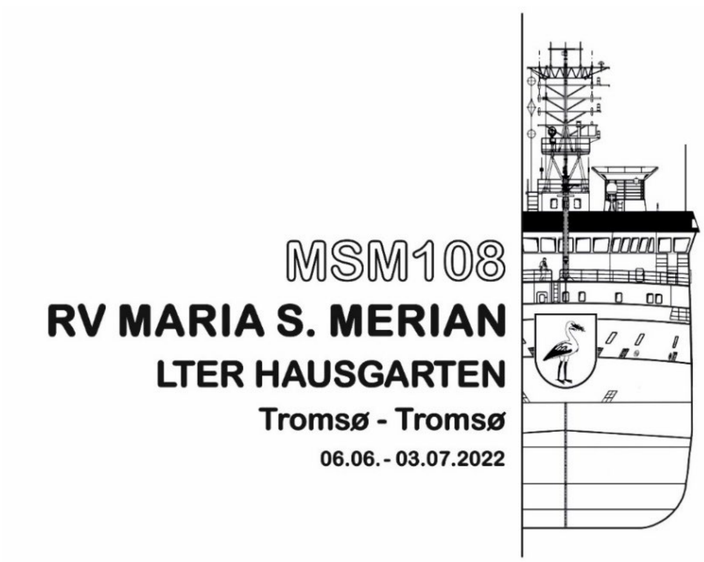
MARIA S. MERIAN-Berichte

LTER HAUSGARTEN 2022

Long-Term Ecological Research in the Fram Strait

Cruise No. MSM108

June 06 – July 03, 2022
Tromsø (Norway) – Tromsø (Norway)
FRAM 2022



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2022

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1 Cruise Summary

1.1 Summary in English

The 108th cruise of the RV MARIA S. MERIAN contributed to the new research programme „Changing Earth - Sustaining our Future" („Erde im Wandel - Unsere Zukunft nachhaltig gestalten") of the Alfred-Wegener-Institute Helmholtz-Center for Polar and Marine Research (AWI) as well as to various large national and international research and infrastructure projects (e.g. FRAM, ARCHES, INTAROS, ICOS, SIOS). The work extended the time-series studies at the LTER (Long-Term Ecological Research) observatory HAUSGARTEN in the Fram Strait between NE Greenland and Svalbard, where we document Global Change induced environmental variations on a polar deep-water ecosystem. This work is carried out in close co-operation between the HGF-MPG Joint Research Group on Deep-Sea Ecology and Technology, the PEBCAO Group ("Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean") at AWI, and the working group Microbial Biogeochemistry at GEOMAR as well as various national and international partners. The expedition was further used to accomplish further installations for the HGF infrastructure project FRAM (Frontiers in Arctic marine Monitoring). The FRAM Ocean Observing System aims at permanent presence at sea, from surface to depth, for the provision of near real-time data on Earth system dynamics, climate variability and ecosystem change. FRAM implements existing and next-generation sensors and observatory platforms, allowing synchronous observation of relevant ocean variables as well as the study of physical, chemical and biological processes in the ocean.

1.2 Zusammenfassung

Die 108. Fahrt der RV MARIA S. MERIAN leistete einen Beitrag zum neuen Forschungs-programm „Erde im Wandel - Unsere Zukunft nachhaltig gestalten" des Alfred-Wegener-Instituts Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) sowie zu verschiedenen großen nationalen und internationalen Forschungs- und Infrastrukturprojekten (z.B. FRAM, ARCHES, INTAROS, ICOS, SIOS). Die Arbeiten erweitern die Zeitreihenuntersuchungen am LTER (Long-Term Ecological Research) Observatorium HAUSGARTEN in der Framstraße zwischen Nord-Ost Grönland und Spitzbergen, wo wir durch den Globalen Wandel bedingte Umwelt-Veränderungen in einem polaren Tiefsee-Ökosystem dokumentieren. Diese Arbeiten werden in enger Zusammenarbeit zwischen der HGF-MPG Brückengruppe Tiefsee-Ökologie und -Technologie und der PEBCAO-Gruppe („Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean") am AWI, der Arbeitsgruppe Mikrobielle Biogeochemie am GEOMAR sowie verschiedenen nationalen und internationalen Partnern durchgeführt. Die Expedition wurde außerdem genutzt, um weitere Installationen für das HGF-Infrastrukturprojekt FRAM (Frontiers in Arctic marine Monitoring) durchzuführen. Ziel des FRAM-Ozeanbeobachtungssystems ist die ständige Präsenz auf See, von der Oberfläche bis in die Tiefe, um Daten über die Dynamik des Erdsystems, Klimaschwankungen und Ökosystemveränderungen in nahezu Echtzeit zu liefern. FRAM setzt bestehende und neuartige Sensoren und Beobachtungsplattformen ein, die eine synchrone Beobachtung relevanter Meeresvariablen sowie die Untersuchung physikalischer, chemischer und biologischer Prozesse im Ozean ermöglichen.

2 Participants

2.1 Principal Investigators

Name	Institution
Soltwedel, Thomas, Dr.	AWI
Hasemann, Christiane, Dr.	AWI
Janssen, Felix, Dr.	AWI
Kraberg, Alexandra, Dr.	AWI
Purser, Autun, Dr.	AWI

2.2 Scientific party

Name	Discipline	Institution
Soltwedel, Thomas, Dr.	Deep-Sea Research, Chief Scientist	AWI
Asendorf, Volker	Crawler-Team, Technician	MPIMM
Barthelmeß, Theresa	Biogeochemistry, PhD Student	GEOMAR
Barz, Jakob	Biogeochemistry, Technician	AWI
Becker, Kevin, Dr.	Biogeochemistry, Scientist	GEOMAR
Becker, Noah	Crawler-Team, Technician	AWI
Böhringer, Lilian	Benthology, Scientist	AWI
Brinkmann, Talea	Planktology, Student	AWI
Dannheim, Jennifer, Dr.	Benthology, Scientist	AWI
Hagemann, Jonas	AUV-Team, Technician	AWI
Hasemann, Christiane, Dr.	Benthology, Scientist	AWI
Hoge, Ulrich, Dipl.-Ing.	Deep-Sea Research, Technician	AWI
Holt, Jonas	Benthology, Student	AWI
Janssen, Felix, Dr.	Crawler-Team, Scientist	AWI
Klüver, Tania	Biogeochemistry, Technician	GEOMAR
Kraberg, Alexandra, Dr.	Planktology, Scientist	AWI
Lehmenhecker, Dipl.-Inf.	Deep-Sea Research, Technician	AWI
Purser, Autun, Dr.	AUV-Team, Scientist	AWI
Schnier, Jannik	Benthology, PhD Student	AWI

2.3 Participating Institutions

AWI — Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung
Am Handelshafen 12, 27570 Bremerhaven, Germany

GEOMAR — GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
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MPIMM — Max-Planck-Institut für Marine Mikrobiologie
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3 Research Program

3.1 Description of the Work

To detect and track the impact of large-scale environmental changes in the transition zone between the northern North Atlantic and the central Arctic Ocean, and to determine experimentally the factors controlling deep-sea biodiversity, the AWI established the LTER (Long-Term Ecological Research) observatory HAUSGARTEN in Fram Strait between Greenland and Svalbard. Since 2014, this observatory is successively extended within the frame of the HGF infrastructure project FRAM (Frontiers in Arctic marine Monitoring) and covers currently 21 permanent sampling sites on the West-Spitsbergen and East-Greenland slope at water depths between 250 and 5500 m (Fig. 3.1). Regular sampling as well as the deployment of moorings and different stationary and mobile free-falling systems (Bottom-Lander, Benthic Crawler), which act as local observation platforms, has taken place since the observatory was established back in 1999. The central HAUSGARTEN station in the eastern Fram Strait (~2500 m water depth) serves as an experimental area for unique biological experiments at the deep seafloor, simulating various scenarios in changing environmental settings.

3.2 Aims of the Cruise

While always fluctuating, the global climate is presently experiencing a period of constantly increasing temperatures, with a warming trend amplified in the Arctic. Besides water temperature increase, expanding ocean acidification will pose another threat to pelagic and benthic life in the Arctic Ocean. The shift from an ice-covered and cold ocean to an ice-free, warmer and acidified ocean will have severe impacts on the polar marine ecosystem and its functioning. Thinner ice may permit better growth of ice algae, but earlier and faster spring melting may reduce their growing season. Altered algal abundance and composition will affect zooplankton community structure and subsequently the flux of particulate organic matter to the seafloor, where the changing quantity and quality of this matter will impact benthic communities. Changes in the predominance of certain trophic pathways will have cascading effects propagating through the entire marine community. Generally, arctic marine organisms will be compromised by temperature regimes approaching the limits of their thermal capacity. As a consequence, warmer waters in the Arctic will allow a northward expansion of sub-arctic and boreal species. Time-series studies at the HAUSGARTEN observatory will provide insights into processes and dynamics within an arctic marine ecosystem and act as a baseline for further investigations of ongoing changes in the Fram Strait. Our observations will significantly contribute to the global community's efforts to understand variations in ecosystem structure and functioning on seasonal to decadal time-scales in an overall warming Arctic and will allow for improved future predictions under different climate scenarios.

3.3 Agenda of the Cruise

The work carried out during the expedition MSM108 will continue our extensive efforts to study ongoing natural and Climate Change induced variations in an arctic marine ecosystem. All activities during the cruise followed the regulations formulated in the Code of Conduct for Responsible Marine Research.

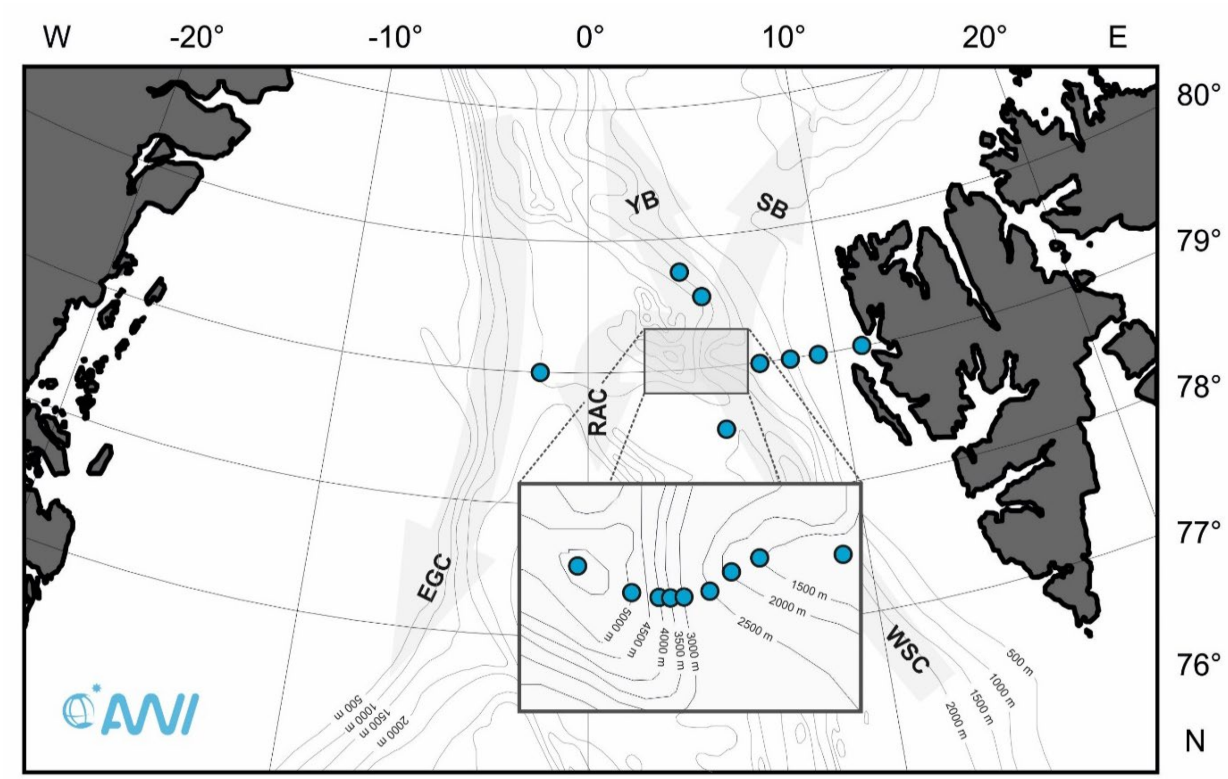

Fig. 3.1 HAUSGARTEN stations sampled during RV MARIA S. MERIAN expedition MSM108.

4 Narrative of the Cruise

The RV MARIA S. MERIAN expedition MSM108 started on 7th of June 2022 in Tromsø, Norway and led to the Fram Strait between Greenland and the Svalbard archipelago. Shortly after leaving the Tromsø Fjord, we were hit by a storm with wind speeds of 9 Bft and gusts of 10 Bft, which caused considerable discomfort for most of the cruise participants. As fast as it came the storm disappeared again and we were able to continue our journey swiftly. In fact, the overall good weather conditions lasted until the end of the cruise.

On 10th of June, we finally reached the study area of this expedition, the LTER observatory HAUSGARTEN in the Fram Strait, the only deep-water connection between the northern North Atlantic and the central Arctic Ocean. Time-series studies at HAUSGARTEN involve ecosystem compartments from the sea surface down to the deep seafloor and the permanent sampling sites of the observatory are regularly sampled both in the water column and on the seabed during our annual cruises in the summer months. During MSM108, water samples were obtained with a CTD / Rosette Water Sampler. The device carries sensors that provide information about water temperature and conductivity (i.e. salinity). Additional instruments used on the device include sensors, which measure dissolved oxygen concentrations, the photosynthetically active radiation, and chlorophyll concentrations in the water, a measure for phytoplankton concentrations in the water column.

Water samples were processed for a range of biogeochemical parameters that allow to determine the distribution, composition and cycling of organic carbon in the water column. Additional samples were taken to study the phytoplankton composition and to determine the heterotrophic microbial activity in the water samples, applying radioisotope methods. To investigate the distribution and abundance of larger zooplankton, we used a Multi-net that, akin to the CTD / Rosette Water Sampler, can take samples at discrete water depths.

Sampling on the seabed was done with cable-connected bottom grabs, i.e. a Multiple Corer and a Giant Box Grab, which cut out certain sediment volumes on the seafloor and bring them on board. Some of the sediment samples were processed on board, however, most of them (e.g. a variety of biogeochemical parameters and the sediment-dwelling fauna) will be analysed in the home lab.

A towed photo/video system provided information about the large-scale distribution of larger animals on the seafloor. An Autonomous Underwater Vehicle (AUV) has repeatedly been deployed to map the deep-sea floor and to complement our efforts to record the distribution patterns of larger organisms. A comparison with data from previous decades provides us with information about temporal changes in environmental parameters and in the density and composition of the bottom-dwelling community.

Free-falling systems (Bottom-Landers), were used to carry out various measurements and experiments on the seafloor. The landers were equipped with a variety of measuring and recording devices, depending on the scientific question. During MSM108, we deployed an experimental system in short-term missions to study the impact of ongoing ocean acidification on the smallest bottom-dwelling deep-sea organisms.

A newly developed autonomously operating moving seafloor platform (Benthic Crawler) was tested and finally deployed for one year at the central HAUSGARTEN station HG-IV at 2500 m water depth. The Benthic Crawler is equipped with oxygen microsensors and incubation chambers to quantify the decomposition of organic material on the deep seafloor. The system was programmed to measure oxygen penetration depths and oxygen consumption rates at the sediment-water interface, then travel a short distance before taking another measurement. Autonomous devices like this crawler allow to obtain seasonal data from the Arctic deep sea, which is generally very difficult to access, especially in the winter months.

Finally, we deployed a special mooring carrying a large concrete housing to test whether this low-cost material could in part replace comparably expensive metal pressure housings in future deep-sea applications.

The highly variable ice conditions in the study area required a fairly high degree of adaptability in station planning. However, thanks to the overall good weather conditions in the study area, the work could be carried out largely as planned. The cruise ended on 2nd of July 2022 in Tromsø.

5 Preliminary Results

5.1 Biogeochemical and Ecological Studies in the Water Column

(A. Kraberg, T. Barthelmeß, J. Barz, N. Becker, T. Brinkmann, T. Klüver)

The project PEBCAO (Plankton Ecology and Biogeochemistry in a Changing Arctic Ocean) focusses on the plankton community and the microbial processes relevant for biogeochemical cycles in the Arctic Ocean. The research acknowledges that the Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea-ice coverage and thickness and an increase in air temperature, which is about twice as fast as the global mean rate. In addition, the chemical equilibrium and the elemental cycling in the surface ocean will alter due to ocean acidification. These environmental changes will have severe consequences for the biogeochemistry and ecology of the Arctic pelagic system. The effects of changes in the environmental conditions on the polar plankton community can only be detected through long-term observation of the species and processes. Our studies on plankton ecology have started in 1991, and since 2009 sampling has been intensified by the PEBCAO team. Our studies are based on combining a broad set of parameters. These include classical bulk measurements and microscopy, optical measurements and satellite observations, molecular genetic approaches, detailed organic matter characterization, and cutting-edge methods for zooplankton observations to study plankton ecology in a holistic approach. Since 2014, the PEBCAO group is linked to the FRAM (Frontiers in Arctic marine Monitoring) Ocean Observatory Team.

Over the past 13 years, we have compiled complementary information on annual variability in phytoplankton composition, primary production, bacterial activity and zooplankton composition (Nöthig et al., 2015). Previous assessments in the observation area indicated that the protist composition in the West Spitsbergen Current in eastern parts of the Fram Strait consistently changed in the summer months. A dominance of diatoms was replaced by a dominance of *Phaeocystis pouchetii* and other small pico- and nanoplankton species. Our recent regular annual observations in Fram Strait suggest that concentrations of transparent exopolymer particles (TEP, i.e. marine gels that regulate the biological carbon pump) in the study area were correlated with the *P. pouchetii* abundance (Engel et al., 2017). These data were complemented by our molecular genetic investigations that provided new insights into eukaryotic microbial community composition with special emphasis on the contribution of pico-eukaryotes to plankton communities (Metfies et al., 2016).

Biogeochemistry, phyto- and zooplankton

Climate-induced changes will impact the biodiversity in pelagic ecosystems. At the base of the food web, we expect small algae to gain more importance in mediating element and matter turnover as well as matter and energy fluxes in future Arctic pelagic systems. In order to examine changes, including the smallest fractions, molecular methods are applied to complement traditional microscopy. The characterization of the communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes with next generation sequencing technology. Besides molecular methods, chemical and biological parameters associated with organic matter composition and microbial activity will be assessed (e.g. chlorophyll *a*, particulate and dissolved organic carbon, and primary production). In addition, light microscopy augmented with scanning electron microscopy will reveal details of the physiological state, division cycles, and morphological variability of individual taxa in the plankton community, and will contribute to biodiversity assessments based on morphotyping of taxa. Shifts at the base of the food web will affect the zooplankton community composition in the Fram Strait. To assess expected changes in zooplankton biodiversity and biogeography, we collect depth stratified net samples.

Bacterioplankton

As part of the FRAM Project, we aim to investigate the bacterial activity and diversity. The degradation of phytoplankton blooms by bacteria has been well documented in recent years for the North Sea around Helgoland, but is still not extensively enough studied in polar regions. The bacterial fraction in the water column is investigated by molecular tools and in incubation experiments. The molecular toolkit covers sequencing approaches as well as Fluorescent In-Situ Hybridization (FISH) microscopy to allow a quantitative analysis. The molecular samples serve the continuation of observations of the diversity of microbial communities (Fadeev et al., *under review*) in the framework of the FRAM project.

24-hour station

In addition to the usual LTER sampling programme at HAUSGARTEN observatory, a 24-hour station with four repeated samplings for bacterio-, phyto- and zooplankton as well as biogeochemical and microbial activity parameters was included in the cruise plan with the main objective to investigate potential diel patterns, e.g. plankton migrations in the water column and biogeochemical changes at short time scales. This study, carried out at the HAUSGARTEN site SV-IV (1300 m water depth) was conceived as a pilot and might be repeated in the future.

Samples for a large variety of parameters have been collected at the permanent HAUSGARTEN sampling sites in the Fram Strait, including the frontal zone separating the warm and cold-water masses originating from the West Spitsbergen Current and the East Greenland Current. Sampling as accomplished by the PEBCAO team from CTD / Rosette Water Sampler casts are summarized in Tables 5.1.1 and 5.1.2.

Table 5.1.1 Biogeochemical parameters sampled from CTD / Rosette Water Sampler casts; Chl *a*: chlorophyll *a*; POC/PON/BSI: particulate organic carbon & nitrogen, biogenic silica; DOM: dissolved organic matter; TEP/CSP: transparent exopolymer particles, Coomassie stainable particles; TA: total alkalinity; NB: "x" indicates that measurements were carried out, "o" indicates that they were omitted. Rows shaded in grey: 24-hour intensive sampling campaign, where samples from CTD / Rosette Water Sampler casts were obtained every six hours.

Station	CTD Cast	Chl *a*	POC/PON/ BSI	Lipids	Flow cytometry	DOM/ Nutrients	TEP/ CSP	TA/pH
SV-I	MSM108_19-1	x	x	x	x	x	x	x
SV-II	MSM108_21-1	x	x	x	x	x	x	o
SV-III	MSM108_25-2	x	x	x	x	x	x	o
SV-IV	MSM108_15-4	x	x	x	x	x	x	x
HG-I shallow	MSM108_14-4	x	x	x	x	x	x	o
HG-I deep	MSM108_14-8	o	x	o	x	x	x	x
HG-II	MSM108_12-4	x	x	x	x	x	x	x
HG-III	MSM108_6-4	x	x	x	x	x	x	x
HG-IV shallow	MSM108_5-5	x	x	x	x	x	x	x
HG-IV deep	MSM108_5-10	o	x	o	x	x	x	x
HG-V	MSM108_4-2	x	x	x	x	x	x	x
HG-VI	MSM108_3-1	x	x	x	x	x	x	x
HG-VII	MSM108_2-1	x	x	x	x	x	x	x
HG-VIII	MSM108_22-1	x	x	x	x	x	x	o
HG-IX shallow	MSM108_27-1	x	x	x	x	x	x	x
HG-IX deep	MSM108_27-6	o	x	o	x	x	x	x
N4 shallow	MSM108_9-1	x	x	x	x	x	x	o
N4 deep	MSM108_9-5	o	x	o	x	x	x	o
N3	MSM108_30-1	x	x	x	x	x	x	x
S3 shallow	MSM108_1-1	x	x	x	x	x	x	x
S3 deep	MSM108_1-4	o	x	o	x	x	x	x
EG-IV	MSM108_45-1	x	x	x	x	x	x	x
SV-IV 24h-1	MSM108_38-2	x	x	x	x	x	x	x
SV-IV 24h-2	MSM108_38-6	x	x	x	x	x	x	x
SV-IV 24h-3	MSM108_38-9	x	x	x	x	x	x	x
SV-IV 24h-4	MSM108_38-12	x	x	x	x	x	x	x

Table 5.1.2 Biological parameters sampled from CTD / Rosette Water Sampler casts (N5 and EG-I, -II, and -III could not be sampled due to heavy ice in the sampling area); NB: "x" indicates that the sample was taken, whereas "o" indicates that it was omitted. Rows shaded in grey: 24-hour intensive sampling campaign, where samples from CTD / Rosette Water Sampler casts were obtained every six hours to a water depth of 500 m.

Station	CTD Cast	Phytoplankton Bacterial cell numbers	Zoo-plankton	Bacterial biomass production	Primary Production	Eukaryotic DNA	Bacterial DNA
SV-I	MSM108_19-1	x	o	x	x	x	x
SV-II	MSM108_21-1	x	o	x	o	x	x
SV-III	MSM108_25-2	x	o	x	o	x	x
SV-IV	MSM108_15-4	x	o	x	x	x	x
HG-I shallow	MSM108_14-4	x	x	x	x	x	x
HG-I deep	MSM108_14-8	o	o	o	o	o	x
HG-II	MSM108_12-4	x	o	x	x	x	x
HG-III	MSM108_6-4	x	o	x	x	x	x
HG-IV shallow	MSM108_5-5	x	o	x	x	x	x
HG-IV deep	MSM108_5-10	o	o	o	o	o	x
HG-V	MSM108_4-2	x	o	x	x	x	x
HG-VI	MSM108_3-1	x	o	x	x	x	x
HG-VII	MSM108_2-1	x	o	x	x	x	x
HG-VIII	MSM108_22-1	x	o	x	o	x	x
HG-IX shallow	MSM108_27-1	x	x	x	x	x	x
HG-IX deep	MSM108_27-6	o	o	o	o	o	x
N4 shallow	MSM108_9-1	x	x	x	x	x	x
N4 deep	MSM 108_9-5	o	o	o	o	o	x
N3	MSM108_30-1	x	o	x	x	x	x
S3 shallow	MSM108_1-1	x	x	x	x	x	x
S3 deep	MSM108_1-4	o	o	o	o	o	x
EG-IV	MSM108_45-1	x	x	x	x	x	x
SV-IV 24h-1	MSM108_38-2	x	x	x	x	x	x
SV-IV 24h-2	MSM108_38-6	x	x	x	x	x	x
SV-IV 24h-3	MSM108_38-9	x	x	x	x	x	x
SV-IV 24h-4	MSM108_38-12	x	x	x	x	x	x

Biogeochemistry, phytoplankton and bacterioplankton

Seawater samples were taken at a minimum of five water depths per station by means of a CTD / Rosette Water Sampler (Fig. 5.1.1) to determine the impact of microbial processes on organic matter cycling. Sampling occurred within the euphotic zone and in deeper layers at selected stations (i.e. S3, HG-I, N4).

Fig. 5.1.1 Recovery of the CTD / Rosette Water Sampler (left) and water subsampling from the instrument's Niskin bottles (right).

All stations were sampled at the surface, above the deep chlorophyll maximum (DCM), within the DCM, below the DCM, and at 100 m water depth. The water from the CTD / Rosette Water Sampler was filtered for analysing biogeochemical parameters such as chlorophyll *a* (unfractionated), total dissolved and particulate organic carbon (TOC, DOC, and POC), total and dissolved and particulate organic nitrogen (TN, DON, and PON), and nutrients. To characterize the diversity of microbes present in the photic zone, fractionated filtrations using pore sizes of 10.0, 3.0, and 0.4 µm were conducted for microbial eukaryotic 18S rRNA amplicon sequencing. In addition, water samples were filtered onto Sterivex filters (0.2 µm) for bacterial/archaeal 16S RNA amplicon sequencing and metagenomics. All samples were preserved, refrigerated or frozen at -20°C and -80°C for storage until analyses in the home laboratories. Particulate organic carbon, biogenic silica, chlorophyll *a*, phytoplankton abundance, molecular data, and zooplankton community composition and distribution will be analysed at AWI, Bremerhaven. Concentrations of the dissolved organic matter, nutrients, lipids, transparent exopolymer particles (TEP), and coomassie stainable particles (CSP) will be analysed at GEOMAR in Kiel. Microbial community analysis based on amplicon sequencing will be done at MPIMM in Bremen.

Multiple methods are applied to determine the phytoplankton and bacterial abundances and growth rates. Microbial process rates (primary production and bacterial biomass production) were determined on board using radio isotope incubations. To determine primary production and release rates of organic carbon by phytoplankton, ^{14}C uptake measurements were conducted according to Steemann Nielsen (1952) and Gargas (1975). Heterotrophic biomass production was determined applying the ^{3}H-leucine incubation method (Kirchman et al., 1985; Simon and Azam, 1992). Phytoplankton and bacterial abundance will be determined using flow-cytometry as well as microscopic methods.

Preliminary processing of the data was, in part, already carried out on board. Spatial distribution patterns of selected parameters along a transect from eastern (SV-I) to western parts of the Fram Strait (HG-IX) are shown in Figure 5.1.2.. Distribution patterns in temperature and salinity along the East-West transect showed the growing influence of melt water in western parts of the Fram Strait (Fig. 5.1.2 a,b). Below 100 m water depth, temperatures become more uniform with the exception or the region between SV-III and HG-I, where warmer waters (approx. 4°C as opposed to approx. 2°C in the rest of the transect) penetrated down to water depths of about 300-400 m. Decreased salinities also persisted in the surface waters at stations SV-II, and SV-IV through HG-II. At the outer Svalbard stations (SV-III, SV-IV), the less saline waters were also associated with peaks in bacterial biomass production, indicated by ^{3}H-leucine incorporation rates (Fig. 5.1.2 c).

Salinity and fluorescence profiles from the 24-hour station at the HAUSGARTEN site SV-IV in eastern parts of the Fram Strait are shown in Figure 5.1.3.. Salinity in the uppermost 40 m of the water column showed distinct differences between sampling points T1 and T2 (06:00 and 12:00, respectively) on the one hand and T3 and T4 (18:00 and 24:00, respectively) on the other (Fig. 5.1.3 a). Below 40 m water depth, salinity almost showed no variation in time. Chlorophyll fluorescence, indicating phytoplankton in the water column, showed clear diurnal patterns (Fig. 5.1.3 b). Interestingly, during the first sampling T1 at 06:00, there appeared to be two peaks in fluorescence, the lower one coinciding with the peak during sampling T2. The deepest fluorescence peak during this study was found at 24:00.

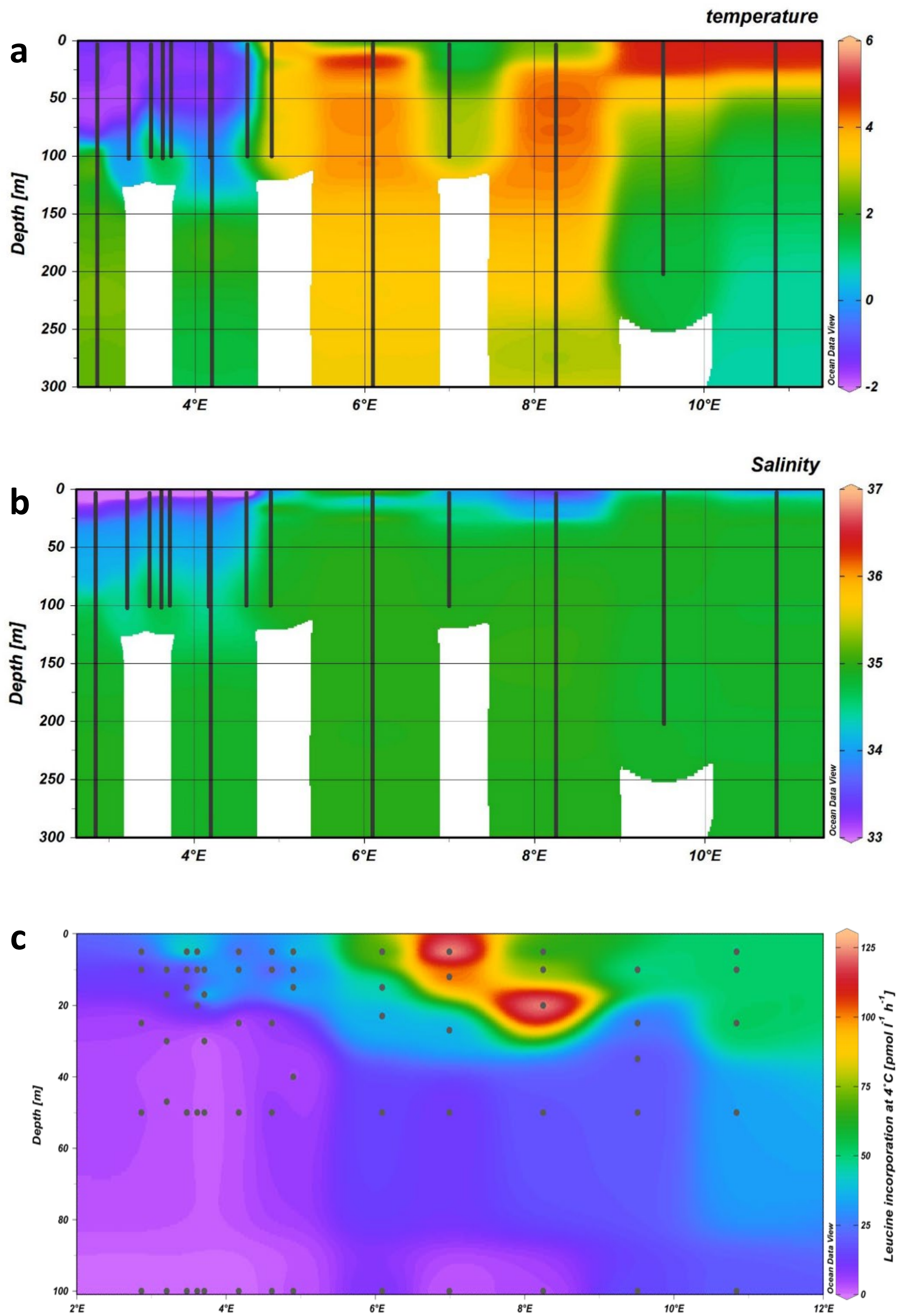

Fig. 5.1.2 Temperature (a), salinity (b), and bacterial biomass (c) along the East-West transect from SV-I to HG-IX.

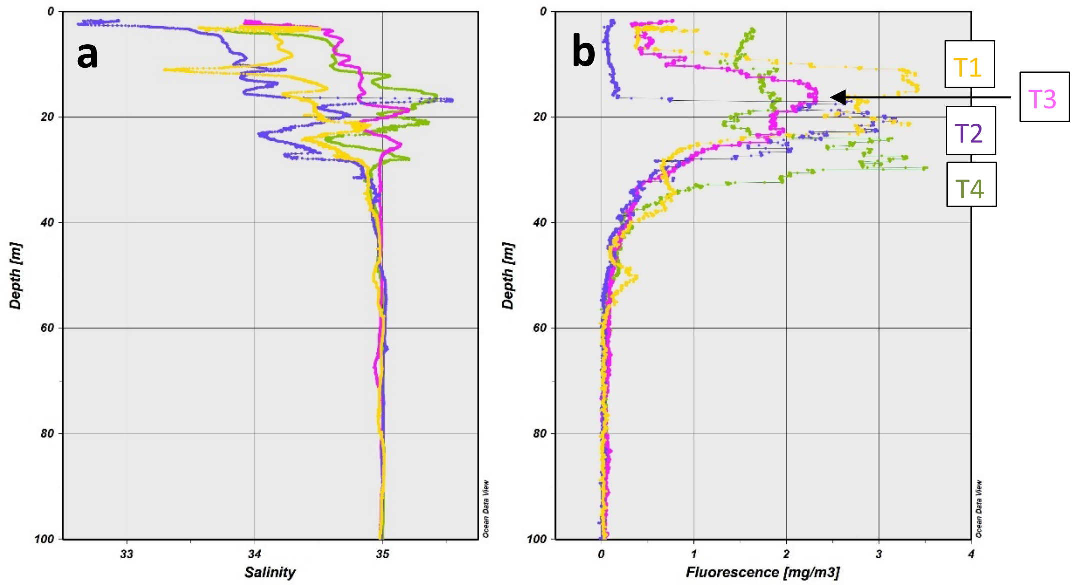

Fig. 5.1.3 (a) Salinity and (b) fluorescence profiles for the 24-h station, indicating vertical changes in the fluorescence maximum (time points for the sampling were T1: 6:00, T2: 12:00, T3: 18:00, and T4: 24:00).

5.2 Biogeochemical and Ecological Studies at the Deep Seafloor

(C. Hasemann, L. Böhringer, J. Dannheim, U. Hoge, J. Holt, A. Purser, J. Schnier)

Due to the prevailing ice conditions during MSM108, benthic studies could finally be conducted at a total of 15 stations out of the 21 permanent HAUSGARTEN sampling sites (Table 5.2.1). In addition, we investigated the small-scale heterogeneity (4x4 km scale) of various biogenic sediment compounds and the benthos around a trench system crossing the Vestnesa Ridge off western Svalbard at approx. 1700 m water depth (Table 5.2.2; see also Chapter 5.5). Our research involves organism size ranges from benthic bacteria up to large epi/megabenthos.

Table 5.2.1 Sediment sampling for benthic studies at HAUSGARTEN permanent sampling sites during MSM108 (MUC: Multiple Corer; GBC: Giant Box Corer).

Site	Station ID	Date	Latitude	Longitude	Depth (m)	Gear
SV-I	MSM108_19-3	18.06.2022	79° 01.32' N	010° 50.35' E	330	MUC
SV-IV	MSM108_15-1	16.06.2022	79° 01.79' N	006° 59.96' E	1280	MUC
SV-IV	MSM108_15-2	16.06.2022	79° 01.78' N	007° 00.01' E	1275	GBC
HG-I	MSM108_14-5	15.06.2022	79° 07.99' N	006° 05.59' E	1259	MUC

HG-I	MSM108_14-6	15.06.2022	79° 07.99' N	006° 05.62' E	1258	GBC
HG-II	MSM108_12-5	14.06.2022	79° 07.50' N	004° 54.03' E	1566	MUC
HG-II	MSM108_12-6	14.06.2022	79° 07.50' N	004° 54.03' E	1551	GBC
HG-III	MSM108_6-2	13.06.2022	79° 06.49' N	004° 36.00' E	1878	MUC
HG-III	MSM108_6-1	13.06.2022	79° 06.49' N	004° 36.00' E	1880	GBC
HG-IV	MSM108_5-9	12.06.2022	79° 03.93' N	004° 10.75' E	2420	MUC
HG-IV	MSM108_5-8	12.06.2022	79° 03.92' N	004° 10.79' E	2420	GBC
HG-V	MSM108_4-1	11.06.2022	79° 03.80' N	003° 41.54' E	2958	MUC
HG-V	MSM108_4-4	11.06.2022	79° 03.81' N	003° 41.50' E	2960	GBC
HG-VI	MSM108_3-3	11.06.2022	79° 03.87' N	003° 36.46' E	3321	MUC
HG-VI	MSM108_3-4	11.06.2022	79° 03.90' N	003° 36.31' E	3339	GBC
HG-VII	MSM108_2-3	11.06.2022	79° 03.60' N	003° 29.41' E	3938	MUC
HG-VII	MSM108_2-4	11.06.2022	79° 03.35' N	003° 30.14' E	3914	GBC
HG-VIII	MSM108_22-3	19.06.2022	79° 02.59' N	003° 12.93' E	4992	MUC
HG-VIII	MSM108_22-4	19.06.2022	79° 02.59' N	003° 12.99' E	4965	GBC
HG-IX	MSM108_27-5	21.06.2022	79° 07.90' N	002° 50.67' E	5549	MUC
HG-IX	MSM108_27-4	21.06.2022	79° 07.54' N	002° 51.26' E	5536	GBC
N3	MSM108_10-1	14.06.2022	79° 36.23' N	005° 10.28' E	2729	MUC
N3	MSM108_10-2	14.06.2022	79° 36.23' N	005° 10.34' E	2728	GBC
N4	MSM108_9-4	14.06.2022	79° 44.36' N	004° 30.31' E	2665	MUC
N4	MSM108_9-3	14.06.2022	79° 44.36' N	004° 30.31' E	2665	GBC
S3	MSM108_1-5	10.06.2022	78° 37.00' N	005° 04.07' E	2312	MUC
S3	MSM108_1-7	10.06.2022	78° 37.00' N	005° 04.07' E	2296	GBC
EG-IV	MSM108_45-4	29.06.2022	79° 48.18' N	002° 47.14' E	2541	MUC
EG-IV	MSM108_45-5	29.06.2022	79° 48.18' N	002° 47.14' E	2542	GBC

Table 5.2.2 Sediment sampling for benthic studies along a trench crossing the Vestnesa Ridge off western Svalbard (MUC: Multiple Corer; GBC: Giant Box Corer).

Site ID	Station ID	Date	Latitude	Longitude	Depth (m)	Gear
T1-C	MSM108_17-1	17.06.2022	79° 19.98' N	005° 49.46' E	1856	GBC
T1-C	MSM108_17-2	17.06.2022	79° 19.98' N	005° 49.47' E	1853	MUC
T1-C	MSM108_17-3	17.06.2022	79° 19.97' N	005° 49.49' E	1844	GBC
T1-N	MSM108_28-1	22.06.2022	79° 20.90' N	005° 52.70' E	1771	GBC
T1-N	MSM108_28-2	22.06.2022	79° 20.90' N	005° 52.70' E	1769	MUC
T1-N	MSM108_28-3	22.06.2022	79° 20.90' N	005° 52.70' E	1770	GBC
T1-S	MSM108_40-1	26.06.2022	79° 19.10' N	005° 46.25' E	1774	GBC
T1-S	MSM108_40-2	26.06.2022	79° 19.10' N	005° 46.25' E	1772	MUC
T2-C	MSM108_36-1	24.06.2022	79° 19.55' N	005° 54.79' E	1794	MUC

T2-C	MSM108_29-1	22.06.2022	79° 19.53' N	005° 54.93' E	1781	GBC
T2-C	MSM108_29-2	22.06.2022	79° 19.52' N	005° 54.99' E	1771	MUC
T2-C	MSM108_29-3	22.06.2022	79° 19.52' N	005° 54.99' E	1778	MUC
T2-N	MSM108_33-1	23.06.2022	79° 20.49' N	005° 57.99' E	1715	GBC
T2-N	MSM108_33-2	23.06.2022	79° 20.49' N	005° 57.99' E	1715	MUC
T2-S	MSM108_34-1	24.06.2022	79° 18.64' N	005° 51.91' E	1713	GBC
T2-S	MSM108_34-2	24.06.2022	79° 18.64' N	005° 51.91' E	1715	GBC
T2-S	MSM108_34-3	24.06.2022	79° 18.64' N	005° 51.91' E	1709	MUC
T3-C	MSM108_23-1	19.06.2022	79° 19.12' N	006° 00.26’ E	1740	GBC
T3-C	MSM108_23-2	19.06.2022	79° 19.11' N	006° 00.25’ E	1741	MUC
T3-C	MSM108_23-3	19.06.2022	79° 19.12' N	006° 00.20’ E	1721	MUC
T3-N	MSM108_24-1	20.06.2022	79° 20.06' N	006° 03.13' E	1669	GBC
T3-N	MSM108_24-2	20.06.2022	79° 20.06' N	006° 03.12' E	1668	MUC
T3-N	MSM108_24-3	20.06.2022	79° 20.07' N	006° 03.12' E	1672	GBC
T3-S	MSM108_39-1	26.06.2022	79° 18.19' N	005° 57.44' E	1666	GBC
T3-S	MSM108_39-2	26.06.2022	79° 18.19' N	005° 57.44' E	1666	MUC

Biogenic sediment compounds and meiofauna

Virtually undisturbed sediment samples were taken using a Multiple Corer (MUC; Fig. 5.2.1). Subsamples were used to analyse a variety of biogenic compounds indicating the input of organic matter to the seafloor (chloroplastic pigments) as well as benthic activity (bacterial exo-enzymes) and biomass (particulate proteins, phospholipids). Sediment-bound chloroplastic pigments (chlorophyll *a* and its degradation products = chloroplastic pigment equivalents, CPE) from phytodetritus sedimentation were already partly analysed on board (left samples will be analysed back in the home lab) applying a fluorometric method. Bacterial activities were analysed in incubation experiments directly after sampling using fluorescein-di-acetate (FDA) as a model substrate. Subsamples to analyse benthic biomass were frozen at -20°C and stored for later analyses at the home lab. Additional samples were taken to analyse the abundance and biomass of bacteria as well as meiofauna densities and the diversity patterns of nematodes.

During MSM108, we successfully sampled all stations along the HAUSGARTEN bathymetric transect off western Svalbard (HG-I through HG-IX) as well as three stations along the latitudinal transect (S3, N3, and N4) and two shallow-water sites on the Svalbard shelf (SV-I, SV-IV). Due to the prevailing ice conditions, we were only able to sample the deepest station along the depth transect off Greenland (EG-IV; 2500 m water depth) in western parts of the Fram Strait.

Fig. 5.2.1 Retrieval of sediment cores right after the recovery of the Multiple Corer, MUC (Photo: J. Schnier).

Comparing bacterial activities along the bathymetric transect crossing the Fram Strait, along the latitudinal transect, and the deep station on the East Greenland rise, we found conspicuous differences. Highest values were detected at the shallowest stations on the Svalbard shelf (8.8 ± 1.0 nmol ml*h^{-1}), compared to the deepest stations along the bathymetric transect (< 0.1 nmol ml*h^{-1}) and the stations along the latitudinal transect (1.3-1.5 nmol ml*h^{-1}). Bacterial activities showed a general trend with decreasing values with increasing water depth (Fig. 5.2.2). However, the deepest station along the bathymetric transect off Svalbard (HG-IX; 5500 m water depth) showed slightly increased values. Station HG-IX is situated at the Molloy Hole, most probably the deepest depression in the Arctic Ocean. Due to its shape, the Molloy Hole seems to act like a huge natural sediment trap and a deposit centre for organic matter settling to the seafloor.

Interestingly, bacterial activities at station EG-IV (2500 m water depth) on the East Greenland continental rise (1.4 ± 0.3 nmol/ml*h^{-1}) are slightly higher than at station HG-IV at a comparable water depth in eastern parts of the Fram Strait (1.1 ± 0.3 nmol/ml*h^{-1}). Higher values observed at station EG-IV could probably be explained by its location close to the ice-edge in western parts of the Fram Strait. Generally increased primary production in the Marginal Ice Zone (MIZ) and subsequently enhanced sedimentation of phytodetritial matter, representing a potential food source to benthic organisms, could probably also explain the increased activity values found at EG-IV.

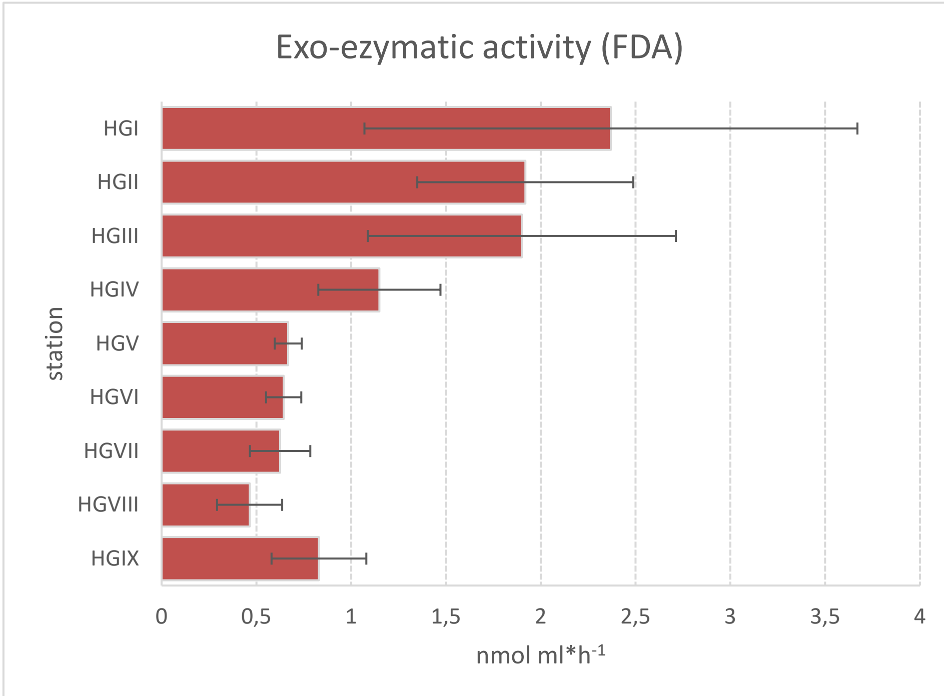

Fig. 5.2.2 Bacterial exo-enzymatic activity (mean values for the uppermost 5 cm of the sediments) at stations along the bathymetric transect off Svalbard.

Macrofaunal diversity

Macrobenthos at HAUSGARTEN has been studied only irregularly over the past 20 years. In the past, the focus has been on investigating depth gradients, horizontal distribution patterns in the sediment, and the temporal variability between 2003, 2007, and 2012 (e.g. Wlodarska-Kowalczuk et al., 2004; Budaeva et al., 2008; Vedenin et al., 2016, 2019). Since 2016, macrofauna has been sampled regularly (Käß et al., 2021) and the samples from MSM108 will continue the time-series work. This will allow the assessment of long-term changes of the deep-sea habitat, macrobenthic biodiversity and the variability of benthic populations at HAUSGARTEN.

We were able to collect 14 samples with a 0.25 m² USNEL Giant Box Corer (GBC). Particularly for deep-sea samples, the GBC is a preferred sampling gear as it reliably provides deep and relatively undisturbed sediment samples. GBC samples were divided into subsamples and the uppermost 12 cm were sieved over 500-µm sieves (Fig. 5.2.3). The macrofauna of the sieve residues were preserved for later taxonomic analysis in the laboratory.

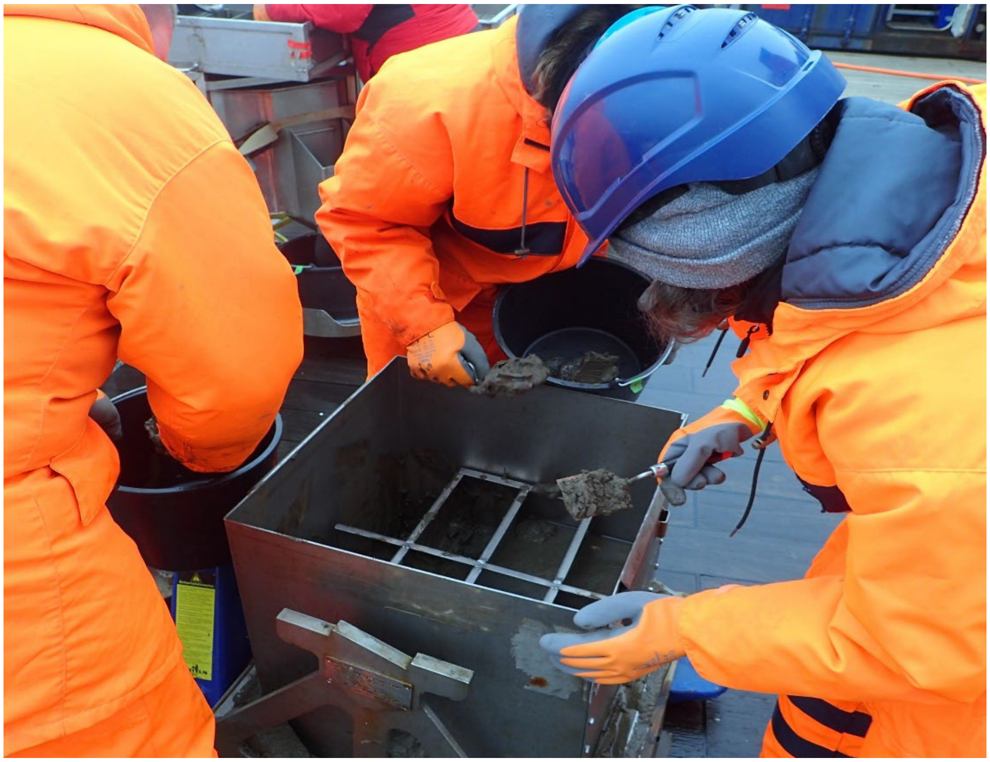

Fig. 5.2.3 Subsampling of the Giant Box Corer (GBC) after retrieval of the gear (Photo: J. Dannheim).

Abundance and composition of megafauna

Epibenthic megafauna are commonly described as all organisms >1.5 cm in length (Grassle et al., 1975) which inhabit the sediment water interface. Benthic megafauna influences the local-scale biogeochemistry (Bett et al., 2001) and the global carbon cycle (Klages et al., 2004), and are therefore important for the structuring of benthic deep-sea communities. Long-term data derived from the HAUSGARTEN observatory provides information to understand benthic megafauna community dynamics at an arctic deep-water site over a long period of time (Soltwedel et al., 2009; Bergmann et al., 2011; Taylor et al., 2017).

Data containing information about the abundance and composition of benthic megafauna were collected via camera surveys using a towed camera system, i.e. the Ocean Floor Observation System (OFOS; Fig. 5.2.4). In total, 13 successful surveys were conducted in the research area. Five of the regularly visited stations in the HAUSGARTEN observatory were revisited and observations were conducted to continue the megafauna time-series studies. At each of the time-series stations, the transect positions were the same as previously used, if permitted by sea-ice coverage. During MSM108, an additional eight camera surveys were conducted in the research area, one survey northwest of Svalbard and seven surveys across a deep-water trench system (see Chapter 5.5).

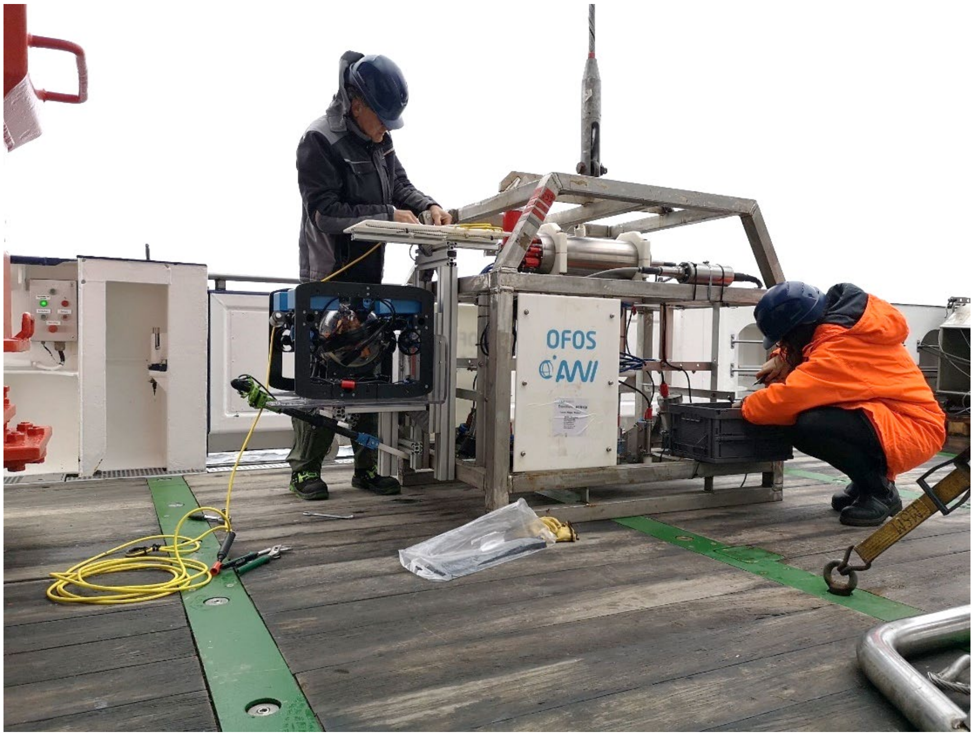

Fig. 5.2.4 The OFOS being prepared for operations during MSM108. The small 'Remora' class ROV is visible on the left of the frame (Photo: J. Schnier).

During all camera surveys, the front flash unfortunately did not work, which resulted in a dark rim on the right side of all images. Unless otherwise stated, the OFOS was towed at an altitude of 1.5-2 m above the seafloor with a ship's speed of 0.5 kn.

In addition to the standard OFOS camera systems, the frame was additionally equipped with the small 'Remora' class ROV developed within the Deep-Sea Research Group at AWI (Fig. 5.2.4). This Mini-ROV was used to carry out close-up video filming of the seafloor throughout a number of deployments.

- *Deployment MSM108_1-8 at S3*

The seafloor at the southernmost HAUSGARTEN site S3 (~2300 m water depth) was primarily made of soft sediments, with small burrows interrupting the smooth surface. Occasional *Cladorhiza* skeletons (Fig. 5.2.5), *Caulophacus* bodies and small dropstones acted as hard substrate for other benthic organisms such as sea anemones, soft corals, and crustaceans. The ship's speed during this transect varied between 0.5 and 0.6 kn.

Fig. 5.2.5 *Cladorhiza* skeleton imaged with the OFOS at the southernmost HAUSGARTEN site during MSM108.

- *Deployment MSM108_5-1 at HG-IV*

The seafloor at the central HAUSGARTEN station HG-IV (~2500 m water depth) was characterized by soft sediments interrupted with small burrows and few dropstones. *Cladorhiza* skeletons and *Caulophacus* bodies again acted as hard substrate for sea anemones, soft corals, and crustaceans. Litter was found to be entrapped by those structures on a few occasions (Fig. 5.2.6). The ship's speed during the transect was 0.6 kn.

Fig. 5.2.6 Plastic litter entangled with a living sponge, imaged with the OFOS at HG-IV during MSM108.

- *Deployment MSM108_14-7 at HG-I*

This camera survey at approx. 1200 m water depth was divided into two parts. The first part covered the standard OFOS transect at HG-I until image no. IMG_0563. The second part surveyed an area of pockmarks to the East of this transect, starting at IMG_0582. The seafloor at HG-I was characterized by polychaete tubes and brittle stars on the otherwise soft sediment (Fig. 5.2.7). During the second part of the survey, pockmarks and microbial mats were found occasionally (Fig. 5.2.8). The ship's speed was 0.6 kn during the entire deployment.

Fig. 5.2.7 Numerous filter-feeding worms (Polychaeta) imaged with the OFOS at HG-I during MSM108.

Fig. 5.2.8 Typical small pockmark feature imaged with the OFOS at HAUSGARTEN site HG-I during MSM108.

- *Deployment MSM108_26-1 northwest of Svalbard*

The seafloor on the shelf northwest of Svalbard (~500 m water depth) was characterized by pebbles and small to big dropstones (Fig. 5.2.9). Occasionally occurring trawl marks streaked through the seafloor. The megafauna was diverse, with soft corals, a variety of sponges, starfishes and brittle stars inhabiting this region. Fish and octopuses were also regularly observed.

Fig. 5.2.9 In contrast to the traditionally visited HAUSGARTEN stations, the pebbly seafloor northwest of Svalbard was abundant with sponge coverage, as in this OFOS image.

- *Deployment MSM108_29-2 at N3*

The sediment at the northern HAUSGARTEN site N3 (~2600 m water depth) was made of soft materials, with dropstones providing a hard substrate. *Caulophacus* sponges were often observed attached to it. This region was predominantly inhabited by *Bathycrinus* stalks, sea cucumbers and small sea anemones (Fig. 5.2.10). During MSM108, the transect was oriented perpendicular to the previous transects at N3 because of the prevailing sea-ice coverage.

Fig. 5.2.10 Typical dropstone community imaged with the OFOS at HAUSGARTEN site N3 during MSM108.

- *Deployment MSM108_43-1 at HG-IX*

The seafloor at the deepest HAUSGARTEN site HG-IX (~5500 m water depth) was characterized by very fine and soft sediments. The sea cucumber *Elpidia heckeri* was the main inhabitant, but occasional agglomerations of sea anemones occurred as well (Fig. 5.2.11). This deployment ended after 18 minutes on the seafloor because of communication problems with the camera system.

Fig. 5.2.11 High density accumulation of anemones and *Elpidia heckeri* imaged at the deepest HAUSGARTEN site.

5.3 Seafloor Mapping Using an Autonomous Underwater Vehicle (AUV)

(A. Purser, N. Becker, Lilian Böhringer, J. Hagemann, J. Holt, S. Lehmenhecker)

The AUV 'Paul' (Fig. 5.3.1) operated by the Deep-Sea Research Group at AWI was brought on expedition MSM108 with the aim of deploying in reasonably ice-free conditions to continue the seafloor photographic and acoustic mapping started during RV POLARSTERN expedition PS121 and continued during the expeditions MSM95 and PS126. During MSM108, a total of twelve dives were attempted across eight deployment stations (Table 5.3.1).

Fig. 5.3.1 Deployment of the Autonomous Underwater Vehicle (AUV) 'Paul' during expedition MSM108.

Table 5.3.1 Details of AUV deployments undertaken during MSM108.

MSM108 AUV-Deployments 2022									Seafloor data		
Date	Time	Location	ID	Station	Depth [m]	Deployment Lat[°N]	Lon[°E]	Notes	Distance [km]	Images	Sonar Files
10.06.2022	06:58:00	S3	-	MSM108_1-2	-	78.616673	5.067728	Device Testdive	-	-	-
	07:55:00	S3	ID-69	MSM108_1-2	25	78.616675	5.0677	Dive Abort, Tailcone Leakage	-	-	-
12.06.2022	08:51:00	HG-IV	ID-70	MSM108_5-2	2367	79.068274	4.194886	Dive Abort, DVL Bottomlog	-	-	-
13.06.2022	07:21:00	-	ID-71	MSM108_7-1	-	79.127809	5.214398	Ground fault test	-	-	-
15.06.2022	11:53:00	HG-I	ID-72	MSM108_14-1	795	79.143201	6.080051	Dive Abort, Bad Navigation, INS error	-	-	-
18.06.2022	09:23:00	SV-II	ID-73_1	MSM108_20-1	215	78.973487	9.443492	Dive 1 - N / S orientation	3	21191	87
	10:51:00	SV-II	ID-73_2	MSM108_20-1	216	78.974696	9.418133	Dive 2 - W/E orientation	4.5		
	12:47:00	SV-II	ID-73_3	MSM108_20-1	214	78.972952	9.415006	Dive 3 - N / S orientation	3.5		
23.06.2022	10:44:00	Pockmarks	ID-74_1	MSM108_23-1	1221	79.094324	6.350283	Dive Abort - Limited altitude	5	9579	47
	13:44:00	Pockmarks	ID-74_2	MSM108_23-1	1202	79.033788	6.686291	Dive Abort - Limited altitude	0.3	203	1
24.06.2022	10:13:00	Canyon	ID-75_1	MSM108_35-1	1800	79.310885	5.862063	-	21.9	17803	121
28.06.2022	08:29:00	Pockmarks	ID-76_1	MSM108_44-1	1205	79.04179	6.664805	Dive Abort - Limited altitude	0.3	821	64
	10:26:00	Pockmarks	ID-76_2	MSM108_44-1	1214	79.044677	6.65345	Dive Abort - Limited altitude	7.5	4520	
Total or max:					**2367**				**46.00**	**48776**	**256**

During the initial four stations, problems with the Inertial Navigation System (INS) prevented the AUV from reaching and mapping the seafloor successfully. During the remaining four stations, the vehicle collected image and acoustic data from HAUSGARTEN station SV-II (previously partially surveyed during MSM95), from a trench system crossing the Vestnesa Ridge, and various pockmark sites on this sub-sea peninsula (see Chapters 5.4 and 5.5). Approx. 46 km of seafloor were surveyed by the AUV, with ~48,000 images (Fig. 5.3.2) and 256 sonar files collected.

During the forthcoming months the acoustic and image data collected during the cruise will be processed with assistance from the AWI bathymetry team to derive high resolution mapping products from the data collected. In addition, features and areas of interest will be used to produce 3D models of the seafloor. A particular focus will be on the physical modelling of the methane seep regions surveyed during MSM108 (see Chapter 5.4) and the deep-sea trench system (see Chapter 5.5).

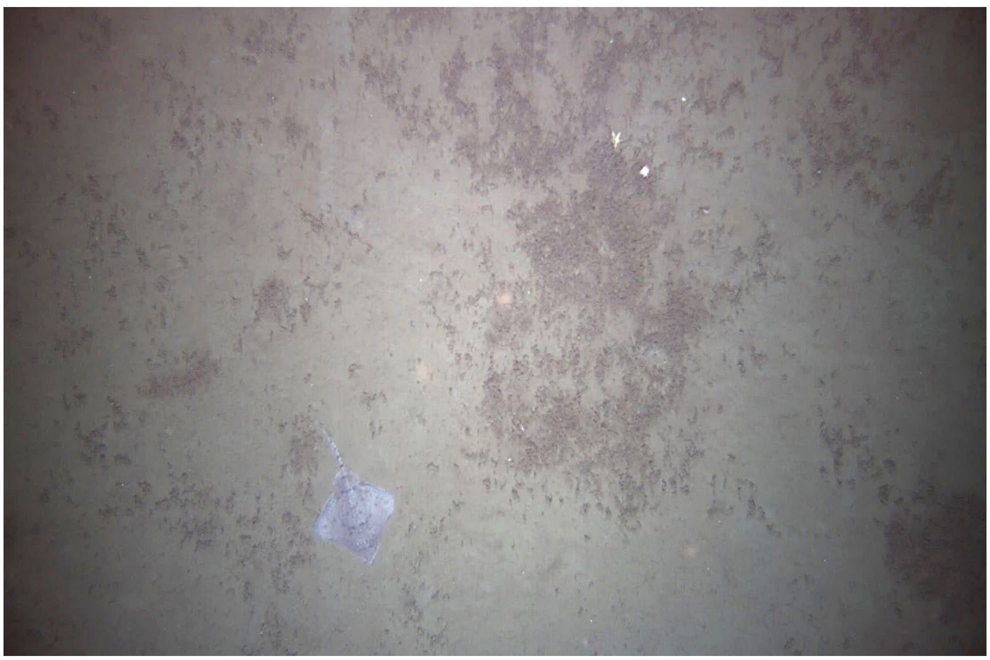

Fig. 5.3.2 A ray fish imaged with the AUV camera system at about 1700 m water depth on the Vestnesa Ridge.

5.4 Multi-scale Mapping of Methane Pockmarks

(L. Böhringer, N. Becker, J. Hagemann, U. Hoge, S. Lehmenhecker, A. Purser)

During the expedition MSM108, we carried out a multidisciplinary project to map areas of the HAUSGARTEN observatory with ship integrated, AUV mounted, and OFOS mounted systems. Despite repeated visits to the region over the years, the higher resolution acoustic systems mounted on RV MARIA S. MERIAN have not been used to bathymetrically investigate areas not directly adjacent to the regularly visited stations. During MSM108, we intended to fill in some of these gaps during periods of poor weather and during short gaps in night schedules.

In order to increase the topographic accuracy of the mapping of the area, bathymetric surveys were carried out using the ship's hull-mounted multibeam echosounders (MBES) Kongsberg EM122 and EM712. The EM122 is a deep-water system for continuous mapping with the full swath potential. It operates at a frequency ranging from 10.5 to 13 kHz within the different transmit sectors. The EM712 is the shallow water systems for surveys <1000 m water depth and operates with higher frequencies in a range of 40-100 kHz. Both systems were set to a maximum swath angle of 65° in equidistant mode. The ship's speed was 7 kn during the bathymetric surveys. During these bathymetric surveys two regions were identified as areas of particular interest: The deep-water trench system selected for a multidisciplinary study (see Chapter 5.5) and an array of larger methane pockmarks. In this section the methane pockmarks are further discussed.

Following identification of the circular pockmark features in the ship bathymetric data (Fig. 5.4.1), both AUV and OFOS deployments were plotted to visually (and in the case of the AUV, also acoustically) survey these seafloor features. Both platforms performed well and collected data successfully.

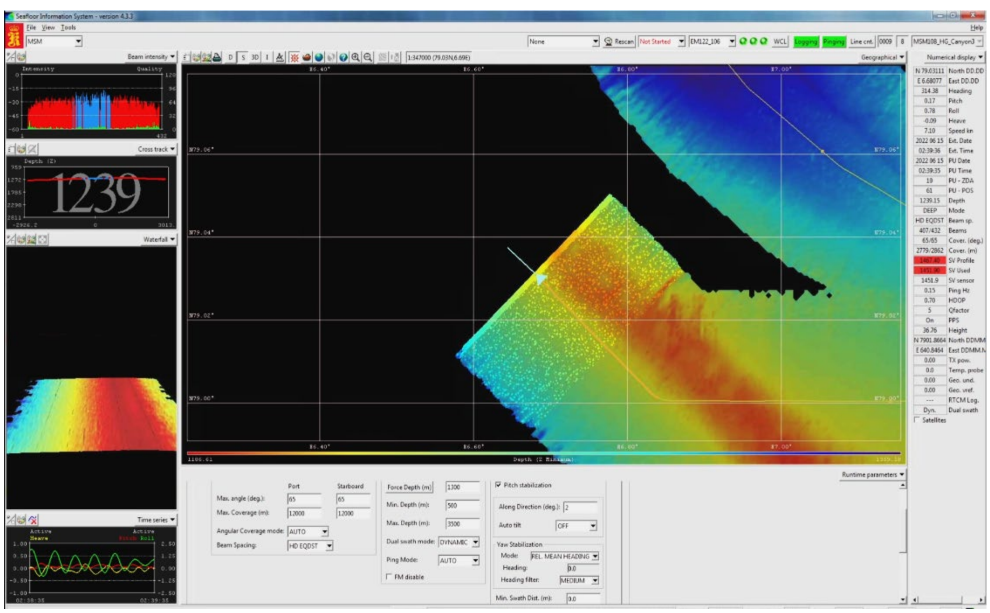

Fig. 5.4.1 Live view of the EM122 echosounder data collection during MSM108. The circular features on the red ridge toward the southeast are the array of pockmarks discovered during MSM108 (Photo: A. Purser).

An extended array of ~100 m diameter pockmark features were discovered at approx. 1700 m water depth on the south-eastern flank of the Vestnesa Ridge. A number of these features were subsequently imaged and acoustically mapped using the AUV 'Paul' (Figures 5.4.2 and 5.4.3). The most northerly pockmark was situated only a few km from HAUSGARTEN station HG-I (Fig. 1.1), and was directly imaged by OFOS. The pockmark features were generally diverse in form, commonly filled with filter feeding fauna and gas hydrates directly exposed at the sediment surface. During the next months a detailed combined mapping effort will be made in conjunction with the AWI bathymetry team to accurately map these interesting features.

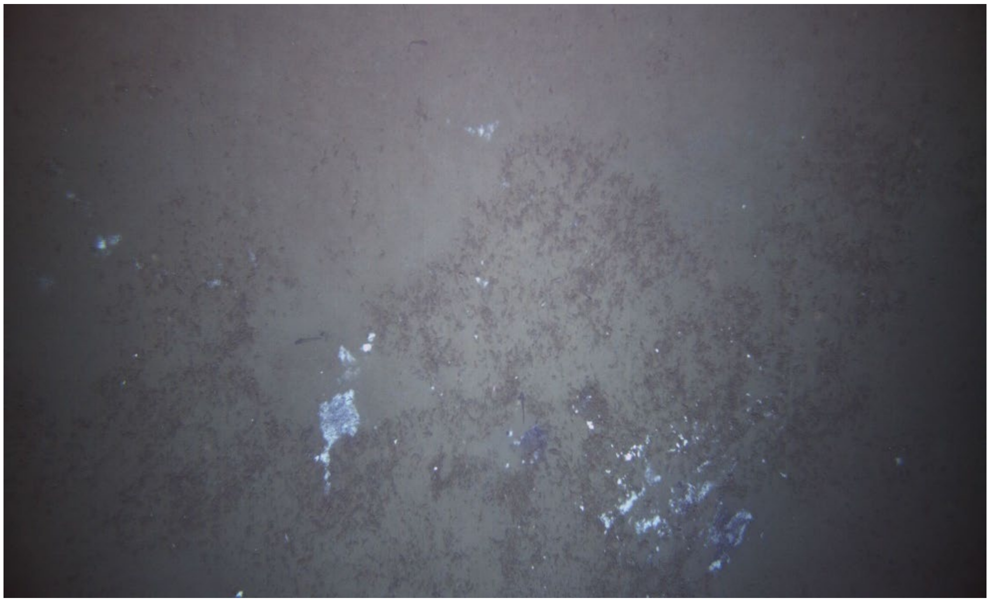

Fig. 5.4.2 Gas hydrates exposed at sediment surface, as imaged by the AUV during expedition MSM108.

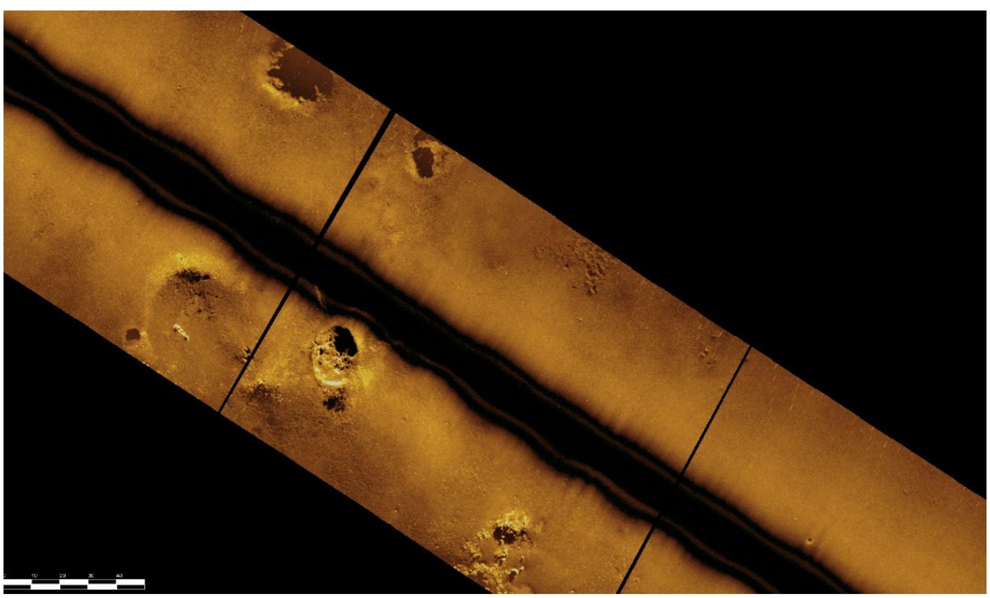

Fig. 5.4.3 Georeferenced acoustic data collected by the AUV 'Paul' and featuring several circular pockmarks.

5.5 Small-scale Heterogeneity Across an Extended Trench System

(J. Dannheim, N. Becker, L. Böhringer, J. Hagemann, C. Hasemann, U. Hoge, J. Holt, S. Lehmenhecker, A. Purser, T. Soltwedel)

During MSM108, we carried out a multidisciplinary project to investigate the small-scale spatial heterogeneity and potential shifts in benthic diversity across a trench system crossing the Vestnesa Ridge in the vicinity of HAUSGARTEN station HG-II (Fig. 1.1). The selected trench section is about 200 m wide and approx. 50 m deep.

In order to increase the topographic accuracy of the mapping of this feature, three detailed bathymetric surveys were carried out. Therefore, the ship's hull-mounted multibeam echosounders (MBES) Kongsberg EM122 and EM712 were operated. Both systems were set to a maximum swath angle of 65° in equidistant mode. The ship's speed was 7 kn during the bathymetric surveys.

The first, zig-zagging exploratory dive of the Ocean Floor Observation System (OFOS) along the trench was used to lay out the study design: three transects T1 - T3 were set across the trench, each with one station north of the trench, one in the centre, and one station south of the trench (Fig. 5.5.1). All stations (North, Centre, South) were 2 km apart from each other, as well as the three transects were at 2 km distance, i.e. a grid of four by four km for sampling.

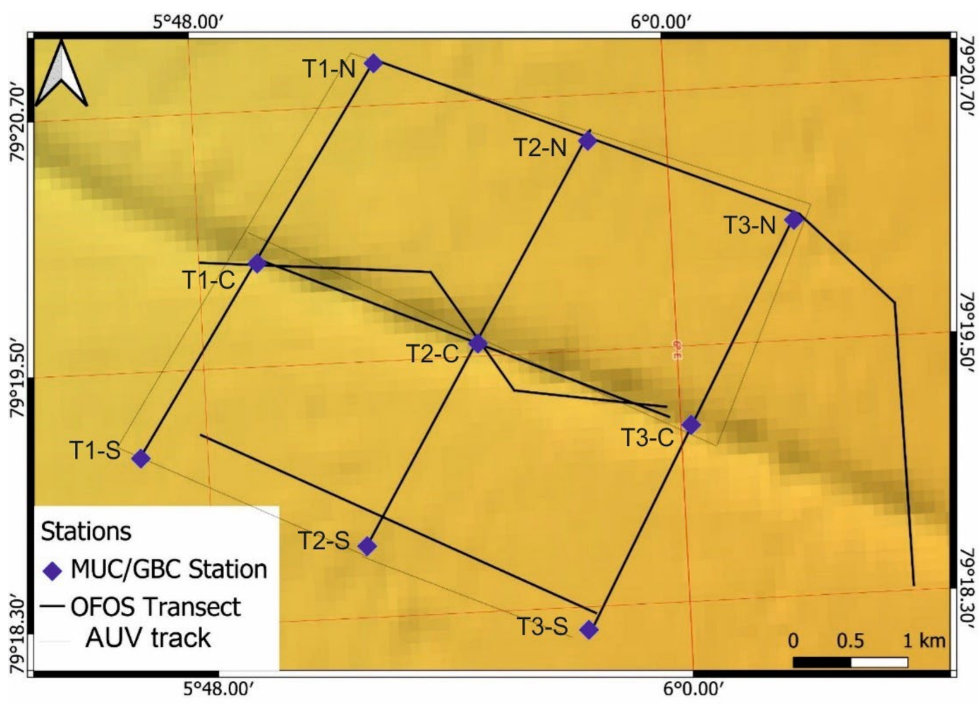

Fig. 5.5.1 Close-up map of the trench section and sampling design for the MUC, GBC, OFOS, and AUV.

In the following, the Ocean Floor Observation System (OFOS) and the Autonomous Underwater Vehicle (AUV) “Paul” delivered high-resolution topographical variability and biodiversity data of megafauna across the trench and the surrounding area. This detailed spatial information was combined with classical point sampling to cover sediment parameters, as well as biodiversity data on meiobenthos and macrobenthos.

The AUV delivered terrain parameters such as bathymetry, backscatter, slope, aspect, rugosity, curvature and underwater pictures. Megafauna density and composition was derived by high-resolution images of OFOS, meiofauna and biogeochemical parameters by the Multiple Corer (MUC), and macrofauna by the 0.25 m² USNEL Giant Box Corer (GBC). In total, we were able to subsample nine MUC and GBC (see Table 5.2.2) and to conduct one successful AUV dive (see Table 5.3.1) and seven OFOS transects (Table 5.5.1; start/end point site IDs for the transects see Fig. 5.5.1).

Table 5.5.1 OFOS transects conducted at the deep-water trench system crossing the Vestnesa Ridge.

Station ID	Date / Time	Latitude	Longitude	Depth (m)	Site ID
MSM108_16-1	16.06.2022 13:43	79° 19.991' N	005° 47.946' E	1794	zig-zag (start)
MSM108_16-1	16.06.2022 21:43	79° 19.217' N	005° 59.839' E	1705	zig-zag (end)
MSM108_23-3	19.06.2022 23:15	79° 18.199' N	005° 57.428' E	1656	T3-S (start)
MSM108_23-3	20.06.2022 03:19	79° 20.070' N	006° 03.102' E	1665	T3-N (end)
MSM108_28-4	22.06.2022 13:36	79° 19.100' N	005° 46.303' E	1768	T1-S (start)
MSM108_28-4	22.06.2022 18:16	79° 20.900' N	005° 52.705' E	1771	T1-N (end)
MSM108_33-3	23.06.2022 21:36	79° 20.487' N	005° 57.994' E	1716	T2-N (start)
MSM108_33-3	24.06.2022 02:38	79° 18.484' N	005° 51.415' E	1710	T2-S (end)
MSM108_37-1	24.06.2022 19:25	79° 19.987' N	005° 49.512' E	1853	T1-C (start)
MSM108_37-1	24.06.2022 23:32	79° 19.068' N	006° 00.405' E	1706	T3-C (end)
MSM108_39-3	26.06.2022 04:56	79° 18.276' N	005° 57.450' E	1672	T3-S (start)
MSM108_39-3	26.06.2022 11:04	79° 19.223' N	005° 46.918' E	1776	T1-S (end)
MSM108_41-1	26.06.2022 15:39	79° 20.897' N	005° 52.680' E	1781	T1-N (start)
MSM108_41-1	26.06.2022 23:46	79° 18.177' N	006° 05.596' E	1627	T3-N (end)

During the OFOS transects crossing the deep-water trench system, changes in megafauna community composition were noted (Fig. 5.5.2). Two kilometres on either side of the trench, brittle stars and polychaete tubes were observed abundantly. Towards the trench they disappeared. In the centre of the trench big orange sea anemones occurred regularly, which were (so far) not observed in any other region in the HAUSGARTEN observatory.

All data will be combined in the near future in order to investigate whether small-scale spatial heterogeneity such as a trench system affects benthic habitats, i.e. environmental parameters and benthic assemblages.

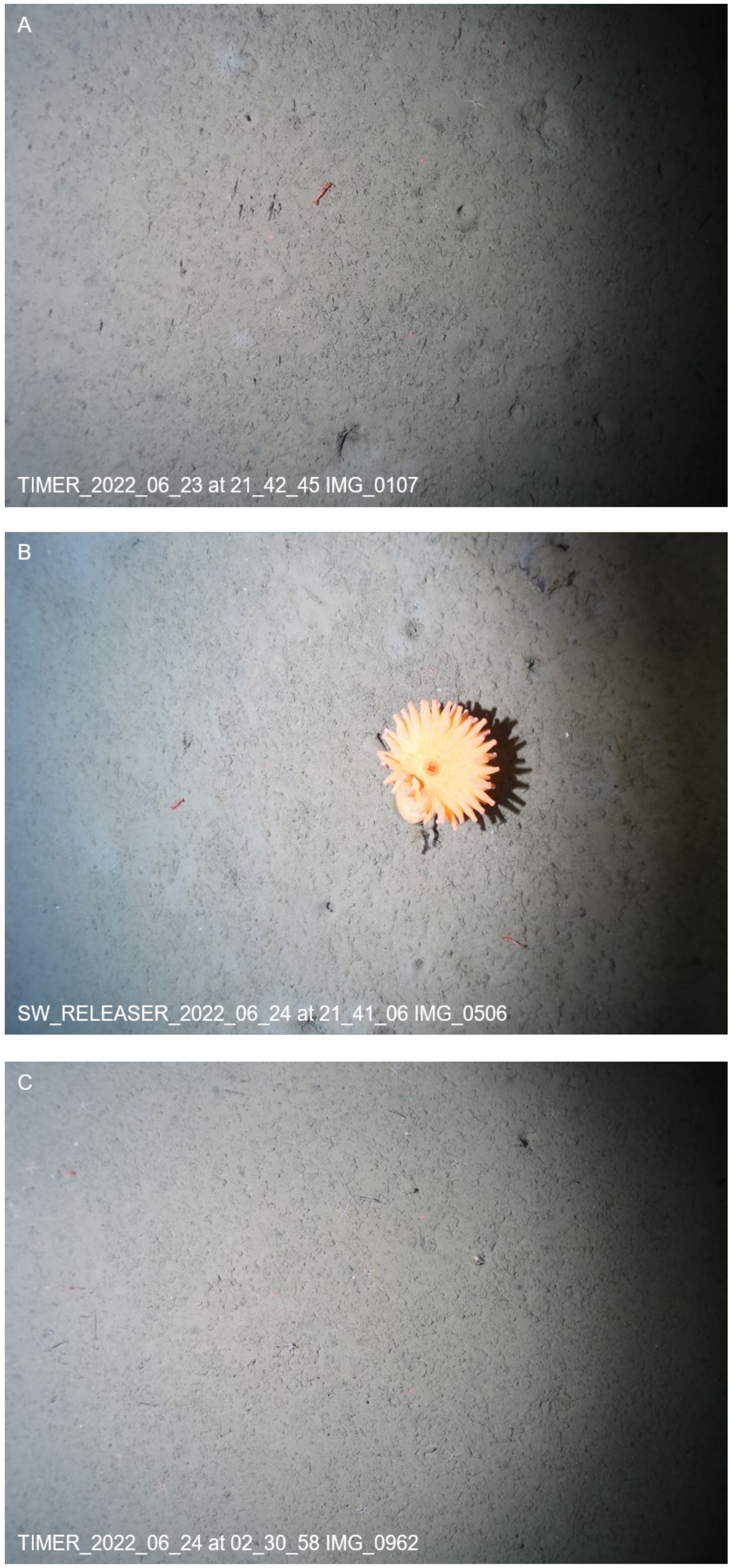

Fig. 5.5.2 Example images of the benthic megafauna community 2 km north (A) and south (C) of the trench system and in the centre of the deep-water trench (B).

5.6 Long-term Observations of Organic Matter Cycling at the Deep Seafloor

(F. Janssen, V. Asendorf, N. Becker, J. Hagemann, U. Hoge, S. Lehmenhecker)

The availability and fate of organic matter is a key ecological measure and links to important ecosystem functions and services. Organic material, originating from the sunlit surface layer and sinking to the seafloor, fuels benthic food webs and sustains benthic life in terms of biomass and biodiversity. It also links directly to the efficiency of the biological pump to remove CO_2 from the atmosphere for long-term storage in the deep ocean. Observations of organic matter cycling at the seafloor inform about potential Climate Change effects on temporal patterns of organic matter production and remineralization in the water column and how they link to benthic processes. In order to cover seasonal dynamics, time-series observations are needed. During MSM108, three benthic platforms were deployed for long-term monitoring of particulate organic matter provision to the seafloor and the response of the benthos including faunal activity and rates of biogeochemical processes (Table 5.6.1): (1) A long-term Bottom-Lander was redeployed after recovery and maintenance of its scientific payload to sample sinking particles, to characterize physical and biogeochemical conditions in the benthic boundary layer (i.e. in the lowermost part of the water column), and to take time-lapse photos of the seafloor. (2) A multi-camera benthic platform, based on a novel concrete-cylinder battery-system, was deployed to deliver more photographs of the seafloor that cover a larger area at higher temporal resolution. (3) A Benthic Crawler was deployed to quantify diffusive as well as total benthic oxygen fluxes by weekly measurements with oxygen sensor microprofilers and benthic chambers, respectively.

Table 5.6.1 Overview of deployments of instruments contributing to long-term observations of benthic organic matter cycling. Latitudes and longitudes in italic font refer to instrument position, non-italic entries represent ship positions.

Station	Event ID	Date and time (UTC)	Instrument	Action	Position	depth (m)	Comment
HG IV	MSM108_5-3	12.06.2022 15:16	Long term Lander	recovered	79° 02.734' N 004° 10.595' E	2526	retrieved from long-term deployment (POLARSTERN PS126, June 2022)
n.a.	MSM108_5-4	12.06.2022 14:36	Benthic Crawler	in the water	79° 02.347' N 004° 11.276' E	n.a.	surface buoyancy test without ballast
HG II	MSM108_12-2	14.06.2022 17:03	Benthic Crawler	deployed	79° 07.369' N 004° 57.726' E	1518	short term deployment
HG II	MSM108_12-2	19.06.2022 15:12	Benthic Crawler	ranging	*79° 07.500' N* *004° 55.800' E*	n.a.	location at seafloor determined by ranging from three points
HG II	MSM108_12-2	22.06.2022 06:46	Benthic Crawler	recovered	79° 07.629' N 004° 56.439' E	1507	after short term deployment
HG IV	MSM108_18-2	17.06.2022 16:53	Long term Lander	deployed	79° 01.896' N 004° 11.877' E	2584	for recovery in 2023 (POLARSTERN PS136)
HG IV	MSM108_42-2	27.06.2022 06:16	Concrete-cylin-der mooring	deployed	79° 01.971' N 004° 19.371' E	2509	for recovery in 2023 (POLARSTERN PS136)
HG IV	MSM108_42-3	27.06.2022 09:29	Benthic Crawler	deployed	79° 02.354' N 004° 17.551' E	2497	for recovery in 2023 (POLARSTERN PS136)
HG IV	MSM108_42-3	27.06.2022 23:05	Benthic Crawler	ranging	*79° 02.262' N* *004° 18.330' E*	n.a.	location at seafloor determined by ranging from three points

Long-term Bottom-Lander

The long-term Bottom-Lander is based on a commercially available lander frame (K/MT 100, K.U.M. Umwelt- und Meerestechnik Kiel GmbH, Kiel, Germany) and equipped with (1) a small sediment trap of the same manufacturer (K/MT 236, 0.25 m^2 collection area, 14 sample bottles), (2) a recording current meter (Aanderaa SeaGuard DW RCM, Xylem Inc./Aanderaa Data Instruments AS, Bergen, Norway) that hosts a CTD, a Doppler Current Sensor (Type DCS 4520 DW), and an oxygen sensor (Type 4330), as well as (3) with a custom-built 'TiPi' camera system (Purser et al., 2020) based on Raspberry Pi camera technology (Raspberry Pi Foundation, Cambridge, UK) that is equipped with an LED lamp (SeaLite, DeepSea Power and Light, San Diego, CA, USA) for seafloor illumination. In addition, the system holds two acoustic releasers (iXblue, Saint-Germain en Laye, FR) to release ballast weights as well as radio and flasher beacons (NOVATECH, metOcean telematics, Dartmouth, NS, CA) to locate the system upon recovery. Since many years, the Long-term Bottom-Lander is deployed as part of the HAUSGARTEN time-series studies to assess seasonality in deep water column and benthic conditions between annual sampling and maintenance cruises. During MSM108, the system was retrieved after a 1-year deployment at the central HAUSGARTEN station (HG-IV) where it has been deployed during RV POLARSTERN expedition PS126 in summer 2021. Time-series data of physical and biogeochemical deep-water column properties (currents, t, S, p, O_2) were collected as well as 14 samples of sinking particles spanning the full annual period. In addition, >700 digital images (3.15 Megapixel resolution) of the seafloor next to the Bottom-Lander were collected at 6 h intervals (Fig. 5.6.1) until the time-lapse camera housing was flooded in December 2021 approx. six months after deployment and the camera stopped working. Luckily the image series covers the initial phase of increased phytodetritus deposition in summer 2021.

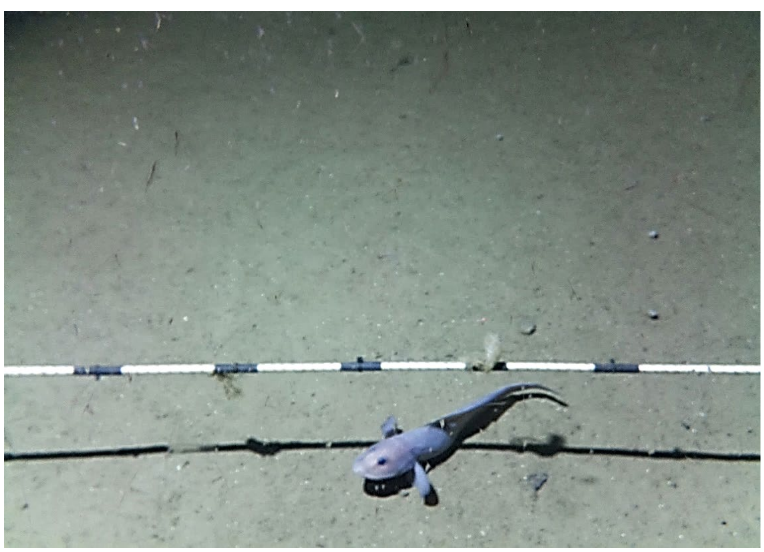

Fig. 5.6.1 Example seafloor-image taken from the time-lapse camera of the long-term lander that is retrieved on 12th of June 2022 before redeployment. The image taken on 1st October 2021 at noon depicts a zoarcid fish and a high concentration of particles / small organisms in the water column (F. Wenzhöfer et al., unpubl.).

Equipped with a recently refurbished sediment trap, a new time-lapse camera, and the same recording current meter the system was redeployed on 14th of June 2022 at the central HAUSGARTEN station HG-IV for another year of observations of the benthic boundary layer as well as seafloor imaging at 6 h intervals.

Concrete-cylinder battery-system mooring

In order to extend the spatiotemporal coverage of seafloor photographs, a second, multi time-lapse camera system was deployed at station HG-IV. Core of the system is a novel concrete pressure housing that was recently developed as part of the 'Deep C Solution' project by the Technical University Dresden, IBB and Carbocon in Dresden, Germany, and AWI with funding from the German Federal Ministry for Economic Affairs and Climate Action (BMWK, formerly BMWi). Beyond the contribution to oceanographic research, the deployment also serves as a first full-scale field demonstration of the new pressure housing technology that could provide power to future underwater missions with high energy demand as an alternative to costly pressure-proof containers made from titanium or stainless steel.

In addition to two 'TiPi' cameras of the same type hosted by the Long-term Bottom-Lander (see above), the system is equipped with two HD cameras (Blackmagic Micro Cinema, Blackmagic Design Lt, Port Melbourne, VIC, Australia). Each camera is setup as an independent system with individual DeepSea SeaLite LED lamps. On both sides of the system, a 'Tipi' and a Blackmagic camera are aligned to image similar areas of the seafloor adjacent to the concrete cylinder to allow for a comparison of results obtained with different imaging devices (Fig. 5.6.2). Three cameras (both TiPis and one of the Blackmagic cameras) are set to continuous imaging at 6 h intervals (4 images d^{-1}). The second Blackmagic camera is programmed to collect one image every 30 min (i.e. 48 images d^{-1}) for a period of 60 d after which recording stops. The elevated temporal resolution in July and August will allow to observe short-lived events (e.g. foraging of motile fauna) during the summer period when a lot for organic matter is expected to arrive at the seafloor and fauna is supposed to be most active. All cameras are powered by 171 D-size primary Li-cells (Saft LSH20) contained in the concrete housing (nominal capacity approx. 190 Ah at 32.4V).

The system was deployed on 27th of June 2022 as a mooring with the concrete cylinder as anchor stone and glass-spheres for buoyancy distributed along the approx. 2400 m long mooring line. Upon release of a twin acoustic releaser (iXblue) next summer, 300 m of coiled rope from a plastic bucket at the top of the cylinder will allow the top buoy (currently located at approx. 100 m water depth) to float to the surface for collection of the mooring. Localization of the system will be facilitated by a radio beacon (XEOS Technologies Inc., Dartmouth, NS, CA) attached to the top buoy.

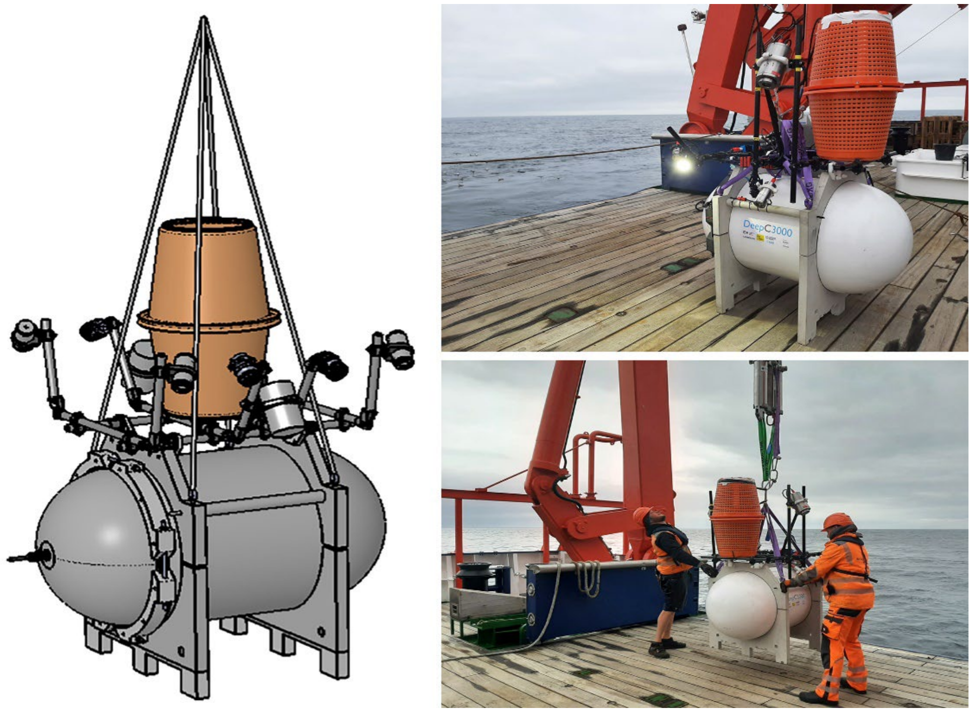

Fig. 5.6.2 The novel concrete-cylinder battery-system mooring with time-lapse cameras and lights attached. Left: Visualization showing the pressure housing made from carbon-reinforced concrete with mounts for cameras and flashes (in grey). Right: The system is deployed on 27th of June 2022 on board RV MARIA S. MERIAN. The orange container on top holds 300 m mooring line released upon recovery (Visualization: F. Wenzhöfer et al., unpubl.; photographs: F. Janssen).

Benthic Crawler

The Benthic Crawler that was used during MSM108 (Fig. 5.6.3) represents the third and most recent generation of mobile benthic sensor platforms developed by the HGF Joint Research Group for Deep-Sea Ecology and Technology at AWI in Bremerhaven and MPI in Bremen. The crawler developments are part of the HGF funded projects ARCHES and FRAM. The new system holds a similar suite of sensors as the predecessor 'Nomad' (Lemburg et al., 2018) while providing more space to add further payload (e.g. an autonomous sediment sampler) in the future. In addition to its newly designed caterpillar drive and frame it also holds, for the first time, a novel, custom-built, pressure-compensated Lithium battery that is rechargeable and comes without a heavy pressure housing.

Core of the current crawler payload are two benthic chambers and a three-channel microprofiler (upper left panel in Fig. 5.6.3). The cylindrical chambers are automatically lowered to the sediment surface and enclose a sediment patch together with a 50-80 mm thick layer of overlying water that is constantly mixed by a stirring device. From the oxygen decrease in the overlying water that is monitored by means of fiberoptical oxygen sensors installed in the chamber lid, the total oxygen flux across the sediment-water interface is determined. The total oxygen flux (Sediment Community Oxygen Demand, SCOD), is an established proxy for the total organic matter remineralization rate of the sediment. Fiberoptical oxygen sensors are also used by the microprofiler to map the vertical distribution of oxygen in the pore waters of the uppermost 10-15 cm of sediment. In steps of a tenth of a millimetre, three sensors are lowered in parallel across the sediment-interface into the sediment. Applying 1D transport reaction models, the observed oxygen distributions are used to calculate diffusive oxygen uptake rates. These represent the contribution of microorganisms and microscopic animals (meiofauna) to the total organic matter remineralization – typically the larger share in deep-sea benthic ecosystems as compared to larger sediment-inhabiting organisms (i.e. macrofauna). Fiberoptical oxygen sensors are calibrated with aerated and deoxygenated water at *in situ* temperature before deployment. At regular intervals, *in situ* calibrations are performed at the seafloor based on (1) measurements in bottom-waters where oxygen concentrations are known from CTD casts and by the crawler's own macro-optode (AADI type 4330) and (2) zero-readings obtained while sensor tips are flushed with oxygen-free calibration solution delivered by peristaltic pumps from gastight storage bags.

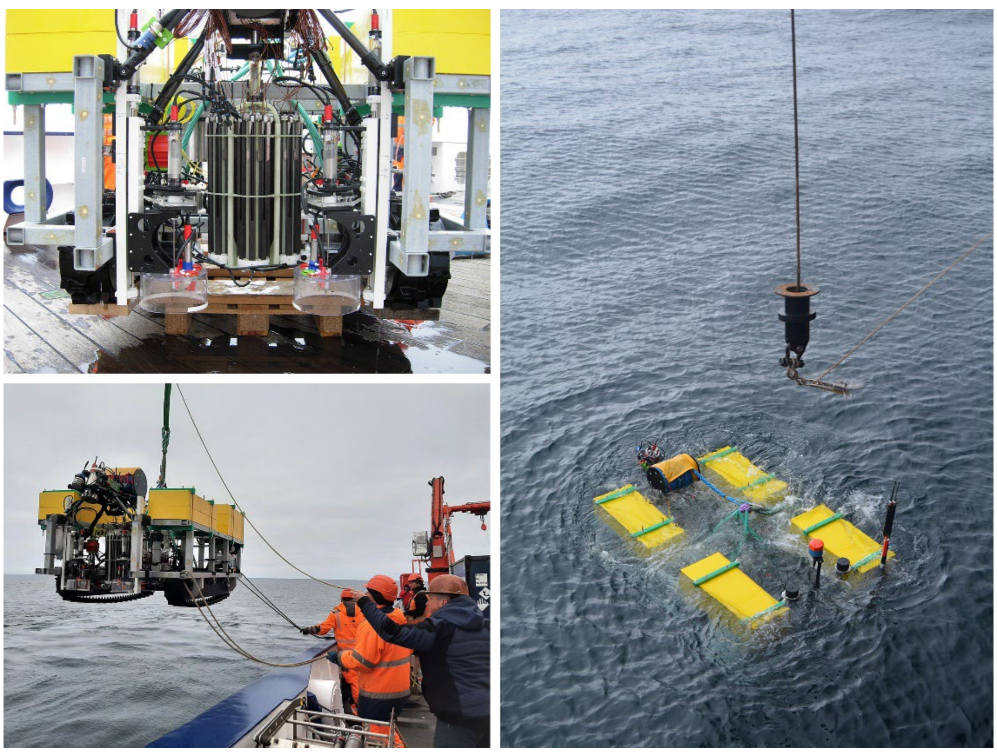

Fig. 5.6.3 The new Benthic Crawler deployed during MSM108. Upper left panel: Front view of the crawler showing the core scientific payload, i.e. the microprofiler in the centre and the benthic chambers to the left and right. Lower right and right: the crawler upon deployment immediately before and shortly after being released to sink down to the seafloor (photographs from upper left panel anti-clockwise: T. Soltwedel, F. Janssen, J. Dannheim).

Further sensor payload of the crawler includes a Doppler Current Sensor (Aanderaa DCS 4520, Xylem Inc./Aanderaa Data Instruments AS, Bergen, Norway) for bottom-water flow observations, an optode (type 4330) of the same manufacturer to record bottom-water oxygen concentrations, an HD camera for imaging of the sediment surface and determination of the chamber penetration depth / overlying water column height (Blackmagic Micro Cinema, Blackmagic Design Lt, Port Melbourne, VIC, Australia), a combined camera/line scanner system to record sediment characteristic and microtopography (3D SmartCam System, Kraken Robotics, Bremen, Germany), and a compass (model Prime, PNI, Santa Rosa, CA, USA) to provide route information while the crawler is moving.

The system is setup to perform weekly measurements over a period of one year. Every week the system wakes up from energy saving mode, moves 10 m away from the last measurement spot while imaging and scanning the sediment surface, performs a microprofiler measurement, moves another 0.1 m, performs a 24 h-benthic chamber incubation and another microprofiler measurement in parallel and takes an image of the sediment patch where chambers and microsensors penetrate the sediment. In total, one 10 m long sediment surface scan, two replicate chamber incubations, and six replicate oxygen profiles are obtained every week. Furthermore, bottom-water oxygen is monitored while the mircoprofiles are recorded and bottom-water current observations are performed every 10 min throughout the period of approx. 1.5 d per week that the crawler is active. Moving towards a new spot every week is necessary in order to always perform oxygen flux measurements on pristine sediment patches. At the same time the transition makes sure that an effect of the crawler platform on bottom-water flow conditions and settling of particles during the week before has no effect on the patch where measurements take place. At the end of the mission the system is called back to the surface by triggering acoustic releasers to release ballast weights and located with the help of Argos satellite- and radio-beacons (XEOS Technologies Inc., Dartmouth, NS, CA).

During MSM108, the system was deployed two times in free-falling mode after release at the sea surface. As an alternative, the system also allows for more precise deployments by means of a launching system. The first crawler deployment took place at station HG-II at 1500 m water depth. This short deployment served as a test run to check the performance of the new system and to collect *in situ* oxygen flux data as a contribution to the HAUSGARTEN long-term time series. During the deployment period, a condensed version of two consecutive measurement cycles was conducted with chamber and profiler runs separated by a short 'sleep' period of the system. The first deployment was mostly successful and flux measurements could be obtained (Fig. 5.6.4). The sole failure concerned the navigation at the seafloor. The system should have moved in a straight line in east-southeast direction (130°, i.e. against the main bottom-water current in the area). Instead, it followed a circular path due to a malfunction of the system's compass. Based on the information on *in situ* system performance obtained from the test deployment (regarding, e.g. navigation, depth of penetration into the surface sediment, orientation and setup of the cameras) the crawler was re-deployed towards the end of the expedition at the central HAUSGARTEN station HG-IV for a full one-year mission.

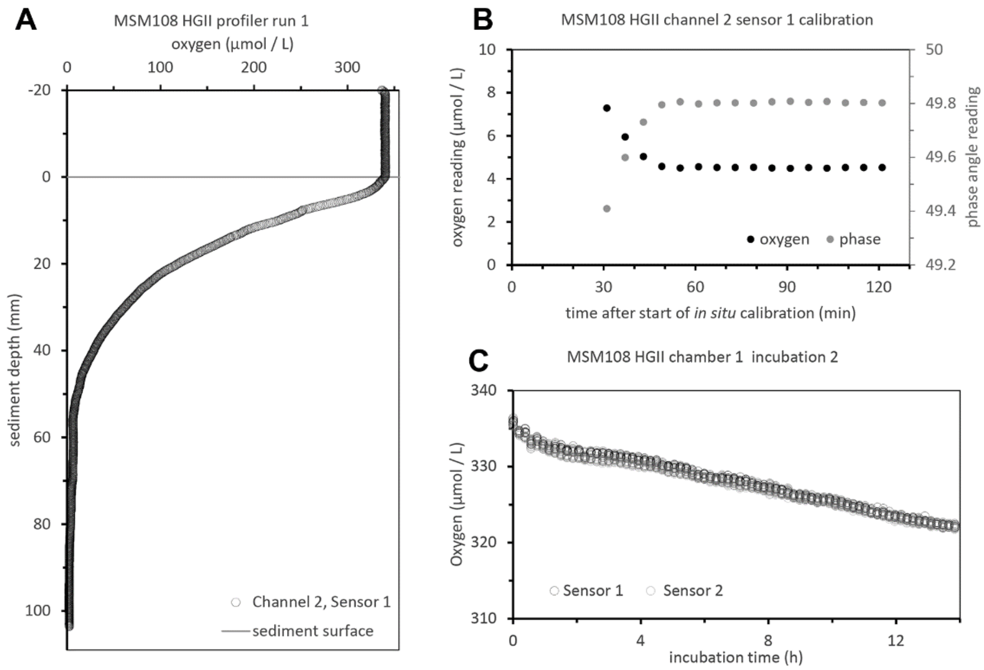

Fig. 5.6.4 Some preliminary plots of data collected with the crawler during the short deployment at station HG-II. Panel A: porewater oxygen profile recorded with a fiberoptical microsensor in the upper 10 cm of sediment. The grey line indicates the sediment surface. Panel B: sensor readings (oxygen and fluorescence phase angle) of the same fiberoptical sensor obtained after recording the profile shown in panel A while the sensor tip was flushed with oxygen-free calibration solution. The calibration information is used to correct microprofile raw oxygen data. Panel C: Time-series recording of oxygen concentrations in the overlying water of benthic chamber 1 during the second incubation. All oxygen data have been normalized to an estimated true bottom-water oxygen concentration of 335 µmol L^{-1} (F. Janssen, F. Wenzhöfer et al., unpublished data).

5.7 *In situ* Experimental Work at the LTER Observatory HAUSGARTEN

(T. Soltwedel, C. Hasemann, J. Hagemann, U. Hoge, S. Lehmenhecker)

Ocean acidification has been identified as a risk to marine ecosystems, and substantial scientific effort has been expended on investigating its effects, mostly in laboratory manipulation experiments. Experimental manipulations of CO_2 concentrations in the field are difficult, and the number of field studies are limited to a few locations. Within the EU project INTAROS (Integrated Arctic Observing System), the LTER observatory HAUSGARTEN was extended with an experimental system to study impacts of ocean acidification on benthic organisms and communities in deep Arctic waters with an autonomous system (Fig. 5.7.1). The Bottom-Lander based so-called arcFOCE (arctic Free Ocean Carbon Enrichment) system was developed to create semi-enclosed test areas on the seafloor where the seawater's pH (an indicator of acidity) can be precisely controlled for weeks or months at a time. The implementation of an arcFOCE for long-term experiments will enable us to generate data on the resistance of arctic marine benthic organisms and communities to a reduction in ocean pH. During the expedition MSM108, we performed two short test deployments of 4-5 days in length with the, in part, newly designed experimental system. Results from these tests were promising, so that we now plan to deploy the arcFOCE system during RV POLARSTERN expedition PS136 in 2023 for an entire year at approx. 1500 m water depth on the Vestnesa Ridge off western Svalbard.

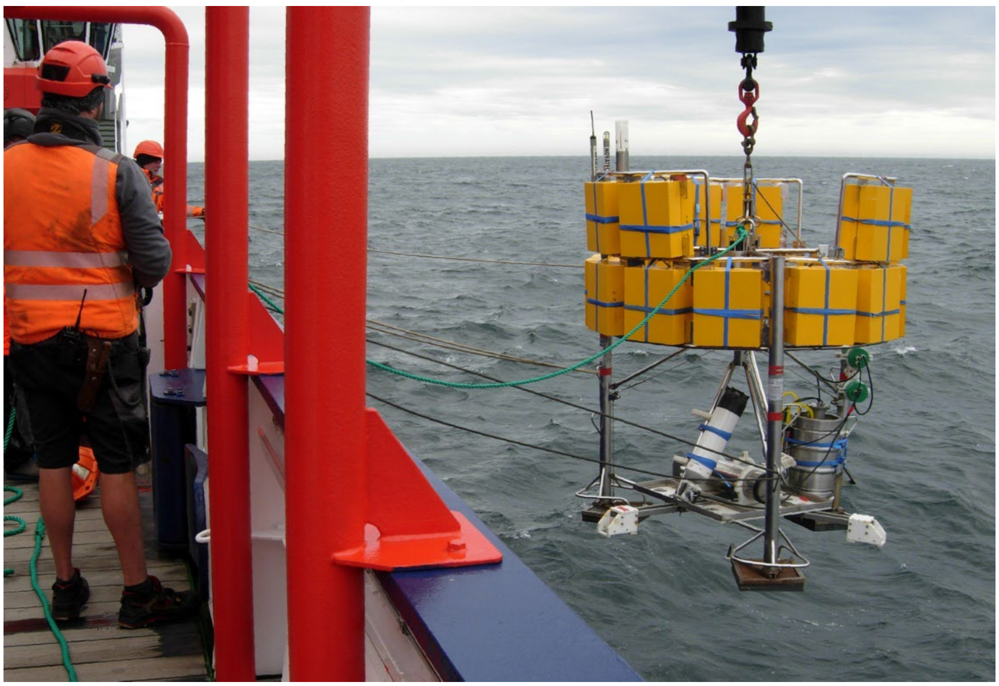

Fig. 5.7.1 Deployment of the Bottom-Lander based arcFOCE experimental set-up during expedition MSM108.

6 Station List

Operation	Date / Time	Latitude	Longitude	Depth (m)	Device
Underway-1	03.06.2022 19:30	69° 40.599' N	018° 59.126' E	1334	WST
Underway-2	07.06.2022 19:48	70° 34.276' N	019° 24.450' E	488	EM122
Underway-3	07.06.2022 19:48	70° 34.276' N	019° 24.450' E	488	VMADCP
Underway-4	07.06.2022 19:48	70° 34.276' N	019° 24.450' E	488	TSG
MSM108_1-1	10.06.2022 06:10	78° 37.000' N	005° 04.062' E	2331	CTD
MSM108_1-2	10.06.2022 07:55	78° 36.631' N	005° 03.918' E	2309	AUV
MSM108_1-3	10.06.2022 09:07	78° 36.519' N	005° 04.739' E	2310	HN
MSM108_1-4	10.06.2022 11:57	78° 36.999' N	005° 04.069' E	2311	CTD
MSM108_1-5	10.06.2022 13:40	78° 36.998' N	005° 04.068' E	2312	MUC
MSM108_1-6	10.06.2022 15:28	78° 36.999' N	005° 04.071' E	2295	MN
MSM108_1-7	10.06.2022 17:26	78° 36.999' N	005° 04.070' E	2296	GBC
MSM108_1-8	10.06.2022 20:13	78° 37.001' N	005° 09.945' E	2303	OFOS
MSM108_1-9	10.06.2022 22:49	78° 36.999' N	005° 09.264' E	2308	OFOS
MSM108_2-1	11.06.2022 06:28	79° 03.611' N	003° 28.566' E	4019	CTD
MSM108_2-2	11.06.2022 06:42	79° 03.611' N	003° 28.568' E	3977	HN
MSM108_2-3	11.06.2022 07:56	79° 03.604' N	003° 29.408' E	3938	MUC
MSM108_2-4	11.06.2022 10:48	79° 03.347' N	003° 30.143' E	3914	GBC
MSM108_3-1	11.06.2022 13:17	79° 03.814' N	003° 36.810' E	3297	CTD
MSM108_3-2	11.06.2022 13:28	79° 03.814' N	003° 36.813' E	3289	HN
MSM108_3-3	11.06.2022 14:40	79° 03.874' N	003° 36.457' E	3321	MUC
MSM108_3-4	11.06.2022 16:50	79° 03.899' N	003° 36.313' E	3339	GBC
MSM108_4-1	11.06.2022 19:29	79° 03.804' N	003° 41.540' E	2958	MUC
MSM108_4-2	11.06.2022 20:48	79° 03.979' N	003° 42.736' E	2869	CTD
MSM108_4-3	11.06.2022 21:05	79° 03.979' N	003° 42.737' E	2871	HN
MSM108_4-4	11.06.2022 22:21	79° 03.807' N	003° 41.499' E	2960	GBC
MSM108_5-1	12.06.2022 01:56	79° 02.150' N	004° 10.262' E	2573	OFOS
MSM108_5-2	12.06.2022 08:51	79° 04.096' N	004° 11.693' E	2402	AUV
MSM108_5-3	12.06.2022 14:24	79° 02.348' N	004° 11.286' E	2554	LANDER
MSM108_5-4	12.06.2022 14:36	79° 02.347' N	004° 11.276' E	2557	CRAWLER
MSM108_5-5	12.06.2022 16:17	79° 04.082' N	004° 10.339' E	2419	CTD
MSM108_5-6	12.06.2022 16:33	79° 04.011' N	004° 10.530' E	2420	HN
MSM108_5-7	12.06.2022 17:38	79° 03.915' N	004° 10.790' E	2419	MN
MSM108_5-8	12.06.2022 19:26	79° 03.916' N	004° 10.791' E	2420	GBC
MSM108_5-9	12.06.2022 21:01	79° 03.926' N	004° 10.750' E	2420	MUC
MSM108_5-10	12.06.2022 23:14	79° 04.122' N	004° 11.710' E	2402	CTD
MSM108_6-1	13.06.2022 01:21	79° 06.485' N	004° 35.996' E	1880	GBC
MSM108_6-2	13.06.2022 02:41	79° 06.486' N	004° 35.999' E	1878	MUC
MSM108_6-3	13.06.2022 04:00	79° 06.706' N	004° 36.814' E	1847	HN

MSM108_6-4	13.06.2022 04:15	79° 06.706' N	004° 36.814' E	1852	CTD
MSM108_7-1	13.06.2022 07:21	79° 07.669' N	005° 12.864' E	1351	AUV
MSM108_7-2	13.06.2022 11:22	79° 07.669' N	005° 12.865' E	1357	OFOS
MSM108_7-3	13.06.2022 15:20	79° 07.790' N	005° 29.935' E	1301	EM122
MSM108_7-4	13.06.2022 15:20	79° 07.820' N	005° 29.942' E	1304	EM712
MSM108_8-1	13.06.2022 19:45	79° 34.175' N	005° 15.086' E	2609	OFOS
MSM108_9-1	13.06.2022 23:54	79° 44.357' N	004° 30.312' E	2668	CTD
MSM108_9-2	14.06.2022 00:08	79° 44.357' N	004° 30.310' E	2663	HN
MSM108_9-3	14.06.2022 01:01	79° 44.357' N	004° 30.309' E	2665	GBC
MSM108_9-4	14.06.2022 02:47	79° 44.358' N	004° 30.310' E	2665	MUC
MSM108_9-5	14.06.2022 05:01	79° 44.089' N	004° 30.311' E	2709	CTD
MSM108_10-1	14.06.2022 07:51	79° 36.231' N	005° 10.282' E	2729	MUC
MSM108_10-2	14.06.2022 09:37	79° 36.228' N	005° 10.339' E	2728	GBC
MSM108_10-3	14.06.2022 10:56	79° 36.149' N	005° 09.195' E	2748	OFOS
MSM108_11-2	14.06.2022 12:55	79° 32.375' N	005° 09.352' E	2700	EM712
MSM108_11-1	14.06.2022 12:55	79° 32.375' N	005° 09.352' E	2700	EM122
MSM108_12-1	14.06.2022 16:48	79° 07.176' N	005° 00.610' E	1511	LANDER
MSM108_12-2	14.06.2022 17:03	79° 07.369' N	004° 57.726' E	1518	CRAWLER
MSM108_12-3	14.06.2022 17:28	79° 07.495' N	004° 54.033' E	1563	HN
MSM108_12-4	14.06.2022 17:42	79° 07.494' N	004° 54.031' E	1566	CTD
MSM108_12-5	14.06.2022 18:28	79° 07.495' N	004° 54.031' E	1566	MUC
MSM108_12-6	14.06.2022 19:35	79° 07.495' N	004° 54.029' E	1551	GBC
MSM108_13-1	14.06.2022 21:46	79° 20.984' N	006° 00.317' E	1702	EM122
MSM108_13-2	14.06.2022 21:46	79° 20.971' N	006° 00.470' E	1702	EM712
MSM108_14-2	15.06.2022 10:12	79° 08.002' N	006° 05.561' E	1261	OFOS
MSM108_14-1	15.06.2022 11:53	79° 08.592' N	006° 04.803' E	1272	AUV
MSM108_14-3	15.06.2022 14:40	79° 07.991' N	006° 05.588' E	1256	HN
MSM108_14-4	15.06.2022 15:00	79° 07.991' N	006° 05.588' E	1258	CTD
MSM108_14-5	15.06.2022 15:38	79° 07.991' N	006° 05.589' E	1259	MUC
MSM108_14-6	15.06.2022 16:35	79° 07.986' N	006° 05.621' E	1258	GBC
MSM108_14-7	15.06.2022 18:18	79° 08.044' N	006° 06.760' E	1259	OFOS
MSM108_14-8	16.06.2022 04:57	79° 08.008' N	006° 05.617' E	1255	CTD
MSM108_15-1	16.06.2022 07:02	79° 01.786' N	006° 59.959' E	1280	MUC
MSM108_15-2	16.06.2022 08:02	79° 01.782' N	007° 00.006' E	1275	GBC
MSM108_15-3	16.06.2022 08:36	79° 01.782' N	007° 00.006' E	1279	HN
MSM108_15-4	16.06.2022 09:27	79° 01.558' N	006° 59.567' E	1275	CTD
MSM108_16-1	16.06.2022 13:43	79° 19.991' N	005° 47.945' E	1795	OFOS
MSM108_17-1	17.06.2022 00:51	79° 19.979' N	005° 49.459' E	1856	GBC
MSM108_17-2	17.06.2022 02:18	79° 19.979' N	005° 49.474' E	1853	MUC
MSM108_17-3	17.06.2022 03:43	79° 19.973' N	005° 49.491' E	1844	GBC
MSM108_18-1	17.06.2022 15:12	79° 01.416' N	004° 11.919' E	2592	MN

MSM108_18-2	17.06.2022 16:53	79° 01.896' N	004° 11.877' E	2584	LANDER
MSM108_19-1	18.06.2022 06:11	79° 01.322' N	010° 50.352' E	330	CTD
MSM108_19-2	18.06.2022 06:29	79° 01.321' N	010° 50.352' E	330	HN
MSM108_19-3	18.06.2022 06:46	79° 01.322' N	010° 50.351' E	330	MUC
MSM108_20-1	18.06.2022 09:23	78° 58.409' N	009° 26.610' E	221	AUV
MSM108_21-1	18.06.2022 14:57	78° 58.809' N	009° 30.971' E	228	CTD
MSM108_21-2	18.06.2022 15:13	78° 58.809' N	009° 30.972' E	228	HN
MSM108_21-3	18.06.2022 15:27	78° 58.809' N	009° 30.971' E	228	MUC
Underway-5	18.06.2022 15:40	78° 58.809' N	009° 30.802' E	228	VMADCP
MSM108_21-4	18.06.2022 16:00	78° 58.809' N	009° 30.803' E	228	MUC
Underway-6	18.06.2022 16:19	78° 59.674' N	009° 21.414' E	216	EM122
MSM108_22-1	19.06.2022 03:00	79° 02.576' N	003° 12.765' E	4985	CTD
MSM108_22-2	19.06.2022 03:16	79° 02.581' N	003° 12.858' E	4977	HN
MSM108_22-3	19.06.2022 04:55	79° 02.586' N	003° 12.933' E	4992	MUC
MSM108_22-4	19.06.2022 08:04	79° 02.586' N	003° 12.985' E	4965	GBC
MSM108_12-1	19.06.2022 14:47	79° 07.394' N	004° 59.854' E	1512	LANDER
MSM108_23-1	19.06.2022 18:11	79° 19.121' N	006° 00.259' E	1740	GBC
MSM108_23-2	19.06.2022 20:56	79° 19.120' N	006° 00.197' E	1721	MUC
MSM108_23-3	19.06.2022 23:12	79° 18.197' N	005° 57.481' E	1656	OFOS
MSM108_24-1	20.06.2022 06:10	79° 20.064' N	006° 03.125' E	1669	GBC
MSM108_24-2	20.06.2022 07:26	79° 20.063' N	006° 03.124' E	1668	MUC
MSM108_24-3	20.06.2022 08:40	79° 20.065' N	006° 03.123' E	1672	GBC
MSM108_25-1	20.06.2022 13:13	79° 00.021' N	008° 15.036' E	881	HN
MSM108_25-2	20.06.2022 13:38	79° 00.020' N	008° 15.039' E	884	CTD
MSM108_26-1	20.06.2022 17:47	79° 30.003' N	008° 29.961' E	290	OFOS
MSM108_27-1	21.06.2022 13:16	79° 07.112' N	002° 51.948' E	5517	CTD
MSM108_27-2	21.06.2022 13:30	79° 07.113' N	002° 51.948' E	5516	HN
MSM108_27-3	21.06.2022 14:35	79° 07.116' N	002° 51.947' E	5514	MN
MSM108_27-4	21.06.2022 17:20	79° 07.543' N	002° 51.258' E	5536	GBC
MSM108_27-5	21.06.2022 20:42	79° 07.903' N	002° 50.673' E	5549	MUC
MSM108_27-6	22.06.2022 00:36	79° 07.999' N	002° 50.537' E	5549	CTD
MSM108_12-2	22.06.2022 06:46	79° 07.629' N	004° 56.439' E	1507	CRAWLER
MSM108_28-1	22.06.2022 09:13	79° 20.903' N	005° 52.697' E	1771	GBC
MSM108_28-2	22.06.2022 10:32	79° 20.903' N	005° 52.698' E	1769	MUC
MSM108_28-3	22.06.2022 11:49	79° 20.902' N	005° 52.700' E	1770	GBC
MSM108_28-4	22.06.2022 13:36	79° 19.100' N	005° 46.304' E	1767	OFOS
MSM108_29-1	22.06.2022 20:13	79° 19.529' N	005° 54.934' E	1781	GBC
MSM108_29-2	22.06.2022 21:32	79° 19.516' N	005° 54.986' E	1771	MUC
MSM108_29-3	22.06.2022 22:50	79° 19.516' N	005° 54.990' E	1778	MUC
MSM108_30-1	23.06.2022 01:13	79° 34.158' N	005° 15.170' E	2627	CTD
MSM108_30-2	23.06.2022 01:43	79° 33.744' N	005° 13.270' E	2692	HN

MSM108_30-3	23.06.2022 02:38	79° 33.743' N	005° 13.267' E	2695	OFOS
MSM108_31-1	23.06.2022 08:57	79° 15.013' N	006° 19.978' E	1560	LANDER
MSM108_32-1	23.06.2022 10:44	79° 05.659' N	006° 21.017' E	1230	AUV
MSM108_33-1	23.06.2022 18:47	79° 20.492' N	005° 57.990' E	1715	GBC
MSM108_33-2	23.06.2022 19:58	79° 20.491' N	005° 57.990' E	1715	MUC
MSM108_33-3	23.06.2022 21:35	79° 20.491' N	005° 57.988' E	1715	OFOS
MSM108_34-1	24.06.2022 04:09	79° 18.636' N	005° 51.909' E	1713	GBC
MSM108_34-2	24.06.2022 05:20	79° 18.636' N	005° 51.909' E	1715	GBC
MSM108_34-3	24.06.2022 06:35	79° 18.636' N	005° 51.908' E	1709	MUC
MSM108_35-1	24.06.2022 10:13	79° 19.336' N	005° 49.031' E	1757	AUV
MSM108_36-1	24.06.2022 17:44	79° 19.550' N	005° 54.790' E	1794	MUC
MSM108_37-1	24.06.2022 19:25	79° 19.986' N	005° 49.512' E	1853	OFOS
MSM108_38-1	25.06.2022 02:38	79° 01.791' N	006° 59.927' E	1279	BOAT
MSM108_38-2	25.06.2022 04:10	79° 01.792' N	006° 59.928' E	1279	CTD
MSM108_38-3	25.06.2022 05:22	79° 01.791' N	006° 59.923' E	1279	MN
MSM108_38-4	25.06.2022 06:01	79° 01.791' N	006° 59.923' E	1278	HN
MSM108_38-5	25.06.2022 08:40	79° 01.791' N	006° 59.930' E	1279	BOAT
MSM108_38-6	25.06.2022 10:27	79° 01.792' N	006° 59.927' E	1280	CTD
MSM108_38-7	25.06.2022 11:11	79° 01.791' N	006° 59.926' E	1282	MN
MSM108_38-8	25.06.2022 14:42	79° 01.791' N	006° 59.926' E	1280	BOAT
MSM108_38-9	25.06.2022 16:21	79° 01.791' N	006° 59.923' E	1278	CTD
MSM108_38-10	25.06.2022 17:07	79° 01.791' N	006° 59.924' E	1278	MN
MSM108_38-11	25.06.2022 20:25	79° 01.791' N	006° 59.919' E	1280	BOAT
MSM108_38-12	25.06.2022 22:12	79° 01.791' N	006° 59.921' E	1276	CTD
MSM108_38-13	25.06.2022 22:57	79° 01.791' N	006° 59.921' E	1275	MN
MSM108_39-1	26.06.2022 02:09	79° 18.188' N	005° 57.443' E	1666	GBC
MSM108_39-2	26.06.2022 03:18	79° 18.188' N	005° 57.444' E	1666	MUC
MSM108_39-3	26.06.2022 04:56	79° 18.276' N	005° 57.455' E	1670	OFOS
MSM108_40-1	26.06.2022 12:34	79° 19.103' N	005° 46.253' E	1774	GBC
MSM108_40-2	26.06.2022 13:47	79° 19.103' N	005° 46.252' E	1772	MUC
MSM108_41-1	26.06.2022 15:38	79° 20.898' N	005° 52.678' E	1783	OFOS
MSM108_42-1	27.06.2022 03:37	79° 01.900' N	004° 11.902' E	2579	MUC
MSM108_42-2	27.06.2022 06:16	79° 01.971' N	004° 19.371' E	2509	MOOR
MSM108_42-3	27.06.2022 09:29	79° 02.354' N	004° 17.551' E	2497	CRAWLER
MSM108_43-1	27.06.2022 18:10	79° 06.408' N	003° 13.694' E	5369	OFOS
MSM108_44-1	28.06.2022 08:29	79° 02.507' N	006° 39.888' E	1213	AUV
MSM108_45-1	29.06.2022 06:26	78° 49.180' N	002° 47.140' W	2538	CTD
MSM108_45-2	29.06.2022 07:02	78° 49.180' N	002° 47.141' W	2538	HN
MSM108_45-3	29.06.2022 08:10	78° 49.181' N	002° 47.140' W	2537	MN
MSM108_45-4	29.06.2022 10:07	78° 49.181' N	002° 47.141' W	2541	MUC
MSM108_45-5	29.06.2022 11:51	78° 49.181' N	002° 47.139' W	2542	GBC

Abbreviation	Description
AUV	Autonomous Underwater Vehicle
CTD	CTD / Rosette Water Sampler
CRAWLER	Benthic Crawler
BOAT	Zodiac
EM122	Multibeam Echosounder EM122
EM712	Multibeam Echosounder EM712
GBC	Giant Box Corer
LANDER	Bottom-Lander
MOOR	Mooring
MSN	Multi-net (Midi)
MUC	Multiple Corer
HN	Hand net
OFOS	Ocean Floor Observation System
TSG	Thermosalinograph
VMADCP	Acoustic Doppler Current Profiler (38kHz)
WST	Weatherstation

7 Data and Sample Storage and Availability

Samples will be processed and stored at AWI and GEOMAR. All OFOS images, videos and metadata will be uploaded to the PANGAEA data library (https://www.pangaea.de). All raw acoustic and image data collected by the AUV during MSM108 will be published and disseminated according to international standards within two years after the end of the cruise at the latest. By default, the CC-BY license will be applied. Processed mapping products derived from the raw data will be made available following associated scientific publication or two years after production. Data acquisition from other types of investigation will be differently time-consuming. The time period from post processing to data provision will vary from one year maximum for sensor data, to several years for organism related datasets. Until then preliminary data will be available to the cruise participants and external users after request to the senior scientist. The finally processed data will be submitted to PANGAEA. The unrestricted data availability from PANGAEA will depend on the required time and effort for acquisition of individual datasets and its status of scientific publication. Data will preferably be published in open access journals.

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