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HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

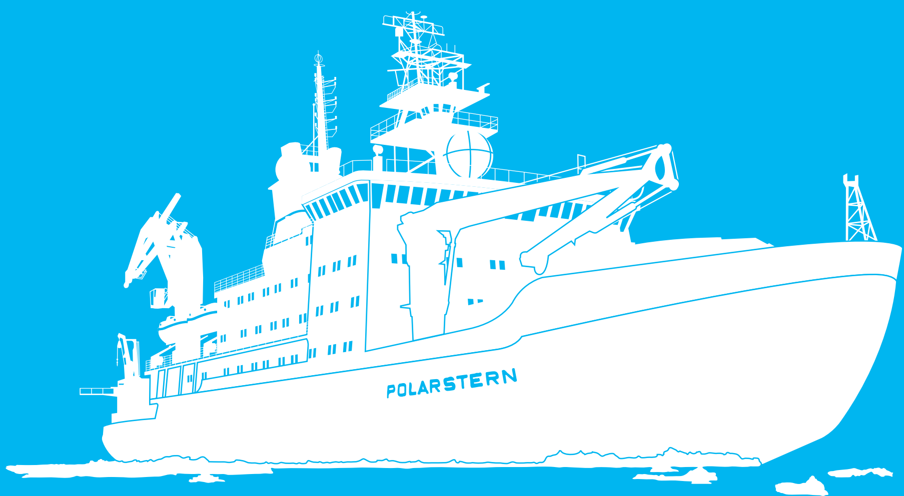
EXPEDITION PROGRAMME
PS136

Polarstern

PS136
Bremerhaven - Tromsø
22 May 2023 - 19 June 2023

Coordinator: Ingo Schewe

Chief Scientist: Thomas Soltwedel



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Bremerhaven, April 2023

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The Programme provides information about the planned goals and scientific work programmes of expeditions of the German research vessel *Polarstern*.
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PS136

22 May 2023 – 19 June 2023

Bremerhaven – Tromsø

Long-Term Ecological Research
at an Arctic marine Observatory

Chief scientist
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Coordinator
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Contents

Appendix

1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Thomas Soltwedel DE.AWI

Die Polarstern Expedition PS136 wird am 22. Mai 2023 in Bremerhaven beginnen und in die Framstraße zwischen Grönland und Spitzbergen führen. Die 4-wöchige Expedition soll genutzt werden, um Beiträge zu verschiedenen nationalen und internationalen Forschungs- und Infrastrukturprojekten (FRAM, MUSE, iFOODis, HiAOOS, ICOS-D, SIOS) sowie dem Forschungsprogramm „Changing Earth – Sustaining our Future” („Erde im Wandel – Unsere Zukunft nachhaltig gestalten”) des Alfred-Wegener-Instituts Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) zu leisten. Im Topic 6 “Marine and Polar Life: Sustaining Biodiversity, Biotic Interactions and Biogeochemical Functions” (Subtopics 6.1 “Future ecosystem functionality” und 6.3 “The future biological carbon pump”) des neuen Forschungsprogramms werden die mit steigenden Wassertemperaturen und dem Rückgang des Meereises verbundenen Ökosystemverschiebungen im Pelagial und im tiefen Ozean ermittelt und quantifiziert sowie Rückkopplungsprozesse auf ozeanographische Prozesse untersucht. Die Untersuchungen beinhalten die Identifizierung räumlicher und zeitlicher Entwicklungen in der Funktion ausgewählter Plankton- und Benthos-Gemeinschaften sowie den Aufbau eines umfassenden Repositoriums für Beobachtungsdaten. Im Rahmen des Subtopics 6.4 „Use and misuse of the ocean: Consequences for marine ecosystems“ werden darüber hinaus der Eintrag von Plastikmüll in den Ozean, vertikale Plastikflüsse von der Meeresoberfläche zum Meeresboden und die Wechselwirkungen zwischen Plastik und marinen Organismen untersucht.

Die Arbeiten stellen einen weiteren Beitrag zur Sicherstellung der Langzeitbeobachtungen am LTER Observatorium HAUSGARTEN dar, in denen der Einfluss von Umweltveränderungen auf ein arktisches Tiefseeökosystem dokumentiert wird. Diese Arbeiten werden in enger Zusammenarbeit der HGF-MPG Brückengruppe für Tiefsee-Ökologie und -Technologie und der PEBCAO-Gruppe („Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean“) des AWI durchgeführt.

Die Expedition soll darüber hinaus genutzt werden, um weitere Installationen im Rahmen der HGF Infrastrukturmaßnahme FRAM (Frontiers in Arctic marine Monitoring) vorzunehmen. Das FRAM Ocean Observing System wird kontinuierliche Untersuchungen von der Meeresoberfläche bis in die Tiefsee ermöglichen und zeitnah Daten zur Erdsystem-Dynamik sowie zu Klima- und Ökosystem-Veränderungen liefern. Daten des Observatoriums werden zu einem besseren Verständnis der Veränderungen in der Ozeanzirkulation, den Wassermasseneigenschaften und des Meereisrückgangs sowie deren Auswirkungen auf das arktische, marine Ökosystem beitragen. FRAM führt Sensoren in Observationsplattformen zusammen, die sowohl die Registrierung von Ozeanvariablen, als auch physiko-chemischer und biologischer Prozesse im Ozean erlauben. Experimentelle und ereignisgesteuerte Systeme ergänzen diese Beobachtungsplattformen. Produkte der Infrastruktur umfassen hochaufgelöste Langzeitdaten sowie Basisdaten für Modelle und die Fernerkundung.

Die technisch und logistisch sehr aufwendige Expedition PS136, während der auch verschiedene autonome, in der Wassersäule (Autonomous Underwater Vehicle, AUV) und auf dem Tiefseeboden agierende Unterwasserfahrzeuge (Benthic Crawler) zum Einsatz kommen sollen, wird am 19. Juni 2023 in Tromsø enden.

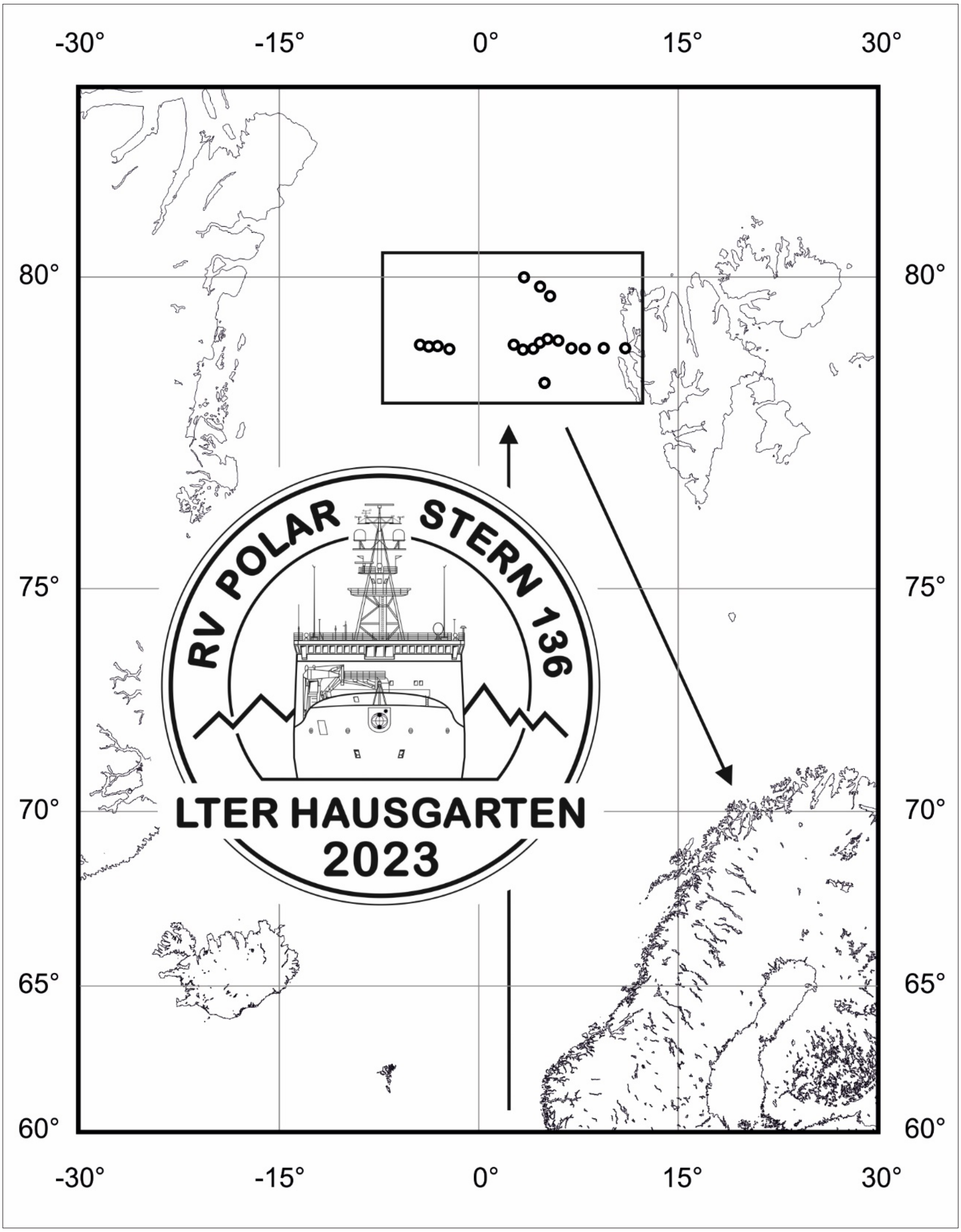

Abb. 1.1 Das Untersuchungsgebiet der Polarstern-Expedition PS136
Fig. 1.1 Study area of Polarstern expedition PS136

SUMMARY AND ITINERARY

The *Polarstern* expedition PS136 will start on 22 May 2023 in Bremerhaven and lead to the Fram Strait between Greenland and the Svalbard archipelago. The expedition will contribute to various large national and international research and infrastructure projects (FRAM, MUSE, iFOODis, HiAOOS, ICOS-D, SIOS) as well as 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). In Topic 6 "Marine and Polar Life: Sustaining Biodiversity, Biotic Interactions and Biogeochemical Functions" (Subtopics 6.1 "Future ecosystem functionality" and 6.3 "The future biological carbon pump") of the new research programme, ecosystem shifts in the pelagic and deep ocean associated with water temperature increase and sea ice retreat are identified and quantified, and feedback processes on oceanographic processes are investigated. These studies include the identification of spatial and temporal developments in the function of selected pelagic and benthic communities and the establishment of a comprehensive repository of observational data. In Subtopic 6.4 "Use and misuse of the ocean: Consequences for marine ecosystems", the input of plastic waste into the ocean, the vertical fluxes of plastic from the sea surface to the seafloor and the interaction between plastic and marine biota are investigated.

The work projected will support the time-series studies at the LTER (Long-Term Ecological Research) observatory HAUSGARTEN, 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 and the PEBCAO Group ("Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean") at AWI.

The expedition will further be used to accomplish 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. It serves national and international tasks towards a better understanding of the effects of change in ocean circulation, water mass properties and sea-ice retreat on Arctic marine ecosystems and their main functions and services. 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. Experimental and event-triggered platforms complement the observational platforms. Products of the infrastructure are continuous long-term data with appropriate resolution in space and time, as well as ground-truthing information for ocean models and remote sensing.

During the technically and logistically very challenging expedition we will, amongst others, use different autonomous underwater vehicles, which will operate in the water column (Autonomous Underwater Vehicle, AUV) and on the deep seafloor (Benthic Crawler). The cruise will end on 19 June 2023 in Tromsø.

2. LTER HAUSGARTEN – IMPACT OF CLIMATE CHANGE ON ARCTIC MARINE ECOSYS

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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. 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, 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, in the transition zone between the northern North Atlantic and the central Arctic Ocean, and includes 21 permanent sampling sites along a depth transect (250 – 5,500 m) and along a latitudinal transect following the 2,500 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 some 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. Frequent visual observations with towed photo/video systems allow the assessment of large-scale epifauna distribution patterns as well as their temporal development.

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 acoustic and side-scan sonar systems at depth by AUV and towed camera sleds within the AWI Deep-Sea Research Group (Purser et al. 2019) has indicated the high-resolution topographical 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 PS136, dedicated attempts to collect spatial data to capture the role of this heterogeneity in biodiversity and biomass estimation are planned to complement investigations on the temporal variability of benthos in the HAUSGARTEN area.

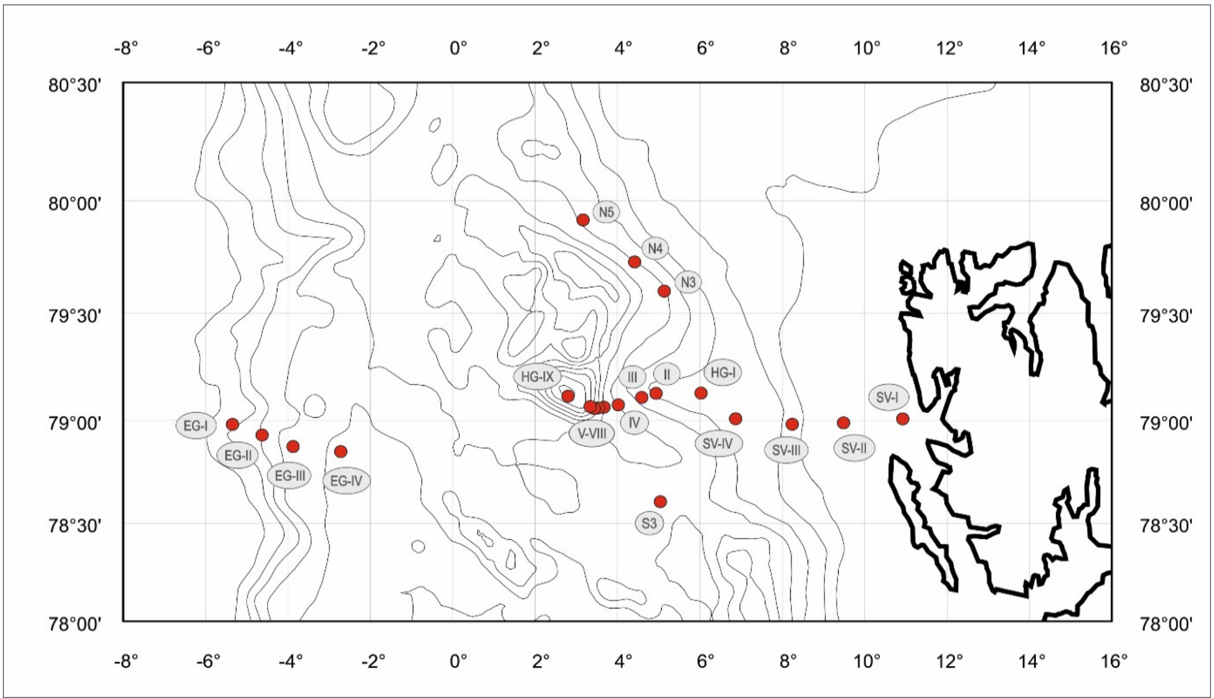

Fig. 2.1: Permanent sampling sites of the LTER (Long-Term Ecological Research) observatory HAUSGARTEN in Fram Strait, Arctic Ocean

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 of the biogeochemical studies at HAUSGARTEN 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 free-falling devices (bottom-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 bottom-lander equipped with sediment traps and cameras for timelapse imaging of the seafloor record the supply of organic material throughout the year.

Work at sea

The current cruise will extend the > 20 years time-series at HAUSGARTEN to detect long-term changes of benthic communities. The composition, diversity, density and biomass of benthic communities will be analyzed 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 analyzed to estimate the food input to the deep seafloor, benthic activities (e.g. bacterial exoenzymatic activity) and the total biomass of the smallest sediment-inhabiting organisms. Results will help to describe eco-status of the benthic ecosystem. Sediments retrieved by the MUC will be analyzed to describe small-scale spatial patterns as vertical gradients within the sediment as well as large-scale patterns at 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, sediment cores will be taken along the HAUSGARTEN depth transect for the analysis of the meiofaunal communities.

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 studied 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. Boxcorer sampling of the macrofauna during PS136 will continue the time-series work to allow the assessment of long-term changes in macrofauna assemblages at HAUSGARTEN.

In addition to boxcorer sampling, an Epibenthic Sledge (EBS) will be used to enhance the biodiversity recorded so far. The EBS will be deployed at five HAUSGARTEN stations, which were frequently sampled during the past 20 years and will allow a comparison to the EBS samples from subarctic waters available at the German Center for Marine Biodiversity Research (Deutsches Zentrum für Marine Biodiversitätsforschung, DZMB). 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.

Long-term megabenthic study

The Ocean Floor Observation and Bathymetry System (OFOBS; Purser et al. 2019) 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 imagery will also be used to quantify litter on the seafloor.

The OFOBS is equipped with a multibeam system allowing to collect spatial data to develop the high-resolution seafloor topographical maps of the HAUSGARTEN. Also, during PS136, the AUV PAUL 3000 will be deployed with its “Benthic” payload configuration (comprising a high-resolution stills camera and sidescan sonar systems) to map extended areas of HAUSGARTEN seafloor.

Larval ecology in the high Arctic

In polar regions, very little is known about how polar benthic invertebrates reproduce. Since 2017, traps, panels, pumps, and nets to collect larvae and newly-settled juvenile invertebrates in the Fram Strait. These efforts have provided some insights into larval development and dispersal of Arctic species, but very few specimens of deep-sea larvae have been collected. During PS136, we plan to continue our efforts to collect larvae and juvenile invertebrates.

A McLane WTS-LV pump will be attached to a free-fall lander and used for deployments at S3, HG-IV, N3, and N5 (~2,500 m). Each deployment should last 24 hours. In addition, an attempt may be made to recover a similar pump lander that was deployed at station N3 in 2021. This recovery will depend on cruise plan timing and gear and personnel availability.

As the cruise plan permits, we would also like to use a multi-net midi (150 µm mesh) to collect larvae from the water column. Tows should be conducted at stations S3, HG-IV, N3, and N5 (Fig. 2.1). At each site, the team will collect zooplankton using small nets (0.5 m diameter, 150 or 63 µm mesh) deployed by hand from *Polarstern* during CTD casts. Nets will be lowered to a depth of 20 m and raised slowly to the surface. One cast with each net should be conducted at every HAUSGARTEN station.

All specimens collected by the various methods will be sorted on board and individually preserved in 0.5 mL vials using 95 % ethanol.

Benthic flux study

At the central HAUSGARTEN site HG-IV (Fig. 2.1), a benthic crawler system (Crawler III; Fig. 2.2) will be recovered after its 12-month mission (deployed in 2022 during *Maria S. Merian* expedition MSM108). The crawler system was pre-programmed to perform > 50 measurements along a transect approx. 1.0 km in length. Crawler III (similar to 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 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 the profiles diffusive oxygen fluxes can be obtained.

Benthic camber incubations, performed at the same time, provide the total oxygen demand of the seafloor. Both measurements combined provide information on the oxygen consumption related to carbon mineralization. The measuring cycles are repeated every week for a period of 12 months in total.

In addition, we will recover a long-term bottom-lander (equipped with sediment traps, current meters and seafloor cameras) and a moored multi-timelapse camera system at HG-IV. Sediment trap samples will provide an estimate on the amount of settling organic matter at the seafloor. The multi-timelapse camera system extends the spatio-temporal coverage of seafloor photographs. Core of the system is a novel concrete pressure housing (Fig. 2.3) 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. Visual information from the multi-timelapse camera system will be compared with benthic oxygen consumption rates.

Fig. 2.2: Benthic Crawler III deployed at the central HAUSGARTEN site during Maria S. MERIAN expedition MSM108 in June 2022

Fig. 2.3: The multi-timelapse camera system with its Deep C 3000 concrete battery housing deployed at HAUSGARTEN during Maria S. MERIAN expedition MSM108

Experimental work at LTER HAUSGARTEN

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 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 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. Before the long-term deployment of the lander-based arcFOCE system at 1,500 m water depth in southern HAUSGARTEN area, a short test deployment at the beginning of the cruise will be performed. After the successful test deployment, the system will re-deployed for one year with a several months operation time-period during the one-year deployment.

Data management

Faunal and 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. Macrofauna data from

EBS samples will be entered to the Senckenberg DZMB Hamburg database to allow further processing and curating of the EBS samples in the DZMB laboratories in Hamburg after expedition. 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).

The expedition will be supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopics 6.1, 6.3 and 6.4.

In all publications based on this expedition, the Grant No. AWI_PS136_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. PEBCAO – PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN THE CHANGING ARCTIC OCEAN

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Grant-No. AWI_PS136_02

Outline

The Arctic Ocean has gained increasing attention in recent decades due to the ongoing significant changes in sea-ice cover and increase in temperature, which is approximately twice as fast as the global average. It is also expected that the chemical equilibrium and the elemental cycling in the surface ocean changes due to ocean acidification. The PEBCAO group began its studies of plankton ecology in Fram Strait (~79°N) in 1991 and intensified its efforts in 2009. Since then, classical mass measurements of biogeochemical parameters, microscopy, optical methods, satellite observations, and molecular genetic approaches have been combined in a holistic approach to collect comprehensive information on the variability of biodiversity, community structure, biomass and distribution of microbial plankton, primary production, bacterial activity, and zooplankton composition annually. As part of the PEBCAO contribution to the HAUSGARTEN/FRAM observatory, this included the deployment of long-term sediment traps and automated water samples on long-term moorings.

The long-term observations and process studies of the past years have already given us first important insights into mechanistic linkages between environmental conditions, biodiversity and ecosystem functionality, but also ongoing change in the marine ecosystem of Fram Strait. For instance, our results clearly indicate that chlorophyll *a* (Chl-a) values increase in summer in the eastern but not in the western Fram Strait (Nöthig et al. 2015, 2020). This is in accordance with the increasing contributions of *Phaeocystis pouchetii* and nanoflagellates to the summer phytoplankton community in relation to diatoms. These changes might be related to decreasing availability of silicic acid in the water column. The amount of silicic acid entering the Eurasian Basin of the Arctic comes mainly from the North Atlantic Water (NAW) inflow (100-400 m water depth) through Fram Strait and the Barents Sea Opening and riverine input from the Laptev Sea. Recent analyses have shown that all these waters from mid-latitudes to subpolar regions in the North Atlantic are affected by decreasing trends in silicic acid concentrations up to 1-2 µm in 25 years (Hátún et al. 2017). This decrease is primarily attributed to reduced winter convection depths since the mid 1990s and an increased influence of nutrient-poor water of mid-latitudes origin (Hátún et al. 2017). Although nitrate limits the total annual net primary production, spring diatom productivity, which is a major part of the total productivity, is strongly controlled by silicic acid supply (Krause et al. 2018). Fram Strait is an ideal location to study this ongoing decline in silicic acid concentrations and investigate potential effects on diatom silicification and phytoplankton community composition. Changes in phytoplankton composition are corroborated by variations in the biogeochemical flux composition (Lalande et al. 2019), as well as in large zooplankton species (caught as so-called “swimmers” in sediment trap samples), which have shown an increase of warm adapted organisms in recent years (Kraft et al. 2013; Bauerfeind et al. 2014; Busch et al. 2015).

We were able to show that *Phaeocystis* sp. controls production of transparent exopolymer particles (TEP) in the Fram Strait (Engel et al. 2017). However, despite the observed shift in phytoplankton community composition the concentration of dissolved organic carbon (DOC) was relatively stable over the last two decades, but we observed a slight decrease in the particulate organic carbon (POC) during the summer months (Engel et al. 2019). Moreover, the data of our long-term sediment-trap programme suggest that over the period 2009-2016 the abundance of *Micromonas polaris* and *Micromonas commoda*-like cells is positively correlated with lower standing stocks of phosphate and nitrate in the upper water-column at the LTER observatory HAUSGARTEN, and that they are exported to the deep sea, despite of their small size (Bachy et al. 2022). All this suggests that already now the ecosystem in Fram Strait is subject to profound changes, likely induced by changing climate conditions, which warrants further, sustained observation. Here it is of particular importance to quickly improve our understanding of the effects of variable sea-ice coverage and the marginal ice zone (MIZ), respectively sea-ice melt on the ecosystems. These effects are predicted to prevail in larger areas of the AO in the future and Fram Strait is an ideal site to study these effects. Its ecosystems are already strongly and regularly intensively affected by sea-ice related processes happening in the MIZ. The impact of these effects is expected to change in the future, also in Fram Strait in consequence to further Arctic environmental change. Biogeographical studies of PEBCAO 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., *submitted*). PEBCAO contributed to year-round interdisciplinary observations indicating that increased meltwater-stratification during spring/summer of 2017 slowed down the biological carbon pump in 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).

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). Seasonal succession of prokaryotic microbes in Fram Strait is related to a succession in the biopolymer pool, which indicates seasonally distinct metabolic regimes (von Jackowski et al. 2022), and is further reflected in clear differences in the particle dynamics between summer and autumn in Fram Strait (von Jackowski et al. 2020). During PS136, PEBCAO will continue these annual time series observations of biological and biogeochemical parameters, complemented by experimental studies of trophic interactions within the planktonic food web.

Objectives

The effects of changes on the polar plankton ecology and biogeochemical processes can only be detected through a combination of dedicated interdisciplinary process studies and long-term observations, as implemented by PEBCAO within the framework of LTER HAUSGARTEN and the FRAM observatory for more than a decade. Overall, the overarching objectives of PEBCAO are to improve the mechanistic understanding of biogeochemical and microbiological feedback processes in the changing Arctic Ocean, to document ongoing and long-term changes in the biotic and abiotic environment and to assess the potential future consequences of these changes. In particular we aim to identify climate-induced changes in the biodiversity of pelagic ecosystems and, concomitantly, in carbon cycling and sequestering and improve our mechanistic understanding of linkages between key environmental parameters and ecosystem functionality in the Arctic Ocean. The objectives are addressed using a range of methodologies:

Primary production is expected to increase in the changing Arctic Ocean, however, it is currently unclear if this will lead to increased export of particulate organic carbon or if organic carbon will remain at the surface, fuelling heterotrophic bacteria. Heterotrophic bacteria play a vital role in global biogeochemical cycles. To better understand bacterial activity, we will determine bacterial abundance, biodiversity and bacterial production. By linking compound dynamics with rate measurements and community structure, we will gain further insights into the flow of carbon through the Arctic food web. To address the effects of global change on microbial biogeochemistry in the Arctic Ocean, we will also continue to monitor concentrations of organic carbon, nitrogen, and phosphorus, as well as specific compounds like amino acids, carbohydrates, and gel particles. To assess cell abundances, we will sample for microscopic counts and flow cytometry that allows us to determine phytoplankton (< 50 µm), bacteria, and viral abundances. Phytoplankton primary production will be determined by radioisotopes (14C-incorporation) and distinguished into particulate primary production (carbon remaining in the cells) and dissolved primary production (organic carbon subsequently released by cells). In addition, primary production will be assessed *in situ* using fast repetition rate fluorometry (FRF) with the FastOcean ADP profiling system.

The increase in primary productivity due to the increase in light availability as the sea-ice retreats, will ultimately be limited by silicic acid availability. Diatoms, compared to other microalgal groups, will likely lower their cell-specific carbon, nitrate and silicic acid uptake rates under silicic limitation or shift towards smaller and less-silicified species, and non-silicifying microalgae will consequently contribute the most to primary productivity. To assess this, we will measure carbon and nutrient uptake rates for bulk and single cell phytoplankton under different silicic acid concentrations using stable isotope incubations. In addition, we will conduct incubations with a stain for silicate frustules (PDMPO) to assess the silicification degree of diatoms under different silicic acid concentrations.

We expect that the small algae at the base of the food web gain importance in mediating element and matter turnover as well as energy fluxes in Arctic pelagic systems. In order to detect changes, also in this smallest fraction of the plankton, traditional microscopy will be complemented by molecular methods that are independent of cell-size and morphological features, and we will determine their contribution to Chl-a biomass. Changes in Eukaryotic microbial communities are tightly linked to prokaryotic community composition. The assessment of the biodiversity and biogeography of Arctic Eukaryotic microbes, including phytoplankton and their linkages to prokaryotic microbial communities, will be 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 Water Sampler 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 water Samplers (RAS) and long-term sediment traps deployed on the FRAM moorings for year-round sampling.

Many zooplankton species are affected by the community composition at the base of the food web as they rely on it as food sources. However, which specific food sources are supporting the zooplankton biomass is relatively unclear due to the difficulties of tracing the carbon from those food sources to the tissues of organisms. Recent research has indicated that carbon isotopes of essential amino acids have potential to trace the proportional contribution of specific microalgae groups to zooplankton biomass (Vane et al. 2023) and during this expedition samples will be taken to refine and apply this approach. Similarly, the zooplankton community composition may shift due to the increasing inflow of warmer Atlantic water into the Fram Strait. Altered zooplankton trophic interactions and community compositions will have consequences for the carbon sequestration and flux. Most of our knowledge on zooplankton species composition and distribution has been derived from traditional multiple net samplers, which integrate depth intervals of up to several hundred meters. Nowadays, optical systems, such as the zooplankton recorder LOKI (Light frame On-sight Key species Investigations), continuously take 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 exactly 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.

Moreover, we will also include research dedicated to protistan parasites. These are severely understudied in the marine realm although they are likely to affect the population dynamics of phytoplankton (including bloom timing and magnitude) and zooplankton. We will therefore conduct a baseline study of the diversity of different parasite groups and their association with potential hosts. This investigation will also form the basis for future biogeographic studies. The analyses will combine different microscopy techniques (LM, SEM, CFLM) as well as molecular data, the latter facilitating observation of parasitism even at times where easily discernible parasite life-cycle stages are absent. In summary, during PS136 the following objectives are addressed:

- Monitoring biogeochemical parameters
- Determine autotrophic and heterotrophic microbial activities
- Monitoring plankton species composition and biomass distribution
- Assessing the flux of particulate organic matter to the seafloor
- Investigating selected phyto- and zooplankton (including their parasites)
- Determining the composition of organic matter and gel particles

Work at sea

Biogeochemical and biological parameters from rosette samples, including the automated filtration system for marine microbes AUTOFIM

We will sample Arctic seawater with the CTD/Rosette Water Sampler at 5-6 depths in the upper 200 m of the water column, and using a peristaltic pump system at the ice-ocean interface. Besides sampling particles in the water column, five sediment traps and two automated water samplers (Remote Access Samplers, RAS; McLane) will be deployed in oceanographic moorings to investigate the vertical particle flux. In addition, we will collect 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) 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).

Primary and bacterial production measurements will be performed on board using 14C bicarbonate and 3H leucine. At selected stations, the FastOcean ADP profiling system will be deployed in the euphotic zone. Using the CTD/Rosette Water Sampler to acquire water from the Chl max we will conduct incubations with a gradient of silicic acid concentrations using a combination of three stable isotope labelled substrates to measure carbon (13C-sodium bicarbonate), nitrate (15N-potassium nitrate) and silicic acid (30Si-silicic acid). The samples for bulk and single cell analysis will be filtered and the filters will be stored at -20° C until analysis at the home lab.

For a second set of incubations we will use a stain for silicate frustules (PDMPO) to assess the silicification degree of diatoms under different silicic acid concentrations. The samples will be fixated with hexamine-buffered formaldehyde and kept in the dark at 4° C until analysis.

Fig. 3.1 The fully automated filtration module AUTOFIM is installed on Polarstern in the "Bugstrahlruderraum" close to the inflow of the ship's pump system.

Phytoplankton blooms that are dominated by a particular species will be filtered on GF/F filters for comparison of patterns in d13C values of that same species cultured in the laboratory. All other samples will be partly filtered and preserved or frozen at -20° C and partly at -80° C for further analyses. At the home laboratory at AWI, we will determine the following parameters to describe the biogeochemistry, biomass and abundance/biodiversity:

- Chlorophyll a concentration (total and fractionated)
- Phytoplankton pigments and major groups (HPLC)
- Dissolved organic carbon (DOC)
- Particulate organic carbon (POC)
- Total dissolved nitrogen (TDN)
- Particulate organic nitrogen (PON)
- Particulate biogenic silica (PbSi)
- Particulate organic phosphorus (POP)
- Dissolved organic phosphorus (DOP)
- Transparent exopolymer particles (TEP)
- Coomassie-stainable particles (CSP)
- Dissolved combined carbohydrates and hydrolysable amino acids
- Phytoplankton, protozooplankton, bacterial and viral abundance
- Phytoplankton and bacterial production
- Prokaryotic and eukaryotic (16S/18S) biodiversity

Flux measurements and sampling of settling aggregates

Measurements of the vertical flux of particulate matter at HAUSGARTEN have been conducted since the establishment of the observatory. By means of these measurements we are able to quantify the export of organic matter from the sea surface to the deep sea, and trace changes in these fluxes over time. Measurements of organic matter fluxes are conducted by bottom-tethered moorings carrying sediment traps at approx. 200 and 1,000 m below sea-surface, and about 200 m above the seafloor.

In addition to moored sediment traps, autonomous infrastructure will be deployed on the HAUSGARTEN moorings to track seasonal changes in the dissolved and particulate constituents of the upper water column. These include remote access water samplers (RAS) that are programmed to collect and preserve water samples (~0.5 L). Besides sediment traps and RAS, the moorings are equipped with current meters, self-recording CTD's, and a suite of biogeochemical sensors. During the *Polarstern* expedition PS136, we will recover moorings and instruments that were deployed during the expedition PS131 in summer 2022.

The BioOptical Platform (BOP) currently deployed in Fram Strait will be recovered and a new one will be deployed to measure size-specific settling velocities of individual particles in relation to their type and composition throughout a whole year. The system has been an integral part of the HAUSGARTEN mooring-array since 2015.

Furthermore, the SWIPS-Particle-Camera, which was deployed during PS131 (2022) will be recovered and redeployed in the HAUSGARTEN as part of the mooring array. Subsequently we will investigate the status of the system with regard to functionality and possible necessary improvements as well as evaluate the collected data in terms of particle statistics over depth and time.

Phytoplankton sampling and processing for light microscopy, SEM and culture studies

Phytoplankton samples for quantitative analysis using the Utermöhl method will be collected from the CTD/Rosette Water Sampler. They will be fixed in hexamin-buffered formalin and stored at 4° C for later analysis in the home laboratory. Additional phytoplankton samples will be taken using a hand net with mesh size 20 µm. A portion of these samples will be analyzed live onboard, to record the biodiversity of the larger phytoplankton taxa. The live samples will also be screened for diatoms and parasites to be taken into culture. Of particular interest is *Melosira arctica* which, on an earlier cruise, was found to harbour a probably undescribed parasite, which we need to bring into culture. The remainder of the sample will be fixed in hexamin-buffered formalin and analysed in more detail using scanning electron microscopy.

Zooplankton sampling

We will study the zooplankton biodiversity and biogeography by deploying a multi net. 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; Fig. 3.2), 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.

Calanus spp. will be collected at two different depths for carbon isotope analysis in amino acids and fatty acids to trace the carbon that has contributed to their biomass to specific clades of phytoplankton. A subset of *Calanus* spp. will be preserved on 100 % ethanol for DNA analysis to confirm the species identification for isotope analyses. Other zooplankton species present will also be sampled for future isotope studies.

Sea-ice sampling

Sea-ice cores will be collected for biological and chemical analyses (microbial biodiversity, Chl-a, nutrients) during ice stations in vicinity of the stations in East Greenland Current reached by ship or helicopter. We will further sample water directly under the ice. If applicable, we will collect cells of *Melosira arctica* samples for compound specific isotope analysis.

Fig. 3.2. 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.

Expected results

Results from pelagic and sea-ice studies are expected to provide a better understanding of i) the variability and biodiversity of pelagic and sea-ice associated biomass with respect to environmental conditions, ii) trophic pathways of microbial biomass, iii) linkages between plankton community composition or biomass and biogeochemistry.

Data management

During our cruises, we sample a large variety of interrelated parameters. Many of the samples (i.e. Chl-a, 16S/18S eDNA, phytoplankton and zooplankton biodiversity etc.) will be analyzed at AWI or GEOMAR within approximately one year after the cruise. We plan that the full data set will be available at the latest about two years after the cruise. Samples taken for microscopical and molecular analyses, which cannot be analyzed within two years after the cruise, will be stored at the AWI for at least ten years and available upon request to other scientists. Data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (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. Analysis of BOP and SWIPS-Particle-Camera is quite time consuming and will therefore be done in the home laboratories at AWI and MARUM.

The expedition will be supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopic 6.1.

In all publications based on this expedition, the Grant No. AWI_PS136_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. PELAGIC BIOGEOCHEMISTRY – NUTRIENTS AND NET COMMUNITY PRODUCTION

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Objectives

Beginning in 2018 during PS114, we have been deploying Remote Access Samplers (RAS; Fig. 4.1) equipped with several sensors (SUNA nitrate, pH, pCO_2, CTD-O_2, PAR and Eco-triplet) in Fram Strait as part of the FRAM/HAUSGARTEN LTO activities. Whenever possible we have deployed four of these biogeochemical packages in two moorings (EGC, F4S and/or F4W-1), targeting sub-surface and core waters of the East Greenland Current and West Spitsbergen Current. Deployments (and eventual recoveries) in this configuration have then been taken place during PS121 in 2019 and PS126 in 2021. In 2022, during PS131, only two biogeochemical packages were deployed in subsurface waters as the other two RAS were deployed elsewhere as part of the ATWICE expedition. With the RAS we collect – typically – 48 seawater samples at roughly weekly intervals, for later analysis of dissolved inorganic and organic nutrients. Additionally, we also collect water samples from CTD/Rosette Water Sampler casts for nutrient analyses onboard. 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 as it has been described in previous booklets and cruise reports (e.g. von Appen 2018; Metfies 2019, 2020; Soltwedel 2021a,b; Kanzow 2022). 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, Matthias Wietz), Physical Oceanography of Polar Oceans (Wilken von-Appen, Mario Hoppmann, Matthias Monsees, Torsten Kanzow) and Deep-Sea Ecology and Technology (Normen Lochthofen). For PS136 we also start 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 will provide an extra RAS to complement out work this year in Fram Strait.

Work at sea

During PS136 we will:

1. collect water samples from CTD-Rosette Water Sampler casts for the analysis onboard, of dissolved nutrients and dissolved oxygen. Dissolved oxygen data will be used to calibrate the CTD-O_2 sensor.

2. deploy two sets of FRAM RAS and sensors (as described above), and one additional RAS (from the NOC) with at least one CTD attached. The two FRAM biogeochemical packages will be deployed in moorings EGC and F4S close to the surface, while the NOC RAS will be deployed in the EGC mooring at approx. 250 m depth.
3. analyze samples from previous RAS deployments (PS126).
4. condcut an incubation experiment on temperature responses and cellular oxygen fluxes in natural phytoplankton communities. Therefore, a natural phytoplankton spring bloom community from the West Spitsbergen Current will be collected by CTD sampling and incubated over a few generation times at three different acclimation temperatures (present day vs. two future scenarios). Then cells will be harvested for various ecophysiological parameters (including oxygen fluxes by Membrane-Inlet-Mass-spectrometry; MIMS) and species composition. Using a ship going MIMS to measure physiological rates is novel and was for the first time successfully tested during PS131 (Kanzow 2022).

Upon mooring recovery, data retrieval, processing and quality control of sensor data will take up to six months. Analysis of nutrients from RAS samples may also take six months or more after the expeditions. We aim to process the data from measurements carried out on board, which will only require further quality control after the expedition.

Phytoplankton from the incubation experiment will be harvested on board and samples will be analyzed at AWI in the upcoming 6 months after return.

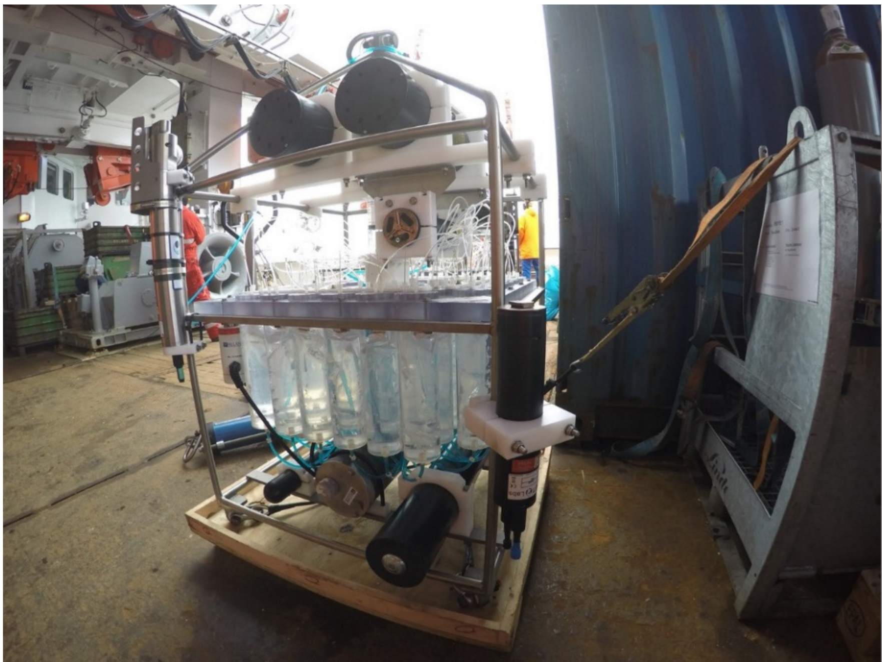

Fig. 4.1 Biogeochemical package consistent of a Remote Access Sampler (RAS) with a CTD-O_2 and a PAR sensor on either side of the frame, pH and pCO_2 sensors on top and an EcoTriplet sensor beneath the frame, as well as a SUNA-Nitrate sensor at the bottom left hand side, next to battery packs for sensors and the RAS

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, and Topic 2, Subtopic 2.1.

In all publications based on this expedition, the Grant No. AWI_PS136_03 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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5. PHYSICAL OCEANOGRAPHY

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Grant-No. AWI_PS136_04

Objectives

The physical conditions that lead to enhanced primary and export production in the Arctic Ocean remain unclear. And 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.

To determine the seasonal changes in nutrient concentrations in the euphotic zone, water samplers have been deployed since 2016 with the most recent deployment in 2022 (PS131) at approximately 20 m and 80 m depth. In total, 24 discrete samples are being taken with weekly to monthly resolution (depending on season) to follow the biological drawdown of nutrients. The moorings are also equipped with a physical and biogeochemical sensor package including SBE37-SMP-ODO (temperature, salinity, oxygen), SAMI pH, SAMI pCO2, Wetlabs PAR (photosynthetically active radiation), Wetlabs Ecotriplet (Chlorophyll and CDOM fluorescence plus scattering), SUNA Deep Nitrate, current meters, and Acoustic Doppler Current Profilers. The combination of these sensors and the water samplers, in combination with the deployment of two profiling winches facilitates the assessment of seasonal stratification and nutrient concentrations above and below the pycnocline. The nutrient drawdown enables an estimate of new production. Furthermore, the samples will be used for DNA sequencing to examine seasonal changes in bacterial community structure. The particle samplers collect and preserve filters for DNA extraction and sequencing that together with the fluorescence sensors allow us to track the progression of phytoplankton biomass and community composition over different seasons. These efforts give us a novel year-round description of biological, chemical, and physical processes in the Fram Strait.

Work at sea

CTD/Rosette Water Sampler

The CTD water sampling will be conducted at the standard HAUSGARTEN stations. Water will be collected both on full water column profiles and on profiles to only 300 m depth. Water samples will be run on the Optimare Precision Salinometer for salinity calibration.

Fig. 5.1: Recovery of the CTD/Rosette Water Sampler from icy waters

Recovery and deployment of moorings

In total four moorings will be recovered on PS136 (Table 5.1), and all will be redeployed with little to no modifications (Fig. 5.2). This comprises a mooring cluster (F4) in open water in the West Spitsbergen Current. At these clusters measurements as shallow as 20 m depth are performed. Depending on the ocean conditions, a fifth mooring (F4-21) may be recovered and re-deployed, as part of the mooring cluster.

Tab. 5.1: List of moorings to be recovered during PS136

Name	Longitude	Latitude	Depth (m)	Top (m)	Deployment Time (yyyy/mm/dd UTC)	Deployment Station
FEVI-44	04°19.94'E	78°59.99'N	2,568	38	2022/07/09 15:25	PS131_30-1
EGC-8	05°23.74'W	78°59.78'N	1,011	47	2022/08/03 17:37	PS131_106-1
F4-W-4	07°01.95'E	79°00.73'N	1,249	132	2022/07/07 12:08	PS131_16-1
F4-S-6	06°57.76'E	79°00.70'N	1,231	16	2022/07/10 08:13	PS131_34-1
F4-21	07°00.03'E	79°00.02'N	1,224	50	2022/07/07 08:54	PS131_15-1

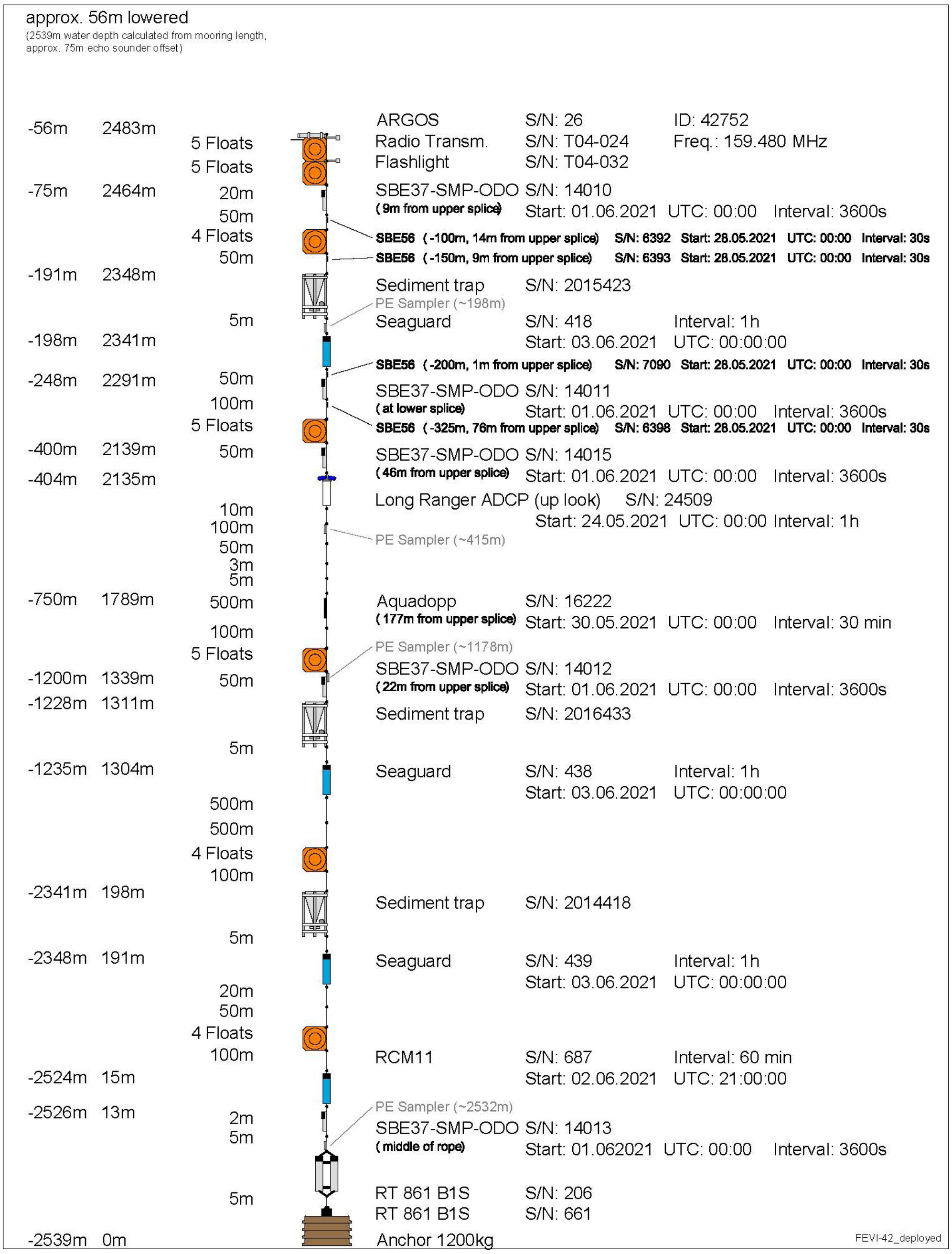

Fig. 5.2 Typical layout of the FEVI mooring installed at the central HAUSGARTEN site HG-IV

Data management

The data recorded by the moored instruments that will be recovered on PS136 and all CTD 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. The mooring that will be deployed on PS136 will be recovered in 2024 and data processed accordingly.

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 2, Subtopic 2.3.

In all publications based on this expedition, the **Grant No. AWI_PS136_04** 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.

6. PHYTOOPTICS

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Grant-No. AWI_PS136_04

Outline

Marine phytoplankton is the basis of the marine food web and also a main component of biogeochemical fluxes, thus, an important source of dissolved and particulate organic substances, including volatile organic substances (e.g. DMS, isoprene, halocarbons). The contribution of the Phytooptics group is the acquisition of high resolved information on the amount and composition of phytoplankton and its pigments, dissolved organic matter and particles along the cruise transect. These data enable via the complementation to satellite and previous field data acquisition the analysis of long-term trends of these parameters in the East Greenland region. During expedition PS136, continuously measurements with optical sensors will be taken at the surface water and also at discrete stations with the light profiler. With that as much as possible collocated data to ocean color sensors OLCI data (launched in February 2016 and April 2018, respectively, on Sentinel-3A and -3B) shall be acquired for validation (The Phytooptics group is within the Sentinel-3 Validation Team). In addition to that, these *in situ* data are important for the validation of the group's own satellite products on phytoplankton composition and its distribution (EOF-PFT; Xi et al. 2021, 2022; PhytoDOAS; Bracher et al. 2009; Sadeghi et al. 2012) and spectral attenuation of underwater light (Dinter et al. 2015; Oelker et al. 2019, 2022). The continuous surface and profile biooptical data are regularly calibrated with measurements at discrete water samples determining the phytoplankton pigment composition using HPLC method and the optical properties using spectrophotometric instrumentation.

Objectives

During PS136, we focus to broaden our sampling frequency of information on phytoplankton, particulate and chromophoric dissolved organic matter (CDOM) abundance and composition by taking continuous optical measurements, which directly give information on inherent and apparent optical properties (IOPs and AOPs, respectively). A similar IOP setup from ISMAR-CNR will be implemented during this cruise to enable the inter-comparison of the IOP data acquired simultaneously from two independent setups. The IOP package from ISMAS-CNR also carries an ECO-VSF3 meter to measure the backscattering coefficient, both continuously and during stations. In addition, surface waters samples will be collected to study the latitudinal distribution and oceanic transport of emerging organic pollutants such as per- and polyfluorinated alkyl substances (PFASs) and plastic associated chemicals and pharmaceuticals and personal care products (PPCPs) the North Atlantic and the Arctic.

The specific objectives of our group on the PS136 are

- to collect a high spatial and temporal resolved data set on phytoplankton (total and composition) and its degradation products at the surface and for the full euphotic zone using continuous optical observations during the cruise and from ocean colour remote sensing calibrated with discrete water sample measurements,
- to develop and validate (global and regional) algorithms and associated radiative transfer models in accordance to the previous objective by using discrete water samples for pigment analysis and absorption measurement,
- to obtain a big data set for ground-truthing ocean color satellite data, specifically from the new Sentinel-3 (A and B) OLCI and the Sentinel-5-Precursor TROPOMI sensors,
- to obtain a spectral characterisation of the underwater light field and its interplay with optical constituents, such as phytoplankton and CDOM abundance and composition.
- to set up an IOP package from ISMAR-CNR to acquire IOP data both in continuous (Co) and cast (Ca) mode (Volpe et al. 2021). Data from this IOP package will be inter-compared with similar data collected by the AWI Phytooptics' ACS underway system and the optical profiler and will contribute to improve our cal/val activity within Copernicus Marine Environment and Monitoring Service,
- to determine the alternative PFASs and PPCPs in seawater from the Western Svalbard to the Eastern Greenland Sea, in order to characterize the distribution of emerging chemicals in seawater of the Arctic Ocean and evaluate the oceanic current transport of emerging organic contaminants (EOCs) into the Arctic.

Work at sea

Active and passive bio-optical measurements for the survey of the underwater light field, specific light attenuation, particle and phytoplankton composition and distribution, shall be performed continuously on the surface water but also in the profile during daily noon-time CTD stations:

1. Continuous measurements of inherent optical properties (IOPs) with a hyperspectral spectrophotometer: For the continuous underway surface sampling an *in situ* spectrophotometer (ACS; Wetlabs) will be operated in flow-through mode to obtain total and particulate matter attenuation and absorption of surface water. The instrument is mounted to a seawater supply taking surface ocean water. A flow-control with a time-programmed filter is mounted to the ACS to allow alternating measurements of the total and the CDOM inherent optical properties of the sea water. Flow-control and debubbler-system ensure water flow through the instrument with no air bubbles. The ACS needs to be operated on the seawater supply at the Nasslabor I, with seawater pumped at Kastenkiel via Spargel with the membrane pump through the Teflon tubing- in order to deliver living phytoplankton cells continuously throughout the cruise, also within the ice.
2. Optical profiler: a second ACS instrument is mounted on a steel frame together with a depth sensor and a set of hyperspectral radiometers (Fig. 6.1) and operated during CTD stations around noon time daily. The frame is lowered down to maximal 150 m with a continuous speed of 0.1 m s^{-1} or during daylight with additionally stops at 5, 10, 15, 20, 25, and 30 m to allow a better collection of radiometric data (see later). The Apparent Optical Properties of water (AOPs) (surface reflectance and light attenuation through the water column) will be estimated based on downwelling and upwelling irradiance

measurements in the surface water profile (down to the 0.1 % light depth) from the radiometers calibrated for the incident sunlight with measurements of a radiometer on deck. The ACS will measure the inherent optical properties (IOPs: total attenuation, scattering and absorption) in the water profile.

3. An IOP package from ISMAR-CNR (Fig. 6.1) will be tested both in continuous (Co) and cast (Ca) mode. This IOP package will be mostly running in “Co” mode with the seawater supply in Nasslabor I, and at about five CTD stations deployed in “Ca” mode to measure the light profiles following the deployment of the Phytooptics’ optial profiler. In addition, the IOP package will be deployed twice, each station: one to measure total absorption and attenuation and one to measure their dissolved portions: this will enable, by subtraction, the particulate contributions to be computed.

4. Discrete measurements of IOPs (absorption) at water samples are performed 1) for samples from the underway surface sampling (as for the ACS flow-through system at from the ship’s sea water pump) at an interval of three hours, and 2) for samples from the CTD station water sampling at six depths within the top 100 m. Water samples for CDOM absorption analysis are filtered through 0.2 µm filters and analyzed onboard with a 2.5-m path length liquid waveguide capillary cell system (LWCC, WPI) following Lefering et al. (2017). Particulate and phytoplankton absorption coefficients are determined with the quantitative filter techniques using sample filtered onto glass-fiber filters QFT-ICAM and measuring them in a portable QFT integrating cavity setup Röttgers et al. (2016).

5. Samples for determination of phytoplankton pigment concentrations and composition are taken at a 3-hourly interval from the underway-sampling system, and from six depths (max. 100 m) at CTD-stations. The water samples are filtered on board immediately after sampling and the filters are thermally shocked in liquid nitrogen. Filters are stored at -80°C until ship is back in Bremerhaven and then will be analyzed within the next three months by High Performance Liquid Chromatography Technique (HPLC) at AWI following Taylor et al. (2011) adapted to our new instrumentation as described in Álvarez et al. (2022).

6. Water samplers are collected from the ship intake system in the wet lab using 1-L PP bottle and 1-L glass bottle for the determination of different chemical groups. All water samples are stored at 0°C cooling room.

Fig. 6.1: AWI's combined TRIOS RAMSES radiometer and WETLABS ACS measuring extinction and absorption (left) and ISMAR's IOP package with an ACS to measure attenuation and absorption and a WETLABS ECO-VSF3 meter to measure the backscattering coefficient (right)

Expected results

Directly on board we aim to analyse the discrete water measurements of particle, phytoplankton and CDOM absorption which should be completed by the end of the expedition. These data will illucidate the distribution of phytoplankton, particles and CDOM at the surface a long the cruise transect and in the vertical for the sampled stations. The phytoplankton pigment composition and their concentrations will be determined back in the home laboratory where also the sensor data will be further processed to obtain quality control hyperspectral particulate and CDOM absorption, reflectance, diffuse attenuation and transmission data. These data then will be used using semi-analytical techniques to determine the spectrally resolved underwater light attenuation and the distribution of phytoplankton total and groups's biomass, CDOM and non-algal particles. Comparison between the same IOP data acquired both by Phytooptics and ISMAR-CNR setups will help us understand the stability of the instrumentation and uncertainty in the IOP data acquired from same instruments but different setups. Surface water samples collected for HZH may add new data set for emerging organic contaminants (EOCs) in the North Atlantic Ocean and the Arctic, and improve models to predict the environmental progression and assess the effect of climate change on the long-range transport and the fate of the EOCs in the Arctic ecosystem.

Data management

The quality controlled optical and pigment sampled during this expedition and further processed to geophysical quantities 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.

This expedition was supported by the Helmholtz Research Programme "Changing Earth–Sustaining our Future" Topic 6, Subtopic 3 and additional funding by Copernicus Marine Service GLOPHYTS project.

In all publications based on this expedition, the Grant No. AWI_PS136_04 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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7. FRAM POLLUTION OBSERVATORY – MONITORING LITTER AND MICROPLASTIC AT HAUSGARTEN

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[2]DE.AWI

Grant-No. AWI_PS136_01

Objectives

Marine litter or marine debris has long been on the political and public agenda as it has been recognized as a rising pollution problem affecting all oceans and coastal areas of the world and more than 1,300 species (Bergmann et al. 2017a). Over time, larger plastic litter items fragment into smaller particles termed ‘microplastics’ (< 5 mm), which have recently received increasing attention (Ryan 2015) as they can be taken up more readily by a wider range of biota and humans.

Analysis of seafloor photographs (Fig. 7.1) taken for the epibenthic megafauna time series at three stations of the HAUSGARTEN observatory (see Chapter 2) indicate that litter rose almost 30-fold between 2004 and 2017 at the northernmost station and reached densities similar to those reported from a canyon near the Portuguese capital Lisbon (Parga Martínez et al. 2020). This increase has prompted a focused study on litter and microplastic pollution in different ecosystem compartments and repeated sampling campaigns to observe temporal trends.

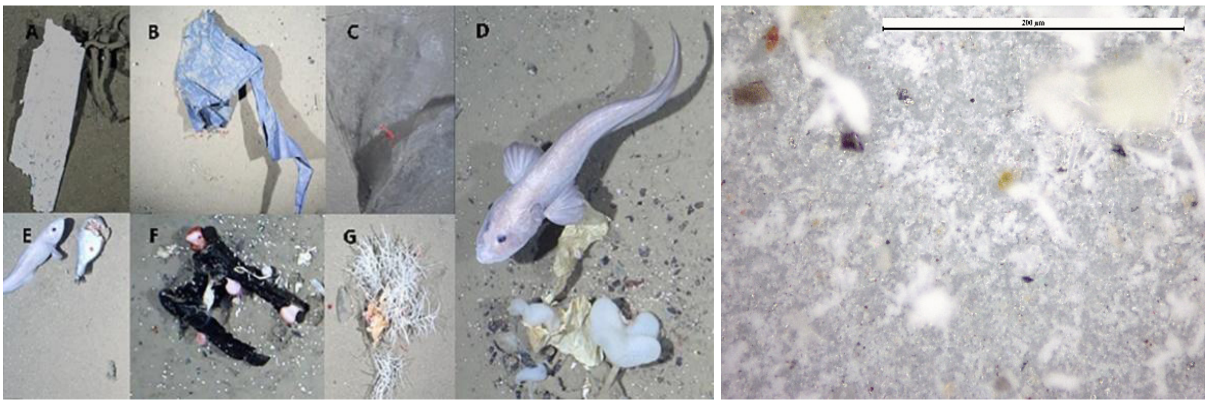

Fig. 7.1: Examples of marine litter and faunal interactions at HAUSGARTEN observatory (left: from Parga-Martinez et al. 2020) and atmospheric microplastics (right: from Allen et al. 2019)

This research has highlighted that Arctic sea ice, sea surface, water column and deep-sea sediments harbour high levels of microplastic pollution, especially the seafloor, with up to ~13,000 microplastics per kg sediment at the northernmost station (Bergmann et al. 2017b; Peeken et al. 2018; Tekman et al. 2020). Plastic has also invaded the Arctic food web (Trevail et al. 2015; Kühn et al. 2018), including sea ice-associated zooplankton (Botterell and Bergmann, *in prep.*). Significant quantities of microplastic in Arctic snow samples indicate that atmospheric transport plays an important role (Bergmann et al. 2019). Recent data even suggest that the sea surface acts as a source of airborne microplastic (Allen et al. 2020). Still, on the whole, the role and processes of atmospheric transport of microplastics have not yet received the merited scientific attention although they are considered to play a key role (Zhang et al. 2020).

Work at sea

Three active air-pumping devices will be fitted to the Peil-Deck (Fig. 7.1) to quantify airborne microplastic pollution in 24-hour time steps throughout the cruise. The transit from Bremerhaven to the HAUSGARTEN area is of particular interest to delineate large-scale pollution patterns and transport processes. In addition, passive air deposition samples will be collected daily (24-hour time steps) throughout the transit and stationary periods of the Bremerhaven to the HAUSGARTEN area *Polarstern* voyage. The passive samples will be collected using MilliQ flush into a glass or aluminium container. This will then be taken to the *Polarstern* on-board laboratory and filtered onto appropriate (1 µm pore) filters using glass vacuum filtration devices (240 V) and the samples (on filter material) retained for analysis. A subsample of the liquid will also be retained (pre-filtration) for quantitative mass analysis, decanted into glass vials in the on-board laboratory.

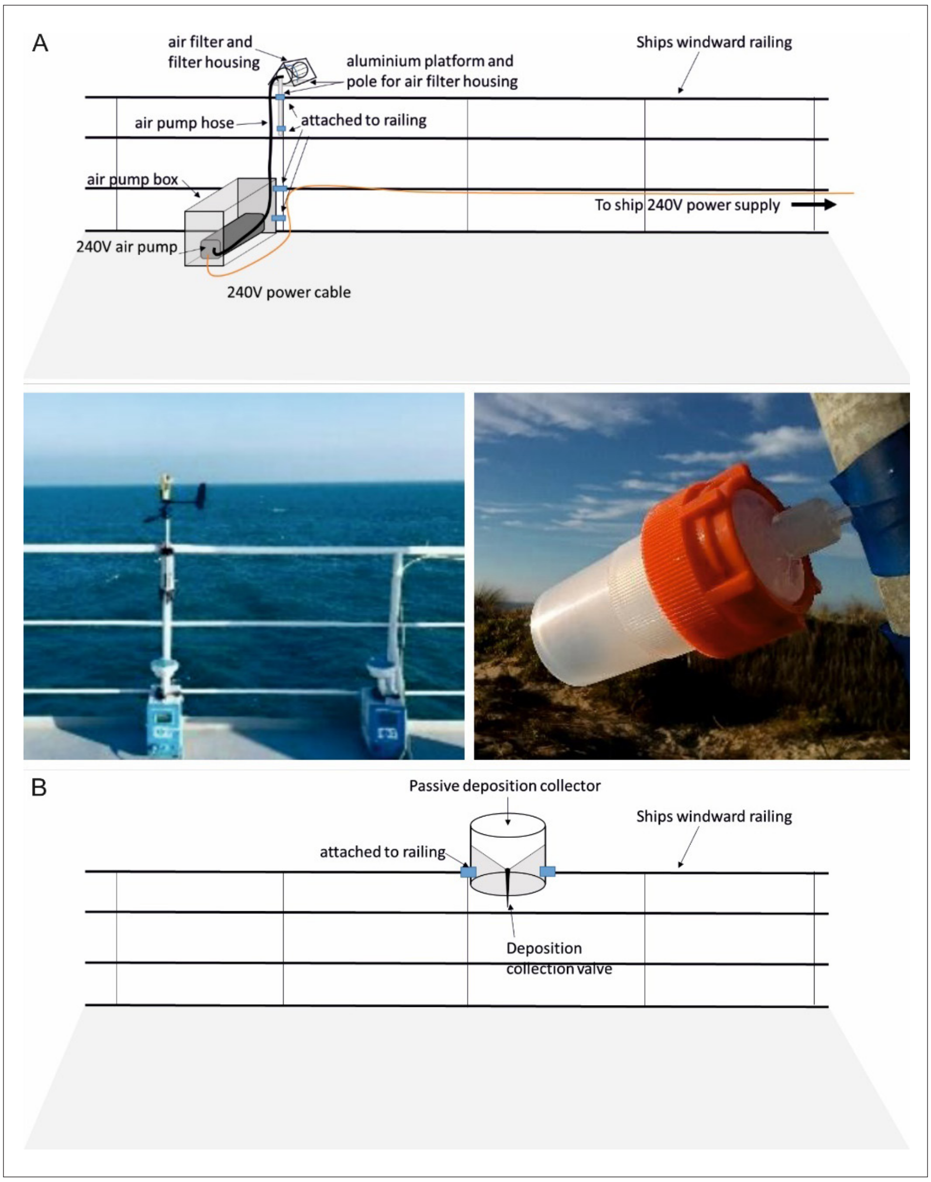

Fig. 7.2: Sketch and photograph of (A) active air-sampling devices and (B) deposition sampler set-up to be used to quantify airborne microplastic

Laboratory work will be conducted during periods of lowest footfall, potentially during the evening or out of peak laboratory use hours, to ensure minimum background contamination of the samples. There is very limited marine air sampling published to date (Liu et al. 2019; Wang et al. 2020; Allen et al. 2019, 2020, 2022), and this survey will follow on from the first high-latitude northern hemisphere analysis of marine air microplastic. In addition, snow samples will be gathered during helicopter flights to ice floes to assess atmospheric fallout. The data will complement previous measurements (Bergmann et al. 2019) and will support the ongoing atmospheric transport analysis of microplastic in the high latitude and Arctic marine environment.

We expect to collect between 10 and 35 atmospheric microplastic samples (subject to wind direction, precipitation and sampling constraints), up to 12 deposition samples as well as up to six surface snow samples per helicopter flight.

Data management

After the cruise, the filters of the atmospheric and snow samples will be analysed at the University of Canterbury, New Zealand. Sediment samples will be analysed by Micro-FTIR spectroscopy at AWI Helgoland.

All data will be 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.

All data will be uploaded to the AWI-operated marine litter portal LITTERBASE (www.litterbase.org). In addition, we aim to publish in open-access journals, so there will be no embargo after publishing.

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 6, Subtopic 6.4.

In all publications based on this expedition, the **Grant No. AWI_PS136_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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8. FLUX-ON-SITE – GREENHOUSE GAS FLUXES AT OCEAN-SEA ICE INTERFACES IN THE ARCTIC OCEAN

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Grant-No. AWI_PS136_05

Objectives

During the FLUX-ON-SITE project we will investigate the dynamics of the greenhouse gases (GHG) nitrous oxide (N_2O) and methane (CH_4) across the water column in the Arctic Ocean, as well the spatial variability of the exchange fluxes of both gases across the sea-ice-air interfaces. The Arctic Ocean reacts strongly to GHG-driven warming since sea ice melting increases heat absorption through reduced albedo ("Arctic Amplification"). Hence, GHG observations are crucial to monitor the ocean's state and its role in the production and exchange of climate-relevant compounds with the atmosphere. To this end, we propose to carry out an extensive multidisciplinary investigation of the magnitude, driving mechanisms and variability of N_2O and CH_4 fluxes across sea-ice-air interfaces in the Fram Strait sector of the Arctic Ocean.

The main foci of the project are (i) the gas exchange across interfaces, (ii) the emissions from the region and their share to the global GHG budget, (iii) the role of submesoscale dynamics in shaping the water column variability of N_2O and CH_4, and (iv) the spatial variability of gas source-sink dynamics in the Fram Strait. The specific research questions to be addressed with the planned working programme are:

- How does the heterogeneous distribution of sea ice at different melting stages impacts the surface exchange N_2O and CH_4?
- Is the Fram Strait a source or sink of atmospheric N_2O and CH_4?
- What is the impact of submesoscale processes in the water column distribution of N_2O and CH_4 and their exchange across the sea-ice-atmosphere interfaces?
- How does the meridional water exchange at the Fram Strait affect the mid-water depth budget of N_2O and CH_4?

Work at sea

During the *Polarstern* expedition PS136, we will conduct

- discrete measurements of N_2O and CH_4 in surface waters
- depth profiles of N_2O and CH_4 across the Fram Strait (focus on 79°N section)

Expected results

We expect large, yet spatially variable N_2O and CH_4 flux gradients within relatively small areas. Moreover, we expect significant physically-driven changes in the basin-wide distribution of N_2O and CH_4. In particular, we expect to be able to determine at what extent the polar outflow provides a source of GHG-undersaturated waters to the subpolar North Atlantic. By resolving these scales of variability (sub-km) we expect to contribute to an improved representation of GHG sea-ice-air fluxes in climate models, and more accurate estimates of the relative weight of this area for the Arctic and global N_2O and CH_4 budgets. Likewise, the planned work at 79°N builds upon surveys conducted by the group in 2018, 2019, and 2021 in the region.

Fig. 8.1: Filling of water samples to assess concentrations of greenhouse gases in surface waters (Photo: A. Nylund, Chalmers University of Technology, Gothenburg, Sweden)

Data management

The raw data derived from the measurements conducted on land (at the Chemical Oceanography Department of GEOMAR) will be stored at the Ocean Science Information System (OSIS; https://portal.geomar.de/osis), which is the central information and research data sharing facility for marine research projects at GEOMAR. OSIS is publicly accessible and can be utilized by all team members as well as national and international collaborators. Metadata and sampling sheets produced during the cruise will be stored immediately in an external driver and subsequently - as complementary files - in OSIS (two weeks after cruise end). Fully processed data sets reporting surface and water column seawater concentrations of N_2O and CH_4 will be uploaded after 12 months. Members of the Kiel Data Management Team (who run OSIS) are active curators of the public repository PANGAEA (https://www.pangaea.de) and will assist us during the preparation of data files for their archival, as well as publication procedures, thereby ensuring long-term archival and access to the research data. All data submitted to PANGAEA will be archived, published and disseminated according to international standards within two years after the end of the expedition at the latest, and will be subject of a 2-year moratorium. By default, the CC-BY license will be applied. Additionally,

N_2O and CH_4 data will be archived in the MEMENTO database (https://memento.geomar.de), which is a widely used tool for international researchers working on trace gas biogeochemistry.

In all publications based on this expedition, the Grant No. AWI_PS136_05 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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A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Beruf/ Profession	Fachrichtung/ Discipline
Andres	Maikani	Student (Master)	Biology
Asendorf	Volker	Technician	Biology
Alexandra	Aves	Scientist	Biology
Bergmann	Melanie	Scientist	Biology
Breunig	Emelie	Student (Master)	Oceanography
Brix	Saskia	Scientist	Biology
Bryan	Natasha	Scientist	Biology
Busack	Michael	Engineer	Engineering Sciences
Dannheim	Jennifer	Scientist	Biology
Flegar	Konstantin	Student (Bachelor)	Engineering Sciences
Freer	Jennifer	Scientist	Biology
Hagemann	Jonas	Engineer	Engineering Sciences
Hasemann	Christiane	Scientist	Biology
Hecken	Timo	Technician	Helicopter Service
Hirschmann	Sophia	PhD student	Biology
Isler	Tea	PhD Student	Bathymetry
Jack	Harding	Pilot	Helicopter Service
Kistrup	Katharina	Volunteer	Biology
Klüver	Tania	Technician	Biology
Knüppel	Nadine	Technician	Biology
Kraberg	Alexandra	Scientist	Biology
Lehmenhecker	Sascha	Engineer	Engineering Sciences
Linse	Katrin	Scientist	Biology
Lochthofen	Normen	Engineer	Engineering Sciences
Ludszuweit	Janine	Technician	Biology
McPherson	Rebecca	Scientist	Oceanography
Metfies	Katja	Scientist	Biology
Neber	Anneke	Student (Bachelor)	Engineering Sciences
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Pohlmann	Marei	Student (Master)	Chemistry
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Purser	Autun	Scientist	Biology
Rehder	Linda	PhD student	Biology
Rohleder	Christian	Scientist	Meterology
Rückert	Sonja	Scientist	Biology
Schewe	Ingo	Scientist	Biology
Schmidt	Lydia	Student (Master)	Biology
Scholz	Daniel	Engineer	Chemistry

Name/ Last name	**Vorname/ First name**	**Beruf/ Profession**	**Fachrichtung/ Discipline**
Schrage	Kharis	PhD student	Biology
Sebastian	Archana	Student (Master)	Oceanography
Seifert	Michael	Technician	Helicopter Service
Soltwedel	Thomas	Lead Scientist	Biology
Thielecke	Antonia	PhD student	Biology
Torres-Valdés	Sinhué	Scientist	Oceanography
Vane	Kim	Scientist	Biology
Vaupel	Lars	Pilot	Helicopter Service
Volpe	Gianluca	Scientist	Oceanography
Wenzel	Anna Julia	Scientist	Meteorology
Xi	Hongyan	Scientist	Oceanography

A.3 SCHIFFSBESATZUNG / SHIP‘S CREW

Name	Vorname / First Name	Position
Wunderlich	Thomas Wolf	Master
Langhinrichs	Jacob	Chiefmate
Eckenfels	Hannes	Chiefmate Cargo
Ziemann	Olaf	Chief
Falk	Stefan	2nd Mate
Peine	Lutz	2nd Mate
Dr. Guba	Klaus	Ships Doc
Müller	Andreas	ELO
Ehrke	Tom	2nd. Eng
Krinfeld	Oleksandr	2nd. Eng
Rusch	Torben	2nd. Eng
Pommerencke	Bernd	SET
Frank	Gerhard	ELO
Schwedka	Thorsten	ELO
Winter	Andreas	ELO
Krüger	Lars	ELO
Brück	Sebastian	Bosun
Keller	Eugen Jürgen	Carpen.
Möller	Falko	MP Rat.
Buchholz	Joscha	MP Rat.
Schade	Tom	MP Rat.
Decker	Jens	MP Rat.
Fink	Anna-Maria	MP Rat.
Weiß	Daniel	MP Rat.
Niebuhr	Tim	MP Rat.
Lutz	Johannes	MP Rat.
Luckhardt	Arne	MP Rat.
Jassmann	Marvin	MP Rat.
Probst	Lorenz	MP Rat.
Clasen	Nils	MP Rat.
Arnold-Becker	André	MP Rat.
Waterstradt	Felix	MP Rat.
Plehn	Marco Markus	Storek.
Matter	Sebastian Udo	Cook
Bogner	Christoph Friedemann	Cooksm.
Lang	Gerd Martin	Cooksm.
Witusch	Petra	Chief Stew.
Ilk	Romy	2nd Stew
Fehrenbach	Martina	2nd Stew

Name	Vorname / First Name	Position
Golla	Gerald	2nd Stew
TBN		2nd Stew
Shi	Wubo	2nd Stew
TBN		2nd Stew
Chen	Quan	Laundrym