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HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

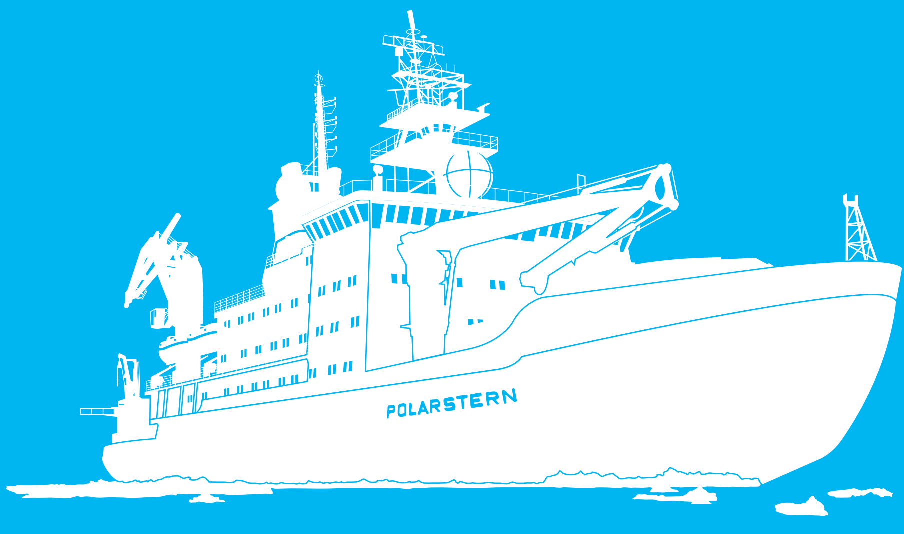
EXPEDITION PROGRAMME PS143/1

Polarstern

PS143/1
Bremerhaven - Tromsø
07 June 2024 - 09 July 2024

Coordinator: Ingo Schewe

Chief Scientist: Frank Wenzhöfer



HELMHOLTZ

Bremerhaven, April 2024

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The Expedition Programme *Polarstern* is issued by
the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven, Germany.

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Contents

1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Frank Wenzhöfer DE.AWI

Das Forschungsschiff *Polarstern* wird am 07. Juni von Bremerhaven aus zur Expedition PS143/1 in die Framstraße zwischen Spitzbergen und Grönland aufbrechen. Während dieser Reise werden die 21 Stationen des LTER HAUSGARTEN sowie zusätzliche Stationen im Bereich Nordost-Grönland und Molloy Deep aufgesucht (Abb. 1.1 und 2.1), um inderdiszipilnäre Arbeiten von der Wassersäule bis zum Meeresboden durchzuführen. Hierfür werden eine Reihe von Beprobungen von Schiff gesteuerten Geräten (z.B. MUC, Kastengreifer, CTD/Rosette, EBS) durchgeführt. Darüber hinaus, kommen aber auch hochkomplexe autonome robotische Forschungsplattformen (Benthic Crawler, Lander, OFOBS) zum Einsatz. Zusätzlich sollen Experimente am Meeresboden mit Hilfe eines ROV (KIEL6000, GEOMAR) gezielt beprobt werden. Hierzu wird in etwa der Häfte der Reise ein aus Austausch von Personal erfolgen, um das ROV-Team an Bord zu nehmen. Die Arbeiten am LTER Observatorium HAUSGARTEN stellen einen weiteren Beitrag zur Sicherstellung der Langzeitbeobachtungen dar, das in diesem Jahr sein 25-jähriges Jubiläm feiert, und in denen der Einfluss von Umweltveränderungen auf ein arktisches Tiefseeökosystem dokumentiert wird. Darüber hinaus wird die Expedition genutzt, um weitere Installationen im Rahmen der HGF Infrastrukturmaßnahme FRAM (Frontiers in Arctic marine Monitoring) vorzunehmen.

Die Hauptziele von LTER HAUSGARTEN, LTO West Spitzbergen Current und dem FRAM Ocean Observing System sind: (i) regelmäßige Beobachtung der benthischen und pelagischen Artenvielfalt und der biogeochemischen Prozesse in Abhängigkeit von den sich ändernden Umweltbedingungen und (ii) ständige Präsenz auf See zur Bereitstellung integrierter und interdisziplinärer Daten über physikalische, biogeochemische und biologische Variablen. Das FRAM-Ozeanbeobachtungssystem unterhält, entwickelt und implementiert hochmoderne synergetische Beobachtungsplattformen für die Polar-, Meeres- und Klimawandelforschung im Ozean und legt - als Prototyp für groß angelegte integrative, autonome Observatorien - die Grundlage für die nachhaltige Überwachung und das Management der ozeanischen Umwelt. Kontinuierliche Beobachtungen werden an der Schnittstelle zwischen Hydrosphäre, Kryosphäre und Atmosphäre sowie Hydrosphäre und Geosphäre durchgeführt. Das Beobachtungssystem ermöglicht die umfassende Erfassung von Prozessen auch während des Winters, des frühen Frühlings und des Spätherbstes (d.h. wenn Schiffe nur selten in der Region sind) oder während episodischer, extremer Ereignisse, die derzeit zu wenig erfasst werden, die aber einen großen Einfluss auf die Trajektorien der saisonalen Entwicklung haben können. Die installierten Komponenten werden dazu beitragen Rückschlüsse auf die Folgen der raschen Erwärmung der arktischen Atmosphäre zu ziehen, die in den letzten Jahrzehnten doppelt so schnell wie der globale Durchschnitt verlaufen ist.

Die übergreifenden wissenschaftlichen Ziele der langfristigen Studien durch die Ozeanbeobachtungssysteme sind:

- tägliche Daten über die Eigenschaften der Meeresoberfläche und der Tiefsee in nahezu Echtzeit liefern,
- die Erwärmung des in den Arktischen Ozean einfließenden Atlantikwassers und die damit verbundenen Veränderungen des Transports und der Eigenschaften zu dokumentieren,
- Untersuchung der Wechselwirkungen und Rückkopplungsmechanismen zwischen Atmosphäre, Kryo-, Hydro-, Bio- und Geosphäre,
- Beobachtungen zu erhalten, um Variationen von täglicher (z.B. relevant für die Vorbedingungen für Phytoplanktonblüten) bis inter-annualer (z.B. relevant für die Entschlüsselung dekadischer Trends) Zeitskala mit Prozessen in der Atmo-, Kryo-, Hydro-, Bio- und Geosphäre zu verknüpfen,
- Quantifizierung von Energie- und Stoffbudgets und -transporten in unterschiedlicher räumlich-zeitlicher Auflösung, von der jahreszeitlichen Dynamik bis zu zwischenjährlichen Unterschieden und dekadischen Veränderungen,
- die Mechanismen zu untersuchen, die die Artenvielfalt pelagischer und benthischer Lebensgemeinschaften bestimmen,
- die Widerstandsfähigkeit der arktischen Meeresorganismen zu untersuchen und Indikatorarten für Veränderungen in den Gemeinschaften zu identifizieren,
- Daten für die Bewertung von Ökosystemfunktionen und der Rolle der biologischen Vielfalt liefern,
- Bereitstellung von Daten zur Bewertung der Qualität von Modellen, die aktuelle und zukünftige Veränderungen im Arktischen Ozean simulieren,
- zu entschlüsseln, wie die Mechanismen des Klimawandels im Nordatlantik und im Arktischen Ozean gekoppelt sind,
- die Plastikverschmutzung im Meereis, in der Wassersäule und auf dem Meeresboden zu bewerten.

Die Expedition endet am 9. Juli in Tromsø. Diese Expedition wird unterstützt vom Helmholtz-Forschungsprogramm “Changing Earth – Sustaining our Future” Topic 2, Subtopics 1, 3 und 4 und Topic 6, Subtopics 1, 2, 3 und 4, und leistet Beiträge zu verschiedenen nationalen und internationalen Forschungs- und Infrastrukturprojekten (FRAM, MUSE, iFOODis, HADAL, HiAOOS, ICOS-D, SIOS, EPOC, AtlantEco, OBAMA-Next and Arctic PASSION).

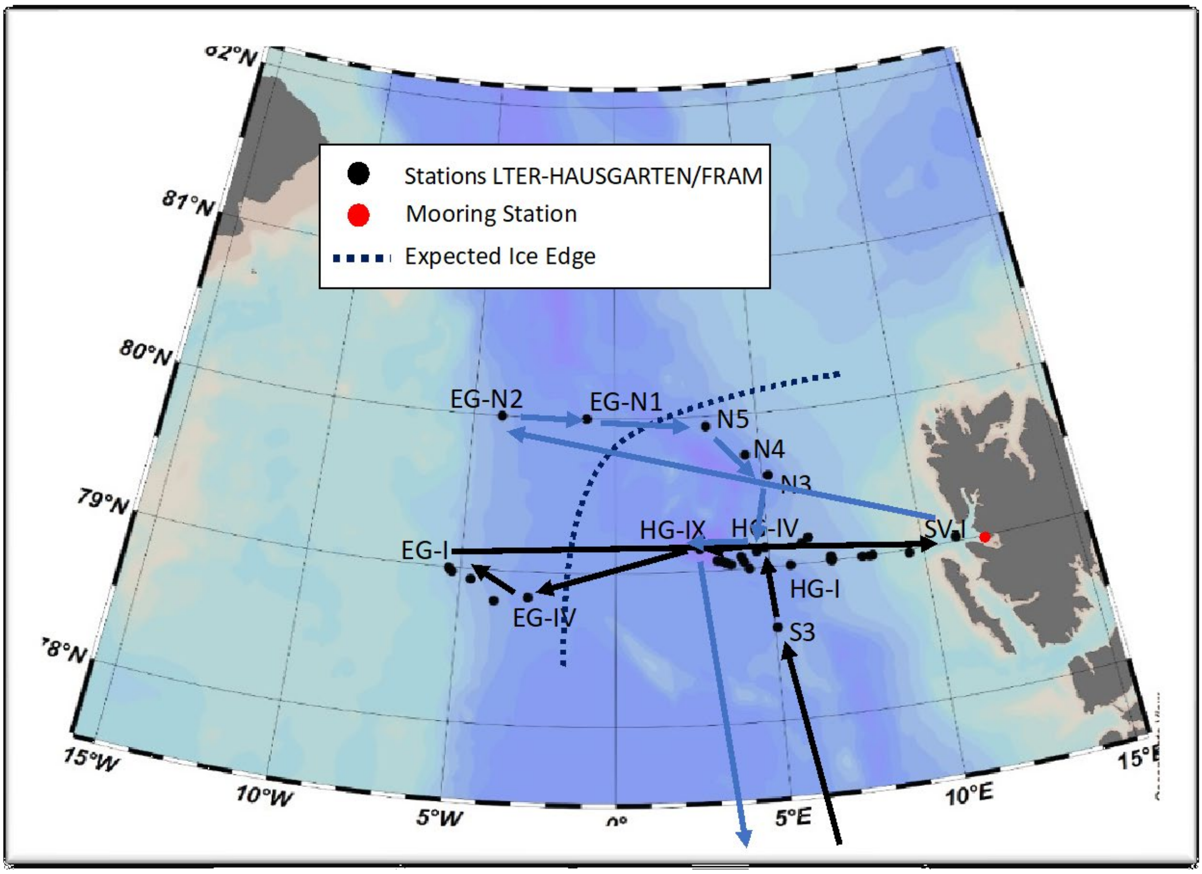

Abb. 1.1: Geplante Fahrtroute in der Framstraße (durchgezogene Linien) und die wichtigsten Messstationen der Polarstern Expedition PS143/1

Fig. 1.1: Planned cruise track in the Fram Strait (solid lines) and main sampling stations of Polarstern expedition PS143/1

SUMMARY AND ITINERARY

On June 7, the research vessel *Polarstern* will depart from Bremerhaven on expedition PS143/1 to the Fram Strait between Spitsbergen and Greenland. During the cruise, the 21 stations of the LTER HAUSGARTEN and additional stations in the North East Greenland area and Molloy Deep (Fig. 1.1 and 2.1) will be visited to carry out inderdiscipilary work from the water column to the seafloor. For this purpose, a series of ship-operated sampling devices (e.g. MUC, box grab, CTD/rosette, EBS) will be used. In addition, highly complex autonomous robotic research platforms (benthic crawler, lander, OFOBS) will also be deployed. Furthermore, experiments on the sea floor will be sampled using an ROV (KIEL6000, GEOMAR). For this purpose, there will be an exchange of personnel about halfway through the cruise to take the ROV-team on board. The work at the LTER observatory HAUSGARTEN represents a further contribution to ensuring long-term observations, which is celebrating its 25th anniversary this year, and in which the influence of environmental changes on an Arctic deep-sea ecosystem is documented. In addition, the expedition will be used to carry out further installations as part of the HGF infrastructure project FRAM (Frontiers in Arctic marine Monitoring).

The main objectives of LTER HAUSGARTEN, LTO West Spitsbergen Current and the FRAM Ocean Observing System are: (i) regular monitoring of benthic and pelagic biodiversity and biogeochemical processes in response to changing environmental conditions and (ii) permanent presence at sea to provide integrated and interdisciplinary data on physical, biogeochemical and biological variables. The FRAM Ocean Observing System maintains, develops and implements state-of-the-art synergistic observing platforms for polar, marine and climate change research in the ocean and lays the foundation for the sustainable monitoring and management of the oceanic environment as a prototype for large-scale integrative, autonomous observatories. Continuous observations are carried out at the interface between hydrosphere, cryosphere and atmosphere as well as hydrosphere and geosphere. The observation system will allow the comprehensive detection of processes even during winter, early spring and late fall (i.e. when ships are rarely in the region) or during episodic, extreme events that are currently under-recorded but can have a major impact on the trajectories of seasonal evolution. The installed components will help to draw conclusions about the consequences of the rapid warming of the Arctic atmosphere, which has been twice as fast as the global average in recent decades. The overarching scientific objectives of the long-term studies by the ocean observation systems are:

- provide daily near-real time data on ocean surface and deep-water properties,
- provide a record documenting the warming of the Atlantic Water inflowing to the Arctic Ocean and its associated changes in transport and properties,
- study interactions and feedback mechanisms between the atmo-, cryo-, hydro-, bio-, and geosphere,
- obtain observations to link variations of daily (e.g., relevant for the preconditioning for phytoplankton blooms) to inter-annual (e.g., relevant to decipher decadal trends) time-scales to processes in the atmo-, cryo-, hydro-, bio- and geosphere,
- quantify budgets and transports of energy and matter at different spatio-temporal resolution from seasonal dynamics to inter-annual differences and decadal changes,
- study the mechanisms which shape biodiversity of pelagic and benthic communities,
- study the resilience of Arctic marine organisms and to identify indicator species for community changes,
- contribute data for the assessment of ecosystem functions, services and the role of biodiversity therein,
- provide data for assessing the quality of models simulating current and future changes in the Arctic Ocean,
- decipher how Climate Change mechanisms in the North Atlantic and the Arctic Ocean are coupled,
- assess plastic pollution in sea-ice, water-column and on the seafloor and to investigate long-term trends in plastic pollution.

2. LTER HAUSGARTEN: IMPACT OF CLIMATE CHANGE ON ARCTIC MARINE ECOSYSTEMS

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Objectives

The marine Arctic has played an essential role in the history of our planet over the past 130 million years and contributes considerably to the present functioning of the Earth and its life. The past decades have seen remarkable changes in key Arctic variables, including a decrease in sea-ice extent and sea-ice thickness, changes in temperature and salinity of Arctic waters, and associated shifts in nutrient distributions and pollution (Bergmann et al. 2022). Since Arctic organisms are highly adapted to extreme environmental conditions with strong seasonal forcing, the accelerating rate of recent climate change challenges the resilience of Arctic life. The stability of a number of Arctic populations and ecosystems is probably not strong enough to withstand the sum of these factors, which might lead to a collapse of subsystems.

Benthos, particularly in deep waters, is a robust ecological indicator for environmental changes, as it is relatively stationary and long-lived and reflects changes in environmental conditions in the oceans (e.g. organic flux to the seabed) at integrated scales (Gage and Tyler 1991; Piepenburg 2005). 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 Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) established the deep-sea observatory HAUSGARTEN, which constitutes the first, and until now only open-ocean long-term observatory in a polar region (Soltwedel et al. 2016).

HAUSGARTEN is located in the eastern Fram Strait and comprises 21 permanent sampling stations along a depth transect (250 - 5500 m) and along a latitudinal transect following the 2500 m isobath crossing the central HAUSGARTEN station (Fig. 2.1). Multidisciplinary research activities at HAUSGARTEN cover almost all compartments of the marine ecosystem from the pelagic zone to the benthic realm, with a focus on benthic processes. 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, have taken place since the observatory was established in 1999. Visual observations were regularly undertaken by towed photo/video systems to assess spatial patterns and temporal dynamics of epibenthic megafauna and habitat characteristics.

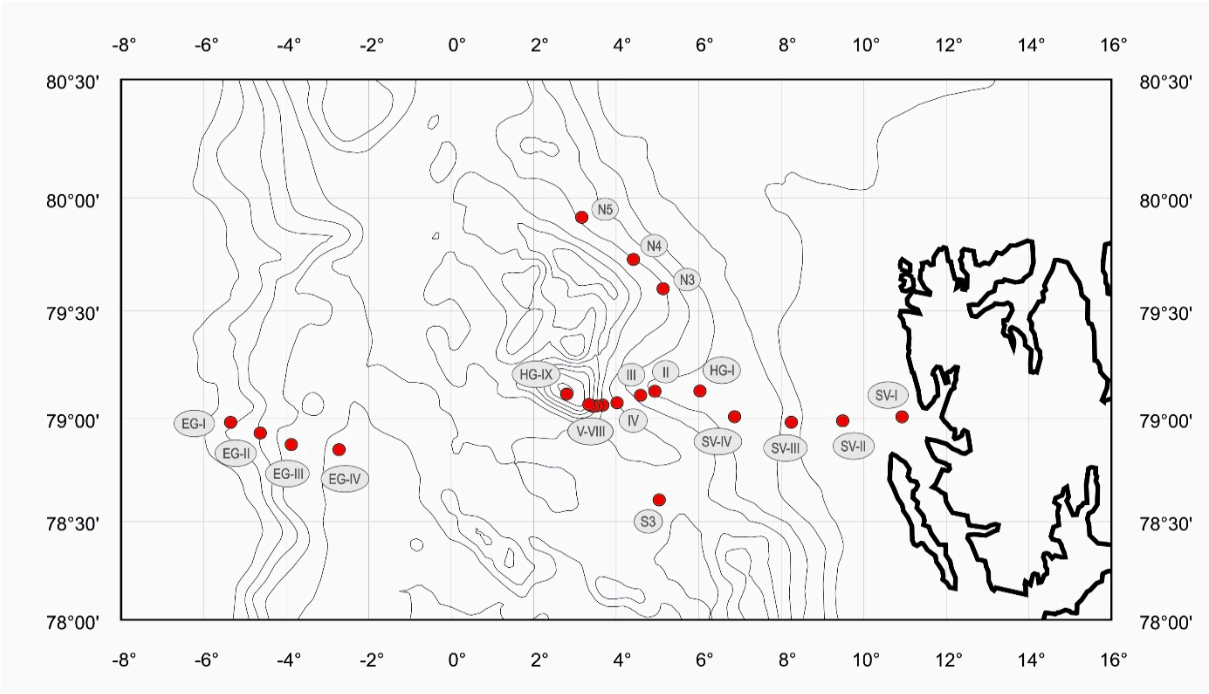

Fig. 2.1: Permanent sampling sites of the LTER (Long-Term Ecological Research) observatory HAUSGARTEN in Fram Strait, Arctic Ocean

Geographical features in the HAUSGARTEN area provide a variety of contrasting marine landscapes and landscape elements (e.g. banks, troughs [marine valleys], ridges and moraines, canyons and pockmarks) that generally shape benthic communities over a variety of different scales (Buhl-Mortensen et al. 2010; 2012). The habitat-diversity (heterogeneity) hypothesis states that an increase in habitat heterogeneity leads to an increase in species diversity, abundance and biomass of all fauna groups (Whittaker et al. 2001; Tews et al. 2004). Improved technologies, particularly the recent deployment of side-scan sonar systems within the Deep-Sea Research Group (Purser et al. 2019), towed across the seafloor by camera sleds, have highlighted the high-resolution topographic variability of many deep-sea areas, including HAUSGARTEN (Schulz et al. 2010; Taylor et al. 2016; Purser 2020). So far, the time-series stations maintained across the region do not capture the high degree of local heterogeneity (in terms of physical seafloor terrain variables such as slope, rugosity, aspect, depth). Therefore, during *Polarstern* expedition PS143/1, dedicated attempts to collect spatial data to capture the role of this heterogeneity in biodiversity and biomass estimation are planned to complement studies on the temporal variability of the benthos in the HAUSGARTEN area.

As these time-series photographs have also brought to light a sevenfold increase in marine debris between 2004 and 2017 (Parga Martínez et al. 2020) a pollution observatory has been added to HAUSGARTEN to assess plastic pollution in all ecosystem compartments. This research has shown particularly high microplastic concentrations in sediments (Tekman et al. 2020). To determine the exposure of sediment-dwelling biota to micro- and nanoplastic pollution, we thus aim to assess ingestion rates and the level of plastic additives in their tissues. In addition, ROV experiments initiated in 2015 to assess the impact of plastic-covered sediments on benthic biogeochemistry, bacterial and meiofaunal abundance will be completed.

Benthic communities are strictly dependent on carbon supply through the water column, which is determined by temporal and spatial variations in the vertical export flux from the euphotic zone but also lateral supply from shelf areas. Most organic carbon is recycled in the pelagic, but a significant fraction of the organic material ultimately reaches the seafloor, where it is either re-mineralized or retained in the sediment record. One of the central questions is to what extent sea-ice cover controls primary production and subsequent export of carbon to the seafloor on a seasonal and interannual scale. Benthic oxygen fluxes provide the best and integrated measurement of the metabolic activity of surface sediments. They quantify benthic carbon mineralization rates and thus can be used to evaluate the efficiency of the biological pump. In order to link long-term variations in surface and sea-ice productivity and consequently in export flux to the seafloor, detailed investigation of the temporal variations in benthic oxygen consumption rates would be very valuable. Yearly measurements with benthic lander provide information on the interannual variations. Benthic crawler, mobile seafloor platforms capable to perform weekly oxygen gradient measurements for a 12-month period, provide information on the seasonal variations. In addition, long-term benthic lander systems equipped with sediment traps and cameras for time-lapse imaging of the seafloor record the supply of organic material throughout the year.

Work at sea

The current cruise will complete the dataset over a 20-years time span and will serve to detect long-term changes of benthic communities. The composition, diversity, density and biomass of benthic communities will be analysed together with environmental data to detect changes due to environmental regime shifts in the deep sea of the Fram Strait. Within a complementary sampling design covering all size classes of benthic communities from meio- to megafauna.

Long-term meiobenthic study

Virtually undisturbed sediment samples are taken using a video-guided multiple corer (MUC). Various biogenic compounds from these sediments are analysed to estimate activities (e.g. bacterial exoenzymatic activity) and the total biomass of the smallest sediment-inhabiting organisms. Results will help to describe ecosystem changes in the benthal of the Arctic Ocean. Sediments retrieved by the MUC will also be analysed for the quantitative and qualitative assessment of the small benthic biota.

Meiofauna spatial and temporal distribution patterns, with special focus on density and diversity of nematode community composition will be analysed.

Sediments are sampled to describe small-scale spatial patterns as vertical gradients within the sediment as well as large-scale patterns for different water depths. The first 15 years of the HAUSGARTEN time series have been or are being evaluated as part of doctoral dissertations focusing on nematode community patterns. In order to continue this unique time series in the future, sediment cores are taken along the HAUSGARTEN depth transect for the analysis of the meiofaunal communities. These cores will also be sub-sampled for various environmental parameters indicative of the food input to the deep seafloor.

In addition, these samples will serve as background information for various biological experiments investigating the causes and effects of gradients on biodiversity patterns and community composition of benthic organisms to be installed at the central HAUSGARTEN station during future expeditions.

Long-term macrobenthic study

Macrobenthos in the HAUSGARTEN area has been studies only irregularly over the past 20 years. The focus has been on investigating depth gradients, horizontal distribution patterns in the sediment and temporal variability between 2003 and 2007. Sampling of the macrofauna during PS143 will continue the time-series work to allow the assessment of long-term changes in the deep-sea habitat, and the fourth sampling of a study of the inter-annual variability of benthic populations at HAUSGARTEN. Samples will be obtained by using a 0.25 m² USNEL box corer (GBC). Particularly for deep-sea samples the box corer is a preferred sampling gear, as it provides reliably deep and relatively undisturbed sediment samples. Box-corer samples will be divided into subsamples and sieved over 500 µm sieves. The macrofauna in the sieve residues will be preserved for later taxonomic analysis in the laboratory.

Additionally to boxcorer sampling, during PS143/1 an Epibenthic Sledge (EBS) will be used to enhance the recorded biodiversity collected. In 2023 (PS136) the EBS was deployed at six Hausgarten stations, which were frequently sampled during the past 20 years. During PS143/1 also six deployments of the EBS are planned. To add knowledge, additional 4 stations, which have not been sampled in 2023, will be choosen to complement the dataset and 2 stations from 2023 will be revisited. In general, the samples will allow a comparison to the EBS samples from subarctic and central arctic waters available at the DZMB complementing the long-term study approach. Epibenthic sledges (EBS) with a bottom shovel to open the sampler box doors on the seafloor only are proven sampling devices to collect macrofaunal organisms on and above the seafloor (Brenke 2005). The EBS will be equipped with a bracket to hold a Posidonia USBL transponder as well as an Aanderaa CTD on deployment. The sampler boxes are referred to as epi-net (lower box) and supra-net (upper box). The mesh size of the nets is 500 µm. The cod ends are equipped with net-buckets containing a 300-µm mesh window following the description of Brenke (2005). Depending on the area, metallic grids about 3 cm mesh size will be attached to the entrance of the samplers to avoid collection of sponges and/or rocks, clogging or damage of the nets.

Currently, all available data of the last years are compiled in the ecological data information system CRITTERBASE. Macrofauna data from EBS samples will be entered to the Senckenberg DZMB Hamburg local database to allow further processing and curating of the EBS samples in the DZMB laboratories in Hamburg after expedition. All data will be entered in CRITTERBASE after sorting.

Long-term megabenthic study and seafloor mapping

The newly constructed Ocean Floor Observation and Bathymetry System II (OFOBS; Purser et al. 2019) was field tested during the PS138 expedition during 2023. During PS143-1 the system will be deployed along previously established and analyzed camera tracks to assess interannual dynamics of megafauna on the seafloor at selected stations (ideally HG-I, HG-IV, N3, S3, but with potential changes made in response to ice and weather conditions). The OFOBS will be towed at 1.5 m altitude for 4-hours at each survey site. A subset of images will be analyzed and compared with previous data to assess interannual dynamics of megafaunal assemblages. The AWI “Remora class” MiniROV will be attached to OFOBS for some deployments and used to close up imaging work, or equipment retrieval, as required.

The imagery will also be used to quantify litter on the seafloor. The OFOBS II is equipped with a multibeam system allowing to collect spatial data to develop the high-resolution seafloor topographical maps of the HAUSGARTEN. During PS143/1 a newly developed sampling net device will be mounted on OFOBS II behind the stil camera. The aim of this net is to allow the directed sampling of fauna on the seafloor, such as small sponges or holothurians. This device will be trialled during the expedition in expectation of extended use during the PS146 Antarctic expedition in Dec 2024.

All data collected with the OFOBS II will be used to test a new data archiving ingest protocol developed by C. Krämmer and L. Boehringer, strictly following the guidelines and metadata schemes presented in Schoening et al. (2022).

Benthic flux study

Seafloor carbon mineralization will be studied in-situ at sites with varying sea-ice conditions (HG-IV, N4) using a benthic lander system (Hoffmann et al. 2018). The benthic O2 uptake is a commonly used measure for the benthic mineralization rate. We plan to measure benthic oxygen consumption rates at different spatial and temporal scales. The benthic lander will be equipped with two different profiling instruments to investigate the oxygen penetration and distribution as well as the benthic oxygen uptake of Arctic deep-sea sediments: i) electrode-microprofiler, for high-resolution pore water profiles (O2, resistivity) across the sediment-water interface, and ii) a deep optode-profiler, to measure the entire oxygen penetration depth. The overall benthic reaction is followed by measurement of sediment community oxygen consumption to calculate carbon turnover rates.

At HG-IV a benthic crawler system (Crawler-III) will be deployed for its 12-month mission (recovery in 2025 during *Polarstern* expedition). The crawler system is pre-programmed to perform >50 measurements along a ca 1.0 km transect. Crawler-III (similar with crawler NOMAD; Lemburg et al. 2018) uses oxygen optodes to measure vertical concentration profiles across the sediment-water interface (one set of profiles each week). Additionally, the crawler is equipped with benthic chambers and a seafloor imaging and scanning camera system to take images of the seafloor combined with a laser scan. From this information we are able to reconstruct the sediment surface at high resolution. When seafloor images and topography scans are overlaid, we will be able to identify hot spots of intensified organic matter accumulation. These two seafloor observations are performed during the 10 m long transect at the beginning of each measuring cycle. At the end of this transect, concentration profiles of oxygen are measured across the sediment water interface. From these profiles diffusive oxygen fluxes can be obtained. Chamber incubations, performed at the same time, provide the total oxygen demand of the seafloor. Both measurements provide information on the oxygen consumption related to carbon mineralization. These cycles are repeated every week for a period of 12-month.

Experimental work at LTER HAUSGARTEN

Carbon enrichment experiment

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 CO2 concentrations in the field are difficult, and the number of field studies are limited to a few locales. The HAUSGARTEN observatory was extended with an experimental system to study impacts of ocean acidification on benthic organisms and communities for the first time in deep Arctic waters with an autonomous system. The autonomous arcFOCE (Arctic Free Ocean Carbon Enrichment) system (Fig. 2.1) 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. The lander-based arcFOCE system was deployed during PS136 in 2023 at 1500 m water depth in southern HAUSGARTEN area. For targeted sampling of the acidification experiment for benthic meiofaunal organisms a deep-diving work-class Remotely Operated Vehicle (ROV Kiel 6000, GEOMAR, Kiel) will be used used.

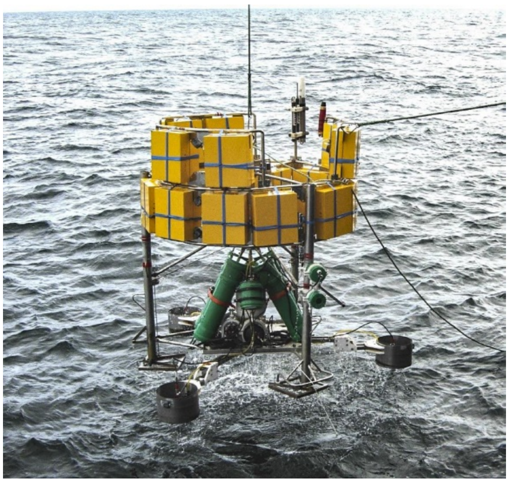

Fig. 2.1: The bottom-lander based arcFOCE (arctic Free Ocean Carbon Enrichment) experimental set-up

Dropstone experiment

There is abundant evidence that habitat structures have important effects on spatial distribution patterns of meiofauna populations in deep-sea environments (Hasemann et al., 2013). A common feature in polar deep-sea regions is the occurrence of dropstones at the deep seafloor, which enhance topographic heterogeneity and alter related hydrodynamic patterns. Changed flow regimes around dropstones can have a direct effect on the colonisation and settlement of meiofauna individuals, and indirect effects on meiofauna communities by the amount of potential food trapped around dropstones and changing sediment characteristics.

To determine and characterise suspected differences in community structure and dynamics of nematode assemblages in relation to the confined flow regime and patchy food availability around dropstone, artificial dropstones with different shapes (rectangular, cylindrical and hemispheric; Fig. 2.2) were deployed at 2,500 m water depth at the central HAUSGARTEN station during HAUSGARTEN expedition PS108 in 2017. Sediment sampling around the dropstone will take place during PS143/1 using the ROV Kiel 6000.

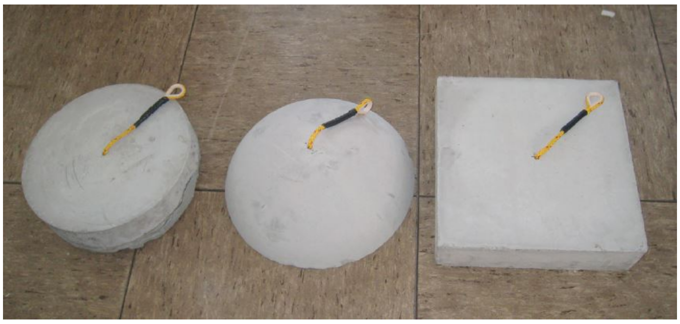

Fig. 2.2: Artificial dropstones (40x40x10 cm) of different shapes (cylindrical, spherical, rectangular)

Larval biology

The hard-bottom-obligate fauna that inhabit dropstones and other solid substrata in the deep Arctic Ocean are severely understudied. Basic parameters such as growth rates and the dynamics of populations and communities are poorly understood. An 18-year experiment (1999 – 2017) at the central HAUSGARTEN station revealed extremely low recruitment of hard-bottom fauna and raised questions about the resilience of these communities to environmental change (Meyer-Kaiser et al. 2019). We deployed experiments in 2019 at two stations: a slope with abundant stone substrata nicknamed “N4,5” and the summit of a rocky reef on the Vestnesa Ridge, east of the central HAUSGARTEN station. Larval traps with attached recruitment panels were deployed at each station to collect settling larvae and newly-settled juvenile organisms (Fig. 2.3). A predator-exclusion experiment at the summit of the rocky reef will reveal the impact of predators on hard-bottom fauna. Community composition and organism size in the control panels will also be used to assess recruitment and growth rates. Finally, a stainer was used to dye the organisms on a rock at each station for growth rate measurement. All experiments will be monitored, and larval traps and dyed organisms will be recovered using ROV Kiel 6000 during PS143/1.

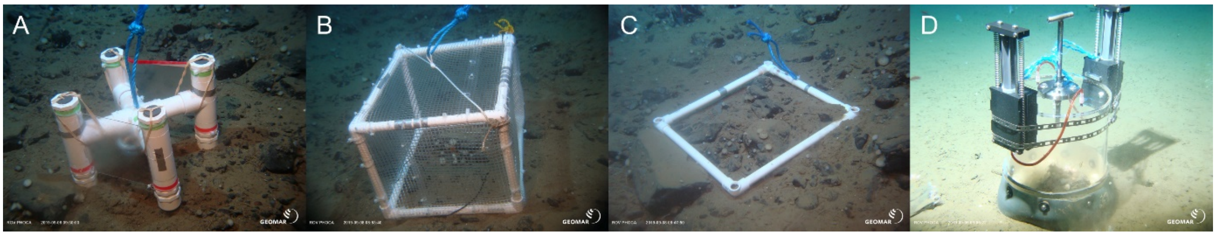

Fig. 2.3: Experiments deployed on the seafloor in 2019. A, larval traps with attached recruitment panels; B, a cage used in the predator-exclusion experiment; C, a control frame in the predator-exclusion experiment; D, the stainer used to dye organisms on a rock.

A key component of organisms' resilience to change is reproduction. Previous studies have revealed temperate-boreal species from the North Atlantic dispersing into the Fram Strait (Berge et al. 2005, Descoteaux et al. 2022), which could lead to species expanding their ranges from lower latitudes into the Arctic basin as temperatures continue to warm. Much less is understood about the reproduction and dispersal of Arctic deep-sea species. We will use a hand net (0.5 m diameter, 150 µm mesh) deployed opportunistically from *Polarstern* during CTD casts to collect larvae. Previous efforts in 2021 and 2023 revealed high densities of *Ophiocten gracilis* larvae. This species is very common on the continental slope in the HAUSGARTEN, so dispersal of its larvae in surface waters shows a tangible link between surface processes and deep-sea communities over the life-cycle of a single organism. The presence of other species, including those that are not found as adults in the Fram Strait, helps increase our understanding of larval dispersal and connectivity in a changing climate.

Pollution Observatory

To obtain benthic specimens for the analysis of micro- and nanoplastic ingestion, surplus samples will be taken from six deployments of the EBS (s. above) These samples will complement and allow a comparison to EBS samples taken in 2023 in the central arctic and at HAUSGARTEN. The nanoplastic and additive burden will be analysed in collaboration with colleagues at UFZ (Annika Jahnke, Dusan Materic). In addition, spare sediment samples from multiple corer deployments will be used, to assess the microplastic and additive concentrations in sediments, allowing comparison with biota and thus determining bioaccumulation.

In 2015, we started three ROV-based experiments at HG-IV to simulate plastic coverage of sponges (*Caulophacus arcticus, Cladorhiza gelida*) and sediments by plastic bag material and heavy rigid plastic plates (Fig. 2.4).

In addition, the new seafloor footage (OFOBS) will be analysed to assess if marine debris quantities continue to accumulate at HAUSGARTEN and continue this time series.

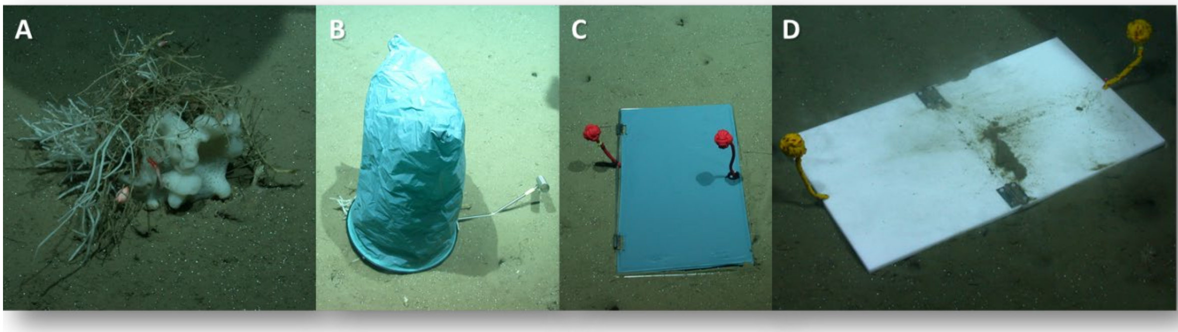

Fig. 2.4: ROV-based experiments to simulate the effects of litter on (A) sponges by plastic bag coverage, on meiofauna and biogeochemical sediment properties by (B) plastic bag coverage and (C) plastic plate coverage (©MARUM, Bremen University).

During PS143/1, these experiments will be revisited with the ROV Kiel 6000. The sponge covers will be lifted and the health status of the sponge dodumented by photography. If possible, the sponges will be sampled. To assess the impact of plastics on sediment oxygen profiles, the ROV will carefully move the plastic covers and place a microprofiler in the area underneath to measure oxygen concentrations at different sediment depths. A control profile from undisturbed sediments at HG-IV will be taken using a lander-based microfíler to enable a comparison. Sediment samples will be taken by push cores in the disturbed area and will be analysed for meiofauna and biogeochemical parameters. A comparison with control push cores will enable assessments of the impact of plastic coverage.

Preliminary (expected) results

Our assessments of benthic biodiversity, function and biogeochemistry will contribute significantly to the existing knowledge of the deep sea and polar regions. By continuing this unique time-series work at HAUSGARTEN in the deep-sea Arctic, we expect not only to improve our understanding of the dynamic diversity and distribution of benthic communities, but also to shed light on how these ecosystems respond to changing environmental conditions over decades (Soltwedel et al., 2016) in times of rapid climate warming.

The sampling of long-term biological experiments at HAUSGARTEN provides a valuable opportunity to investigate the complex interactions between benthic organisms and their environment in the context of rapid environmental change in the Arctic. Through in situ experimental manipulations, we aim to deepen our understanding of the drivers of deep-sea biodiversity and to shed light on the impact of anthropogenic influences on the Arctic ecosystem.

The results will add to our (Piepenburg et al. 2024) and various other databases in relation to the Arctic fauna and thus will feed into international networks such as CBMP (Circumpolar Biodiversity Monitoring Program) and ADBO (Atlantic-Arctic Distributed Biological Observatory), as well as panels for scientific advice such as the Conservation of Arctic Flora and Fauna (CAFF) in the Arctic Council and the Arctic Monitoring and Assessment Program (AMAP).

Data management

Environmental, image, video and acoustic mapping data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data

Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the expedition at the latest. By default, the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopic 1 and 3.

In all publications based on this expedition, the **Grant No. AWI_ PS143/1_01** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. http://dx.doi.org/10.17815/jlsrf-3-163.

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3. PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN A CHANGING ARCTIC OCEAN

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Outline

The PEBCAO group (Plankton Ecology and Biogeochemistry in a Changing Arctic Ocean) is a collaboration between colleagues from AWI and GEOMAR and focusses on plankton community ecology and the microbial processes relevant for biogeochemical cycles of the Arctic Ocean. This is timely research since the Arctic Ocean is currently undergoing considerable environmental change particularly with the pronounced decrease in sea ice and increase in temperature, with the latter rising at twice the rate as the global average. In addition, the chemical equilibrium and the elemental cycling in the surface ocean are likely to alter e.g. due to ocean acidification. These environmental changes will have consequences for the biogeochemistry and ecology of the Arctic pelagic system and therefore detailed monitoring of existing conditions is vital. PEBCAO has therefore carried out an integrated monitoring programme of biological (bacterial and eukaryotic phytoplankton as well as zooplankton) and biogeochemical parameters in the HAUSGARTEN area since 2009 to document and better understand the projected changes.

For instance, biogeographical studies of PEBCAO based on 18S metabarcoding indicate that a year-round semi-stationary sea-ice edge serves as a strong biogeographical boundary between Atlantic conditions to the southeast and polar conditions to the Northwest of Fram Strait (Metfies et al., 2016). In 2017, the MIZ extended further eastwards and southwards into Fram Strait than in average years, with profound impacts on the ecosystems. Sea ice melt in a sub-mesoscale filament, characterized by a thin surface meltwater layer, led to comprehensive changes in plankton-biodiversity, carbon export and primary production in vicinity of the filament (Fadeev et al., 2021). Here, a combination of the latest biological and physical underway-measurements has proven very useful to map the physical environment and eukaryotic microbial community composition in a sub-mesoscale filament with high spatial resolution (Weiss et al., 2024 accepted). Considerable impacts of such filaments were also demonstrated for the biogeography of zooplankton and were considered as a potential accelerator of atlantification (Kaiser et al. 2021).

PEBCAO contributed to year-round interdisciplinary observations indicating that increased meltwater-stratification during spring/summer of 2017 slowed down the biological carbon pump in AW the central Fram Strait with significant impacts for on pelagic and benthic communities in comparison to the warmer year 2018 (von Appen et al., 2021). The data suggest, that sea-ice melt might serve as a barrier for a northward movement of temperate phytoplankton taxa in Fram Strait (Oldenburg et al., 2024; accepted). Furthermore, based on our year-round automated water-sampling we characterized the annual succession of microbial communities at a station in West Spitsbergen Current (WSC) and East Greenland Current (EGC). The ice-free WSC displayed a marked separation into a productive summer (dominated by diatoms and carbohydrate-degrading bacteria) and regenerative winter state (dominated by heterotrophic Syndiniales, radiolarians, chemoautotrophic bacteria, and archaea). In the EGC, deeper sampling depth, ice cover and polar water masses concurred with weaker seasonality and a stronger heterotrophic signature. Low ice cover and advection of Atlantic Water coincided with diminished abundances of chemoautotrophic bacteria while others such as *Phaeocystis* increased, suggesting that Atlantification alters microbiome structure and eventually the biological carbon pump (Wietz et al., 2021).

Furthermore, recent results indicate, that a change in microbiome structure might also affect the biological carbon pump. For instance, we found, strong correlations between *Phaeocystis* and transparent exopolymer particle concentration (TEP), which are known to play a crucial role in the biological carbon pump (Engel et al. 2017). Moreover, although concentrations of dissolved organic carbon (DOC) were relatively stable over the last two decades, we observed a slight decrease in the particulate organic carbon (POC) during the summer months (Engel et al. 2019). While these results point to inter annual changes in the Fram Strait, von Jackowski et al. (2022) additionally observed an intra annual (seasonal) succession of prokaryotic microbes, that was related to a succession in the biopolymer pool, indicating seasonally distinct metabolic regimes.

Mycoplankton (defined here as saprotrophic and parasitic fungi and pseudofungi (oomycetes)) has not yet been a focus of these investigations. This is although their ecological impact can be considerable, e. g. by controlling the population size of bloom-forming species (Buaya et al. 2019), and this group is still considerably under-investigated in the marine realm. Even in well-studied areas such as the North Sea new species are being described (Buaya et al. 2017), but in polar regions, with few exceptions the diversity and dynamics of the mycoplankton remain to be discovered (Hassett et al. 2019 a,b). PS143/1 will be used to carry out an intensive sampling campaign for this taxon group (co-ordinated with PS 143/2) to investigate the diversity and distribution of this group or organisms and to bring both true fungi and oomycete into culture for later analysis. This work is carried out in collaboration with the group of Dr Marlis Reich at the University of Bremen.

Objectives

The PEBCAO group investigates the long-term dynamics in water column processes in the FRAM Strait, including phyto- and zooplankton diversity and more recently the diversity of parasitic plankton, as well as the links between these communities and environmental (physical chemical and biochemical) parameters and processes. There will be several specific objectives:

(1) Co-ordinated sampling campaign between PS143/1 and PS143/2 to sample 15 HAUSGARTEN stations for an intensive analysis of mycoplankton diversity

(2) The assessment of the biodiversity and biogeography of Arctic eukaryotic microbes, including phytoplankton and their linkages to prokaryotic microbial communities based on analyses of eDNA via 16S and 18S meta-barcoding, and quantitative PCR. A suite of automated sampling devices in addition to classical sampling via Niskin bottles attached to a CTD-rosette will be used to collect samples for eDNA analyses. This includes the automated filtration device AUTOFIM deployed on *Polarstern* for underway filtration, automated Remote Access Samplers (RAS) and long-term sediment traps deployed on the FRAM-moorings for year round sampling.

(3) Deployment of multiple net samplers, which integrate depth intervals of up to several hundred meters in conjunction with the zooplankton recorder LOKI (Light frame On-sight Key species Investigations). LOKI continuously takes pictures of the organisms during vertical casts from 1,000 m to the surface. Linked to each picture, hydrographical parameters are being recorded, i.e. salinity, temperature, oxygen concentration, and fluorescence. This will allow us to identify distribution patterns of key taxa in relation to environmental conditions. We will also use the UVP5 (Underwater Vision Profiler), which is mounted on the ship´s CTD to also tackle zooplankton distribution patterns, albeit with much less taxonomic resolution than with LOKI.

(4) Testing the CytoSub automated flow cytometer for routine use on *Polarstern*. The instrument will be used on loan from the CNRS LOG ULCO and run continuously on both PS143/1 and PS143/2. The CytoSub is specifically designed to characterize each particle and to record the corresponding optical pulse shape, which can be combined with imagery of selected particles, mainly in the bigger size range. Moreover, this automated Flow Cytometer does not only focus on Pico- and Nanophytoplankton (as current benchtop FCM do) but can measure the whole size range up to microphytoplankton single cells and colonies, for example of Phaeocystis sp. which is giving a big advantage compared to traditional flow cytometry. The CytoSub will provide an opportunity to assess microbial functional diversity continuously at and between stations and facilitate investigations of interactions and associations between different populations. The CytoSub will be deployed in transit from Bremerhaven to HAUSGARTEN, in the HAUSGARTEN area itself and if possible, on discrete samples.

(5) Establishment of cultures of oomycete parasites as well as potential diatom hosts on PS143/1 (on PS143 cultures will be initiated for fungal plankton). Co-cultures of parasites and their hosts will be used for experiments planned in the upcoming INDIFUN-AI BMBF project in which we wish to investigate the utility of using parasites and saprotrophic fungi as indicators of environmental change.

(6) To identify climate-induced changes in carbon cycling and sequestering and improve the mechanistic understanding of biogeochemical and microbiological feedback processes in the changing Arctic Ocean, we will assess organic carbon and nitrogen both in dissolved and particulate form with a special focus on (gel-) particles and their associated bacterial communities. In addition, we will measure the productivity of phytoplankton and bacteria using labelled isotope incorporation.

Work at sea

CTD samples

At each station samples will be taken from the CTD-Rosette and processed for a range of biological and biogeochemical parameters:

Biogeochemistry

In order to investigate the effects of global change and anthropogenic pollution on the microbial community and biogeochemistry in the Arctic Ocean, we will continue to monitor the concentrations of organic carbon and nitrogen as well as specific compounds such as amino acids, lipids, carbohydrates, and gel particles. Furthermore, we will continue to assess cell abundances via flow cytometry to determine the distribution of phytoplankton, bacteria and viruses and confocal laser scanning microscopy (CLSM) and CLASI-FISH to analyse gel particle associated bacterial community structure.

Additionally, we will collect microplastic particles (> 300 µm) at selected stations from the surface water via the moon pool. Subsequently, we will analyse the biodiversity and function of plastic-associated bacteria using 16S amplicon sequencing and metatranscriptomics, focusing on potential pathogens and their resistance mechanisms against antibiotics. This will allow us to better understand the potential risks of microplastic to human and ecosystem health.

All parameters except microplastic particles will be sampled from the water column using a CTD/rosette sampler at 5-6 depths in the upper 200 m. At selected stations amino acids, carbohydrates, and gel particles will be sampled at 5 additional depth between 200m and the sea floor to further investigate the export of carbon into the deep sea. Bacterial and primary production measurements will be performed at sea using 3H leucine and 14C bicarbonate incorporation, respectively. Phytoplankton primary production will be distinguished into particulate primary production (carbon remaining in the cells) and dissolved primary production (organic carbon exudation by cells).

Molecular Observatory

We will collect water and suspended particles for eDNA analyses of the microbial communities close to the surface (~ 10 m) with the automated filtration system for marine microbes AUTOFIM (Fig. 3.1) and at 5-6 different depth in the photic zone using Niskin-bottles mounted on a CTD rosette. Using AUTOFIM, we will collect seawater samples at regular intervals (~ 1° longitude/latitude on the way to the study area starting as soon as possible after *Polarstern* has left Bremerhaven), while the CTD will be deployed at the permanent stations of the HAUSGARTEN observatory.

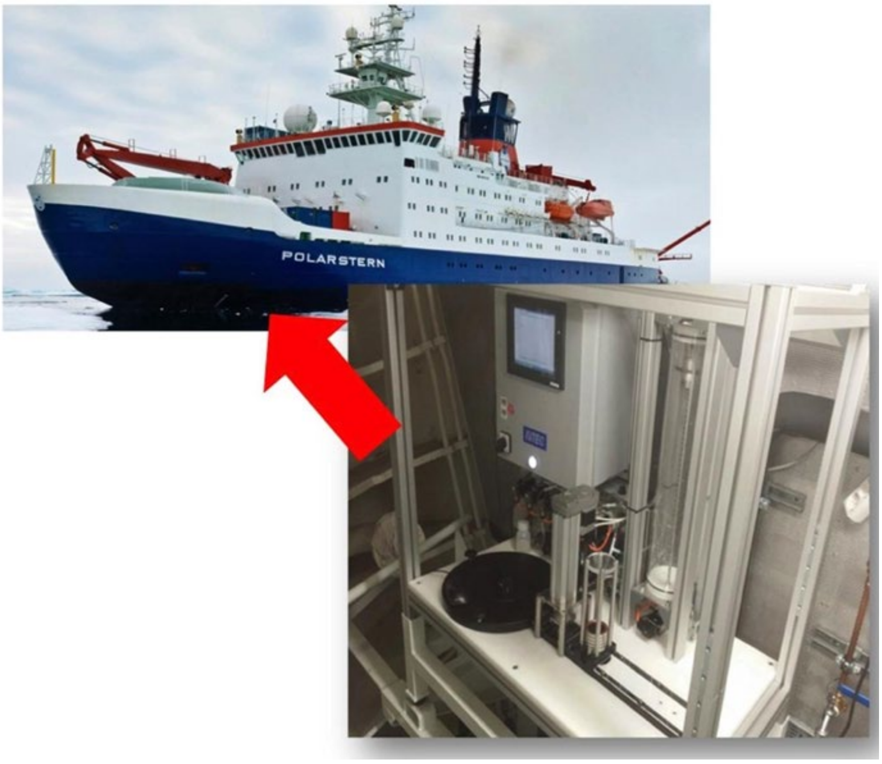

Fig. 3.1: The fully automated filtration module AUTOFIM is installed on POLARSTERN in the "Bugstrahlruderraum" close to the inflow of the ships-pump system. AUTOFIM is suitable for collecting samples with a maximum volume of 5 Liters. Filtration can be triggered on-demand or after fixed intervals.

Phytoplankton/mycoplankton analyses

At all stations samples from 4-5 depths (surface, 10, above chlorophyll maximum, chlorophyll maximum and below the chlorophyll maximum) wil be collected from the CTD Rosette and fixed in Formalin (for overall diversity) as well as Lugol iodine solution (for detailed assessments of fungal particles) respectively. These will be analysed post-cruise in Bremerhaven using a Planktoscope, a modular device for the high-throughput analysis of phytoplankton samples. For quality control purposes selected samples will also be analysed using inverted and scanning electron microscopy. The Formalin fixed samples will be additionally used for CARD-FISH analysis.

In addition, net samples (20 µm mesh size) will be collected at all stations. Live samples will be analysed semi-quantitatively onboard and documented with images to produce a preliminary taxon list for the phytoplankton in general and to document possible infections of diatoms by fungi and oomycetes. An aliquot of the raw sample will be fixed in formalin for more detailed counts and taxonomic evaluation in the home laboratory after the cruise. In addition, the live samples will be used for the establishment of phytoplankton cultures (see below).

At 15 stations, 2 l of water from the CTD Rosette will be collected for molecular analyses to specifically target fungal and parasitic (especially oomycete) diversity (Fig. 3.2).

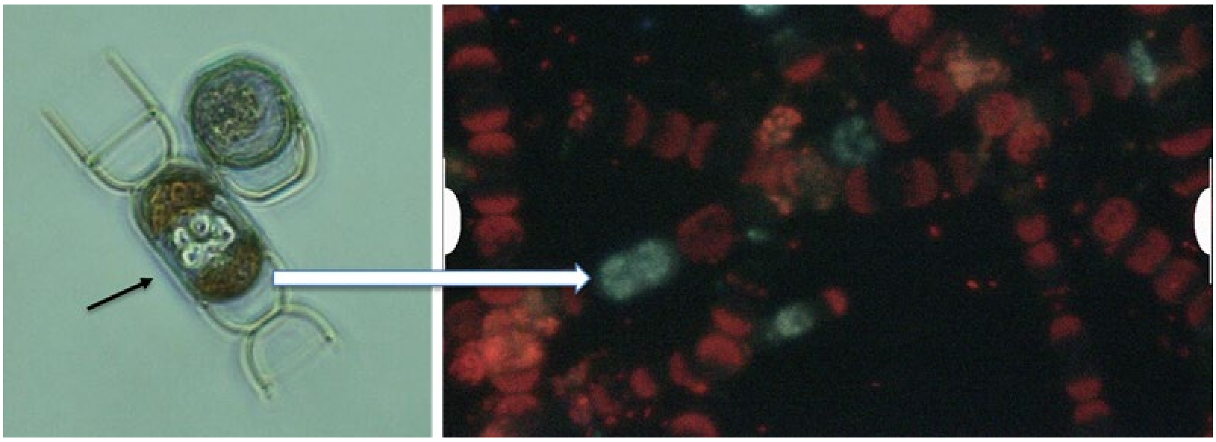

Fig. 3.2: As yet unidentified parasitic infection (possibly an oomycete) in the ice-associated diatom Melosira arctic

Net samples (Phyto/Zoo/Mycoplankton)

Phyto/Mycoplankton

At each station we will carry out net hauls with a 20 µm hand net to assess the diversity of live phytoplankton, including parasitic plankton (oomycetes). The samples will be screened semi-quantitatively onboard to generate a preliminary. An aliquot of the raw sample will be fixed in formalin for more detailed counts and taxonomic evaluation in the home laboratory after the cruise. In addition, the live samples will be used for the establishment of phytoplankton cultures (see below).

Zooplankton

We will study the zooplankton biodiversity and biogeography by deploying a multi net (Fig. 3.3). These net samples will be immediately preserved in 4 % formalin, buffered with hexamethylentetramin, and later the mesozooplankton composition, biomass, size structure and depth distribution will be determined using the lab-based ZooScan system (Cornils et al. 2022). Standard multi- sampling depths are 1,500–1,000–500–200–50 m, and, thus, these nets integrate over several hundred meters. To determine the fine scale vertical distribution of key species, we therefore also use an optical system, the zooplankton recorder LOKI (Lightframe On-sight Key species Investigations), which continuously takes pictures of organisms and particles at a frame rate of approx. 20 f sec-1 during casts from 1,000 m to the surface. At each CTD station, we will also deploy an UVP5 which also takes images of particles and zooplankton but at less optical resolution than LOKI. However, this allows to get a better spatial distribution of zooplankton abundances in the entire HAUSGARTEN area.

Fig. 3.3: The LOKI (Lightframe On-sight Key species Investigations) during deployment in the Fram Strait. The LOKI is equipped with a 150 µm plankton net that leads to a flow-through chamber with a 6.3 Mpix camera and LED flash lights; images are stored on the under-water computer unit, and will be down-loaded onboard immediately after each cast.

CytoSub and FluoroProbe

The two devices will be connected to the same underway sea water supply as the ferry box and other continuous measuring instruments (pCO_2, photo-physiology) to continuously measure the phytoplankton community composition, abundance, and the biomass variably at high frequency (see Fig. 1). During stations, the FluoroProbe will be also used in a modified profiling configuration, to measure *in-vivo* fluorescence down to 170m. Water from different depths, collected with the CTD rosette, will be used to create discrete depth profiles with the CytoSub, by applying three protocols (one especially for Picophytoplankton, one for Nano- and microphytoplankton and one for taking pictures of microphytoplankton).

Cultivation work

In preparation for the BMBF project INDIFUN-AI (to start in September 2024), all net samples will be screened for oomycetes and fungal particles. A focus will lie on the diatoms *Pseudo-nitzschia* and *Melosira arctica* and their associated parasites as they were already observed to carry parasites on previous HAUSGARTEN cruises. However, any oomycete detected will be isolated and taken into culture using different concentrations of the F/2 medium.

In summary, the following parameters are sampled as part of the long-term PEBCAO sampling campaign:

- Chlorophyll a concentration
- Dissolved organic carbon (DOC)
- Dissolved organic phosphorus (DOP)
- Particulate organic carbon (POC)
- Total dissolved nitrogen (TDN)
- Particulate organic nitrogen (PON)
- Inorganic nutrients
- Transparent exopolymer particles (TEP)
- Coomassie-stainable particles (CSP)
- Total alkalinity (TA)

- Hydrolysable amino acids (dAA)
- RNA
- CLSM/ CLASI-FISH
- Dissolved combined carbohydrates (dCCHO)
- lipids
- Phytoplankton, bacterial and virus abundance (Flow Cytometry)
- Primary production (C-14 method)
- Heterotrophic bacterial production (3H-Leucin)
- Analysis of phytoplankton net hauls (20 µm mesh size) and Utermöhl samples
- Analysis of zooplankton taxon composition
- Molecular information on distributional patterns of protists and bacteria
- Microscopy-based data on the phytoplankton community composition

Preliminary (expected) results

Onboard the biodiversity of live microplankton based on net-sampling will be carried out and an image-annotated taxon list will be available by the end of the cruise. Preliminary data from the first deployment of CytoSub/BBE probe will also become available by the end of the cruise. Past analyses have shown that during summer, the chlorophyll a concentration is increasing in the eastern Fram strait, influenced by warmer Atlantic waters, compared to the western Fram Straight, which is mainly influenced by colder, less saline Arctic waters (Soltwedel and Bornemann 2023; Wietz et al. 2024). Underway measurements of the surface phytoplankton community will help to visualize this sptial change and detect shifts immediately, for example as a response to different water masses. In Arctic oceanic waters, *Phaeocystis pouchetii* is blooming in July (Schoemann et al. 2005), while the biomass of diatoms is decreasing during summer after a strong spring bloom (Soltwedel and Bornemann 2023). With the help of the CytoSub (Figs. 3.4 and 3.5), it also might be possible to detect *P. pouchetii* cells in different life stages, as well as discriminate haptophytes from brown algae with the Fluoroprobe. However, the dominating phytoplankton class is eukaryotic picophytoplankton, especially chlorophytes like *Micromonas polaris* and *Micromonas commoda* are high in abundance (Bachy et al. 2022) which can be detected with the CytoSub (RedPico) and, if their biomass is big enough, with the Fluoroprobe (green algae or raw data analysis).

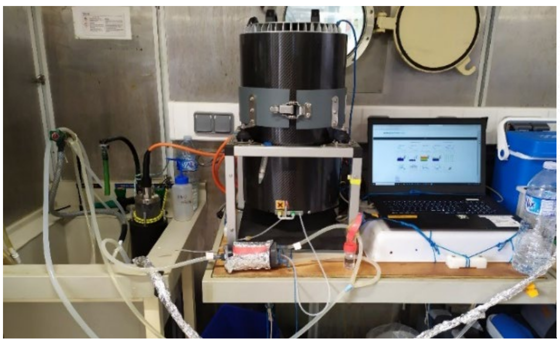

Fig. 3.4: setup of Flow Cytometer and FluoroProbe duringa cruise (credits: F. Artigas)

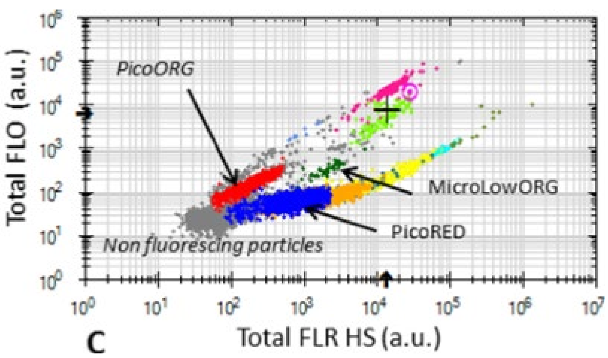

Fig. 3.5: example of cytogram from the North Sea, highlighting chlorophyll a containing Picophytoplankton in blue (Thyssen et al. 2015)

Sets of filtered frozen or Formalin-fixed samples (for biogeochemical parameters, phyto- and zooplankton analyses) will be stored for later analysis in the home laboratories at AWI and GEOMAR. It is envisaged that analysis will take place within one year after the cruise.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the expedition at the latest. By default, the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

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In all publications based on this expedition, the **Grant No. AWI_ PS143/1_02** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. http://dx.doi.org/10.17815/jlsrf-3-163.

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4. PHYSICAL OCEANOGRAPHY

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Grant-No. AWI_PS143/1_03

Objectives

The physical conditions that lead to enhanced primary and export production in the Arctic Ocean remain unclear. With both, rapid increases in ocean temperatures amplified in the Arctic region and sea ice retreat of the past two decades, the connection between these physical changes and the effect on polar marine ecosystem only increases in importance.

The intermittent presence of sea ice and meltwater affects both the physical and biochemical vertical structure of the water column but also limits *in situ* observations to summer months when the ice has retreated. The effects of changes in the environmental conditions on the polar marine biodiversity can only be detected through long-term observation of the species and processes. The FRAM multidisciplinary observatory attempts to observe the coupling across the system atmosphere, upper ocean, pelagic, and benthic environments.

The LTER (Long-Term Ecological Research) observatory HAUSGARTEN includes CTD water sampling stations in the Atlantic-influenced West Spitsbergen Current towards the East of Fram Strait, in the Arctic-influenced East Greenland Current to the West, and in the transition regions in the central and northern parts of the region. The FRAM observatory includes moored year-round observations for sensor data and sample collection in representative stations of those contrasting water masses. These observations span the whole water column with an emphasis on the upper euphotic zone.

Work at sea

CTD/Rosette Water Sampler

The CTD rosette will be deployed at the standard HAUSGARTEN stations. The full set of standard calibrated sensors will be operated to collect water column profiles of among others temperature, salinity, oxygen concentration, chlorophyll concentration, and transmissivity. Water samples will be collected both on full water column profiles and on profiles to only 300 m depth.

Preliminary (expected) results

We expect to collect CTD profiles at the long-term Hausgarten stations. This will allow us to quantify the state of the upper ocean in Fram Strait in 2024 in the context of the previously determined typical interannual variability of the system. Given the globally exceptionally warm upper ocean temperatures in the months preceding the cruise, we expect yet another record (or near record) warm summer in Fram Strait.

Data management

CTD data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the expedition at the latest. By default, the CC-BY license will be applied.

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 2, Subtopic 1 and Topic 6, Subtopic 3.

In all publications based on this expedition, the **Grant No. AWI_ PS143/1_03** will be quoted and the following publication will be cited:

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5. PELAGIC BIOGEOCHEMISTRY: NUTRIENTS

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Grant-No. AWI_PS143/1_04

Objectives

Since PS114 (2018) we have been deploying remote access samplers (RAS) equipped with several sensors (SUNA nitrate, pH, pCO_2, CTD-O_2, PAR and Eco-triplet) and carrying out dissolved nutrient measurements in Fram Strait as part of the FRAM/HAUSGARTEN LTO activities. The rationale of our work has already been decribed in previous booklets and cruise reports (e.g., von Appen 2018; Metfies 2019, 2020; Soltwedel 2021a,b; Kansow 2022), but our aim is to use data from sensors and RAS deployments, in combination with data from CTD casts to assess temporal variability of biogeochemical variables associated with inflowing and outflowing water masses in Fram Strait. This, will allow us to evaluate the role of water property exchange in the deepest gateway of the Arctic, within the context of Arctic Ocean nutrient budgets. As in previous expeditions, we carry out these deployments in collaboration colleagues within the FRAM community; the Microbial Observatory (Katja Metfies, Christina Bienhold, Anja Nicolaus and Mathias Wietz), Physical Oceanography of Polar Oceans (Wilken von-Appen, Mario Hoppmann, Matthias Monsees, Torsten Kanzow) and Deep-Sea Ecology and Technology (Normen Lochtofen). For expeditions PS136 and now PS143_1/2 we also started a new collaboration with colleagues (Adrian Martin and Peter Brown) from the National Oceanography Centre, Southampton (UK) as part of their BIOPOLE programme (https://biopole.ac.uk/). They have provided an extra RAS to complement out work and this RAS will be recovered on PS143/2. Since PS131 (2022) we have also started measuring dissolved oxygen in seawater samples collected from CTD casts with the aim of generating calibrated CTD-O_2.

Work at sea

During PS143/1:

a) We will collect water samples from CTD-Rosette casts for the analysis onboard of dissolved oxygen in seawater. These data will be used to calibrate the CTD-O_2 sensor.
b) We will also collect samples from CTD-Rosette casts for later analysis of dissolved nutrients.

Preliminary (expected) results

Data from dissolved oxygen measurements onboard will be processed for further quality controlled after the expedition and then will be made available to the physical oceanography team for the calibration of the CTD-O_2 sensors.

Samples collected for dissolved nutrient observations will be analysed within the following 6 months upon return of Polarsten to Bremerhaven at the end of the 2024 Arctic season. Data processing will be done within 2 months of sample analysis.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the cruise at the latest. By default, the CC-BY license will be applied.

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 6, Subtopic 6.2 and 6.3, Topic 2, Subtopic 2.1.

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6. BIOGEOCHEMISTRY AND MICROBIAL ECOLOGY OF MOLLOY DEEP

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Grant-No. AWI_PS143/1_05

Outline

The amount of organic material that escapes mineralization and is retained in the sediment record is the single most important factor determining the O_2 levels of the global ocean. Today we have a reasonably good understanding of the processes that are responsible for the mineralization of organic material. But many areas of the deep sea are still poorly explored. Deep-sea (or hadal) trenches, for example, only account for less than 2% of the global seabed area, but could via sediment focusing act as regionally important but unexplored traps for organic material. Benthic mineralization is mainly driven by vast numbers of bacteria and archaea, with direct or indirect contributions by viruses, fungi, protists, and meiofauna. Currently, even the most basic information on abundance and distribution of microbes and small eukaryotes in deep sea and trench sediments are missing. We want to quantify the carbon mineralization-efficiency of sediments in the Molloy Deep (5.5 km) and at adjacent shallower reference sites, identify the key players for the processing and compare process rates and microbial communities with other deep sea and trench ecosystems.

Objectives

The proposed work will target two sites covering a depth range of 2.5 to 5.5 km within and around the Molloy Deep in the Fram Strait (Arctic Ocean). The specific research aims include:

Quantification of the pelagic export and benthic mineralization of organic carbon

Using state-of-the-art lander technology, we will measure in situ benthic oxygen consumption rates within and around the Molloy Deep. The data will provide a unique assessment of the regional benthic carbon mineralization rates and fill data gaps in the current global data base. The involved diagenetic pathways will be quantified from porewater profiles and the distribution of solid-state iron and manganese, and dissolved inorganic nitrogen as wella as onboard measurements of sulfate reduction, denitrification, and anammox. The site-specific turn-over rates will be linked to the pelagic activity and sedimentation rates derived form the distribution of natural radionucleides, but will also be linked to long-term assessments of pelagic productivity at the respective sites estimated from remote sensing (Wenzhöfer and Glud 2002; Jørgensen et al. 2022). Thereby we will assess the quantitative link between surface primary production and underlying benthic activity, and evaluate the potential importance of horizontal transport of organic material in the complex benthic seascape of the region.

Characterization of the quantity and quality of deposited organic material

Recovered sediment cores will be used to assess the source, quantity and quality of organic material deposited at the respective sites. Beside basic quantification of total organic carbon (TOC) and the sedimentary C:N ratio, the analyses will include detailed pyrolysis for assessing lability, stable isotopes ($\delta^{13}C$, $\delta^{15}N$ signatures), phytodetrital pigments, and biomarkers using procedures that we have applied in other deep-sea and hadal settings. In particular, bacterial and archaeal tetraether lipid biomarkers will be analyzed to relate their composition and distribution to *in situ* benthic oxygen consumption rates, water depth, and hydrostatic pressure. To assess the effect of turbidites on geochemical and microbial succession, on-board incubations of sediment samples will be made.

Exploring microbial communities in relation to food supply, depth, and hydrostatic pressure

Benthic and pelagic viral, bacterial, archaeal, fungal, microalgal, and meiofaunal abundances will be determined using different techniques. Novel virus-host systems will be isolated from sediment and water samples. The phylogenetic composition of the microbial communities will be analyzed through next-generation sequencing (metagenomics and amplicon sequencing). To that end, DNA will be extracted from recovered sediment cores and water samples applying procedures we have used in other deep-sea and hadal settings. The biodiversity and biogeography of nematodes and other meiofaunal groups will be studied using molecular (DNA metabarcoding) and traditional taxonomical techniques (morphological identification).

To assess the effect of hydrostatic pressure on marine microbes, on-board pressure-tank experiments will be carried out: 1) Rates of benthic microbial processes like aerobic respiration, nitrification, denitrification, anammox, and sulfate reduction will be measured at different pressure levels. 2) Viral production will be analyzed in dependence of hydrostatic pressure. 3) Mineralization efficiency and microbial community succession of diatom-dominated marine snow will be studied under increasing pressure levels, which simulates the descent of marine snow into a high-pressure environment. 4) Viability of diatoms settled onto deep-sea sediments will be assessed in on-board light incubations; identity and pressure tolerance of revived diatom species will be determined through 18S amplicon sequencing and pressure-tank incubations, respectively.

Exploring the biogeochemical function and community composition in the deep sea

The proposed study is essential for understanding carbon and nitrogen cycling, pelagic-benthic coupling and benthic community structures in this very important region of the Arctic Ocean. However, the work should also be seen in the context of a wider ambition of exploring life and biogeochemical function of the deep sea. The proposed work in the productive region of the Molloy Deep within the Fram Strait will greatly complement investigations on hadal systems of different biogeographic provinces. The combined data will provide generic insights on the biogeochemical function and life in deep-sea and hadal trench systems underlying different productivity regimes. The analysis on community structures will explore the extent by which deep basins and trench systems act as isolated biogeographic habitats dominated by unique co-evolving communities or if they represent interconnected extreme environments.

Work at sea

We plan to address ecosystem functions, such as benthic respiration, remineralization and matter transport, microbial and meiofaunal biodiversity, in the Molloy Deep (5500 m) and adjacent abyssal and bathyal sediments of the Arctic Ocean. The main focus will be on *in situ* benthic flux measurements and sediment sampling. Measurements will be added to the existing scarce data base of deep sea and hadal data. We will perform *in situ* measurements using a new Hadal-benthic Flux Lander (11,000 m) to study benthic oxygen uptake and fluxes of other solutes at the sediment water interface (Wenzhöfer and Glud 2002; Glud et al. 2013). The Lander is equipped with two benthic chambers and a 2-axis microprofiler. The benthic chambers are used to measure total exchange rates of the sediment integrating all relevant solute transport processes (diffusion, advection and fauna-mediated transport) and an area of 400 cm^2. During the deployment, an oxygen optode measures changes in the oxygen concentration of the enclosed overlying water (total oxygen uptake, TOU) and 7 syringes take water samples at pre-programmed time intervals for analyses of DIC and nutrients. Furthermore, the enclosed sediments are retrieved and sampled on board for total organic carbon (TOC) and photopigment content as well as for abundances of microorganisms and fauna. The X-Y microprofiler will be used to perform multiple vertical oxygen profiles across the sediment-water interface. It is equipped with up to 9 O_2 electrodes, 1 conductivity sensor and 1 temperature sensor capable to perform multiple vertical sets of concentration profiles along a horizontal distance of 50 cm. Measurements across the water-sediment interface and within the upper sediment layer will be performed with a vertical resolution of 100 µm and extending over a total length of 15 – 25 cm. The X-Y microprofiler will be used to quantify the diffusive oxygen uptake (DOU), which is generally assigned to microbial respiration.

A multiple corer (MUC) will be used, in order to retrieve undisturbed sediment samples. Sediments will be analyzed for various biogenic sediment compounds indicating the input of organic matter to the seafloor as well as the activity and biomass of the small sediment-inhabiting biota. Due to the limited number of personnel on board sediment cores will be sectioned (1 cm slices to 10 cm, then in 2 cm slices to 20 cm and then in 5 cm slices to the bottom of the core) and samples stored according to the analyses performed later in the home laboratory.

Preliminary (expected) results

The result will add to our growing database on microbial carbon mineralization in deep-sea (Jørgensen et al. 2022) and hadal settings (Glud et al. 2021; Wenzhöfer et al. 2016) and allow for comparison between hadal environments experiencing different regimes of vertical carbon export. Additionally, a multidisciplinary and quantitative approach will be applied to explore the connection, composition, and structure of benthic communities in the deepest area of the Arctic Ocean using up-to-date methods and technologies. The insight will be compared with similar investigations that we have conducted in the eutrophic Atacama Trench and oligotrophic Kermadec Trench region. This will provide a generic insight on biogeochemical function and community compositions in hadal trench and deep-sea regions.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the expedition at the latest. By default, the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopic 3; and the Center of Excellence; “Danish Center for Hadal Research – HADAL (DNRF145)”.

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APPENDIX

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

A.3 SCHIFFSBESATZUNG / SHIP‘S CREW

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DE.DWD	Deutscher Wetterdienst Seewetteramt Bernhard Nocht Str. 76 20359 Hamburg Germany
DE.GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Wischofstr. 1 – 3 24148 Kiel Germany
DE.HS-Bremerhaven	Hochschule Bremerhaven An der Karlstadt 8 27568 Bremerhaven Germany
DE.MPIMM	Max-Plank-Institut für Marine Mikrobiologie Celsiusstraße 1 28359 Bremen Germany
DE.NHC	Northern HeliCopter GmbH Gorch-Fock-Str. 103 26721 Emden Germany
DE.SENCKENBERG	Senckenberg am Meer Martin-Luther-King-Platz 3 20146 Hamburg Germany Senckenberg Forschungsinstitut und Naturmuseum Senckenberganlage 25 60325 Frankfurt am Main Germany
DE.TUBR	Technische Universität Braunschweig Langer Kamp 19C 38106 Braunschweig Germany

DE.UNI-Bremen	Universität Bremen Bibliothekstrasse 1 28359 Bremen Germany
DE.UNI-HAMBURG	Universität Hamburg Bundesstraße 55 20146 Hamburg Germany
DE.UNI-Hannover	Leibniz Universität Hannover Welfengarten 1 30167 Hannover Germany
DE.UNI-Oldenburg	Carl von Ossietzky Universität Oldenburg Carl-von-Ossietzky-Straße 9-13 26132 Oldenburg Germany
DE.UNI-Rostock	Universität Rostock Universitätsplatz 10 18055 Rostock Germany
DK.SDU	University of Southern Denmark Campusvej 55 5230 Odense Danmark
EDU.WHOI	Woods Hole Oceanographic Institution 266 Woods Hole Road 02543 Woods Hole, MA United States
IS.HI	University of Iceland Sturlugata 7 102 Reykjavik Iceland
IS.MFRI	Marine & Freshwater Research Institute Fornbúðir 5 220 Hafnarfjörður Iceland
UK.CAM	University of Cambridge Downing Street CB2 3EJ Cambridge United Kigdom
UK.NOC	National Oceanography Centre European Way SO14 3ZH Southampton United Kingdom
UK.UNI-SOUTHAMPTON	University of Southampton University Road SO17 1BJ Southampton United Kingdom
Not on board / Not in the field	
DK.KU	Københavns Universitet Nørregade 10 1165 Københavns Danmark

FR.Université du Littoral Côte d'Opale	Université du Littoral Côte d'Opale 220 Av. de l'Université 59140 Dunkerque France
SE.SU	Stockholms Universitet Svante Arrhenius vag 20A 10691 Stockholm Sweden

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Aehle	Moritz	DE.UNI-Hamburg	Student (Master)	Biology
Bauer	Leonie Claudia	DE.UNI-Hamburg	Student (Bachelor)	Oceanography
Bergmann	Melanie	DE.AWI	Scientist	Biology
Bierbaum	Lisann Sofie Martha	DE.UNI-Oldenburg	Student (Bachelor)	Oceanography
Böckmann	Kyra Marie	DE.AWI	Technician	Biology
Brix-Elsig	Saskia Bianca	DE.SENCKENBERG	Scientist	Biology
Chen	Yen-Ting	DK.SDU	PhD student	Biology
Cuno	Patrick	DE.GEOMAR	Engineer	Engineering Sciences
Dannheim	Jennifer	DE.AWI	Scientist	Biology
Dieckvoß	Katrina	DE.AWI	HiWi	Biology
Dörmbach	Barbara	DE.UNI-Oldenburg	Student (Master)	Biology
Farrell	Eilish	DE.AWI	PhD student	Biology
Fuchs	Daniel	DE.DRF	Technician	Helicopter Service
Fürst Soerensen	Lisbeth	DK.SDU	PhD student	Biology
Glud	Ronnie	DK.SDU	Scientist	Oceanography
Gober	Emilie	DE.HS-Bremerhaven	Student (Master)	Biology
Hasemann	Christiane	DE.AWI	Scientist	Biology
Hirschmann	Sophia Carolin	DE.GEOMAR	PhD student	Biology
Hoge	Ulrich	DE.AWI	Engineer	Engineering Sciences
Huusmann	Hannes	DE.GEOMAR	Engineer	Engineering Sciences
Khan	Tasnuva Ferdous Ming	UK.CAM	PhD student	Biology
Kraberg	Alexandra	DE.AWI	Scientist	Biology
Krauß	Florian	DE.AWI	Scientist	Oceanography
Kurbjuhn	Torge	DE.GEOMAR	Technician	Data
Kwan	Yick Hang	DK.SDU	PhD student	Biology
Láruson	Áki Jarl	IS.MFRI	Scientist	Biology
Malz	Amelie	DE.UNI-Hannover	Student (Master)	Biology
Maring	Johannes	DE.AWI	Technician	Engineering Sciences
Matthiessen	Torge	DE.GEOMAR	Technician	Engineering Sciences
Meyer-Kaiser	Kirstin Sage	EDU.WHOI	Scientist	Biology
Nordhausen	Axel	DE.MPIMM	Technician	Engineering Sciences
Otte	Frank	DE.DWD	Scientist	Meteorology

Pérez Rodríguez	Marta	DE.TU-Braunschweig	Scientist	Geology
Pieper	Martin	DE.GEOMAR	Engineer	Engineering Sciences
Purser	Autun	DE.AWI	Scientist	Biology
Schaubensteiner	Stefan	DE.NHC	Pilot	Helicopter Service
Schewe	Ingo	DE.AWI	Scientist	Biology
Schmidt	Lydia Anastasia	DE.SENCKENBERG	Student (Master)	Biology
Schnier	Jannik	DE.AWI	PhD student	Biology
Seifert	Michael	DE.DRF	Technician	Helicopter Service
Silberberg	Jona	DE.CAU	Student (Master)	Biology
Soltwedel	Thomas	DE.AWI	Scientist	Biology
Stief	Peter Herbert	DK.SDU	Scientist	Biology
Striewski	Peter	DE.GEOMAR	Engineer	Engineering Sciences
Suck	Inken	DE.GEOMAR	Scientist	Biology
Suter	Patrick	DE.DWD	Scientist	Meteorology
Taylor	James	DE.GEOMAR	Scientist	Biology
Uhlir	Carolin Diana	DE.AWI	Scientist	Biology
Vaupel	Lars	DE.NHC	Pilot	Helicopter Service
vom Hagen	Tina	DE.AWI	HiWi	Biology
Weichert	Frank	DE.AWI	Engineer	Engineering Sciences
Wenzhöfer	Frank	DE.AWI	Scientist	Biology
Weston	Johanna	EDU.WHOI	Scientist	Biology
Weyand	Philipp	DE.GEOMAR	Scientist	Biology
Williams	James Alexander Bowen	UK.UNI-SOUTHAMPTON	PhD student	Oceanography
Xiao	Wenjie	DK.SDU	Scientist	Oceanography

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

Name/ Last Name	Vorname/ First name	Position/ Rank
Kentges	Felix	Master
Langhinrichs	Jacob	C/M
Janik	Michael	2/M Cargo
Grafe	Jens	C/E
Hering	Igor	2/M
Rathke	Jannik	2/M
Dr. Gößmann-Lange	Petra	Doc
Müller	Andreas	E/E Com.
Brose	Thomas	2/E
Bähler	Stefanie	2/E
Farysch	Tim	2/E
Redmer	Jens	E/E SET
Kliemann	Olaf	E/E Brücke
Hüttebräucker	Olaf	E/E Labor
Pliet	Johannes	E/E Sys
Jäger	Vladimir	E/E Winde
Sedlak	Andreas	Bosun
Neisner	Winfried	Carpenter
Burzan	Gerd-	Ekkehard MPR
Klee	Philipp	MPR
Klähn	Anton	MPR
TBN		MPR
TBN		MPR
Rhau	Lars-Peter	MPR
Siemon	Leon	MPR
Meier	Jan	MPR
Münzenberger	Börge	MPR
Hänert	Ove	MPR
Schwarz	Uwe	MPR
Klinger	Dana	MPR
Wendt	Meyk	MPR
Preußner	Jörg	Fitter/E
Hofmann	Werner	Cook
Hammelmann	Louisa	2./Cook
TBN		2./Cook
Pieper	Daniel	C/Stew.
TBN		Stew./Nurse
Dibenau	Torsten	2./Stew.
Brändli	Monika	2./Stew.
TBN		2./Stew.
Arendt	Rene	2./Stew.

Cheng	Qi	2./Stew.
Chen	Dansheng	2./Stew.
Schneider	Denise	Trainee