ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

786
2024

Berichte
zur Polar- und Meeresforschung

Reports on Polar and Marine Research

The MOSES Sternfahrt Expeditions of the Research Vessels ALBIS, LITTORINA, LUDWIG PRANDTL and MYA II to the Elbe River, Elbe Estuary and German Bight in 2023

Edited by
Ingeborg Bussmann, Holger Brix, Philipp Fischer, Norbert Kamjunke, Martin Krauss, Björn Raupers and Tina Sanders

with contributions of the participants

HELMHOLTZ

Die Berichte zur Polar- und Meeresforschung werden vom Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) in Bremerhaven, Deutschland, in Fortsetzung der vormaligen Berichte zur Polarforschung herausgegeben. Sie erscheinen in unregelmäßiger Abfolge.

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The Reports on Polar and Marine Research contain presentations and results of research activities in polar regions and in the seas either carried out by the AWI or with its support.

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Titel: Der MOSES-Container an Deck der Littorina während des Sonnenaufgangs im Hafen von Helgoland. (Foto: B. Raupers, GEOMAR)

Cover: The MOSES container on deck of Littorina while the sun is rising at the harbour of Heligoland. (Photo: B. Raupers, GEOMAR)

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Please cite or link this publication using the identifiers

https://epic.awi.de/id/eprint/58855/

https://doi.org/10.57738/BzPM_0786_2024

ISSN 1866-3192

The MOSES Sternfahrten 2023
with RV *Albis*, RV *Littorina*, RV *Ludwig Prandtl*,
RV *Mya II*

Czech Elbe	**28.06. – 30.06.2023**
Binnen Elbe	**03.07. – 11.07.2023**
Tide Elbe	**23.08. – 28.08.2023**
Sternfahrt_10	**29.08. – 15.09.2023**
Sylt Transects	**January – December 2023**

Modular Observation Solutions for Earth Systems

Chief Scientists
Martin Krauss (UFZ) – land based
Norbert Kamjunke (UFZ) – RV *Albis*
Tina Sanders (Hereon) – RV *Ludwig Prandtl*
Holger Brix (Hereon) – RV *Ludwig Prandtl*
Björn Raupers (GEOMAR) – RV *Littorina*
Ingeborg Bussmann (AWI) – RV *Mya II*

Coordinator
Ingeborg Bussmann

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Im Rahmen des PoF-IV-Programms der Helmholtz-Gemeinschaft wurden im Jahr 2023 mehrere separate Expeditionen durchgeführt, um einen Beitrag zu den Forschungszielen des MOSES-Konsortiums zu leisten. Die Expeditionen erstreckten sich über ein weites Gebiet, von der Elbquelle in der Tschechischen Republik entlang der Elbe, der Tideelbe bis in die Deutsche Bucht der Nordsee.

Neben den bereits durchgeführten Fahrten wurden zudem Untersuchungen zu Treibhausgasen, Nährstoffen, Kohlenstoffverbindungen und der Hydrographie durchgeführt. Zudem wurden neue Kolleginnen und Kollegen mit neuen Parametern in die Gruppe aufgenommen, was zu einer Stärkung der Zusammenarbeit mit dem PoF IV Subtopic 4.1 führte. Die Verteilung und Transport von Sprengstoff, organischen und anorganischen Mikro-Schadstoffen, Spurenelementen, kunststoffassoziierten Chemikalien und Nanoplastik aus dem besiedelten Fluss Hinterland in die Nordsee konnte untersucht werden (siehe Kapitel 2).

Die Umsetzung des ehrgeizigen Programms war nur durch eine enge Zusammenarbeit zwischen den Helmholtz-Partnern und ihren Forschungsschiffen möglich. Zu den beteiligten Partnern zählten das UFZ mit der *Albis*, Hereon mit der *Ludwig Prandtl*, das Geomar mit der *Littorina* und das AWI mit der *Mya II*. Zudem wurde das Programm durch die tatkräftige Unter–stützung der Schiffsbesatzungen maßgeblich vorangebracht.

Die Expedition begann im Juni 2023 im Riesengebirge (Krkonoše), wo die Elbe entspringt, und führte bis zur tschechisch-deutschen Grenze. Der nächste Teil entlang der Elbe folgte im Juli des selben Jahres. Ein vielfältiges Set von Flaschen, Fläschchen und Schalen wurde mit Flusswasser, Flusssediment sowie mit Proben aus den Nebenflüssen der Elbe und aus Kläranlagen befüllt. Als nächster Schritt wurde Ende August die Tideelbe beprobt. Um einen besseren Zugang zum unvermischten Flusswasser zu erhalten, wurde die Beprobung gegen die Tide und flussaufwärts durchgeführt, beginnend bei Ebbe auf der Insel Scharhörn. Im Hamburger Hafen wurden ebenfalls mehrere Becken beprobt. Auf dem Rückweg nach Cuxhaven stoppte die *Ludwig Prandtl* mehrmals, um separate Sedimentproben zu nehmen. Der letzte Teil der Expeditionsreihe war Stern_10, die die Deutsche Bucht von Ende August bis Mitte September abdeckte. Im Gegensatz zu den Vorjahren wurde 2023 versucht, den Lagrange-Ansatz zu erweitern und einem theoretischen Wasserpaket zu folgen. Zu diesem Zweck wurden 12 Drifter aus der Gruppe von Jochen Horstmann (Hereon) eingesetzt. Im Vorfeld der Fahrt wurden der optimale Ort und die optimale Zeit modelliert bzw. berechnet. Die Drifter wurden an den ersten Tagen in der Elbmündung ausgesetzt und dann mit Forschungsschiffen und einer Vielzahl von Wasserproben in der Nähe der Drifter verfolgt. Um die Dauer dieser Verfolgung zu verlängern, wurden die Schiffe nacheinander eingesetzt. Um die Kontinuität der Messsensoren zu gewährleisten und zusätzlichen Platz im Labor zu schaffen, wurde der MOSES-Container im Vorfeld ausgestattet und dann von Schiff zu Schiff weitergegeben.

In den vergangenen Jahren wurde ein IT-System zum Austausch von Daten und Informationen zwischen den Schiffen auf der Nordsee implementiert. Im aktuellen Jahr lag der Fokus auf der zeitnahen Bereitstellung der Positionsdaten der Drifter. Die Kommunikation zwischen dem MOSES-Container auf den verschiedenen Schiffen und dem AWI-Storage-Center (über die Landstation auf Helgoland) wurde dabei über die Landstation auf Helgoland geleitet.

Insgesamt haben die Fahrten und Messungen sehr gut funktioniert und das fast fünfjährige Training und die erlangte Routine in der interinstitutionellen Zusammenarbeit im Rahmen des MOSES-Projekts hat sich als echter Gewinn für die Helmholtz-Küstenforschung erwiesen. Die schiffsgestützten Messungen und die enge Zusammenarbeit mit den Datenzentren und Datenmanagern der beteiligten Institute ermöglichten eine nahtlose Übergabe der Daten vom Feld an die Landbesatzung und vor allem an die Modellierer, die die Drifter zuhause live und online verfolgten und die Schiffe zu den besten Beprobungsstellen führten, um das Wasserpaket der Elbe in der Nordsee auch noch mehrere Wochen nach Verlassen der Elbmündung in Cuxhaven zu beproben. Dieser integrative Ansatz zwischen den verschiedenen Helmholtz-Zentren, den Forschern und den Schiffsbesatzungen erwies sich erneut als herausragend in der Küstenforschung.

Die durchgeführten Fahrten und Messungen waren insgesamt sehr erfolgreich und das fast fünfjährige Training sowie die erlangte Routine in der interinstitutionellen Zusammenarbeit im Rahmen des MOSES-Projekts haben sich als echter Gewinn für die Helmholtz-Küstenforschung erwiesen. Die schiffsgestützten Messungen und die enge Zusammenarbeit mit den Datenzentren und Datenmanagern der beteiligten Institute ermöglichten eine nahtlose Übergabe der Daten vom Feld an die Landbesatzung und insbesondere an die Modellierer.

Diese führten die Schiffe zu den besten Beprobungsstellen in der Nähe der Drifter, um das Wasserpaket der Elbe in der Nordsee auch noch mehrere Wochen nach Verlassen der Elbmündung in Cuxhaven zu beproben. Die genannten Beprobungen wurden von den an Land befindlichen Wissenschaftlerinnen und Wissenschaftlern live und online verfolgt. Der integrative Ansatz zwischen den verschiedenen Helmholtz-Zentren, den Forschenden und den Schiffsbesatzungen erwies sich einmal mehr als herausragend in der Küstenforschung.

SUMMARY AND ITINERARY

In 2023, several expeditions were conducted by the MOSES consortium in order to contribute to the research objectives outlined in the Helmholtz Association's PoF IV programme. These expeditions spanned a wide range of geographic locations, including the Elbe source in the Czech Republic, the Elbe River, the tidal Elbe, and the German Bight in the North Sea.

In addition to previous cruises, a range of additional parameters were assessed, including greenhouse gases, nutrients, carbon compounds and hydrography. New colleagues with new parameters (pollutants) joined our group, thereby strengthening our collaboration with PoF IV Topic 4.1. This enabled us to investigate the distribution of explosives, organic and inorganic micropollutants, trace elements, plastic-associated chemicals and nanoplastic from the populated river hinterland into the North Sea (see Chapter 2).

The ambitious programme was only possible through a strong cooperative effort between the Helmholtz partners and their research vessels. These included UFZ with the *Albis*, Hereon with the *Ludwig Prandtl*, Geomar with the *Littorina* and AWI with the *Mya II*. Additionally, the ship's crews provided invaluable support, demonstrating remarkable dedication and commitment.

The expedition commenced in June 2023 at Krkonoše (Giant Mountains), the source of the Elbe River, situated on the Czech/German border. The next phase of the expedition involved the Elbe River in July. A diverse range of containers, including bottles, vials and trays, were filled with river water, river sediment, samples from the Elbe tributaries and waste water treatments.

At the end of August, the next stage of the expedition involved the tidal Elbe River. In order to facilitate access to the unmixed river water, sampling was conducted against the tide, commencing at low tide on the island of Scharhörn. In Hamburg Port, several basins were also sampled. On the return journey to Cuxhaven, *Ludwig Prandtl* stopped on several occasions to allow for separate sediment sampling. The final phase of the expedition series was Stern_10, which spanned the German Bight from the end of August until mid-September. In contrast to previous years, in 2023 we attempted to extend the Lagrangian approach of following a theoretical water parcel. To this end, 12 drifters from the group of Jochen Horstmann (hereafter referred to as "drifters") were deployed. Prior to the cruise, the optimal location and time for deployment had been modelled and calculated. The drifters were initially deployed in the vicinity of the Elbe mouth, and then followed up with the research vessels for additional water sampling in the vicinity of these drifters. To extend the duration of this tracking, the vessels were operated one after the other. To ensure the continuity of the measuring sensors and to provide additional laboratory space, the MOSES container had been equipped in advance before being transferred from ship to ship.

In previous years, an IT system had been established to facilitate the exchange of data and information between the ships operating in the North Sea. This year, the objective was to rapidly provide the position data of the drifters. Consequently, the communication from the MOSES container on the different ships was directed to the AWI-storage centre (via the landstation on Heligoland) and subsequently back again.

Overall, the cruises and measurements were conducted effectively, and the extensive training and experience gained through inter-institutional collaboration within the MOSES project proved invaluable for Helmholtz Coastal Science. The ship provided support for measurements, while the close cooperation between the data centres and data managers of the participating institutes facilitated a seamless transfer of data from the field to the land crew and, in particular, to the modelers, who monitored the drifter tracks online at their home institutes and guided the ships to the most optimal sampling locations to sample the water parcel in the North Sea, even several weeks after it had left the Elbe mouth in Cuxhaven. This integrative approach among the different Helmholtz centres, researchers and ship crews was once again demonstrated to be outstanding in the field of coastal science.

2. MEASURED PARAMETERS

In addition to the sampling scheme of the previous cruises, several new colleagues have joined us in 2023, so a variety of new compounds will be analysed. Therefore, a short description of the different parameters is given in this overview. Details of the sampling plan can be found in the tables in the appendix.

Carbon compounds*

Analysed by Ingeborg Bussmann (AWI), Götz Flöser (Hereon), Norbert Kamjunke (UFZ), Björn Raupers (GEOMAR)

Rivers drain terrestrial environments and transport significant amounts of particulate and dissolved matter to the ocean. These materials undergo significant transformation processes within the river and adjacent estuarine and coastal systems. This is particularly the case for dissolved nutrients and carbon, which undergo complex biogeochemical transformations, including utilisation by autotrophic and heterotrophic microbes and subsequent recycling (Kamjunke et al, 2023). To assess these processes, the different compounds of the carbonate system, as well as the organic carbon and its chemical composition, were analysed.

**dissolved inorganic and organic carbon (DIC, DOC), particulate carbon (POC), total alkalinity (TA), dissolved organic carbon (DOM)*

Dual stable isotopes of nitrate

Analysed by Tina Sanders (Hereon)

The dual stable isotopes of nitrate are a good tool for unravelling the internal processes of the nitrogen cycle throughout the river. Fractionation during the processes that lead to enrichment or depletion of the natural supply. We have taken samples for isotopic analysis in the freshwater part, the tidal Elbe and the North Sea.

Explosives

Analysed by Björn Raupers (GEOMAR)

During the cruise, water samples were taken to be tested for Munition Compounds (MC). These munitions compounds, such as TNT, RDX, HMX and DNB, leach into the ocean from dumped munitions. Most of the munitions were dumped after the end of the Second World War (WWII). An estimated 1,300,000 tonnes of munitions and an additional 9,000 tonnes of chemical warfare agents were dumped in the German North Sea (Böttcher et al., 2011). In the first twenty years after the Second World War, some of the munitions were recovered to recycle the metal shells into resources for industry and construction materials. But much of the dumped munitions remained on the seabed. Now, eighty years later, many of the shells have corroded to the point where the MC can now dissolve into the sea. The German North Sea presents a unique challenge when it comes to locating munitions dumps, as most of it is covered by sand and mud. A whole team at GEOMAR is dedicated to detecting MC at sea and locating new dumping sites. As the MOSES cruise covers a larger area, random samples were taken along the way to check for elevated levels of MC in the water column.

Greenhouse gases

Analysed by Matthias Koschorrek (UFZ), Tina Sanders (Hereon), Ingeborg Bussmann (AWI)

The most prominent greenhouse gas is undoubtedly CO2, but CH4 and N2O have a much greater warming potential (x 12, x 109). As a result, these gases are increasingly the focus of scientific attention. The aim of this study was to investigate if and where these gases are a source or sink to the atmosphere. Discrete water samples were taken in the Czech and German parts of the Elbe and analysed by gas chromatography for CO2, CH4 and N2O. In the Tidal Elbe and the German Bight, they were analysed continuously with a degassing unit followed by an analyser.

Multielement-samples (MES)

Analysed by Daniel Pröfrock (Hereon)

The aim was to investigate the impact of the ongoing reduced water discharge of the Elbe River on the concentration level and spatial distribution of dissolved trace metals in the North Sea. Throughout the cruise, discrete water samples were taken for multi-element analysis. The samples were stored in refrigerated conditions and transported to the laboratory immediately after sampling. The samples were filtered through 0.45 µm pre-cleaned PC filters to remove the SPM fraction. All samples were stabilised with nitric acid after filtration. All samples were measured using seaFAST-ICP-MS/MS to quantify dissolved trace metals at each sampling location.

Nanoplastic

Analysed by Dusan Materic (UFZ)

The aim of this study is to characterise and quantify nanoplastics in Elbe and North Sea samples. We will focus on both water and sediment samples. We will perform Thermal Desorption Proton Transfer Reaction Mass Spectrometry (TD-PTR-MS) analysis for the organic matter of certain pre-defined size groups and perform fingerprinting for known common plastics such as PE, PET, PP, PS, PVC and tyre wear particles (https://iopscience.iop.org/article/10.1088/1748-9326/ac68f7/meta and https://doi.org/10.1016/j.scitotenv.2022.157371). This will result in a unique and, to our knowledge, the first quantitative riverine data on nanoplastic concentrations. The high resolution of our sampling will provide further insights into the sources and transport dynamics of this novel pollutant.

Nutrients (silicate, phosphate, nitrite, nitrate, ammonium)

Analysed by Ingeborg Bussmann (AWI), Norbert Kamjunke (UFZ), Björn Raupers (GEOMAR), Tina Sanders (Hereon)

Nutrients are essential for the formation of organic matter, i.e. primary production by photosynthesis. High levels of primary production can lead to the depletion of one or more nutrients, limiting autotrophic processes. The reverse process is heterotrophic decomposition of organic matter, which releases nutrients and makes them available for primary production. Therefore, all nutrients in the study area were sampled to assess whether autotrophic or heterotrophic processes predominate.

Organic micropollutants

Analysed by Martin Krauss, Jörg Ahlheim, Margit Petre, Paul Schulz, Werner Brack, Janek Paul Dann, Lillie Jeal Elizabeth Freemantle, Qiuguo Fu (UFZ)

The aim was to investigate the transport and distribution patterns of organic micropollutants along the Elbe River and their potential dilution and distribution in the North Sea.

Water samples for the analysis of organic micropollutants were collected during all ship cruises, on land in the Czech Republic and at selected smaller tributaries and WWTPs that contribute significantly to the discharge into the Inner Elbe and Tide Elbe. For surface waters, grab samples were taken near the surface, while WWTP effluents were collected as 24-hour composite samples by the WWTP operators. Samples were immediately cooled to 4°C and frozen at -20°C upon arrival at the laboratory. Different sample preparation approaches were used to cover different classes of compounds. For a general screening of medium polar and non-polar compounds, an aliquot of 650 ml was filtered to approximately 0.7 µm using glass fibre filters and solid phase extracted using Chromabond HR-X (Macherey-Nagel).

Samples were analysed by LC-HRMS on an Exploris 480 MS (Thermo Scientific) in positive and negative ion mode. For the targeted screening, 750 micropollutants of different classes known or suspected to occur in the aquatic environment were quantified, while a non-targeted data evaluation approach was used to identify changes in micropollutant patterns along the river Elbe and to identify the source of previously unknown compounds. For persistent and highly polar compounds, an aliquot of 25 ml was filtered to approximately 0.7 µm using glass fibre filters, followed by lyophilization for enrichment. The final enriched samples were analysed by SFC-MS/MS for persistent mobile and toxic chemicals (PMT) and also by LC-MS/MS for per- and polyfluorinated substances (PFAS). Both measurements were performed in positive and negative ion modes. In addition, tyre rubber derived contaminants (TRDC) are enriched by SPE and further analysed by LC-MS/MS. The targeted quantification of about 200 compounds at trace levels is underway to understand the persistence and mobility of micropollutants along the Elbe River to the sea.

Pesticides and UV filters

Analysed by Marlen Heinz, Kathrin Fisch, Julius Kühn-Institute (ÖPV)

Water samples for the additional analysis of pesticides and UV filters were collected during the cruise on the Inner Elbe, Tide-Elbe and Sternfahrt_10 and selected smaller tributaries. All samples were taken simultaneously with the organic micropollutant samples of Krauss et al. and their stations in order to increase the number of organic micropollutants investigated. At the sampling stations, two 500 ml samples were collected and stored in glass bottles; one for analysis by LC-MS/MS and one for analysis by GC-MS/MS. The glass bottles for GC-MS/MS analysis contained 50 ml of dichloromethane (DCM). The DCM is required for the analysis of pesticides belonging to the volatile class of pyrethroids. The samples were stored at 4°C in the laboratory of the Julius Kühn Institute, Berlin, until further analysis. Samples for the analysis of polar pesticides and UV filters (131 compounds in total) by LC-MS/MS were enriched and purified on land by solid phase extraction. Samples for non-polar pesticides (15 compounds) are cleaned by liquid-liquid extraction for analysis by GC-MS/MS. For data quality control some stations were sampled in duplicate.

Plastic-associated chemicals

Mara Römerscheid, Martin Simoneit, Nadin Ulrich, Alexander Böhme, Annika Jahnke (UFZ)

Within the P-LEACH innovation pool project (www.ufz.de/p-leach), we aim to characterise chemicals released from plastics in the environment, with a focus on plastic additives that are added to the polymer during manufacture to improve functionality for its intended use. Our focus is on additives with known hazard potential to humans and/or the environment, identified using Groh et al. 2019 (https://doi.org/10.1016/j.scitotenv.2018.10.015).

We focus on sediment samples from the Czech Republic, the free-flowing part of the Elbe, the tidal Elbe and the German Bight to identify and quantify specific plastic additives. Sediments are freeze-dried and subjected to pressurised liquid extraction (PLE), purified by flash chromatography and quantified by LC and GC-MS(MS).

Trace metals

Björn Raupers (GEOMAR)

Trace metal samples were collected to investigate the distribution of various elements such as dissolved and particulate Pb, Hg, Cu, Zn, Cd, Ni, Mn, Fe, U in the Elbe estuary and the North Sea. The samples will be further processed and analysed with an inductively coupled plasma mass spectrometer (ICP-MS) to determine the concentrations of the different species. The samples were taken to be compared with samples from the follow-up project, called ElbeXtreme. ElbeXtreme focuses on the impact of extreme events such as droughts, heat waves and floods on ecosystems. The variation in trace metal concentrations will be an important indicator of how these extreme events might affect the ecosystem of the Elbe estuary.

3. CZECH ELBE (28.06 – 30.06.2023)

Jörg Ahlheim[1], Martin Krauss[1], Anna Matoušů[2], Patrik Pejsar[2]
[1]DE.UFZ
[2]CZ.CAS

A land-based sampling campaign was carried out along the Czech part of the Elbe (Labe) from 27 to 29 June 2002. As the central stretch between Pardubice and Strekov contains 24 weirs, hydraulic retention times in this part are long and a Langrangian sampling approach was not considered meaningful. Therefore, samples were collected over three days, covering the entire stretch from the Krkonoše Mountains to the Czech-German border (Fig. 3.1).

Water samples for organic micropollutants, nano-/microplastics and multi-element analysis were taken from the main river and the six largest tributaries at the sites shown in Figure 3.1. In addition, two wastewater treatment plant effluents and one wastewater polishing pond were sampled. Sediment samples could only be collected at three sites. Details on the station list can be found in Tab. A.3

Fig. 3.1: Locations of the sampling sites along the Labe (red) and its main tributaries (green)

4. BINNEN ELBE (03.07 – 11.07.2023, 2023_MOSES_ELBE-NORTHSEA_INLAND)

Sven Bauth, Heike Goretzka, Norbert Kamjunke, Ute Link DE.UFZ

Objectives

The MOSES campaign "ELBE 2023" covered the entire river Elbe, from its source in the Czech Republic to the German freshwater section, the tidal Elbe and finally the German Bight. In the German freshwater section of the Elbe, a number of physico-chemical and biological parameters were measured along the river using *Albis*, which travelled between Schmilka (km-4, German border) and Geesthacht (km-585, near Hamburg). This approach, known as Lagrangian, was used to gain a comprehensive understanding of the river's characteristics (Fig. 4.1). The scientific focus in 2023 was on pollutants, with a particular emphasis on pharmaceuticals, herbicides and microplastics. This involved sampling not only the water but also the sediments and using passive samplers (see Fig. 4.2). In addition, a land-based team sampled smaller tributaries and effluents from large sewage treatment plants that discharged directly into the Elbe River in parallel with the ship.

Work on the river

Fig. 4.1: Map of the Elbe sampling sites in Germany from Schmilka (Elbe km 4) towards Geestacht (Elbe km 585). Blue dots indicate the sampling stations, red dots the stations at tributary mouths.

Fig. 4.2: Horizontal water sampler and sediment sampling at Albis (Photos by N. Kamjunke)

Preliminary results

The biomass of phytoplankton (chlorophyll a) increased by a factor of 10 between river km O-350 (Fig. 4.3). At the same time, dissolved nutrient concentrations decreased due to uptake by algae. Phytoplankton growth ceased at km-350 when phosphate was depleted. In addition, concentrations of dissolved silicate and, for the first time, nitrate reached detection limits. The concentration of total nitrogen decreased due to denitrification.

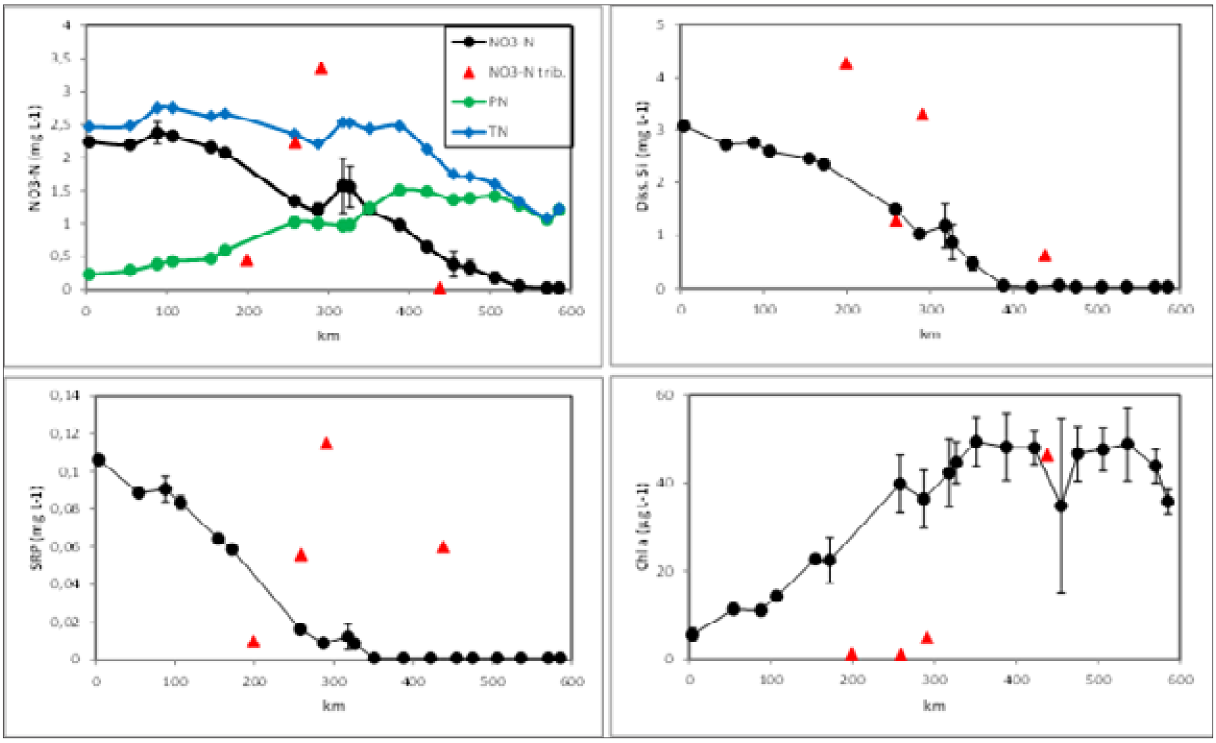

Fig. 4.3: Longitudinal dynamics of dissolved nutrients (nitrate, silica and soluble reactive phosphorus) and chlorophyll a. Black dots: River Elbe, red triangles: tributaries, PN: particulate nitrogen, TN: total nitrogen.

References

Kamjunke N, von Tümpling W, Hoff A, Koschorreck M (2023) Water chemistry of Lagrangian samplings of Inland Elbe 2023 (MOSES Hydrological Extremes). Helmholtz Centre for Environmental Research – UFZ, PANGAEA, https://doi.org/10.1594/PANGAEA.963359

5. TIDE-ELBE (23.08. – 28.08.2023, PR20230821)

Götz Flöser[1], Heike Goretzka[2], Pascal Hoppe[1], Annika Jahnke[2], Ute Link[2], Tina Sanders[1], Leon Schmidt[1], Gesa Schulz[1]

[1]DE.Hereon
[2]DE.UFZ

Objectives

The Tide-Elbe transect cruises managed by Hereon started in the North Sea near the island of Scharhörn and ended in Oortkaten, behind the port of Hamburg (Fig. 5.1). The Tide-Elbe sampling continued the sampling of the river Elbe. In Cuxhaven, we installed the MOSES container on *Ludwig Prandtl*, which contained a FerryBox system and will be used on the following cruises (Fig. 5.2). We also installed a Picarro system coupled with an equilibrator to measure the greenhouse gases CH_4, N_2O and CO_2 simultaneously. Traditionally, water samples have also been taken for nutrient analysis and nitrogen stable isotopes.

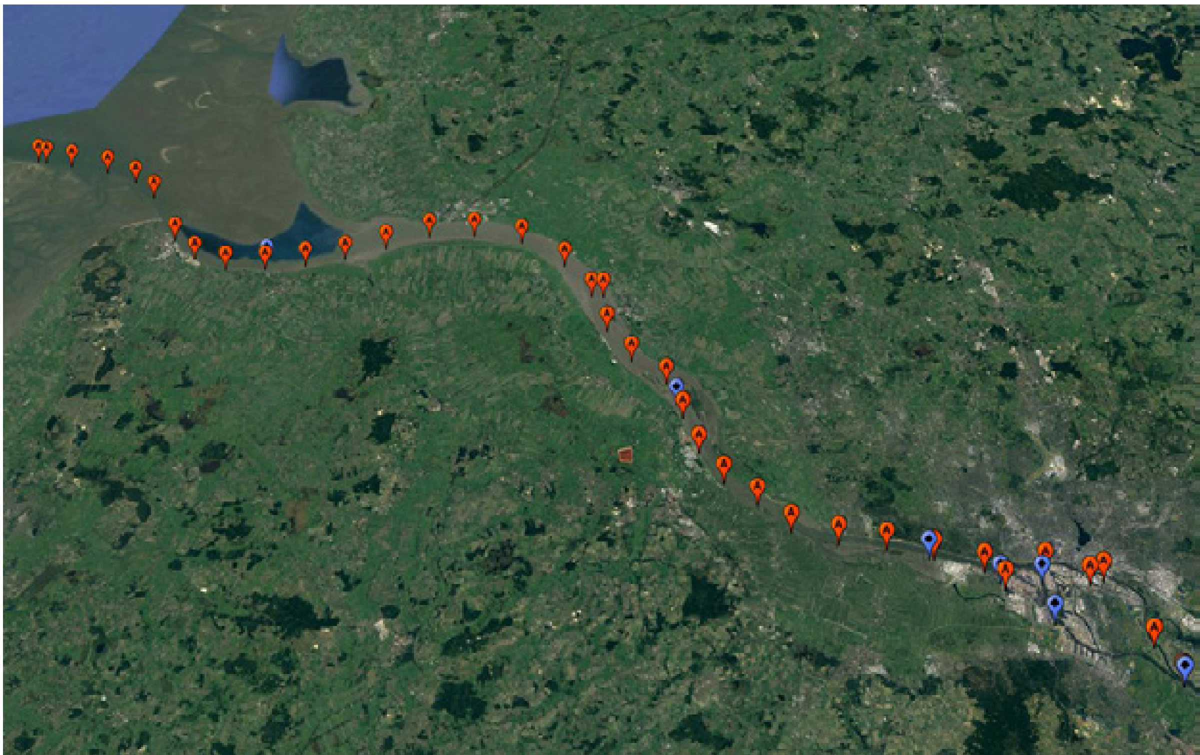

Fig. 5.1: Sampling sites in the Tide-Elbe: Red symbols indicate water samples during the cruise on the 22. and 23. 08.2023. Blue symbols indicate water and sediment samples on 25. and 28.8.2023

Fig. 5.2: MOSES container on the Ludwig Prandtl in the Tide-Elbe cruise. Sampling of water and gas samples during the cruise (Photos by T. Sanders)

Preliminary results

Figure 5.3 shows the preliminary data from the tidal Elbe. Salinity, oxygen, turbidity and temperature were measured using FerryBox sensors, while nutrient concentrations were determined from water samples using the AA3 autoanalyzer. The Elbe km measurement starts at the German-Czech border, with the Port of Hamburg at km 600 and Cuxhaven and the North Sea at km 720.

The oxygen saturation of the water entering the port area was slightly supersaturated. Inside the port of Hamburg, the saturation decreased to less than 30%. During the outflow towards the North Sea, the oxygen saturation recovered and increased again to about 100%. Ammonium and nitrite peaked in the area of the port of Hamburg, decreased to almost zero and increased again towards the North Sea, but to a lesser extent. The concentration of nitrate and silicate first decreased in the estuary and then increased when entering the Hamburg harbour area, where remineralisation of fresh organic matter occurs. Both nutrients showed a conservative mixing in the salinity gradient towards the North Sea.

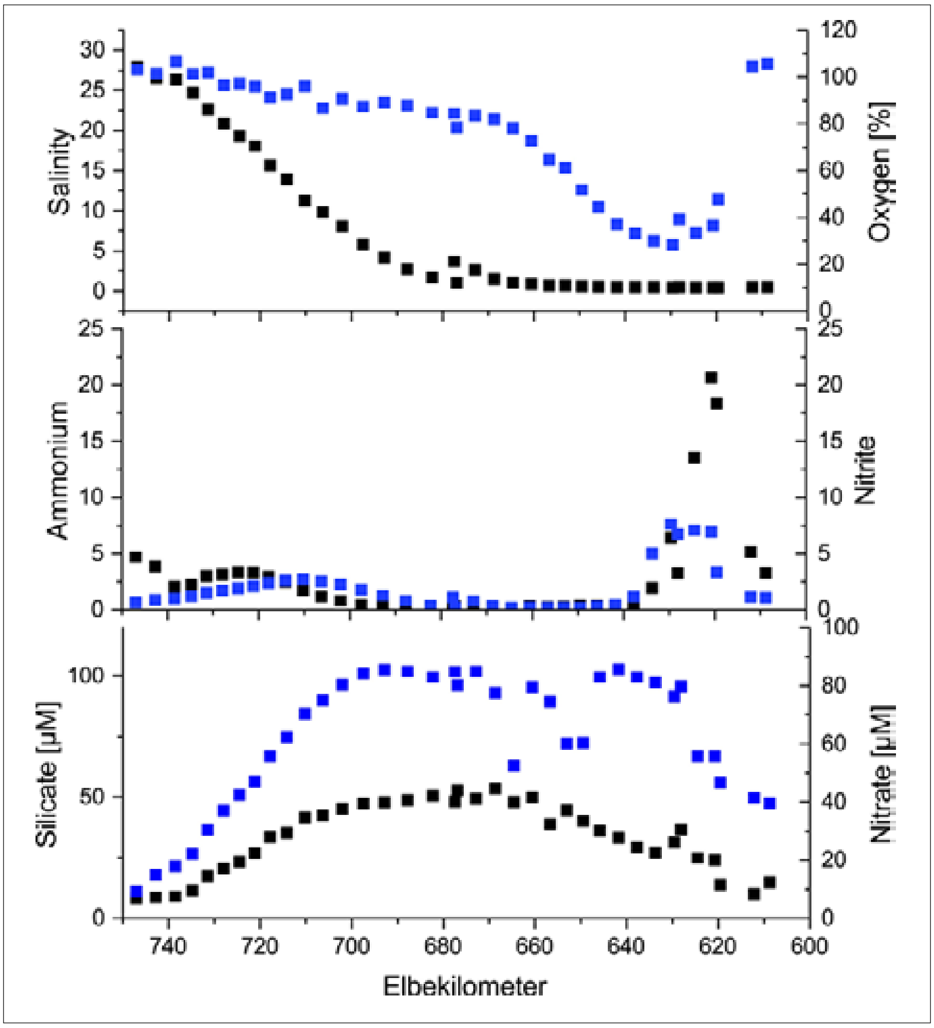

Fig. 5.3: First preliminary results of salinity, oxygen saturation (in blue), ammonium, nitrite (in blue), nitrate (in blue) and silicate plotted versus the Elbe kilometers (Hamburg port at km-600, Cuxhaven at km-720).

6. STERNFAHRT_10

Objectives

There were two main objectives for the Stern_10 cruises: as an extension of the previous Elbe freshwater and Elbe tidal cruises, the distribution of the observed contaminants transported by the Elbe River was to be followed in the North Sea. In addition, we focused on the distribution of the Elbe water, i.e. the fate of an Elbe water parcel within the southern North Sea. For this purpose, drifters were deployed from the ships and their position was monitored by the Hereon colleagues. For each group of drifters, we planned to measure our basic and extended hydrographic parameters several times during their journey. As the speed of the drifters' distribution could not be determined in advance, the entire Stern_10 campaign was planned with subsequent ship cruises lasting a total of three weeks (Fig. 6.1).

To ensure that the parameters were measured using the same methods, the MOSES laboratory container was transferred from ship to ship with all its contents. The container was equipped with the communication setup, a Pocket FerryBox for basic hydrographic parameters and a LosGatos setup for dissolved methane measurements (Fig. 6-2; [Bussmann, et al. 2023]). On each cruise, the participants added their own individual special equipment, (mostly) for water sampling (Fig. 6.3). It was therefore more of a 'relay cruise' than a 'Sternfahrt' ('star cruise', the term previously used for several ships operating simultaneously). Nevertheless, we covered the south-eastern part of the North Sea up to the island of Amrum.

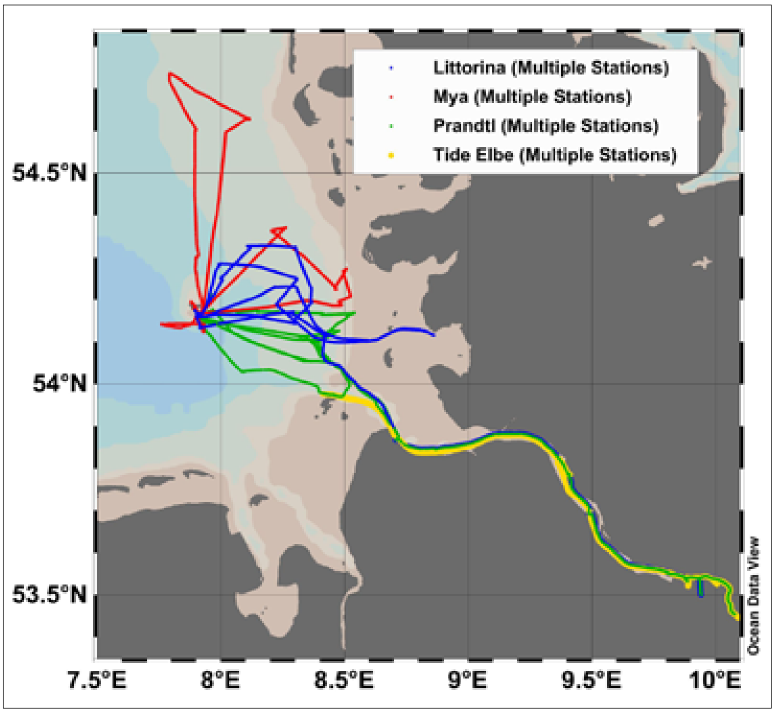

Fig. 6.1: Cruise track of Mya (red), LudwigPrandtl (green), Littorina (blue) and Tide-Elbe with Prandlt (yellow) on Sternfahrt_10

Fig. 6.2: Instrument set-up in the MOSES lab-container, with FerryBox and LosGatos on the right side and water sampling set-up on the left side. (Photos by I. Bussmann)

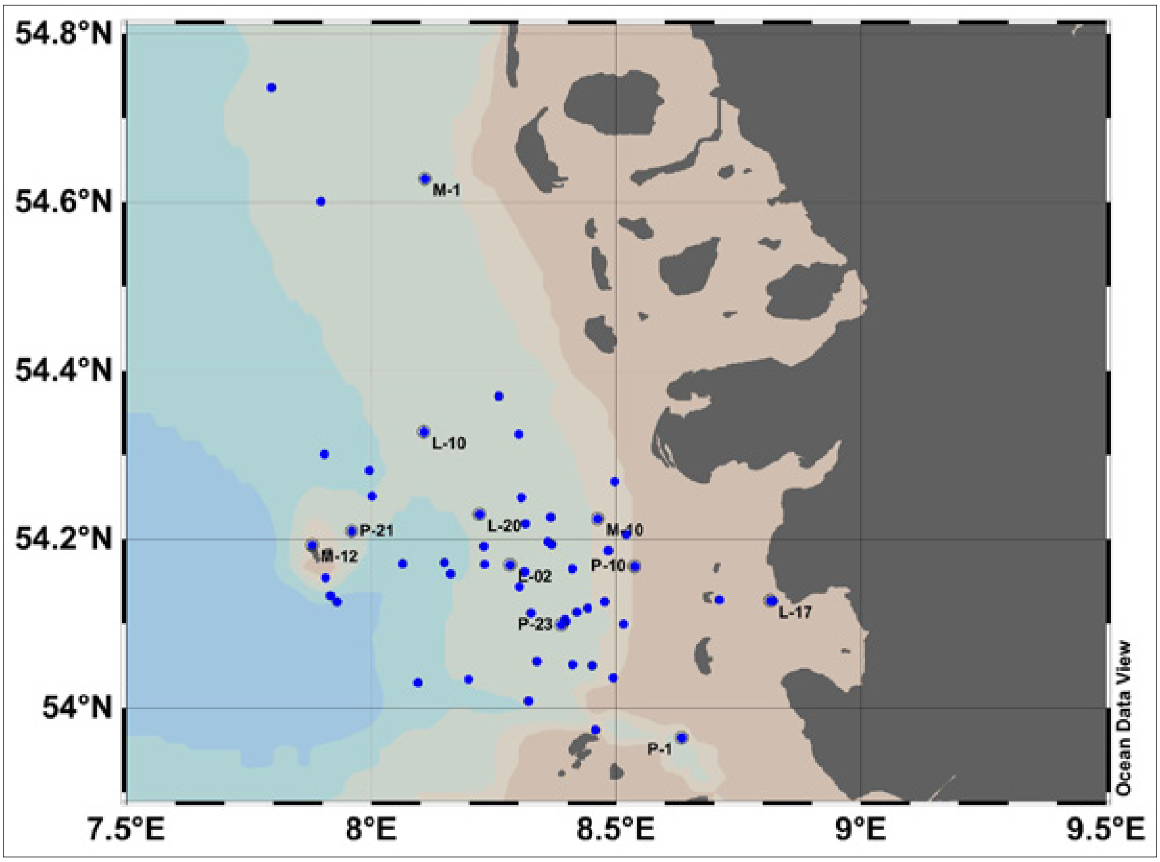

Fig. 6.3: Stations for water sampling during Stern_10 (blue dots), numbers indicate big stations with additional samples for various pollutants and sediment sampling.

Work at sea with *Ludwig Prandtl* (29.08.2023 – 01.09.2023, HYDREX_2023_German_Bight_Stern_10-1)

Holger Brix[1], Ingeborg Bussmann[2] Götz Flöser[1], Heike Goretzka[3], Ute Link[3], Hendrik Rust[1]

[1]DE.Hereon
[2]DE.AWI
[3]DE.UFZ

The first leg of the Stern_10 campaign was initially scheduled to begin on 28 August 2023. As there was an issue with the timing of the *Ludwig Prandtl* crossing under the Elbe bridges in Hamburg during the Tide Elbe campaign part, the Stern_10 part had to be rescheduled to begin on August 29. August 28 (part of the Tide Elbe campaign) was used to assemble and dry-test the drifters that were to be deployed in the Elbe outflow section of the German Bight.

On the first day of Stern_10 (29 August 2023), *Ludwig Prandtl* left Cuxhaven, Alter Fischereihafen at 08:11 UTC with calm, overcast conditions, headed to a first station, one hour twenty minutes downstream for initial testing. The *Ludwig Prandtl* then sailed into the northern branch of the Elbe valley and deployed four drifters at 10:43 UTC. Another three drifters were subsequently (11:24 UTC) deployed in the southern branch. The drifter deployment locations had been determined with the help of numerical model experiments (that were designed to determine the probability of drifters standing soon after deployment for a variety of locations in the Elbe valley) and online drift forecasts using the operational BSH model for the German Bight at https://hcdc.hereon.de/drift-now/.

Unfortunately, the container USV had multiple short breakdowns during the entire duration of the cruise leading to interruptions of the underway measurements due to issues with the electrical circuitry as soon as the system had to be switched to winch operation for taking sediment samples.

For the rest of the campaign, *Ludwig Prandtl* either followed the drifters and sampled the water body close to them or occupied MOSES hydrographic stations from earlier Stern campaigns. The nights were spent on Helgoland.

The CTD was deployed from the frame on the starboard side. Three cylinders could be filled with ~2 L of seawater in selected depths. From these water volumes, samples were taken for the determination of DIC and CH_4 (Fig. 6.4). Multielement samples came from the little crane, also on the starboard side (Fig. 6.5). Nutrient samples were taken from the FerryBox water outflow in the MOSES container.

The first cruise day ended after a total of seven stations at 15:05 UTC in Helgoland.

On the second day (30 August) winds were stronger and considerable wave heights impacted work. Between departure (05:14 UTC) and return (13:25 UTC) to Heligoland a total of seven stations were occupied.

After a severe storm during the night from 30 to 31 August, conditions had calmed somewhat down so that a safe cruise was possible. Departure (05:15 UTC), return (13:32 UTC) with seven stations. Only the northern drifter group could be reached for measurements, the southern group had drifted into shallower waters that could not be reached, also as the weather conditions deteriorated during the day (Fig. 6.6).

On 1 September, *Ludwig Prandtl* left Heligoland at 05:05 UTC in calm, sunny conditions with scattered clouds. There were problems with the sea water supply for the container (7:40 – 8:23) and the supply had to be switched to the ballast water pump. At 8:25 the electricity and water supply for the container stopped and were restarted around 8:38. After a total of three stations this cruise leg ended at 11:13 UTC in Cuxhaven with removal of the MOSES container (storage on land for the next cruise leg).

Details on the station list, the sensors used and locations for data access can be found in Tab.A 5.1 and 5.2

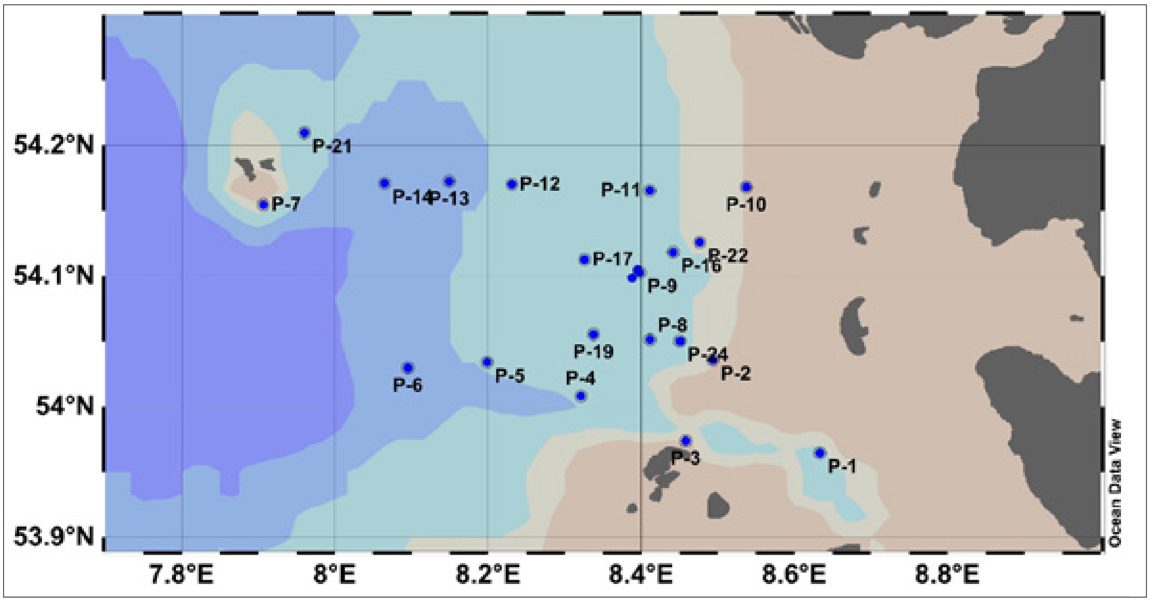

Fig. 6.4: Stations for water sampling during Stern_10-1 with Ludwig Prandtl (blue dots)

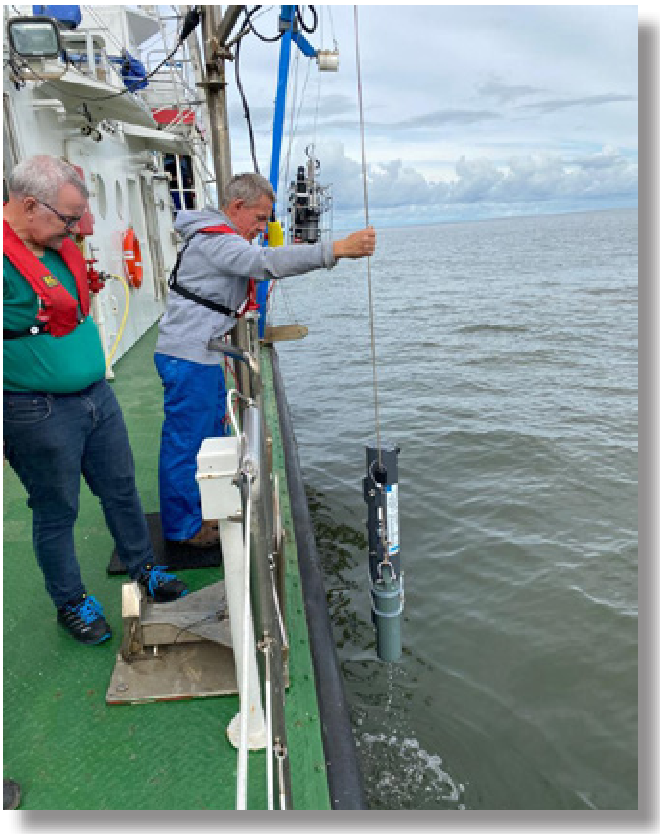

Fig. 6.5: Sampling with the 'Goflo' multielement sampler (Photo by H. Brix)

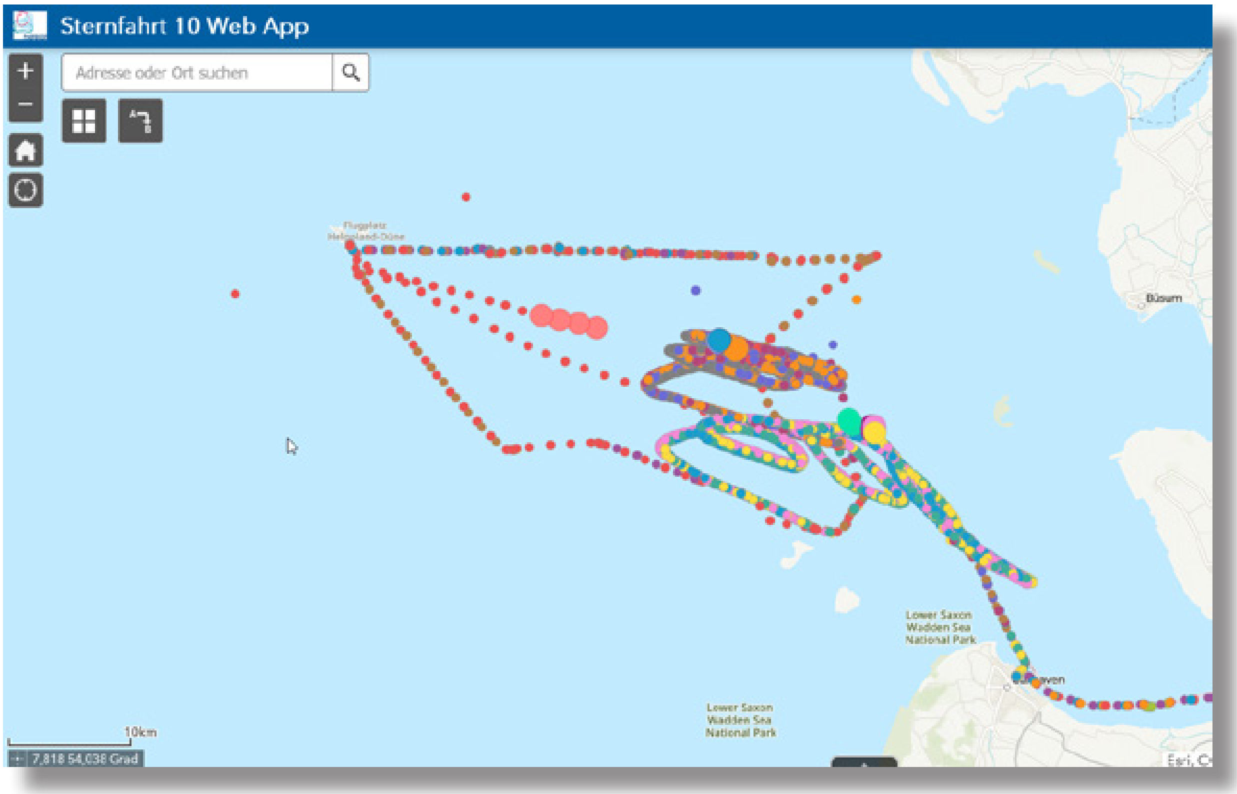

Fig. 6.6: Drifter pathways as of 31 August 08:35. The lines from and to Heligoland and around Cuxhaven are drifters on board of Ludwig Prandtl.

Work at sea with *Littorina* (2.9. – 9.9.2023, HYDREX_2023_German_Bight_Stern_10-2)

Sayoni Bhattacharya[1], Ingeborg Bussmann[2], Claas Faber[1], Dirk Sarpe[1], Björn Raupers[1],

[1]DE.GEOMAR
[2]DE.AWI

Fig. 6.7: The MOSES container on deck of Littorina while the sun is rising at the harbor of Heligoland. (Photo by B. Raupers)

The *Littorina* cruise L23-12 (Sternfahrt_10-2) was conducted as a joint survey of the German North Sea. Together with the *Ludwig Prandtl* and the *Mya II*, *Littorina* covered the area where the Elbe flows into the North Sea. This year, the ships surveyed in sequence in order to measure over a longer period of time. This year a large number of drifters were deployed to follow individual water parcels. The first set of drifters was deployed from *Ludwig Prandtl* during the first week of the campaign. These drifters were the target locations for *Littorina* in the second week of the survey (Fig. 6.7).

Littorina started its journey on 2 September 2023 in its home port Kiel and ended the journey on 9 September 2023 also in Kiel. During the cruise the ship visited the ports of Cuxhaven. Heligoland and Büsum. The transit from Kiel through the Nord-Ostsee-Kanal (NOK) took

11 hours. After passing the NOK, the vessel reached the port of Cuxhaven to pick up additional personnel and equipment. Figure 6.10 shows the loading of the container specially designed for this mission. The MOSES container (Fig. 6.11) is equipped with a variety of sensor systems, GPS equipment and laboratory space. The measurement campaign started on 4 September 2003. The Littorina sailed north towards Heligoland to cover as many drift positions as possible. On 5 September, the ship sampled north-east of Heligoland, on 6 September it went to Büsum and on 7 September it returned to Heligoland where the MOSES container was unloaded and stored to be picked up by *Mya II* the following week. The routes are shown in Figure 6.8 and the waypoints are shown in Figure 6.9. A detailed list of all stations is given in Tab. 6.1 in the Appendix.

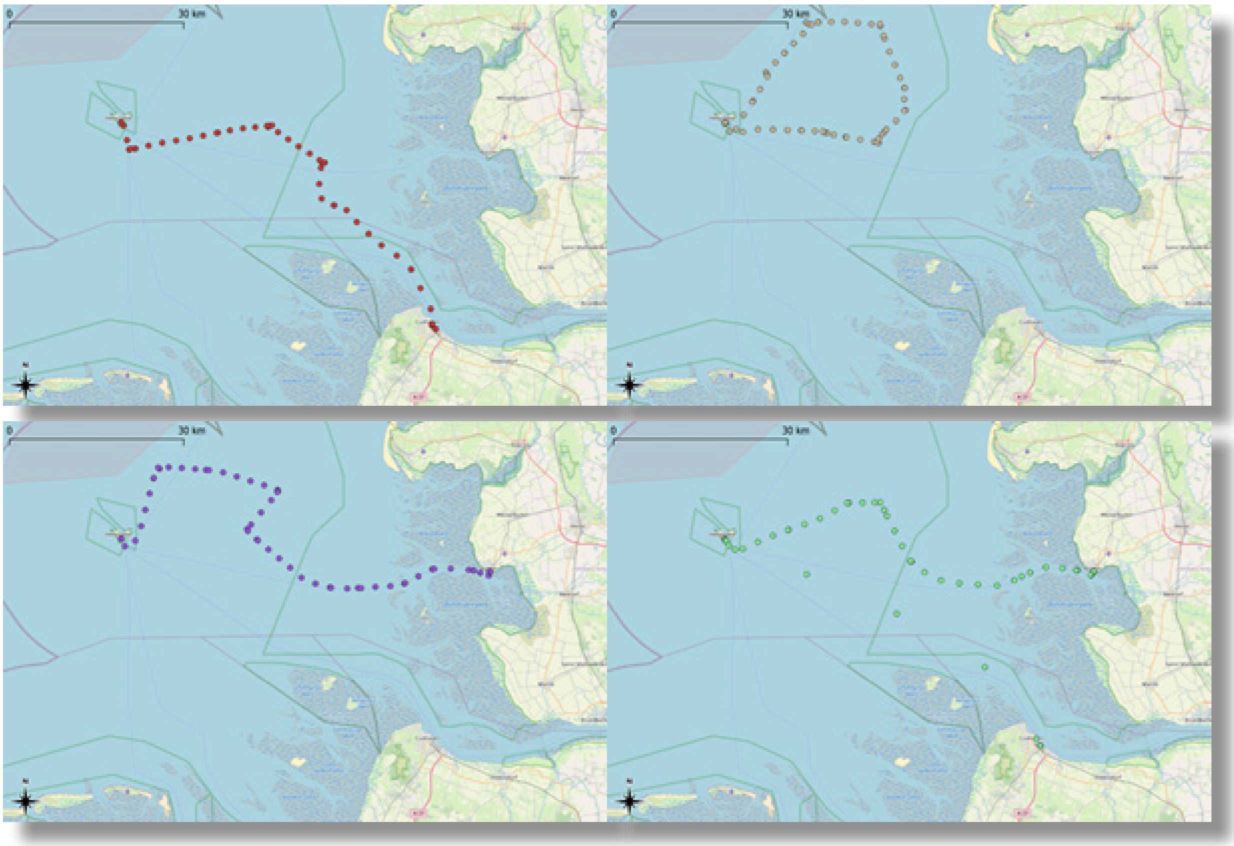

Fig. 6.8: The routes of Littorina during the four days of sampling. Starting on 4 September (top left) and ending on the 7 September (bottom right).

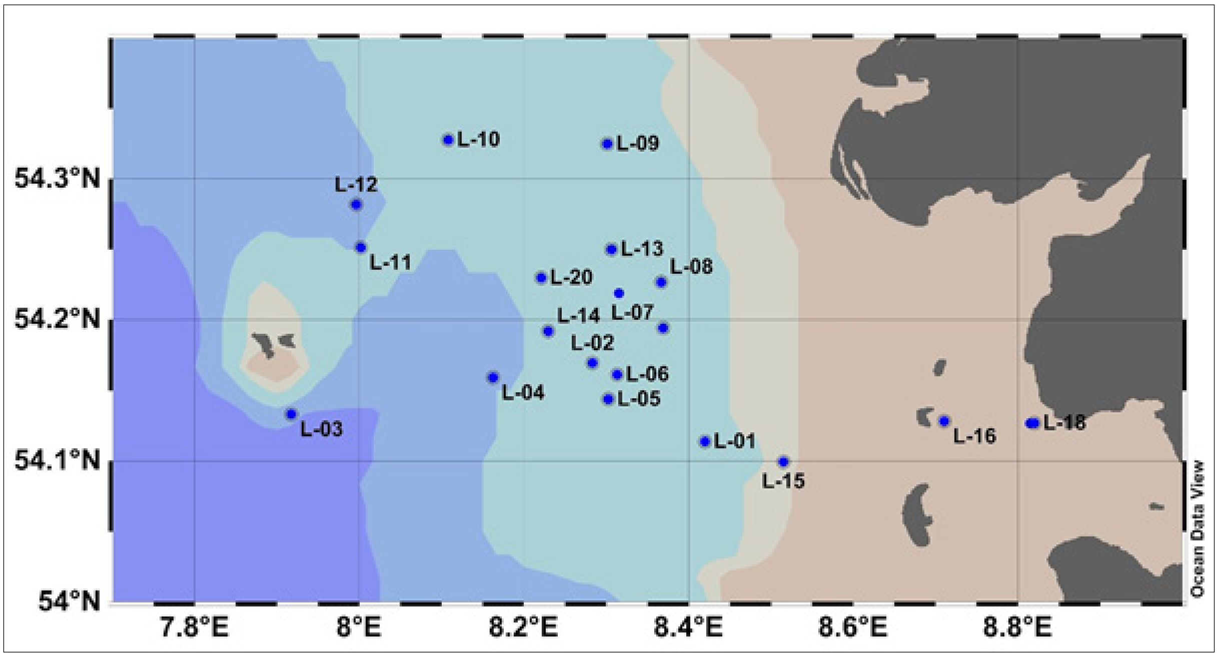

Fig. 6.9: Waypoints of Littorina during MOSES Stern_10-2.

For onboard measurements, a suite of sensors (e.g. EXO CTD, Opus nitrate, Contros pCO2, Shallow water TA) was placed in a 200 L tank on deck, which was continuously supplied with surface water (from 3 m depth) from the Littorina's underwater water supply during transects. The flow rate was set at approximately 100 L/min to allow rapid exchange of the total volume of water within the box. Despite the rapid water exchange, a two-minute turnover time should be taken into account when processing the data. Another prototype sensor system was tested in the dry laboratory at Littorina. It can be used to measure dissolved inorganic carbon (DIC). In order to evaluate the data from this system, additional samples were required, which were taken together with discrete DIC samples every 30 minutes. The DIC samples were then poisoned with HgCl2 (Fig. 6.15) and stored at room temperature. The nutrient samples were kept frozen. The LosGatos and FerryBox analysers were set up for continuous measurements of methane and basic hydrographic parameters in surface water. Both systems were installed in the MOSES container before the cruise. CTD casts were performed at each station. Additional water samples were collected for Munitions Compound (MC) and trace metals. For the MC samples, 1 L of seawater was collected from each depth of the CTD rosette (Fig. 6.13) and filtered through an inline syringe filter followed by a solid phase extraction column. The SPE columns were frozen. Trace metal samples were collected using GoFlo bottles (Fig. 6.13). For each sample, 200 mL of water was filtered through trace metal-free filters in a clean, lab-like environment. Sediment samples were taken every two days to be analysed for microplastics (Fig. 6.14).

Stations were either determined by the position of the drifters. If the drifters were not available due to shallow water, old waypoints from previous cruises were added to the track. Weather conditions were ideal throughout the cruise, which made the work very easy.

The shallow waters close to the coast in the German North Sea were a major problem for the Littorina during this cruise. Most of the drifters drifted into the waters west of Büsum, St. Peter Ording, Nordstrand and Pelworm. As a result, the Littorina crew was unable to access these drifters. The crew deployed another set of drifters (Fig. 6.12) further out to sea between Büsum and Heligoland. These drifted rapidly with each tide into Danish waters.

Details of the crew, station list, sensors used and data access locations are given in Tab. A.5.3 and Tab. A.5.4.

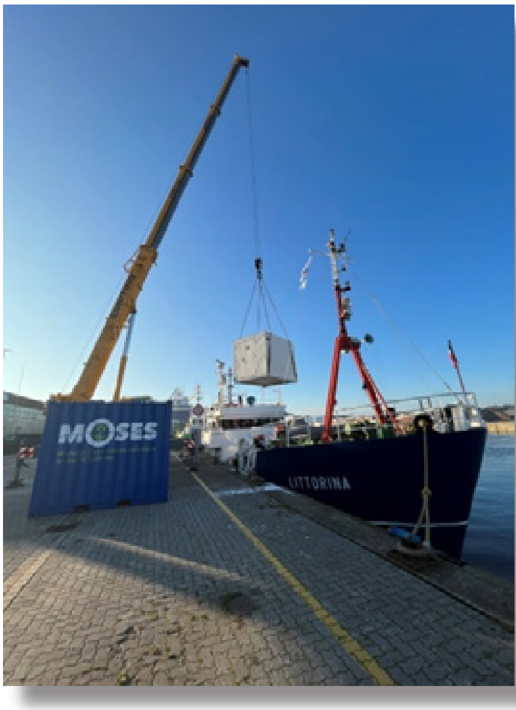

Fig. 6.10: The white laboratory container being unloaded from Littorina (left) and the MOSES container being loaded at its final location (right),

Photos by B. Raupers and Ines Reinisch.

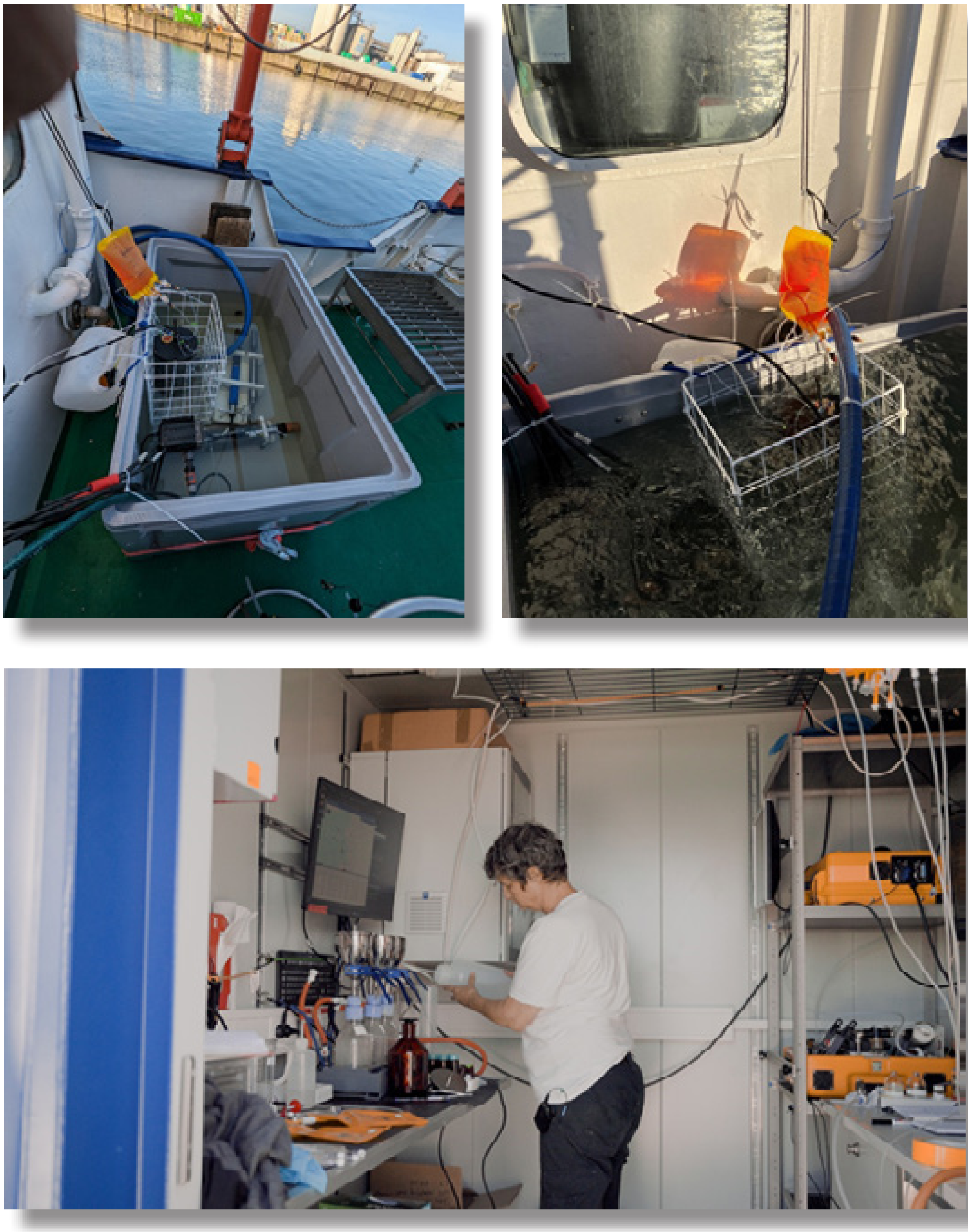

Fig. 6.11: Sensors installed on Littorina. Sensors installed in a 500 L tank without (left) and with seawater (middle) The FerryBox and LosGatos analyzer installed in the MOSES container (right),

Photos by S. Bhattacharya, A. Nicolas and Ines Reinisch.

Fig. 6.12: Deployment of the third set of drifters from Littorina. C. Faber and D. Stieg watching a set of deployed drifters (left). S. Bhattacharya deploying another drifter (middle) and a pair of new deployed drifters (right). (Photos by I. Bussmann & B. Raupers)

Fig. 6.13: C. Faber and S. Bhattacharya preparing the CTD rosette for the next deployment (left). B. Raupers, D. Etzdorf and D. Stieg deploying a GoFlo bottle (middle). Processing trace metal samples in the clean lab box by A. Nicolas (right). (Photos by A. Nicolas & I. Reinisch)

Fig. 6.14: Processing sediment samples from a Van-Veen grab. (Photo by I. Reinisch)

Fig. 6.15: C. Faber and S. Bhattacharya poisoning DIC samples on deck in the harbor of Büsum. (Photo by I. Reinisch)

Work at sea with *Mya II* (11.9. – 14.9.2023, HYDREX_2023_German_Bight_Stern_10-3)

Norbert Anselm[1], Ingeborg Bussmann[1], Philipp Fischer[1], Daniel Kolb[2], Jessica Markowsi[1],

[1]DE.AWI
[2]DE.UFZ

The cruise preparations beforehand all had relied on the participation of the new *Uthörn*. Unfortunately, there were still severe technical problems with the new ship. Thus, we changed our plans on short notice and asked for the *Mya II* from Sylt.

On 11 September, the *Mya II* arrived at the port of Heligoland shortly before 16:00. Fortunately, the crane operator was persuaded to position the MOSES container onto the Mya II on this day (Fig. 6.16). The swatch locks were all prepared and the container fixed in easily. With the door opening towards the back, all sides could now be reached with ease. The water supply was easily attached, as was the electricity cable via adapter to the USV of the ship. While one half of the team was engaged in setting up the laboratory within the container and sorting through the boxes, the other half was engaged in setting up the communication network. Details regarding this process can be found in the section on communication and IT.

On 12 September, we departed from port at 7:00, heading north towards the transponders located west of the island of Amrum. As we were partially outside the range of the communication network, we had to estimate the precise locations of the transponders. However, we sampled near transponder #310 and within the group of transponders #323-325, as well as two "normal" stations from last year's cruises (Fig. 6.17). The wind velocity was moderate, yet still somewhat turbulent, to cause some cases of sea-sickness. Technical issues with the d-ship system of the *Mya II* resulted in the absence of data (position and wind data) on 11 and 12 September.

On 13 September, we had a strong northerly wind (up to 19 m/s) and the sea was very rough. We could only sample one station west off Heligoland and had to return to the port around 10:00 UTC.

On 14 September, the sea was calm once more, and all participants had recovered from their sea sickness. We proceeded eastwards, approaching the transponders located to the west of St. Peter-Ording. To track the positions of the transponders, we employed the app provided by Hereon, either on our personal computers on the bridge or with the computer in the MOSES container (Fig. 6.19). Prior to entering the port of Heligoland, our final station was situated in the vicinity of the AWI's underwater laboratory. It is our intention to compare our data. Upon arrival in port, the container was closed and the boxes, samples and equipment were sorted (Fig. 6.18). On 15 September, the container was unloaded using a crane and placed in front of the Dive Center. The *Mya II* then proceeded to List on Sylt, her home port.

Details on the station list, the sensors used and locations for data access can be found in Tab. A.5.5 and A.5.6

Fig. 6.16: Preparing the MOSES Lab-Container for loading. (Photo by I. Bussmann)

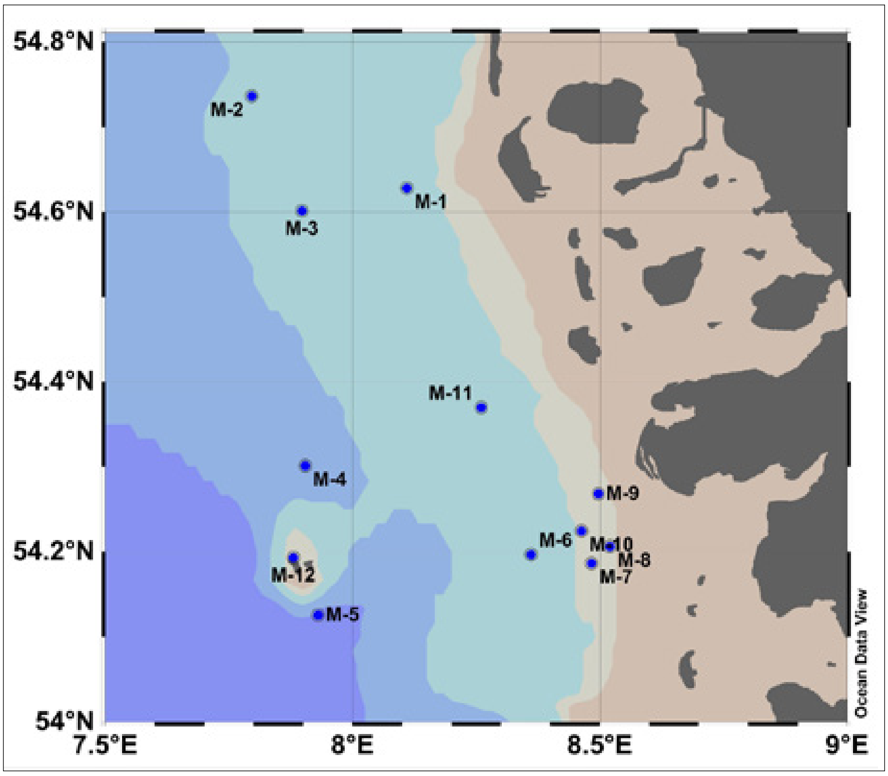

Fig. 6.17: Stations for water sampling with Mya II.

Fig. 6.18: The Mya II with the MOSES Container at Helgoland. (Photo by I. Bussmann)

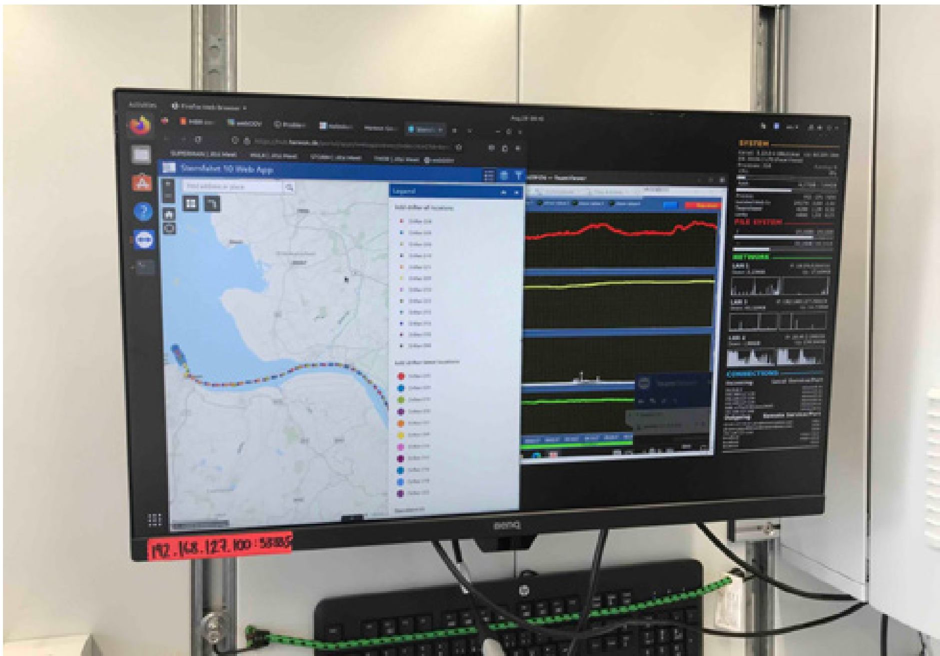

Fig. 6.19: Screen in the lab-container displaying the position of the transponders and the basic hydrographic parameters from the FerryBox. (Photo by I. Bussmann)

Communication, IT and Data Management

The preparation for IT and data management commenced in July. The drifter data provided and deployed by HEREON was forwarded by the HEREON IT section to a designated space at ftp.awi.de during the course of the campaign. Its content was preprocessed and streamlined in order to meet the requirements of the NRT data format (O2A team 2022), and then provided to the O2A framework (Koppe et al. 2015).

Hence, drifter positional data was made available via several instances:

- from the HEREON drifter webapp (ESRI-based)
- from the O2A near real-time database (https://dashboard.awi.de/data/)
- from the BELUGA navigator https://beluga.geomar.de/moses-stern-10 operated by GEOMAR

The MOSES lab container itself was not significantly altered. Only the Kongsberg MBR system was added to the server rack and the associated antenna was mounted to each vessel where possible. The complementary land station was installed at the lighthouse at Helgoland several days prior to the official campaign start. The MBR system was operational immediately upon the antennas being in range.

As in previous cruises (Bussmann et al. 2023), the ferrybox data was made available as soon as possible on board in a webODV instance (https://webodv.awi.de/). Consequently, a separate processing unit was installed on the rack to host the ODV services exclusively and in time for the network within the lab container.

Preliminary results of Stern_10

This year was the first one in which we employed the Lagrangian sampling scheme, as previously implemented in the Elbe River and subsequently into the North Sea. At the outset of our cruise, three groups, comprising three to four drifters each, were deployed. The optimal location and timing had been previously modelled. Consequently, two groups were deployed at the southern and northern parts of the Elbe mouth. The drifters reached relatively high velocities (up to 1.8 m/s) and exhibited ellipsoidal movements, gradually moving northward. However, within a few days, several drifters became stranded within the Bight of Mellum, while others reached the area of Amrum, situated further north.

The implementation of this novel approach presented a number of challenges, particularly in terms of the flexibility required for cruise planning. This was only possible (at least when within range of the antenna systems) by using nrt information on the transponder positions (provided by Hereon and Geomar servers). The drifters themselves were hardly visible in the water. The track of the drifters also showed that most of the Elbe water seems to stay within the Meldorf Bay and the North Frisian Wadden Sea for a longer period of time. However, further discussion and interpretation of the drifter data is required.

In a first evaluation of the data, we calculated the distance between the ship and the transponder positions (R-Studio, Geosphere) and set a limit of 2,000 m for the measurement of the same water parcel. Figure 6.20 shows the change in salinity and chlorophyll (as measured with the FerryBox on the way) of the water parcel indicated by drifter #310. Over 18 days, this water parcel moved northwards while its salinity increased and its chlorophyll decreased.

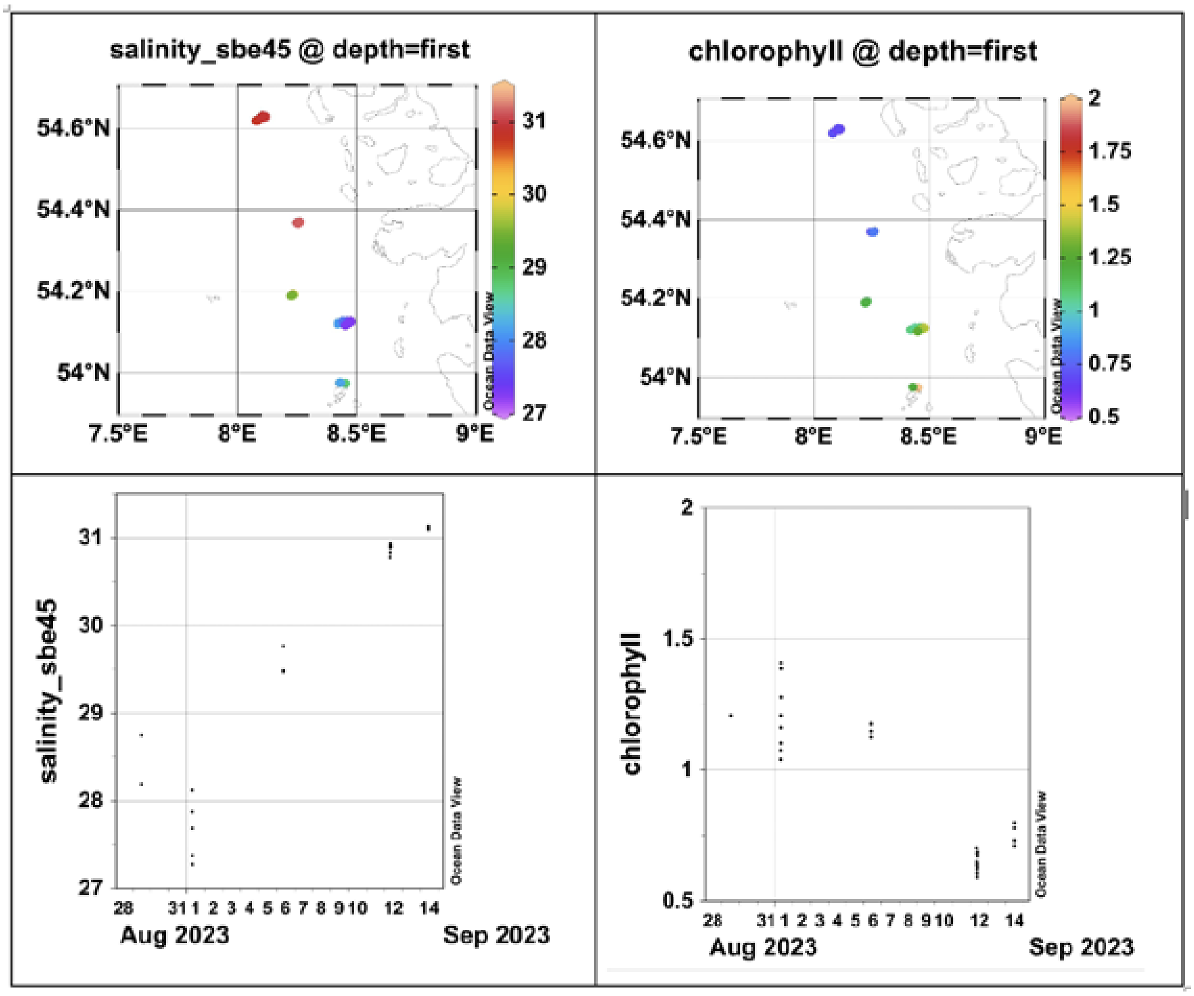

Fig: 6.20: Change in salinity and chlorophyll (as measured with the ferry box on the way) of the water parcel indicated by drifter #310

7. TRANSECT CRUISES WEST OFF SYLT (BUTENDIECK TRANSECTS)

Ingeborg Bussmann, Lasse Sander DE.AWI

Objectives

As a spatial extension of our main research area, the monthly cruises with *Mya II* (if possible, on the first Wednesday of each month) were continued in 2023, designated as the Butendiek-Transects. The cruises commenced from List (Sylt) and proceeded in a westerly direction towards approximately 7.5°E (Fig. 7-1). The inboard FerryBox continuously measured the basic hydrographic parameters (T, S, pH, O2, chlorophyll, pCO2). This data will be used to assess the influence of the Elbe inflow to the northern German Bight. The following dates were selected for the cruises: 10.01., 06.02., 27.02., 05.04., 03.05., 15.06., 15.08., 31.08., 27.09., 17.10. and 14.12.2023.

The following figures present a comprehensive overview of data from 2021, 2022, and 2023.

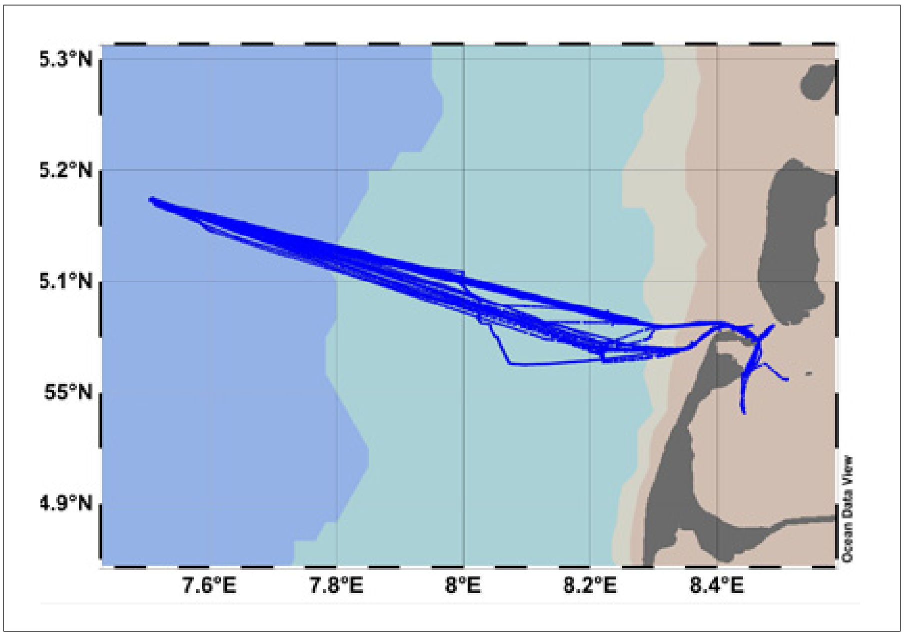

Fig. 7.1: Track of Mya II on the monthly western cruises

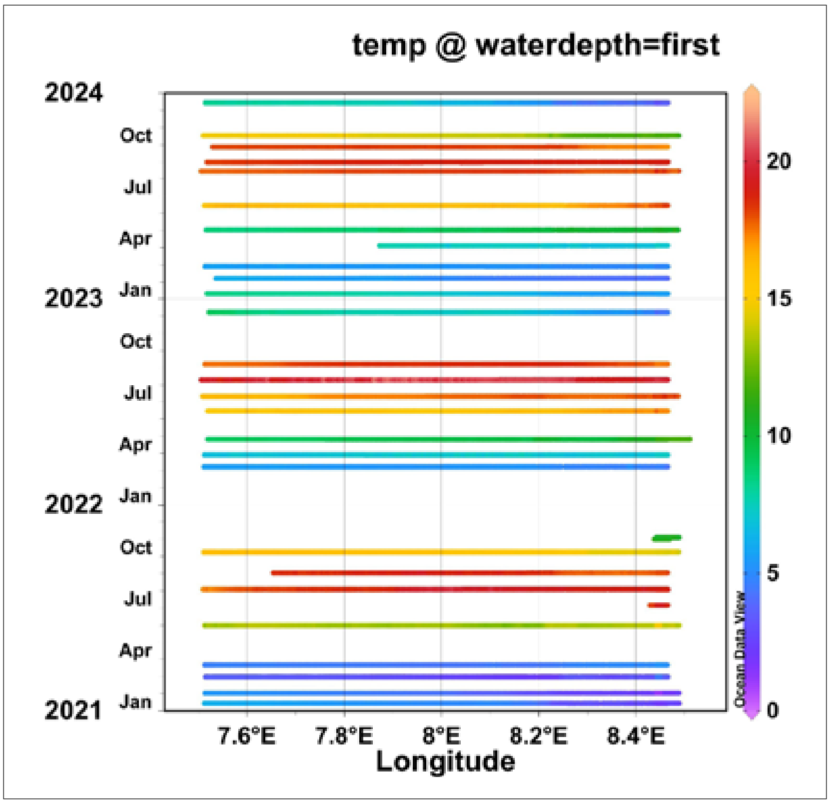

Fig. 7.2: Temperature profiles in surface waters from 2021 to 2023.

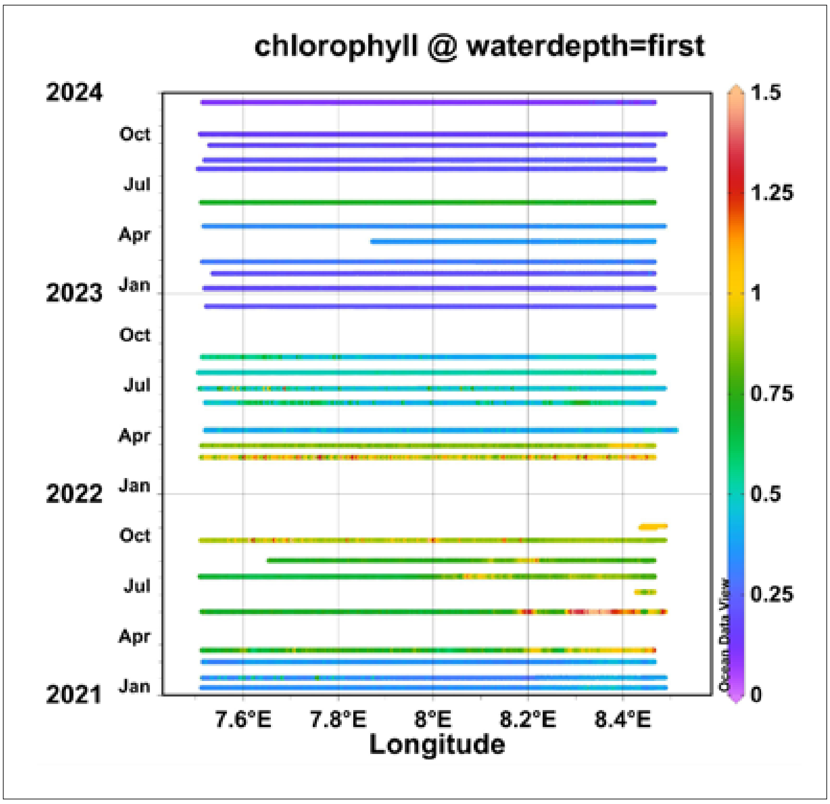

Fig. 7.3: Chlorophyll profiles in surface waters from 2021 to 2023.

Preliminary results

The mean temperature in the preceding years was 11.9 ± 5.9 °C, with a range of 1.0 to 21.2 °C. The mean temperature for 2023 was within the same range, at 11.6 ± 0.5 °C. However, the water temperature in winter (January/February) was 2.5 °C higher than in previous years (Fig. 7.2).

The average salinity in the previous years was 30.7 ± 1.5 PSU, with a range of 11.7 to 34.6. The average for 2023 was within the same range, with an average of 30.9 ± 1.6 PSU.

The average chlorophyll content in the previous years was 0.5 ± 0.3 µg/L, with a range of 0.1 to 1.9 µg/L. The average for 2023 was somewhat lower, at 0.3 ± 0.2 µg/L. However, the spring bloom in 2023 was not as pronounced as in previous years (Fig. 7.3).

Data management

The data can be found at https://dashboard.awi.de/data-ingest/index.html# (vessel:mya_ii:fb….) or at awi.dship.de and the respective dates.

8. REFERENCES

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O2A team. 2022. "NRT Data Format" https://spaces.awi.de/x/OBOVEg

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APPENDIX

A.1 PARTICIPATING INSTITUTIONS

A.2 PARTICIPATING RESEARCH VESSELS

A.2 CRUISE PARTICIPANTS

A.3 TABLES FOR CZECH ELBE

A.4 TABLES FOR TIDE ELBE 2023

A.5 TABLES FOR STERNFAHRT_10

A.1 PARTICIPATING INSTITUTIONS

Tab. A.1.1: Participating institutions and their address

Institution	Address
DE.AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
CZ.CAS	Biology Centre of the CAS, Branišovská 1160/31, 370 05 České Budějovice Czech Republic
DE.Geomar	Geomar Helmholtz-Zentrum für Ozeanforschung Kiel Wischhofstraße 1-3 24148 Kiel Germany
DE.Hereon	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung Max-Planck-Str. 1 21502 Geesthacht Germany
DE.JKI	Julius Kühn-Institut Königin-Luise-Str. 19, 14195 Berlin Germany
DE.UFZ	Helmholtz Centre for Environmental Research GmbH – UFZ Brückstr. 3a 39114 Magdeburg Germany
DE.UFZ	Helmholtz Centre for Environmental Research GmbH – UFZ Permoserstr. 15 04318 Leipzig Germany

Tab. A.1.2: Participating research vessels

A.2 CRUISE PARTICIPANTS **Ships**	**Name of Cruise**	**Start Date**	**End Date**	**Name of Chief Scientist**
Albis	Binnen-Elbe	03.07.2023	11.07.2023	Norbert Kamjunke
Ludwig Prandtl	Tide-Elbe	23.08.2023	28.08.2023	Tina Sanders
Ludwig Prandtl	Sternfahrt_10-1	29.08.2023	01.09.2023	Holger Brix
Littorina	Sternfahrt_10-2	04.09.2023	08.09.2023	Björn Raupers
Mya II	Sternfahrt_10-3	12.09.2023	14-09-2023	Ingeborg Bussmann

A.2 CRUISE PARTICIPANTS

Tab. A.2.1: Cruise Participants of Binnen-Elbe

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Albis	Bauth	Sven	UFZ	Captain
Albis	Goretzka	Heike	UFZ	Technician
Albis	Kamjunke	Norbert	UFZ	Scientist
Albis	Link	Ute	UFZ	Technician

Tab. A.2.2: Cruise Participants of Tide-Elbe

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Ludwig Prandtl	Schacht	Marco	Hereon	Captain
Ludwig Prandtl	Heinze	Detlef	Hereon	Shipman
Ludwig Prandtl	Schulz	Gesa	Hereon	Scientist (23./24.8.)
Ludwig Prandtl	Sanders	Tina	Hereon	Scientist
Ludwig Prandtl	Schmidt	Leon	Hereon	Technician (23./24.8.)
Ludwig Prandtl	Hoppe	Pascal	Hereon	PhD-Student (25./28.8.)
Ludwig Prandtl	Flöser	Götz	Hereon	Scientist (28.8.)
Ludwig Prandtl	Link	Ute	UFZ	Technician (23./24.8.)
Ludwig Prandtl	Goretzka	Heike	UFZ	Technician (23./24.8.)
Ludwig Prandtl	Jahnke	Annika	UFZ	Scientist (25.8.)

Tab. A.2.3: Cruise Participants of Sternfahrt_10

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Mya II	Hildebrandt	Valentin	Reederei Laeisz	Captain
Mya II	Stellmanns	This	Reederei Laeisz	Shipman
Mya II	Fischer	Philipp	AWI	Scientist
Mya II	Kolb	Daniel	UFZ	Technician
Mya II	Markowsky	Jessica	AWI	Technician
Mya II	Anselm	Norbert	AWI	IT
Mya II	Bussmann	Ingeborg	AWI	Scientist

Ship	**Name / Last name**	**Vorname / First name**	**Institut / Institute**	**Beruf / Profession**
Littorina	Nicolas	Angele	GEOMAR	PhD Student
Littorina	Bhattacharya	Sayoni	GEOMAR	PhD Student
Littorina	Sarpe	Dirk	GEOMAR	IT / Scientist (Helgoland → Kiel)
Littorina	Faber	Claas	GEOMAR	IT / Scientist (Kiel → Büsum)
Littorina	Bussmann	Ingeborg	AWI	Scientist
Littorina	Raupers	Björn	GEOMAR	Scientist
Littorina	Reinisch	Ines	Ines Reinisch Design & Film	Film team
Littorina	Thielen	Bianca	Ines Reinisch Design & Film	Film team
Littorina	Flindt	Danny	Briese Research	Captain
Littorina	Stieg	Devin	Briese Research	Ship Machinist
Littorina	Etzdorf	Detlef	Briese Research	Seaman
Littorina	Kazarian	Grant	Briese Research	Cook
Ludwig Prandtl	Schacht	Marco	Hereon	Captain
Ludwig Prandtl	Heinze	Detlef	Hereon	Shipman
Ludwig Prandtl	Brix	Holger	Hereon	Scientist
Ludwig Prandtl	Flöser	Götz	Hereon	Scientist
Ludwig Prandtl	Bussmann	Ingeborg	AWI	Scientist
Ludwig Prandtl	Rust	Hendrik	Hereon	Technician, (29 August only)
Ludwig Prandtl	Link	Ute	UFZ	Technician
Ludwig Prandtl	Goretzka	Heike	UFZ	Technician

A.3 TABLES FOR CZECH ELBE

Tab. 3.1: Sampling sites at the Czech Elbe campaign

All samples were analyzed for Organic Micropollutants, Micropollutants and trace metals. Water samples were additionally analyzed for C/N, Chlorophyll-a, nutrients, dissolved organic carbon (DOC), dissolved organic nitrogen (DON), pH, conductivity, and oxygen. Sediment samples were additionally analyzed for total organic carbon (TOC).

Station	Site description	Date	Latitude	Longitude	Elbe river kilometer from origin	River kilometer from Cuxhaven (used in Czech systems)	Type of site	Water	Sediment
Labe_1	Špindlerův Mlýn	27.06.2023	50.7360	15.6084	8.0	1087.0	Labe / Elbe	x	
Labe / Elbe_1	Špindlerův Mlýn	27.06.2023	50.7360	15.6084	8.0	1087.0	Labe / Elbe	x	
Labe_1a	Les Království	27.06.2023	50.4598	15.7655	53.6	1041.4	Dam	x	
Labe_2	Verdek	27.06.2023	50.4444	15.7932	56.0	1039.0	Labe / Elbe	x	
Labe_2a	Heřmanice nad Labem	27.06.2023	50.3800	15.9207	74.0	1032.2	Dam	x	x
Labe_trib1	Orlice / Hradec Králové	28.06.2023	50.2060	15.8286	101.1	993.9	tributary	x	
Labe_3	Němčice nad Labem	28.06.2023	50.0969	15.8039	116.0	978.7	Labe / Elbe	x	
Labe_4	Valy nad Labem	28.06.2023	50.0324	15.6175	140.0	955.0	Labe / Elbe	x	
Labe_trib2	Jizera / Nový Vestec	28.06.2023	50.1841	14.7311	227.1	867.9	tributary	x	

Station	Site description	Date	Latitude	Longitude	Elbe river kilometer from origin	River kilometer from Cuxhaven (used in Czech systems)	Type of site	Water	Sediment
Labe_4a	Kostelec nad Labem	28.06.2023	50.2377	14.5931	237.4	857.6	Labe / Elbe	x	x
Labe_5	Obříství	28.06.2023	50.2959	14.4820	250.0	845.0	Labe / Elbe	x	
Labe_trib3	Vltava / Vrbno	29.06.2023	50.3195	14.4500	259.0	836.0	tributary	x	
Labe_6b	Křivenice	29.06.2023	50.4110	14.4312	268.0	825.4	Labe / Elbe	x	
Labe_6a	České Kopisty	29.06.2023	50.5275	14.1683	299.8	795.2	Dam	x	x
Labe_trib4	Ohře / Litoměřice	29.06.2023	50.5287	14.1381	304.2	790.8	tributary	x	
Labe_7b	Střekov	29.06.2023	50.6482	14.0456	326.0	769.0	Labe / Elbe	x	
Labe_trib5	Bilina / Ústí	29.06.2023	50.6577	14.0437	330.7	764.3	tributary	x	
Labe_trib6	Ploučnice / Děčín	29.06.2023	50.7756	14.2176	354.9	740.1	tributary	x	
Labe_8	Hřensko	29.06.2023	50.8751	14.2355	367.0	728.0	Labe / Elbe	x	
Labe WWTP1 effluent	COV* Vrchlabi effluent	27.06.2023	50.5922	15.6137	29.4	1065.6	WWTP**	x	
Labe WWTP5 effluent	COV* Pardubice effluent	28.06.2023	50.0459	15.6944	132.0	963.0	WWTP**	x	

Station	Site description	Date	Latitude	Longitude	Elbe river kilometer from origin	River kilometer from Cuxhaven (used in Czech systems)	Type of site	Water	Sediment
Labe WWTP1 influent	COV* Vrchlabi influent	27.06.2023	50.5922	15.6137	29.4	1065.6	WWTP**	x	
Labe WWTP5 influent	COV* Pardubice influent-ind	28.06.2023	50.0459	15.6944	132.0	963.0	WWTP**	x	
Labe WWTP5 influent	COV* Pardubice influent-mun	28.06.2023	50.0459	15.6944	132.0	963.0	WWTP**	x	
Labe WWTP7	COV* Spolana Neratovice Pond	28.06.2023	50.2809	14.5331	248.0	846.0	WWTP**	x	

WWTP = Waste water treatment plant; COV = čistírna odpadních vod, czech for waste water treatment

A.4 TABLES FOR TIDE ELBE 2023

Tab. 4.1: List for stations

Samples for C/N, Chl a, nutrients, DON, Nitrate Isotope colleagues from Hereon (contact T. Sanders). Samples for DOM, DOC and Chl a will be analyzed by colleagues from UFZ (N. Kamjunke). TA (AWI)

ID	Date	Time [UTC]	Elbe kilometer [km]	Lat	Long	Sample
1180	23.08.2023	07:20	747.0	53.975466	8.444185	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1181	23.08.2023	07:40	742.8	53.968146	8.504189	C/N, Chl a, nutrients, DON, Nitrate Isotope
1182	23.08.2023	08:00	738.5	53.959737	8.568061	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1183	23.08.2023	08:20	734.7	53.946071	8.620931	C/N, Chl a, nutrients, DON, Nitrate Isotope
1184	23.08.2023	08:40	731.4	53.926441	8.659563	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1185	23.08.2023	09:00	728.0	53.973097	8.459454	C/N, Chl a, nutrients, DON, Nitrate Isotope
1186	23.08.2023	09:20	724.5	53.872840	8.715235	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1187	23.08.2023	09:40	721.2	53.849342	8.755445	C/N, Chl a, nutrients, DON, Nitrate Isotope
1188	23.08.2023	10:00	717.9	53.837508	8.807433	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1189	23.08.2023	10:20	714.2	53.837944	8.868426	C/N, Chl a, nutrients, DON, Nitrate Isotope
1190	23.08.2023	10:40	710.3	53.842787	8.929179	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1191	23.08.2023	11:00	706.3	53.849585	8.989114	C/N, Chl a, nutrients, DON, Nitrate Isotope
1192	23.08.2023	11:20	702.1	53.862444	9.049935	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC

ID	Date	Time [UTC]	Elbe kilometer [km]	Lat	Long	Sample
1193	23.08.2023	11:40	697.5	53.877037	9.115388	C/N, Chl a, nutrients, DON, Nitrate Isotope
1194	23.08.2023	12:00	692.8	53.878140	9.186127	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1195	23.08.2023	12:20	687.8	53.869557	9.261502	C/N, Chl a, nutrients, DON, Nitrate Isotope
1196	23.08.2023	12:40	682.3	53.842030	9.329786	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1197	23.08.2023	13:00	676.9	53.805432	9.389154	C/N, Chl a, nutrients, DON, Nitrate Isotope
1198	24.08.2023	07:30	677.5	53.806061	9.371405	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1199	24.08.2023	07:50	672.9	53.767726	9.394251	C/N, Chl a, nutrients, DON, Nitrate Isotope
1200	24.08.2023	08:10	668.7	53.735999	9.429298	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1201	24.08.2023	08:30	664.6	53.712323	9.478087	C/N, Chl a, nutrients, DON, Nitrate Isotope
1202	24.08.2023	08:50	660.6	53.678707	9.498732	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1203	24.08.2023	09:10	656.7	53.645578	9.518060	C/N, Chl a, nutrients, DON, Nitrate Isotope
1204	24.08.2023	09:30	653.1	53.618192	9.548794	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1205	24.08.2023	09:50	649.5	53.598419	9.590664	C/N, Chl a, nutrients, DON, Nitrate Isotope
1206	24.08.2023	10:10	645.8	53.575403	9.631076	C/N, Chl a, nutrients, DON, Nitrate Isotope
1107	24.08.2023	10:30	641.8	53.565349	9.690145	C/N, Chl a, nutrients, DON, Nitrate Isotope
1208	24.08.2023	10:50	637.8	53.560392	9.750804	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1209	24.08.2023	11:10	633.8	53.552493	9.809287	C/N, Chl a, nutrients, DON, Nitrate Isotope
1210	24.08.2023	11:30	629.6	53.541914	9.870072	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1211	24.08.2023	11:46	628.2	53.527739	9.891268	C/N, Chl a, nutrients, DON, Nitrate Isotope

ID	Date	Time [UTC]	Elbe kilometer [km]	Lat	Long	Sample
1212	24.08.2023	12:14	624.5	53.541917	9.947347	C/N, Chl a, nutrients, DON, Nitrate Isotope
1213	24.08.2023	12:40	620.8	53.530473	9.999114	C/N, Chl a, nutrients, DON, Nitrate Isotope
1214	24.08.2023	12:50	619.5	53.533993	10.017868	C/N, Chl a, nutrients, DON, Nitrate Isotope, TA, DIC, DOM, DOC
1215	24.08.2023	13:25	612.2	53.482291	10.055525	C/N, Chl a, nutrients, DON, Nitrate Isotope
1216	24.08.2023	13:40	608.8	53.456005	10.076150	C/N, Chl a, nutrients, DON, Nitrate Isotope
1217	25.08.2023	04:18	608.7	53.454947	10.076907	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments
1218	28.08.2023	05:24	608.6	53.454162	10.077870	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments
1219	28.08.2023	06:47	624.8	53.500864	9.942282	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments
1220	28.08.2023	07:16	625.0	53.531840	9.938919	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments
1221	28.08.2023	07:53	628.5	53.532390	9.886599	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments
1222	28.08.2023	08:38	634.2	53.552486	9.802617	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments
1223	28.08.2023	10:49	662.2	53.691783	9.490894	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments
1224	28.08.2023	13:59	714.2	53.845372	8.868479	C/N, Chl a, nutrients, DON, Nitrate Isotope, Sediments

Tab. 4.2: Instruments on the Tide Elbe

On the way / vertical	Parameter(s)	Responsible person	Instrument name	Sensor ID HYDREX_2023_Tide_Elbe	remarks
on the way	hydrographic parameters	Bussmann I.	MOSES-Labor-Container mit pocket ferry box pfb awi [4079]	vessel:prandtl:moses_ moblab:pfb_ awi_751801:salinity_ sbe45_0001	
on the way	CO2, Methan, N2O	Sanders, Tina Schulz, Gesa	Picarro	https://hcdc.hereon.de/ campaign_db/#/download	

A.5 TABLES FOR STERNFAHRT_10

Tab. 5.1: Station list for *Ludwig Prandtl*

Water samples were taken from a Niskin water sampler for analysis of methane (CH4) and DOC, POC & DIC (dissolved and particulate organic carbon, dissolved inorganic carbon), TA (total alkalinity). Samples for nutrients (Silicate, nitrate, nitrite, phosphate, ammonia); chlorophyll (Chl) and dissolved organic matter (DOM) were taken from the overflow of ferrybox seawater supply. Niskin water samples were taken at the end of the CTD time. Multielement-samples (MES) were taken after sampling with CTD and FerryBox with a special metal-free equipment ('Goflo'). Data will be published in the pangea database. Station names in brackets indicate replicate stations from Stern_9 in 2022.

Station ID	Device	Start time (datetime UTC)	Stop time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
P-1 (P-1-S9)	in situ CTD	29.08.2023 09:16	29.08.2023 09:23	53.9645	8.6333	14	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
							Organic Micropollutants, Micropollutants, Nano-Plastic DOM
P-2	in situ CTD	29.08.2023 10:28	29.08.2023 10:33	54.0357	8.4937	9	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
		29.08.2023 10:45		54.03457	8.4926		deployment of the drifters #304, #316, #318, #321
P-3	in situ CTD	29.08.2023 11:28	29.08.2023 11:36	53.9738	8.4581	20	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
		29.08.2023 11:32		53.9739	8.4578		deployment of the drifters #305, #309, #310, #312
P-4 (P-3-S9)	in situ CTD	29.08.2023 12:12	29.08.2023 12:20	54.0080	8.3212	14	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-5 (P-4-S9)	in situ CTD	29.08.2023 12:48	29.08.2023 12:54	54.0340	8.1987	16	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES

Station ID	Device	Start time (datetime UTC)	Stop time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
P-6 (P-5-S9)	in situ CTD	29.08.2023 13:21	29.08.2023 13:29	54.0297	8.0953	22	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-7 (P-10-S9)	in situ CTD	29.08.2023 14:35	29.08.2023 14:45	54.1546	7.9067	31	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-8	in situ CTD	30.08.2023 07:23	30.08.2023 07:29	54.0513	8.4111	16	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
		30.08.2023 07:44					electricity break down
P-9	in situ CTD	30.08.2023 08:23	30.08.2023 08:28	54.1027	8.3978	16	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-10	in situ CTD	30.08.2023 09:32	30.08.2023 09:36	54.1680	8.5371	10	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES, sediment sample Organic Micropollutants, Micropollutants, Nano-Plastic, DOM
P-11 (L-16-S9)	in situ CTD	30.08.2023 10:19	30.08.2023 10:25	54.1653	8.4108	14	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-12 (L-05-S9)	in situ CTD	30.08.2023 11:17	30.08.2023 11:22	54.1703	8.2310	19	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-13 (L-06-S9)	in situ CTD	30.08.2023 11:52	30.08.2023 11:59	54.1724	8.1491	21	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
		30.08.2023 13:09					electricity break down
P-14 (L-07-S9)	in situ CTD	30.08.2023 12:28	30.08.2023 12:34	54.1710	8.0646	27	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
		31.08.2023 05:31					electricity break down
P-15	in situ CTD	31.08.2023 07:22	31.08.2023 07:27	54.1048	8.3951	15	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-16 (L-13-S9)	in situ CTD	31.08.2023 07:50	31.08.2023 07:53	54.1182	8.4417	9	DOC, POC , NS, Chl-a, DOC, DIC, TA, CH4, MES

Station ID	Device	Start time (datetime UTC)	Stop time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
P-17	in situ CTD	31.08.2023 08:41	31.08.2023 08:46	54.1125	8.3259	16	DOC, POC , NS, Chl-a, DOC, DIC, TA, CH4, MES
P-18 (L-03-S9)	in situ CTD	31.08.2023 09:26	31.08.2023 09:31	54.0503	8.4515	14	DOC, POC , NS, Chl-a, DOC, DIC, TA, CH4, MES
P-19 (L-23-S9)	in situ CTD	31.08.2023 10:13	31.08.2023 10:19	54.0553	8.3374	17	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-21	in situ CTD	31.08.2023 12:51	31.08.2023 12:55	54.2097	7.9604	16	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES Organic Micropollutants, Micropollutants, Nano-Plastic, DOM
P-22	in situ CTD	01.09.2023 07:35	01.09.2023 07:44	54.1259	8.4765	5	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES
P-23	in situ CTD	01.09.2023 08:25	01.09.2023 08:31	54.0986	8.3879	16	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES, sediment sample Organic Micropollutants, Micropollutants, Nano-Plastic, DOM
P-24 (L-03-S9)	in situ CTD	01.09.2023 09:17	01.09.2023 09:22	54.0503	8.4503	13	DOC, POC, NS, Chl-a, DOC, DIC, TA, CH4, MES Organic Micropollutants, Micropollutants, Nano-Plastic, DOM

Tab. 5.2: Instruments on *Ludwig Prandtl* on Stern_10-2

On the way/ vertical	Parameter(s)	Responsible person	Instrument name	Sensor ID https://dashboard.awi.de/data-ingest/index.html HYDREX_2023_German_Bight_Stern10-2	Remarks
vertical		Götz Flöser	CTD313	vessel:prandtl_hzg:ctd_hzg_313	
on the way	coordinates	Götz Flöser	DSHIP	vessel:prandtl_hzg:dship_prandtl_01:latitude_0001 vessel:prandtl_hzg:dship_prandtl_01:longitude_0001	
on the way	weather station	Götz Flöser	weather station GMX600	vessel:Prandtl_hzg:weather_station_hzg_1957ps001	
on the way	hydrographic parameters	Bussmann I.	MOSES-Labor-Container mit pocket ferry box pfb awi [4079]	vessel:prandtl:moses_moblab:pfb_awi_751801:salinity_se45_0001	time offset 150 sec with in situ pump #1
on the way	dissolved CH4 and CO2	Bussmann I.	MOSES-Labor-Container mit LosGatos #3599 [6977] with Degasser: 3K6018060000DGE4 [5261]	vessel:prandtl:moses_moblab:losgatos_awi_3599:co2_ppm	time offset 200 sec
vertical	sediment samples	Holger Brix	grab sampler		
vertical	multielement samples	Holger Brix	Goflo		
vertical	particle size distribution	Holger Brix	LISST200		

Tab. 5.3: Station List for *Littorina*

If there is no special indication the amount of sea water filtered was 500 mL for the POC samples and 200 mL filtered for the trace metal samples. Samples for CH4, TA, DIC, POC, nutrients were taken from the rosette. Samples for explosives, trace metals and pollutants were taken from the GoFlo, samples for DOM and Chlorophyll were taken from the ferryBox outlet. Station names in brackets indicate replicate stations from Stern_9 in 2022.

Station ID	Device	Start time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
L-01	CTD	2023-09-04 10:45	54.1138	8.4199	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC (250 ml), TA, DIC, NS, Explosives
	GoFlo				1	Trace metals (150 ml)
	GoFlo				5	Trace metals (150 ml)
	Water sampler				10	Explosives
	GoFlo				10	Trace metals (150 ml), Explosives
L-02	CTD	2023-09-04 11:50	54.1696	8.2835	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC (250 ml), TA, DIC, NS, Explosives, DOM, Chlorophyll
	GoFlo				1	Trace metals (150 ml), Organic Micropollutants, Micropollutants, Nano-Plastic, DOM
	GoFlo				9	Trace metals (150 ml)
	Water sampler				16	Explosives
	GoFlo				16	Trace metals (150 ml)
	Grab sampler				16	Sediment for nano plastics
L-03	CTD	2023-09-04 14:04	54.1331	7.9174	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives
	GoFlo				1	Trace metals (150 ml)

Station ID	Device	Start time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
	GoFlo				20	Trace metals (150 ml)
	Water sampler				37	Explosives
	GoFlo				37	Trace metals (150 ml)
L-04	CTD	2023-09-05 6:19	54.1592	8.1626	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				9	Trace metals
	Water sampler				18	Explosives
	GoFlo				18	Trace metals
	drifter	2023-09-05 6:42	54.1618	8.1485		deployment of drifters #323, #324, #325
L-05	CTD	2023-09-05 7:24	54.1439	8.3025	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				7	Trace metals
	Water sampler				15	Explosives
	GoFlo				15	Trace metals, Explosives
L-06 (L-12-S9)	CTD	2023-09-05 7:59	54.1613	8.3130	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS
	GoFlo				1	Trace metals
	GoFlo				6	Trace metals
	GoFlo				12	Trace metals
	drifter	2023-09-05 08:00	54.1614	8.3143		Drifter #319
L-07	CTD	2023-09-05 8:30	54.1941	8.3689	values below	Conductivity, Temperature, Density

Station ID	Device	Start time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
	Water sampler				1	CH4, DOC, POC (250 mL), TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				6	Trace metals
	Water sampler				13	Explosives
	GoFlo				13	Trace metals
L-08 (L-17-S9)	CTD	2023-09-05 8:57	54.2265	8.3666	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC (250 mL), TA, DIC, NS
	GoFlo				1	Trace metals
	GoFlo				6	Trace metals
	GoFlo				12	Trace metals
L-09 (L-18-S9)	CTD	2023-09-05 10:01	54.3248	8.3013	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				6	Trace metals
	Water sampler				13	Explosives
	GoFlo				13	Trace metals
	drifter	2023-09-05 9:57				deployment of drifters #319
L-10 (L-19-S9)	CTD	2023-09-05 11:08	54.3276	8.1081	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives, DOM, Chlorophyll
	GoFlo				1	Trace metals (150 ml), Organic Micropollutants, Micropollutants, Nano-Plastic, DOM
	GoFlo				7	Trace metals

Station ID	Device	Start time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
	Water sampler				15	Explosives
	GoFlo				15	Trace metals
	Grab sampler				15	sediment for nano plastics
L-11 (L-20-S9)	CTD	2023-09-05 12:19	54.2512	8.0019	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				10	Trace metals
	Water sampler				20	Explosives
	GoFlo				20	Trace metals
L-12	CTD	2023-09-06 7:08	54.2817	7.9964	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				10	Trace metals
	Water sampler				20	Explosives
	GoFlo				20	Trace metals
L-13	CTD	2023-09-06 8:50	54.2498	8.3065	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				7	Trace metals
	Water sampler				13	Explosives
	GoFlo				13	Trace metals
L-14	CTD	2023-09-06 9:32	54.1918	8.2298	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, Explosives

Station ID	Device	Start time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
	GoFlo				1	Trace metals
	GoFlo				8	Trace metals
	Water sampler				16	Explosives
	GoFlo				16	Trace metals
L-15	CTD	2023-09-06 11:15	54.0993	8.5152	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC (300 mL), TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				5	Trace metals
	Water sampler				10	Explosives
	GoFlo				10	Trace metals
L-16	CTD	2023-09-06 12:18	54.1282	8.7106	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC (250 mL), TA, DIC, NS, Explosives
	GoFlo				1	Trace metals
	GoFlo				6	Trace metals
	Water sampler				12	Explosives
	GoFlo				12	Trace metals
L-17	CTD	2023-09-06 12:51	54.1267	8.8151	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC (250 mL), TA, DIC, NS, Explosives, DOM, Chlorophyll
	GoFlo				1	Trace metals (150 ml), Organic Micropollutants, Micropollutants, Nano-Plastic, DOM
	GoFlo				7	Trace metals
	Water sampler				13	Explosives
	GoFlo				13	Trace metals
	Grab sampler				13	sediment for nano plastics

Station ID	Device	Start time (datetime UTC)	Latitude	Longitude	Water depth (m)	Remarks
L-18	CTD	2023-09-07 5:09	54.1269	8.8203	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC (250 mL), TA, DIC, NS
	GoFlo				1	Trace metals
	GoFlo				7	Trace metals
	GoFlo				14	Trace metals
L-19	CTD	2023-09-07 7:33	54.2187	8.3152	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, DOM, Chlorophyll
	GoFlo				1	Trace metals
	GoFlo				7	Trace metals
	GoFlo				14	Trace metals
L-20	CTD	2023-09-07 8:06	54.2297	8.2212	values below	Conductivity, Temperature, Density
	Water sampler				1	CH4, DOC, POC, TA, DIC, NS, DOM, Chlorophyll
	GoFlo				1	Trace metals (150 ml), Organic Micropollutants, Micropollutants, Nano-Plastic, DOM
	GoFlo				7	Trace metals
	GoFlo				13	Trace metals
	Grab sampler				13	Sediment for nano plastics

Tab. 5.4: Instruments on the *Littorina* on Stern_10-2

On the way/ vertical	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-ingest/ index.html HYDREX_2023_German_Bight_Stern10-2,	Remarks
On the way	Longitude / Latitude	C. Faber	Littorina Navigation	vessel:littorina:lat_0001;vessel:littorina:lon_0001	
On the way	wind speed, wind direction	C. Faber	Furuno FI-501 Wind logger	vessel:littorina:wind_furuno_fi-501_001:wind_dir_rel;vessel:littorina:wind_furuno_fi-501_001:wind_speed_rel	**relative** wind speed and direction
On the way	compass & navigation	C. Faber		vessel:littorina:course_0001; vessel:littorina:heading_0001; vessel:littorina:speed_0001	for calculation of true wind
On the way	hydrographic parameters	Bussmann I.	MOSES-Lab-container mit pocket ferry box pfb awi [4079]	vessel:littorina:moses_moblab:pfb_awi_751801:salinity_sbe45_0001	
On the way	dissolved CH4	Bussmann I.	MOSES-Labor-Container mit LosGatos #3599 [6977] with Degasser: 3K6018060000DGE4 [5261]	vessel:littorina:moses_moblab:losgatos_awi_3599:co2_ppm	
On the way	pH: ph_P0235, temperature,	S. Bhattacharya	SAMI pH Sensor	vessel:littorina:sami_ph_geomar_p0235	Not in nrt
On the way	Nitrate: salinity, temperature, salinity	S. Bhattacharya	OPUS Nitrate Sensor	vessel:littorina:opus_geomar_71f9	Not in nrt
On the way	pH	S. Bhattacharya	Lab on Chip pH	vessel:littorina:loc_ph_gmr_a7105-07-003	Not in nrt

On the way	**Hydrography: conductivity, oxygen, salinity, diss. solids, temperature,**	**S. Bhattacharya**	**EXO CTD**	**vessel:littorina:exo1_geomar_0001**	**Not in nrt**
On the way	Dissolved methane	S. Bhattacharya	Pro OCEAN CH4 Sensor	vessel:littorina:methane_geomar_37-477-25	Not in nrt
Vertical	Hydrography: conductivity, pressure, salinity, temperature, oxygen_saturation, oxygen_ concentration_ mll, oxygen_ concentration, pH, density, sound_ velocity,	B. Raupers	CTD rosette	vessel:littorina:ctd_geomar_1070210	

Tab. 5.5: Station list for *Mya II*

Water samples were taken from a Niskin water sampler for analysis of methane (CH_4), DOC and POC (dissolved and particulate carbon), TA (total alkalinity), DIC (dissolved inorganic carbon) and NS (nutrients). Numbers in brackets indicate the filtered water volume. All samples were taken from the surface 1 – 2 m. Data will be published in the pangea database. Station names in brackets indicate replicate stations from Stern_9 in 2022.

Station ID	**Device**	**Start time (datetime UTC)**	**Latitude**	**Longitude**	**Bottom depth (m)**	**Remarks**
M-1	**CTD**	**2023-09-12 08:44**	54.6280	8.1099	14.0	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
	stainless steel bucket					DOM, Chl-a (500 ml), Organic Micropollutants, Micropollutants, Nano-Plastic
	grab corer	2023-09-12 09:06	54.6292	8.1119	14.2	Nano-Plastic
M-2	CTD	2023-09-12 10:44	54.7364	7.7964	18.3	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M3 (P-21-S9)	CTD	2023-09-12 12:06	54.6012	7.8977	14.1	old P-21
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M4 (P-11-S9)	CTD	2023-09-12 14:17	54.3013	7.9044	21.6	old P-11
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M5 (U-22-S9)	CTD	2023-09-13 07:26	54.1256	7.9304	41.2	old U-21
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M-6	CTD	2023-09-14 07:01	54.1970	8.3613	12.6	

Station ID	Device	Start time (datetime UTC)	Latitude	Longitude	Bottom depth (m)	Remarks
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M-7	CTD	2023-09-14 07:35	54.1866	8.4834	8.9	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M-8	CTD	2023-09-14 08:01	54.2062	8.5201	7.6	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (250 ml)
M-9	CTD	2023-09-14 08:37	54.2685	8.4969	8.8	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M-10	**CTD**	**2023-09-14 09:16**	**54.2245**	**8.4630**	**10.8**	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
	stainless steel bucket					DOM, Chl-a (500 ml), Organic Micropollutants, Micropollutants, Nano-Plastic
	Grab corer	2023-09-14 09:25	54.2247	8.4680	11	Nano-Plastic
M-11	CTD	2023-09-14 11:10	54.3700	8.2603	15.8	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
M-12	**CTD**	**2023-09-14 13:25**	**54.1932**	**7.8803**	10	
	Niskin water sampler					CH_4, DIC, NS, DOC, POC (500 ml)
	stainless steel bucket					DOM, Chl-a (500 ml), Organic Micropollutants, Micropollutants Nano-Plastic
	Grab corer	2023-09-14 13:39	54.1935	7.8801	10.3	Nano-Plastic

Tab. 5.6: Instruments on the *Mya II* on Stern_10-3

On the way/ vertical	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-ingest/index.html **HYDREX_2023_German_Bight_Stern10-3**	Remarks
on the way	position	N. Anselm	d-ship Mya	vessel:mya_ii:dgps:longitude	with respective date(s)
on the way	wind speed, wind direction	N. Anselm	d-ship		with respective date(s)
on the way	hydrographic parameters	Bussmann I.	MOSES-Labor-Container mit pocket ferry box pfb awi [4079]	vessel:mya_ii:moses_moblab:pfb_awi_751801:salinity_sbe45_0001	time offset 150 sec with in situ pump #1
on the way	dissolved CH_4 and CO_2	Bussmann I.	MOSES-Labor-Container mit LosGatos #3599 [6977] with Degasser: 3K6018060000DGE4 [5261]	vessel:mya_ii:moses_moblab:losgatos_awi_3599:co2_ppm	time offset 200 sec
on the way	communication unit	N. Anselm	IPU	hulk [8047]	no data
vertical	hydrographic parameters	Bussmann I.	CTD 1420		no data stored on instrument

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