°59.996	1°59.999	50	8	HE611 42-8
HE611 42-10	55°59.996	1°59.999	30	10	HE611 42-10
HE611 42-12	55°59.996	1°59.999	3.2	12	HE611 42-12
HE611 43-4	55°0.011	1°59.939	19.4	4	HE611 43-4
HE611 43-6	55°0.011	1°59.939	10	6	HE611 43-6
HE611 43-9	55°0.011	1°59.939	4.7	9	HE611 43-9
HE611 44-1	54°23.999	2°44.970	25.3	1	HE611 44-1
HE611 44-6	54°23.999	2°44.970	15	6	HE611 44-6
HE611 44-11	54°23.999	2°44.970	4.1	11	HE611 44-11
HE611 45-1	55°0.016	3°29.998	34.6	1	HE611 45-1
HE611 45-7	55°0.016	3°29.998	20.8	7	HE611 45-7
HE611 45-8	55°0.016	3°29.998	4	8	HE611 45-8
HE611 46-3	55°29.986	4°10.073	28.5	3	HE611 46-3
HE611 46-6	55°29.986	4°10.073	14.5	6	HE611 46-6
HE611 46-9	55°29.986	4°10.073	3.5	9	HE611 46-9
HE611 46-Inku1	55°29.986	4°10.073	32	MUC	HE611 46-Inku1
HE611 46-Inku2	55°29.986	4°10.073	32	MUC	HE611 46-Inku2
HE611 46-Inku3	55°29.986	4°10.073	32	MUC	HE611 46-Inku3
HE611 46-Inku4	55°29.986	4°10.073	32	MUC	HE611 46-Inku4
HE611 47-2	55°58.806	3°28.849	68.1	2	HE611 47-2
HE611 47-4	55°58.806	3°28.849	54.1	4	HE611 47-4
HE611 47-6	55°58.806	3°28.849	34.8	6	HE611 47-6
HE611 47-8	55°58.806	3°28.849	20.2	8	HE611 47-8
HE611 47-12	55°58.806	3°28.849	4	12	HE611 47-12
HE611 48-5	55°58.756	4°59.866	40.2	5	HE611 48-5
HE611 48-7	55°58.756	4°59.866	20	7	HE611 48-7
HE611 48-9	55°58.756	4°59.866	4	9	HE611 48-9
HE611 49-3	55°59.995	6°29.962	38.5	3	HE611 49-3
HE611 49-6	55°59.995	6°29.962	20	6	HE611 49-6
HE611 49-11	55°59.995	6°29.962	3.8	11	HE611 49-11

Table 11.1.2: DOM sampling stations. CTD sampling was conducted at various depths. Multicorer (MUC) samples were used to acquire bottom water (BW) and porewater (PW).

Station	**Date**	**Latitude**	**Longitude**	**CTD Sampling / Number of depths**	**MUC Sampling**
1	Nov 08 2022	54º 33.35' N	10º 45.1' E	3	
2	Nov 08 2022	54º 7.17' N	11º 7.98' E	3	BW
3	Nov 08 2022	55º 6.02' N	14º 0.02' E	3	
4	Nov 09 2022	55º 34.2' N	16º 22.23' E	5	BW

5	Nov 09 2022	56º 0.02' N	16º 49.83' E	3	
6	Nov 09 2022	56º 59.99' N	17º 36.02' E	5	
7	Nov 10 2022	57º 48.02' N	17º 54.02' E	5	
8	Nov 10 2022	58º 32.53' N	18º 13.93' E	5	BW; PW
9	Nov 11 2022	56º 59.99' N	20º 10.9' E	6	
10	Nov 11 2022	57º 0' N	19º 30.07' E	5	
11	Nov 13 2022	54º 31.82' N	10º 2.32' E	2	
12	Nov 14 2022	54º 33.01' N	10º 46.05' E	2	BW; PW
13	Nov 14 2022	54º 36.5' N	10º 46.08' E	2	
14	Nov 14 2022	54º 39.19' N	10º 46' E	2	
15	Nov 15 2022	54º 35.7' N	11º3.27' E	2	
17	Nov 15 2022	54º 32.52' N	11º 18.2' E	2	
19	Nov 15 2022	54º 27.31' N	11º 31.2' E	2	BW
20	Nov 18 2022	55º 30' N	10º 57.47' E	2	
21	Nov 18 2022	56º 23.47' N	11º 26.38' E	2	
22	Nov 19 2022	57º31.79' N	11º 10.69' E	3	
23	Nov 19 2022	57º 53.98' N	10º 41.61' E	5	
24	Nov 19 2022	58º 0' N	8º 29.76' E	5	
25	Nov 20 2022	55º 59.99' N	6º 29.96' E	2	
26	Nov 20 2022	54º 48.49' N	6º 44.63' E	2	BW
27	Nov 21 2022	54º 23.99' N	5º 15' E	2	
28	Nov 21 2022	54º 24' N	6º 15' E	2	
29	Nov 21 2022	53º 59.94' N	6º 13.77' E	2	BW
30	Nov 21 2022	54º 24' N	7º 30.03' E	2	
31	Nov 21 2022	54º 3.7' N	8º 0.94' E	2	BW; PW
32	Nov 24 2022	55º 0.02' N	7º 30.02' E	2	BW; PW
33	Nov 25 2022	57º 29.96' N	7º 29.81' E	5	
34	Nov 25 2022	58º 0' N	5º 30.04' E	5	
35	Nov 26 2022	58º 25.78' N	9º 28.78' E	5	BW
36	Nov 28 2022	57º 0.01' N	5º 14.94' E	2	
37	Nov 28 2022	56º 59.97' N	3º 44.92' E	2	
38	Nov 28 2022	57º 0.05' N	2º 14.6' E	2	
39	Nov 29 2022	56º 59.98' N	1º 0' E	2	
40	Nov 29 2022	56º 59.99' N	0º 30' W	2	
41	Nov 29 2022	56º 00.02 N	0º 29.98 E	2	
42	Nov 29 2022	56º 00.00 N	2º 00.00 E	2	
43	Nov 30 2022	55º 00.01 N	1º 58.79 E	2	
44	Nov 30 2022	54º 24.00 N	2º 44.97 E	2	
45	Nov 30 2022	55º 00.02 N	3º 30.00 E	2	
46	Nov 30 2022	55º 29.99 N	4º 10.07 E	2	
47	Nov 30 2022	55º 58.80 N	3º 28.85 E	2	
48	Dec 01 2022	55º 58.76 N	4º 59.86 E	2	

Table 11.1.3: Radium samples collected per station, with date, location and depths collected.

Station	Date	Latitude	Longitude	Number of depths	Depths Sampled
1	Nov 08 2022	54º 33.35' N	10º 45.1' E	1	SW
2	Nov 08 2022	54º 7.17' N	11º 7.98' E	1	SW
3	Nov 08 2022	55º 6.02' N	14º 0.02' E	1	SW
4	Nov 09 2022	55º 34.2' N	16º 22.23' E	1	SW
5	Nov 09 2022	56º 0.02' N	16º 49.83' E	1	SW
6	Nov 09 2022	56º 59.99' N	17º 36.02' E	1	SW
7	Nov 10 2022	57º 48.02' N	17º 54.02' E	1	SW
8	Nov 10 2022	58º 32.53' N	18º 13.93' E	3	SW; BW; mid
9	Nov 11 2022	56º 59.99' N	20º 10.9' E	1	SW
10	Nov 11 2022	57º 0' N	19º 30.07' E	3	SW; BW; mid
11	Nov 13 2022	54º 31.82' N	10º 2.32' E	2	SW; BW
12	Nov 14 2022	54º 33.01' N	10º 46.05' E	2	SW; BW
13	Nov 14 2022	54º 36.5' N	10º 46.08' E	2	SW; BW
14	Nov 14 2022	54º 39.19' N	10º 46' E	2	SW; BW
15	Nov 15 2022	54º 35.7' N	11º3.27' E	2	SW; BW
17	Nov 15 2022	54º 32.52' N	11º 18.2' E	2	SW; BW
19	Nov 15 2022	54º 27.31' N	11º 31.2' E	2	SW; BW
20	Nov 18 2022	55º 30' N	10º 57.47' E	1	SW
22	Nov 19 2022	57º31.79' N	11º 10.69' E	2	SW; BW
23	Nov 19 2022	57º 53.98' N	10º 41.61' E	2	SW; BW
24	Nov 19 2022	58º 0' N	8º 29.76' E	3	SW; BW; mid
25	Nov 20 2022	55º 59.99' N	6º 29.96' E	1	SW
26	Nov 20 2022	54º 48.49' N	6º 44.63' E	1	SW
27	Nov 21 2022	54º 23.99' N	5º 15' E	1	SW
28	Nov 21 2022	54º 24' N	6º 15' E	1	SW
29	Nov 21 2022	53º 59.94' N	6º 13.77' E	1	SW
30	Nov 21 2022	54º 24' N	7º 30.03' E	1	SW
31	Nov 21 2022	54º 3.7' N	8º 0.94' E	1	SW
32	Nov 24 2022	55º 0.02' N	7º 30.02' E	1	SW
33	Nov 25 2022	57º 29.96' N	7º 29.81' E	3	SW; BW; mid
34	Nov 25 2022	58º 0' N	5º 30.04' E	3	SW; BW; mid
35	Nov 26 2022	58º 25.78' N	9º 28.78' E	3	SW; BW; mid
36	Nov 28 2022	57º 0.01' N	5º 14.94' E	1	SW
37	Nov 28 2022	56º 59.97' N	3º 44.92' E	1	SW
38	Nov 28 2022	57º 0.05' N	2º 14.6' E	1	SW
39	Nov 29 2022	56º 59.98' N	1º 0' E	1	SW
40	Nov 29 2022	56º 59.99' N	0º 30' W	1	SW
41	Nov 29 2022	56º 00.02 N	0º 29.98 E	2	SW; BW
42	Nov 29 2022	56º 00.00 N	2º 00.00 E	2	SW; BW
43	Nov 30 2022	55º 00.01 N	1º 58.79 E	1	SW
44	Nov 30 2022	54º 24.00 N	2º 44.97 E	1	SW
45	Nov 30 2022	55º 00.02 N	3º 30.00 E	1	SW
46	Nov 30 2022	55º 29.99 N	4º 10.07 E	1	SW
47	Nov 30 2022	55º 58.80 N	3º 28.85 E	2	SW; BW
48	Dec 01 2022	55º 58.76 N	4º 59.86 E	1	SW

49	Dec 01 2022	55º 59.99 N	6º 29.96 E	1	SW

Table 11.1.4: Carbonate samples collected per station, with date, location and depths collected.

Station	Date	Latitude	Longitude	Number of depths	Depths Sampled (m)
1	Nov 08 2022	54º 33.35' N	10º 45.1' E	3	3; 11; 22
2	Nov 08 2022	54º 7.17' N	11º 7.98' E	3	2; 11; 21
3	Nov 08 2022	55º 6.02' N	14º 0.02' E	3	3; 33; 43
4	Nov 09 2022	55º 34.2' N	16º 22.23' E	5	3; 25; 40; 51; 66
5	Nov 09 2022	56º 0.02' N	16º 49.83' E	3	3; 18; 34
6	Nov 09 2022	56º 59.99' N	17º 36.02' E	5	4; 26; 50; 70; 100
7	Nov 10 2022	57º 48.02' N	17º 54.02' E	5	4; 26; 50; 70; 100
8	Nov 10 2022	58º 32.53' N	18º 13.93' E	7	2; 40; 100; 251; 352; Ra-BW; Ra-mid
9	Nov 11 2022	56º 59.99' N	20º 10.9' E	6	5; 35; 61; 80; 119; 161
10	Nov 11 2022	57º 0' N	19º 30.07' E	7	4; 50; 80; 120; 170; Ra-BW; Ra-mid
11	Nov 13 2022	54º 31.82' N	10º 2.32' E	6	4; 7; 13; 17; 23; Ra-BW
12	Nov 14 2022	54º 33.01' N	10º 46.05' E	3	4; 19; Ra-BW
13	Nov 14 2022	54º 36.5' N	10º 46.08' E	3	4; 17; Ra-BW
14	Nov 14 2022	54º 39.19' N	10º 46' E	3	3; 19; Ra-BW
15	Nov 15 2022	54º 35.7' N	11º3.27' E	3	3; 7; 28
17	Nov 15 2022	54º 32.52' N	11º 18.2' E	3	3; 25; Ra-BW
19	Nov 15 2022	54º 27.31' N	11º 31.2' E	3	3; 22; Ra-BW
20	Nov 18 2022	55º 30' N	10º 57.47' E	2	3; 13
21				2	4; 14
22	Nov 19 2022	57º31.79' N	11º 10.69' E	4	4; 16; 36; Ra-BW
23	Nov 19 2022	57º 53.98' N	10º 41.61' E	6	4; 31; 71; 100; 137; BW
24	Nov 19 2022	58º 0' N	8º 29.76' E	10	4; 50; 61; 100; 200; 300; 450; 513; Ra-BW; Ra-mid
25	Nov 20 2022	55º 59.99' N	6º 29.96' E	2	4; 40
26	Nov 20 2022	54º 48.49' N	6º 44.63' E	2	4; 37
27	Nov 21 2022	54º 23.99' N	5º 15' E	2	3; 38
28	Nov 21 2022	54º 24' N	6º 15' E	2	4; 31
29	Nov 21 2022	53º 59.94' N	6º 13.77' E	2	4; 29
30	Nov 21 2022	54º 24' N	7º 30.03' E	2	5; 21
31	Nov 21 2022	54º 3.7' N	8º 0.94' E	2	3; 24
32	Nov 24 2022	55º 0.02' N	7º 30.02' E	2	5; 23
33	Nov 25 2022	57º 29.96' N	7º 29.81' E	9	196; 149; 116; 76; 60; 49; 41; 10; Ra-BW
34	Nov 25 2022	58º 0' N	5º 30.04' E	9	8; 51; 75; 101; 125; 152; 217; Ra-BW; Ra-mid
35	Nov 26 2022	58º 25.78' N	9º 28.78' E	11	5; 59; 100; 150; 200; 250; 350; 400; 502; Ra-BW; Ra-mid
36	Nov 28 2022	57º 0.01' N	5º 14.94' E	2	5; 51

37	Nov 28 2022	56º 59.97' N	3º 44.92' E	2	5; 61
38	Nov 28 2022	57º 0.05' N	2º 14.6' E	3	4; 50; 76
39	Nov 29 2022	56º 59.98' N	1º 0' E	2	5; 87
40	Nov 29 2022	56º 59.99' N	0º 30' W	2	3; 75
41	Nov 29 2022	56º 00.02 N	0º 29.98 E	7	4; 20; 30; 50; 70; 80; Ra-BW
42	Nov 29 2022	56º 00.00 N	2º 00.00 E	7	3; 30; 50; 58; 70; 82; Ra-BW
43	Nov 30 2022	55º 00.01 N	1º 58.79 E	3	5; 10; 19
44	Nov 30 2022	54º 24.00 N	2º 44.97 E	3	4; 15; 25
45	Nov 30 2022	55º 00.02 N	3º 30.00 E	3	4; 21; 35
46	Nov 30 2022	55º 29.99 N	4º 10.07 E	3	4; 15; 29
47	Nov 30 2022	55º 58.80 N	3º 28.85 E	5	4; 20; 35; 54; 68
48	Dec 01 2022	55º 58.76 N	4º 59.86 E	3	4; 20; 40
49	Dec 01 2022	55º 59.99 N	6º 29.96 E	3	4; 20; 38.5

Table 11.1.5: Stations sampled for trace metal analysis.

Station	**Date**	**Latitude**	**Longitude**	**CTD rosette Sampling / Number of Depths**	**Pore Water Sampling / Number of Depths**	**MUC Sampling / Core Length [cm]**
1	Nov 08 2022	54º 33.35' N	10º 45.12' E	3		
2	Nov 08 2022	54º 7.17' N	11º 7.98' E	3	22	36
3	Nov 08 2022	55º 6.02' N	14º 0.02' E	3		
4	Nov 09 2022	55º 34.20' N	16º 22.23' E	5	22	29
5	Nov 09 2022	56º 0.02' N	16º 49.83' E	3		
6	Nov 09 2022	56º 59.99' N	17º 36.02' E	5		
7	Nov 10 2022	57º 48.02' N	17º 54.02' E	5		
8	Nov 10 2022	58º 32.53' N	18º 13.93' E	5	17	29
9	Nov 11 2022	56º 59.99' N	20º 10.90' E	5		
10	Nov 11 2022	57º 0.01' N	19º 30.07' E	5		
11	Nov 13 2022	54º 31.82' N	10º 2.32' E	6		
12	Nov 14 2022	54º 33.01' N	10º 46.05' E	2	12	38
13	Nov 14 2022	54º 36.49' N	10º 46.08' E	2		
14	Nov 14 2022	54º 39.19' N	10º 46.00' E	2		
15	Nov 15 2022	54º 35.70' N	11º 3.27' E	3		
17	Nov 15 2022	54º 32.52' N	11º 18.20' E	2		
19	Nov 15 2022	54º 27.31' N	11º 31.18' E	2	14	24
20	Nov 18 2022	55º 29.99' N	10º 57.47' E	2		
21	Nov 18 2022	56º 23.47' N	11º 26.38' E	2		
22	Nov 19 2022	57º 31.79' N	11º 10.69' E	3		
23	Nov 19 2022	57º 53.98' N	10º 41.61' E	5		
24	Nov 19 2022	58º 0.07' N	8º 29.76' E	8		
25	Nov 20 2022	55º 59.99' N	6º 29.96' E	2		
26	Nov 20 2022	54º 48.49' N	6º 44.63' E	2	17	22
27	Nov 21 2022	54º 23.99' N	5º 14.94' E	2		
28	Nov 21 2022	54º 24.01' N	6º 14.95' E	2		
29	Nov 21 2022	53º 59.94' N	6º 13.77' E	2	14	17

30	Nov 21 2022	54º 24.00' N	7º 30.03' E	2		
31	Nov 21 2022	54º 3.73' N	8º 0.94' E	2	18	27
32	Nov 24 2022	55º 0.02' N	7º 30.02' E	2		16
33	Nov 25 2022	57º 29.96' N	7º 29.81' E	8		
34	Nov 25 2022	57º 59.97' N	5º 30.04' E	7		
35	Nov 26 2022	58º 25.78' N	9º 28.78' E	9	21	41
36	Nov 28 2022	57º 0.01' N	5º 14.94' E	2		
37	Nov 28 2022	56º 59.97' N	3º 44.92' E	2		
38	Nov 28 2022	57º 0.05' N	2º 14.59' E	3		
39	Nov 29 2022	56º 59.98' N	0º 59.99' E	2		
40	Nov 29 2022	56º 59.99' N	0º 30.00' W	2		
41	Nov 29 2022	56º 00.02' N	0º 29.98' E	6		
42	Nov 29 2022	56º 00.00' N	2º 00.00' E	6		
43	Nov 30 2022	55º 00.01' N	1º 58.79' E	3		
44	Nov 30 2022	54º 24.00' N	2º 44.97' E	3		
45	Nov 30 2022	55º 00.02' N	3º 30.00' E	3		
46	Nov 30 2022	55º 29.99' N	4º 10.07' E	3		
47	Nov 30 2022	55º 58.80' N	3º 28.85' E	5		
48	Dec 01 2022	55º 58.76' N	4º 59.86' E	3		
49	Dec 01 2022	55º 59.98' N	6º 29.95' E	3		

Table 11.1.6: Stations and used gear for the process study that was done during bad weather conditions.

Site	Date	Time	Latitude	Longitude	Depth	Gear
FB	14.11.2022	08:00:00	54° 33.00' N	10º 46.02' E	25	CTD, MUC, Camera
FB-T3	14.11.2022	10:00:00	54° 36.48' N	10º 46.02' E	20	CTD
FB-T4	14.11.2022	13:00:00	54° 39.18' N	10º 46.02' E	22	CTD, Camera
FB-T1	15.11.2022	08:00:00	54° 21.21' N	10º 46.02' E	15	CTD, Camera
FB-T2	15.11.2022	10:00:00	54° 25.62' N	10º 46.02' E	13	CTD
LB-T4	15.11.2022	16:00:00	54° 16.74' N	11º 23.82' E	23	CTD, Camera
LB-T1	16.11.2022	08:00:00	54° 1.08' N	10º 58.86' E	23	CTD, Camera
LB-T2	16.11.2022	10:00:00	54° 4.44' N	11º 4.26' E	23	CTD
LB	16.11.2022	14:00:00	54° 8.214' N	11º 8.154' E	25	CTD, MUC, Camera
LB-T3	17.11.2022	08:00:00	54° 12.12' N	11º 16.86' E	21	CTD
MB-T1	17.11.2022	10:00:00	54° 9.372' N	11º 35.748' E	16	CTD, Camera
MB	17.11.2022	15:00:00	54° 13.404' N	11º 35.748' E	25	CTD, MUC, Camera
MB-T2	18.11.2022	08:00:00	54° 17.58' N	11º 35.748' E	25	CTD
MB-T3	18.11.2022	10:00:00	54° 22.74' N	11º 35.748' E	25	CTD
MB-T4	18.11.2022	15:00:00	54° 28.50' N	11º 35.748' E	24	CTD, Camera
ST-T1	19.11.2022	08:00:00	54° 13.50' N	12º 3.60' E	14	CTD, Camera
ST-T2	19.11.2022	10:00:00	54° 13.62' N	11º 59.76' E	17	CTD

ST	19.11.2022	14:00:00	54° 15.358' N	11º 56.358' E	25	CTD, MUC, Camera
ST-T3	20.11.2022	08:00:00	54° 20.82' N	11º 51.60' E	21	CTD
ST-T4	20.11.2022	10:00:00	54° 28.02' N	11º 45.84' E	20	CTD, Camera

11.2 Selected Pictures of Shipboard Operations and Sample Processing

Figure 11.2.1: MUC core to be sampled for porewater (Ann-Cathrin Rohrweber / Hereon)

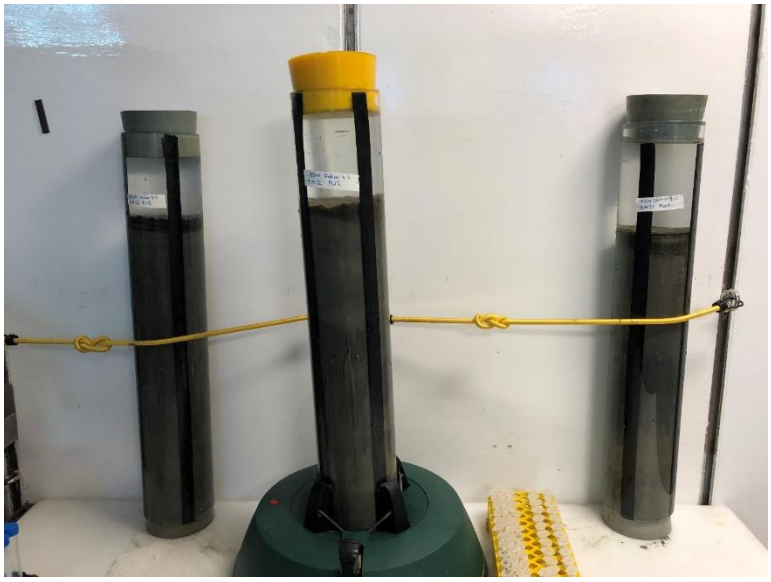

Figure 11.2.2: MUC cores ready to be sampled for porewater (Ann-Cathrin Rohrweber / Hereon)

Figure 11.2.3: Taking porewater from the cores (Ann-Cathrin Rohrweber / Hereon)

Figure 11.2.4: CTD for water sampling (Chantal Mears / Hereon)

Figure 11.2.5: Taking water from the CTD (Ann-Cathrin Rohrweber / Hereon)

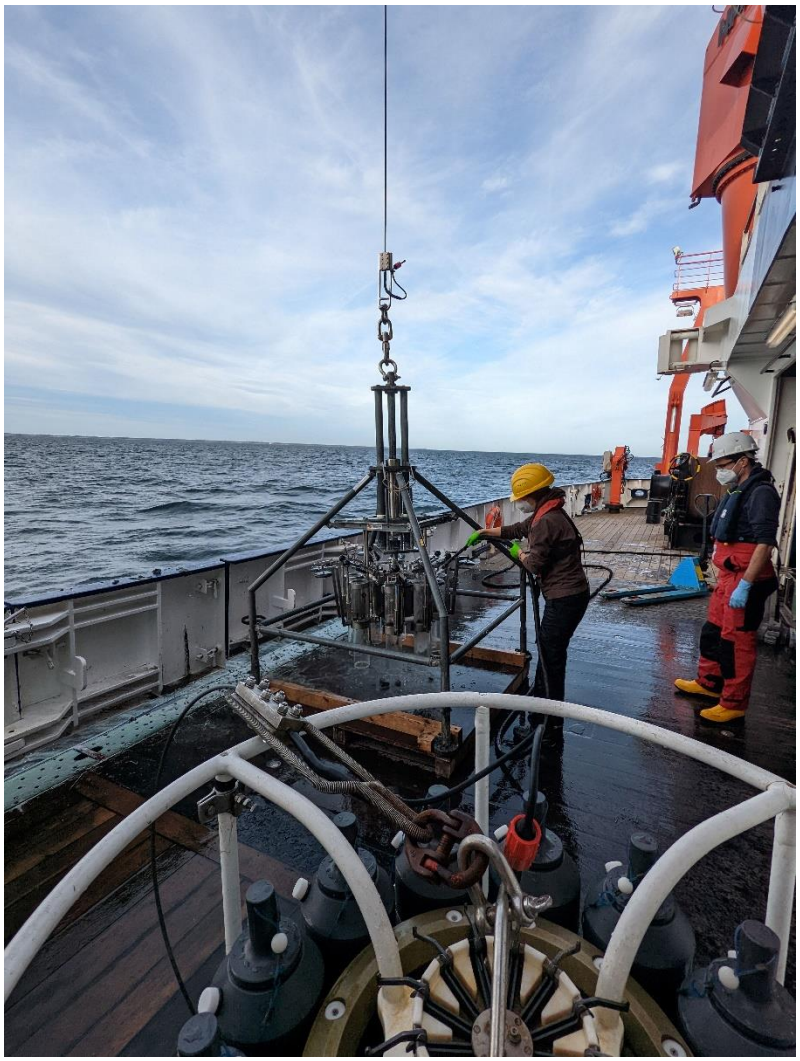

Figure 11.2.6: Cleaning the multicorer (MUC) in preparation for the next deployment (Dariya Baiko / University of Oldenburg)