HEINCKE-Berichte

Marine-Geological Practical Training at Sea
Master Course LV 63-345

Cruise No. HE661

May 15 – May 21, 2025

Bremerhaven (Germany) – Bremerhaven (Germany)

UHH MARGEO

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2025

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1 Cruise Summary

(Malgorzata Szuba)

1.1 Summary in English

The research cruise HE661 was conducted on the research vessel HEINCKE from May 15th to 21st, 2025. The cruise began and ended at Bremerhaven Handelshafen, Germany, while research was undertaken in the work area within the Norwegian Exclusive Economic Zone (EEZ). Nine students of the master's programme Geosciences at the University of Hamburg were participating in the research investigation as part of the course "Marin-Geologisches Praktikum auf See" (63-345). The objective of the course was to introduce the students to the standard methodology of water, suspension, and sediment sampling as well as to the geophysical survey method of hydroacoustics. The students learned how to apply and operate sampling equipment independently and gained insights into the procedures of bathymetric surveys. Working on the vessel gave the students a better understanding of the biogeochemistry, sedimentology and ecology of the North Sea, as well as its importance in the oil and gas exploration and sustainable energy sectors. Due to unstable weather conditions during the first few days of the cruise, in total 23 stations were operated and sampled within five days. Because of excessive wave height and technical issues, the Bottom Water Sampler and the Multicorer could not be used at all stations. The complete dataset and all samples were transferred to the research groups at the University of Hamburg for in-depth analysis and further investigation.

1.2 Zusammenfassung

Die Forschungsfahrt HE661 wurde auf dem Forschungsschiff HEINCKE vom 15. bis zum 21. Mai 2025 durchgeführt. Die Expedition startete und endete im Handelshafen in Bremerhaven, Deutschland, während die Forschungsarbeiten im Arbeitsgebiet in der Ausschließlichen Wirtschaftszone (AWZ) von Norwegen ausgeführt worden sind. Neun Studierende des Master-Studiengangs Geowissenschaften der Universität Hamburg nahmen an der Forschungsfahrt im Rahmen der Lehrveranstaltung „Marin-Geologisches Praktikum auf See" (63-345) teil. Das Ziel dieser Fahrt war die Einführung der Studierenden und das Erlernen der gängigen Beprobungsmethoden von Wasser, Suspension und Sedimenten sowie der geophysikalischen Untersuchungsverfahren der Hydroakustik. Die Studierenden lernten die Beprobungsgeräte eigenständig zu betätigen und wurden in die Prozesse der bathymetrischen Vermessungen eingearbeitet. Mit der praktischen Arbeit auf dem Schiff konnten die Studierenden ihr Verständnis der Biogeochemie, Sedimentologie und Ökologie der Nordsee vertiefen und ihr Wissen über die ökonomische Relevanz der Nordsee in Hinblick auf Erdöl- und Erdgasexploration sowie erneuerbare Energien erweitern. Aufgrund der schlechten Wetterlage zu Beginn der Fahrt konnten insgesamt 23 Stationen innerhalb von fünf Tagen angefahren und beprobt werden. Durch zu hohen Wellengang und aufgrund technischer Störungen konnten der Bodenwasserschöpfer und Multicorer nicht an jeder Station eingesetzt werden. Der vollständige Datensatz und sämtliches Probenmaterial wurden im Anschluss an die Fahrt an die Arbeitsgruppen der Universität Hamburg zur detaillierten Analyse und weiteren Untersuchung weitergegeben.

2 Participants

2.1 Principal Investigators

Name	Institution
Lahajnar, Niko, Dr.	UHH, IfGeol
Lüdmann, Thomas, Dr.	UHH, IfGeol

2.2 Scientific Party

Name	Discipline	Institution
Lahajnar, Niko, Dr.	Chief Scientist, Biogeochemistry	UHH, IfGeol
Lüdmann, Thomas, Dr.	Hydroacoustics, Sequence Stratigraphy	UHH, IfGeol
Schulz, Gesa, Dr.	Research assistant, Biogeochemistry	UHH, IfGeol
Groms, Nele	Student (M.Sc.)	UHH, IfGeol
Hierlemann, Tim	Student (M.Sc.)	UHH, IfGeol
Kast, Jakob	Student (M.Sc.)	UHH, IfGeol
Lewe, Julia	Student (M.Sc.)	UHH, IfGeol
Papke, Giulia	Student (M.Sc.)	UHH, IfGeol
Pierau, Emily	Student (M.Sc.)	UHH, IfGeol
Röschmann, Liza	Student (M.Sc.)	UHH, IfGeol
Suchau, Caroline	Student (M.Sc.)	UHH, IfGeol
Szuba, Malgorzata	Student (M.Sc.)	UHH, IfGeol

2.3 Participating Institutions

UHH, IfGeol Institute for Geology, University of Hamburg

3 Research Program

3.1 Description of the Work Area

(Malgorzata Szuba)

The area studied during the research cruise HE661 is located in the northern North Sea south of Norway, within the Norwegian Exclusive Economic Sector (EEZ). It extends between 56°00.00'N – 58°00.00'N and 002°00.00'E – 004°00.00'E, where all sampled stations are located (Fig. 3.1). Within the work area, the sedimentary seafloor cover predominantly dates from Pleistocene to Holocene and consists mostly of fine- to middle-grained sands.

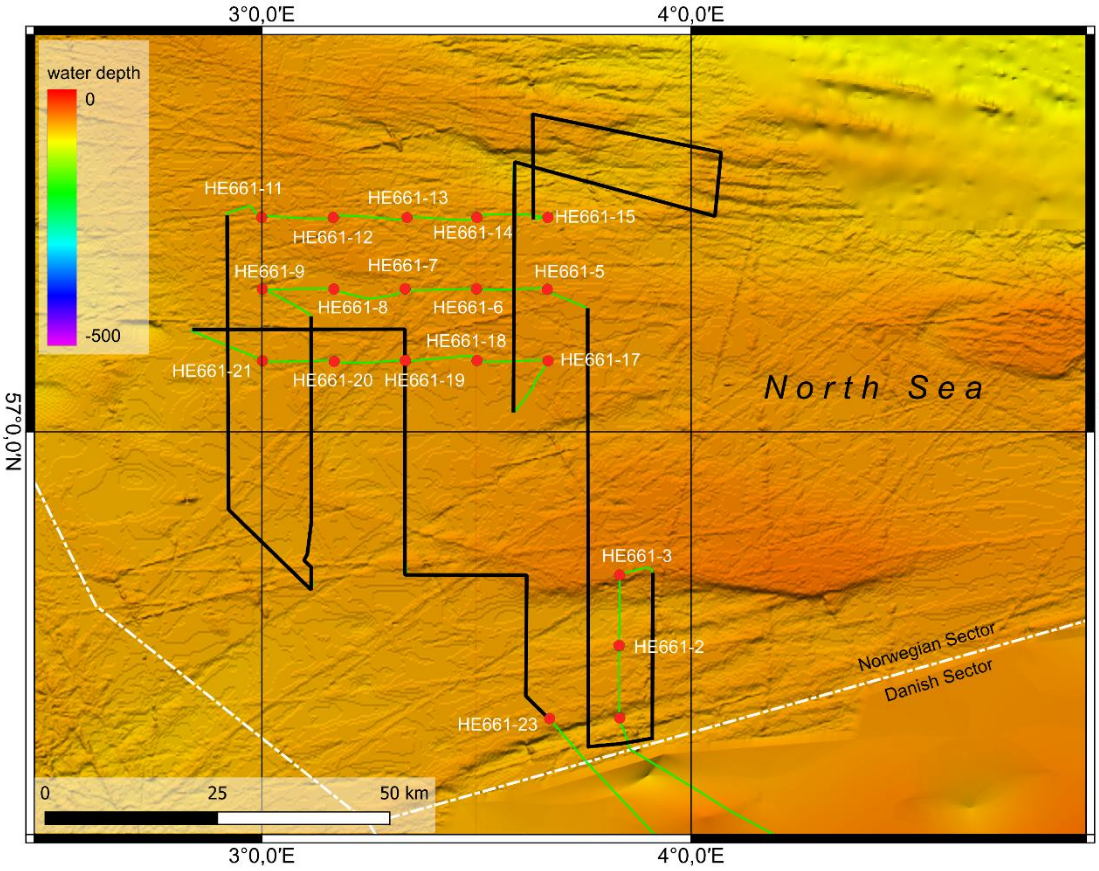


Fig. 3.1 Overview map of the work area with the trajectory of the HE661 cruise. Black lines represent hydroacoustic profile tracks and the red dots depict the location of the sampling stations with their respective number, both embedded in a bathymetric base map.

The North Sea is an epicontinental shelf sea of 570,000 km^2 lying on the NW termination of the European plate (Schwarzer et al., 2019). The sea is engulfed by the British Islands in the west, Scandinavia in the northeast and the European mainland in the south and east. The bordering countries are Great Britain (England, Scotland), Norway, Sweden, Denmark, Germany, The Netherlands, Belgium, and France. The North Sea exhibits an average depth of 94 m, with greatest depth >700 m in the Norwegian Trench (Skagerrak) and shallowest depths <20 m at the Dogger Bank (Schwarzer et al., 2019). The English Channel is connecting the North Sea with the Atlantic Ocean, while the Skagerrak Strait serves as a passage between the North Sea and the Baltic Sea. To the north, the North Sea opens into the Northern Atlantic Ocean and the Norwegian Sea. The

North Sea is divided into a southern, central, and northern part, which depict at times a distinct geologic-tectonic evolution throughout geologic history.

The crystalline basement, at 8 to 10 km depths, originates from the Pre-Cambrian terranes Laurentia, Baltica, and Avalonia that underwent deformation during the Caledonian Orogeny from the Upper Cambrian until the Lower Devonian (490 – 390 Ma). Following the completion of mountain uplift, the Caledonides experienced gravitational collapse and extensive erosion from the Middle Devonian on, leading to the accumulation of thick sequences of the Old Red Sandstone Continent facies (Patruno et al., 2022). The Variscan Orogeny set in in the late Devonian and lasted until the Lower Permian (380 – 290 Ma) leading to mountain building across the European plate. During the Carboniferous, the southern North Sea region was located at the equator and was flooded under a tropical climate resulting in the deposition of carbonates. The northern North Sea region however was exposed to a deltaic swamp environment in which prominent coal deposits were accumulated (Schwarzer et al., 2019). The Permian marked the termination of the Variscan mountain building and the beginning of its gravitational collapse and widespread erosion. After the orogeny, the crust underwent subsidence with concurrent intense volcanism and extension that lasted until the Triassic (Schwarzer et al., 2019). In this period, the southern and northern Permian basins were formed within the North Sea region and the Rotliegend sediments were deposited in these newly developed depocentres (Patruno et al., 2022). Towards the end of the Upper Permian, the North Sea region underwent transgression and thick salt and evaporite deposits of the Zechstein group were accumulated (Patruno et al., 2022). In the Upper Triassic salt tectonics initiated as the Permian salt deposits were mobilized. The main rifting phase in the North Sea region was initiated in the Middle Jurassic due to the ascent of a major mantle plume beneath the central North Sea and the development of a thermal dome (Patruno et al., 2022). The intense period of extension culminated in the formation of the prominent Central Graben and Viking Graben, part of the Jurassic horst-graben morphology (Patruno et al., 2022). With the collapse of the thermal dome and a subsequent transgression thick clay sediments were accumulated in the grabens and subsequently sealed with overlying Cretaceous sediments, constituting one of the most significant hydrocarbon deposits of the North Sea (Schwarzer et al., 2019). In the early Cenozoic the North Sea underwent thermal subsidence due to lithospheric cooling and experienced far-field compression of the Alpine orogeny (Clausen et al., 2012; Patruno et al., 2022). During this epoch, seafloor spreading initiated in the North Atlantic Ocean putting the crust beneath the North Sea under a complex stress regime (Patruno et al., 2022). In the Eocene, the North Sea took its present basin shape. Throughout the Paleogene and Miocene, mostly carbonate and siliciclastic deposits were accumulated during multiple regressive-transgressive cycles (Clausen et al., 2012; Schwarzer et al., 2019). Since the beginning of the Paleogene, the climate began to cool down gradually until it reached its minimum in the Pleistocene. This epoch is marked by several glacial-interglacial cycles and glacial, marine, and fluviatile sedimentation (Patruno et al., 2022). Ice shields developed on both the southern and northern hemisphere. During the last glacial maximum, the Weichsel Ice Age. the North Sea was entirely dry and the Doggerland connected Scandinavia, the British Isles, and the European mainland (Schwarzer et al., 2019). With the Holocene, the last glacial period ended and at 8 ka the Doggerland was flooded again with the present coastlines and the Wadden Sea developing (Schwarzer et al., 2019). However, the North Sea has been experiencing isostatic rebound since the removal of glacial overburden following ice sheet melting. The uplift continues in the northern North Sea to this day.

3.2 Aims of the Cruise

(Liza Röschmann)

The educational goal of this research cruise was to instruct Master students of geosciences in marine sampling methods. Theoretical basic knowledge could thus be converted into practice. The specialized focus of this research trip was marine geology and biogeochemistry and their different methods. The samples collected during the cruise included plankton, water and soil samples.

The Master students' team was split into four groups of two to three people. Each day, one group was responsible for a specific measuring instrument and used it several times which allowed the students to practice the handling of the device and to manage a station independently. This includes communication with the bridge and the winch, securing, describing, preparing and storing samples for further analyses in the laboratory and finally accurate documentation. In cases of bad weather or unfavorable environmental conditions (e.g., high waves or too coarse-grained sediment), the students had to decide whether a measuring device could be used or not. Together, the nine students gained a lot of experience, mastered challenges and strengthened their team spirit.

During the week on board, the students got to know everyday life on a research vessel. After the measurements were completed, they also learned the most important vocabulary and knots. To deepen their knowledge of the North Sea, presentations were given on various topics (e.g., hydrology, geology and sediments of the North Sea) followed by discussions. At night, the bathymetry of the North Sea was recorded using hydroacoustic methods. Therefore, each group took over a night shift to ensure proper data recording.

3.3 Agenda of the Cruise

(Liza Röschmann and Niko Lahajnar)

The students were divided into four groups of two or three people, each responsible for one of the main devices (CTD, BWS or MUC) or for taking charge of the station for the day. Station management included using the SECCHI disk, the APSTEIN net and the van Veen Grab (vVG), as well as communicating with the bridge. Station work was well defined to avoid contamination of the samples. Each station began with the SECCHI disk, which was lowered into the water by hand to determine the visibility. Next, the APSTEIN net, which had a mesh size of 25 µm, was lowered directly from the deck into the water, reaching a depth of around 5 metres, in order to collect phytoplankton samples. These samples were then examined under a microscope and identified.

The first device operated with the winch was the CTD, which involved communication with the winch operator and the bridge. Physical measurements were taken on the way down to the seabed, after which the depths at which water samples were to be taken were decided based on the measured profiles during the downcast. Usually, the first four bottles were closed just above the seabed (at least 2 m, but typically 6–10 m above the seabed due to the large wave height), and then four more bottles were closed at the fluorescence maximum in the water column, followed by four more bottles at the surface. The water samples were then filtered, with between 2 and 10 litres per filter depending on when the filter was sufficiently loaded for further analysis. The loaded filters were stored in a refrigerator for further analysis, resulting in a total of 57 filter samples.

The next device lowered into the water was the bottom water sampler (BWS). It was slowly lowered to a depth of between 52 and 70 metres, where it remained stationary for at least three minutes. The trigger was then activated, closing the three NISKIN bottles installed horizontally at heights of 28.5, 58.0 and 110.5 cm above the seabed. The BWS was not used at the first two stations, but successfully collected samples at 16 subsequent stations, despite a few second attempts. The water from the NISKIN bottles was extracted and filtered in the same way as the CTD. Typically, 5 litres were filtered, though often less water (between 4.1 and 5.0 litres) could be extracted from the lowest bottle (28.5 cm above the seabed). The filtration process produced 48 filters, which were refrigerated and stored in the laboratory for further analysis.

The vVG was then used to gain an initial impression of the sediment on the seabed and to measure its permeability. It was lowered to the seabed where it closed under its own weight, bringing sediment on board. To measure the permeability, an unmixed sediment sample was taken from the closed vVG using a cylinder. This was then used to carry out the permeability measurements. The sediment was released from the vVG onto a wooden board, where the students began describing the sediment in terms of grain size, color, and bycatch. The multicorer (MUC) was used to describe the stratification and color of the sediment. The MUC consists of eight PLEXIGLAS tubes that are lowered into the seabed. These tubes penetrate the sediment under their own weight, enabling them to take undisturbed sediment samples. When pulled up, the tubes were closed and, ideally, eight cores were brought on deck. Once back on deck, three cores were taken and described based on their general characteristics. However, this sometimes made it very difficult to extract good cores.

However, if the sediment became too coarse-grained, the tubes could be damaged. This is why, beforehand, a decision was made with regard to the vVG sediment as to whether the MUC could be used. If three cores could be recovered, one was photographed and described using the MUNSELL colour chart, for example. Of the three cores, the first two centimetres of one core, including some bottom surface water, were removed for micropalaeontological studies. The first five centimetres of a second core were cut into one-centimetre sections for biogeochemical studies. The third core was only used as a backup in case the first two cores were damaged. With the completion of the MUC, the station was also completed.

Every evening, scientific presentations were held on various topics related to the North Sea, and the ship's terminology and knots were practised. The daily schedule for the following day was discussed, and it was decided which group would operate which device, who would be on the night shift, and who would deliver the presentations. One of the groups started the night shift, during which they had to monitor seismic and hydroacoustic measurements. These profiles were usually conducted between 7 pm and 7 am ship time.

During the final evening seminar, the students were required to demonstrate their understanding of the maritime terminology they had learned. All the important knots used on maritime vessels were tested, and their practical application was demonstrated.

The 'Principles of Responsible Research', established by the DFG Senate Commission for Oceanography and the German Marine Research Consortium (KDM), and the 'Code of Conduct for Responsible Marine Research in the Deep and High Seas of the OSPAR Maritime Area', published by the Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), were applied and implemented for cruise HE661. The DFG “Mitigation measures for the operation of seismic and hydroacoustic sources with pulsed sound emissions” were applied. All works were conducted within the EEZ of Norway upon prior permission being granted by the Norwegian authorities.

4 Narrative of the Cruise

(Giulia Papke)

On **Wednesday, May 14th, 2025**, at 11:30 UTC, the scientific team – comprising nine students, the chief scientist, the hydroacoustic scientist, and the supporting scientist – arrived at the Handelshafen in Bremerhaven, Germany, to embark on RV HEINCKE.

After a brief introductory meeting on deck, the group moved into their assigned cabins at 12:00 UTC and proceeded to unpack and prepare the wet laboratory. This lab was equipped with all necessary tools and instruments required for the planned sampling and analysis procedures, including filtration units, microscopes, and permeability measurement equipment.

At 15:15 UTC, the scientific party had their first meal in the officers' mess. The remainder of the afternoon allowed for a brief shore excursion in Bremerhaven before the vessel departed on schedule the next morning.

Thursday, May 15th, 2025

The first breakfast aboard was served at 05:15 UTC. Shortly thereafter, RV HEINCKE departed the pier at 05:30 UTC and passed the lock in Bremerhaven at around 06:00 UTC, heading towards the first station. A mandatory safety briefing was held by the second officer, including a presentation in the dry lab, a tour of the vessel, and a safety drill at the muster station, during which proper usage of life vests and immersion suits was demonstrated. Between 07:15 and 09:15 UTC, all instruments were assembled, and the chief scientist introduced the students to the structure and expectations of the cruise.

After lunch at 09:15 UTC, the ship reached the test station at 11:15 UTC, where all scientific instruments were tested. Due to adverse weather, the captain opted for a sheltered area near the island of Helgoland. All equipment was successfully tested by 13:00 UTC, and the vessel continued its transit to the primary research area in the Norwegian sector of the North Sea.

Following the afternoon coffee break at 13:00 UTC, the scientific party met to organize procedures for the upcoming stations. As sea conditions worsened – with wave heights of 3 to 3.5 meters – several participants began experiencing seasickness. A scientific seminar at 17:00 UTC featured a presentation by Jakob Kast on *Marine Sampling Procedures: Acoustic Methods*, followed by an instruction from the chief scientist on nautical terminology and knot-tying, a component of the final assessment.

Friday, May 16th, 2025

Rough weather overnight led the captain and chief scientist to postpone scientific operations until 12:00 UTC. At this point, waves had reached 3.5 to 4 meters, and several students were affected by motion sickness. Nevertheless, seven of the nine students participated in operations at the first station (HE661-01) within the designated Norwegian research area.

A standard sampling sequence was implemented at five stations throughout the cruise: (1) SECCHI disk and APSTEIN-net, (2) CTD, (3) BWS, (4) vVG, and (5) MUC. Depending on operational feasibility, additional instruments were occasionally mounted to the CTD at the final station of each day. The "clean ship" policy was strictly followed during all sampling procedures, prohibiting any overboard discharge.

On this day, only three stations (HE661-01 to -03) were completed, with the BWS and MUC deployed solely at the final station. All students participated in this concluding operation. The daily evening seminar included further nautical training and a presentation by Tim Hierlemann on *Marine Sampling Methods: Sediment and Water*. Later that evening Thomas Lüdmann instructed T. Hierlemann and J. Kast on MULTIBEAM (MBES) and sub-bottom profiler (SES, INNOMAR) systems for their upcoming night shift, which ran daily from 16:00 to 05:00 UTC. Each student contributed to one half of a night shift (22:00–05:00 UTC) during the cruise.

Saturday, May 17th, 2025

For the first time, all five planned stations (HE661-05 to -09) were completed. Station work began at 05:55 UTC and concluded with the fifth station starting at 14:35 UTC. Transit between stations took approximately one hour. All instruments were successfully deployed, except for the MUC at the fifth station.

The evening seminar at 17:30 UTC included two presentations: Emily Pierau on *North Sea: Phytoplankton and Zooplankton* and Liza Röschmann on *Offshore Wind Parks in the North Sea*. The night shift was covered by Nele Grolms, Malgorzata Szuba, and Julia Lewe. Towards the morning, deteriorating weather caused software malfunctions in the SES system. Station HE661-10 concluded at 05:06 UTC.

Sunday, May 18th, 2025

Stations HE661-11 to -15 were completed, starting at 06:00 UTC. At station HE661-13, the MUC had to be redeployed due to a snagged safety net and subsequently suffered core loss due to wave impact. Other instruments were operated without issues. During the evening seminar, the final set of knots and nautical terms were taught, followed by two presentations: Caroline Suchau on *North Sea: Eutrophication and Environmental Challenges* and Giulia Papke on *Oil and Gas in the North Sea: Deposits and Extraction*. These students also conducted the night shift, which was uneventful due to favorable weather conditions.

Monday, May 19th, 2025

This marked the final day of full station work. Five stations (HE661-17 to -21) were completed during the day starting at 05:58 UTC and ending at 14:35 UTC. The sixth station (HE661-22) started at 15:56 UTC and was completed by 03:40 UTC. The weather remained stable, and sampling with BWS and MUC was mainly successful, yielding high-quality sediment cores. The evening seminar included a general organizational review and student presentations by Julia Lewe on *Sediment Dynamics in the North Sea* and Malgorzata Szuba on *Geological Evolution and Tectonics of the North Sea*.

Tuesday, May 20th, 2025

On the last full day at sea, the first station of the day and also last station of the expedition (HE661-23) began at 04:00 UTC and was entirely executed by the students without direct supervision. After its successful completion at 05:00 UTC and the following breakfast, the scientific party dismantled and cleaned the laboratory equipment as well as the lab itself. The rest of the morning was allocated to packing, finalizing protocols, and reviewing knots and terminology. At 12:00 UTC Nele Grolms held a presentation on *North Sea: Hydrography*. At 13:30 UTC, the chief engineer led a tour of the engine room. In the evening seminar, starting at 17:00 UTC the students were tested on nautical terminology and knots. The day concluded with a retrospective presentation by the chief scientist, who shared insights and photographs from previous research expeditions. The students spent the remainder of the evening completing their entry in the RV HEINCKE guestbook.

Wednesday, May 21st, 2025

RV HEINCKE passed the Bremerhaven lock at 06:00 UTC and docked at 06:30 UTC. The cabins were cleared and cleaned by the scientific party and inspected by the chief mate. At 08:30 UTC, four members of the scientific party departed Bremerhaven. The rest remained until all gear was transferred to customs and, later, to the storage facility of the University of Hamburg. By 14:00 UTC, the scientific team arrived back at the university.

Daily mealtimes were as follows: breakfast at 05:15 UTC, lunch at 09:15 UTC, coffee and cake at 13:00 UTC, and dinner at 15:15 UTC.

5 Preliminary Results

5.1 Water Sampling

5.1.1 SECCHI Disk

(Emily Pierau)

The SECCHI disk is a metal disk which can be 20 cm – 50 cm in diameter. The disk used on the HE661 expedition is 30 cm in diameter. The top of the disk is divided into four equally sized colored sectors, which are alternately black and white. In the center of the disk is a metal loop to which the rope is attached. The rope has colored markings at every meter so that the depth can be determined. A weight is attached to the bottom of the disk to facilitate immersion and to stabilize the disk vertically when it is lowered into the water.

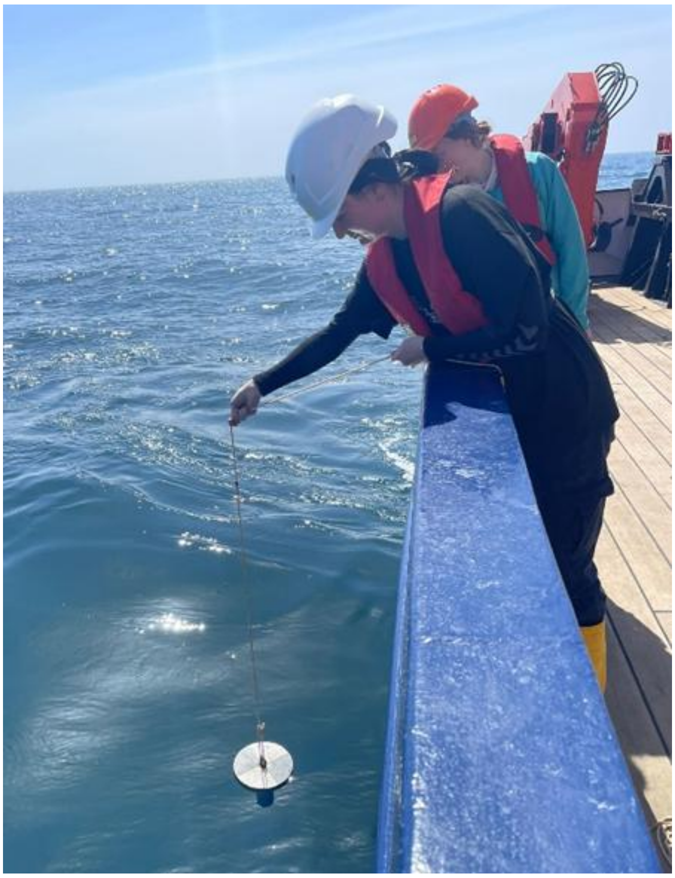


Fig. 5.1 Lowering the SECCHI disk into the water during the HE661 expedition.

The SECCHI disk was used to manually determine the visibility depth of the upper water layer. This depth of visibility can then be used to draw conclusions about the spread of the euphotic zone. The water transparency of the euphotic zone is influenced by sunlight, as this in turn influences photosynthetic processes, such as the growth of phytoplankton (Marra et al., 2014). When using the SECCHI disk, it was ensured that it was lowered slowly into the water (Fig. 5.1). The marks on the rope were counted and the disk was lowered until it was no longer visible. If the disk is no longer visible between two marks, the distance to the previous mark is estimated. Various factors, such as rough sea conditions, light reflection from the water or drifting of the SECCHI disk due to currents, could make the determination difficult. If such cases occurred, they were noted in the protocol.

At all 23 stations of the HE661 expedition, the visibility could be determined using the SECCHI disk (Fig. 5.2). The highest visible depth measured was at station 3 with 14 m and at station 2 with 12 m. The water depth at these two stations were 53 m and 63 m. The shallowest depths measured were at station 8 with 4.5 m and at station 9 with 4.5 m. The water depths at these stations were 61 m and 63 m.

The ratio between the visible depth and total water depth (Fig. 5.3) indicates no direct correlation. However, it is evident that the highest visible depths can be found in the south-east and north-east regions. The stations at which the shallowest visible water depths were measured are located in the north-western region (e.g., Station 8 and 9). Variations in current velocity at the different stations may have affected the measurement results by causing the SECCHI disk to drift. In addition, the inconsistent solar radiation at the various stations could also have influenced the results.

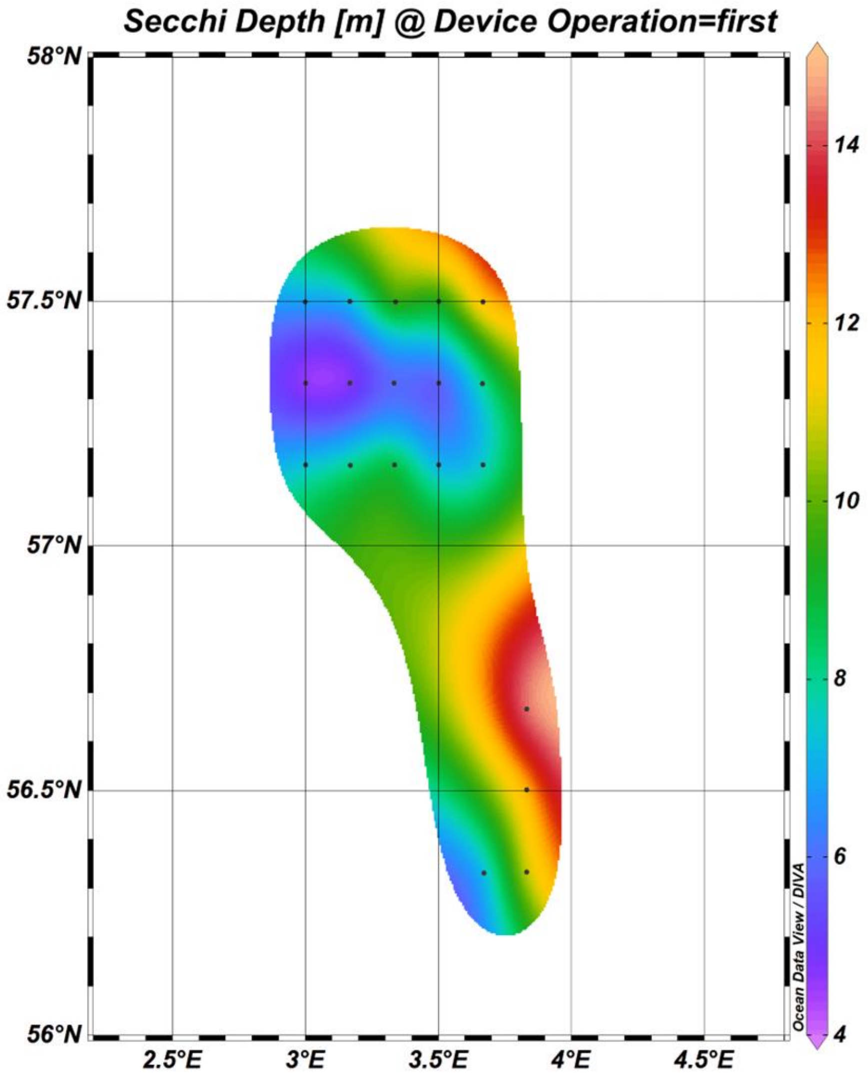


Fig. 5.2 Depth of visibility (SECCHI Depth) in the study area of HE661.

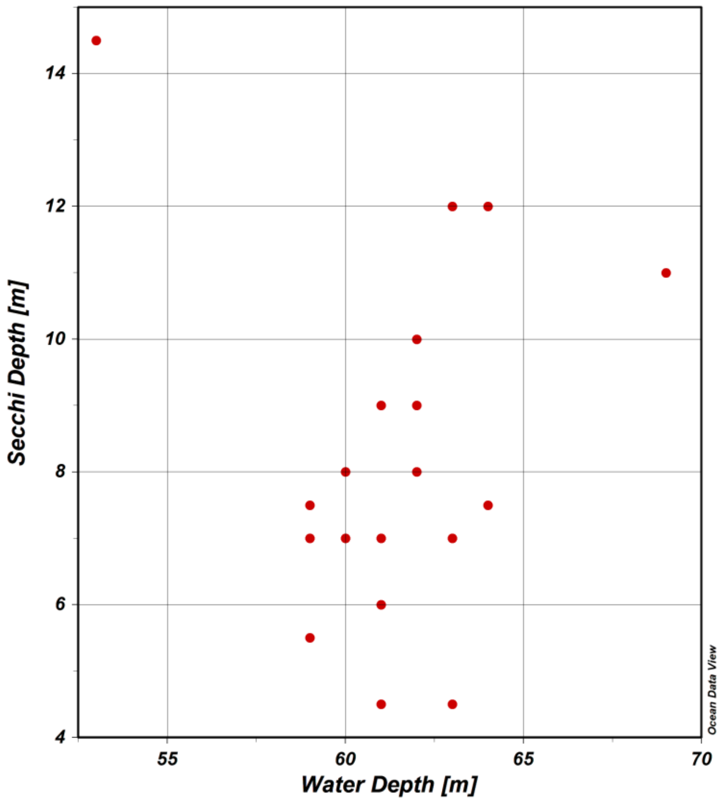


Fig. 5.3 Visible depth (SECCHI Depth) and water depth in comparison at the stations of HE661.

5.1.2 Plankton Sampling (APSTEIN-net)

(Emily Pierau)

During the HE661 expedition, an APSTEIN-net was used to extract plankton from surface water. At all stations, the APSTEIN-net was always used after the SECCHI disk. The phytoplankton net is funnel-shaped and at the end of the net is a cylinder with a valve in which the plankton accumulates. The net is 50 cm long and has an inlet diameter of 30 cm and a mesh size of 25 µm. The net is attached with a three-point suspension with a weight on a rope with one-meter markings. The weight allows the plankton net to sink more easily into the water, nevertheless at some stations the net drifted under the ship due to rough sea conditions. If this was the case, the sample was taken at the stern instead of the starboard side to prevent the net from getting caught in the ship's propeller. This was noted in the protocol.

At all stations, the net was lowered to a water depth of 5 m to achieve better comparability of the samples. The sample obtained was then poured into a beaker by opening the valve. To reduce losses, the net was rinsed with seawater. In the wet laboratory, a part of the sample was transferred to a Petri disk and was then examined under the ZEISS STEMI 508 stereo microscope (Fig. 5.4). With the help of literature on plankton (Kraberg et al. 2010, Larink and Westheide 2011), various specimens were identified.

As it was not always possible to identify the specimens precisely, some taxa were only identified to genus or family level. Many different types of plankton typical of the North Sea were observed in various abundances at the stations.

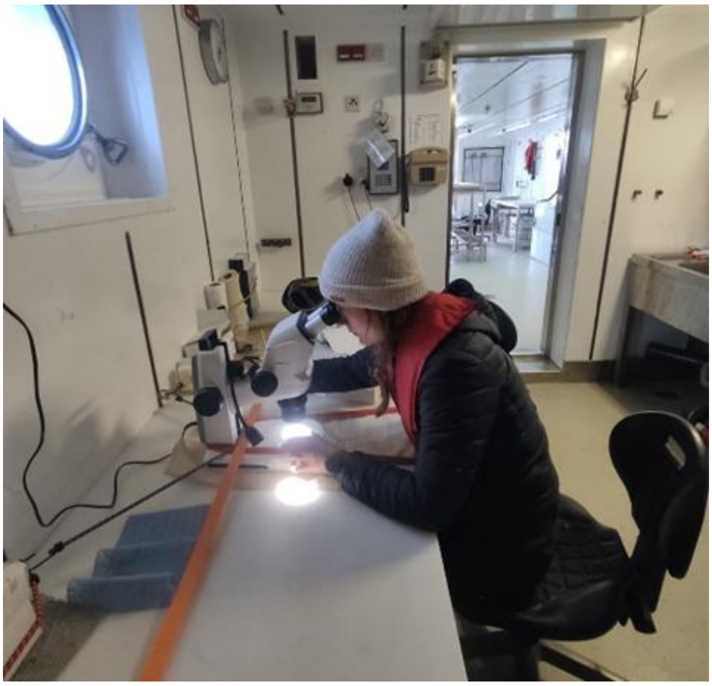


Fig. 5.4 STEMI 508 stereo microscope used during the HE661 expedition.

Diatoms of the genera *Chaetoceros sp.* (especially *C. offinis* and *C. decipiens*) were particularly dominant at almost all stations, and the genera *Rhizosolenia sp.* (at station 15), *Coscinodiscus sp*. (at stations 11, 19, 20) and *Leptocylindrus sp.* (at station 19) were also found. The dinoflagellate genus *Ceratium sp.* was present at 10 of 23 stations. However, the number of diatoms predominated in the samples. This dominance of diatoms over dinoflagellates could be due to increased silicate concentrations in the water, as diatoms use silicate to build their shells. In addition, crustaceans (*Copepoda sp*.) were found (Fig. 5.5), which were particularly dominant at station 5 and at station 8 Ctenophora (*Mnemiopsis leidyi*) was recorded. Specimens belonging to the meroplankton, such as the red-pigmented *Spatangus sp.* (Echinodermata) in the larval stage were also very dominant and were present at 10 stations (Fig. 5.5).

Overall, during the HE661 expedition, diatoms and dinoflagellates were found at almost all stations, so it can be assumed that a plankton bloom has spread. Probably due to high nutrient inputs and the warm temperatures in May. At the stations (e.g., 1, 2 and 3) where neither diatoms nor dinoflagellates were found in the samples, the plankton bloom appears to be less developed.

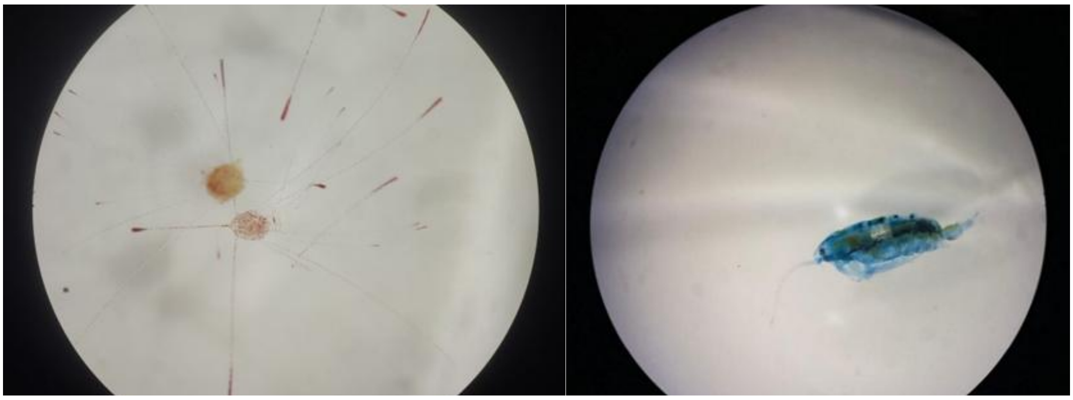


Fig. 5.5 *Spatangus sp.* (Echinodermata) in the larval stage (left) and *Copepoda sp*. (Crustacea) under the microscope (right).

5.1.3 Conductivity-Temperature-Depth (CTD) Rosette Sampler

(Nele Grolms and Gesa Schulz)

A CTD system was used at all 19 daytime stations to collect hydrographic data and water samples from different water depths. This instrument combines two key components: CTD probes at the base, which continuously measure conductivity, temperature, and depth. In addition to the core measurements, the CTD is equipped with extra sensors to simultaneously collect data on salinity, dissolved oxygen concentration, fluorescence (chlorophyll-a) and transmission (turbidity). Above of the sensors, a rosette of 12 NISKIN bottles are installed, each with a capacity of 10 l. The entire setup is protected by a cylindrical metal frame to prevent damage during deployment and retrieval (see Fig. 5.6).

Before each deployment, the CTD system had to be manually prepared. All NISKIN bottles were primed by opening the end caps and securing them with the tensioned lanyard system. The air valves were hand-tightened shut, petcocks were closed, and protective caps were removed from all sensors. A visual inspection of the frame and sensor array was performed to ensure the system was in working order. On deck, flushing devices were still attached to protect the sensors until the moment of deployment. Simultaneously, the SEASAVE V7 software was launched on the acquisition computer. Both the station ID and the corresponding DSHIP-ID were entered into the real-time data interface, but data logging was not yet started. Just before the CTD entered the water, the deck unit was powered on, as the device carries high voltage it must not be touched when powered.

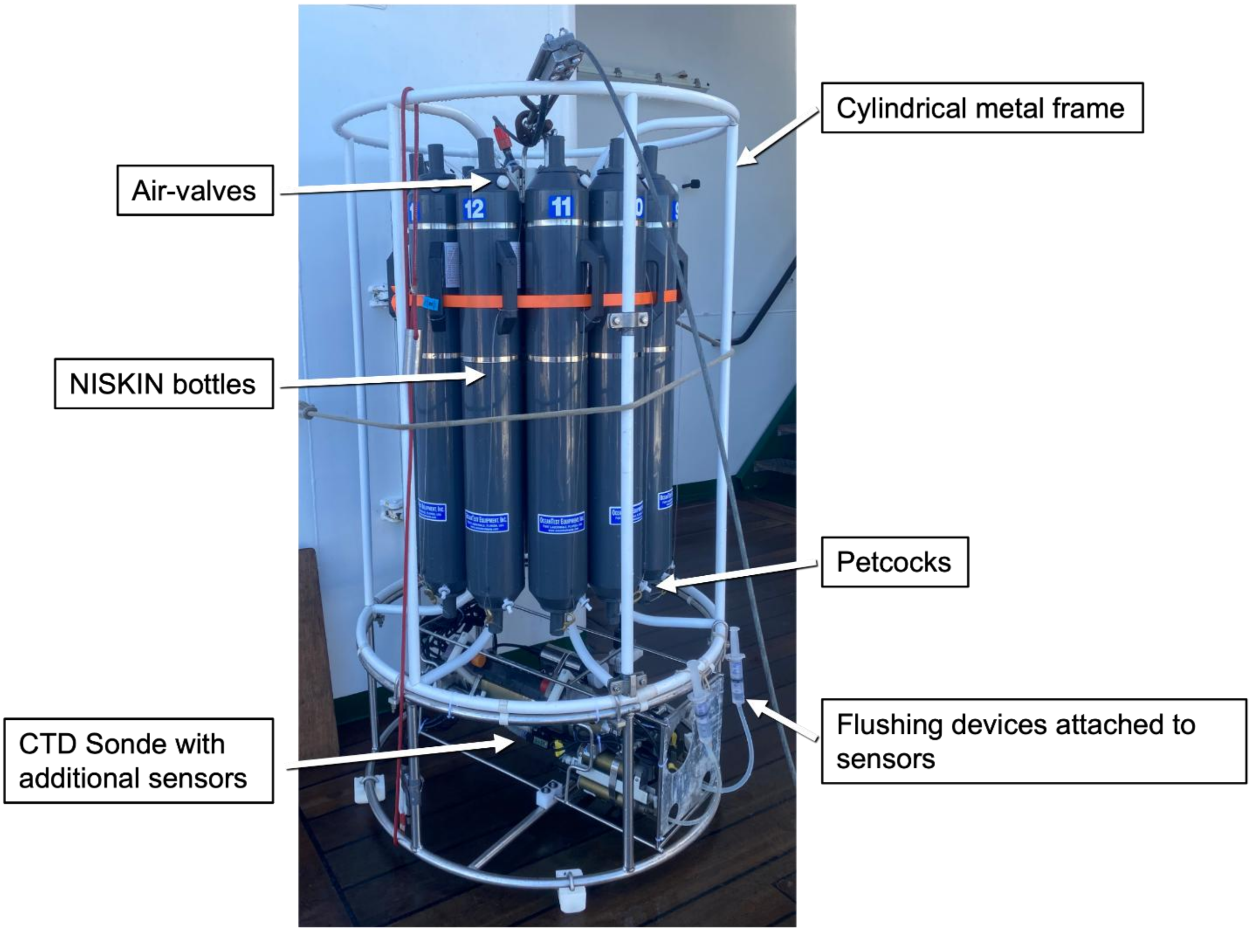


Fig. 5.6 CTD with description of main components.

After the CTD reached a depth of 5 meters, the system was stopped to allow the pumps to fully pressurize. Once stable, data logging was initiated and the CTD was briefly brought back toward the surface to clear the initial startup data. Then, the CTD was lowered at a steady rate to approximately 5 m above seafloor, based on real-time readings from the echo sounder and altimeter, averaging at a depth of 56.3 m. At this point, the first set of four NISKIN bottles were closed. On the way up the next set of four bottles was triggered at depths corresponding to the chlorophyll maximum, as identified in the real-time fluorescence profile recorded during the downcast, averaging at a depth of 31.9 m. The final NISKIN bottle set of four was fired right below the surface, at an average depth of 2.05 m. At each daytime station, samples of three different water depths were taken. After the full vertical profile was completed and all samples collected, the acquisition was stopped, and the deck unit was switched off before the instrument reached the surface and was handled by the crew. Once back on deck, the CTD frame was secured with lashing straps, and all sensors were flushed with MILLI-Q water using the attached flushing devices. Additional flushing was performed to clean the hooks and valves, ensuring no salt or particles remained. The flushing devices, consisting of two syringes and silicon tubing, were then left attached to protect the sensors until the next deployment. Water samples were collected directly after retrieval of the CTD. Bottom water (bottles 1, 2, 3 and 4) was transferred via silicone tubing into a large canister; chlorophyll maximum water (bottles 5, 6, 7, 8) and surface water (bottles 9, 10, 11, 12) were collected into separate canisters using the same method. To ensure uncontaminated samples, all tubes and canisters were rinsed twice with the respective sample water before filling. All protocols were completed in duplicate. Finally, data files from the cast were backed up to the onboard server, and preliminary data processing was initiated using the MANAGE CTD tool and visualized with OCEAN DATA VIEW (ODV).

Fig. 5.7 Filtration set-up with the main components.

Immediately after sampling, water from all sampled water depths was filtered using a multi-unit filtration system (see Fig. 5.7). Each of the five available units consisted of a funnel, a filter holder, and a clamp to secure the glass fiber filters (WHATMAN GF/F, 0.7 µm pore size, 47 mm diameter). These filters had been pre-combusted at 450 °C and individually weighed (ranging between 120.77 and 138.62 mg) before use. For each station, two filters were used in parallel. Water samples were poured into the funnels using 2-liter PE bottles for each sample depth. A membrane pump created a vacuum to draw the water through the filters and into a shared tank with a capacity of 26 liters. The tank needed regular emptying to avoid overflow. For precautions, a WOULFF bottle, used as a water trap, was connected to the water tank and pump to avoid water being sucked into the pump. On average, 7.95 liters were filtered from the bottom water samples, 5.68 liters from surface water, and 5.71 liters from the estimated chlorophyll maximum depth. The actual filtration volume depended on the water flow through the filters. After filtration, the filters, now holding suspended particles, were carefully handled with tweezers, placed back into labeled storage boxes, and kept refrigerated until the end of the expedition and further analysis.

To visualize the first results, a north to south transect, including the stations 1, 2, 3, 5, 15, and 17, was created (see Fig. 5.8). The transect can be described based on four measured parameters, including temperature, salinity, dissolved oxygen concentration, and the Chlorophyll fluorescence (fluorometer) (see Fig. 5.9)

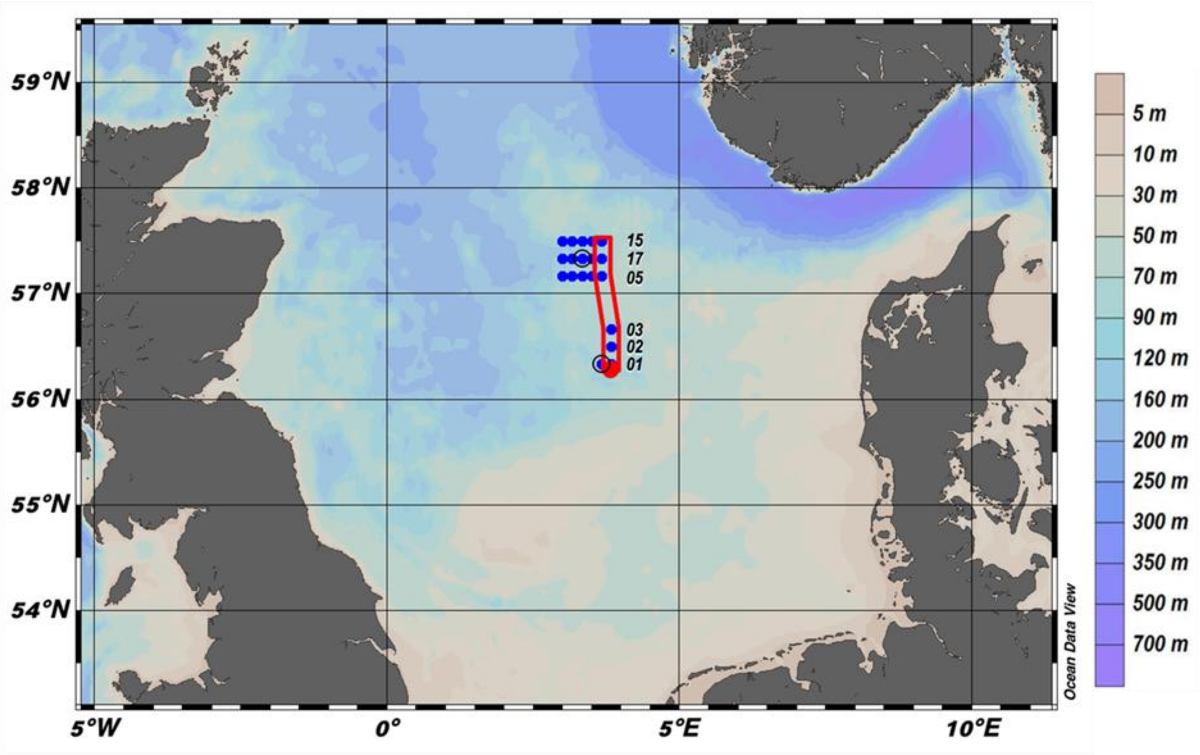


Fig. 5.8 Map of the study area showing the stations of cruise HE661 with their respective station numbers and water depths. The selected section (N–S transect) is highlighted in red.

The recorded temperature profiles show a range between approximately 7.5 °C and 11 °C across all stations. A pronounced thermocline, defined as a zone of rapid temperature decrease with depth, is observed at most stations at around 30 m depth (van Leeuween et al., 2015). This stratification becomes progressively deeper and more diffuse toward station 5, with surface temperatures ranging from approximately 10 to 11 °C and bottom water temperatures near 8 °C.

Such thermal stratification is characteristic of the North Sea during this time of year and reflects seasonal warming by more solar heating of the surface layer (van Leeuween et al., 2015). Stations 1, 2, 3, and 17 exhibit highly comparable temperature profiles, with stations 1 and 2 displaying the coldest bottom water temperatures. At station 5, the thermocline appears deeper, and the water column is overall slightly warmer. Station 15 deviates most noticeably from the others, exhibiting the highest temperatures throughout the profile and a more diffuse and less defined thermocline structure.

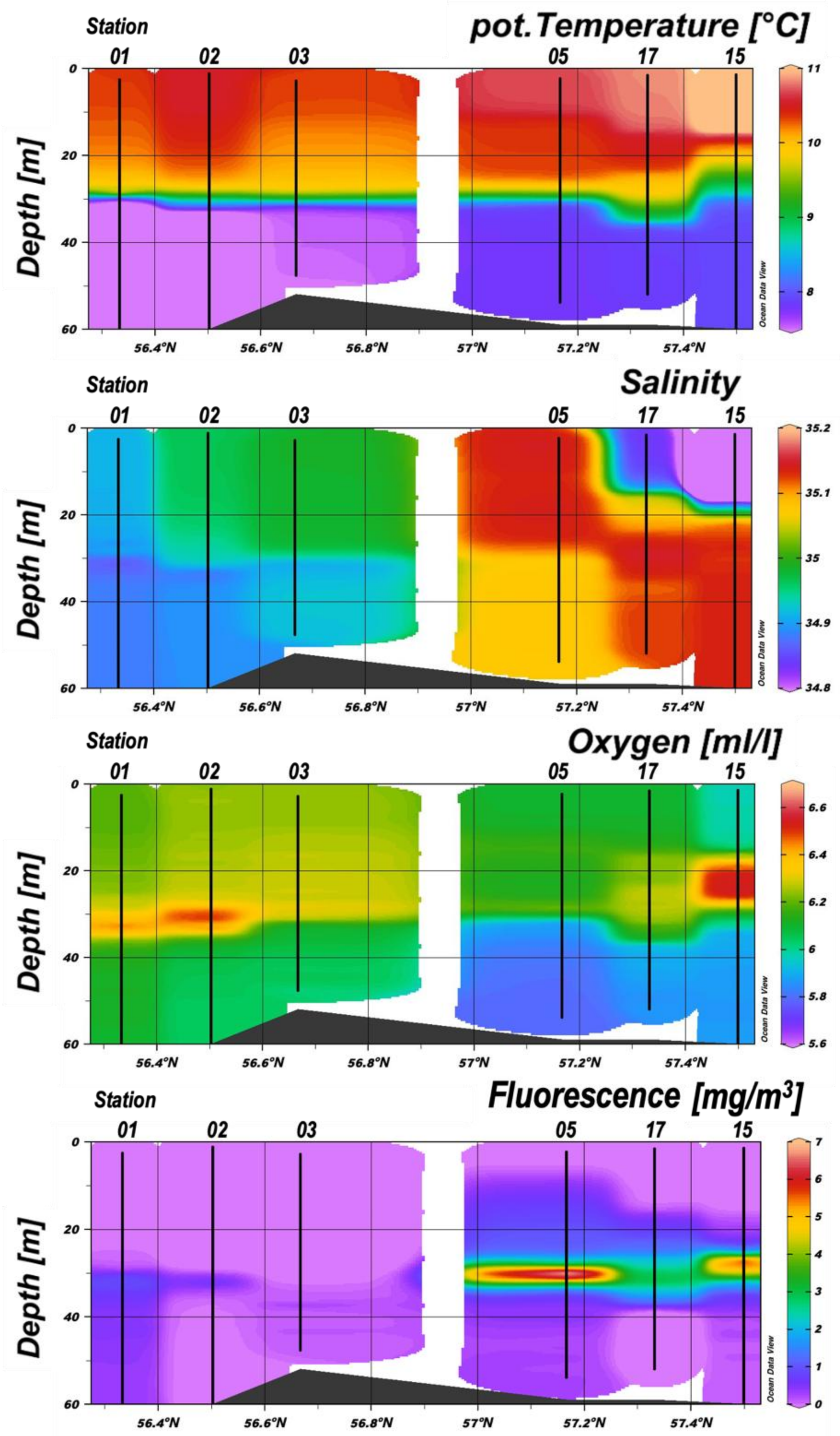


Fig. 5.9 Profiles from the N-S transect, showing the distribution of temperature (°C), salinity, dissolved oxygen concentration (ml/l) and fluorescence (chlorophyll in mg/m^3). Vertical black lines mark the locations of the stations along the transect, each labelled with its corresponding station number.

The salinity data reveal a north to south gradient, with overall values ranging from approximately 34.8 to 35.2. As salinity is reported according to the Practical Salinity Scale (PSS), all values are dimensionless. Stations 1 to 3 exhibit relatively low and vertically homogeneous salinities (~34.8 – 35). In contrast, salinity increases markedly toward the northern stations, this might be due to the stronger influence of higher saline Atlantic waters. A halocline is pronounced at stations 5 and 15, where surface salinities are slightly lower (~ 34.8) and bottom salinities reach up to ~ 35.2. The halocline is most pronounced around 20m depth. These observations are consistent with typical North Sea conditions during the stratified summer and spring season (Becker et al., 2005).

The oxygen concentration along the transect varies between approximately 5.6 and 6.6 ml/l. In the southern part of the section (stations 1 to 3), oxygen levels are relatively homogeneous, with values ranging from 6.0 to 6.4 ml/l. A local maximum is observed at around 30 m depth at stations 1 and 2, likely associated with enhanced oxygen input in the mid-water column through mixing or biological production. In contrast, the northern part of the transect (stations 06 to 09) exhibits overall lower oxygen values, ranging from 5.8 to 6.1 ml/l. With a local maximum at 20 – 30 m depth most visible at station 15 and a regional minimum visible indicated by station 17 and 15. It is observable that surface waters here contain overall higher oxygen concentrations. Generally, a horizontal trend is evident, showing decreasing bottom oxygen concentrations from south to north as well as a vertical trend where a distinct separation between oxygen-rich surface waters and oxygen-depleted bottom layers can be seen.

This stratification is consistent with seasonal dynamics in the North Sea. Elevated oxygen concentrations in the upper water column are attributed to atmospheric exchange and photosynthetic activity. In contrast, reduced concentrations in deeper layers result from microbial respiration and the remineralization of sinking organic material. This is further amplified by the presence of a thermocline and halocline, as identified in the temperature and salinity profiles, which inhibit vertical mixing and reduce oxygen replenishment at depth (Rovelli et al., 2016).

The fluorometer data, used here as a proxy for chlorophyll concentration and thus phytoplankton biomass, exhibit notable differences across the transect. Overall, fluorescence values range from nearly 0 to over 6 mg/m³, with distinct spatial patterns between the northern and southern stations. At stations 1 to 3, chlorophyll concentrations remain low throughout the water column. Only a small local maximum subsurface signal is visible around 40 m at station 1 expanding to station 2, with fluorescence values generally not exceeding 2 mg/m³. This suggests relatively low phytoplankton biomass and limited primary production in this region.

In contrast, a pronounced subsurface chlorophyll maximum is observed at stations 5, 17 and 15, the northern part of the transect. The peak occurs consistently between 30 and 35 m depth, with the highest signal at station 5, where the overall highest values are visible. Such a chlorophyll distribution is characteristic of stratified shelf systems during late spring and early summer. The location of the maximum aligns with the depth range where light is still available for photosynthesis, and regenerated nutrients from deeper layers become accessible. The stratified water column, indicated by the thermocline and halocline, further supports phytoplankton accumulation by limiting vertical mixing (Rovelli et al., 2016).

This pattern is also consistent with the oxygen data. The chlorophyll maximum roughly overlaps with local oxygen maxima at the same depth, indicating active photosynthesis. In contrast, the low chlorophyll concentrations in the southern section align with a more uniform oxygen distribution, pointing to lower biological productivity.

To complement the transect overview, a more detailed comparison is made between two stations within the section, focusing on four parameters salinity, temperature, dissolved oxygen concentration, and chlorophyll fluorescence (see Fig. 5.10). Station 1 (HE661-01), located in the central North Sea, and station 15 (HE661-15), situated closer to the Norwegian coast and the Norwegian Trench. Station 1 shows a generally well-mixed water column with moderate stratification. Temperature increased from ~7 °C to ~10.2 °C, with a well-defined thermocline between around 30 m. Salinity remained mostly uniform (~35), indicating minimal variations. Oxygen values were high throughout, with a slight mid-depth maximum. Fluorescence shows a broad peak between 20 – 40 m, aligning with the oxygen maximum and indicating active photosynthesis. These conditions suggest enhanced vertical mixing. Station 15 exhibits a stratified water column, with a broader thermocline between 40 m and 25 m and a concurrent halocline. A temperature rise is observable from ~8 °C at depth to 11.5 °C at the surface, with salinity increasing from ~33.5 to nearly 35. Elevated oxygen concentrations (~6.5 ml/l) are observed in the upper water column, while values decrease to ~5.7 ml/l below a depth of approximately 40 m. Fluorescence features a clear peak (~17 to 35 m), indicating active primary production. These features point to seasonal stratification with limited vertical exchange. Both stations reflect an overall well-mixed water column with notable regional differences in the water column profile and biological activity. Station 15 displays increased stratification marked by a distinct thermocline and halocline. Elevated oxygen and chlorophyll concentrations in the upper layers suggest a local algal bloom. In contrast, station 1, situated more in the central North Sea, shows a more homogeneous profile with moderate, temperature-driven stratification and more uniform salinity, indicating stronger vertical mixing and lower subsurface productivity. The comparison highlights how regional differences in mixing and hydrographic conditions influence both the intensity of algal blooms and their impact on key parameters in the North Sea.

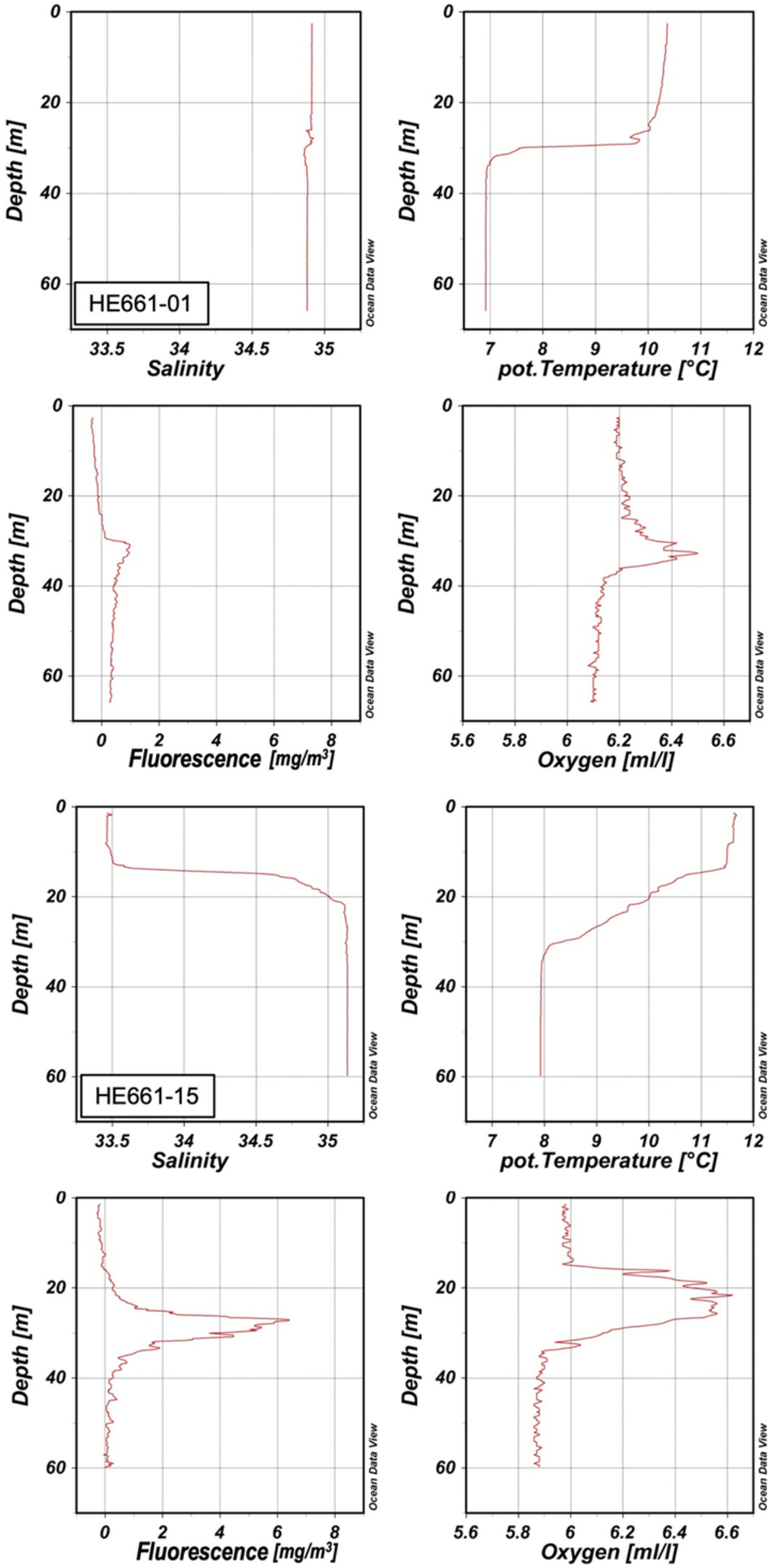


Fig. 5.10 CTD profiles from Station HE661-01 and 15 showing vertical distributions of salinity, temperature (°C), chlorophyll fluorescence (mg/m3), and dissolved oxygen concentration (ml/l).

5.1.4 Bottom Water Sampler (BWS)

(Caroline Suchau)

The BWS is a device designed to collect water samples just above the seafloor, particularly at depths where the CTD cannot be used. Its primary purpose is to investigate suspended particles and organisms in near-bottom waters.

The BWS used on the HE661 expedition was built by the company K.U.M in Kiel, Germany and is a multisampling system with up to 5 NISKIN bottles that can be mounted on a rotatable metal rod at the centre of the construction. A NISKIN bottle is a non-metallic, free-flushing sampler recommended for general purpose water sampling. The bottles can be installed at adjustable heights ranging from 10 cm to 155 cm above the seafloor. During this cruise, 3 bottles, each with a volume of 5 l, were attached at 28.5 cm, 58 cm and 110.5 cm above seafloor (Fig. 5.11).

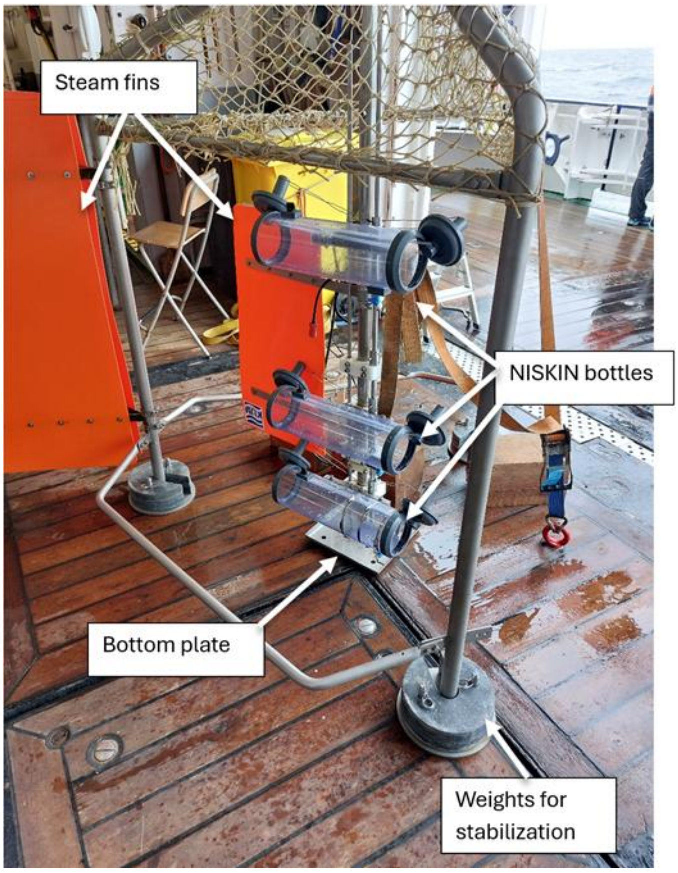


Fig. 5.11 Bottom Water Sampler (BWS) used during cruise HE661.

Due to the 120° rotatable central rod and the strategically placed Streaming fins attached on the rod and the frame, the system can align itself with the current. This ensures that the NISKIN bottles are optimally oriented in the flow direction, allowing for effective flushing and representative sampling of near-bottom water masses. Attached weights keep the BWS stable on the ground (Fig. 5.11). The system can be activated by a pre-programmed command initiated through an electric control unit (Fig. 5.13). When the BWS is placed on the ground, a plate attached to the bottom of the of the central rod is pushed upwards. This activates a timer which triggers the actual closing mechanism. As the BWS makes contact with the seafloor, sediment can be swirled up and potentially enter the bottles, affecting the sample quality. Therefore, a timer must be used to delay the closing process until the water has cleared. Depending on local conditions, the timer can be set between 60 seconds and 6 hours. Considering the relatively strong flow velocities in the North Sea, a delay of only three minutes was chosen for this cruise. If bottom contact of the BWS is interrupted through different circumstances, the three-minute timer resets and starts again from the beginning. To ensure that the bottles were closed properly, the BWS was left on the ground for about 6 minutes.

A wire loop is attached to the mechanism that keeps the bottles open and is connected to the control unit via a cable. A small section of this wire is uninsulated. When the timer expires, an electric current is applied to the wire, causing it to burn through at the uninsulated point and break. The duration of this process can vary depending on the salinity of the surrounding water. Once the wire burns through, it releases a metal rod to which the bottle lids where attached (Fig. 5.12). While the lids were held open, a rubber band connecting both lids was under tension. When the rod is released, the elastic contracts and pulls the lids tightly onto the bottle openings, sealing them. Before each station, the cable loop and the closing mechanism must be reset and prepared for operation.

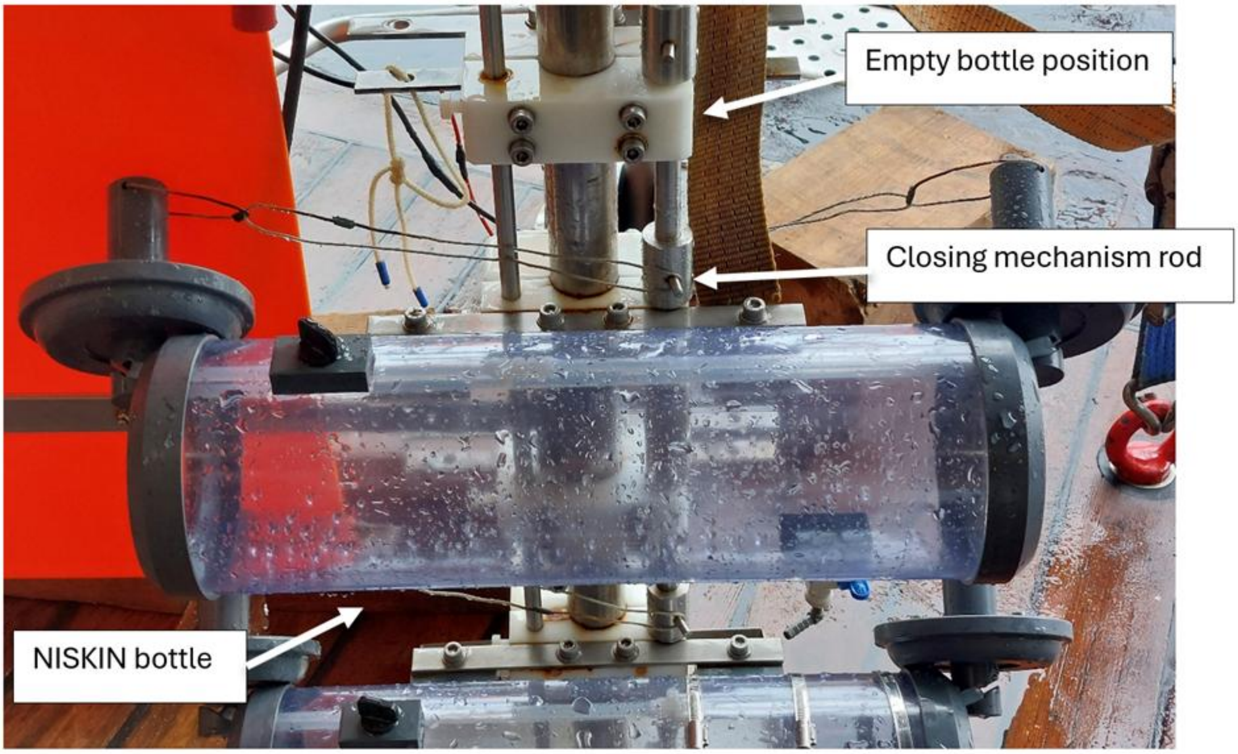


Fig. 5.12 Closeup of the BWS used during cruise HE661.

Due to challenging weather conditions during the first two stations, the BWS was only put into operation starting from station 3. Since then, it has functioned almost without any issues. Sampling was successful at a rate of 80 %. Only at station 12 no samples could be taken due to a defect in the electric control unit. A connection point was broken and could not be replaced immediately. At stations 5, 6, and 7, the closing mechanism did not trigger on the first try, requiring the sampling process to be repeated. In all three cases, the second attempt was successful, and all bottles were properly closed.

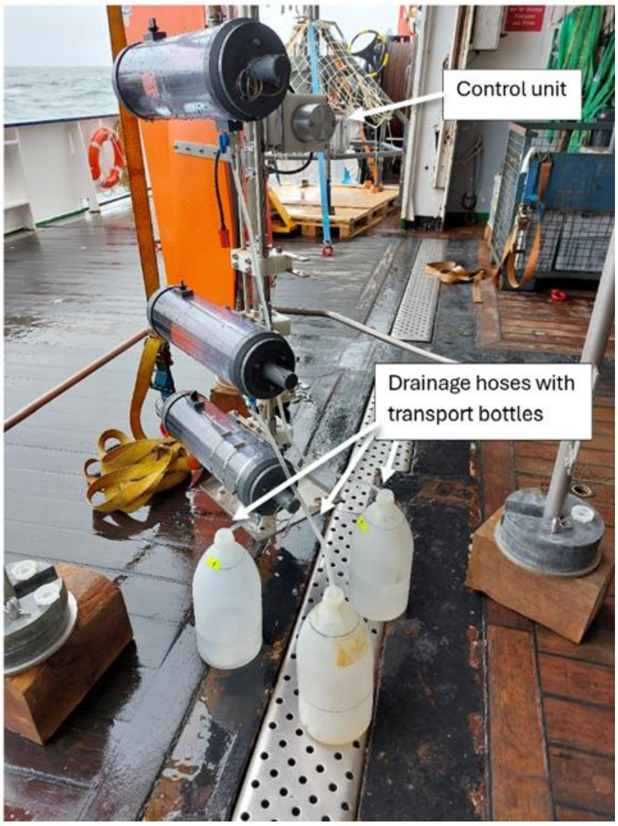


Fig. 5.13 Drainage of BWS NISKIN bottles.

After the BWS was brought back on deck, the water was drained from the NISKIN bottles (Fig. 5.13) and then filtered through previously weighted filters. The process is the same as described previously in the chapter about the samples taken by the CTD (see Chapter 5.1.3). The suspended particles were analysed after the cruise. In the laboratory of the Institute of Geology at the University of Hamburg, the samples were first dried. The dried filters were then weighed and based on the volume of filtered water and the weight of the empty filters. The following formula was used for the calculation of the suspended matter:

$$suspended\ matter\ \left[\frac{mg}{l}\right] = \frac{m_{dried\ sample} - m_{empty\ filter}}{filtered\ water\ [l]}$$

At a height of 28.5 cm above the ground, the concentration of suspended matter ranges from 1.15 mg/l at station 21 to 6.28 mg/l at station 20. At 58 cm above the ground, the lowest concentration is observed at station 21 with 0.82 mg/l, while the highest value of 2.73 mg/l is recorded at station 14. At a height of 110.5 cm above the ground, suspended matter concentrations vary between 0.82 mg/l at station 21 and 3.24 mg/l at station 13. The highest average concentration of suspended matter, measuring 2.12 mg/l, was observed in the lowest sampled layer at 28.5 cm above ground. In contrast, the concentrations in the two upper layers were lower and relatively similar, with an average of approximately 1.31 mg/l in each case (Fig. 5.14).

Higher amounts of suspended matter can be explained by a higher primary productivity. Current velocities also have an impact on the amount of suspended matter. Possible could be a local plankton bloom. However more data and analyses would be necessary to clarify the reason for this spike.

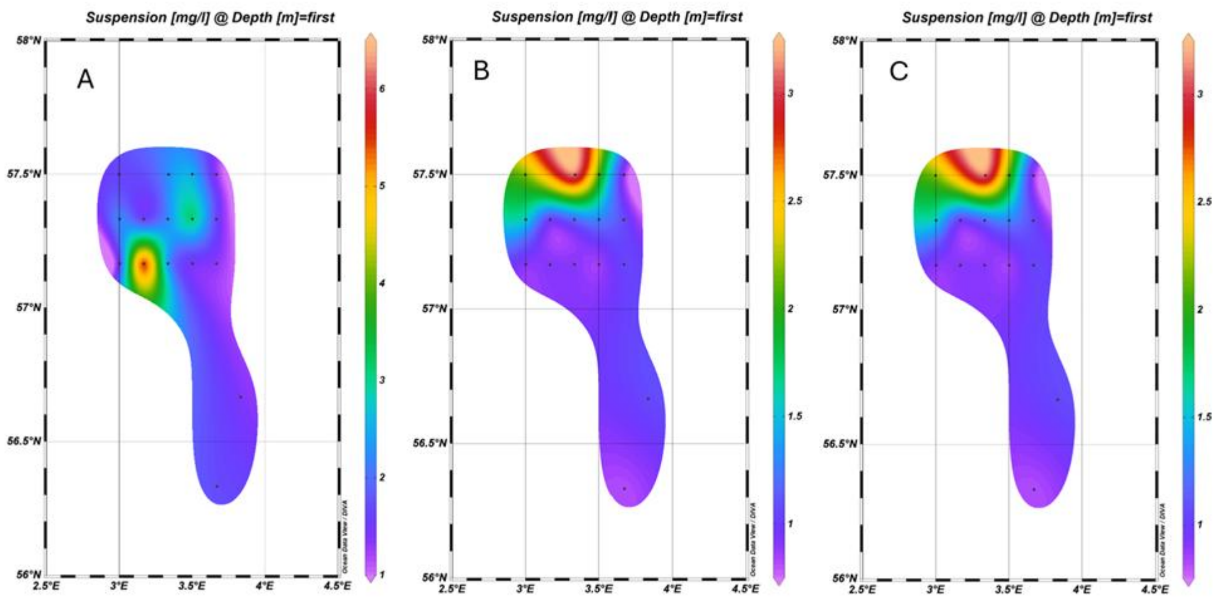


Fig. 5.14 Suspended matter in mg/l at 28.5 cm (A), 58 cm (B) and 110.5 cm (C) above the ground.

5.1.5 Thermosalinograph (TSG)

(Caroline Suchau)

The Thermosalinograph (TSG) is an instrument used to accurately determine and document sea surface conductivity and temperature up to a water depth of about four meters while the ship is in motion. Therefore, the seawater is continuously sucked into the ship's hull at a flow rate of about 30 l/min. Constantly measured data and derived variables (salinity and sound velocity in the water body) are output in real-time. The salinity is specified according to the Practical Salinity Scale (PSS) and is therefore dimensionless and the temperature is stated in degree Celsius (°C).

Mounted to the hull of RV HEINCKE is the SBE 21 SEABIRD Thermosalinograph combined with the externally mounted, remote Seabird temperature sensor SBE 38. To minimize potential bias in the water temperature data caused by engine heat, the SBE 38 sensor is installed at the seawater intake near the bow, allowing sea surface temperature to be measured with minimal thermal influence from the hull. Since the TSG is an online system, measurement data could be recorded continuously throughout the entire duration of the HE661 expedition. As data collection was not restricted to station work, a comprehensive overview of the general temperature and salinity conditions of the working area, which was entirely within the Norwegian EEZ, was achieved. Over the cruise, a total of 5298 measurements were taken by the TSG. The results of the TSG measurements are presented in Fig. 5.15.

With an average salinity of 34.61, the values closely resemble those of Atlantic water, which typically is above 35 (Otto et al., 1990; Winther and Johannessen, 2006). The Atlantic water enters the North Sea through its northern boundary. Stations located in the north-northeastern part of the study area showed reduced salinity levels, with values near 33 (Fig. 5.15), indicating an influence of Baltic Sea outflow through the Skagerrak (Otto et al., 1990; Winther and Johannessen, 2006). In the working area, salinity values ranged between 21.32 and 35.13. Measurements below 32 were isolated and may indicate either measurement errors or possible freshwater influence from the vessel.

Temperature measured within the working area on the HE661 expedition varied from 10.0 °C to 12.5 °C. The highest temperatures were observed in the north-northeast part of the area, where the influence of the Skagerrak can also be observed. The average temperature measured was 10.8 °C.

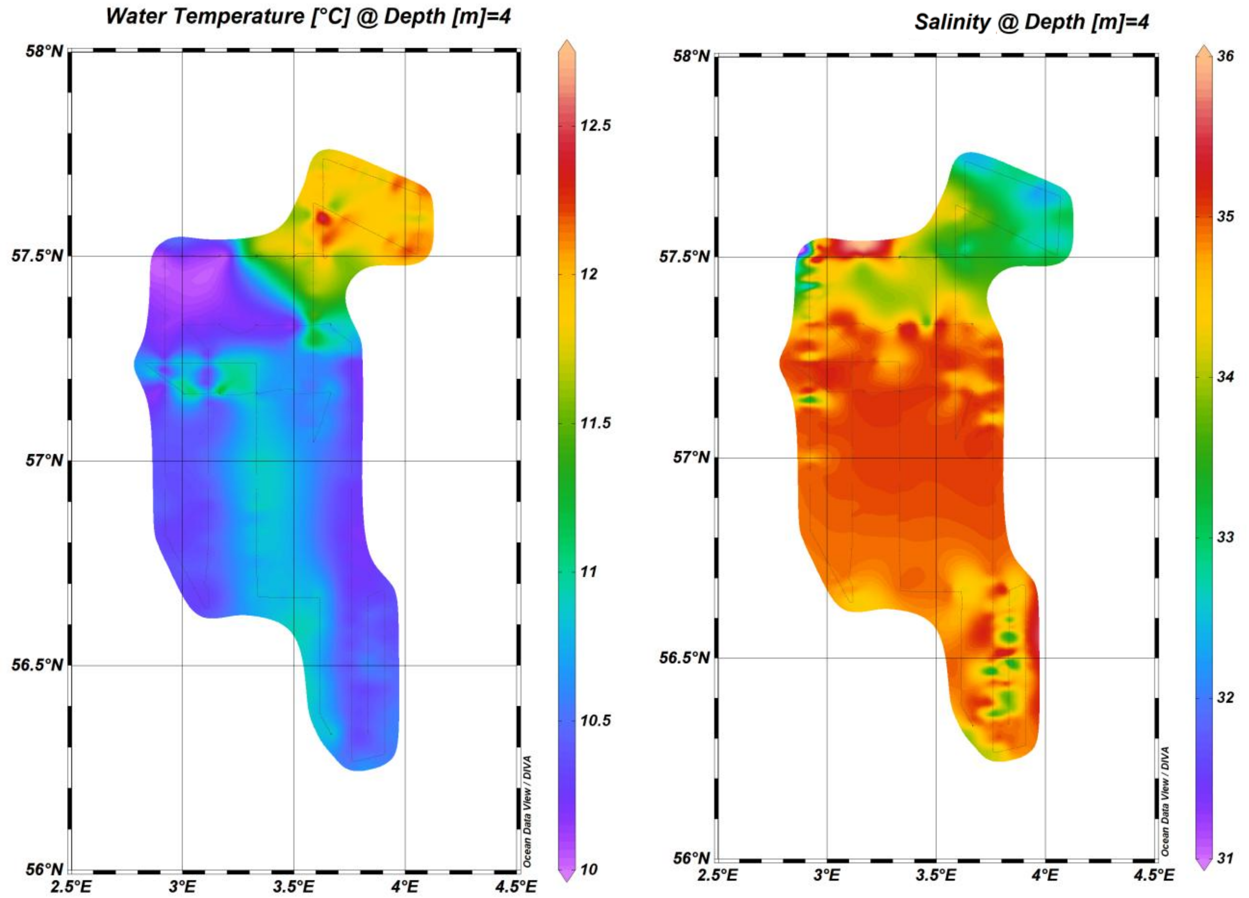


Fig. 5.15 Thermosalinograph data: left: Water temperature in °C; right: Water salinity.

5.2 Sediment Sampling

(Julia Lewe)

To understand the grain size distribution, organic content and sediment composition, it is essential to collect surface sediment samples. Therefore, in addition to water sampling, surface sediment samples were collected at 19 stations in the Norwegian sector. Since sediment sampling disturbs the water column and introduces suspended particles, it is conducted only after the CTD and bottom water sampling have been completed. The devices, used to collect the samples, were the vVG and the MUC. The vVG was successfully deployed at all 19 stations and captures sediment through a scooping motion. The MUC takes undisturbed sediment cores but was not used or failed on several attempts due to cohesive sediments and rough sea. The MUC was not used at stations 01 and 02 and was therefore deployed at only 17 stations.

5.2.1 Surface Sediment Sampling (van-Veen-Grab, vVG)

The vVG sampler (Fig. 5.16) is used to collect surface sediment samples prior to the MUC. This is particularly important as the vVG is more robust and provides an initial assessment of sediment characteristics. If the sediment contains coarse material, gravel, or large components, there is a risk of damaging the MUC. A disadvantage of vVG is that the grabbing motion disturbs the sediment layering to some extent. As a result, the exact penetration depth cannot be accurately determined, however it is approximately 10 cm.

Fig. 5.16 The van-Veen-Grab on deck.

To sample the sediment, the vVG was lowered to the seafloor. Driven by its own weight, the grab embeds itself in the surface sediment. As the device is lifted, the grabbing scoops are drawn together, capturing the sediment. Once the vVG is on deck, a sample for permeability analysis was collected using an acrylic glass cylinder**.** For this purpose, the mesh on top of the grab was opened, the cylinder is carefully inserted into the sediment and sealed at the top with a plug. The negative pressure created by the plug facilitates the extraction of the sediment sample and the placement of the plug at the bottom of the cylinder. The sample is transported to the laboratory.

Once the sample for permeability analysis has been secured, the vVG is placed on a wooden plank and the scoops are opened to expose the remaining sediment. Photographs are taken (see Chapter 11.7.3), and the sediment is described regarding grain size, color (using the MUNSELL Color Chart), smell, layering, and the presence of organic remains such as shells and borrows. After all observations and documentation are complete, the sediment is removed from deck.

The sediment mostly consisted of fine to medium sand with a low proportion of silt and clay. Some of the samples also contained dark, organic-rich lenses, indicating reduction processes. Considering the organisms, mollusks, annelids, arthropods and echinoderms were identified. All samples included shells and shell fragments and most often also worms or burrows and filtration tubes. Additionally, a live hermit crab was found at Station 15. Benthic organisms such as starfish and sea urchins were found at station 3, 6, 18, 19, and 20.

To determine sediment permeability (Fig. 5.18), the bottom plug of the acrylic glass is replaced with a plug that has a hole in the center and is connected to a rubber tube with a valve at the end. To prevent sediment from entering the tube, a moistened filter paper is placed over the plug before mounting the sample. After placing the sample in the holder and adding seawater until the water column reaches at least 7.5 cm, the valve is opened, and a stopwatch is started. The time is recorded when a noticeable change in the water column becomes visible. Throughout the process, the sediment remained fully submerged.

When comparing the permeability with the grain size, a clear correlation is observed at stations 11, 12, 13, 14, and 15, where coarser grain sizes are associated with higher permeability values (Fig. 5.17). At the other stations, particularly at stations 3, 6, 17, and 21, this trend is not evident. The absence of a consistent relationship between grain size and permeability at these sites can be attributed to the generally low variation in grain size and the subjective perception involved in grain size classification based on visual and tactile assessment. At two stations, permeability measurements had to be repeated. At Station 6, the filter shifted during the first attempt, and at station 18, a shell obstructed the flow.

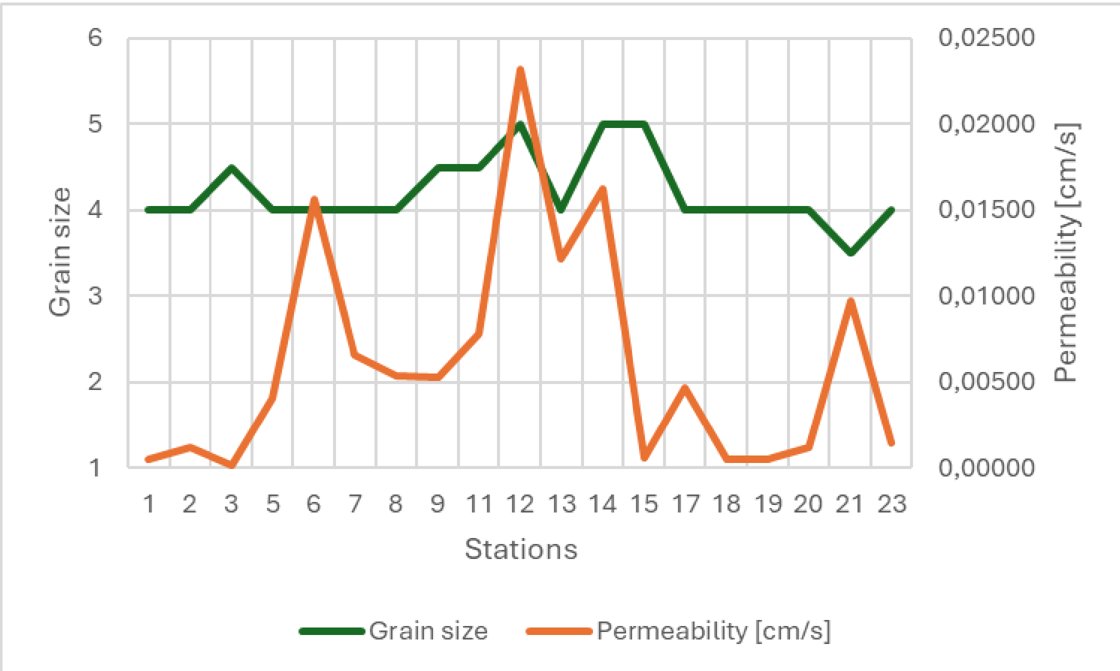


Fig. 5.17 Permeability [cm/s] plotted with the grain size for station 01 to 23. Grain size is represented as class values: 1 = Clay, 2 = Fine silt, 3 = Coarse silt, 4 = Fine sand, 5 = Medium sand, 6 = Coarse sand.

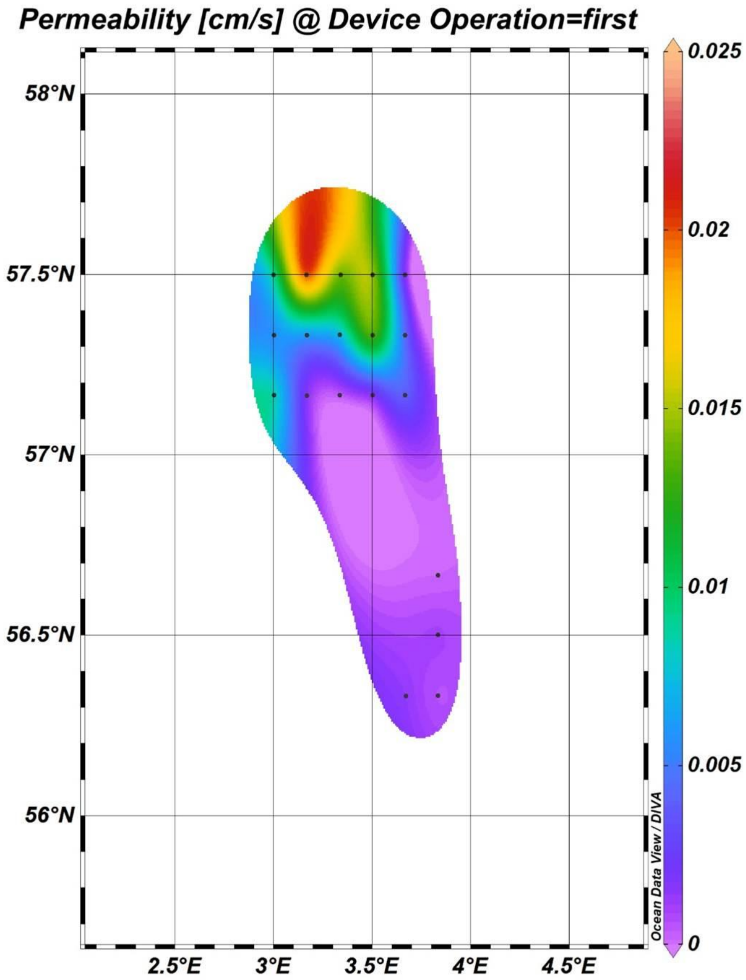


Fig. 5.18 Map of the permeability (cm/s) in the study area of HE661.

5.2.2 Multicorer (MUC)

During the HE661 expedition, the MUC was used to collect undisturbed surface sediment samples (Fig. 5.19). The MUC consists of a hexagonal metal frame with feet, which stabilize the device once it is in contact with the seafloor. A central rail is connected to the central part, which holds eight polycarbonate sampling tubes. To prepare the MUC for sampling, the upper flaps are first tensioned. Subsequently, the tubes are inserted, and the lower flaps are tensioned. To prevent the cable from getting caught on the tubes and potentially damaging the device, the MUC is covered with a net that is tied to the metal frame by using the clove hitch. After preparation is completed, the MUC is lifted by the winch, initially only a few centimetres above the deck floor, to remove the metal rods from the central rail. These rods prevent the central part with the tubes from falling to the ground and damaging the device while on deck (Fig. 5.19). After the rods are removed, the MUC is lowered at a speed of 0.5 m/s to approximately 5 m above the seafloor, where it remains for one minute to stabilize and settle in the water column. Subsequently, it is lowered slowly to the seafloor at a speed of 0.3 m/s. The cable is then paid out an additional 2 m to ensure slack. The MUC penetrates the sediment under its own weight. After a settling time of approximately two minutes the device is retrieved. The upward movement triggers an automatic mechanism that closes both the upper and lower flaps of the tubes, thereby capturing the sediment sample. Once the MUC is back on deck, the metal rods are reinserted into the central rail. The longest and best-preserved sediment cores are then sealed with a plug at the top and afterwards at the bottom. Since the sediment was relatively cohesive and the penetration depth was shallow, we sometimes first removed some of the water using a tube to facilitate the sealing process. At least one core was collected for further sampling occasionally two cores were available.

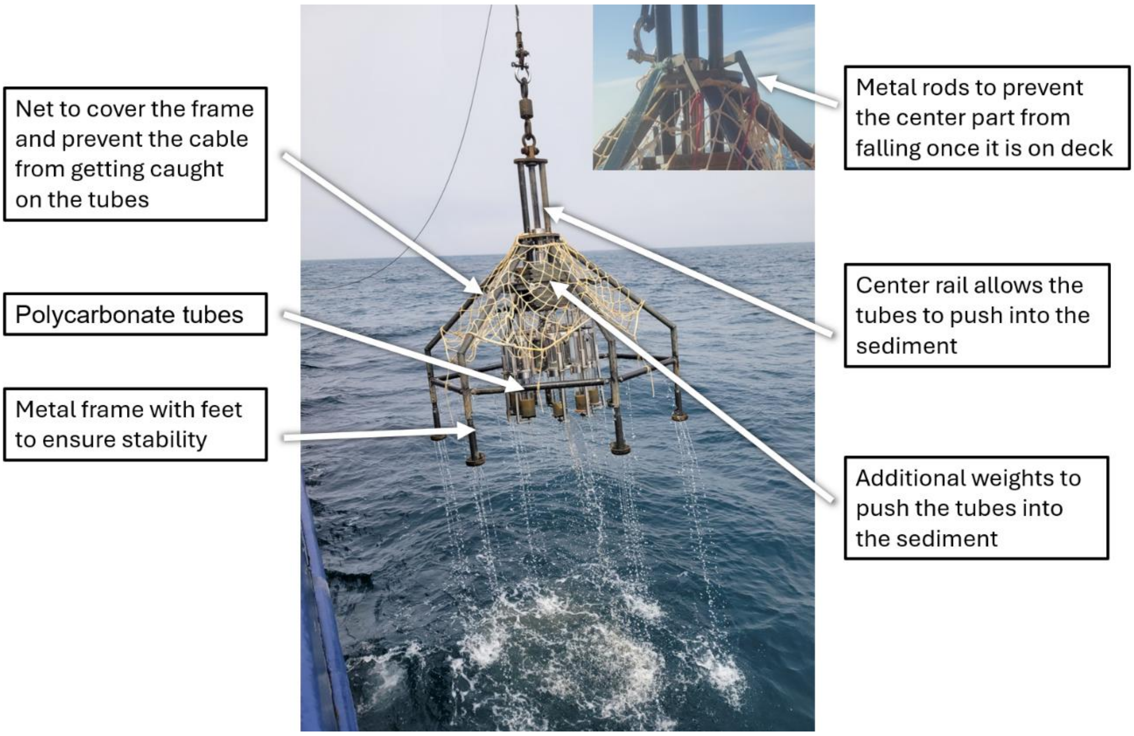


Fig. 5.19 The MUC after taking samples, with a short description.

At first, photographs of the core were taken, and horizons and organisms were documented (see chapter 11.7.4). Subsequently, the core was mounted on a steal cylinder and the tube was lowered until the sediment surface was reached. The uppermost 2 cm, along with some of the surface water were removed and stored in a plastic container in the refrigerator. This sample will later be analyzed by the micropaleontological working group of the University of Hamburg. Afterwards, samples were then taken at intervals of 1 cm.. The samples were sealed in plastic bags and stored in the freezer for further analysis. The sediment sampled by the MUC shows minimal variations in grain size throughout the study area (Fig. 5.20). The sediment consists mostly of fine sand, with a slight shift from fine to medium sand towards the southwest of the study area. The colors were described using the Munsell Color Chart. Most cores were gray-brown, darker at the bottom, and transitioned to a more brownish hue towards the top (see chapter 11.7.4). Some cores additionally contained interbedded dark lenses. This darkening with increasing sediment depth was also observed in the vVG and indicates reduction processes.

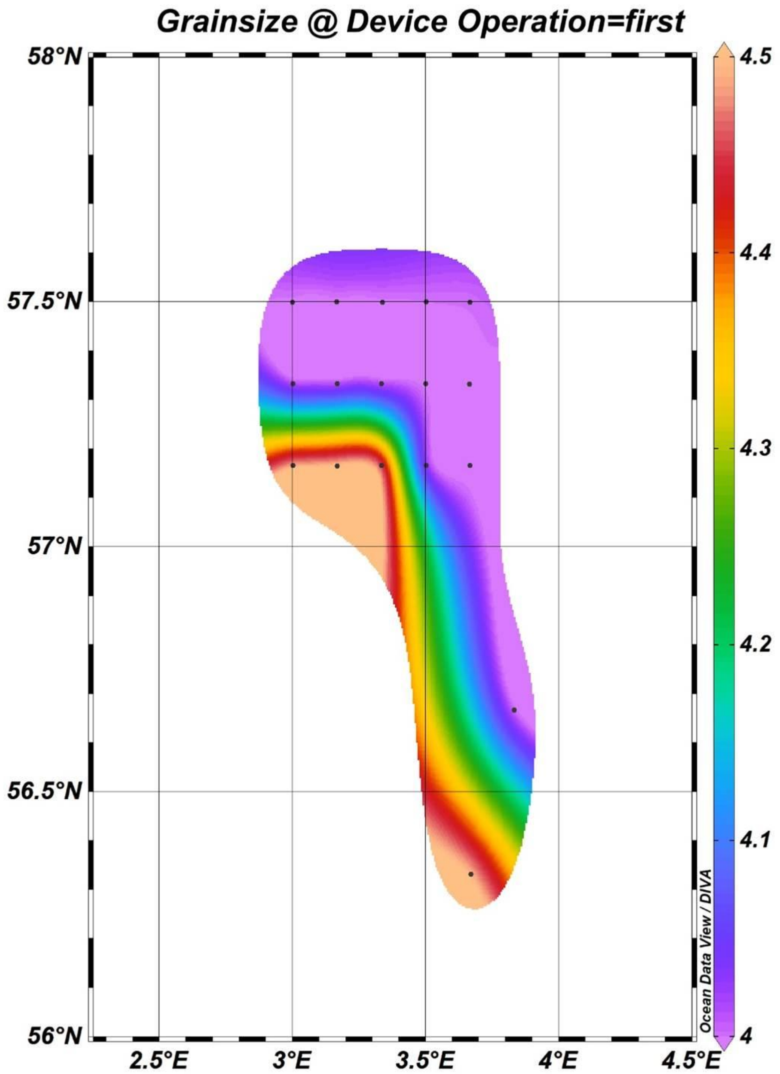


Fig. 5.20 Map of the grain size (arbitrary values) in the study area of HE661. Key for Grain size: 1=clay, 2=fine silt, 3=coarse silt, 4=fine sand, 5=middle sand, 6=coarse sand, 7=gravel/rubble.

5.3 Underway Hydroacoustics

(Jakob Kast, Thomas Lüdmann)

The hydroacoustic survey conducted during this cruise took place within the Exclusive Economic Zone (EEZ) of Norway. Three devices were used throughout the survey. All of them are hull-mounted devices. The multibeam echo sounder (MBES) KONGSBERG EM712 and the sub-bottom profiler (SBES) INNOMAR SES2000 were employed along four profiles within the Norwegian EEZ (Fig. 5.21). To minimize disruptions to other sampling operations, these surveys were conducted at night. In addition, the acoustic doppler current profiler (ADCP) TELEDYNE RDI WORKHORSE MARINER (600 kHz) operated continuously within the Norwegian EEZ. At four stations, a VALEPORT MIDAS sound velocity profiler (SVP) was mounted to the CTD to record sound velocity profiles of the water column. The aim of the survey was to improve the understanding of the bathymetry, shallow sediment structures, and current dynamics in the study area.

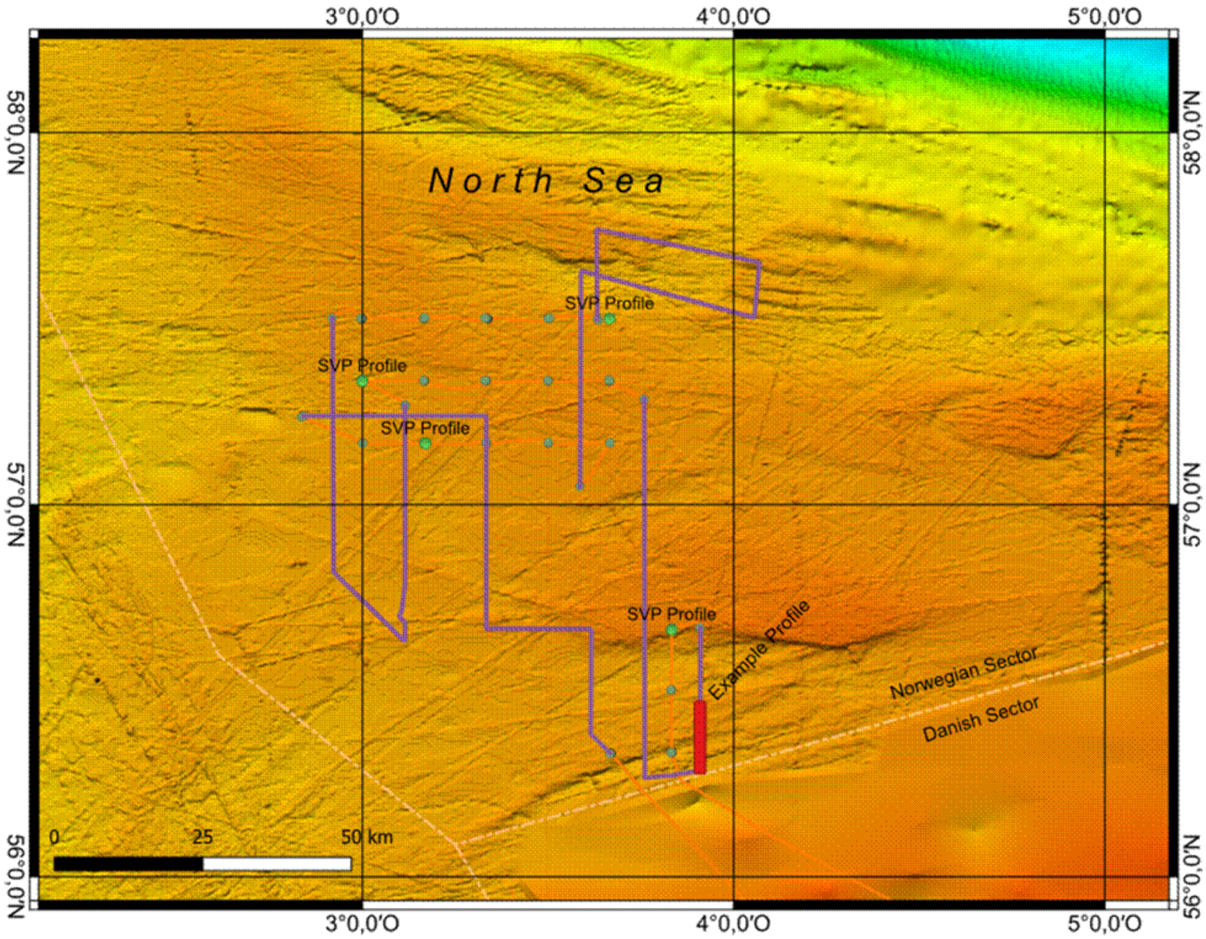


Fig. 5.21 HE661 stations, including highlighted stations where sound velocity measurements were taken. Overview of recorded hydroacoustic tracks for MBES and SBES (purple). The red area shows the site that is described in further detail in this report.

The MBES is a hull-mounted sonar system used for mapping the seafloor. It employs transducers that form both transmitting and receiving fan-shaped beams to record a two-dimensional map of seafloor morphology. The swath angle was set to 130°, resulting in a swath width of approximately four times the water depth, about 240 m at a depth of 60 m. The MBES was operated in single swath and shallow water ping mode, with high density equidistant beam spacing. By recording the amplitude of the reflected signal, information about the acoustic properties of the seabed can be obtained. It may allow the classification of the seafloor habitat. The SBES emits a narrow sonar beam of approximately 4° at a low frequency to achieve a penetration depth of up to 50 m into the underlying sediments. The MBES bathymetric data was processed using QPS QIMERA, the backscatter data was processed with the QPS FM GEOCODER TOOLBOX. The INNOMAR SES2000 system employs parametric acoustics, generating two slightly different signals around 100 kHz, which produce a secondary low frequency in the range of 4 to 15 kHz. During the entire cruise a secondary frequency of 6 kHz was used. All utilized sonars were interfaced to the IXSea PHINS III Inertial navigation system (INS) to compensate for ship movements. However, during the survey, the heave compensation of the SBES did not function properly. Errors in the resulting data were subsequently corrected during post-processing. For processing the SBES data, the SCHLUMBERGER PETREL software was used. To avoid interference between the MBES and SBES system, which both emits frequencies of around 100 kHz, they were triggered alternatingly. The ADCP is a sonar instrument used to measure current velocity profiles in the water column. It emits acoustic pulses and detects the Doppler shift of backscattered signals to calculate current speed and direction at varying depths. The ADCP was setup for 45 bins of 1 m and a blank distance of 2 m as well as 5 pings per ensemble.

The approximately 10.8 km-long profile (Fig. 5.23a,) recorded with the MBES shows the bathymetry of the seafloor, with water depths of approximately 65–80 m. A valley and ridge system striking NE-SW can be seen in the bathymetry data. In analogy to this, Fig. 5.23b, presents the backscatter intensity of the same profile. Depending on the character of the seafloor, the backscatter intensity varies. When the intensity is high, a large portion of the acoustic signal is reflected, which is typically the result of dense materials (e.g. sand, gravel, rocks). Conversely, low intensity indicates low-density materials (e.g. mud, silt). Due to weather conditions, with waves of up to 3.5 m during the first survey block, the resolution of the recorded data, particularly of the MBES, is limited, with a higher-than-normal noise floor and other errors in the data. Recording the sound velocity in the water column using an SVP is necessary to achieve accurate depth measurements when using the MBES and SBES. A diagram of the velocity profiles is shown in Fig. 5.22. All four profiles display stratification of the water column, with a steep decline in sound velocity from approximately 1491 m/s to 1482 m/s at a depth of 30-35 m. Additional indications of stratification can be seen in the ADCP data (Fig. 5.24). The data of the ADCP shows an increase in current velocity from approximately 250 mm/s to 1200 mm/s at a depth of 32 m. This change is consistent along the sampled profile. Additionally, there is also a shift in the direction of the current. While the current flows in a southeast direction at shallow depths, at a depth of 25–30 m, there is a directional change, with fluctuations between the northern and eastern current directions.

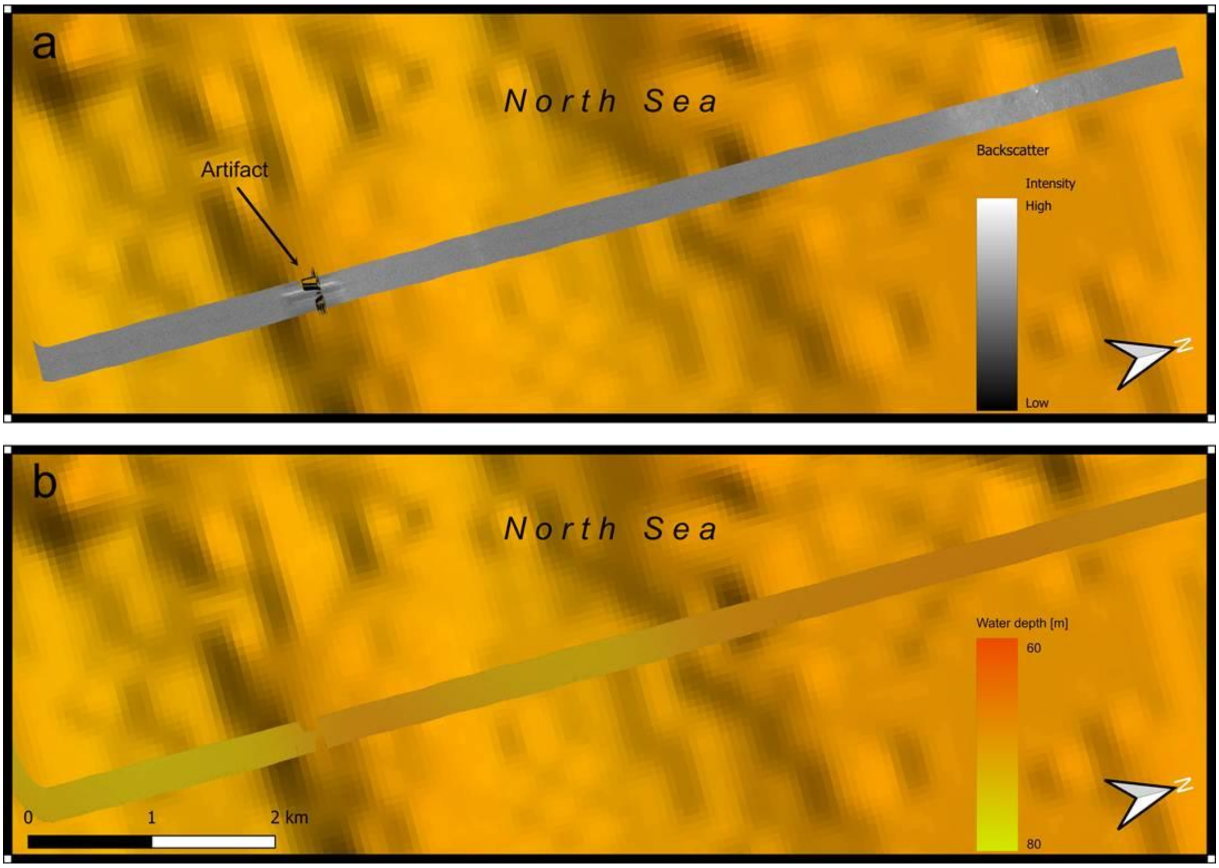


Fig. 5.22 Example profile of the backscatter intensity (a) bathymetric profile (b) recorded with the MBES, overlaid on the EMODnet Digital Bathymetry (DTM 2024). Water depths range from 65 to 80 m. Backscatter data is shown in grayscale with lighter areas for high intensity and darker areas for lower intensities. Arrow points to an artefact caused by ship movement in heavy swell.

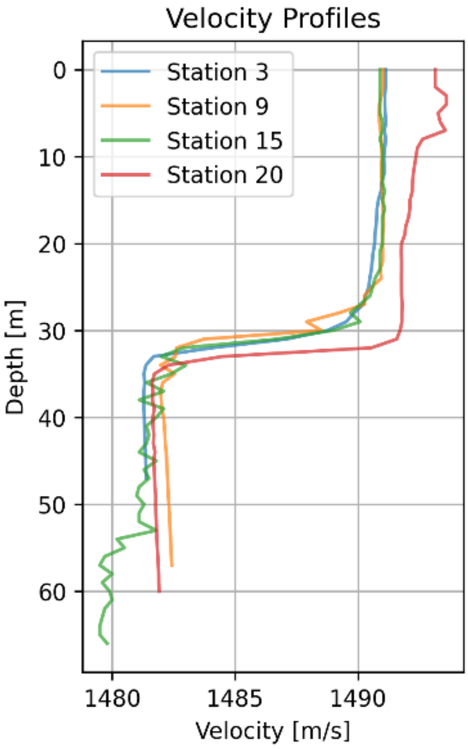


Fig. 5.23 Sound velocity profiles from stations 3, 9, 15 and 20 in the study area. Depth increases downward, and sound velocity (m/s) is plotted horizontally.

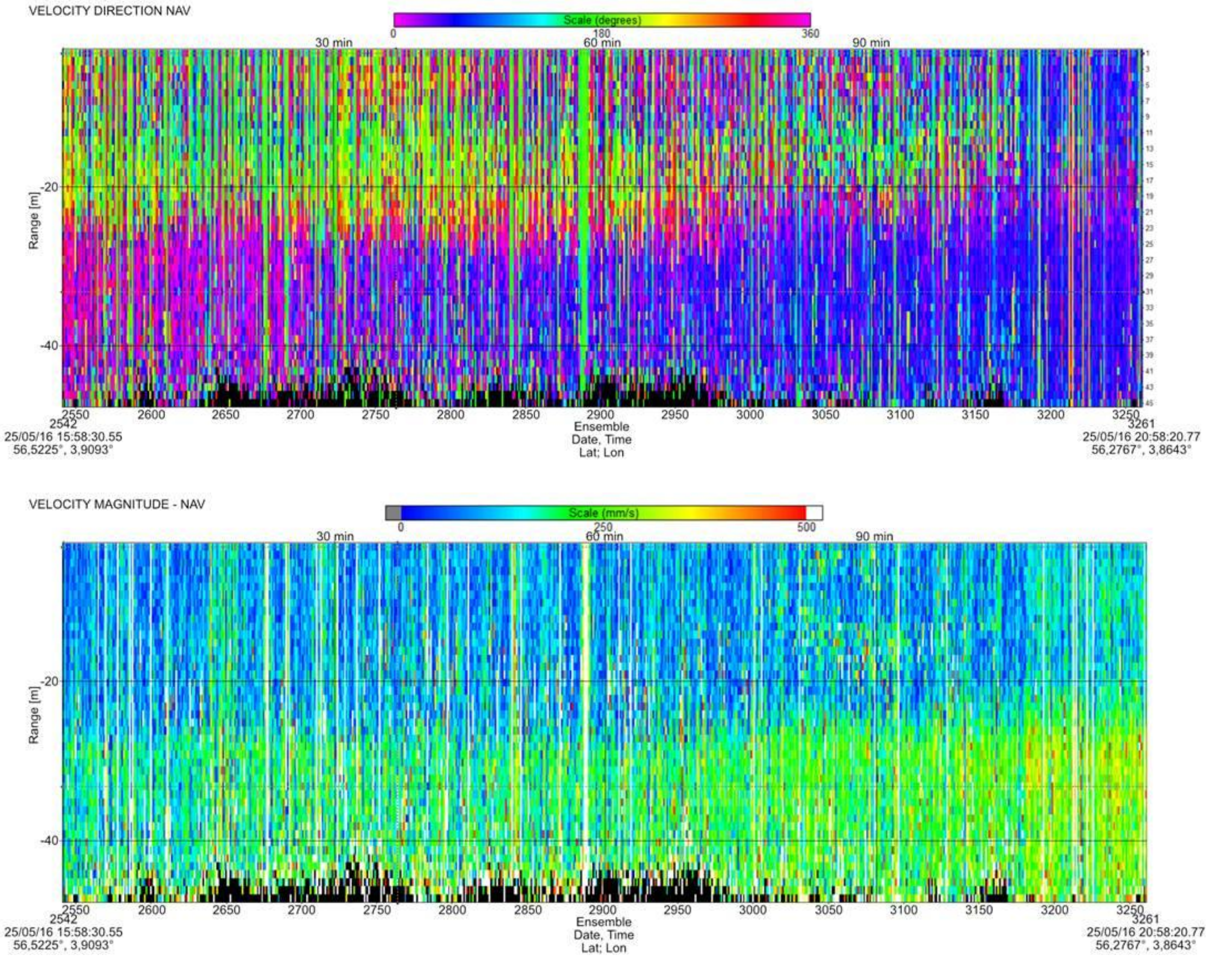


Fig. 5.24 ADCP data showing changes in current direction (top) and current speed (bottom) with water depth along the example profile.

The example profile of the SBES (Fig. 5.25) runs perpendicular to a valley and ridge system that strikes NE–SW. The height difference between the ridge and the valley is approximately 7 m. The width of the ridge is 4000 m. Internally, the ridge exhibits inclined stratification, with layers dipping towards the south. These internal reflectors downlap onto another reflector that is roughly in line with the adjacent valleys. Given the major influence of Quaternary glaciations on the sedimentary geology of the North Sea (Graham et al., 2011), it is likely that the ridge was formed as part of a glacial moraine (Fabbri et al., 2018). The area of the depression (800 – 3400 m) has volatile and highly inclined reflections.

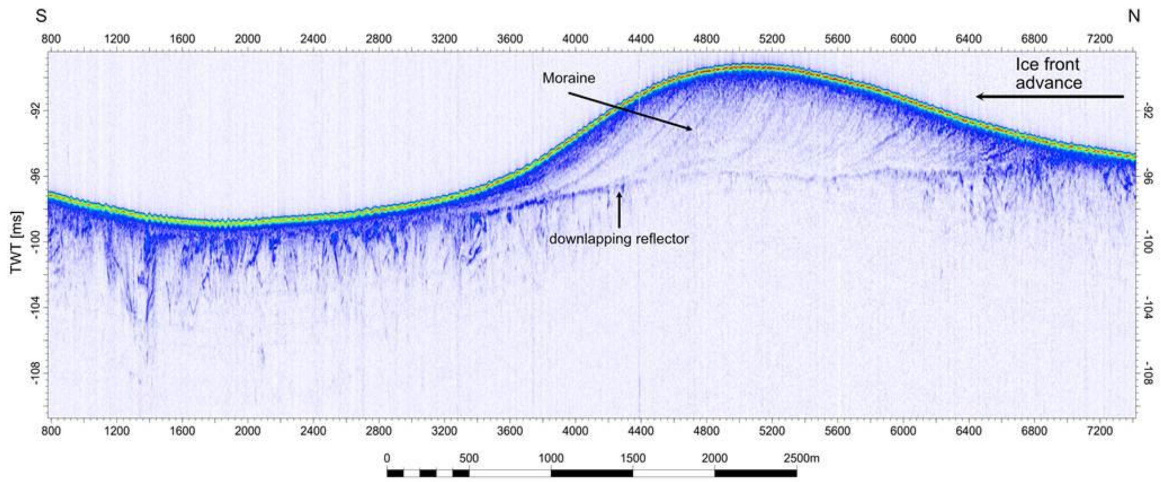


Fig. 5.25 Example SBES profile (Location can be seen in Fig. 5.21) of the North Sea, showing a moraine with internal reflections and downlapping contacts to an underlying reflector. Vertical exaggeration is 100 times. Arrow shows direction of ice front advance.

6 Station List HE661

Table 6.1 WST: Weather Station; TSG: Thermosalinograph; Secdisk: SECCHI-Disk; APN: Plankton-Net (APSTEIN-net); CTD: CTD-Rosette; BWS: BWS; GRAB: van Veen Grab; MUC: Multicorer; MB/SES/ADCP: MULTIBEAM / SES 2000 / ADCP.

Station No.	Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/Recovery
HEINCKE	dd.mm.yyyy		[UTC]	[°N]	[°E]	[m]	
HE661_0_ Underway-5	15.05.2025	WST	5:39	53°31.931'	008°34.701'	5	station start
HE661_0_ Underway-6	15.05.2025	TSG	8:39	53°53.557'	008°04.019'	10	station start
HE661_1-1	16.05.2025	Secdisk	12:22	56°19.993'	003°49.992'	69	in the water
HE661_1-2	16.05.2025	APN	12:27	56°20.001'	003°49.983'	71	in the water
HE661_1-3	16.05.2025	CTD	12:38	56°20.001'	003°49.949'	69	max depth/on ground
HE661_1-4	16.05.2025	GRAB	12:47	56°20.000'	003°49.917'	70	max depth/on ground
HE661_2-1	16.05.2025	Secdisk	14:16	56°30.131'	003°49.917'	63	in the water
HE661_2-2	16.05.2025	APN	14:20	56°30.134'	003°49.917'	63	in the water
HE661_2-3	16.05.2025	CTD	14:30	56°30.133'	003°49.889'	62	max depth/on ground
HE661_2-4	16.05.2025	GRAB	14:39	56°30.132'	003°49.881'	63	max depth/on ground
HE661_3-1	16.05.2025	Secdisk	15:57	56°39.989'	003°49.989'	53	in the water
HE661_3-2	16.05.2025	APN	16:02	56°39.993'	003°49.981'	52	in the water
HE661_3-3	16.05.2025	CTD	16:11	56°39.991'	003°49.928'	52	max depth/on ground
HE661_3-4	16.05.2025	BWS	16:23	56°39.995'	003°49.901'	52	max depth/on ground
HE661_3-5	16.05.2025	GRAB	16:35	56°39.987'	003°49.907'	52	max depth/on ground
HE661_3-6	16.05.2025	MUC	17:04	56°39.996'	003°49.926'	52	max depth/on ground
HE661_4-1	16.05.2025	MB	17:51	56°40.124'	003°54.566'	53	station start
HE661_4-1	16.05.2025	MB	17:51	56°40.109'	003°54.568'	53	profile start
HE661_4-1	17.05.2025	MB	5:19	57°16.954'	003°45.546'	61	profile end
HE661_4-1	17.05.2025	MB	5:19	57°16.978'	003°45.546'	60	station end
HE661_5-1	17.05.2025	Secdisk	5:55	57°19.933'	003°39.922'	60	in the water
HE661_5-2	17.05.2025	APN	6:00	57°19.936'	003°39.939'	59	in the water
HE661_5-3	17.05.2025	CTD	6:11	57°19.930'	003°39.974'	59	max depth/on ground
HE661_5-5	17.05.2025	BWS	6:42	57°20.003'	003°39.938'	59	max depth/on ground
HE661_5-6	17.05.2025	GRAB	6:55	57°19.995'	003°39.951'	59	max depth/on ground
HE661_5-7	17.05.2025	MUC	7:07	57°19.987'	003°39.962'	60	max depth/on ground
HE661_6-1	17.05.2025	Secdisk	8:05	57°19.976'	003°30.044'	4	in the water
HE661_6-2	17.05.2025	APN	8:07	57°19.972'	003°30.046'	5	in the water
HE661_6-3	17.05.2025	CTD	8:18	57°19.958'	003°30.016'	59	max depth/on ground
HE661_6-4	17.05.2025	BWS	8:29	57°19.946'	003°29.987'	60	max depth/on ground

Station No.	**Date**	**Gear**	**Time**	**Latitude**	**Longitude**	**Water Depth**	**Remarks/Recovery**
HEINCKE	**dd.mm.yyyy**		**[UTC]**	**[°N]**	**[°E]**	**[m]**	
HE661_6-5	17.05.2025	GRAB	8:43	57°19.961'	003°29.975'	59	max depth/on ground
HE661_6-6	17.05.2025	MUC	8:52	57°19.965'	003°29.956'	58	max depth/on ground
HE661_7-1	17.05.2025	Secdisk	10:26	57°19.987'	003°20.018'	61	in the water
HE661_7-2	17.05.2025	APN	10:28	57°19.983'	003°20.005'	59	in the water
HE661_7-3	17.05.2025	CTD	10:39	57°19.984'	003°19.955'	61	max depth/on ground
HE661_7-4	17.05.2025	BWS	11:05	57°19.984'	003°19.939'	61	in the water
HE661_7-5	17.05.2025	GRAB	11:23	57°19.991'	003°19.902'	61	max depth/on ground
HE661_7-6	17.05.2025	MUC	11:42	57°19.989'	003°19.919'	60	max depth/on ground
HE661_8-1	17.05.2025	Secdisk	12:53	57°19.977'	003°10.032'	61	in the water
HE661_8-2	17.05.2025	APN	12:54	57°19.982'	003°10.009'	63	in the water
HE661_8-3	17.05.2025	CTD	13:06	57°19.987'	003°09.960'	62	max depth/on ground
HE661_8-4	17.05.2025	BWS	13:16	57°19.992'	003°09.920'	62	in the water
HE661_8-5	17.05.2025	GRAB	13:31	57°19.976'	003°09.911'	65	max depth/on ground
HE661_8-6	17.05.2025	MUC	13:40	57°19.992'	003°09.933'	62	max depth/on ground
HE661_9-1	17.05.2025	Secdisk	14:35	57°19.969'	003°00.079'	63	in the water
HE661_9-2	17.05.2025	APN	14:37	57°19.965'	003°00.071'	65	in the water
HE661_9-3	17.05.2025	CTD	14:49	57°19.980'	003°00.010'	65	max depth/on ground
HE661_9-4	17.05.2025	BWS	15:03	57°19.989'	002°59.994'	63	max depth/on ground
HE661_9-5	17.05.2025	GRAB	15:15	57°19.979'	002°59.995'	64	max depth/on ground
HE661_10-1	17.05.2025	MB	16:02	57°16.072'	003°06.906'	63	station start
HE661_10-1	17.05.2025	MB	16:03	57°15.802'	003°06.894'	63	profile start
HE661_10-1	18.05.2025	MB	5:06	57°30.030'	002°55.127'	61	profile end
HE661_10-1	18.05.2025	MB	5:06	57°30.060'	002°55.125'	62	station end
HE661_11-1	18.05.2025	Secdisk	6:00	57°29.961'	002°59.928'	61	in the water
HE661_11-2	18.05.2025	APN	6:05	57°29.935'	002°59.928'	60	in the water
HE661_11-3	18.05.2025	CTD	6:15	57°29.964'	002°59.870'	61	max depth/on ground
HE661_11-4	18.05.2025	BWS	6:28	57°29.986'	002°59.846'	61	max depth/on ground
HE661_11-5	18.05.2025	GRAB	6:40	57°30.015'	002°59.797'	60	max depth/on ground
HE661_11-6	18.05.2025	MUC	6:51	57°30.041'	002°59.783'	60	max depth/on ground
HE661_12-1	18.05.2025	Secdisk	7:51	57°29.999'	003°09.953'	59	in the water
HE661_12-2	18.05.2025	APN	7:54	57°29.992'	003°09.971'	61	in the water
HE661_12-3	18.05.2025	CTD	8:03	57°30.023'	003°09.992'	59	max depth/on ground
HE661_12-4	18.05.2025	BWS	8:15	57°30.026'	003°09.941'	58	max depth/on ground
HE661_12-5	18.05.2025	GRAB	8:30	57°30.027'	003°09.897'	60	max depth/on ground
HE661_12-6	18.05.2025	MUC	8:41	57°30.045'	003°09.926'	61	max depth/on ground
HE661_13-1	18.05.2025	Secdisk	10:23	57°29.985'	003°20.287'	62	in the water

Station No.	Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/Recovery
HEINCKE	dd.mm.yyyy		[UTC]	[°N]	[°E]	[m]	
HE661_13-2	18.05.2025	APN	10:28	57°29.982'	003°20.247'	61	in the water
HE661_13-3	18.05.2025	CTD	10:38	57°30.020'	003°20.187'	62	max depth/on ground
HE661_13-4	18.05.2025	BWS	10:46	57°30.043'	003°20.124'	61	in the water
HE661_13-5	18.05.2025	GRAB	11:00	57°30.068'	003°20.069'	61	max depth/on ground
HE661_13-6	18.05.2025	MUC	11:27	57°30.081'	003°19.841'	61	max depth/on ground
HE661_14-1	18.05.2025	Secdisk	12:22	57°30.005'	003°30.075'	62	in the water
HE661_14-2	18.05.2025	APN	12:26	57°30.007'	003°30.061'	62	in the water
HE661_14-3	18.05.2025	CTD	12:36	57°29.993'	003°30.043'	64	max depth/on ground
HE661_14-4	18.05.2025	BWS	12:43	57°29.997'	003°30.026'	63	in the water
HE661_14-5	18.05.2025	GRAB	12:58	57°29.994'	003°30.016'	62	max depth/on ground
HE661_14-6	18.05.2025	MUC	13:09	57°30.000'	003°30.003'	63	max depth/on ground
HE661_15-1	18.05.2025	Secdisk	14:02	57°29.977'	003°39.977'	64	in the water
HE661_15-2	18.05.2025	APN	14:07	57°29.975'	003°39.967'	66	in the water
HE661_15-3	18.05.2025	CTD	14:16	57°29.975'	003°39.950'	65	max depth/on ground
HE661_15-4	18.05.2025	BWS	14:26	57°29.966'	003°39.937'	65	max depth/on ground
HE661_15-5	18.05.2025	GRAB	14:37	57°29.974'	003°39.930'	64	max depth/on ground
HE661_15-6	18.05.2025	MUC	14:48	57°29.969'	003°39.925'	64	max depth/on ground
HE661_16-1	18.05.2025	MB	15:12	57°29.767'	003°38.146'	64	station start
HE661_16-1	18.05.2025	MB	15:14	57°29.968'	003°37.991'	64	profile start
HE661_16-1	19.05.2025	MB	4:53	57°02.990'	003°35.168'	60	profile end
HE661_16-1	19.05.2025	MB	4:54	57°02.930'	003°35.169'	60	station end
HE661_17-1	19.05.2025	Secdisk	5:58	57°09.956'	003°39.980'	59	in the water
HE661_17-2	19.05.2025	APN	6:03	57°09.975'	003°39.988'	58	in the water
HE661_17-3	19.05.2025	CTD	6:12	57°09.970'	003°39.999'	59	max depth/on ground
HE661_17-4	19.05.2025	BWS	6:25	57°09.956'	003°39.999'	58	max depth/on ground
HE661_17-5	19.05.2025	GRAB	6:36	57°09.956'	003°39.988'	59	max depth/on ground
HE661_17-6	19.05.2025	MUC	6:46	57°09.961'	003°39.988'	58	max depth/on ground
HE661_18-1	19.05.2025	Secdisk	7:37	57°09.970'	003°30.076'	60	in the water
HE661_18-2	19.05.2025	APN	7:40	57°09.973'	003°30.070'	60	in the water
HE661_18-3	19.05.2025	CTD	7:50	57°09.981'	003°30.068'	59	max depth/on ground
HE661_18-4	19.05.2025	BWS	8:01	57°09.983'	003°30.052'	61	max depth/on ground
HE661_18-5	19.05.2025	GRAB	8:12	57°09.996'	003°30.065'	60	max depth/on ground
HE661_18-6	19.05.2025	MUC	8:22	57°09.990'	003°30.061'	59	max depth/on ground
HE661_19-1	19.05.2025	Secdisk	10:29	57°09.986'	003°20.039'	61	in the water
HE661_19-2	19.05.2025	APN	10:33	57°09.979'	003°20.014'	60	in the water
HE661_19-3	19.05.2025	CTD	10:43	57°09.985'	003°19.994'	60	max depth/on ground

Station No.	**Date**	**Gear**	**Time**	**Latitude**	**Longitude**	**Water Depth**	**Remarks/Recovery**
HEINCKE	**dd.mm.yyyy**		**[UTC]**	**[°N]**	**[°E]**	**[m]**	
HE661_19-4	19.05.2025	BWS	10:51	57°09.986'	003°19.991'	61	in the water
HE661_19-5	19.05.2025	GRAB	11:05	57°09.988'	003°19.997'	60	max depth/on ground
HE661_19-6	19.05.2025	MUC	11:15	57°09.999'	003°19.994'	60	max depth/on ground
HE661_20-1	19.05.2025	Secdisk	12:09	57°09.935'	003°10.072'	62	in the water
HE661_20-3	19.05.2025	APN	12:13	57°09.939'	003°10.049'	62	in the water
HE661_20-2	19.05.2025	CTD	12:22	57°09.948'	003°10.046'	61	max depth/on ground
HE661_20-4	19.05.2025	BWS	12:33	57°09.973'	003°10.027'	61	max depth/on ground
HE661_20-5	19.05.2025	GRAB	12:45	57°10.009'	003°10.020'	61	max depth/on ground
HE661_20-6	19.05.2025	MUC	12:54	57°10.042'	003°10.024'	62	max depth/on ground
HE661_21-1	19.05.2025	Secdisk	13:52	57°09.946'	003°00.071'	64	in the water
HE661_21-2	19.05.2025	APN	13:55	57°09.936'	003°00.048'	64	in the water
HE661_21-3	19.05.2025	CTD	14:04	57°09.933'	003°00.042'	65	max depth/on ground
HE661_21-4	19.05.2025	BWS	14:15	57°09.941'	003°00.036'	64	max depth/on ground
HE661_21-5	19.05.2025	GRAB	14:26	57°09.940'	003°00.042'	64	max depth/on ground
HE661_21-6	19.05.2025	MUC	14:35	57°09.937'	003°00.034'	64	max depth/on ground
HE661_22-1	19.05.2025	MB	15:56	57°14.126'	002°50.158'	68	station start
HE661_22-1	19.05.2025	MB	15:59	57°14.291'	002°50.489'	68	profile start
HE661_22-1	20.05.2025	MB	3:40	56°19.996'	003°39.993'	63	profile end
HE661_22-1	20.05.2025	MB	3:40	56°19.986'	003°40.004'	63	station end
HE661_23-1	20.05.2025	Secdisk	3:49	56°19.894'	003°40.204'	63	in the water
HE661_23-2	20.05.2025	APN	3:52	56°19.882'	003°40.176'	64	in the water
HE661_23-3	20.05.2025	CTD	4:01	56°19.859'	003°40.128'	63	max depth/on ground
HE661_23-4	20.05.2025	BWS	4:11	56°19.851'	003°40.082'	63	max depth/on ground
HE661_23-5	20.05.2025	GRAB	4:22	56°19.846'	003°40.074'	63	max depth/on ground
HE661_23-6	20.05.2025	MUC	4:44	56°19.841'	003°40.031'	64	max depth/on ground

7 Data and Sample Storage and Availability

The hydrographic raw data collected by the CTD and the data from the TSG will be uploaded to the PANGAEA database within 12 months of the end of the cruise. Data from analysis of Filtration and sediment samples will be shared on PANGAEA later on.

The Seismic Data (MULTIBEAM, PARASOUND) will be transferred to the Norwegian authorities and will not be published. Seismic and ADCP data will be shared upon request. Contact information can be found in Tab. 7.1 below.

Table 7.1 Overview of data availability.

Type	Database	Contact
Hydrography data (CTD & TSG)	PANGAEA	niko.lahajnar@uni-hamburg.de
Sediment Data (vVG, MUC)	PANGAEA	niko.lahajnar@uni-hamburg.de
Seismic (MULTIBEAM, PARASOUND) & ADCP data	Upon request	thomas.luedmann@uni-hamburg.de

8 Acknowledgements

We thank our captain and the whole crew of the RV HEINCKE for their great support throughout our work and daily tasks allowing a positive environment. Futhermore, we want to thank our chief scientist, Dr. Niko Lahajnar, for realizing the cruise and his support during the expedition. His expertise and guidance enhanced the scientific value of the cruise. In addition, we want to express our gratitude to Dr. Gesa Schulz for assisting us in the laboratory, especially the CTD, and Dr. Thomas Lüdmann for introducing us into the seismic fundamentals. This research was made possible thanks to the generous financial support of the DFG (Deutsche Forschungsgemeinschaft) funding the expedition.

Last but not least, we express gratitude to the Norwegian and Danish authorities for granting permission to conduct our research in the Norwegian EEZ. We would like to acknowledge the valuable support of the AWI Schiffskoordination (Ingo Schewe, Sanne Bochert, Marius Hirsekorn, Bjela König, Claudia Klages, Derk Apetz, Sandra Tippenhauer, Ralf Krocker, Stefanie Klüver, Matthias von Häfen, and all other supporters).

9 References

Clausen, O. R., Nielsen, S. B., Egholm, D. L., & Gołędowski, B. (2012). Cenozoic structures in the eastern North Sea Basin – A case for salt tectonics. Tectonophysics, 514, 156-167.

Becker, G., Frohse, A., Klein, H., Löwe, P., Schulz, A., 2005. Die ozeanographischen Verhältnisse der Nordsee. In: Bund-Länder-Messprogramm für die Meeresumwelt von Nord- und Ostsee (Eds.) Messprogramm Meeresumwelt Zustandsbericht 1999 – 2002 für Nordsee und Ostsee. Bundesamt für Seeschifffahrt und Hydrographie, Hamburg/Rostock, pp. 11-14.

EMODnet Digital Bathymetry (DTM 2024). https://doi.org/10.12770/cf51df64-56f9-4a99-b1aa-36b8d7b743a1

Fabbri, S.C., Buechi, M.W., Horstmeyer, H., Hilbe, M., Hübscher, C., Schmelzbach, C., Weiss, B., Anselmetti, F.S., 2018. A subaquatic moraine complex in overdeepened Lake Thun (Switzerland) unravelling the deglaciation history of the Aare Glacier. Quaternary Science Reviews 187, 62–79. https://doi.org/10.1016/ j.quascirev.2018.03.010

Graham, A.G.C., Stoker, M.S., Lonergan, L., Bradwell, T., Stewart, M.A., 2011. The Pleistocene Glaciations of the North Sea Basin, in: Developments in Quaternary Sciences. Elsevier, pp. 261–278. https://doi.org/10.1016/B978-0-444-53447-7.00021-0

Kraberg, A., Baumann, M., Dürselen, C.-D. (2010). Coastal Phytoplankton Photo Guide for Northern European Seas. Verlag Dr. Friedrich Pfeil, München, 204 p.

Larink, O., Westheide, W. (2011). Coastal Plankton Photo Guide for European Seas 2nd edition. Verlag Dr. Friedrich Pfeil, München, 191 p.

Marra, J. F., Lance, V. P., Vaillancourt, R. D., & Hargreaves, B. R. (2014). Resolving the ocean's euphotic zone. Deep Sea Research Part I: Oceanographic Research Papers, 83, 45-50.

Otto, L., et al. "Review of the physical oceanography of the North Sea." Netherlands journal of sea research 26.2-4 (1990): 161-238.

Patruno, S., Kombrink, H., & Archer, S. G. (2022). Cross-border stratigraphy of the Northern, Central and Southern North Sea: a comparative tectono-stratigraphic megasequence synthesis. The Geological Society of London.

Rovelli, L., Dengler, M., Schmidt, M., Sommer, S., Linke, P., & McGinnis, D. F. (2016). Thermocline mixing and vertical oxygen fluxes in the stratified central North Sea. Biogeosciences, 13(5), 1609–1620. https://doi.org/10.5194/bg-13-1609-2016.

Schwarzer, K., Ricklefs, K., Lohrberg, A., Valerius, J., (2019). Die geologische Entwicklung von Nord-und ostsee. Die Küste, 87, 343-376.

Schlitzer, R. (2025). Ocean Data View, https://odv.awi.de.

van Leeuwen, S., Tett, P., Mills, D., & van Der Molen, J. (2015). Stratified and nonstratified areas in the N orth S ea: Long-term variability and biological and policy implications. Journal of Geophysical Research: Oceans, 120(7), 4670-4686.

Winther, Nina Gjerde, and Johnny A. Johannessen. "North Sea circulation: Atlantic inflow and its destination." Journal of Geophysical Research: Oceans 111.C12 (2006).

10 Abbreviations

ADCP – Acoustic Doppler Current Profiler

APN – APSTEIN-net (Plankton net)

AWI – Alfred Wegner Institut

BWS – BWS

CTD – Conductivity-Temperature-Depth Rosette Sampler

DFG – Deutsche Forschungsgemeinschaft

EEZ – Exclusive Economic Zone

INS – Internal Navigation System

M.Sc. – Master of Science

MB – MULTIBEAM

MBES – Multibeam Echo Sounder

MUC – Multicorer

ODV – Ocean Data View

PSS – Practical Salinity Scale

TSG – Thermosalinograph

SBES – Singlebeam Echo Sounder

Secdisk – SECCHI Disk

SVP – Sound Velocity Profiler

UHH – University of Hamburg

UTC – Coordinated Universal Time

vVG or GRAB – Van Veen Grab Sampler

11 Appendices

11.1 Protocol: SECCHI-Disk depth

Table 11.1 List of the SECCHI Disk depth at the different stations.

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	SECCHI Depth
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[m]
HE661	1	16.05.2025	12:22	003°49.96'	56°20.01'	70.00	11.0
HE661	2	16.05.2025	14:15	003°49.91'	56°30.13'	64.00	12.0
HE661	3	16.05.2025	16:56	003°49.99'	56°39.99'	52.00	14.5
HE661	5	17.05.2025	05:53	003°39.92'	57°19.93'	59.00	8.0
HE661	6	17.05.2025	08:04	003°30.05'	57°19.97'	59.00	5.5
HE661	7	17.05.2025	10:25	003°20.02'	57°19.99'	60.20	6.0
HE661	8	17.05.2025	12:52	003°10.01'	57°19.98'	63.00	4.5
HE661	9	17.05.2025	14:33	003°60.02'	57°19.99'	62.80	4.5
HE661	11	18.05.2025	06:04	002°59.87'	57°29.96'	60.00	7.0
HE661	12	18.05.2025	07:51	003°09.96'	57°29.99'	58.00	7.0
HE661	13	18.05.2025	10:22	003°19.83'	57°30.09'	61.00	10.0
HE661	14	18.05.2025	12:22	003°30.07'	57°30.00'	61.00	9.0
HE661	15	18.05.2025	14:02	003°39.94'	57°29.98'	65.00	12.0
HE661	17	19.05.2025	05:58	003°40.00'	57°09.96'	58.50	7.5
HE661	18	19.05.2025	07:36	003°30.06'	57°09.97'	60.00	7.0
HE661	19	19.05.2025	10:29	003°20.04'	57°09.99'	61.00	9.0
HE661	20	19.05.2025	12:06	003°10.09'	57°09.94'	61.00	8.0
HE661	21	19.05.2025	13:50	003°00.05'	57°09.94'	63.00	7.5
HE661	23	20.05.2025	03:47	003°40.22'	56°19.90'	63.00	7.0

11.2 Protocol: Plankton Net (APSTEIN-net)

Table 11.2 List and detailed protocols of the plankton samples taken with the APSTEIN-net at the different stations.

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Description
		dd/mm/yyyy	[UTC]	[°E]	[°N]	[m]	[m]	
HE661	1	16.05.2025	12:22	003°49.96'	56°20.01'	70.00	5	Copepoda (high abundance); Echinoidea: *Spatangus pluteus*; microscopic brownish-green points; Alga?: platy structure, visible by eye; mussel fragment?: pale opaque
HE661	2	16.05.2025	14:15	003°49.91'	56°30.13'	64.00	5	Copepoda and fragments (high abundance); Echinoidea: *Spatangus pluteus*; antropogen?: blue string like structure
HE661	3	16.05.2025	16:56	003°49.99'	56°39.99'	52.00	5	Copepoda; Echinoidea: *Spatangus pluteus*; green filamentous body; more components compared to before
HE661	5	17.05.2025	05:53	003°39.92'	57°19.93'	59.00	5	Copepoda; Echinoidea: *Spatangus pluteus*; plenty zooplankton
HE661	6	17.05.2025	08:04	003°30.05'	57°19.97'	59.00	5	Diatomeen: *Chaetoceros*; Echinoidea: *Spatangus pluteus*; almost no plankton; string-like structure
HE661	7	17.05.2025	10:25	003°20.02'	57°19.99'	60.20	5	Diatomeen: *Chaetoceros*, Dinoflagellat: *Ceratium*, *Dinophycis acuta*? (zooplankton), Echinoidea: *Spatangus pluteus*; string like structure; more phytoplankton than zooplankton
HE661	8	17.05.2025	12:52	003°10.01'	57°19.98'	63.00	5	Diatomeen: *Chaetoceros*; Phytoplankton: yellow inside; red filamentous structure, low plankton concentration
HE661	9	17.05.2025	14:33	003°60.02'	57°19.99'	62.80	5	Diatomeen: *Chaetoceros* (high abundance); Dinoflagellat: *Ceratium*; Echinoidea: *Spatangus pluteus;* Ctenophora: *Mnemiopsis Leidyi;* small phytoplankton

Cruise	**Station**	**Date**	**Time**	**Longitude**	**Latitude**	**Bot. Depth**	**Sample Depth**	**Description**
		dd/mm/yyyy	**[UTC]**	**[°E]**	**[°N]**	**[m]**	**[m]**	
HE661	11	18.05.2025	06:04	002°59.87'	57°29.96'	60.00	5	Diatomeen: *Chaetoceros* (high abundance); *Coscinodiscus concinus*?; brownish Foraminifera
HE661	12	18.05.2025	07:51	003°09.96'	57°29.99'	58.00	5	Diatomeen: *Chaetoceros affiuis, Chaetoceres descipien*; Dinoflagellat: *Ceratium*; small tube with dark marks at outside
HE661	13	18.05.2025	10:22	003°19.83'	57°30.09'	61.00	5	Diatomeen: *Chaetoceros*; Dinoflagellat: *Ceratium*; Copepoda (orange and green species); shift in Fauna compared to before
HE661	14	18.05.2025	12:22	003°30.07'	57°30.00'	61.00	5	Diatomeen: *Chaetoceros*; Copepoda; spherical structure with green points; Metamorphosis?: fish like shaped; brownish filamentous structure; green spherical structure with 2 longer and 2 shorter extremity
HE661	15	18.05.2025	14:02	003°39.94'	57°29.98'	65.00	5	Diatomeen: *Rhizosolenia*; Dinoflagellat: *Ceratium*; Echinoidea: *Spatangus pluteus*; *Profodrilus*?: outside transparen inside purple transparent; purple glassy structure (movement: trembling); green small structure (movement: trembling), possible synthetic fibers
HE661	17	19.05.2025	05:58	003°40.00'	57°09.96'	58.50	5	Diatomeen: *Chaetoceros*; Dinoflagellat: *Ceratium*; Echinoidea: *Spatangus pluteus*; green, half opend bowl structure; larva?: blue spherical structure
HE661	18	19.05.2025	07:36	003°30.06'	57°09.97'	60.00	5	Diatomeen: *Chaetoceros* (high abundance), yellow transparent spherical Diatomeen?; Dinoflagellat: *Ceratium*; Echinoidea: *Spatangus pluteus*;; green yellow filament frayed ends visible by eye

Cruise	**Station**	**Date**	**Time**	**Longitude**	**Latitude**	**Bot. Depth**	**Sample Depth**	**Description**
		dd/mm/yyyy	**[UTC]**	**[°E]**	**[°N]**	**[m]**	**[m]**	
HE661	19	19.05.2025	10:29	003°20.04'	57°09.99'	61.00	5	Diatomeen: *Leptocylindrus minimus* (high abundance), *Coscinodiscus conccinus* (high abundance)*/Bacillariophyceae*; Dinoflagellat: *Ceratium*
HE661	20	19.05.2025	12:06	003°10.09'	57°09.93'	61.00	5	Diatomeen: *Chaetoceros* (high abundance), *Coscinodiscus conccinus* (high abundance); Dinoflagellat: *Ceratium*; Copepoda; orange dark points on lightgreen transparent matrix; transparent green yellow spot; green transparent and top dark yellow-orange spot
HE661	21	19.05.2025	13:50	003°00.05'	57°09.94'	63.00	5	Diatomeen (high abundance): *Stephanopyxis*, yellow transparent Diatomeen; transparent structure with blue points
HE661	23	20.05.2025	03:47	003°40.22'	56°19.90'	63.00	5	Echinoidea: *Spatangus pluteus* (high abundance); Diatomeen?: spheric small orange structure; green filamentous structure in different size; Larva?: big green transparent spheric structure, less diversity

11.3 Protocol: Conductivity-Temperature-Depth Rosette Sampler (CTD)

Table 11.3 List of sampled stations, depths sampled in the water column and amount of filtrated sample with the CTD.

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Filtrated Amount	Filter empty
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[m]	[l]	[mg]
HE661	1	16.05.2025	12:38	003°49.96'	56°20.01'	65.60	65.60	7.0	129.45
HE661	1	16.05.2025	12:38	003°49.96'	56°20.01'	65.60	30.10	5.0	129.13
HE661	1	16.05.2025	12:38	003°49.96'	56°20.01'	65.60	1.30	7.0	138.62
HE661	2	16.05.2025	14:25	003°49.91'	56°30.13'	59.70	59.30	7.0	131.55
HE661	2	16.05.2025	14:25	003°49.91'	56°30.13'	59.70	31.30	6.0	127.96
HE661	2	16.05.2025	14:25	003°49.91'	56°30.13'	59.70	1.70	8.0	128.51
HE661	3	16.05.2025	16:06	003°49.99'	56°39.99'	46.70	46.70	8.0	128.92
HE661	3	16.05.2025	16:06	003°49.99'	56°39.99'	46.70	31.10	8.0	125.95
HE661	3	16.05.2025	16:06	003°49.99'	56°39.99'	46.70	1.80	8.0	128.64
HE661	5	17.05.2025	06:07	003°39.92'	57°19.93'	58.20	51.50	5.5	129.84
HE661	5	17.05.2025	06:07	003°39.92'	57°19.93'	58.20	30.50	4.0	128.93
HE661	5	17.05.2025	06:07	003°39.92'	57°19.93'	58.20	1.80	5.5	128.40
HE661	6	17.05.2025	08:14	003°30.05'	57°19.97'	59.00	51.00	10.0	126.43
HE661	6	17.05.2025	08:14	003°30.05'	57°19.97'	59.00	31.10	4.0	124.95
HE661	6	17.05.2025	08:14	003°30.05'	57°19.97'	59.00	2.90	10.5	128.38
HE661	7	17.05.2025	10:32	003°20.02'	57°19.99'	60.00	54.20	9.0	130.07
HE661	7	17.05.2025	10:32	003°20.02'	57°19.99'	60.00	26.10	4.5	125.27
HE661	7	17.05.2025	10:32	003°20.02'	57°19.99'	60.00	2.00	4.0	136.38
HE661	8	17.05.2025	13:02	003°10.01'	57°19.98'	56.00	56.00	10.0	128.89

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Filtrated Amount	Filter empty
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[m]	[l]	[mg]
HE661	8	17.05.2025	13:02	003°10.01'	57°19.98'	56.00	27.70	5.0	128.74
HE661	8	17.05.2025	13:02	003°10.01'	57°19.98'	56.00	2.00	3.0	120.99
HE661	9	17.05.2025	14:39	003°60.02'	57°19.99'	64.00	58.10	11.5	129.90
HE661	9	17.05.2025	14:39	003°60.02'	57°19.99'	64.00	32.20	4.5	130.51
HE661	9	17.05.2025	14:39	003°60.02'	57°19.99'	64.00	2.20	3.5	129.83
HE661	11	18.05.2025	6:09	002°59.87'	57°29.96'	60.00	52.30	6.0	126.82
HE661	11	18.05.2025	6:09	002°59.87'	57°29.96'	60.00	36.10	6.0	128.87
HE661	11	18.05.2025	6:09	002°59.87'	57°29.96'	60.00	2.00	6.0	127.55
HE661	12	18.05.2025	07:58	003°09.96'	57°29.99'	58.50	52.80	7.0	136.91
HE661	12	18.05.2025	07:58	003°09.96'	57°29.99'	58.50	36.20	5.5	129.11
HE661	12	18.05.2025	07:58	003°09.96'	57°29.99'	58.50	1.30	6.0	129.62
HE661	13	18.05.2025	10:31	003°19.83'	57°30.09'	62.20	55.20	7.0	126.45
HE661	13	18.05.2025	10:31	003°19.83'	57°30.09'	62.20	32.80	4.0	130.59
HE661	13	18.05.2025	10:31	003°19.83'	57°30.09'	62.20	2.30	6.0	125.85
HE661	14	18.05.2025	12:30	003°30.07'	57°30.00'	61.00	57.30	7.0	129.78
HE661	14	18.05.2025	12:30	003°30.07'	57°30.00'	61.00	35.70	8.0	129.62
HE661	14	18.05.2025	12:30	003°30.07'	57°30.00'	61.00	2.40	6.5	128.31
HE661	15	18.05.2025	14:11	003°39.94'	57°29.98'	64.00	59.20	8.0	122.37
HE661	15	18.05.2025	14:11	003°39.94'	57°29.98'	64.00	27.40	6.0	130.72
HE661	15	18.05.2025	14:11	003°39.94'	57°29.98'	64.00	2.20	6.0	137.26
HE661	17	19.05.2025	06:03	003°40.00'	57°09.96'	53.40	53.40	10.0	126.04
HE661	17	19.05.2025	06:03	003°40.00'	57°09.96'	53.40	29.90	5.0	125.61

Cruise	**Station**	**Date**	**Time**	**Longitude**	**Latitude**	**Bot. Depth**	**Sample Depth**	**Filtrated Amount**	**Filter empty**
		dd.mm.yyyy	**[UTC]**	**[°E]**	**[°N]**	**[m]**	**[m]**	**[l]**	**[mg]**
HE661	17	19.05.2025	06:03	003°40.00'	57°09.96'	53.40	1.70	3.5	127.83
HE661	18	19.05.2025	07:44	003°30.06'	57°09.97'	60.00	56.80	6.0	129.96
HE661	18	19.05.2025	07:44	003°30.06'	57°09.97'	60.00	34.60	10.0	128.22
HE661	18	19.05.2025	07:44	003°30.06'	57°09.97'	60.00	2.90	3.5	123.15
HE661	19	19.05.2025	10:38	003°20.04'	57°09.99'	58.00	58.00	8.0	128.91
HE661	19	19.05.2025	10:38	003°20.04'	57°09.99'	58.00	33.50	5.0	122.80
HE661	19	19.05.2025	10:38	003°20.04'	57°09.99'	58.00	1.60	3.0	125.84
HE661	20	19.05.2025	12:17	003°10.09'	57°09.93'	60.20	60.20	8.0	124.23
HE661	20	19.05.2025	12:17	003°10.09'	57°09.93'	60.20	30.90	8.0	128.58
HE661	20	19.05.2025	12:17	003°10.09'	57°09.93'	60.20	1.90	4.0	120.77
HE661	21	19.05.2025	13:58	003°00.05'	57°09.94'	63.00	61.00	8.0	126.51
HE661	21	19.05.2025	13:58	003°00.05'	57°09.94'	63.00	32.00	2.0	127.34
HE661	21	19.05.2025	13:58	003°00.05'	57°09.94'	63.00	2.80	6.0	126.55
HE661	23	20.05.2025	03:56	003°40.22'	56°19.90'	60.20	60.20	8.0	125.56
HE661	23	20.05.2025	03:56	003°40.22'	56°19.90'	60.20	37.80	8.0	126.00
HE661	23	20.05.2025	03:56	003°40.22'	56°19.90'	60.20	2.10	8.0	121.73

11.4 Protocol: Bottom Water Sampler (BWS)

Table 11.4 List of the location of stations and sampled depth above the seafloor from the BWS.

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Depth above Seafloor	Filtrated Amount	Filter empty
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[l]	[l]	[mg]
HE661	3	16.05.2025	16:21	003°49.99'	56°39.99'	53.0	110.50	5.00	128.88
HE661	3	16.05.2025	16:21	003°49.99'	56°39.99'	53.0	58.00	5.00	126.72
HE661	3	16.05.2025	16:21	003°49.99'	56°39.99'	53.0	28.50	4.90	129.69
HE661	5	17.05.2025	6:38	003°39.92'	57°19.93'	59.5	110.50	5.00	129.8
HE661	5	17.05.2025	6:38	003°39.92'	57°19.93'	59.5	58.00	5.00	129.44
HE661	5	17.05.2025	6:38	003°39.92'	57°19.93'	59.5	28.50	4.10	128.32
HE661	6	17.05.2025	8:25	003°30.05'	57°19.97'	60.0	110.50	5.00	129.19
HE661	6	17.05.2025	8:25	003°30.05'	57°19.97'	60.0	58.00	5.00	128.03
HE661	6	17.05.2025	8:25	003°30.05'	57°19.97'	60.0	28.50	4.85	131.3
HE661	7	17.05.2025	11:06	003°20.02'	57°19.99'	60.0	110.50	5.00	130.77
HE661	7	17.05.2025	11:06	003°20.02'	57°19.99'	60.0	58.00	5.00	129.44
HE661	7	17.05.2025	11:06	003°20.02'	57°19.99'	60.0	28.50	5.00	126.8
HE661	8	17.05.2025	13:13	003°10.01'	57°19.98'	62.0	110.50	5.00	130.06
HE661	8	17.05.2025	13:13	003°10.01'	57°19.98'	62.0	58.00	5.00	129.14
HE661	8	17.05.2025	13:13	003°10.01'	57°19.98'	62.0	28.50	5.00	125.24
HE661	9	17.05.2025	14:58	003°60.02'	57°19.99'	64.5	110.50	5.00	124.83
HE661	9	17.05.2025	14:58	003°60.02'	57°19.99'	64.5	58.00	5.00	124.34
HE661	9	17.05.2025	14:58	003°60.02'	57°19.99'	64.5	28.50	5.00	124.25
HE661	11	18.05.2025	6:22	002°59.87'	57°29.96'	59.7	110.50	5.00	124.05

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Depth above Seafloor	Filtrated Amount	Filter empty
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[l]	[l]	[mg]
HE661	11	18.05.2025	6:22	002°59.87'	57°29.96'	59.7	58.00	5.00	127.64
HE661	11	18.05.2025	6:22	002°59.87'	57°29.96'	59.7	28.50	5.00	134.52
HE661	12	18.05.2025	8:09	003°09.96'	57°29.99'	58.0	110.50	-	-
HE661	12	18.05.2025	8:09	003°09.96'	57°29.99'	58.0	58.00	-	-
HE661	12	18.05.2025	8:09	003°09.96'	57°29.99'	58.0	28.50	-	-
HE661	13	18.05.2025	10:44	003°19.83'	57°30.09'	61.0	110.50	5.00	122.193
HE661	13	18.05.2025	10:44	003°19.83'	57°30.09'	61.0	58.00	5.00	132.352
HE661	13	18.05.2025	10:44	003°19.83'	57°30.09'	61.0	28.50	5.00	122.039
HE661	14	18.05.2025	12:45	003°30.07'	57°30.00'	63.0	110.50	5.00	128.67
HE661	14	18.05.2025	12:45	003°30.07'	57°30.00'	63.0	58.00	5.00	127.05
HE661	14	18.05.2025	12:45	003°30.07'	57°30.00'	63.0	28.50	4.70	126.2
HE661	15	18.05.2025	14:22	003°39.94'	57°29.98'	64.5	110.50	5.00	123.68
HE661	15	18.05.2025	14:22	003°39.94'	57°29.98'	64.5	58.00	5.00	129.4
HE661	15	18.05.2025	14:22	003°39.94'	57°29.98'	64.5	28.50	5.00	126.27
HE661	17	19.05.2025	6:22	003°40.00'	57°09.96'	58.0	110.50	5.00	126.98
HE661	17	19.05.2025	6:22	003°40.00'	57°09.96'	58.0	58.00	5.00	121.898
HE661	17	19.05.2025	6:22	003°40.00'	57°09.96'	58.0	28.50	5.00	128.25
HE661	18	19.05.2025	7:56	003°30.06'	57°09.97'	59.5	110.50	5.00	125.83
HE661	18	19.05.2025	7:56	003°30.06'	57°09.97'	59.5	58.00	5.00	125.26
HE661	18	19.05.2025	7:56	003°30.06'	57°09.97'	59.5	28.50	5.00	122.59
HE661	19	19.05.2025	10:49	003°20.04'	57°09.99'	60	110.50	5.00	128.07
HE661	19	19.05.2025	10:49	003°20.04'	57°09.99'	60	58.00	5.00	127.18

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Depth above Seafloor	Filtrated Amount	Filter empty
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[l]	[l]	[mg]
HE661	19	19.05.2025	10:49	003°20.04'	57°09.99'	60	28.50	4.36	125.75
HE661	20	19.05.2025	12:33	003°10.09'	57°09.93'	60	110.50	5.00	125.44
HE661	20	19.05.2025	12:33	003°10.09'	57°09.93'	60	58.00	5.00	128.57
HE661	20	19.05.2025	12:33	003°10.09'	57°09.93'	60	28.50	4.89	127.91
HE661	21	19.05.2025	14:15	003°00.05'	57°09.94'	63	110.50	5.00	122.954
HE661	21	19.05.2025	14:15	003°00.05'	57°09.94'	63	58.00	5.00	124.76
HE661	21	19.05.2025	14:15	003°00.05'	57°09.94'	63	28.50	5.00	126.08
HE661	23	20.05.2025	4:11	003°40.22'	56°19.90'	63	110.50	5.00	125
HE661	23	20.05.2025	4:11	003°40.22'	56°19.90'	63	58.00	5.00	126.59
HE661	23	20.05.2025	4:11	003°40.22'	56°19.90'	63	28.50	5.00	121.512

11.5 Protocol: Van Veen Grab (vVG) and Sediment Permeability

Table 11.5 List and protocols of the sediment samples from the vVG and the permeability. Sediment colours were determined with the MUNSELL Color Chart. Key for Grain size: 1=clay, 2=fine silt, 3=coarse silt, 4=fine sand, 5=middle sand, 6=coarse sand, 7=gravel/rubble.

Cruise	Station	Date	Time	Longtiude	Latitude	Bot. Depth	Grain size	Permeability	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]		[cm/s]	
HE661	1	16.05.2025	12:45	003°49.96'	56°20.01'	70.00	4	0.00049	0-3cm u fS 10Y3/2; 3-9cm u fS 10Y3/; 9+cm u fS 10Y3/2; sporadic mussel fragments from 9cm, worm; samples: 0-2cm (Micropal), 0-1cm (biogeochemistry)
HE661	2	16.05.2025	14:37	003°49.91'	56°30.13'	64.00	4	0.00117	0-2cm fS 2,5Y4/3; 2-6cm u fS 7,5Y2/1; 6+cm u fS 10Y4/2; undamaged mussels, mussel fragments in the upper 4-7cm; samples: 0-2cm (Schmiedl), 0-1cm (biogeochemistry)
HE661	3	16.05.2025	16:33	003°49.99'	56°39.99'	52.00	4,5	0.00012	0-8cm fS-mS 2,5Y5/3; 8+cm fs,ms,o, 2,5Y2/1; mussels, mussel fragments, Echniodermata in the 0-8cm, sporadic worms beginning after ab 8cm
HE661	5	17.05.2025	06:54	003°39.92'	57°19.93'	59.00	4	0.00404	0-3cm ms,fs,u, 2,5Y4/3; 3-7,5cm lenses: u, fs, otherwise ms 2,5Y3/1; mussels, mussel fragments, plenty worms; no picture

Cruise	Station	Date	Time	Longtiude	Latitude	Bot. Depth	Grain size	Permeability	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]		[cm/s]	
HE661	6	17.05.2025	08:41	003°30.05'	57°19.97'	59.00	3,4,5	0.01560	0-4 cm U, mS, fS, 2,5Y5/3; 4+ cm U, mS, fS, 2,5Y4/2; lenses U, mS, fS, 2,5Y2/1, mussels, mussel fragments, Echinodermata, worms; samples: 0-2 cm (Micropal)
HE661	7	17.05.2025	11:18	003°20.02'	57°19.99'	60.20	3,4,5	0.00661	0-4,5 cm U, fS, mS, 5Y3/2; 4,5+ cm U, fS, mS, 2,5Y4/4; lenses U, fS, mS, 2,5Y2/1; mussels, mussel fragments, worms; samples: 0-2 cm (Micropal)
HE661	8	17.05.2025	13:27	003°10.01'	57°19.98'	63.00	3,4,5	0.00538	In core (MUC) no bedding visible, in Grab different bedding visible: 1. U, fS, mS, 2,5Y5/3; 2. U, fS, mS, 2,5Y4/2; 3. U, fS, mS, 2,5Y2/1; In core (MUC) only top Layer visible; mussels, mussel fragments, sporadic worms, Aphrodita; samples: 0-2cm (Micropal), 0-1cm (biogeochemestry)
HE661	9	17.05.2025	15:13	003°60.02'	57°19.99'	62.80	4,5	0.00527	0-5 cm fS, mS; 5Y5/3; 5+ cm fS, mS 5Y3/2; lenses fS, mS, 5Y3/3; sporadic worms, mussels, mussel fragments; sample: 0-1 cm Biogeochemistry

Cruise	**Station**	**Date**	**Time**	**Longtiude**	**Latitude**	**Bot. Depth**	**Grain size**	**Permeability**	**Description**
		dd.mm.yyyy	**[UTC]**	**[°E]**	**[°N]**	**[m]**		**[cm/s]**	
HE661	11	18.05.2025	6:40	002°59.87'	57°29.96'	60.00	4,5	0.00779	generel: fS, mS, plenty mussel fragments; from 4 cm, mussels, organic rich lenses (muddy, peaty smell): 0-4 cm 5Y5/4; 4+ cm 5Y4/2; lenses 5Y2/1; samples: 0-2 cm (Micropal)
HE661	12	18.05.2025	8:28	003°09.96'	57°29.99'	58.00	5	0.02323	No bedding, mS, 2,5Y4/4; dark organic rich lenses; medium mussel fragments, small fine tubes (filtration tubes), plant remains (roots with stem); samples: 0-2 cm (Micropal)
HE661	13	18.05.2025	11:00	003°19.83'	57°30.09'	61.00	4	0.01218	generel: fS, less mS, tubes (filtration tubes), sporadic mussel fragments, Cedephora, mussels, one worm; 0-2 cm 5Y4/3; 2+ cm 7,5Y3/2; lenses 7,5Y2/1, organic rich; compared to station 12: less mussel fragments
HE661	14	18.05.2025	12:57	003°30.07'	57°30.00'	61.00	5	0.01622	0-10 cm mS, 2,5Y4/2; 10+ cm, mS, fS, 2,5Y4/1; lenses 2,5Y3/1; Layer begging from 10 cm: mussel fragments, dark organic rich lenses; filtration tubes at top and first 2 cm

Cruise	**Station**	**Date**	**Time**	**Longtiude**	**Latitude**	**Bot. Depth**	**Grain size**	**Permeability**	**Description**
		dd.mm.yyyy	**[UTC]**	**[°E]**	**[°N]**	**[m]**		**[cm/s]**	
HE661	15	18.05.2025	14:35	003°39,.94'	57°29.98'	65.00	5	0.00057	mS, 5Y4/2; no bedding, organic rich lenses with plenty mussel fragments (big mussels), filtration tubes (at top and first 2 cm), worm, hermit crab (alive), one glacial erratic (4*3*3 cm), mussels
HE661	17	19.05.2025	6:34	003°40.00'	57°09.96'	58.50	3,4,5	0.00464	0-3cm 5Y 4/3, fS-mS, less u; 3-9cm 5Y 3/2 fS-mS, few black lenses: 5Y 3/1 => plenty organic; mussel fragments, worm tunnels and worms, few whole mussels
HE661	18	19.05.2025	8:10	003°30.06'	57°09.97'	60.00	(3),4,5	0.00046	0-7cm 5Y 4/4; 7-14cm 5Y 3/2; 14-16cm 5Y 2/2; fS-mS (few u/t); whole mussels, 2 starfish, worm tunnels, mussel fragments
HE661	19	19.05.2025	11:03	003°20.04'	57°09.99'	61.00	3,4,5	0.00049	0-5cm 5Y 5/4, s, few whole mussels, few mussel fragments; 5-8cm lenses (organic rich), 5Y 3/1; 8-11cm 5Y 4/2; deeper more mussel fragments and alive sea urchin, s; from 5cm higher T/U content

Cruise	Station	Date	Time	Longtiude	Latitude	Bot. Depth	Grain size	Permeability	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]		[cm/s]	
HE661	20	19.05.2025	12:42	003°10.09'	57°09.93'	61.00	3,4,5	0.00121	0-3cm 5Y 4/3, S; 3-5cm 5Y 3/2, S dark (organic rich), T and U content about 20%; no vertical worm tunnels, dark lenses, 3 sea urchins (Clypeaster)
HE661	21	19.05.2025	14:24	003°00.05'	57°09.94'	63.00	3,4	0.00974	0-3cm 5Y 4/4, fS with low T and U content; from 3cm 5Y 3/2, fS with low T and U content, extra dark organic lenses (5Y 3/1); mussel fragments deeper more than at top
HE661	23	20.05.2025	3:47	003°40.22'	56°19.90'	63.00	(3),4,5	0.00142	0-3cm 5Y 4/2, fS-mS (low T/U content), whole mussels and plenty big mussel fragments; 3-8cm 5Y 3/1; partly dark lenses (5Y 2/2), organic with muddy smell, fS-mS (low T/U content)

11.6 Protocol: Multicorer (MUC)

Table 11.6 List and protocols of the sediment samples taken with the MUC. Sediment colours were determined with the MUNSELL Color Chart. Key for Grain size: 1=clay, 2=fine silt, 3=coarse silt, 4=fine sand, 5=middle sand, 6=coarse sand, 7=gravel/rubble.

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Penetration Depth	Grain size	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[cm]	[m]		
HE661	3	16.05.2025	16:59	003°49.99'	56°39.99'	52.00	0-2	0.12	4	0-1 cm mussel fragments, color: 5Y4/3; 1-2 cm less mussel fragments, color: 5Y5/3; 2-3 cm 5Y5/3, 3-4 cm mussel fragments, dark lenses, color: 5Y5/3, 4-5 cm mussel fragments, 5Y 4/4; 5-6cm 1x mussel fragment 5Y5/3; 6-7cm mussel fragment, 5Y 4/3; 7-8 cm 5Y3/2; sampels from core HE661-03-02
HE661	3	16.05.2025	16:59	003°49.99'	56°39.99'	52.00	0-5	0.12	4	0-1 cm mussel fragments, color: 5Y4/3; 1-2 cm less mussel fragments, color: 5Y5/3; 2-3 cm 5Y5/3, 3-4 cm mussel fragments, dark lenses, color: 5Y5/3, 4-5 cm mussel fragments, 5Y 4/4; 5-6cm 1x mussel fragment 5Y5/3; 6-7cm mussel fragment, 5Y 4/3; 7-8 cm 5Y3/2; sampels from core HE661-03-02
HE661	5	17.05.2025	07:00	003°39.92'	57°19.93'	59.00	0-1	0.01	4	Mussel at surface, mussel fragments in core, homogeneous fS, 5Y4/4

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Penetration Depth	Grain size	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[cm]	[m]		
HE661	6	17.05.2025	08:47	003°30.05'	57°19.97'	59.00	0-2	0.07	4	Plenty whole mussels, big mussels, big mussel fragments, homogeneous fS, 5Y4/3
HE661	7	17.05.2025	11:40	003°20.02'	57°19.99'	60.20	0-2	0.11	4	0-1 cm grey-brown 2,5Y3/1 and 2,5Y4/6; from 1cm grey-brown mussel fragments, s, 5Y3/2, whole mussels at bottom, 4-5 cm few lenses, 5Y3/2
HE661	7	17.05.2025	11:40	003°20.02'	57°19.99'	60.20	0-5	0.11	4	0-1 cm grey-brown 2,5Y3/1 and 2,5Y4/6; from 1cm grey-brown mussel fragments, s, 5Y3/2, whole mussels at bottom, 4-5 cm few lenses, 5Y3/2
HE661	8	17.05.2025	13:37	003°10.01'	57°19.98'	63.00		0.05	4	0-2 cm big mussel fragments, worm, 5Y5/4, 2-5 cm, s 5Y4/3
HE661	9	17.05.2025	15:13	003°60.02'	57°19.99'	62.80				No core sampling possible
HE661	11	18.05.2025	6:50	002°59.87'	57°29.96'	60.00	0-2	0.09	4	Mussel fragments, 2,5Y5/3, fS,ms
HE661	12	18.05.2025	8:52	003°09.96'	57°29.99'	58.00	0-4	0.06	4	Mussel fragments, one layer, 2,5Y5/4, 1try unsuccessful, 2. Try successful
HE661	13	18.05.2025	11:22	003°19.83'	57°30.09'	61.00	0-1	0.02	4	Mussel fragments, 2,5Y4/3, fS, 1. try unsuccessful, 2. Try successful

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Penetration Depth	Grain size	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[cm]	[m]		
HE661	14	18.05.2025	13:03	003°30.07'	57°30.00'	61.00	0-5	0.05	4	5Y4/2, Crustacea, mussel fragments, homogeneous layer, dark lenses, probably organic rich
HE661	15	18.05.2025	14:44	003°39,.94'	57°29.98'	65.00	0-3	0.03	4	Plenty mussel fragments, dark lenses (anoxic and organic?) fS-mS, 5Y4/3
HE661	17	19.05.2025	06:40	003°40.00'	57°09.96'	58.50	0-2	0.13	4	Mussel fragments at surface; 0-5 cm 2,5Y4/4; 5-8 cm dark layer downwards, 2,5 Y 3/1; 8-13 cm mussel fragments 2,5 Y 3/2, fS-mS, u
HE661	17	19.05.2025	06:40	003°40.00'	57°09.96'	58.50	0-5	0.13	4	Mussel fragments at surface; 0-5 cm 2,5Y4/4; 5-8 cm dark layer downwards, 2,5 Y 3/1; 8-13 cm mussel fragments 2,5 Y 3/2, fS-mS, u
HE661	18	19.05.2025	08:17	003°30.06'	57°09.97'	60.00	0-2	0.13	4	fS-mS, u, mussels and mussel fragments, jellyfish in water column 0-6 cm 2,5Y4/4, 6-13 cm 2,5Y4/3 lenses: 2,5Y3/1
HE661	19	19.05.2025	08:18	003°30.06'	57°09.97'	60.00	0-5	0.13	5	fS-mS, u, mussels and mussel fragments, jellyfish in water column 0-6 cm 2,5Y4/4, 6-13 cm 2,5Y4/3 lenses: 2,5Y3/1

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Penetration Depth	Grain size	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[cm]	[m]		
HE661	19	19.05.2025	11:12	003°20.04'	57°09.99'	61.00	0-2	0.14	4	fS, u, 0-7 cm, mussels and mussel fragments, 2,5Y5/4, 7-14 cm 2,5Y4/2, crossed by dark areas 2,5Y3/1
HE661	20	19.05.2025	11:13	003°20.04'	57°09.99'	61.00	0-5	0.14	5	fS, u, 0-7 cm, mussels and mussel fragments, 2,5Y5/4, 7-14 cm 2,5Y4/2, crossed by dark areas 2,5Y3/1
HE661	20	19.05.2025	12:51	003°10.09'	57°09.93'	61.00	0-2	0.12	4	Mussel fragments, sea urchin, u fS, 0-2 cm 2,5 Y 5/4; 2-7 cm 2,5Y4/2; 7-12 cm vertical lenses 2,5Y3/1
HE661	20	19.05.2025	12:52	003°10.09'	57°09.93'	61.00	0-5	0.12	5	Mussel fragments, sea urchin, u fS, 0-2 cm 2,5 Y 5/4; 2-7 cm 2,5Y4/2; 7-12 cm vertical lenses 2,5Y3/1
HE661	21	19.05.2025	14:32	003°00.05'	57°09.94'	63.00	0-2	0.09	4	0-1 cm 2,5Y4/2; 1-2 cm 2,5Y4/6; 2-5 cm 2,5Y5/4; 5-9 cm 2,5Y4/2, mussel fragments
HE661	21	19.05.2025	14:33	003°00.05'	57°09.94'	63.00	0-5	0.09	5	0-1 cm 2,5Y4/2; 1-2 cm 2,5Y4/6; 2-5 cm 2,5Y5/4; 5-9 cm 2,5Y4/2, mussel fragments
HE661	23	20.05.2025	04:41	003°40.22'	56°19.90'	63.00	0-2	0.12	4	Mussel fragments, mussels; 0-2 cm 2,5Y5/4, fS,ms; 2-4 cm 5Y4/2 fS, mS, 4-12 cm 2,5Y3/1, well developed dark layer

Cruise	Station	Date	Time	Longitude	Latitude	Bot. Depth	Sample Depth	Penetration Depth	Grain size	Description
		dd.mm.yyyy	[UTC]	[°E]	[°N]	[m]	[cm]	[m]		
HE661	23	20.05.2025	04:42	003°40.22'	56°19.90'	63.00	0-5	0.12	5	Mussel fragments, mussels; 0-2 cm 2,5Y5/4, fS,ms; 2-4 cm 5Y4/2 fS, mS, 4-12 cm 2,5Y3/1, well developed dark layer

11.7 Selected Pictures of Samples

11.7.1 Filter of CTD

Fig. 11.1 CTD-Filters of stations 1 – 7.

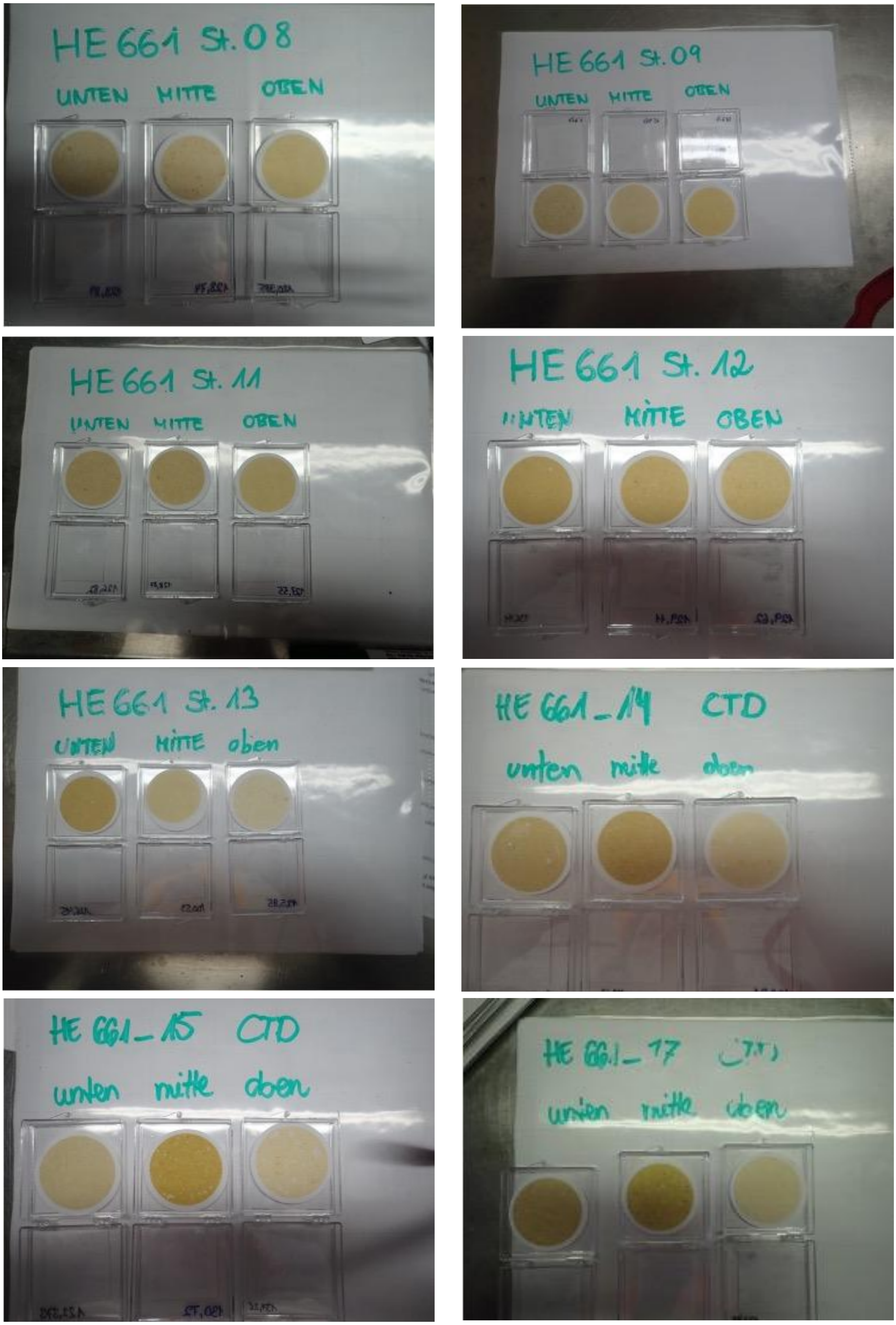


Fig. 11.2 CTD-Filters of stations 8 – 17.

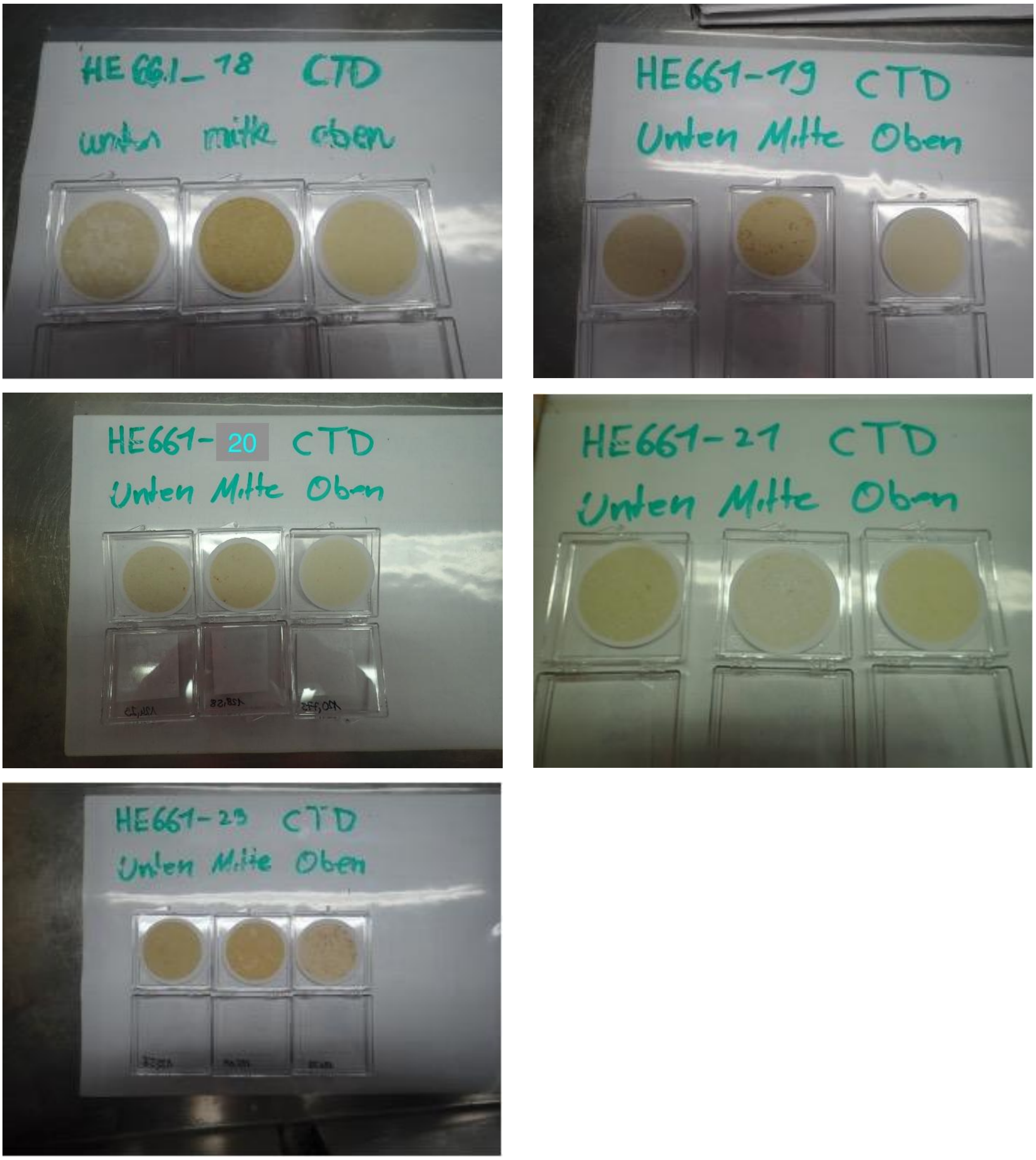
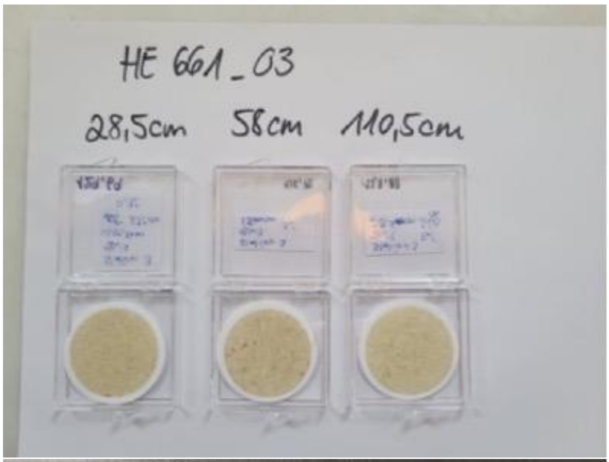
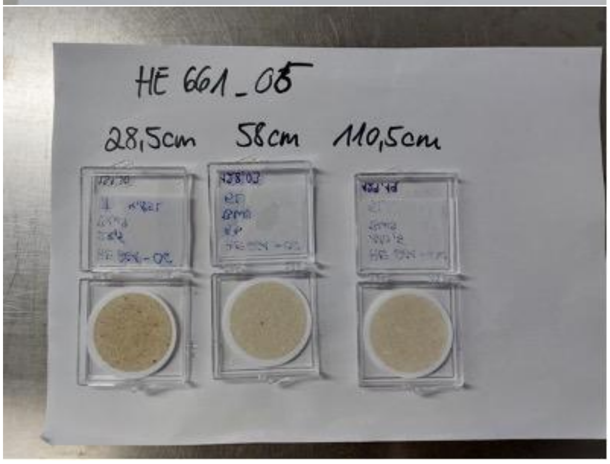


Fig. 11.3 CTD-Filters of stations 18 – 23.

11.7.2 Filter of BWS





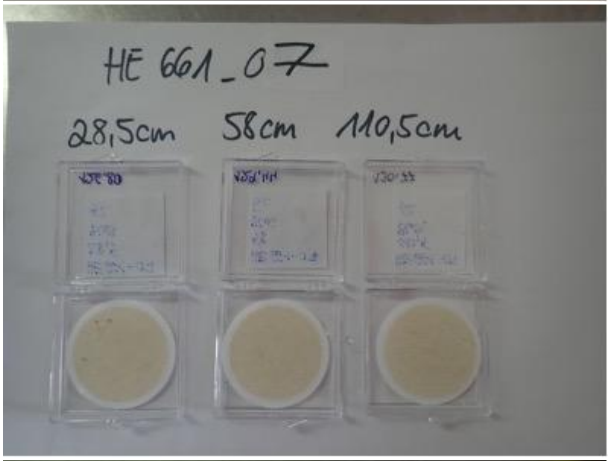
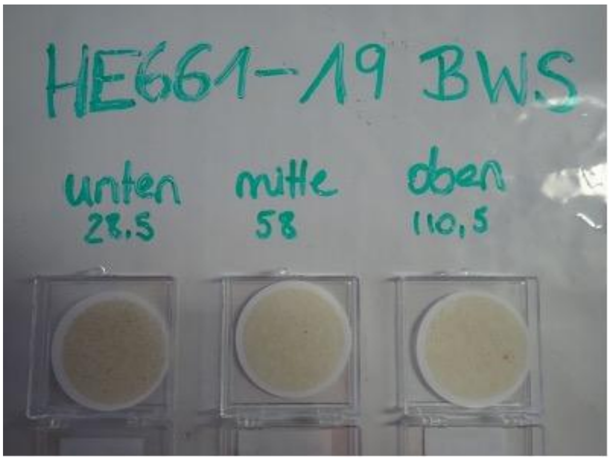
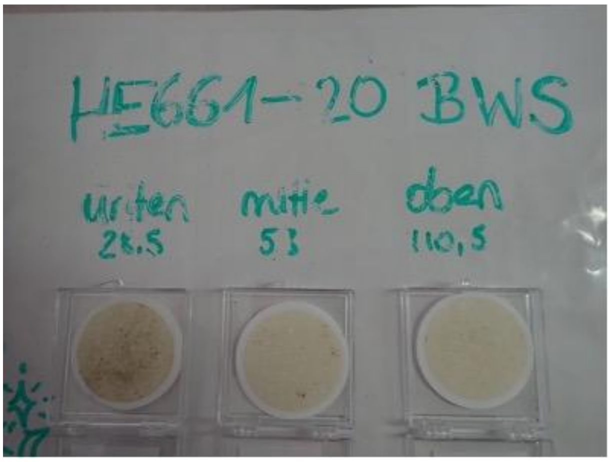


Fig. 11.4 BWS-Filters of stations 3 – 13.





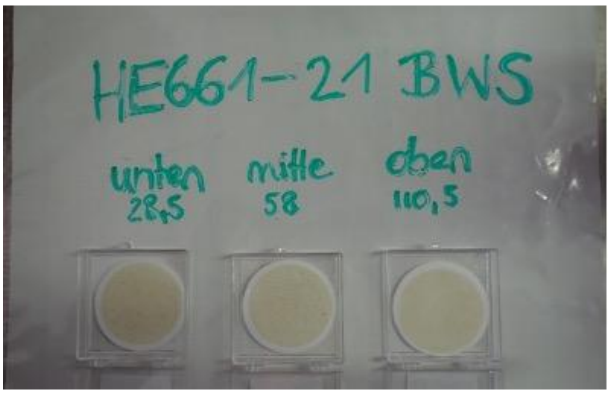


Fig. 11.5 CTD-Filters of stations 14 – 23.

11.7.3 Sediment Samples vVG

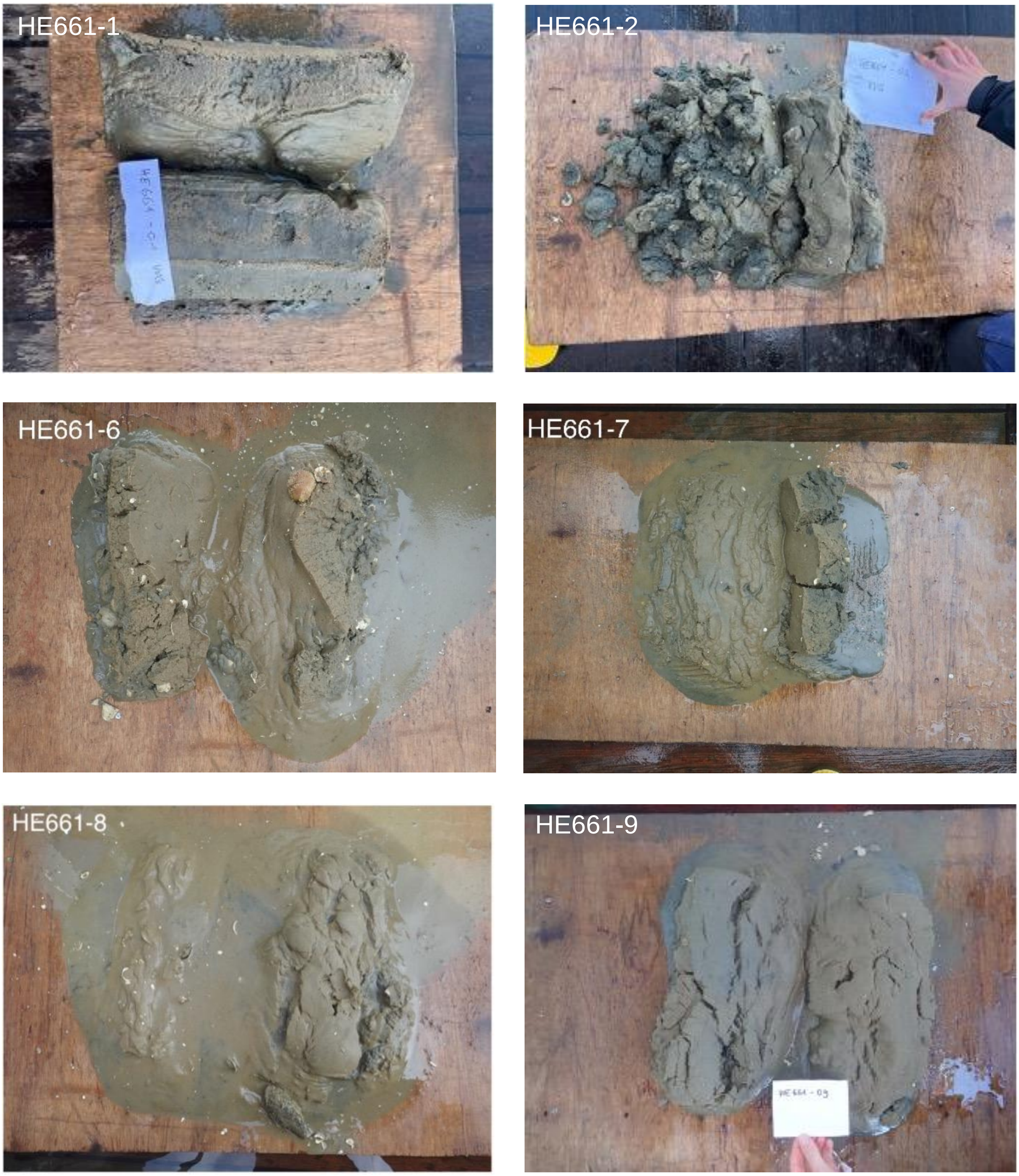


Fig. 11.6 vVG samples of stations 1 – 9.

Fig. 11.7 vVG samples of stations 11 – 19.

Fig. 11.8 vVG samples of stations 20 – 22.

11.7.4 Cores MUC

Fig. 11.9 Cores MUC of stations 1 – 13.

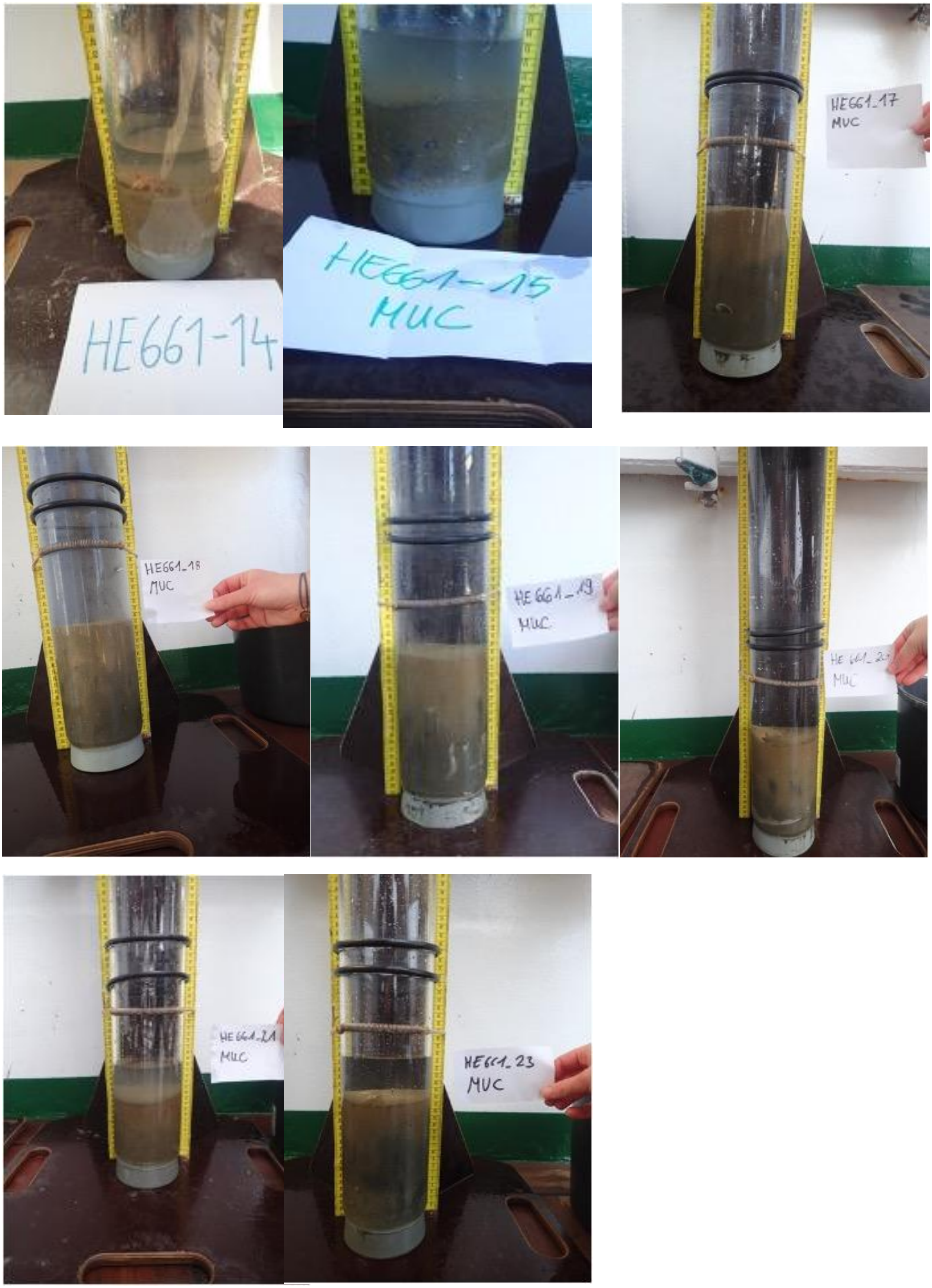


Fig. 11.10 Cores MUC of stations 14 – 23.

11.8 Selected Pictures of Shipboard Operations

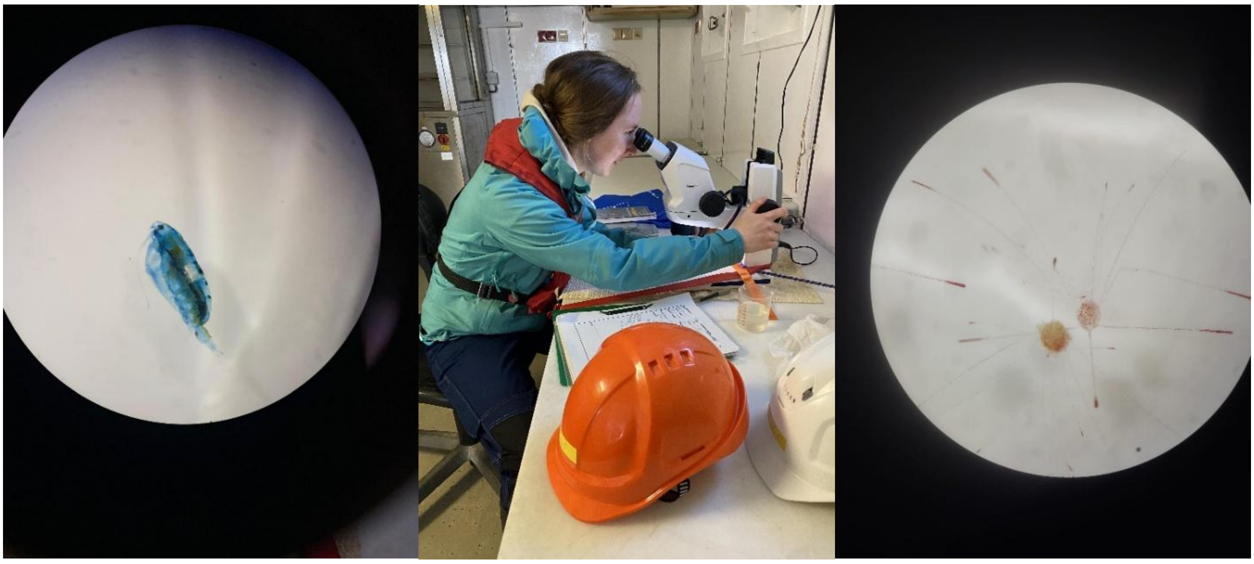


Fig. 11.11 Microscope work in the ship's lab.

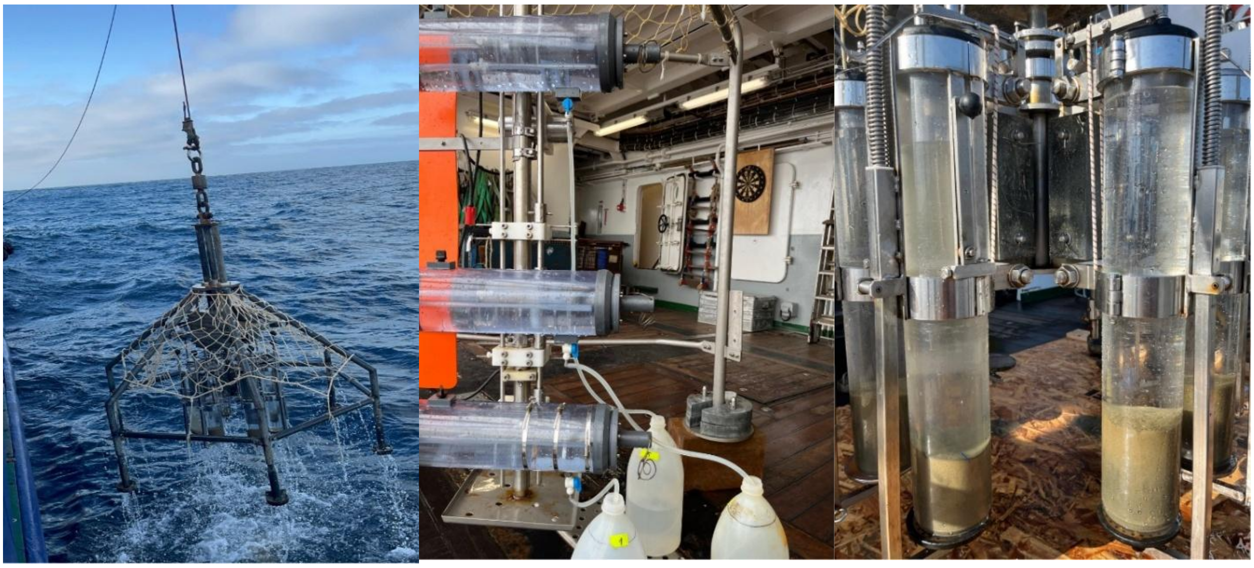


Fig. 11.12 left: MUC; middle: filling bottles at the BWS; right: cores MUC.

Fig. 11.13 left: Permeability; middle: CTD; right: filtration.

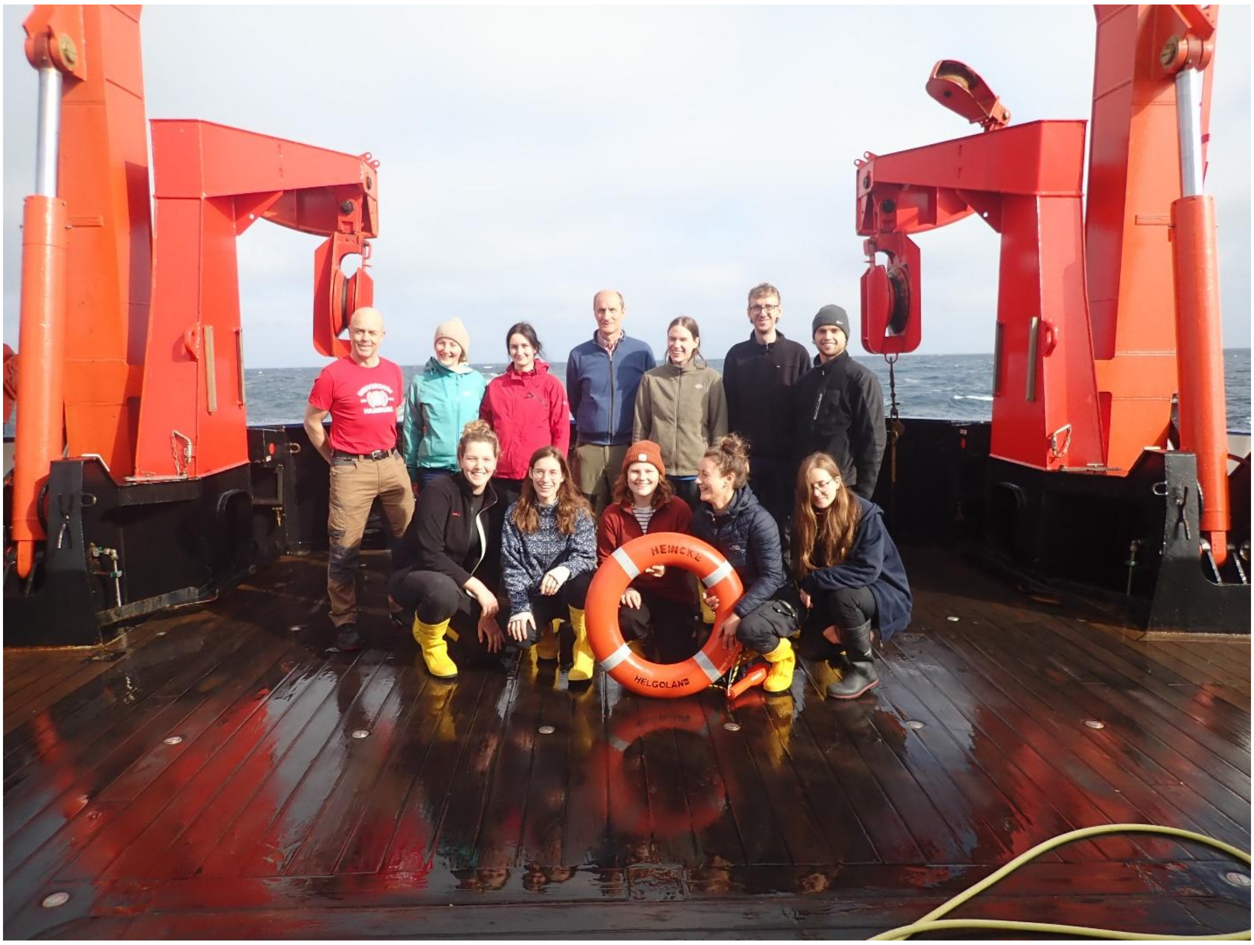


Fig. 11.14 Photo of the scientific party HE661.