Institute of Oceanology
Polish Academy of Sciences

Report from the RV Oceania research cruise

AREX 2023

LEG I (15.06 - 23.06.2023)

Cruise leader: Dr Przemysław Makuch

LEG II (24.06 - 06.07.2023)
LEG III (07.06 - 24.07.2023)

Cruise leader: Dr Agnieszka Beszczyńska-Möller

LEG IVa (25.07 - 02.08.2023)
LEG IVb (03.08 - 12.08.2023)
LEG IVc (13.08 - 20.09.2023)

Cruise leader: Dr Mikołaj Mazurkiewicz

LEG IVd (21.08 - 24.08.2023)

Cruise leader: Prof. Jan Marcin Węsławski

LEG V (25.08 - 09.09.2023)

Cruise leader: Dr Joanna Pawłowska

AREX 2023 cruise PI/coordinator: Dr Agnieszka Beszczyńska-Möller

Content

1 Scientific background of the AREX2023 cruise

1.1 Long-term large-scale Arctic monitoring program AREX

Oceanographic, physical, atmospheric, and biochemical measurements conducted since 1987 in the Nordic Seas and the Fram Strait region by the Institute of Oceanology of the Polish Academy of Sciences in Sopot aim to investigate and describe the processes shaping atmospheric exchanges, ocean climate, and the ecosystem of sub-Arctic and Arctic regions, with a particular focus on the European Arctic.

The annual summer AREX measurement expeditions include multidisciplinary in situ oceanographic, optical, acoustic, biogeochemical, biological, and atmospheric observations in the Nordic Seas, the Fram Strait, and the fjords of western Svalbard, and in recent years also in the ice-free areas of the Arctic Ocean. These measurements are carried out each year at approximately the same time along a regular observational grid covering more than 300 research stations in the Norwegian Sea, Greenland Sea, the entrance to the Barents Sea, the Fram Strait, the fjords of western Svalbard (Hornsund, Isfjorden, Kongsfjorden), and the southern part of the Nansen Basin.

Time series of key oceanic variables (EOVs, Essential Ocean Variables), collected over more than 30 years of measurements within the AREX program, make it possible to monitor changes occurring at different temporal scales in the physical and biological environment of the Arctic, as well as to improve existing ocean, sea-ice, and climate models for the Arctic region.

The AREX program has also represented IOPAN's contribution to research conducted within international collaborations such as VEINS (Variability of Exchanges in the Nordic Seas, 1997–2000), ASOF-N (Arctic and subArctic Oceanic Fluxes North, 2003–2005), DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environment Studies, 2006–2009), as well as several Polish–Norwegian projects (Polish-Norwegian Research Programme) including AWAKE (1 and 2), PAVE, POLNOR, CLISE, CDOM-HEAT, and DWARF (2013–2016). The collected data are also used in numerous NCN and NCBR projects and in doctoral research.

The measurements planned during the AREX 2023 cruise also constitute IOPAN's contribution to the implementation of the international projects EU HE HiAOOS (2023–2026), HE MARBEFES (2022–2026), EraNET MarTERA BIOGLIDER (2022–2023), and the ArgoPoland infrastructure project (Euro-Argo ERIC), the Polish–Norwegian GRIEG projects (PHARMARINE, RAW, and NEEDED), as well as other projects carried out in international collaboration (ACCESS, ADAMANT, CLIMB, PROSPECTOR, ANALOG, OPTYKA-BIS, CoastDark, Alkenon).

Long-term measurements on standard sections and stations represent IOPAN's and Poland's contribution to the international Arctic observation program ADBO (Atlantic Arctic Distributed Biological Observatory), as well as to long-term ocean observational time series that form part of the ICES Report on Ocean Climate, published annually by the ICES Ocean Hydrography Working Group (OHWG).

1.2 International and national projects during the AREX2023 cruise

1.2.1 PHARMARINE

The project “Transport of pharmaceuticals used in human therapy by ocean currents and the impact of these compounds on marine organisms in the European Arctic” (**PHARMARINE**) received funding under the GRIEG call for Polish–Norwegian research projects. The results obtained will provide new empirical information on the biological effects of pharmaceuticals and the risks they pose to the Arctic marine ecosystem.

The aim of the research planned within the project is to determine the pathways and forms of transport of commonly used pharmaceuticals carried by ocean currents from the more contaminated areas of continental Europe to the European Arctic, to investigate the processes of bioaccumulation and biomagnification of drugs in the Arctic, and to assess the influence of pharmaceutical pollutants on sedentary benthic fauna. As a result of the conducted studies, stress indicators caused by the presence of pharmaceuticals will be defined in animals. These indicators may be used as tools for forecasting and assessing environmental risks associated with the presence of pharmaceuticals in the Arctic ecosystem.

1.2.2 HE MARBEFES

The **MARBEFES** project is based on the concept that biodiversity constitutes a continuous and interconnected system in space and time, transcending traditional boundaries such as "estuary," "coast," or "open waters." MARBEFES considers the gradient from river to ocean, utilizing 12 Broad Transect Belts across four major EU marine regions – the Arctic, Baltic, Atlantic, and Mediterranean. The primary goal of MARBEFES is to establish clear links between biodiversity, ecosystem functions, and the societal benefits they provide. This goal is achieved through an innovative set of ecological, economic, and socio-cultural tools, enabling a comprehensive valuation to support sustainable policy and management of marine ecosystems.

1.2.3 Argo Poland

The **Argo Poland** Infrastructure Project - Poland's participation in the European Research Infrastructure Consortium Euro-Argo ERIC has been ongoing since 2008, representing Poland's contribution to modern oceanographic research using Argo profiling floats. The Argo system is an organized network of 4,000 autonomous, drifting research devices that profile the water column of the world's oceans. Poland's involvement in the Argo network began with the deployment of Argo floats in the Arctic in 2008, and since 2016, the measurement system has been expanded to the Baltic Sea. From 2021 to 2026, new measurements and data analyses are planned, as well as an extension of research to include polar fjords. In addition to standard floats, advanced biogeochemical Argo floats (BGC-Argo) will be utilized. The project includes innovative development activities, such as continued work on a float recovery system and improvements in data processing and quality control for Argo float data.

1.2.4 HE HiAOOS

The **HiAOOS - High Arctic Ocean Observing System** project aims to develop, implement, and validate new ocean observation technologies to improve the acquisition of measurement data from the ice-covered regions of the Arctic Ocean. A network of multifunctional, moored measurement arrays will be deployed for two years in the Nansen Basin, the Amundsen Basin, and north of Svalbard. To better utilize the capabilities of the new observation system, new methods and tools for data analysis and visualization will be developed, including the use of modern machine learning techniques. For training purposes and to enable the use of new data and methods by a wide range of stakeholders, the Blue Insight platform will be developed, serving as a digital analog of the studied Arctic Ocean regions.

1.2.5 ERA.Net MarTERA BIOGLIDER

The BIOGLIDER project aims to develop and prepare for deployment a multi-platform intelligent solution for autonomous underwater vehicles (gliders) designed to collect observational data in marine ecosystems. Through close collaboration between industrial and scientific partners, BIOGLIDER will combine the specialized expertise of partners from France, Norway, Poland, and Cyprus in new technologies, including sensors for physical and biological measurements in the ocean and the use of autonomous underwater vehicles, in order to obtain new observations of marine ecosystems in the extreme environment of the Nordic Seas and the Arctic Ocean. Within BIOGLIDER, a miniaturized underwater imaging system (profiling video camera) and a scientific echosounder for biological measurements will be integrated, along with a new acoustic telemetry system designed to transmit data between measurement instruments located on fixed underwater observing platforms and gliders operating in the water column. These solutions are intended to enable, in the future, near-real-time monitoring of the poorly understood mesopelagic ecosystem for applications in marine research and environmental exploration.

1.2.6 International observing network A-DBO

The **Atlantic-Arctic Distributed Biological Observatory (A-DBO)** is an international initiative focused on creating a comprehensive observational network for climate and environmental monitoring in the Atlantic sector of the Arctic Ocean—one of the key gateway regions to the Arctic, currently experiencing rapid environmental, climatic, and ecosystem changes. Together with the pioneering observatory in the Pacific sector of the Arctic Ocean (DBO), the DBO in the Davis Strait/Baffin Bay, and the Siberian DBO, the Atlantic DBO (A-DBO) aims to make a significant contribution to the pan-Arctic observational collaboration network. IOPAN is among the initiators of the A-DBO, with data from the long-term observational program AREX representing its contribution to the A-DBO observational network.

1.2.7 NCN reFRAME

The **reFRAME - Recirculation of Atlantic Water in the Fram Strait and its Interactions with the Ocean-Climate System** project aims to reconstruct the environmental conditions in the Fram Strait from the early Holocene to the present day. To achieve this, the project involves analyzing a series of marine sediment cores collected across the width of the strait, including the continental shelves on both sides and the deep central part. This research will provide the most comprehensive possible picture of the marine environment in this region over the last several thousand years. The main objective of the study is to reconstruct the activity of the Atlantic Return Current during this period.

1.2.8 NEEDED

The main objective of the NCN GRIEG project “Sedimentary ancient DNA – a new proxy to investigate the impact of environmental change on past and present biodiversity in Nordic Seas (NEEDED)” is to use DNA preserved in water and in modern and fossil marine sediments to describe changes in microeukaryotic communities in the geological past. The biodiversity data obtained in this way will be combined with information on environmental changes provided by classical paleoceanographic indicators (so-called proxies). This will enable the reconstruction of the history of marine life and ecosystem changes in the Nordic Seas over the past 20,000 years.

1.2.9 Resilience of Arctic marine biodiversity to environmental change: a paleogenomics approach

The goal of the National Geographic Society project "Resilience of Arctic marine biodiversity to environmental change: a paleogenomics approach" is to reconstruct changes in marine biodiversity in Kongsfjorden over the past ~150 years, that is, during a period of intensified anthropogenic activity in this region. Combining molecular analyses with classical paleoceanographic indicators will allow the reconstruction of changes in key environmental parameters (e.g., temperature and salinity, sea ice) as well as a detailed description of changes in marine biodiversity.

1.2.10 NCN PROSPECTOR

The **PROSPECTOR** project is based on the main hypothesis that dissolved organic matter (DOM) released from permafrost is highly bioavailable and contains sufficient organic acids to significantly contribute to ocean acidification and substantially alter the marine carbonate system in Arctic shelf seas. The objectives of the project include characterizing the acid-base properties of DOM released from permafrost, quantifying the impact of organic acids of varying strength and concentration on the marine carbonate system under different environmental conditions, assessing the lability of permafrost-derived DOM, and estimating the extent of DOM's influence on the marine carbonate system and the pH of seawater.

1.2.11 NCN SURETY

The **SURETY** project aims to develop an optical method for determining surfactant activity, potentially eliminating the need for surface water sampling in the future. The project proposes the use of optical fluorescence measurements of surfactants and voltammetric measurements of surfactant activity (using the "mercury drop" method) to identify a new optical index of surfactant activity. This index, when incorporated into a mathematical formula alongside wind speed, is expected to provide better alignment with measured gas exchange velocity values than existing models that rely solely on wind speed.

2 Research program of the AREX2023 cruise

2.1 Research tasks during Leg I (Gdańsk – Tromsø)

- Determination of marine aerosol characteristics such as size distributions, concentrations, optical properties, and the share of light-absorbing aerosol within the marine aerosol composition (Task I.3).
- Determination of CO_2 fluxes in the near-surface atmospheric layer (SURETY project, Task I.3).
- Determination of sensible and latent heat fluxes between the sea and the atmosphere (Task I.3).
- Determination of meteorological conditions during the measurements (SURETY project, Task I.3).
- Estimation of corrections for ship-motion effects on wind speed and direction (SURETY project).
- Determination of gradient turbulent fluxes (Task I.3).
- Identification of relationships between the enrichment of the sea surface microlayer in CDOM and (i) gas-exchange velocity between the sea and the atmosphere, (ii) the occurrence of various sources of organic matter in the surface layer (Task I.3, SURETY project).
- Determination of spatial variability of pCO_2 and the structure of the carbonate system in surface waters (SURETY project, Task II.7).
- Assessment of meroplankton diversity based on molecular methods and taxonomic analyses (W.Patuła's PhD project, HIMERO project).
- Installation and implementation of the new Starlink Maritime system. Integration with the shipboard ecudo.pl data acquisition system. Modification of vessel-system policies related to Starlink Maritime data-limit management.
- Conducting empirical measurements of the inherent optical properties of the surface seawater layer, characteristics related to trichromatic water-color perception, and basic biogeochemical properties of water constituents, across diverse marine areas from the Baltic Sea to selected regions of the North Atlantic (Task I.1).
- Collection of video footage and photographs for the project "Tales of Mother Earth" (MARBEFES project).

2.2 Research tasks during Leg II (Gdańsk – Longyearbyen)

- Study of the structure and dynamics of the Norwegian Atlantic Current and the West Spitsbergen Current in the eastern part of the Norwegian Sea, the Greenland Sea, and the entrance to the Barents Sea (Task I.4).
- Investigation of the variability of temperature and salinity and ocean currents on the shelf and continental slope in the eastern part of the Norwegian Sea, the Greenland Sea, and the entrance to the Barents Sea (Task I.4).
- Study of the volume and heat transport in the Norwegian Atlantic Current and the West Spitsbergen Current (Task I.4).
- Determination of marine aerosol characteristics such as size distributions, concentrations, optical properties, and the contribution of absorbing aerosol to the composition of marine aerosol (Task I.3).
- Determination of the influence of aerosol on radiative fluxes at the sea surface (Task I.3).
- Determination of vertical CO_2 fluxes in the near-surface atmospheric layer (Task I.3).
- Determination of sensible and latent heat fluxes between the sea and the atmosphere (Task I.3).

- Determination of meteorological conditions during the measurements (Task I.3).
- Determination of Black Carbon concentrations in the near-surface atmospheric layer (Task I.3).
- Determination of the spatial variability of pCO_2 and the structure of the carbonate system in surface waters (SURETY project, Task II.7).
- Determination of the enrichment of the sea surface microlayer with organic matter (Task I.3, SURETY project).
- Identification of the qualitative and quantitative composition and distribution patterns of plankton communities (protist plankton and zooplankton) in the epi- and mesopelagic zones of the West Spitsbergen Current, in the context of environmental conditions (Task I.5).
- Assessment of the genetic diversity of zooplankton organisms in Atlantic and Arctic waters of the Nordic Seas (Task I.5).
- Identification of meroplankton diversity based on molecular methods and taxonomic analysis (PhD project by W. Patuła, HIMERO project).

2.3 Research tasks during Leg III Longyearbyen – Longyearbyen

- Study of the structure and dynamics of the West Spitsbergen Current in the Fram Strait and the Arctic Ocean Boundary Current in the ice-free region north of Svalbard (Task I.4).
- Study of the variability of temperature, salinity, and ocean currents on the shelf and continental slope west and north of Svalbard (Task I.4).
- Study of the volume and heat transport in the West Spitsbergen Current (Task I.4).
- Study of acoustic propagation conditions for underwater data transmission in Arctic environments (BIOGLIDER project).
- Determination of marine aerosol characteristics such as size distributions, concentrations, optical properties, and the share of absorbing aerosol in the marine aerosol composition (Task I.3).
- Determination of the impact of aerosol on radiative fluxes at the sea surface (Task I.3).
- Determination of vertical CO_2 fluxes in the near-surface atmospheric layer (Task I.3).
- Determination of sensible and latent heat fluxes between the sea and the atmosphere (Task I.3).
- Determination of meteorological conditions during the measurements (Task I.3).
- Determination of the enrichment of the sea surface microlayer in organic matter (Task I.3, SURETY project).
- Determination of the spatial variability of pCO_2 and the structure of the carbonate system in surface waters (SURETY project, Task II.7).
- Identification of the qualitative–quantitative composition and distribution patterns of plankton communities (protozooplankton and zooplankton) in the epi- and mesopelagic zone of the West Spitsbergen Current, in relation to environmental conditions (Task I.5).
- Assessment of the genetic diversity of zooplankton organisms in Atlantic and Arctic waters of the Nordic Seas (Task I.5).
- Identification of meroplankton diversity based on molecular methods and taxonomic analysis (doctoral project of W. Patuła, HIMERO project).

2.4 Research tasks during Leg IVa (Horsund)

2.4.1 Marine Ecology Department - plankton (PEP)

- Characterizing meroplankton diversity using molecular methods and taxonomic analysis (PhD project by W. Patuła, HIMERO project; collaboration with Task I.5).
- Expanding the genetic reference database of nuclear 18S rRNA and mitochondrial 16S rRNA for selected planktonic organisms, and estimating zooplankton diversity in the European Arctic based on metabarcoding (HIDEA project, project leader: Dr hab. A. Weydmann-Zwolicka, University of Gdańsk; collaboration with Task I.5).
- Comparing habitat and feeding preferences between twin zooplankton species characterized by different centers of distribution (Arctic or boreal) across three regions of the Polar Front: the Atlantic zone, the Arctic zone, and the mixing zone (TWINS project).
- Determining the qualitative and quantitative composition and spatial distribution patterns of plankton communities in Hornsund Fjord and its adjacent waters, in relation to environmental conditions (Task I.5).
- Assessing zooplankton availability on the foraging grounds of the little auk in front of Hornsund Fjord (Task I.5).

2.4.2 Marine Ecology Department - plankton (PFBP)

- Determining the foraging resources of the little auk nesting in Hornsund (HOR) using WP2 nets (180 µm) and optical methods (LOPC, UVP) (Task I.7, LAPSE and SEAPOP III projects).
- Investigating the variability of carotenoids in key Arctic zooplankton species (Calanus copepods) and its impact on diet quality and the condition of their main predators — planktivorous seabirds (little auks) during the breeding season (Task I.7, ORANGE project).
- Identifying the distribution characteristics and qualitative–quantitative composition of plankton communities in Hornsund (HOR) in relation to environmental factors using traditional methods (plankton nets, bathometers) and optical methods (LOPC, UVP) (statutory research Task I.7, ANNCA project, CoastDark project, RAW project).

2.4.3 Marine Ecology Department - benthos (PEB)

- Determination of the taxonomic composition, biomass and abundance of macro- and meiozoobenthos, as well as benthic biodiversity assessed using metagenomic methods at monitoring stations in Hornsund fjord (Task III.1, MetaDiva project).
- Assessment of the diversity and distribution patterns of Kinorhyncha, with particular emphasis on species with a broad geographic range, based on morphological and molecular analysis (Task III.1).
- Conduct 10-minute video recordings of the seafloor along a depth transect (approximately from 20 to 200 m) in order to analyze biodiversity, seafloor characteristics, and tracks left by organisms while moving, etc. (B. Oleszczuk).

2.4.4 Marine Ecology Department (PFE)

- Assessment of the chemical composition of seawater in Hornsund Fjord in terms of the availability of nutrients required for the development of kelp forests, as well as identification of factors that may potentially inhibit their growth (ANALOG project).

2.4.5 Marine Chemistry and Biochemistry Department (PBM)

- Determination of the variability of the carbonate system and its controlling factors in the surface layer and the water column (PROSPECTOR project).
- Determination of the bioavailability and acid–base properties of dissolved organic matter released from sediments and delivered from land (PROSPECTOR project).

2.4.6 Marine Dynamics Department - physical oceanography (POO)

- Study of thermohaline and oxygen properties and the distribution of water masses in Hornsund Fjord and in the western Spitsbergen shelf region (Task I.4).
- Determination of meteorological conditions during the measurements (Task I.3).

2.4.7 Marine Physics Department - marine optics (PTM)

- Identification of the optical properties of the waters of Svalbard fjords, including for the purpose of developing local satellite algorithms to determine the concentrations of seawater constituents in the North Atlantic (Task II.5).
- Studies of the spectral characteristics of vertical profiles of solar light attenuation in the water column and surface spectral reflectance distributions (COPs) (Task II.5).
- Determination of the spectral absorption and beam attenuation coefficients in the vertical profile, as well as the concentrations of chlorophyll a and suspended matter (acs) (Task II.5, DOMinEA).
- Characterization of variability in the inherent optical properties of seawater in relation to the concentration, composition, and size distribution of suspended particle populations present in these waters (Task I.1).
- Determination of the influence of marine particles of different sizes in four size fractions—pico- (0.2 µm–2 µm), ultra- (2 µm–5 µm), nano- (5 µm–20 µm), and microplankton (20 µm–200 µm)—on the shape and magnitude of the spectral light attenuation coefficient (ap), separated into phytoplankton (aph) and detritus (ad) components (DOMinEA, Task I.1).
- Quantitative and qualitative determination of the composition of dissolved organic matter using DOM absorption and fluorescence, salinity, temperature, dissolved oxygen (DO), DOC, chlorophyll a and other pigments, and lignin concentrations as markers of terrestrially derived material (DOMinEA).
- Determination, in the vertical profile (down to 200 m), of the spectral absorption and beam attenuation coefficients as well as the concentrations of chlorophyll a and suspended matter (acs) (Task II.5, DOMinEA).
- Determination of the spectral characteristics of vertical profiles of solar light attenuation in the water column and surface spectral reflectance distributions using the C-PrOPS profiling radiometer (Biospherical) and Ramses radiometer sets (TRIOS) (Task II.5).
- Determination of primary production in the water column using the C14 method in order to compare the effects of mineral substances and nutrients supplied by river runoff and melting glaciers on its magnitude (Task I.2, project RAW).

2.5 Research tasks during Leg IVb (Kongsfjorden, Magdalenefjorden)

2.5.1 Marine Ecology Department - plankton (PEP)

- Identification of meroplankton diversity based on molecular methods and taxonomic analysis (PhD project by W. Patuła, HIMERO project; collaboration with Task I.5).
- Expansion of the genetic reference database for nuclear 18S rRNA and mitochondrial 16S rRNA of selected planktonic organisms, and assessment of zooplankton diversity in the European Arctic based on metabarcoding (NCN HIDEA project, project leader Dr. habil. A. Weydmann-Zwolicka, University of Gdańsk; collaboration with Task I.5).

2.5.2 Marine Ecology Department - plankton (PFBP)

- Determination of the food availability at the foraging grounds of little auks breeding in Kongsfjorden (KGF) and Magdalenefjorden (MG) using WP2 nets (180 µm) and optical methods (LOPC, UVP) (Task I.7, LAPSE and SEAPOP III projects).
- Investigation of carotenoid variability in key Arctic zooplankton species (Calanus copepods) and its influence on diet quality and the condition of their main predators—planktivorous seabirds (little auks)—during the breeding season in KGF and MG (Task I.7, ORANGE project).
- Assessment of the distribution patterns and qualitative–quantitative composition of plankton communities in Kongsfjorden (KGF) in relation to environmental conditions, using traditional methods (plankton nets, bathometers) and optical methods (LOPC, UVP) (statutory research Task I.7, ANNCA project, CoastDark project, RAW project).

2.5.3 Marine Ecology Department - benthos (PEB)

- Determination of the taxonomic composition, biomass and abundance of macro- and meiozoobenthos, as well as benthic biodiversity using metagenomic methods, at monitoring stations in Kongsfjorden (Task III.1).
- Determination of pharmaceutical concentrations in the tissues of benthic organisms in Kongsfjorden (PHARMARINE project, M. Mazurkiewicz).
- Investigation of the community of underwater Hydrozoa meadows associated with *Chlamys islandica*.

2.5.4 Marine Ecology Department (PFE)

- Assessment of the chemical composition of seawater in Kongsfjorden in terms of the availability of nutrients required for the development of kelp forests, as well as identification of factors that may potentially inhibit their development (ANALOG project).

2.5.5 Marine Chemistry and Biochemistry Department (PBM)

- Determination of the variability of the carbonate system and the factors controlling it in the surface layer and the water column (PROSPECTOR project).
- Determination of the bioavailability and acid–base properties of dissolved organic matter released from sediments and delivered from land (PROSPECTOR project).

2.5.6 Marine Chemistry and Biochemistry Department (WZEM)

- Determining the impact of climate change on the concentration and bioavailability of mercury (Hg) by examining Hg levels in sediments and water near thawing permafrost and glaciers in the Kongsfjorden and Magdalenefjorden fjords (Task II.8).

2.5.7 Marine Dynamics Department - physical oceanography (POO)

- Study of thermohaline and oxygen properties, as well as the distribution of water masses in Kongsfjorden and in the area of the western Svalbard shelf (Task I.4).

2.5.8 Marine Physics Department - marine optics (PTM)

- Investigation of the optical properties of the waters of Spitsbergen fjords, including for the purpose of developing local satellite algorithms to determine the concentration of seawater constituents in the North Atlantic (Task II.5).
- Study of the spectral characteristics of vertical profiles of solar light attenuation in the water column and surface spectral reflectance distributions (COPs) (Task II.5).
- Determination of spectral absorption and beam attenuation coefficients in the vertical profile, as well as concentrations of chlorophyll a and suspended matter (acs) (Task II.5, DOMinEA).
- Characterization of the variability of inherent optical properties of seawater in relation to the concentration, composition, and size distribution of suspended particle populations occurring in these waters (Task I.1).
- Determination of the influence of suspended marine particles of different sizes in four size fractions—pico- (0.2 µm–2 µm), ultra- (2 µm–5 µm), nano- (5 µm–20 µm), and microplankton (20 µm–200 µm)—on the shape of the light attenuation coefficient spectrum and its magnitude (ap), partitioned into phytoplankton (aph) and detritus (ad) (DOMinEA, Task I.1).
- Quantitative and qualitative determination of the composition of dissolved organic matter using DOM absorption and fluorescence, salinity, temperature, dissolved oxygen (DO), dissolved organic carbon (DOC), chlorophyll a and other pigments, and lignin concentrations as markers of terrestrially derived material (DOMinEA).
- Determination, in the vertical profile (down to 200 m), of spectral absorption and beam attenuation coefficients as well as chlorophyll a concentration and suspended matter (acs) (Task II.5, DOMinEA).
- Determination of the spectral characteristics of vertical profiles of solar light attenuation in the water column and surface spectral reflectance distributions using the profiling radiometer C-PrOPS (Biospherical) and Ramses radiometer systems (TRIOS) (Task II.5).

2.6 Research tasks during Leg IVc (Isfjorden)

2.6.1 Marine Ecology Department - plankton (PEP)

- Characterization of meroplankton diversity based on molecular methods and taxonomic analysis (PhD project of W. Patuła, HIMERO project; collaboration under Task I.5).
- Characterization of the spatial distribution and qualitative–quantitative structure of plankton communities in Isfjorden in relation to environmental conditions, using traditional methods (plankton nets, bathometers) and optical methods (LOPC, UVP) (statutory research Task I.7, NCN PRELUDIUM “ANNCA”, NCN OPUS CoastDark, GRIEG RAW).

2.6.2 Marine Ecology Department (PFE)

- Assessment of the chemical composition of seawater in Isfjorden in terms of the availability of nutrients required for the development of kelp forests, as well as identification of factors that may potentially inhibit their growth (ANALOG project).

2.6.3 Marine Physics Department - marine optics (PTM)

- Investigation of the optical properties of the waters of Spitsbergen fjords, including for the purpose of developing local satellite algorithms to determine the concentration of seawater constituents in the North Atlantic (Task II.5).
- Study of the spectral characteristics of vertical profiles of solar light attenuation in the water column and surface spectral reflectance distributions (COPs) (Task II.5).
- Determination of spectral absorption and beam attenuation coefficients in the vertical profile, as well as concentrations of chlorophyll a and suspended matter (acs) (Task II.5, DOMinEA).
- Characterization of the variability of inherent optical properties of seawater in relation to the concentration, composition, and size distribution of suspended particle populations occurring in these waters (Task I.1).
- Determination of the influence of suspended marine particles of different sizes in four size fractions—pico- (0.2 µm–2 µm), ultra- (2 µm–5 µm), nano- (5 µm–20 µm), and microplankton (20 µm–200 µm)—on the shape of the light attenuation coefficient spectrum and its magnitude (ap), partitioned into phytoplankton (aph) and detritus (ad) (DOMinEA, Task I.1).
- Quantitative and qualitative determination of the composition of dissolved organic matter using DOM absorption and fluorescence, salinity, temperature, dissolved oxygen (DO), dissolved organic carbon (DOC), chlorophyll a and other pigments, and lignin concentrations as markers of terrestrially derived material (DOMinEA).
- Determination, in the vertical profile (down to 200 m), of spectral absorption and beam attenuation coefficients as well as chlorophyll a concentration and suspended matter (acs) (Task II.5, DOMinEA).
- Determination of the spectral characteristics of vertical profiles of solar light attenuation in the water column and surface spectral reflectance distributions using the profiling radiometer C-PrOPS (Biospherical) and Ramses radiometer systems (TRIOS) (Task II.5).

2.6.4 Marine Chemistry and Biochemistry Department (WZEM)

- Assessment of the impact of climate change on the concentration and bioavailability of mercury (Hg) through the analysis of Hg levels in sediments and seawater near thawing permafrost and glaciers in Billefjorden (Task II.8).
- Determination of the variability of the carbonate system and its controlling factors in the surface layer and the water column (PROSPECTOR project).
- Determination of the bioavailability and acid–base properties of dissolved organic matter released from sediments and supplied from land (PROSPECTOR project).

2.7 Research tasks during Leg IVd (Isfjorden)

- Collaboration with Academia Sinica – Taiwan – Polish Academy of Sciences: research project on epifauna and identification of monitoring sites parallel to studies conducted in Taiwan.

- • ADAMANT project – NCN – DAINA: completion of coastal zone studies in ice-covered and ice-free areas.
- ARK – Land Promontories project – Miljovernfond Sysselmannen: inspection of headlands in western Spitsbergen for the presence of invasive species and marine debris (plastic).
- MARBEFES project: completion of habitat mapping of Spitsbergen fjord seafloors – underwater photography and collaboration with artists – PGS Sopot.

2.8 Research tasks during Leg V Longyearbyen - Tromsø - Gdańsk

2.8.1 Paleooceanography Department

- Reconstruction of changes in the marine environment on the northwestern European shelf after the last glaciation, using foraminifera as the primary paleoenvironmental indicator, supplemented with biogeochemical and genomic proxies (Task III.2, projects NEEDED, Alkenon, reFrame, and the National Geographic Society project Resilience of Arctic marine biodiversity to environmental change: a paleogenomics approach).
- Concentrations and origin of microplastics in the Nordic Seas, University of Warsaw project.

3 General schedule of the AREX2023 cruise

Table 3.1. General schedule of the AREX2023 cruise

Leg	Date	Region	Cruise leader	Comments
I	**15.06-23.07.2023**	Gdańsk - Tromsø (transit)	Przemysław Makuch	
II	**24.06-06.07.2023**	Tromsø-LYR (Norwegian and Greenland Sea)	Agnieszka Beszczyńska-Möller	
	06.07.2023 (czwartek)	stay in LYR (logistics) crew exchange		0800-2400
III	**07.07-24.07.2023**	Longyearbyen – Longyearbyen (Fram Strait, Southern Nansen Basin)	Agnieszka Beszczyńska-Möller	
	24.07.2023	postój techniczny LYR crew exchange		0800-2400
IVa	**25.07-02.08.2023**	LYR-LYR (Hornsund)	Mikołaj Mazurkiewicz	
IVb	**03.08-12.08.2023**	LYR-LYR (Kongsfjorden, Krossfjorden, Magdalenefjorden)	Mikołaj Mazurkiewicz	
IVc	**13.08-20.08.2023**	LYR-LYR (Isfjorden)	Mikołaj Mazurkiewicz	
IVd	**21.08-24.08.2023**	LYR-LYR (Isfjorden coastal areas)	Jan Marcin Węsławski	arrival 21.08 14:00
	24/25.08.2022	postój techniczny LYR crew exchange		arrival LYR latest at 24.08 17:00
V	**25.08-10.09.202**	Longyearbyen - Tromsø - Gdańsk	Joanna Pawłowska	

4 Itinerary of the AREX2023 cruise

Time given as Local Time (CEST).

15 June	Departure from Gdańsk at 10:00, start of the cruise. Transit toward the Danish Straits.
16 June	Transit toward station PhM1. Aerosol, chemical, and optical measurements.
17 June	Transit toward station PhM3. Aerosol, chemical, and optical measurements.
18 June	Aerosol, chemical, and optical measurements.
19 June	Measurements at station PhM3, transit toward station PhM5. Aerosol, chemical, and optical measurements.
20 June	Transit toward station PhM5. Aerosol, chemical, and optical measurements.
21 June	Transit toward station PhM5. Measurements at station PhM5. Transit to Malangen fjord. Aerosol, chemical, and optical measurements.
22 June	00:00 arrival in the port of Tromsø. Stay in Tromsø.
23 June	Arrival of part of the research team at 13:00. Boarding and passport control at the police checkpoint at 14:30. Water taken at Quay 1. Departure from Quay 1 in the centre at 23:30. Approach to the fuel bunker at 24:00.
24 June	Departure to sea after refuelling ~02:30. Transit to station H1 (9.5–10 kn). Very good weather, sea state 0, wind up to 1B.
25 June	Start of measurements on section H from H1 at 03:10 LT. Continuation to H11. Plankton nets at H3, H4, H10. Very good weather 0–1B, wave to 0.5 m. At night 1–2B. Night failure of the large winch cable connector, repair and continuation.
26 June	Continuation of measurements on section H (H12 to H17). Plankton nets at H13. Very good weather 0–2B, wave up to 1 m.
27 June	Continuation of measurements on section H to H19, finished 11:00 LT. Transit to section K, start of measurements at K18 at 20:40 LT to K17. Very good weather 0–1B, waves up to 0.5 m.
28 June	Continuation of measurements on section K from K16 to K11. Good weather 0–2B, waves up to 1 m.
29 June	Continuation of measurements on section K from K10 to K3. Slightly worse weather 2–3B, waves 0.5-1 m.
30 June	Continuation of measurements on section K from K2 to K–3. Finish of K at 11:00 LT. Good weather 2–3B, wave to 1 m. Transit to Bear Island to the stop site, stay until 19:00. Transit to section V2, start of measurements at V21 at 20:00 LT, measurements to V26.
1 July	Continuation of measurements on section V2. Measurements from V27 to V38, completed at 19:10 LT. Good weather, approx. 3B, waves 1–1.5 m, increasing. Due to worsening forecast on section N (up to 6–7B, waves up to 3 m, wind ENE–NE), decision made to transit to section S.
2 July	Start of measurements on section S from S0 at 03:40 LT. Continuation on section S to S9. Good weather, 2–3B, waves up to 1 m.
3 July	Continuation of measurements on section S from station S9P to S16. Good weather, 2–3B, waves up to 1 m.
4 July	Continuation of measurements on section S to station S18. Ice edge at approx. 000°. Moderately good weather, wind 3–4B, increasing waves to 1.5 m, additional swell. Completion of measurements on section S at 13:00 LT. Transit to Longyearbyen (approx. 24 h). Very good weather, light wind 1–2B.
5 July	Entry into Isfjorden. Stop at Bjoerndalen for fishing. Transit to Longyearbyen. Approach to refuelling at 14:30 LT; refuelling for approx. 2.5 h. Anchoring in Longyearbyen. Very good weather, sunny and warm, light wind 1–2B.
6 July	Crew exchange, 2 persons disembarking, 2 persons boarding at approx. 15:00 LT. Approach to the quay at 18:30 LT. Water loading, garbage removal. Departure from the quay and departure from Longyearbyen at 20:30 LT. Transit to section N. Very good weather, wind 1–2B, waves < 0.5 m. Installation of the oxygen sensor SBE43 on the SBE CTD system.
7 July	Transit to section N; start of measurements from N5 at 11:15 LT. At station N5 incorrect oxygen readings from SBE43. Repair (cable replacement). At station N4 plankton nets and acoustic tests. Good weather, wind 2–3B, waves approx. 0.5 m. Continuation to station N2. In the evening worsening weather, wind 3B, waves 0.7–0.8 m.
8 July	Continuation of measurements on section N from station N2. Wind increasing to 4B, waves up to 1 m.
9 July	Continuation of measurements on section N from station N to station N. Wind 3–4B, waves approx. 1 m.
10 July	Continuation of measurements on section N from station N to station N. Wind 3–4B, at times 5B, waves approx. 1 m, occasionally strong swell. Completion of measurements on section N at station N–15 at 21:40 LT. During sampling at station N–15, loss of one bottle (Niskin) from the rosette. Transit to the end of section S.
11 July	Measurements at station S19 from 02:40 to 05:55 LT. Transit to the end of section Z. En route avoidance of a large ice field extending to approx. 001°30'E. Start of measurements at station Z15 at 13:30 LT. Good weather, wind approx. 3B, waves 0.6–0.8 m. Continuation to Z13.
12 July	Continuation of measurements on section Z from Z12 to Z7. Average weather, increasing wind approx. 3–4B, waves up to 1 m.
13 July	Continuation of measurements on section Z from Z6 to Z1, completion at 12:00 LT. Average weather, wind increasing approx. 3–4B, waves up to 1 m. Due to an unfavourable forecast west of northern Svalbard (EB2 and EX), decision made to move to the region north of Svalbard. Transit to section WB via Smeerenburgfjorden.

14 July	Transit to section WB, start of measurements at WB1 at 07:50 LT. Continuation of measurements toward the ice edge to station WB12. Continuation of the section along the ice edge eastward (stations WB13E to WB16E). Very good weather, 1–2B, waves up to 0.5 m.
15 July	Continuation of section WB along the ice edge (station WB17E) and then back toward shore from station WB17E to station WB27E (a section parallel to the original WB, shifted eastward, ending near Moffen). Completion of the WB section at 18:20 LT. Very good weather, 1–2B, waves up to 0.5 m, later deteriorating to 3–4B.
16 July	Transit to section Y, start of measurements at station Y13 at 03:20 LT. Continuation of measurements on section Y to station Y1, ending at 19:30 LT. Average weather near the ice (3–4B), worsening rapidly toward land, waves increasing to over 1 m. Due to very unfavourable 2-day forecast in the EX and EB2 region, decision to enter Magdalenafjorden.
17 July	Night entry into Magdalenafjorden and anchoring in the inner bay (deep part). Rosette repair (due to failure of the bottle-triggering system, likely linked to the controller module in the probe; transfer of new sensors to the old probe). Rosette tests. Very good weather in the fjord, no waves.
18 July	Continued anchoring in Magdalenafjorden. Good weather in the fjord, stronger afternoon wind. Move to a more sheltered anchorage farther north. Forecast for Wednesday improving from the south.
19 July	Anchoring in Magdalenafjorden, departure from anchor at 11:00 LT. Exit from the fjord and transit to the mouth of Kongsfjorden. Positioning and drift-testing in the central part of the fjord entrance (depth 220–290 m). CTD station. Very good weather, no wind, no waves.
20 July	Departure from Krossfjorden at 06:00 LT. Transit to section EB2. Start of measurements at station EB2-1 at 08:50 LT. Continuation of EB2 section to station EB2-6. Good weather, wind 2–3B, waves initially up to 1 m, later decreasing to 0.5 m.
21 July	Continuation of measurements on section EB2 from station EB2-6P to station EB2-11. Very good weather, wind 1–2B, waves below 0.5 m.
22 July	Continuation of measurements on section EB2 from station EB2-11P to station EB2-12. Completion of EB2 at station EB2-12 near the ice edge at 08:40 LT. Transit to the western end of section EX. Start of EX section at station EX13P at 13:50 LT (station between EX13 and EX14; reaching EX14 impossible due to ice). Because of limited time remaining in the leg and significant station duration awhen using the large winch (additional 30–40 min per station due to manual cable handling), decision to switch to the small winch and perform shortened casts only to ~1500 m (limit from available wire on the small winch). Note: for CTD casts not reaching the bottom, LADCP quality is significantly degraded. Very good weather, wind up to 1B, no waves.
23 July	Continuation of measurements on section EX from station EX8P to station EX1. Completion of EX1 at 16:30 LT. Transit to LYR, packing equipment from legs II and III. Very good weather, wind up to 1B, no waves. Planned arrival to LYR around 07:00 LT.
24 July	Arrival of part of research team at 15:40 and boarding. At 19:00 arrival of the remaining team. At 20:00 approach to the quay and unloading of equipment delivered by *Horyzont*.
25 July	Anchoring in Longyearbyen.
26 July	Anchoring in Longyearbyen.
27 July	Around 12:30 departure to sea toward Hornsund. Good weather during transit, sea state 1B.
28 July	Morning: anchoring in the front of the Polish Polar Station in Hornsund. Short trip to the station for part of the research team and ship crew. Around 12:30 start of research. Start at station HB3 — plankton and optical measurements first, then benthic sampling. Next HB2 and HB1 — benthic only. Good weather, light swell inside the fjord.
29 July	After midnight entry into Brepolen and plankton + optical measurements at station H3. Then transit to R13 — optical measurements and start of CTD/LOPC section toward station R0. LOPC towed between stations. Next transit to Rm1/C1 — seafloor video survey, then start of CTD transect toward station Rm6. Additional seafloor video at Rm3/C2 and Rm6/C3. Good weather.
30 July	Transit to station C4 — seafloor video; then AR station — plankton sampling. Next transfer to station GH2 in Gåshamna — start of primary production measurements. Transfer to Hans Glacier to station HB2 — further primary production measurements. Additional seafloor video. Good weather.
31 July	After midnight — seafloor video at stations D1–D4 and additionally GH2. Then transit to H4 — plankton and optical measurements; then H2 and H1 — plankton + optical. Additionally at H1 sediment sampling with Van Veen grab for Kinorhyncha studies (Gregorczyk/Grzelak). Then transit to stations A and B for seafloor video. Around 18:00 transit to station AUK22 (start of the auk colony). Good weather, sea state 2B.
1 August	Research at the auk colony along transect AUK22–AUK19, then transit to profile AUK18/H7–AUK13, with LOPC towed between stations. Good weather, sea state 2–3B. Further transit to profile AUK12–AUK7. LOPC towed between AUK7 and AUK11/H6. Optical measurements also at AUK11/H6. Deteriorating sea state to 4–5B. Transit to station AUK9. Due to strong wind and sea state ~5B, AUK7 was skipped and the vessel left directly to AUK4.
2 August	Plankton and optical measurements at station AUK4. Improved sea state ~4B. Further measurements at stations AUK3 and AUK2 (plankton + optics). Then transit to the Hornsund base and anchoring. Transfer of sediment samples from Piotr Wieczorek to Ewa Korejwo. Around 13:30 departure toward Longyearbyen.
3 August	Around 03:00 entry into Adventfjorden and anchoring. At ~13:00 transfer of Ewa Korejwo to the airport. Around 15:00 transfer of remaining research team members to the airport and boarding of new team. At 18:00 approach to the quay for water and fuel. Around 20:00 departure from the quay to anchor due to very strong wind. Anchorage until 23:30, then departure toward Kongsfjorden to station V6.

4 August	At 12:00 start of plankton research at station V6. Multinet malfunction. Further plankton sampling at stations V10 and V12. Sea state 2–3B.
5 August	After midnight transit to station V14; plankton and optical sampling. Then dredging at station KChla1 with four hauls along the 100 m isobath. Transfer to Ny-Ålesund. Sediment and water sampling at KO_OC_AR23_1 and KO_OC_AR23_2, followed by anchoring near Ny-Ålesund. Transport by Zodiac of organisms and equipment for the UG scientific team (Pharmarine project), and receiving samples for M. Zabłocka, J. Wiktor and S. Kwaśniewski. Then transit to station MZ1, and then to station Camera1. Due to heavy ice under Kongsbreen, departure to the fjord center to station KB3 — plankton + optical sampling; further transfer to KB2 with more plankton + optical work. Good sea state, cloudy.
6 August	After 08:00 start of work at station Mi2 (benthos + camera), then transfer to station E4 — benthic research. Then transfer to KB1 — plankton + optical sampling, then KB0 — plankton + optical. Frequent rain showers.
7 August	Night anchorage at Ny-Ålesund; morning failed attempt to approach Kongsbreen to station KB5 due to ice. Vessel moved to Krossfjorden for further research. From 10:00 optical measurements at station Kross11. Then stations Kros7, Kros5, Kros10, and Kros9 — with added seafloor video. At Kros9 the rosette stopped working; blown fuse and cable short were diagnosed, but repairs failed. Ship CTD and Niskin samplers used instead. Anchorage until morning.
8 August	After breakfast the rosette was repaired (cable soldering). CTD cast at Kros9 performed to calibrate against ship's CTD. Transit to Kros8 — optical measurements + seafloor video. Then transfer to Kongsfjorden under Kongsbreen to station KB5 — optical + plankton sampling, then benthic sampling. Station completed around 20:00. Then transit to Ny-Ålesund for a short landing of researchers and crew to meet UG & GUMed teams and collect items for ship transport.
9 August	At 00:00 departure to station 1RK008 to begin CTD/LOPC transect. Due to strong currents and winds, LOPC towing abandoned; instead vertical LOPC casts at each station. From station 1RK004A conditions improved; LOPC towing resumed between stations until KB0. Then transit to KChla1 for CTD work, then across the cross-fjord CTD transect from 2RK001 to 2RK007. At stations 2RK006 and 2RK007 anchoring and additional seafloor video. Next, transit to station V14 for ACS measurements (device previously malfunctioning). Then transit to Magdalenafjorden.
10 August	Shortly after midnight arrival in Magdalenafjorden. CTD sampling and sediment collection with Gemax at stations MA_OC_AR23_4, MA_OC_AR23_3 (shifted closer to fjord axis), and MA_OC_AR23_1. Finished around 04:00. Station MA_OC_AR23_2 abandoned due to heavy ice. Anchorage until breakfast. Around 08:00 contact with UG ornithologists camping in Magdalenafjorden. Ornithology team arrived on board with samples ~09:30. At 13:00 departure for plankton research. Stations M7, M6, M5, M3, M1 with LOPC towing between stations.
11 August	After 01:00 arrival at M1 and completion of LOPC transect. Then stations M9, M8, M10, M2, and M4 with continued plankton research. Around 12:00 completion of research in the Magdalenafjorden forefield and transit to station V6. Around 15:00 arrival at V6 and repetition of the Multinet cast (previously malfunctioned). Then departure toward Isfjorden.
12 August	At 02:30 arrival at station Moni1 and optical sampling. Around 10:00 arrival in Longyearbyen and anchoring. At 23:00 approach to the quay and receiving part of the equipment from the shore team of Tomek Jankowski.
13 August	Alongside until 10:30. Morning loading of remaining equipment from the Jankowski team and divers. After 10:30 departure toward Eidembukta to land the Jankowski team. Arrival around 16:45. Landing completed around 20:00 and departure to station Moni2 around 22:00 — optical and chemical sampling. Then transit to Dicksonfjorden.
14 August	Around 06:00 arrival at station PRO_02 — chemical sampling. Then around 10:30 station Moni13 — optical sampling; then PRO_09 — rosette; then PRO_10 — rosette; then transit to station S2 to deploy divers. Waiting for the first dive. During the second dive transit to station Moni4/PRO_KKM2 — optical sampling + Gemax sediments. Then pickup of divers and transit to station SGD19/HIMERO1 — CTD + water sampling; plankton net sampling abandoned due to strong drift. Overnight departure toward Grønfjorden.
15 August	Transit to Grønfjorden and anchorage near station GF until breakfast. At 08:00 landing divers at GF in Grønfjorden. Waiting for dive completion, then transit to station Moni3 — optical sampling. After completion, return to pick up divers. Then transit to station Moni5/PRO_KKM3 — optical + Gemax sampling. Then optical work at Moni6 and Moni12.
16 August	ight transit toward station S1. At 08:00 landing divers at S1. Then transit to station ISA — plankton sampling. Around 11:30 pickup of divers and transit to Sassenfjorden to station Moni10 — optical sampling. Then transfer to Tempelfjorden to station Moni14 — optical sampling; then station IT3 — plankton sampling; then station R5/IT2 — optical + plankton sampling; then station IT1 — plankton sampling, finished around 23:00. Transit toward the Sassenelva mouth.
17 August	After 00:00 attempt to approach the Sassenelva mouth (station PRO_01) to collect surface freshwater. Attempt failed due to strong NE wind toward shore. Anchorage. At 06:00 arrival at station S1 to drop divers again. Anchoring during dive; later pickup of divers and transit to Longyearbyen to station IA1 — plankton sampling. During work, pickup of new steward and disembarkation of divers. Around 13:00 departure to station IA2 and then IA3 — plankton sampling. Then transit to station ISA2/HIMERO4 — plankton sampling. Then heading toward Billefjorden. En route, at station PRO_KKM4 sediment sampling with Gemax. Then optical work at MONI7, then chemical sampling at BI_OC_AR23_7. Then transit to MONI8/PRO_06 and anchoring overnight.
18 August	After breakfast start of sampling (optical + chemical) at MONI7/PRO06. Then combined station MONI9/SGD9/HIMERO3/BI_OC_AR23_6/PRO_05 — optical, plankton, and chemical sampling. Then chemical stations BI_OC_AR23_5 and BI_OC_AR23_4. Then transit toward the river outlet from the Horbyebreen glacier — chemical sampling including freshwater from Zodiac. Then transit toward Nordenskjöldbreen. Strong southern

	wind prevented sampling at BI_OC_AR23_3. Decision to move deeper under the glacier to station IB1 — plankton sampling. Then plankton + chemical sampling at station IB2/BI_OC_AR23_2. Completion around 22:00 and anchoring overnight awaiting improved weather.
19 August	After breakfast research at station BAB (plankton, chemistry, sediments). Then barbecue, and at 14:00 start of the LOPC transect toward station ISA. Mid-transect stop at station ISF3/HIMERO2 — plankton sampling.
20 August	Around 01:30 completion of the LOPC transect. Anchorage. Then transit to station SGD19/HIMERO1 — repeated plankton sampling + drop camera. Around 12:30 arrival at Eidembukta and pickup of Tomek Jankowski's shore team.
21 August	Entry into Isfjorden. Stop and crew exchange, start of Stage IVd. Start of measurements in Isfjorden.
22 August	Work in Isfjorden in coastal and shallow areas.
23 August	Work in Isfjorden in coastal and shallow areas.
24 August	Completion of work in Isfjorden, crew exchange. Start of Leg V.
25 August	Departure from Isfjorden, transit to Kongsfjorden.
26 August	Work in Kongsfjorden.
27 August	Work in Kongsfjorden, transit to Storfjordrenna.
28 August	Work in the Storfjordrenna region, transit to Kveithola Trough.
29 August	Work in the Kveithola Trough, transit to Bjørnoyrenna
30 August	Work in the Bjørnøyrenna region, transit to Tromsø
1 September	Transit to Tromsø, entry into the port of Tromsø.
2 September	Transit to Gdańsk.
3 September	Transit to Gdańsk.
4 September	Transit to Gdańsk.
5 September	Transit to Gdańsk.
6 September	Transit to Gdańsk.
7 September	Transit to Gdańsk.
8 September	Transit to Gdańsk.
9 September	Arrival to Gdańsk. Completion of Leg V and the end of the AREX 2023 cruise.

5 Mesurements and sampling program during Leg I

5.1 General information about Leg I

Continuous measurements (chemical and aerosol) were carried out along the entire route from Gdańsk to Tromsø. Ecological research was planned at three sampling stations: PhM1, PhM3, and PhM5. During the passage from Gdańsk to Tromsø, optical measurements were also performed at selected stations (some during drift and some while the vessel was underway). Throughout the entire voyage, two artists observed and documented the work on board, collecting material for their project.

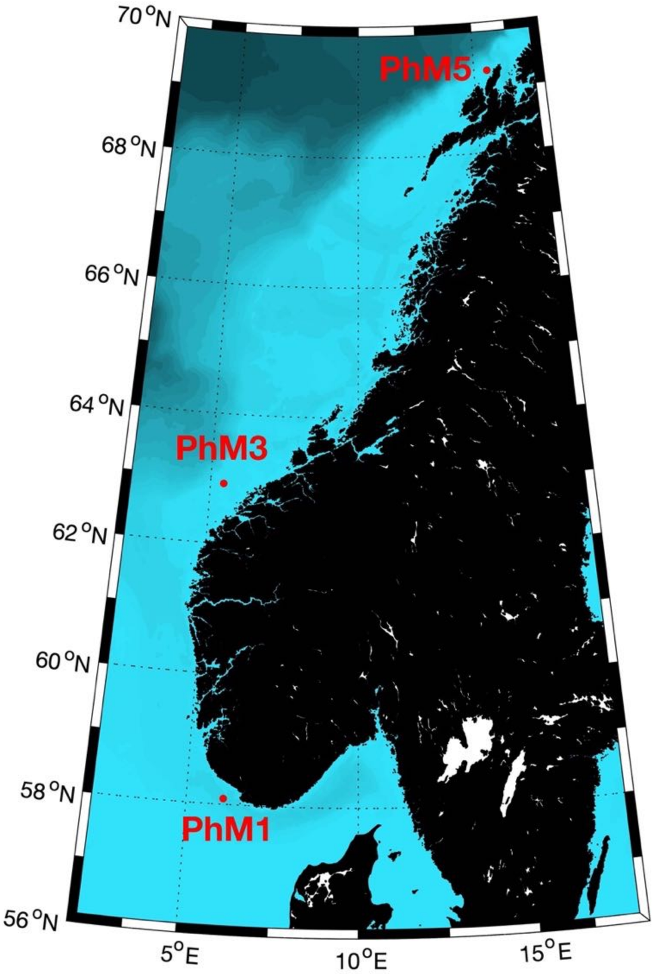

Figure 5.1. Map of the measurement stations during Leg I of the AREX2023 cruise.

Table 5.1. Station list during AREX2023 Leg I.

Station	Latitude °N	Longitude °E	Sampling
PhM1	58.088	6.078	Water/plankton samples
PhM3	62.924	5.448	Water/plankton samples
PhM5	69.260	15.560	Water/plankton samples
FerStation	69.340	18.511	Surface sediment samples

5.2 Detailed description of aerosol and meteorological measurements

During Stage I of the AREX2023 cruise, continuous measurements and station measurements were carried out using the following instruments:

- Sonic anemometers by GiLL (WindMaster and WindMaster Pro), mounted on both sides of the ship, up to 2 meters outside the ship's outline, which minimizes disturbances to the airflow around the vessel.
- Two optical analyzers by Li-COR: an open-path model (7500) and a closed-path model with a heated intake tube (7200), to eliminate disturbances in the CO_2 absorption spectrum caused by overlap with the water vapor absorption spectrum.
- An IMU inertial measurement sensor by SBG.
- A VAISALA WXT 530 meteorological station mounted about 8.5 m above the deck, closer to the bow.

During continuous measurements from departure from the port entrance in Gdańsk until arrival in Longyearbyen, a wide range of parameters was recorded, including:

- Using GiLL and LiCOR: wind velocity components (u,v,w), dry CO_2 concentration in the free atmosphere (10 m above the sea surface, in calm and wavy conditions), water vapor concentration (H_2O) in the free atmosphere, total pressure, air temperature.
- Using the IMU: acceleration components (x,y,z), angular velocity components (x,y,z), temperature.
- Using the VAISALA station: standard meteorological parameters in accordance with the global SHIP standard.

The measurements allow for determining the range of parameters necessary for interpreting atmospheric measurement data:

- The effect of ship motion on the vertical (w) component of wind velocity, in order to remove disturbances and reduce error in calculating the gas transfer velocity coefficient (k) (data from GiLL, IMU, and vessel speed and heading data from the bridge).
- Disturbances to airflow around the GiLL sensors caused by the ship's structure, for the same purposes as above (GiLL data).
- Wind speed and direction, which determine the coefficients used in calculating air–sea exchange fluxes (GiLL data).
- Sensible and latent heat fluxes (LiCOR, GiLL, IMU, VAISALA data).
- Friction velocity (u*) to determine the correct positioning of the anemometers and to compute momentum fluxes (GiLL, IMU, VAISALA).
- Gas transfer velocity coefficient (k), which controls the intensity of gas exchange across the sea surface (GiLL, IMU, VAISALA).

Using the pCO_2 data in seawater, also measured during this stage, fluxes of water vapor and CO_2 will be computed under varying weather and water conditions and different mixed-layer depths (LiCOR, GiLL, IMU, VAISALA data). Additionally, information on the content and thickness of the surface microlayer will be used to analyze how the gas transfer velocity coefficient (k) affects CO_2 exchange across the sea surface (LiCOR, GiLL, IMU, VAISALA data).

Measurements of pCO_2, pO_2, SST, and SSS were also conducted. These parameters were measured using a system consisting of a thermosalinograph, a Fibox oxygen sensor, and a Picarro analyzer for measuring pCO_2 concentration in the surface water layer.

5.3 Detailed description of plankton sampling (HIMERO)

At each station, environmental conditions were measured using a CTD probe mounted on a rosette. Using Niskin bottles, water was collected from 5 depth levels (PhM1, PhM3, PhM5), which was then filtered through filters of different pore sizes for chlorophyll a analysis.

As part of the HIMERO project, one plankton sample was collected at each station using a Juday net (56 µm) from bottom to surface, then preserved in 95% ethanol, which was replaced after 24 hours.

As part of the PHARMARINE project, three hauls were performed at each station using a WP2 plankton net (180 µm), after which the samples were pooled, placed in zip-lock bags, and frozen at –80°C for further analysis of pharmaceutical content in zooplankton.

5.4 Detailed description of optical measurements

During Leg I of the AREX 2023 cruise, measurements and sample collection were carried out for the Marine and Atmospheric Optics Laboratory to assess selected optical and biogeochemical properties of seawater at six measurement stations (five stations with the vessel stopped — X02, X03, X04/Phm3, X05, X06; and one station X01 with a limited measurement programme conducted while the vessel was drifting). Additionally, at 24 locations, recordings of the observable water colour were performed underway during the vessel's transit (locations U01 to U24).

Table 5.2. List of stations with optical measurements carried out during the AREX2023 Leg I.

Date	Time UTC	Station (X) or underway location (U)	Latitude (degrees N)	Longitude (degrees E)
2023-06-16	07:30	U01	55.191	13.266
2023-06-16	**08:30**	**X01**	**55.237**	**13.026**
2023-06-16	10:26	U02	55.404	12.709
2023-06-16	15:01	U03	56.072	12.631
2023-06-17	06:27	U04	57.879	10.181
2023-06-17	08:22	U05	57.886	9.617
2023-06-17	**10:28**	**X02**	**57.895**	**9.121**
2023-06-17	14:36	U06	57.918	7.981
2023-06-18	07:01	U07	59.267	4.680
2023-06-18	09:03	U08	59.581	4.6068
2023-06-18	**10:07**	**X03**	**59.712**	**4.573**
2023-06-18	13:01	U09	60.088	4.491
2023-06-18	15:12	U10	60.416	4.381
2023-06-19	06:59	U11	62.787	5.334
2023-06-19	**09:03**	**X04/PhM3**	**62.920**	**5.451**
2023-06-19	10:28	U12	63.053	5.604
2023-06-19	12:14	U13	63.313	5.897
2023-06-19	14:52	U14	63.678	6.342
2023-06-20	07:00	U15	65.913	9.364
2023-06-20	**09:06**	**X05**	**66.177**	**9.730**
2023-06-20	11:10	U16	66.422	10.080

2023-06-20	13:03	U17	66.695	10.475
2023-06-20	15:03	U18	66.981	10.905
2023-06-21	06:40	U19	69.096	15.110
2023-06-21	**09:13**	**X06**	**69.259**	**15.560**
2023-06-21	11:01	U20	69.348	16.004
2023-06-21	13:28	U21	69.551	17.026
2023-06-21	15:20	U22	69.614	17.832
2023-06-21	17:04	U23	69.443	18.402
2023-06-21	18:05	U24	69.343	18.509

Work and empirical material collected at the measurement stations

Directly at the measurement stations:

- the range (depth) of visibility of the standard Secchi disk (zSD) was determined;
- images documenting the color of the water column and the surface of the submerged Secchi disk were recorded using an "RGB" digital camera immersed just below the water surface;
- in situ measurements of the spectral values of the light backscattering coefficient in water (bb) were performed using a "HydroScat-4" meter (HobiLabs) (measurements were taken in the layer just below the sea surface and in a vertical profile in the water column);
- surface seawater samples were collected for further measurements and work carried out directly in the ship's laboratory or after the cruise in the onshore laboratories at IOPAN.

In the ship's laboratory, immediately after station work:

- appropriate water samples were prepared, after which measurements of the spectra of the light attenuation coefficient by the sum of suspended and dissolved substances in seawater (cn), and the light absorption coefficient by dissolved substances (aCDOM), were immediately carried out using the "Viper" photometer (TriOS);
- samples of suspended matter (filtration on appropriate filters) were prepared for storage to allow later analysis of total suspended matter concentration (SPM), concentrations of the organic and inorganic fractions of suspended matter (POM and PIM) (gravimetric method and combustion), chlorophyll a concentration (Chla) and concentrations of other phytoplankton pigments (HPLC and spectrophotometric methods), as well as spectra of light absorption by total suspended particles (ap) and separated into phytoplankton and non-algal particles (aph and ad) (laboratory spectrophotometric measurements);
- preserved water samples were prepared for later analysis of suspended particle size distributions (PSD) (measured with a Coulter counter);
- water samples were prepared for reference laboratory measurements of the spectra of the light absorption coefficient by dissolved substances (aCDOM) in the onshore IOPAN laboratories (laboratory spectrophotometric measurements).

The data obtained from direct measurements or laboratory analyses of selected inherent optical properties will allow the calculation of additional optical quantities, including: spectra of the light attenuation coefficients by particles (cp), and spectra of the light scattering and backscattering coefficients by particles (bp and bbp). The recorded images of the submerged Secchi disk and the water column will allow the calculation of a quantitative water-color index according to the trichromatic color perception mechanism, i.e., the color angle ("alpha"), as well as determination of the classification of the investigated waters within the traditional Forel–Ule color scale (FU index).

At the locations of periodic observations, the color of the water column was recorded from above the water surface using an "RGB" camera. Based on these recordings, the values of the color angle ("alpha") and the FU index were determined for the examined surface waters. Laboratory measurements on the samples collected during the cruise stage were mostly carried out in the fourth quarter of 2023. The empirical material collected during the cruise from the regions of the northern Atlantic (the North Sea and the Norwegian Sea) will be used by members of the Marine and Atmospheric Optics Laboratory in future scientific publications being prepared, as a supplement to the data collected in the Baltic Sea region and the Arctic fjords of Spitsbergen.

5.5 Activities for optimization of the shipboard data acquisition system

Installation of new Wi-Fi systems: 4 new Ubiquiti UAP-IW-HD access points. Each was connected to the Starlink Maritime network with set limits. The stability and coverage of the Wi-Fi network were improved; Wi-Fi coverage is now available throughout *Oceania* below deck and in the wheelhouse. A new Starlink Maritime system was installed — a new maritime antenna. The new antenna is adapted for use at sea; a tariff plan with 50 GB of monthly data transfer was purchased. Additionally, a 1 Mbps transfer limiter ("throttle") was set. All devices in the ship's LAN/Wi-Fi network received this limit. This significantly improved the operating conditions of the maritime Starlink — the slower rate of data consumption results in large savings in fees.

The router scripts on the ship were modified to better detect communication interruptions of both the old and new Starlink Maritime systems. Priorities were set so that the new Starlink Maritime system is selected only after the signal from the old Starlink and LTE is lost.
The optical system collecting data from pyranometers was connected to the *Lewiatan* system, which sends data online to the Institute. The new Starlink Maritime satellite system provides greater possibilities for using this mechanism to send online data to the Institute.

5.6 Activities involving the collection of photographic and video material

During the cruise, two artists, as part of a collaboration with the Polish Art Gallery in Sopot, collected photographic and video material, which will be used for the realization of the project "Stories of Mother Nature".

6 Mesurement and sampling program during Legs II and III

6.1 General information about Leg II-III

In 2023 the oceanic part of the AREX 2023 cruise was, as usual, divided into Leg II, covering measurements between the northern tip of Norway and Sørkapp, and Leg III, covering sections in Fram Strait (a detailed description of both legs is provided in the cruise calendar in section 4). Due to the need to shorten the duration of the oceanic leg, the section at the entrance to the Barents Sea (Barents Sea Opening, section V1) was abandoned, and Leg II began with a section in the eastern part of the Norwegian Sea (section H).

During Leg II of the cruise, in the open-ocean region and the southern Fram Strait, favourable meteorological conditions prevailed (up to 2–3°B, wave height up to 1–1.5 m). During Leg III in Fram Strait and the area north of Svalbard, conditions initially deteriorated moderately (to 3–4°B, wave height up to 2 m). Toward the end of Leg III, a passing strong low-pressure system generated storm conditions (up to 7–8°B), forcing nearly a 3-day stop in a sheltered fjord. Ice conditions in the northern Fram Strait were moderate, whereas north of Svalbard predominantly unfavourable, preventing access to the eastern NB section and continuation of sections WB and Y beyond the upper part of the continental slope.

6.2 Detailed description of oceanographic measurements

The distribution of measurement stations during the oceanic part of the AREX2023 cruise (Legs II and III) is shown in Figure 6.1. During the oceanic legs of the AREX2023 cruise, hydrographic measurements including pressure, temperature, salinity, dissolved oxygen concentration, and fluorescence (as a proxy for chlorophyll-a concentration) were carried out at 206 CTD stations on profiles extending down to the seabed: 79 CTD stations during Leg II and 127 stations during Leg III. At selected stations, water samples were collected at specific depths using a rosette sampler in order to calibrate the conductivity sensor and the dissolved oxygen sensor (4 stations). At 11 stations, water samples were also collected at selected depths for nutrient analysis from up to 11 standard depths (0, 10, 25, 50, 75, 100, 150, 200, 400, 750, 1000 m). These samples were frozen on board, and their analyses will be carried out after the cruise in the IOPAN laboratory. The list of stations with measurement descriptions is presented in Table 6.1.

Hydrographic measurements were made using a SeaBird CTD 9/11+ system. The primary measuring device was the SeaBird CTD 9/11+ probe mounted on a SeaBird SBE32 rosette sampler equipped with twelve 12-liter Niskin bottles. The SeaBird CTD 9/11+ probe was equipped with a dual set of temperature and conductivity sensors (first temperature sensor SBE3 SN4670, first conductivity sensor SBE4 SN3342, second temperature sensor SBE3 SN2937, second conductivity sensor SBE4 SN3322) and a Digiquartz pressure sensor 410K-105 SN100967. The most recent calibration of the temperature and conductivity sensors took place in May 2023, and of the pressure sensor in April 2018.

Additionally, from Leg III onward, the CTD probe was equipped with a dissolved oxygen sensor (standard SeaBird SBE43 SN1620, calibrated in June 2023). During Leg II, the oxygen sensor was not used due to a delayed return from calibration by the manufacturer. The sensor was delivered to Longyearbyen only during the stopover between Legs II and III.

The CTD probe was also equipped with a SeaPoint fluorometer SN2935 and a Benthos PSA-916 altimeter. In addition, a mechanical bottom-contact sensor (weight on a ~5 m line) was used; however, its operation was not always reliable (e.g., during strong swell or strong vessel drift).

Table 6.1 Technical specification of CTD 9/11+ sensors used during the AREX 2023 cruise.

SBE9/11+ CTD system (new body, new CT sets)		
Sensor	Serial number	Calibration date
Pressure	275	2018-04-18
Condictivity	3342 3322	2023-05-11 2023-05-11
Temperature	4670 2937	2023-05-31 2023-05-11
Dissolved oxygen SBE43	1620	2023-06-13
Fluorometer	Seapoint	-

The Teledyne RDI WorkHorse 300 kHz LADCP acoustic current meter, SN21589, was installed in a downward-looking configuration (acoustic transducers facing downward) and used at every CTD station. The collected hydrographic data were stored on the CTD acquisition computer, with a backup copy on the same machine. Preliminary data processing was carried out continuously, while the final data will be available after salinity measurements of the collected water samples and post-cruise calibration. LADCP data were saved in individual files and downloaded from the instrument memory after each station.

Throughout the entire cruise, measurements of ocean currents in the upper layer (approximately 200 m) were conducted during ship transit using an RDI VM-ADCP (Vessel Mounted Acoustic Doppler Current Profiler) Ocean Surveyor operating at 150 Hz. VM-ADCP measurements were carried out in BroadBand mode with averaging in 8 m cells.

The CTD, VM-ADCP, and LADCP data collected during the AREX2023 cruise were processed following standard procedures consistent with the recommended best practice documentation for the instruments used. Processed data, converted to NetCDF format containing a full set of metadata for each measurement and a common DOI for the dataset from Legs II and III of the AREX2023 cruise, will be archived in the ODIS eCUDO database and made publicly available after an embargo period.

During Leg II, two ARGO profiling floats were also deployed along section K at 75°N. One Core Argo float (measuring pressure, temperature, salinity, and dissolved oxygen) was deployed at station K3 in the core of Atlantic Water (at 15°25'E), while the second Core Argo float was deployed at station K12 in the outer (western) branch of the Atlantic Water flow (at 8°30'E). Each float deployment was preceded by carrying out a CTD cast to obtain reference data. The Argo floats were deployed manually over the ship’s side while the vessel was moving at minimum speed (up to 1 knot). Information about the deployed floats was reported to the Coriolis DAC.

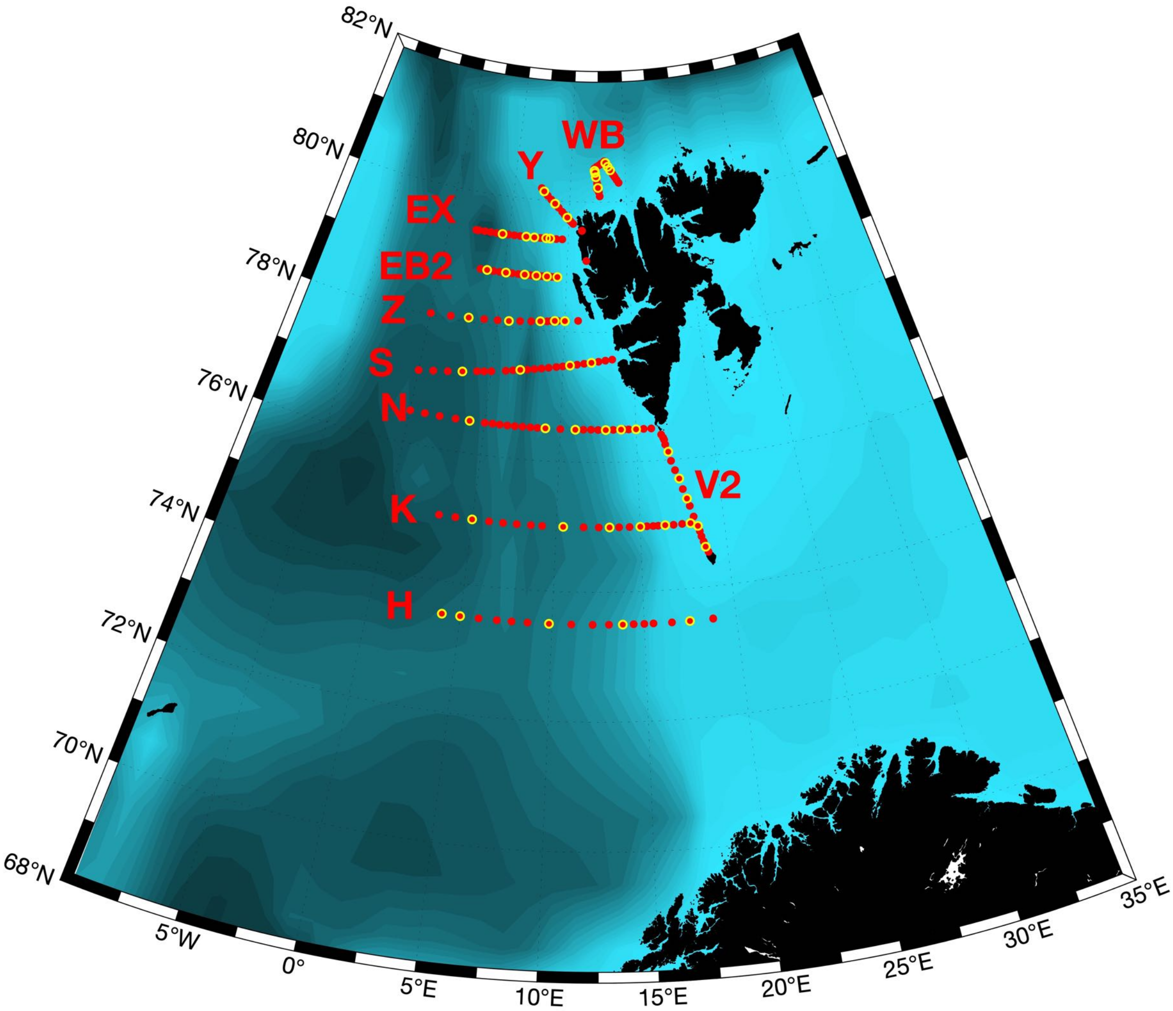

Figure 6.1 Stations occupied during Legs II and III of the AREX 2023 cruise. Red dots show CTD casts, yellow circles indicate plankton sampling.

Table 6.2 List of stations during legs II and III of the AREX2023 cruise.

File	Station	Latitude (°N)	Longitude (°E)	Water depth (m)	Max pressure (dbar)	Day	Month	Year	Hour	Min
AR23_004.awi	H1	73.502	18.746	424	423	25	6	2023	0	58
AR23_005.awi	H3	73.501	17.481	427	426	25	6	2023	4	15
AR23_006.awi	H6	73.500	16.502	448	448	25	6	2023	8	15
AR23_007.awi	H7	73.501	15.500	481	480	25	6	2023	10	58
AR23_008.awi	H8	73.500	15.000	689	691	25	6	2023	12	44
AR23_009.awi	H9	73.502	14.424	1009	1017	25	6	2023	15	18
AR23_010.awi	H10	73.500	13.835	1285	1297	25	6	2023	17	42
AR23_011.awi	H10	73.501	13.086	1577	1596	25	6	2023	20	57
AR23_012.awi	H11	73.500	12.200	1805	1827	25	6	2023	23	50
AR23_013.awi	H12	73.501	11.043	2063	2090	26	6	2023	3	30
AR23_014.awi	H13	73.500	9.833	2310	2328	26	6	2023	7	59
AR23_015.awi	H14	73.500	8.669	2487	2522	26	6	2023	11	50

AR23_016.awi	H15	73.500	7.801	3108	3160	26	6	2023	15	30
AR23_017.awi	H16	73.500	7.001	1653	1576	26	6	2023	19	52
AR23_018.awi	H17	73.500	6.007	1921	1945	26	6	2023	22	46
AR23_019.awi	H18	73.500	4.998	2748	2791	27	6	2023	2	12
AR23_020.awi	H19	73.500	4.001	2873	2919	27	6	2023	6	44
AR23_021.awi	K18	75.000	2.997	2472	2495	27	6	2023	18	40
AR23_022.awi	K17	75.001	3.976	3048	3098	27	6	2023	22	5
AR23_023.awi	K16	75.001	4.982	3074	3125	28	6	2023	2	17
AR23_024.awi	K15	75.001	5.998	2824	2871	28	6	2023	7	6
AR23_025.awi	K14	75.000	6.835	1980	2005	28	6	2023	10	44
AR23_026.awi	K13	75.000	7.651	2122	2151	28	6	2023	13	45
AR23_027.awi	K12	75.001	8.496	2989	3038	28	6	2023	17	6
AR23_028.awi	K11	75.000	9.168	2616	2656	28	6	2023	21	0
AR23_029.awi	K10	75.000	10.419	2514	2539	29	6	2023	1	42
AR23_030.awi	K9	75.000	11.633	2359	2394	29	6	2023	6	8
AR23_031.awi	K8	74.999	12.537	2142	2171	29	6	2023	9	57
AR23_032.awi	K7	74.999	13.179	1977	2003	29	6	2023	13	1
AR23_033.awi	K6	74.999	13.747	1800	1822	29	6	2023	15	53
AR23_034.awi	K5	74.999	14.370	1511	1529	29	6	2023	18	41
AR23_035.awi	K4	74.997	15.006	1111	1122	29	6	2023	21	23
AR23_036.awi	K3	75.000	15.404	811	815	29	6	2023	23	24
AR23_037.awi	K2	74.999	15.774	329	327	30	6	2023	1	9
AR23_038.awi	K1	74.999	16.071	217	214	30	6	2023	2	21
AR23_039.awi	K0	75.000	16.490	239	236	30	6	2023	3	31
AR23_040.awi	K-1	74.997	16.988	131	129	30	6	2023	5	50
AR23_041.awi	K-2	75.000	17.499	118	116	30	6	2023	7	14
AR23_042.awi	K-3	75.000	18.000	157	156	30	6	2023	8	34
AR23_043.awi	V21	74.534	18.884	26	23	30	6	2023	18	9
AR23_044.awi	V22	74.617	18.749	69	68	30	6	2023	19	4
AR23_045.awi	V23	74.700	18.664	101	100	30	6	2023	20	7
AR23_046.awi	V24	74.783	18.568	235	233	30	6	2023	21	5
AR23_047.awi	V25	74.865	18.504	204	201	30	6	2023	22	9
AR23_048.awi	V26	74.948	18.422	75	71	30	6	2023	23	15
AR23_049.awi	V27	75.097	18.223	73	68	1	7	2023	0	41
AR23_050.awi	V28	75.266	18.053	65	60	1	7	2023	2	16
AR23_051.awi	V29	75.383	17.923	105	102	1	7	2023	3	28
AR23_052.awi	V30	75.534	17.721	130	126	1	7	2023	5	16
AR23_053.awi	V31	75.700	17.557	214	212	1	7	2023	6	46
AR23_054.awi	V32	75.834	17.338	293	292	1	7	2023	9	5
AR23_055.awi	V33	75.982	17.134	320	318	1	7	2023	10	40

AR23_056.awi	V34	76.125	17.002	287	285	1	7	2023	12	17
AR23_057.awi	V35	76.239	16.842	216	212	1	7	2023	14	37
AR23_058.awi	V36	76.314	16.791	107	102	1	7	2023	15	35
AR23_059.awi	V37	76.346	16.739	54	48	1	7	2023	16	8
AR23_060.awi	V38	76.397	16.625	33	28	1	7	2023	16	51
AR23_061.awi	S0	77.581	13.504	145	140	2	7	2023	1	37
AR23_062.awi	S1	77.567	13.017	136	131	2	7	2023	2	48
AR23_063.awi	S2	77.550	12.526	97	93	2	7	2023	3	52
AR23_064.awi	S3	77.533	12.021	176	172	2	7	2023	4	56
AR23_065.awi	S4	77.517	11.501	276	276	2	7	2023	6	57
AR23_066.awi	S5	77.501	10.998	723	728	2	7	2023	8	14
AR23_067.awi	S6	77.484	10.499	1248	1259	2	7	2023	9	51
AR23_068.awi	S7	77.467	9.995	1605	1623	2	7	2023	12	38
AR23_069.awi	S7P	77.453	9.540	1918	1935	2	7	2023	14	40
AR23_070.awi	S8	77.434	8.995	2051	2079	2	7	2023	17	4
AR23_071.awi	S8P	77.417	8.499	1248	1262	2	7	2023	19	33
AR23_072.awi	S9	77.400	8.007	2293	2324	2	7	2023	21	25
AR23_073.awi	S9P	77.383	7.507	3526	3588	3	7	2023	0	8
AR23_074.awi	S10	77.370	7.014	2637	2676	3	7	2023	3	58
AR23_075.awi	S11	77.353	6.508	2082	2111	3	7	2023	7	12
AR23_076.awi	S12	77.334	6.006	2574	2612	3	7	2023	10	7
AR23_077.awi	S13	77.300	5.011	2343	2376	3	7	2023	13	38
AR23_078.awi	S14	77.284	4.503	2198	2227	3	7	2023	16	37
AR23_079.awi	S15	77.271	4.018	2574	2613	3	7	2023	19	27
AR23_080.awi	S16	77.234	3.010	2889	2934	3	7	2023	23	12
AR23_081.awi	S17	77.200	2.006	3186	3239	4	7	2023	3	14
AR23_082.awi	S18	77.167	1.006	3182	3236	4	7	2023	7	47
AR23_083.awi	N5	76.500	16.001	55	52	7	7	2023	9	20
AR23_084.awi	N4P	76.500	15.498	147	142	7	7	2023	10	43
AR23_085.awi	N4	76.499	14.999	167	164	7	7	2023	11	53
AR23_086.awi	N3P	76.501	14.514	219	215	7	7	2023	14	39
AR23_087.awi	N3PP	76.502	14.197	407	405	7	7	2023	15	31
AR23_088.awi	N3	76.501	14.011	757	761	7	7	2023	16	35
AR23_089.awi	N2P	76.500	13.495	1250	1263	7	7	2023	18	33
AR23_090.awi	N2	76.499	13.000	1532	1550	7	7	2023	21	7
AR23_091.awi	N1P	76.500	12.498	1739	1759	7	7	2023	23	24
AR23_092.awi	N1	76.504	12.031	1886	1909	8	7	2023	2	4
AR23_093.awi	N0P	76.502	11.524	2000	2029	8	7	2023	4	56
AR23_094.awi	N0	76.500	10.995	2076	2105	8	7	2023	7	57
AR23_095.awi	N-1	76.501	10.004	2208	2237	8	7	2023	12	2

AR23_096.awi	N-2	76.502	9.019	2260	2293	8	7	2023	15	49
AR23_097.awi	N-3	76.501	8.492	2264	2297	8	7	2023	19	23
AR23_098.awi	N-4	76.502	8.025	1805	1827	8	7	2023	22	25
AR23_099.awi	N-5	76.502	7.509	2477	2513	9	7	2023	1	18
AR23_100.awi	N-6	76.500	6.995	2815	2861	9	7	2023	5	1
AR23_101.awi	N-7	76.499	6.499	2457	2492	9	7	2023	8	50
AR23_102.awi	N-8	76.500	5.998	2521	2560	9	7	2023	12	8
AR23_103.awi	N-9	76.503	5.517	2531	2569	9	7	2023	15	22
AR23_104.awi	N-10	76.500	5.003	2360	2389	9	7	2023	19	2
AR23_105.awi	N-11	76.500	3.999	2518	2555	9	7	2023	22	52
AR23_106.awi	N-12	76.500	3.061	2903	2949	10	7	2023	2	45
AR23_107.awi	N-13	76.499	2.001	3207	3260	10	7	2023	7	31
AR23_108.awi	N-14	76.500	1.003	3208	3261	10	7	2023	12	6
AR23_109.awi	N-15	76.499	0.023	3158	3211	10	7	2023	16	26
AR23_110.awi	S19	77.131	0.009	3184	3237	11	7	2023	0	43
AR23_111.awi	Z15	78.028	0.009	3065	3116	11	7	2023	11	21
AR23_112.awi	Z14	78.047	1.496	3063	3116	11	7	2023	16	43
AR23_113.awi	Z13	78.067	2.835	3038	3090	11	7	2023	21	54
AR23_114.awi	Z12	78.080	3.985	2849	2895	12	7	2023	2	29
AR23_115.awi	Z11	78.091	4.991	2449	2497	12	7	2023	6	25
AR23_116.awi	Z10	78.100	5.833	2479	2515	12	7	2023	10	4
AR23_117.awi	Z9	78.116	6.665	2261	2294	12	7	2023	13	23
AR23_118.awi	Z8	78.129	7.489	3431	3494	12	7	2023	16	47
AR23_119.awi	Z7	78.141	8.171	2200	2229	12	7	2023	20	53
AR23_120.awi	Z6	78.146	8.675	1544	1560	13	7	2023	0	0
AR23_121.awi	Z5	78.155	8.992	1103	1111	13	7	2023	2	16
AR23_122.awi	Z4	78.160	9.249	711	714	13	7	2023	3	49
AR23_123.awi	Z3	78.162	9.487	271	268	13	7	2023	5	22
AR23_124.awi	Z2	78.165	10.004	266	267	13	7	2023	6	32
AR23_125.awi	Z1	78.175	10.995	260	259	13	7	2023	9	31
AR23_126.awi	WB1	80.090	12.639	186	185	14	7	2023	5	50
AR23_127.awi	WB2	80.155	12.560	182	182	14	7	2023	6	45
AR23_128.awi	WB3	80.219	12.484	188	187	14	7	2023	7	39
AR23_131.awi	WB4	80.287	12.406	191	187	14	7	2023	10	45
AR23_132.awi	WB5	80.352	12.329	167	163	14	7	2023	11	47
AR23_133.awi	WB6	80.383	12.289	183	179	14	7	2023	12	40
AR23_134.awi	WB7	80.417	12.259	227	223	14	7	2023	14	3
AR23_135.awi	WB8	80.434	12.226	353	352	14	7	2023	14	57
AR23_136.awi	WB9	80.449	12.213	467	466	14	7	2023	15	48
AR23_137.awi	WB10	80.465	12.201	574	575	14	7	2023	17	17

AR23_138.awi	WB11	80.482	12.166	650	654	14	7	2023	18	19
AR23_139.awi	WB12	80.516	12.134	815	821	14	7	2023	19	42
AR23_140.awi	WB13E	80.543	12.347	901	909	14	7	2023	21	4
AR23_141.awi	WB14E	80.565	12.579	944	951	14	7	2023	22	39
AR23_142.awi	WB15E	80.593	12.771	957	963	15	7	2023	0	6
AR23_143.awi	WB16E	80.626	13.040	862	867	15	7	2023	1	35
AR23_144.awi	WB17E	80.601	13.168	728	730	15	7	2023	3	3
AR23_145.awi	WB18E	80.572	13.275	568	569	15	7	2023	4	31
AR23_146.awi	WB19E	80.543	13.385	414	413	15	7	2023	5	37
AR23_147.awi	WB20E	80.515	13.496	290	289	15	7	2023	7	49
AR23_148.awi	WB21E	80.488	13.600	218	216	15	7	2023	8	58
AR23_149.awi	WB22E	80.462	13.703	210	206	15	7	2023	11	12
AR23_150.awi	WB23E	80.433	13.814	189	186	15	7	2023	12	2
AR23_151.awi	WB24E	80.406	13.922	156	152	15	7	2023	13	23
AR23_152.awi	WB25E	80.378	14.029	122	120	15	7	2023	14	11
AR23_153.awi	WB26E	80.339	14.176	78	73	15	7	2023	15	4
AR23_154.awi	WB27E	80.293	14.354	52	46	15	7	2023	16	4
AR23_155.awi	Y13	80.180	7.433	557	557	16	7	2023	1	24
AR23_156.awi	Y12	80.133	7.676	535	535	16	7	2023	2	36
AR23_157.awi	Y11	80.072	8.012	508	508	16	7	2023	4	20
AR23_158.awi	Y10	80.016	8.351	495	495	16	7	2023	5	30
AR23_159.awi	Y9	79.957	8.714	480	482	16	7	2023	6	54
AR23_160.awi	Y8	79.899	9.046	455	457	16	7	2023	8	41
AR23_161.awi	Y7	79.839	9.376	455	455	16	7	2023	10	1
AR23_162.awi	Y6	79.795	9.607	427	426	16	7	2023	11	18
AR23_163.awi	Y5	79.755	9.842	373	371	16	7	2023	12	28
AR23_164.awi	Y4	79.731	9.947	309	307	16	7	2023	14	38
AR23_165.awi	Y3	79.708	10.086	138	132	16	7	2023	15	36
AR23_166.awi	Y2	79.684	10.231	88	84	16	7	2023	16	29
AR23_167.awi	Y1	79.661	10.362	32	28	16	7	2023	17	13
AR23_168.awi	AT1	79.560	11.126	100	97	17	7	2023	8	7
AR23_169.awi	AT2	79.558	11.128	103	96	18	7	2023	16	10
AR23_170.awi	AT3	79.096	11.538	247	246	19	7	2023	14	54
AR23_171.awi	EB2-1	78.834	9.265	203	201	20	7	2023	6	49
AR23_172.awi	EB2-1P	78.834	9.017	211	210	20	7	2023	8	36
AR23_173.awi	EB2-2	78.833	8.767	213	211	20	7	2023	9	35
AR23_174.awi	EB2-2P	78.834	8.607	380	376	20	7	2023	10	26
AR23_175.awi	EB2-3	78.834	8.438	652	655	20	7	2023	11	29
AR23_176.awi	EB2-3P	78.833	8.264	837	842	20	7	2023	13	1
AR23_177.awi	EB2-4	78.834	8.093	958	965	20	7	2023	14	16

AR23_178.awi	EB2-4P	78.834	7.846	1057	1067	20	7	2023	15	57
AR23_179.awi	EB2-5	78.834	7.596	1099	1111	20	7	2023	17	32
AR23_180.awi	EB2-5P	78.832	7.348	1184	1196	20	7	2023	20	18
AR23_181.awi	EB2-6	78.834	7.099	1340	1353	20	7	2023	22	41
AR23_182.awi	EB2-6P	78.833	6.879	1546	1555	21	7	2023	1	22
AR23_183.awi	EB2-7	78.834	6.666	1728	1749	21	7	2023	3	23
AR23_184.awi	EB2-7P	78.834	6.419	2034	2063	21	7	2023	5	23
AR23_185.awi	EB2-8	78.833	6.164	2312	2343	21	7	2023	8	0
AR23_186.awi	EB2-9	78.834	5.662	2519	2555	21	7	2023	10	46
AR23_187.awi	EB2-9P	78.833	5.414	2571	2607	21	7	2023	13	52
AR23_188.awi	EB2-10	78.833	5.169	2595	2635	21	7	2023	16	35
AR23_189.awi	EB2-10P	78.832	4.666	2724	2754	21	7	2023	19	33
AR23_190.awi	EB2-11	78.832	4.167	2362	2394	21	7	2023	23	0
AR23_191.awi	EB2-11P	78.834	3.664	2250	2281	22	7	2023	2	0
AR23_192.awi	EB2-12	78.835	3.121	2397	2432	22	7	2023	4	39
AR23_193.awi	EX13P	79.415	2.268	1638	1560	22	7	2023	11	57
AR23_194.awi	EX13	79.416	2.497	1664	1587	22	7	2023	13	57
AR23_195.awi	EX12	79.417	2.998	1669	1590	22	7	2023	15	45
AR23_196.awi	EX11	79.417	3.499	1682	1605	22	7	2023	17	40
AR23_197.awi	EX10	79.415	3.993	1660	1584	22	7	2023	19	52
AR23_198.awi	EX9	79.415	4.495	1664	1587	22	7	2023	22	1
AR23_199.awi	EX8P	79.418	4.990	1650	1573	23	7	2023	0	13
AR23_200.awi	EX8	79.417	5.488	1673	1596	23	7	2023	2	23
AR23_201.awi	EX7P	79.417	5.987	1681	1604	23	7	2023	4	6
AR23_202.awi	EX7	79.417	6.484	1417	1434	23	7	2023	5	48
AR23_203.awi	EX5P	79.417	7.162	1098	1110	23	7	2023	7	54
AR23_204.awi	EX4P	79.416	7.662	762	768	23	7	2023	9	18
AR23_205.awi	EX4	79.418	7.918	479	479	23	7	2023	10	16
AR23_206.awi	EX3P	79.419	8.152	280	277	23	7	2023	11	17
AR23_207.awi	EX3	79.418	8.492	190	187	23	7	2023	12	17
AR23_208.awi	EX2	79.416	8.999	130	128	23	7	2023	13	23
AR23_209.awi	EX1	79.417	9.499	126	122	23	7	2023	14	20

6.3 Detailed description of aerosol, meteorological, and surface microlayer measurements

During Legs II and III of the AREX2023 cruise, continuous measurements and station measurements were carried out using the following instruments:

- Sonic anemometers by GiLL (WindMaster and WindMaster Pro), mounted on both sides of the ship, up to 2 meters beyond the ship's outline, which minimizes disturbances to the airflow around the vessel.
- Two optical analyzers by Li-COR: an open-path model (7500) and a closed-path model with a heated sampling tube (7200), to eliminate disturbances in the CO_2 absorption spectrum caused by overlap with the water vapor absorption spectrum.
- An IMU inertial measurement sensor by SBG.
- A VAISALA WXT 530 meteorological station mounted approximately 8.5 m above the ship's deck, closer to the bow.

During continuous measurements carried out in Legs II and III, a wide set of parameters was recorded, including among others:

- • Using GiLL and LiCOR: wind velocity components (u, v, w), dry CO_2 concentration in the free atmosphere (10 m above the sea surface, under calm and wavy conditions), H_2O vapor concentration in the free atmosphere, total pressure, air temperature.
- Using the IMU: acceleration components (x, y, z), angular velocity components (x, y, z), temperature.
- Using the VAISALA station: standard meteorological parameters consistent with the global SHIP standard.

The measured data will allow determination of the range of parameters necessary for interpreting atmospheric measurement data:

- • The effect of ship motion on the vertical (w) component of wind speed, to eliminate disturbances and reduce errors in calculating the gas transfer velocity coefficient (k) (data from GiLL and IMU, and ship heading and speed data from the bridge).
- Airflow disturbances around the GiLL sensors caused by the ship's structure for the same purposes as above (GiLL data).
- Wind speed and direction, which influence the coefficients used in calculating air–sea exchange fluxes (GiLL data).
- Sensible and latent heat fluxes (LiCOR, GiLL, IMU, VAISALA data).
- Friction velocity (u*) to determine the correct placement of the anemometers and calculate momentum fluxes (GiLL, IMU, VAISALA).
- Gas transfer velocity coefficient (k), which determines the intensity of gas exchange across the sea surface (GiLL, IMU, VAISALA).

Using the pCO_2 data in seawater, also measured during this leg, fluxes of water vapor and CO_2 will be calculated under varying weather conditions and varying water parameters and mixed-layer depth (LiCOR, GiLL, IMU, VAISALA data). Additionally, using information on the content and thickness of the sea surface microlayer, the effect of the gas transfer velocity coefficient (k) on CO_2 exchange across the sea surface will be analyzed (LiCOR, GiLL, IMU, VAISALA data).

Measurements of pCO_2, pO_2, SST, and SSS were also carried out. These parameters were measured using a system consisting of a thermosalinograph, a Fibox oxygen sensor, and a Picarro analyzer for measuring pCO_2 concentration in the surface water layer.

During Leg II of the AREX2023 cruise, water from the surface microlayer and subsurface layer was collected at 14 stations (Figure 6.2). Water was collected along transect K (9 stations), transects H and S (2 stations each), and one station on transect V2. During Leg III, water from the surface microlayer and subsurface layer was collected at 16 stations. Water was collected along transect N (8 stations), transect EB2 (5 stations), and EX (3 stations).

Stations on transects K, N, EB2, and EX, running zonally, will allow assessment of the spreading of freshwater (from glaciers and land) from the coast into the open ocean. The research aims to investigate/measure the type and concentration of organic matter present in the surface layer and the concentration and species composition of phytoplankton. The next step is to examine the enrichment of the marine surface microlayer with organic matter and search for relationships between this enrichment and the concentrations of phytoplankton and land-derived organic matter.

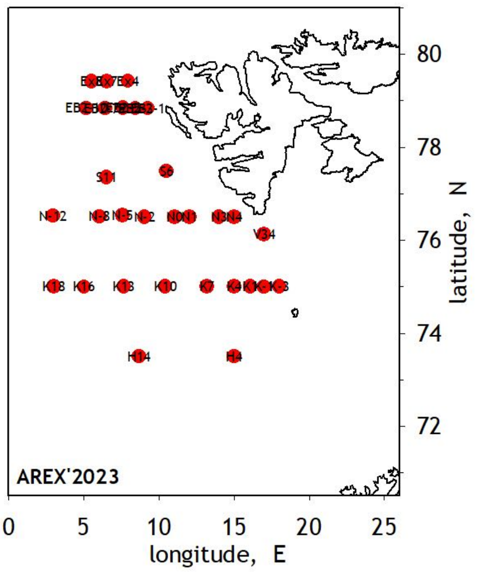

Figure 6.2 Stations for sampling the surface microlayer during Legs II and III of the AREX2023 cruise

6.4 Detailed description of plankton measurements

Zooplankton research during the oceanic legs of the AREX2023 cruise was carried out using recommended methods applied in ecological studies of marine zooplankton, with procedures and tools adapted to the research objectives. According to the theoretical plan, zooplankton sampling was to be conducted at fixed research stations selected from among the hydrographic stations of the main cruise program. At each station, zooplankton samples were collected while the vessel was drifting (rarely while anchored). Sampling was planned as vertical hauls from the upper 200-meter layer of the sea (from the epipelagic zone), carried out in layers defined in relation to the thermal–salinity structure of the water column at a given station.

Based on previous hydrographic results, zooplankton sampling is typically planned in three layers: in the surface layer with uniform temperature and salinity, in the thermocline and halocline layer (the layer of temperature and salinity gradients), and in the layer extending below the gradient down to the lower boundary of the epipelagic zone, characterized by uniform changes in temperature and salinity with depth. The thickness of the layers is determined individually at each station based on temperature and salinity profiles.

The primary sampling gear was a WP-2 zooplankton net with a 0.180 mm mesh size. The net is equipped with a mechanical closing system, which closes the net by tightening a rope loop in the upper, non-filtering part of the net. The closing system is activated mechanically using a Nansen-type net closing device. For additional tasks, a WP-3 plankton net with a 1.0 mm mesh and a Juday plankton net with a 0.064 mm mesh were also used.

During Legs II and III of the AREX2023 cruise, a total of 193 samples from zooplankton nets were collected at 53 stations. Samples were collected for long-term zooplankton monitoring (at all stations, Task I.5) and for the following projects: HIMERO (14 stations) and HIDEA (13 stations). A detailed list of stations, collected samples, and haul depths is given in Table 6.3.

Table 6.3 Plankton sampling stations during Legs II and III of AREX2023.

Project	Station	Log number	Sampling tool	Depth from [m]	Depth to [m]
Monitoring	H3	005_2023	WP-2/180	200	30
Monitoring	H3	005_2023	WP-2/180	30	10
Monitoring	H3	005_2023	WP-2/180	10	0
HIMERO	H3	005_2023	Juday/56	412	0
Monitoring	H4	008_2023	WP-2/180	200	80
Monitoring	H4	008_2023	WP-2/180	80	30
Monitoring	H4	008_2023	WP-2/180	30	0
HIDEA	H4	008_2023	WP-2/180	50	0
HIDEA	H4	008_2023	WP-2/180	50	0
Monitoring	H10	011_2023	WP-2/180	200	50
Monitoring	H10	011_2023	WP-2/180	50	10
Monitoring	H10	011_2023	WP-2/180	10	0
Monitoring	H13	014_2023	WP-2/180	200	65
Monitoring	H13	014_2023	WP-2/180	65	25
Monitoring	H13	014_2023	WP-2/180	25	10
Monitoring	H13	014_2023	WP-2/180	10	0
Monitoring	H18	019_2023	WP-2/180	200	90
Monitoring	H18	019_2023	WP-2/180	90	20
Monitoring	H18	019_2023	WP-2/180	20	10
Monitoring	H18	019_2023	WP-2/180	10	0
HIDEA	H18	019_2023	WP-2/180	50	0
HIDEA	H18	019_2023	WP-2/180	50	0
Monitoring	K16	023_2023	WP-2/180	200	20
Monitoring	K16	023_2023	WP-2/180	20	10
Monitoring	K16	023_2023	WP-2/180	10	0
HIDEA	K16	023_2023	WP-2/180	50	0
HIDEA	K16	023_2023	WP-2/180	50	0
Monitoring	K10	029_2023	WP-2/180	200	25
Monitoring	K10	029_2023	WP-2/180	25	15
Monitoring	K10	029_2023	WP-2/180	15	0
Monitoring	K7	032_2023	WP-2/180	200	30
Monitoring	K7	032_2023	WP-2/180	30	10
Monitoring	K7	032_2023	WP-2/180	10	0
Monitoring	K4	035_2023	WP-2/180	200	25
Monitoring	K4	035_2023	WP-2/180	25	15
Monitoring	K4	035_2023	WP-2/180	15	0
HIDEA	K4	035_2023	WP-2/180	50	0
HIDEA	K4	035_2023	WP-2/180	50	0
Monitoring	K0	039_2023	WP-2/180	200	75
Monitoring	K0	039_2023	WP-2/180	75	65
Monitoring	K0	039_2023	WP-2/180	65	15
Monitoring	K0	039_2023	WP-2/180	15	0
Monitoring	K-3	043_2023	WP-2/180	147	52
Monitoring	K-3	043_2023	WP-2/180	52	20
Monitoring	K-3	043_2023	WP-2/180	20	10
Monitoring	K-3	043_2023	WP-2/180	10	0
HIMERO	K-3	043_2023	Juday/56	147	0
HIMERO	V22	044_2023	Juday/56	62	0
HIMERO	V26	048_2023	Juday/56	65	0

HIMERO	V29	051_2023	Juday/56	92	0
Monitoring	V31	053_2023	WP-2/180	200	0
Monitoring	V31	053_2023	WP-2/180	20	0
Monitoring	V31	053_2023	WP-2/180	10	0
HIMERO	V31	053_2023	Juday/56	202	0
Monitoring	V34	056_2023	WP-2/180	200	65
Monitoring	V34	056_2023	WP-2/180	65	35
Monitoring	V34	056_2023	WP-2/180	35	25
Monitoring	V34	056_2023	WP-2/180	25	0
HIMERO	V34	056_2023	Juday/56	272	0
Monitoring	S3	064_2023	WP-2/180	168	20
Monitoring	S3	064_2023	WP-2/180	20	10
Monitoring	S3	064_2023	WP-2/180	10	0
HIMERO	S3	064_2023	Juday/56	168	0
Monitoring	S6	067_2023	WP-2/180	200	25
Monitoring	S6	067_2023	WP-2/180	25	10
Monitoring	S6	067_2023	WP-2/180	10	0
HIDEA	S6	067_2023	WP-2/180	50	0
HIDEA	S6	067_2023	WP-2/180	50	0
Monitoring	S8	070_2023	WP-2/180	200	20
Monitoring	S8	070_2023	WP-2/180	20	10
Monitoring	S8	070_2023	WP-2/180	10	0
Monitoring	S10	074_2023	WP-2/180	200	20
Monitoring	S10	074_2023	WP-2/180	20	10
Monitoring	S10	074_2023	WP-2/180	10	0
Monitoring	S16	080_2023	WP-2/180	200	0
Monitoring	S16	080_2023	WP-2/180	25	10
Monitoring	S16	080_2023	WP-2/180	10	0
HIDEA	S16	080_2023	WP-2/180	50	0
HIDEA	S16	080_2023	WP-2/180	50	0
Monitoring	N4	085_2023	WP-2/180	158	115
Monitoring	N4	085_2023	WP-2/180	115	85
Monitoring	N4	085_2023	WP-2/180	85	25
Monitoring	N4	085_2023	WP-2/180	25	0
HIMERO	N4	085_2023	WP-2/180	157	0
Monitoring	N3	088_2023	WP-2/180	200	120
Monitoring	N3	088_2023	WP-2/180	120	25
Monitoring	N3	088_2023	WP-2/180	25	0
Monitoring	N2	090_2023	WP-2/180	200	60
Monitoring	N2	090_2023	WP-2/180	60	10
Monitoring	N2	090_2023	WP-2/180	10	0
HIDEA	N2	090_2023	WP-2/180	50	0
HIDEA	N2	090_2023	WP-2/180	50	0
Monitoring	N0	094_2023	WP-2/180	200	40
Monitoring	N0	094_2023	WP-2/180	40	20
Monitoring	N0	094_2023	WP-2/180	20	0
Monitoring	N-2	096_2023	WP-2/180	200	50
Monitoring	N-2	096_2023	WP-2/180	50	10
Monitoring	N-2	096_2023	WP-2/180	10	0
Monitoring	N-11	105_2023	WP-2/180	200	0
Monitoring	N-11	105_2023	WP-2/180	25	10
Monitoring	N-11	105_2023	WP-2/180	10	0
HIDEA	N-11	105_2023	WP-2/180	50	0
HIDEA	N-11	105_2023	WP-2/180	50	0
Monitoring	Z13	113_2023	WP-2/180	200	25
Monitoring	Z13	113_2023	WP-2/180	25	10
Monitoring	Z13	113_2023	WP-2/180	10	0
Monitoring	Z10	116_2023	WP-2/180	200	40
Monitoring	Z10	116_2023	WP-2/180	40	10
Monitoring	Z10	116_2023	WP-2/180	10	0
Monitoring	Z7	119_2023	WP-2/180	200	70
Monitoring	Z7	119_2023	WP-2/180	70	10

Monitoring	Z7	119_2023	WP-2/180	10	0
Monitoring	Z4	122_2023	WP-2/180	200	40
Monitoring	Z4	122_2023	WP-2/180	40	18
Monitoring	Z4	122_2023	WP-2/180	18	0
Monitoring	Z2	124_2023	WP-2/180	200	40
Monitoring	Z2	124_2023	WP-2/180	40	20
Monitoring	Z2	124_2023	WP-2/180	20	0
HIMERO	Z2	124_2023	WP-2/180	260	0
Monitoring	WB3	128_2023	WP-2/180	185	50
Monitoring	WB3	128_2023	WP-2/180	50	35
Monitoring	WB3	128_2023	WP-2/180	35	0
HIMERO	WB3	128_2023	WP-2/180	185	0
Monitoring	WB6	132_2023	WP-2/180	175	30
Monitoring	WB6	132_2023	WP-2/180	30	10
Monitoring	WB6	132_2023	WP-2/180	10	0
Monitoring	WB9	136_2023	WP-2/180	200	50
Monitoring	WB9	136_2023	WP-2/180	50	15
Monitoring	WB9	136_2023	WP-2/180	15	0
Monitoring	WB11	138_2023	WP-2/180	200	40
Monitoring	WB11	138_2023	WP-2/180	40	20
Monitoring	WB11	138_2023	WP-2/180	20	0
Monitoring	WB17E	144_2023	WP-2/180	200	45
Monitoring	WB17E	144_2023	WP-2/180	45	10
Monitoring	WB17E	144_2023	WP-2/180	10	0
Monitoring	WB19E	146_2023	WP-2/180	200	80
Monitoring	WB19E	146_2023	WP-2/180	80	18
Monitoring	WB19E	146_2023	WP-2/180	18	0
HIDEA	WB19E	146_2023	WP-2/180	50	0
HIDEA	WB19E	146_2023	WP-2/180	50	0
Monitoring	WB21E	148_2023	WP-2/180	200	140
Monitoring	WB21E	148_2023	WP-2/180	140	18
Monitoring	WB21E	148_2023	WP-2/180	18	0
HIMERO	WB21E	148_2023	WP-2/180	210	0
Monitoring	Y12	156_2023	WP-2/180	200	60
Monitoring	Y12	156_2023	WP-2/180	60	10
Monitoring	Y12	156_2023	WP-2/180	10	0
Monitoring	Y9	159_2023	WP-2/180	200	55
Monitoring	Y9	159_2023	WP-2/180	55	18
Monitoring	Y9	159_2023	WP-2/180	18	0
HIDEA	Y9	159_2023	WP-2/180	50	0
HIDEA	Y9	159_2023	WP-2/180	50	0
Monitoring	Y5	163_2023	WP-2/180	200	30
Monitoring	Y5	163_2023	WP-2/180	30	10
Monitoring	Y5	163_2023	WP-2/180	10	0
HIMERO	Y5	163_2023	WP-2/180	360	0
Monitoring	EB2-1	171_2023	WP-2/180	195	30
Monitoring	EB2-1	171_2023	WP-2/180	30	20
Monitoring	EB2-1	171_2023	WP-2/180	20	0
HIMERO	EB2-1	171_2023	Juday/56	195	0
Monitoring	EB2-3	175_2023	WP-2/180	200	40
Monitoring	EB2-3	175_2023	WP-2/180	40	25
Monitoring	EB2-3	175_2023	WP-2/180	25	0
Monitoring	EB2-5	179_2023	WP-2/180	200	20
Monitoring	EB2-5	179_2023	WP-2/180	20	10
Monitoring	EB2-5	179_2023	WP-2/180	10	0
HIDEA	EB2-5	179_2023	WP-2/180	50	0
HIDEA	EB2-5	179_2023	WP-2/180	50	0
Monitoring	EB2-7	183_2023	WP-2/180	200	40
Monitoring	EB2-7	183_2023	WP-2/180	40	20
Monitoring	EB2-7	183_2023	WP-2/180	20	0
Monitoring	EB2-10	188_2023	WP-2/180	200	20
Monitoring	EB2-10	188_2023	WP-2/180	20	10

Monitoring	EB2-10	188_2023	WP-2/180	10	0
Monitoring	EB2-11P	191_2023	WP-2/180	200	80
Monitoring	EB2-11P	191_2023	WP-2/180	80	20
Monitoring	EB2-11P	191_2023	WP-2/180	20	0
HIDEA	EB2-11P	191_2023	WP-2/180	50	0
HIDEA	EB2-11P	191_2023	WP-2/180	50	0
Monitoring	EX9	198_2023	WP-2/180	200	60
Monitoring	EX9	198_2023	WP-2/180	60	30
Monitoring	EX9	198_2023	WP-2/180	30	0
Monitoring	EX7	202_2023	WP-2/180	200	40
Monitoring	EX7	202_2023	WP-2/180	40	20
Monitoring	EX7	202_2023	WP-2/180	20	0
Monitoring	EX5P	203_2023	WP-2/180	200	30
Monitoring	EX5P	203_2023	WP-2/180	30	10
Monitoring	EX5P	203_2023	WP-2/180	10	0
HIDEA	EX5P	203_2023	WP-2/180	50	0
HIDEA	EX5P	203_2023	WP-2/180	50	0
Monitoring	EX3P	206_2023	WP-2/180	200	0
HIMERO	EX3	207_2023	Juday/56	180	0

6.5 Comments of the Leg II and III cruise leader

Legs II and III of the AREX2023 cruise proceeded without disruptions, with excellent cooperation between the Captain and the ship’s crew and the scientific team. A persistent technical issue (also occurring during previous cruises) was the large winch, which required manual cable handling. This significantly increased the working time at deep stations. The bottle-closing system on the rosette also frequently malfunctioned. The most probable cause of the recurring problem is wear of the rosette pylon, and replacement is recommended.

7 Mesurements and sampling program during Leg IVa

7.1 General information about Leg IVa

Leg IVa covered research in the area of southern Svalbard, the Hornsund fjord and part of the Norwegian Sea. It began and ended in Longyearbyen, accompanied by scientific team exchanges. Departure from the port took place on Thursday (27 July 2023) instead of Monday (24 July 2023), as originally planned, due to procedural issues. On Friday morning (28 July 2023), the vessel anchored near the Polish Polar Station in Hornsund, where Piotr Wieczorek was disembarked, and part of the scientific team made a short visit to the station. Around noon, research activities began. Due to the limited time available, the scientific leader and the scientific crew decided that measurements would be carried out at as many shared stations as possible. A decision was also made to limit primary production measurements to one replicate at each of the two stations.

For most of the leg, weather conditions were very good, which significantly facilitated the progress of the work. Only strong winds and swell toward the end of the leg, in open waters, forced the cancellation of sampling at the westernmost stations.

Table 7.1. List of stations during leg IVa of the AREX2023 crusise with measurements and responsible groups.

Station	Water depth (m)	Date	Time UTC	Lat (deg min N)	Lon (deg min E)	Measuremet	ZEM bentos	ZEM PFE	ZChiBM WZEM/	ZFM Optyka	ZEM PEP	ZEM PFBP	ZDM OOLab
HB3	243	2023-07-28	10:50:00	76 58.070	15 44.202	CTD Idronaut; 9xVan Veen, 3x Box Corer; acs, C-OPs,Trios; 10 x net WP2/180, 10 x net WP3/1000	x	x		x	x		x
HB2	74	2023-07-28	16:29:00	76 59.999	16 05.402	CTD Idronaut; 9xVan Veen, 3x Box Corer;	x						x
HB1	120	2023-07-28	18:51:00	77 00.127	16 27.805	CTD Idronaut; 9xVan Veen, 3x Box Corer	x						x
H3	130	2023-07-28	22:24:00	77 0.522	16 29.902	CTD with Seabird SBE911+; acs, C-OPs,Trios; 5x net WP-2/180; 4x net Juday/56;		x		x	x		x
H3_2	127	2023-07-28	23:48:00	77 00.514	16 29.842	CTD with Seabird SBE911+							x
R13	71	2023-07-29	01:38:00	77 01.987	16 32.9514	CTD with Seabird SBE911+;acs, C-OPs,Trios				x			x
R12	133	2023-07-29	04:27:00	77 00.824	16 30.618	CTD with Seabird SBE911+							x
R11	124	2023-07-29	05:18:00	76 59.894	16 25.517	CTD with Seabird SBE911+							x
R10	117	2023-07-29	06:00:00	76 59.352	16 21.079	CTD with Seabird SBE911+							x
R9	104	2023-07-29	06:49:00	76 58.829	16 14.174	CTD with Seabird SBE911+							x
R8	47	2023-07-29	07:31:00	76 59.254	16 8.202	CTD with Seabird SBE911+							x
R7	76	2023-07-29	08:07:00	76 59.645	16 4.338	CTD with Seabird SBE911+							x
R6	108	2023-07-29	08:48:00	77 0.023	15 59.882	CTD with Seabird SBE911+							x

R5	170	2023-07-29	09:37:00	76 59.550	15 53.340	CTD with Seabird SBE911+							x
R4	222	2023-07-29	10:27:00	76 58.980	15 46.158	CTD with Seabird SBE911+							x
R3	104	2023-07-29	11:20:00	76 58.355	15 39.620	CTD with Seabird SBE911+							x
R2	153	2023-07-29	12:10:00	76 57.701	15 33.426	CTD with Seabird SBE911+							x
R1	127	2023-07-29	13:00:00	76 57.022	15 26.780	CTD with Seabird SBE911+							x
R0	162	2023-07-29	13:48:00	76 56.234	15 21.915	CTD with Seabird SBE911+							x
RM1	68	2023-07-29	14:42:00	76 59.618	15 14.499	CTD with Seabird SBE911+							x
C1	69	2023-07-29	14:45:00	76 59.617	15 14.465	DROP CAMERA	x						
RM2	126	2023-07-29	15:57:00	76 58.649	15 16.218	CTD with Seabird SBE911+							x
C2	136	2023-07-29	16:48:00	76 57.767	15 18.296	DROP CAMERA	x						
RM3	132	2023-07-29	16:49:00	76 57.764	15 18.295	CTD with Seabird SBE911+							x
RM4	165	2023-07-29	18:02:00	76 57.026	15 19.995	CTD with Seabird SBE911+							x
RM5	142	2023-07-29	19:08:00	76 55.262	15 23.600	CTD with Seabird SBE911+							x
C3	87	2023-07-29	19:52:00	76 54.646	15 25.341	DROP CAMERA	x						
RM6	84	2023-07-29	19:53:00	76 54.633	15 25.325	CTD with Seabird SBE911+							x
C4	30	2023-07-29	21:21:00	76 53.111	15 16.371	DROP CAMERA	x						
AR	104	2023-07-29	22:24:00	76 51.362	15 15.349	CTD with Seabird SBE911+, 10 x net WP2/180, 10 x net WP3/1000							x
GH2	32	2023-07-30	03:02:00	76 56.834	15 49.363	CTD with Seabird SBE911+;acs, C-OPs,Trios, primary production exposition			x	x			x
GH2_2	32	2023-07-30	07:47:00	76 56.832	15 49.381	CTD with Seabird SBE911+;acs, C-OPs,Trios, primary production exposition				x			x
GH2_3	30	2023-07-30	10:28:00	76 56.812	15 49.468	CTD with Seabird SBE911+;acs, C-OPs,Trios, primary production exposition				x			x
HB1	23	2023-07-30	11:40:00	76 59.983	15 37.579	CTD with Seabird SBE911+;acs, C-OPs,Trios, primary production exposition			x	x		x	x
HB1_1	21	2023-07-30	12:38:00	77 0.2568	15 37.490	CTD with Seabird SBE911+;acs, C-OPs,Trios, primary production exposition				x		x	x
HB1	22	2023-07-30	14:44:00	77 00.337	15 38.431	DROP CAMERA	x						x
HB1_2	17	2023-07-30	16:43:00	77 00.343	15 38.440	CTD with Seabird SBE911+;acs, C-OPs,Trios, primary production exposition				x		x	x

HB1_3	19	2023-07-30	18:52:00	77 00.347	15 38.423	CTD with Seabird SBE911+;acs, C-OPs,Trios, primary production exposition				x			x
D1	71	2023-07-30	20:31:00	76 59.553	15 40.744	DROP CAMERA	x						x
D2	133	2023-07-30	21:28:00	76 58.730	15 41.118	DROP CAMERA	x						x
GH2	34	2023-07-31	00:41:00	76 56.816	15 49.243	DROP CAMERA	x					x	x
H4	106	2023-07-31	01:54:00	76 59.977	16 0.097	CTD with Seabird SBE911+;acs, C-OPs,Trios; net MPS/180; 4x net Juday/56;		x		x	x	x	x
H4_2	107	2023-07-31	03:20:00	76 59.976	15 59.980	CTD with Seabird SBE911+							x
H2	225	2023-07-31	06:26:00	76 59.04	15 45.442	CTD with Seabird SBE911+;acs, C-OPs,Trios, net MPS/180; 4x net Juday/56;		x		x	x	x	x
H2_2	225	2023-07-31	07:20:00	76 59.042	15 45.499	CTD with Seabird SBE911+							x
H1	159	2023-07-31	09:53:00	76 56.261	15 21.676	CTD with Seabird SBE911+;acs, C-OPs,Trios; net MPS/180; 4x net Juday/56; 2x net WP-2/180		x	x	x	x	x	x
H1_2	159	2023-07-31	10:26:00	76 56.258	15 21.460	CTD with Seabird SBE911+							x
H1_3	87	2023-07-31	11:23:00	76 56.239	15 21.317	CTD with Seabird SBE911+							x
A	106	2023-07-31	15:09:00	76 57.028	15 02.773	DROP CAMERA	x						x
B	37	2023-07-31	16:15:00	76 54.092	14 58.012	DROP CAMERA	x						
AUK22	38	2023-07-31	20:36:00	76 26.922	16 8.127	CTD with Seabird SBE911+; net WP-2/500;					x		x
AUK21	90	2023-07-31	21:31:00	76 25.714	15 48.390	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
D3	107	2023-07-31	22:42:00	76 56.940	15 43.514	DROP CAMERA	x						
AUK20	147	2023-07-31	22:55:00	76 22.594	15 27.553	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
D4	71	2023-07-31	23:40:00	76 56.460	15 44.254	DROP CAMERA	x						
AUK19	210	2023-08-01	00:24:00	76 18.805	14 58.496	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
AUK18	910	2023-08-01	02:34:00	76 19.283	14 02.102	CTD with Seabird SBE911+; net WP-2/500; net MPS/180;					x	x	x
AUK16	211	2023-08-01	07:09:00	76 24.563	14 40.001	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
AUK15	181	2023-08-01	09:21:00	76 28.310	15 03.911	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
AUK14	98	2023-08-01	11:47:00	76 32.958	15 27.329	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
AUK13	38	2023-08-01	13:46:00	76 35.789	15 46.731	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
AUK12	53	2023-08-01	15:12:00	76 45.022	15 18.397	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
AUK11	219	2023-08-01	18:47:00	76 40.960	14 49.202	CTD with Seabird SBE911+;acs, C-OPs,Trios, net WP-2/500; net MPS/180;				x	x	x	x

AUK9	209	2023-08-01	22:25:00	76 34.879	14 06.395	CTD with Seabird SBE911+; net WP-2/500; 3x net WP2/180					x	x	x
AUK4	208	2023-08-02	00:59:00	76 42.530	13 33.811	CTD with Seabird SBE911+;acs, C-OPs,Trios; net WP-2/500;				x	x	x	x
AUK3	97	2023-08-02	04:09:00	76 46.801	14 6.202	CTD with Seabird SBE911+; net WP-2/500;					x	x	x
AUK2	106	2023-08-02	05:51:00	76 52.031	14 44.847	CTD with Seabird SBE911+; DROP CAMERA;acs, C-OPs,Trios; net WP-2/500;	x			x	x	x	x

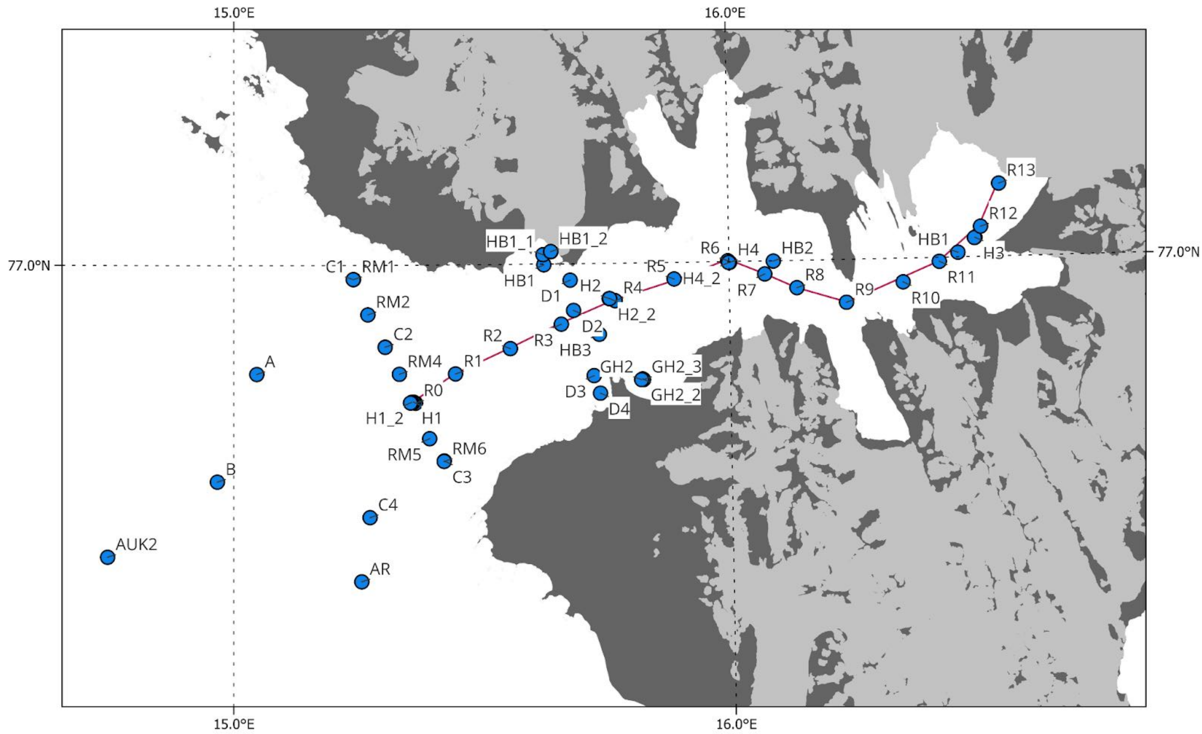

Figure 7.1 Map of stations in Hornsund during Leg IVa.
Continuous measurement transects using LOPC–CTD–F–O–T are marked with a purple line.

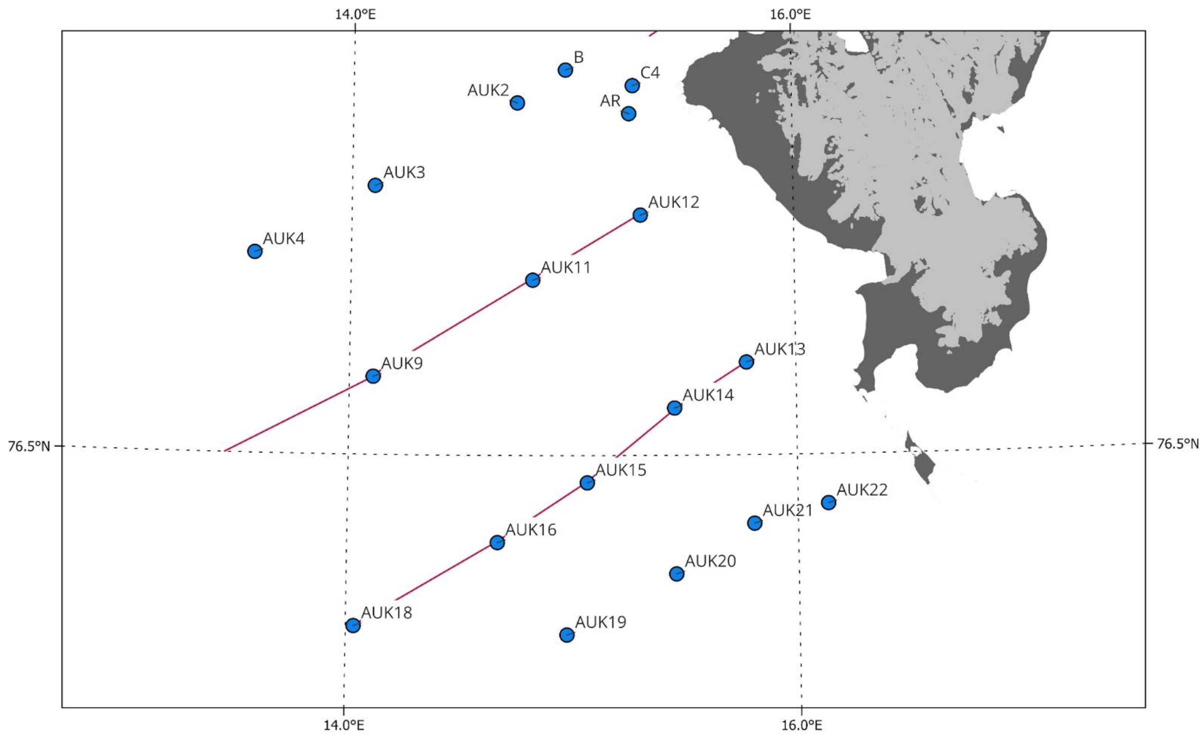

Figure 7.2 Map of stations at the Hornsund forefront during Leg IVa.
Continuous measurement transects using LOPC–CTD–F–O–T are marked with a purple line.

7.2 Detailed description of biological measurements – plankton (PEP)

Description of methods and measurement equipment

Research aimed at determining the qualitative and quantitative composition and distribution patterns of zooplankton in relation to environmental conditions in Hornsund Fjord and its offshore area, as well as in Kongsfjorden, and for assessing zooplankton abundance at the little auk feeding grounds in front of Hornsund Fjord, during the fjord Legs IVa and IVb (Hornsund and Kongsfjorden), was carried out using recommended methods applied in ecological studies of marine zooplankton, using procedures and tools adapted to the research objectives. According to the theoretical plan, zooplankton sampling was intended to be conducted at fixed monitoring stations selected as long-term zooplankton monitoring sites. At each station, zooplankton samples were collected during the vessel's drift or, if possible, while the vessel was anchored. Sampling was planned as vertical hauls from depths as close to the bottom as possible to the surface, in layers, with layer boundaries determined according to the temperature–salinity structure of the water column at the station. Based on previous hydrographic research, zooplankton collection is typically planned in five layers. The thickness of the layers is determined at each station based on vertical temperature and salinity profiles.

The primary sampling equipment was a MultiNet type Midi zooplankton net with a 0.180 mm mesh size. The MultiNet is equipped with sensors for pressure, conductivity, temperature, and fluorescence. Opening and closing of individual nets at specified depths is remotely operated from the vessel. In the event of MultiNet malfunction, samples can be collected using a WP-2 zooplankton net with 0.180 mm mesh size. The WP-2 net is equipped with a mechanical closing system that shuts the net by tightening a rope loop in the upper, non-filtering section of the net. The closing system is triggered mechanically using a Nansen-type closing device. For additional tasks, a WP-3 plankton net with 1.0 mm mesh and a Juday net with 0.064 mm mesh were also used.

For the HIMERO project, samples were collected using the above Juday net from the entire water column and, when possible, also as three stratified samples, with layer boundaries determined by the position of the halocline at each station. In addition, at each station, water samples (approximately 1 L) were collected for filtration through a two-filter set for chlorophyll-a determination (water-collection depths were selected based on fluorescence peaks — real-time measurements — and with respect to depth layers associated with the halocline). Filtered water samples were wrapped in aluminum foil and frozen at –80°C.

For the HIDEA project, zooplankton samples (WP2-180 net, 50–0 m layer) and water samples (1 L from three depths: 0, 25, 50 m) for bacterioplankton and protist plankton genetic analyses were collected. Half of the zooplankton samples were preserved in ethanol, and the remainder in buffered formaldehyde with borax. Water samples were filtered through two filters of different porosity, wrapped in aluminum foil, and frozen at –80°C.

For the TWINS project, samples were collected using two plankton nets: WP2/190 and WP3/1000. Samples were collected in layers — WP2/180 for 10 layers within the upper 100 m, and WP3/1000 for layers every 20 m throughout the entire water column.

Description of measured parameters and collected samples

Zooplankton samples collected for the main research objective—i.e., to determine the qualitative and quantitative composition and distribution patterns of zooplankton in the fjords and on the forefields of Svalbard fjords—were faunistic zooplankton samples collected in stratified vertical hauls using a MultiNet type Midi net with a 0.180 mm mesh size (or, in case of MultiNet malfunction, using a WP-2 net with a 0.180 mm mesh size). On the forefield of Hornsund Fjord, faunistic zooplankton samples were collected with a WP-2 net with a 0.500 mm mesh size.

After collection, zooplankton samples are transferred from the net's collector into sample containers (bottles), and immediately preserved with a 4% buffered formaldehyde solution in seawater, buffered with borax. Containers are labeled on the outside using a waterproof marker with an individual sample number and basic metadata (station name, name and thickness of the sampled layer, sampling date, type of net). In addition, each container receives an internal pencil-written label on tracing paper, containing the individual number and metadata. Containers (bottles) are placed in dedicated transport crates.

In total, during Leg IVa, 32 faunistic samples were collected on the research transect in Hornsund Fjord, 16 faunistic samples on the fjord forefield, as well as 16 faunistic samples for the HIMERO project and 4 or 8 samples for the HIDEA project.

Samples collected for the TWINS project were partially processed on board. Using a stereomicroscope, organisms were identified and selected in bulk for stable isotope analyses and genetic analyses of copepods, while the remaining parts of the samples were preserved in ethanol. In total, 43 samples for faunistic analysis, over 250 samples for stable isotope analysis, and 60 samples for genetic analysis were collected.

List of measurement/sampling stations

MPS stations in the fjord and forefield: H1 fjord mouth, H2 fjord centre, H4 inner fjord, H3 Brepollen, H6 shelf, H7 continental slope.

WP-2/500 stations on the fjord forefield: AUK1, AUK22, AUK21, AUK20, AUK19, AUK18, AUK16, AUK15, AUK14, AUK13, AUK12, AUK11, AUK9, AUK4, AUK3, AUK2.

WP-3/1000 stations: AR, HB3.

WP-2/180 stations: AR, HB3, AUK9.

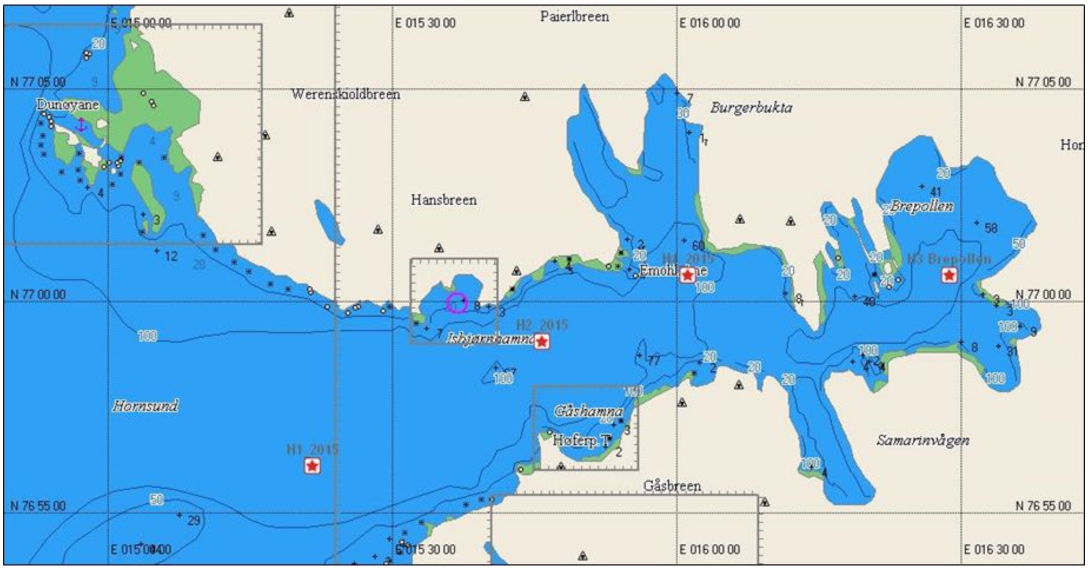

Figure 7.3 Map of stations in Hornsund during the leg IVa.

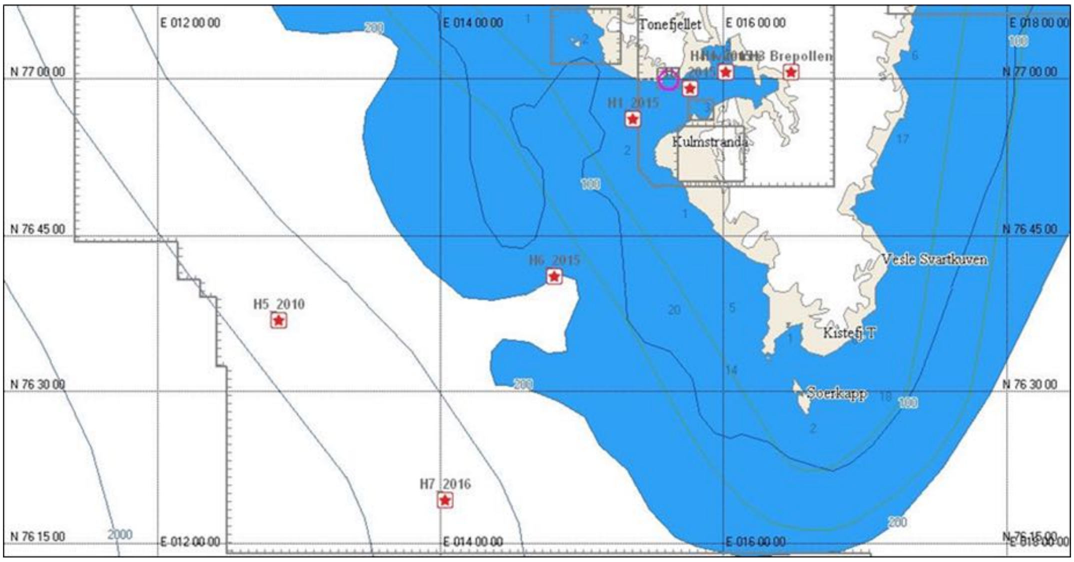

Figure 7.4 Map of stations in Hornsund and at the forefield during the leg IVa (PEP).

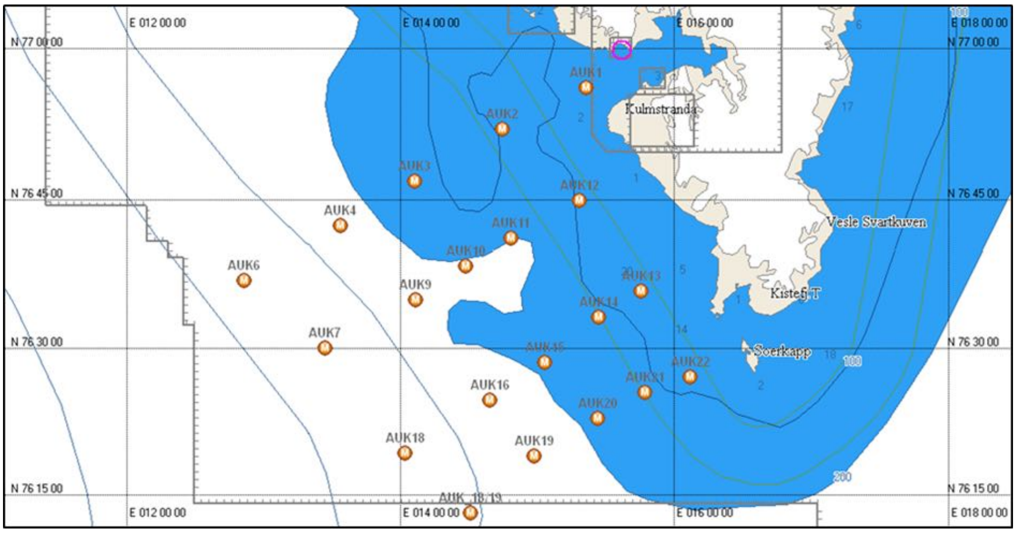

Figure 7.5 Map of stations at the Hornsund forefield during the leg IVa (AUK stations).

Preliminary results and plans for samples and data

During the cruise, no preliminary analytical results were obtained due to the nature of the methods required for processing the collected samples, including the lack of possibility to perform microscopic analyses on board.

Analytical work on the zooplankton samples collected for faunistic studies — qualitative and quantitative analysis of zooplankton composition — will be carried out after the cruise in the laboratory, using optical microscopes and reference literature, in accordance with standard zooplankton laboratory procedures. The results of laboratory microscopic analyses — information on species composition and abundance of zooplankton organisms in the samples — will form the basis for calculating the standardised composition and abundance of zooplankton.

In subsequent stages, standard data on zooplankton composition and abundance, together with collected environmental data, will be used for analyses of zooplankton occurrence in the environment, according to the needs of individual research tasks. Stable isotope analyses and genetic analyses of selected zooplankton individuals will be performed in specialised laboratories.

7.3 Detailed description of biological measurements – plankton (PFBP)

Description of methods and measurement equipment

The composition and distribution of zooplankton are studied using both traditional methods (plankton nets) and automated optical methods (laser optical plankton counter — LOPC and underwater camera — UVP). In addition, the LOPC platform is equipped with several supplementary sensors: CTD, fluorometer, oxygen probe, and a turbidity meter. The non-invasive optical methods are carried out in high–spatial-resolution mode — vertical profiles and transects operated in oscillating mode.

Description of measured parameters and collected samples

Pigments: chlorophyll *a*, carotenoids (Niskin bottle) — seawater filtered through Whatman glass fiber filters (GF/F, nominal pore size 0.7 µm). The material retained on the filter was stored in a freezer (–80°C).

Nano- and microplankton samples (Niskin bottle) — samples preserved with Lugol’s solution.

Mesozooplankton samples (WP2 net) — samples preserved in 4% formalin in seawater buffered with borax, or in ethanol, or frozen.

Abundance, distribution, and composition of plankton and marine aggregates: LOPC–CTD–F–O–T, UVP.

List of sampling/measurement stations

Stations: H4, H2, H1, AUK21, AUK20, AUK19, AUK 18, AUK16, AUK15, AUK14, AUK13, AUK12, AUK11, AUK9, AUK4, AUK3, AUK2, Hb1, GH2

Sections: the LOPC–CTD–F–O–T platform performed continuous measurements along transects in oscillating mode between 50 m and the surface, plus UVP vertical profiles between stations R0–R13, AUK14–AUK16, and AUK21–AUK11.

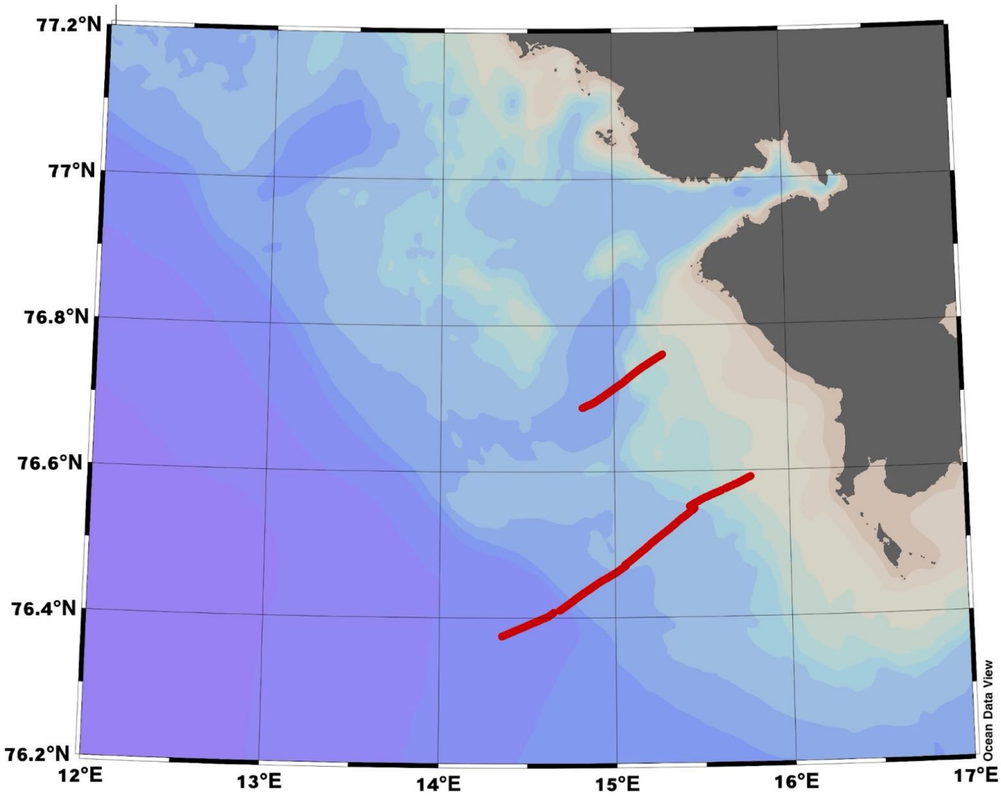

Figure 7.6 LOPC sections at the Hornsund forefield during the AREX2023 cruise leg IVa.

Preliminary results from LOPC sections

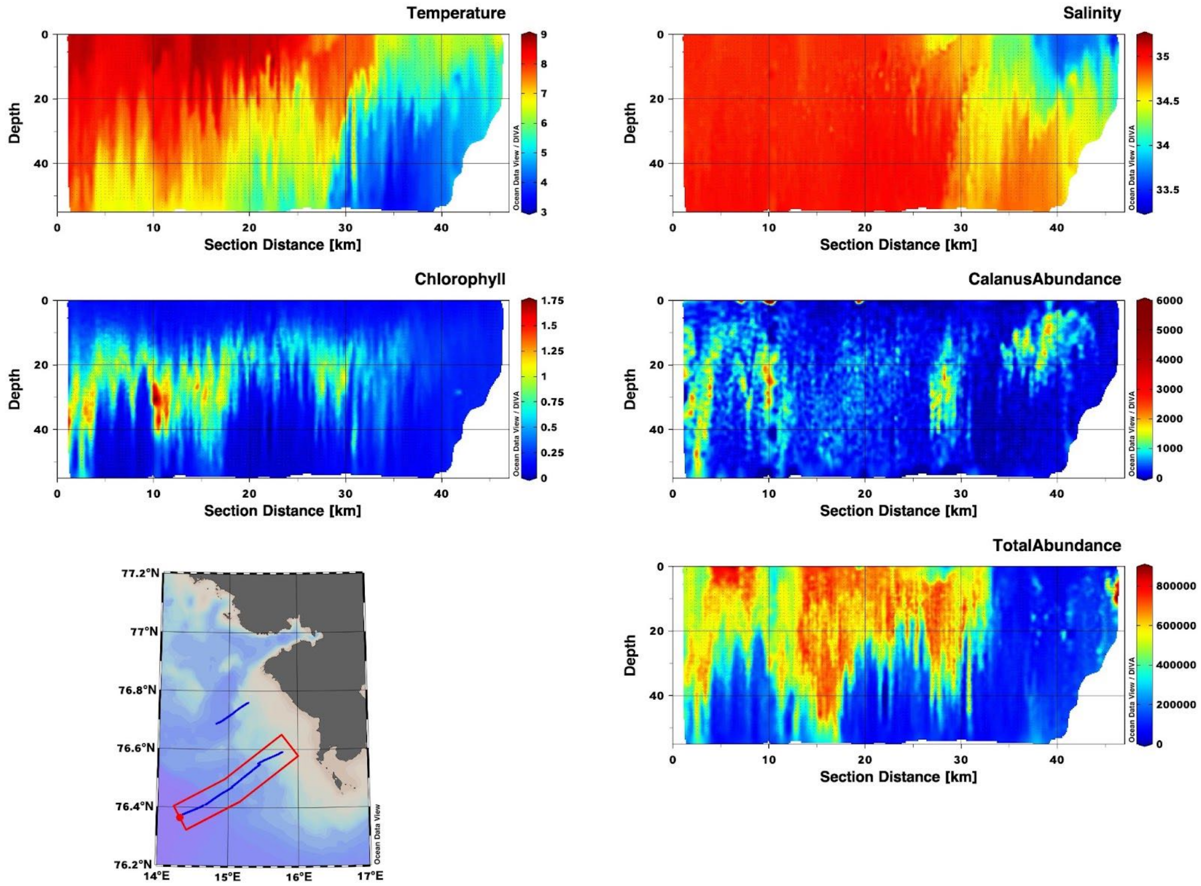

Figure 7.7 Preliminary LOPC measurement results from the Hornsund forefield.

Further processing of samples/data collected during the cruise

The samples will be subjected to qualitative and quantitative analysis at IOPAN. Measurements from the LOPC and UVP were stored on an external hard drive. Further analysis of the measurements will be carried out at IOPAN.

7.4 Detailed description of biological measurements – benthos (PEB)

Description of methods and measurement equipment

Soft-bottom sediments were collected using a van Veen grab and a box-corer. Additionally, 10-minute underwater videos of the seafloor were recorded using a DROP CAMERA system. The filming setup consisted of a metal frame, cable, two lasers, two cameras, two lamps with batteries, and a shipboard computer used for recording/monitoring the camera feed and the distance to the bottom.

Description of measured parameters and collected samples

To extract macrofauna from sediments collected with the van Veen grab, the material was sieved through a 500 µm mesh. To extract Kinorhyncha from van Veen sediments, the samples were processed on board using the bubble and blot method. From the sediments collected with the box-corer, cores were taken for grain-size analysis, carbon and nitrogen content, pigment concentration, and meiofauna. Additionally, surface sediment was collected with a sterile spatula for eDNA analyses.

The underwater videos will be used to analyze the tracks left by benthic organisms as they move across the seabed, as well as to characterize the seafloor and the benthic macrofauna present at each station.

List of sampling/measurement stations

Samples were collected at the following stations: HB1, HB2, HB3 (soft-bottom sediments), and C1, C2, C3, C4, HB1, D1, D2, D3, D4, GH2, A, B, AUK2 (camera recordings) (Tab. 3; Figure 7.1).

Further processing of samples/data collected during the cruise

Macrofauna samples obtained after sieving the sediments on a 500 µm mesh were placed in containers and preserved in a 10% formalin solution in seawater. The remaining sediment samples were frozen at –20°C (for grain-size analysis, carbon content, eDNA), at –80°C (pigment content), or preserved in formalin (meiofauna). Kinorhyncha obtained using the bubble and blot method were preliminarily identified under a stereomicroscope on board; some were preserved in 10% formalin in seawater, and others in ethanol. The underwater videos were preliminarily reviewed and described with regard to seafloor characteristics and dominant macrofauna. They were transferred for further analysis.

7.5 Detailed description of chemical measurements (ZChiBM WZEM/PBM)

Description of methods and measurement equipment

As part of the PROSPECTOR project (Permafrost-Released OrganicS amPlify ocEan aCidificaTiOn in the aRctic?), water-column samples were collected at three measurement stations: HB1 (station influenced by a tidewater glacier), GH2 (station located at a short distance from a river mouth, without direct glacial influence), and H1 (reference station).

At stations HB1 and GH2, an STD profile was conducted, and at selected depths, seawater samples were collected using the rosette sampler to determine biochemical properties (parameters listed below). At the reference station (H1), an STD profile was made and surface water was collected. The collected samples were then either analysed directly on board (spectrophotometric pH measurement using a HydroFIA system) or appropriately prepared and preserved for later analyses in the IOPAN laboratories.

Description of measured parameters and collected samples

During Leg IVa, the following chemical parameters were measured:

- total alkalinity
- concentration of suspended and dissolved organic and inorganic carbon
- chlorophyll-a concentration
- biogenic substances
- concentration of trace elements, analysis of the bioavailable Fe fraction (extraction with L-ascorbic acid and sodium dithionite; 2-line ferrihydrite) and amorphous minerals
- pH (measured on board immediately after sample collection)
- total mercury

Water samples for total alkalinity and dissolved inorganic carbon were preserved with $HgCl_2$ and stored in sample crates until delivery to the IOPAN laboratory. Samples for dissolved organic carbon, mercury, and trace metals were properly prepared (filtered), preserved, and stored in a refrigerator at +8°C until delivery to the IOPAN laboratory. Samples for analyses of biogenic substances were frozen at –20°C until delivery to the IOPAN laboratory. Filters obtained after filtration of seawater samples were frozen at –20°C for later laboratory analyses.

List of measurement/sampling stations

Chemical measurements were carried out at stations GH2, HB1, and H1.

Further processing of data/samples collected during the cruise

Samples collected during the cruise are currently being analysed in the laboratories of the Department of Marine Chemistry and Biochemistry at IOPAN. The samples obtained during the cruise will form an important part of the dataset collected within the PROSPECTOR project (implemented in 2021–2024). The data collected during the cruise will be presented in a manuscript forming part of the doctoral dissertation of MSc Fernando Aguado Gonzalo, a doctoral candidate at the International Environmental Doctoral School, conducted at the Institute of Oceanology PAS in Sopot. Additionally, the results will be presented at the Ocean Sciences Meeting 2024.

7.6 Detailed description of optical measurements (ZFM)

Description of methods and measurement equipment

During Leg IVb of the AREX 2023 expedition, as part of the tasks of the Remote Sensing of the Sea Laboratory (Task II.5), the Ocean and Atmosphere Optics Laboratory (Task I.1), and the DOMinEA and RAW projects, research was conducted at selected stations using the following instruments:

1) **Optical–hydrological probe** for measuring the inherent optical properties of seawater, consisting of:

- CTD probe (Conductivity–Temperature–Depth), Seabird SBE 49 FastCAT;
- Absorption and attenuation meter AC-s (WetStar). The AC-s measures total non-water absorption a(λ) and light attenuation c(λ) by suspended particles and dissolved substances in seawater in 80 spectral channels (400–700 nm). The AC-s signal is then corrected for scattering (assuming that absorption at 715 nm equals 0 in seawater; Zaneveld et al., 1994);
- Three-channel WetStar fluorometer for measuring CDOM fluorescence. The fluorometer measures CDOM fluorescence intensity in three narrow spectral channels:
  - Channel 1 (CH1), ex./em. 310/450 nm — two fluorescence maxima (C and M peaks) typical of marine humic-like substances;
  - Channel 2 (CH2), ex./em. 280/450 nm — fluorescence maximum (A peak) typical of terrestrial humic-like substances;
  - Channel 3 (CH3), ex./em. 280/350 nm — fluorescence maximum (T peak) characteristic of protein-like derivatives (Coble, 1996)
- DH4 data integrator (WetLabs Inc.).

Using the optical–hydrological probe (at selected stations), vertical profiles were carried out from the surface down to approximately 180 m, or to 2 m above the seabed. The profiling depth depended on the local bottom depth, the length of the measurement line, and the prevailing weather conditions. All optical components of the probe were routinely cleaned.

Figure 7.8 Optical-hydrological probe.

2) Optical profiling system – COPs (Compact Optical Profiling System), Biospherical Instruments Inc. A system consisting of two radiometers used to determine the apparent optical properties of seawater; one measures upwelling radiance, and the other measures irradiance. The COPs system is equipped with 19 spectral channels (340, 380, 395, 412, 443, 465, 490, 510, 520, 532, 555, 565, 589, 625, 665, 683, 710, 765 nm, and a PAR channel).

The COPs system was deployed from the ship's side in free-fall mode, away from the ship's shadow, to the depth of the lower boundary of the euphotic zone or to the seabed (depending on the local depth), or to a shallower depth if required by weather conditions. The underwater measurements were complemented by simultaneous above-water irradiance measurements Es(λ) using a sensor mounted on the ship's deck. These measurements were used to calculate the PAR level in the profiles and the water colour ("ocean color").

Figure 7.9 COPs - Compact Optical Profiling system.

3) Upwelling radiance float – RAMSES (TRIOS) – a radiometer mounted on a specially constructed frame that enables measurements just below the water surface, regardless of weather conditions. The underwater measurements were complemented by simultaneous above-water irradiance measurements using a sensor mounted on the ship's deck..

Primary production measurements were carried out using the C-14 method. The methodology for determining PP assumes a 4-hour exposure of previously collected and prepared water samples at appropriate depths under natural environmental conditions. PP incubations were conducted at stations GH2 and HB1 (Table 3, Figure 7.1).

Seawater was collected at the following depths: 0, 1, 2, 3, 5, 7, 10, 15, 20, and 25 m at station GH2, and 0, 1, 2, 3, 5, 7, 10, and 15 m at station HB1.

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In addition to primary production measurements at the specified depths, samples were collected for the determination of chlorophyll, carotenoid, and phycobilin concentrations.

Figure 7.10 RAMSES oraz TRIOS optical systems.

Description of measured parameters and collected samples

Seawater samples were collected using a rosette equipped with 10-L Niskin bottles (or a 30-L bottle) from discrete depths. The depths were selected based on temperature, salinity, and chlorophyll-a profiles taken immediately prior to sampling. The aim was to collect water samples from the surface, the chlorophyll-a maximum, the deep chlorophyll-a maximum (if present), and from near the bottom.

Samples were collected for the following parameters:

- aCDOM(λ) – light absorption by CDOM
- apl – light absorption by suspended particles
- FDOM – excitation–emission matrices (EEMs) of DOM fluorescence
- DOC – dissolved organic carbon concentration
- Chl-a – chlorophyll-a concentration
- HPLC – concentrations of chlorophyll and accessory pigments
- Lignin phenols – lignin concentration
- SPM – suspended particulate matter concentration
- Size fractions – for some of the above parameters, additional samples were collected from size-fractionated suspended particulate material: 20 µm, 5 µm, and 2 µm.

Lista stacji pomiarowych/poboru prób

Table 7.2. Station list of optical measurements by ZFM during the AREX2023 cruise leg IVa with measured parameters

No	Date	Time	Station	Depth	latitude degrees N	longitude degrees E	CDOM	FDOM	DOC	lignin	Chla	HPLC	fik	fractions	SPM	apl
		[UTC]		[m]	°	°	-	-	-	-	-	-	-	-	-	-
1	28.07.2023	15:00	HB3	0	76.97	15.74	X	X	X	X	X	X	-	-	-	-
				18			X	X	X	X	X	X	-	-	-	-
				60			X	X	X	X	X	X	-	-	-	-
				80			X	X	X	X	X	X	-	-	-	-
				220			X	X	-	-	-	-	-	-	-	-
2	29.07.2023	01:00	H3	0-wiadro	77.01	16.50	-	-	-	-	X	X	-	X	X	X
				0			X	X	X	X	X	X	-	-	-	-
				2			X	X	X	X	X	X	-	-	-	-
				20			X	X	X	X	X	X	-	-	-	-
				90			X	X	X	X	X	X	-	-	-	-
				120			X	X	X	-	-	-	-	-	-	-
3	29.07.2023	04:00	R13	0	67.03	16.55	X	X	X	X	X	X	-	-	-	-

				15			X	X	X	X	X	X	-	-	-	-
				25			X	X	X	X	X	X	-	-	-	-
				55			X	X	X	X	-	-	-	-	-	-
4	30.07.2023	07:06	GH2	0	76.95	15.82	X	X	X	X	X	X	X	-	-	X
		07:00		1			-	-	-	-	X	X	X	-	-	X
		06:52		2			-	-	-	-	X	X	X	-	-	X
		06:43		3			-	-	-	-	X	X	X	-	-	X
		06:35		5			-	-	-	-	X	X	X	-	-	X
		06:28		7			-	-	-	-	X	X	X	-	-	X
		06:00		10			-	-	-	-	X	X	X	-	-	X
		05:48		15			-	-	-	-	X	X	X	-	-	X
		05:40		20			X	X	-	-	X	X	X	-	-	X
		05:20		25			X	X	X	X	X	X	X	-	-	X
5	30.07.2023	15:55	HB1	0	77.00	15.63	X	X	X	X	X	X	X	-	-	X
		15:48		1			-	-	-	-	X	X	X	-	-	X
		15:42		2			-	-	-	-	X	X	X	-	-	X
		15:35		3			-	-	-	-	X	X	X	-	-	X
		15:28		5			-	-	-	-	X	X	X	-	-	X
		15:08		7			X	X	-	-	X	X	X	-	-	X
		15:05		10			X	X	-	-	X	X	X	-	-	X
		14:45		15			X	X	X	X	X	X	X	-	-	X
6	31.07.2023	04:20	H4	0-wiadro	77.00	16.00	-	-	-	-	X	X	X	X	X	X
				0			X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				25			X	X	X	X	X	X	-	-	-	-
				55			X	X	X	X	X	X	-	-	-	-
				97			X	X	X	X	X	X	-	-	-	-
7	31.07.2023	08:00	H2	0	76.98	15.76	X	X	X	X	X	X	-	-	-	-
				25			X	X	X	X	X	X	-	-	-	-
				65			X	X	X	X	X	X	-	-	-	-
				110			X	X	X	X	X	X	-	-	-	-
				165			X	X	X	X	-	-	-	-	-	-
				215			X	X	X	X	-	-	-	-	-	-
8	31.07.2023	12:00	H1	0-wiadro	76.94	15.36	-	-	-	-	X	X	X	X	X	X
		13:30		0			X	X	X	X	X	X	-	-	-	-
				25			X	X	X	X	X	X	-	-	-	-
				50			X	X	X	X	X	X	-	-	-	-
				80			X	X	X	X	X	X	-	-	-	-
				115			X	-	X	X	X	X	-	-	-	-
				150			X	-	X	X	-	-	-	-	-	-
9	01.08.2023	21:10	AUK11	0	76.68	14.79	X	X	-	-	X	X	-	-	-	-
				20			X	X	-	-	X	X	-	-	-	-
				50			X	X	-	-	X	X	-	-	-	-
				70			X	X	-	-	X	X	-	-	-	-
				155			X	X	-	-	-	-	-	-	-	-
				211			X	X	-	-	-	-	-	-	-	-
10	02.08.2023	03:20	AUK4	0	76.71	13.56	X	X	-	-	X	X	-	-	-	-
				20			X	X	-	-	X	X	-	-	-	-
				60			X	X	-	-	X	X	-	-	-	-
				100			X	X	-	-	-	-	-	-	-	-
11	02.08.2023	05:51	AUK2	0	76.87	14.75	X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				20			X	X	X	X	X	X	-	-	-	-
				60			X	X	X	X	X	X	-	-	-	-
				95			X	X	X	X	-	-	-	-	-	-

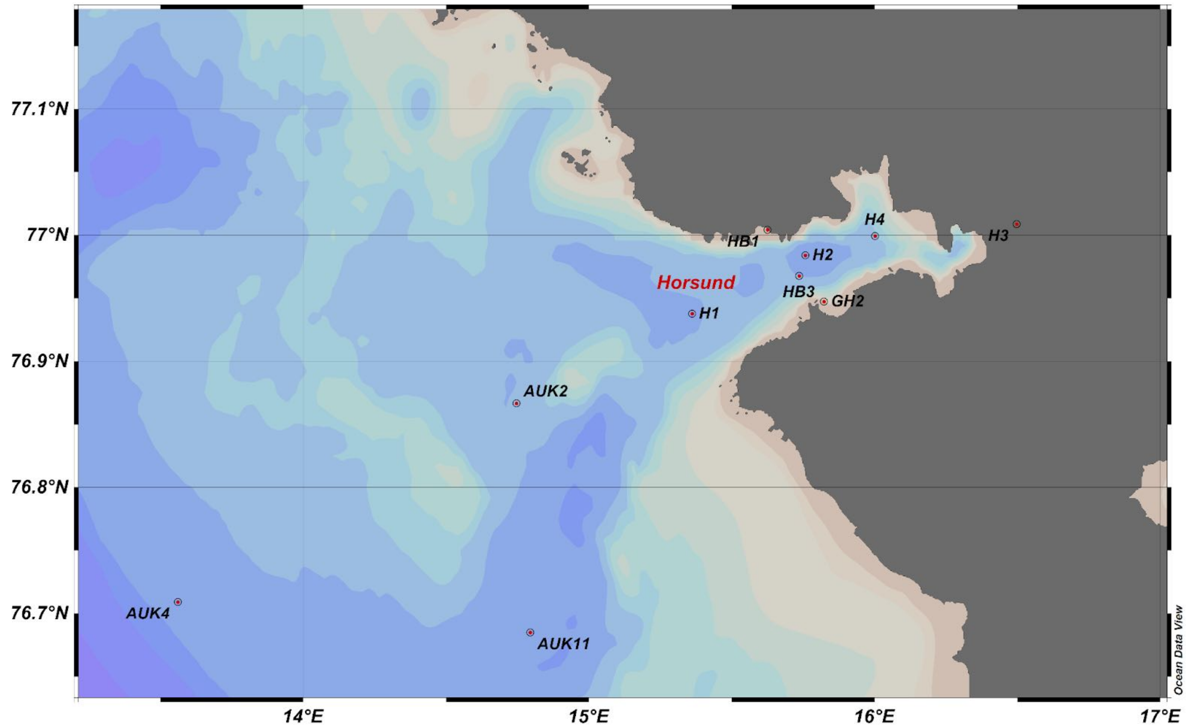

Figure 7.11 Optical measurements stations in Hornsund during the AREX2023 leg IVa.

Preliminary results

A preliminary analysis of the obtained chlorophyll and carotenoid concentrations showed variability both spatially and within the water column. Approximately two-times higher chlorophyll-a concentrations were observed at station GH2 – located in the river outflow area – compared to the glacial-front region (station HB1).

Further processing of data/samples collected during the cruise

Data on the amount of produced organic matter (PP) in the glacial-front region and the river outflow area will be used to analyse the influence of material originating from these sources on the productivity of the Hornsund ecosystems (RAW project).

aCDOM(λ) – measured spectrophotometrically using a dual-beam spectrophotometer (Lambda 650, Perkin Elmer) in a 10-cm quartz cuvette over the spectral range 240–700 nm. MQ water was used as a reference.

EEM – measured spectrophotometrically using a HORIBA Aqualog spectrofluorometer over an excitation range of 240–600 nm (3 nm step) and an emission range of 246.65–829.44 nm (2.33 nm step). The signal integration time was 8 s.

Lignin phenols – samples for determining lignin concentration in seawater will be transported in March 2024 to the AQUA Laboratory at the Technical University of Denmark in Copenhagen. There, they will be oxidised using CuO and subsequently analysed by HPLC.

The aCDOM(λ) and EEM data will be used to perform multivariate analysis (PARAFAC model). The results of this analysis, together with the measured concentrations of phenolic compounds, will be used for quantitative and qualitative studies of dissolved organic matter in the fjords of western Spitsbergen.

Chl-a – after extraction in ethanol (24 h), the samples were measured spectrophotometrically using a dual-beam spectrophotometer (Lambda 650, Perkin Elmer) in a 2-cm quartz cuvette over the spectral range 250–700 nm.

SPM – will be determined gravimetrically.

HPLC – samples for pigment analysis will be measured using high-performance liquid chromatography.

a_{pl} – measured spectrophotometrically using a dual-beam spectrophotometer (Lambda 650, Perkin Elmer). Measurements were performed on filters.

DOC – measurements will be carried out in the ZChiBM laboratory using a TOC-L analyser (Shimadzu).

Particle size distribution – measured using a Coulter counter.

The samples collected during the cruise will form an important part of the dataset gathered within the DOMinEA project (2022–2025). The data collected during the cruise will be presented at an international conference and described in a scientific publication.

7.7 Detailed description of oceanographic measurements (ZDM POO)

The Observational Oceanography Laboratory of the Department of Physical Oceanography conducted measurements in Hornsund at long-term monitoring stations as part of Task I.4 (glacial bays, central and lateral basins of the fjord). Transects (spatially dense vertical profiles) were carried out along and across the fjord axis to investigate the distribution of water masses and fjord water dynamics.

Additionally, CTD measurements were performed at most stations occupied by other research groups in the fjord, as well as on the shelf and slope of southwestern Spitsbergen. At a subset of stations (18 profiles) measured with the SBE 9/11+, water samples were collected using a Niskin rosette at defined depths for use in various projects involving plankton, benthos, optical, chemical, and other studies. In total, 52 CTD casts were completed with the SeaBird 9/11+ system (files AR23_210–261) and five casts with the Idronaut system (files fiords001–005).

Table 7.3. CTD stations during the AREX2023 cruise leg IVa.

CTD file	Station	Depth (m)	Start				Bottles depths (m)	Bottles numbers
			Date	Time UTC	Lat (deg min N)	Lon (deg min E)		
Measurements with SeaBird 9/11+								
AR23_210	H3	130	28.07.23	22:24	77 0.522	16 29.9016	121, 91, 91, 21, 20, 2, 2, 1, 1	1, 2, 3, 4, 5, 6, 8, 9, 10
AR23_211	H3_2	127	28.07.23	23:48	77 0.5136	16 29.8422	116, 85, 50, 25, 5, 1, 1, 1, 1, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11
AR23_212	R13	71	29.07.23	01:38	77 1.9872	16 32.9514	60, 55, 55, 25, 25, 15, 15, 1, 1, 1, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_213	R12	133	29.07.23	04:27	77 0.8244	16 30.618	xx	xx
AR23_214	R11	124	29.07.23	05:18	76 59.8944	16 25.5168	xx	xx
AR23_215	R10	117	29.07.23	06:00	76 59.352	16 21.0792	xx	xx
AR23_216	R9	104	29.07.23	06:49	76 58.8288	16 14.1738	xx	xx
AR23_217	R8	47	29.07.23	07:31	76 59.2536	16 8.202	xx	xx
AR23_218	R7	76	29.07.23	08:07	76 59.6448	16 4.338	xx	xx
AR23_219	R6	108	29.07.23	08:48	77 0.0228	15 59.8818	xx	xx
AR23_220	R5	170	29.07.23	09:37	76 59.55	15 53.34	xx	xx
AR23_221	R4	222	29.07.23	10:27	76 58.98	15 46.158	xx	xx
AR23_222	R3	104	29.07.23	11:20	76 58.3548	15 39.6204	xx	xx
AR23_223	R2	153	29.07.23	12:10	76 57.7008	15 33.426	xx	xx
AR23_224	R1	127	29.07.23	13:00	76 57.0216	15 26.7804	xx	xx
AR23_225	R0	162	29.07.23	13:48	76 56.2344	15 21.915	xx	xx
AR23_226	RM1	68	29.07.23	14:42	76 59.6184	15 14.4996	xx	xx

AR23_227	RM2	126	29.07.23	15:57	76 58.6488	15 16.218	xx	xx
AR23_228	RM3	132	29.07.23	16:49	76 57.7644	15 18.2952	xx	xx
AR23_229	RM4	165	29.07.23	18:02	76 57.0264	15 19.9956	xx	xx
AR23_230	RM5	142	29.07.23	19:08	76 55.2618	15 23.6004	xx	xx
AR23_231	RM6	84	29.07.23	19:53	76 54.633	15 25.3248	xx	xx
AR23_232	AR	104	29.07.23	22:24	76 51.3618	15 15.3492	95, 95, 50, 50, 36, 35, 25, 25, 15, 15, 5	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_233	GH2	32	30.07.23	03:02	76 56.8344	15 49.3632	xx	xx
AR23_234	GH2_2	32	30.07.23	07:47	76 56.832	15 49.3812	xx	xx
AR23_235	GH2_3	30	30.07.23	10:28	76 56.8116	15 49.4682	xx	xx
AR23_236	HB1	23	30.07.23	11:40	76 59.9832	15 37.5792	xx	xx
AR23_237	HB1_1	21	30.07.23	12:38	77 0.2568	15 37.4904	xx	xx
AR23_238	HB1_2	17	30.07.23	16:43	77 0.3432	15 38.4402	xx	xx
AR23_239	HB1_3	19	30.07.23	18:52	77 0.3426	15 38.4228	xx	xx
AR23_240	H4	106	31.07.23	01:54	76 59.9736	16 0.0972	97, 97, 55, 55, 25, 25, 10, 10, 2, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11
AR23_241	H4_2	107	31.07.23	03:20	76 59.976	15 59.9796	98, 98, 65, 65, 45, 45, 25, 25, 10, 2, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_242	H2	225	31.07.23	06:26	76 59.04	15 45.4416	215, 215, 165, 165, 155, 155, 60, 60, 5, 5, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_243	H2_2	225	31.07.23	07:20	76 59.0424	15 45.4992	111, 111, 65, 65, 25, 25, 1, 1	1, 2, 3, 4, 5, 6, 8, 9
AR23_244	H1	159	31.07.23	09:53	76 56.2614	15 21.6756	1, 2, 2, 1, 1, 2, 2	1, 2, 3, 4, 5, 6, 8
AR23_245	H1_2	159	31.07.23	10:26	76 56.2584	15 21.4602	150, 140, 140, 115, 115, 81, 51, 25, 8, 2, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_246	H1_3	159	31.07.23	11:23	76 56.2386	15 21.3168	81, 81, 50, 51, 25, 25, 2, 2, 2, 2, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_247	AUK22	38	31.07.23	20:36	76 26.922	16 8.127	xx	xx
AR23_248	AUK21	90	31.07.23	21:31	76 25.7136	15 48.39	50, 50, 35, 35, 26, 25, 15, 16, 5, 5	1, 2, 3, 4, 5, 6, 8, 9, 10, 11
AR23_249	AUK20	147	31.07.23	22:55	76 22.5936	15 27.5526	xx	xx
AR23_250	AUK19	210	01.08.23	00:24	76 18.8046	14 58.4964	xx	xx
AR23_251	AUK18	910	01.08.23	02:34	76 19.2828	14 2.1024	xx	xx
AR23_252	AUK16	211	01.08.23	07:09	76 24.5628	14 40.0008	xx	xx
AR23_253	AUK15	181	01.08.23	09:21	76 28.3104	15 3.9108	50, 35, 26, 15, 6	1, 2, 3, 4, 5
AR23_254	AUK14	98	01.08.23	11:47	76 32.958	15 27.3294	xx	xx
AR23_255	AUK13	38	01.08.23	13:46	76 35.7888	15 46.731	xx	xx
AR23_256	AUK12	53	01.08.23	15:12	76 45.0216	15 18.3966	48, 36, 26, 15, 5	1, 2, 3, 4, 5
AR23_257	AUK11	219	01.08.23	18:47	76 40.9602	14 49.2024	211, 155, 71, 71, 51, 51, 21, 21, 2, 2, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_258	AUK9	209	01.08.23	22:25	76 34.8792	14 6.3948	198, 198, 102, 102, 49, 49, 35, 34, 26, 16, 6	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_259	AUK4	208	02.08.23	00:59	76 42.5304	13 33.8112	204, 100, 60, 61, 20, 21, 4, 4	1, 2, 3, 4, 5, 6, 8, 9
AR23_260	AUK3	97	02.08.23	04:09	76 46.8012	14 6.2022	xx	xx
AR23_261	AUK2	106	02.08.23	05:51	76 52.0308	14 44.847	96, 95, 60, 61, 20, 20, 10, 10, 1, 1, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
Measurements with Idronaut								
fiords001	HB3	243	28.07.23	10:50	76 58.0728	15 44.2032	xx	xx
fiords002	HB2	74	28.07.23	16:29	76 59.9940	16 5.5590	xx	xx
fiords003	HB1	112	28.07.23	18:50	76 59.9988	16 5.4108	xx	xx

Description of methods and measurement equipment

Measurements were carried out at research stations by performing profiles from the surface to the seabed within the fjord and at the shallower shelf stations. At deeper stations located in front of the fjord, casts were limited to ~200 m to save time (except for the deepest station, AUK18, where a full-depth profile to 910 m was obtained). In most cases, the SBE 9/11+ system with a Sea-Bird Electronics rosette was used. A new system based on an Idronaut probe mounted inside a protective cage was also tested.

The CTD rosette system, standard for oceanographic surveys, was equipped with a pressure sensor, a dual set of temperature and conductivity sensors, a dissolved oxygen sensor, a fluorescence sensor, and an altimeter. Information on the individual sensors used in both CTD systems is provided in Table XX (identical systems to those used during Legs II and III).

The rosette was fitted with 11 Niskin bottles, each with a volume of 10 litres, allowing fast collection of large water volumes. During operations, occasional failures of individual Niskin bottles to close were observed; wherever possible, duplicate water samples were collected from all or most depths (with exceptions at stations where the number of target depths was highest).

Throughout the entire Leg, additional information on ocean currents was collected using a vessel-mounted acoustic Doppler current profiler (VM-ADCP, RDI) installed in the ship's hull.

7.8 Detailed description of biological measurements (PFE)

Description of methods and measurement equipment

As part of the ANALOG project, water column samples were collected at selected stations using a rosette sampler. In addition, CTD data were used to precisely determine the depths from which the samples were taken for subsequent analyses. On board the vessel, the samples were filtered and preserved appropriately before being delivered for chemical analysis.

Description of measured parameters and collected samples

Seawater samples were collected within the main research task aimed at characterising the chemical composition of seawater in Hornsund. The study focuses on the availability of nutrients essential for the development of kelp forests, as well as identifying potential factors limiting their growth. Samples were collected from various depths in the water column using the rosette, guided by CTD station data.

The seawater samples were taken for the determination of selected metals, ions, and dissolved organic carbon. The collected material was preserved on board using hydrochloric acid, nitric acid, or mercuric chloride, depending on the planned chemical analyses. Samples were stored on the vessel in properly labelled and identified containers.

The preserved seawater samples were transported under +4°C conditions to the Institute of Oceanology, Polish Academy of Sciences.

List of measurement/sampling stations

H1, H2, H3, H4, HB3

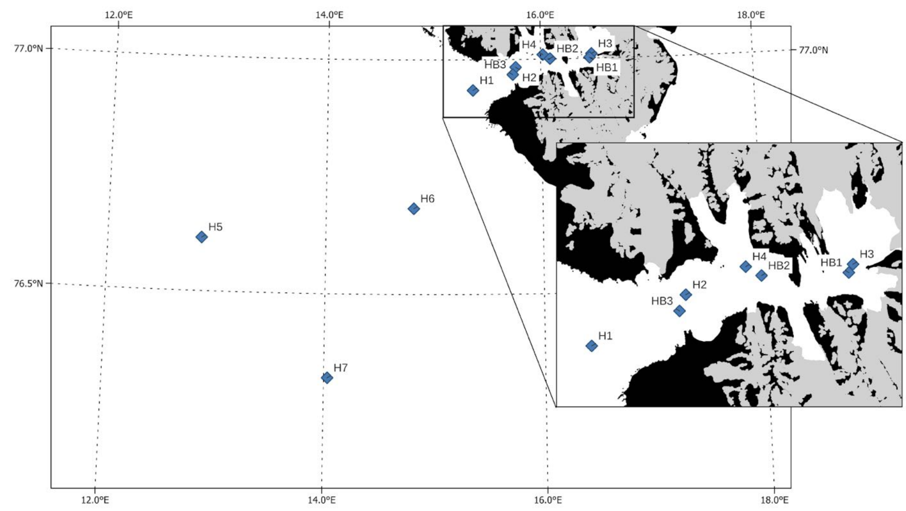

Figure 7.12 Stations occupied by ZEM PFE in Hornsund and at its forefield during the Leg IVa.

Preliminary results

The seawater samples collected during the cruise are currently being analysed by researchers at the University of Silesia in Katowice and Adam Mickiewicz University in Poznań as part of an established scientific collaboration. These research institutions are equipped with specialised analytical instruments and are analysing the collected samples using ion chromatography (for ion determination) and inductively coupled plasma mass spectrometry (for metal analysis).

Further processing of data/samples collected during the cruise

The results obtained from the analyses of the samples collected during the cruise will form an important part of the dataset gathered within the ANALOG project. The findings will be published in high-impact scientific journals indexed in the Philadelphia list and presented at national and international conferences.

7.9 Comments of the Leg IVa cruise leader

Cooperation with the ship's crew was excellent. Special appreciation is due to the cook for providing a variety of meals and accommodating individuals with different dietary preferences.

During the cruise, the team used a large water sampler that had not been repaired since AREX22. In the event of a rosette malfunction or inability to use it, working with the faulty sampler significantly prolonged station operations.

Inexperienced personnel assigned to the cruise should receive clear and easy-to-understand instructions, consistent with the information provided in the cruise plan. In the future, it may be advisable to require the inclusion of detailed sampling methodology so that the chief scientist can better support inexperienced participants.

The logistics of transporting equipment to and from Longyearbyen via the *Horyzont II* vessel should be improved, particularly to avoid situations where retrieving equipment from the ship at the end of a leg becomes problematic, as this can complicate subsequent cruise legs.

Information regarding any transport of personnel should be included in the cruise plan, specifying the number of people, the amount of equipment being transported, as well as the planned logistics and the dates of loading and unloading. This will support both scientific planning and the ship's crew, especially the cook, in better organising meals.

8 Mesurements and sampling program during Leg IVb

8.1 General information about Leg IVb

Leg IVb covered the area of northwestern Spitsbergen, including the fjords Kongsfjorden, Krossfjorden, Magdalenafjord, and the open waters northwest of Magdalenafjord. It began and ended in Longyearbyen, accompanied by a crew change. During the leg, the vessel anchored twice near Ny-Ålesund: the first time to deliver mussels collected during dredging to researchers from UG and GUMed, and to collect samples from NPI scientists; the second time, the entire crew was allowed to go ashore for a short visit to Ny-Ålesund. The scientific team also visited the King's Bay marine laboratories. During fieldwork in Magdalenafjord, contact was established with a team of ornithologists studying the local little auk colony, and samples were collected from them. During the leg, both the Multinet and the rosette system experienced failures. Both pieces of equipment were repaired by the Scientific Equipment Specialists. Weather conditions during the leg were generally good; only the ice conditions near the Kongsbreen glacier caused delays, allowing sampling at station KB1/V1 only on the third attempt.

Table 8.1. List of stations during leg IVb of the AREX2023 cruise with measurements and responsible groups.

Station	Water depth (m)	Date	Time UTC	Lat (deg min N)	Lon (deg min E)	Measuremet	ZEM bentos	ZEM PFE	ZChiBM WZEM/P	ZFM Optyka	ZEM PEP	ZEM PFBP	ZDM OOLab
V6	1127	2023-08-04	10:07:00	78 54.456	7 45.8868	CTD with Seabird SBE911+; 4x net WP-2/180; net MPS/180;					X	X	X
V10	347	2023-08-04	14:45:00	78 56.13	8 32.052	CTD with Seabird SBE911+; 5x net WP-2/180; 4x net Juday/56;		X			X	X	X
V12	222	2023-08-04	19:20:00	78 58.6944	9 30.7128	CTD with Seabird SBE911+; 5x net WP-2/180; 4x net Juday/56;		X			X	X	X
V14	269	2023-08-04	22:44:00	79 0.3972	10 28.7028	CTD with Seabird SBE911+; C-OPs,Trios; 5x net WP-2/180; 4x net Juday/56;		X		X	X	X	X
V14_2	280	2023-08-05	00:17:00	78 59.7792	10 30.465	CTD with Seabird SBE911+						X	X
KChla1	100	2023-08-05	03:13:00	78 57.933	11 14.472	triangle dredge	X						
KChla1	100	2023-08-05	03:43:00	78 57.933	11 14.472	triangle dredge	X						
KChla1	100	2023-08-05	04:11:00	78 57.933	11 14.472	triangle dredge	X						
KChla1	100	2023-08-05	04:40:00	78 58.155	11 14.456	triangle dredge	X						
KO_OC_AR 23_1	162	2023-08-05	07:22:00	78 56.2656	11 56.232	CTD with Seabird SBE911+;GEMAX							X
KO_OC_AR 23_4	310	2023-08-05	09:52:00	78 59.502	11 47.1462	CTD with Seabird SBE911+;GEMAX							X
MZ1	83	2023-08-06	14:22:00	78 57.8484	12 17.4234	CTD with Seabird SBE911+;acs, C-OPs,Trios				X			X
CAM1	55	2023-08-06	16:44:00	78 57.086	12 20.240	DROP CAMERA	X						X
KB3	350	2023-08-06	19:50:00	78 57.0078	11 56.25	CTD with Seabird SBE911+;acs, C-OPs,Trios; net MPS/180; 4x net Juday/56;		X		X	X	X	X

KB3_2	57	2023-08-06	20:52:00	78 57.5412	11 53.8284	CTD with Seabird SBE911+							X
KB2	265	2023-08-06	00:13:00	78 58.6116	11 44.4876	CTD with Seabird SBE911+;acs, C-OPs,Trios; net MPS/180, 4x net Juday/56;		X		X	X	X	X
KB2_2	276	2023-08-06	01:17:00	78 58.6248	11 44.358	CTD with Seabird SBE911+							X
Mi2	73	2023-08-06	07:01:00	78 59.9316	11 59.0754	CTD with Seabird SBE911+; DROP CAMERA; 9 x Van Veen, 3 x Box Corer	X	X					X
E4	289	2023-08-06	10:14:00	78 59.4246	11 34.6956	CTD with Seabird SBE911+; 9 x Van Veen; 3 x Box Corer	X						X
KB1	370	2023-08-07	14:50:00	79 0.6366	11 23.8848	CTD with Seabird SBE911+;acs, C-OPs,Trios; net MPS/180, 4x net Juday/56; 2x net WP-2/180;		X		X	X	X	X
KB1_2	67	2023-08-07	16:18:00	79 0.7428	11 23.28	CTD with Seabird SBE911+							X
KB0	315	2023-08-07	20:26:00	79 2.5812	11 7.7628	CTD with Seabird SBE911+;acs, C-OPs,Trios; net MPS/180, 4x net Juday/56;		X		X	X	X	X
KB0_2	142	2023-08-07	21:34:00	79 2.5764	11 7.9416	CTD with Seabird SBE911+							X
Kros11	330	2023-08-07	08:00:00	79 8.046	11 42.6504	CTD with Seabird SBE911+;acs, C-OPs,Trios				X			X
Kros7	66	2023-08-08	12:00:00	79 12.0606	12 9.8472	CTD with Seabird SBE911+; DROP CAMERA;acs, C-OPs,Trios	X			X			X
Kros5	167	2023-08-08	14:27:00	79 14.1576	11 53.682	CTD with Seabird SBE911+; DROP CAMERA	X			X			X
Kros10	54	2023-08-08	16:43:00	79 17.634	12 4.8492	CTD with Seabird SBE911+; DROP CAMERA;acs, C-OPs,Trios	X			X			X
KROS9	58	2023-08-08	19:14:00	79 15.960	11 51.471	DROP CAMERA;acs, C-OPs,Trios;ctd(statkowe)	X			X			X
Kros8	90	2023-08-09	08:17:00	79 15.8286	12 7.5846	CTD with Seabird SBE911+; DROP CAMERA;acs, C-OPs,Trios	X			X			X
KB5/V1	81	2023-08-09	12:49:00	78 53.2128	12 25.5072	CTD with Seabird SBE911+; DROP CAMERA; 9 x Van Veen, 3 x Box Corer;acs, C-OPs,Trios; net MPS/180, 4x net Juday/56, 2x net WP-2/180	X	X		X	X		X
KB5/V1_2	83	2023-08-09	13:50:00	78 53.22	12 25.5096	CTD with Seabird SBE911+							X
1RK008	46	2023-08-09	23:28:00	78 54.1812	12 17.7936	CTD with Seabird SBE911+							X
1RK007	106	2023-08-09	00:07:00	78 54.9546	12 14.2602	CTD with Seabird SBE911+							X
1RK006a	101	2023-08-09	00:46:00	78 55.4316	12 9.7272	CTD with Seabird SBE911+							X
1RK006	169	2023-08-09	01:22:00	78 56.0148	12 4.9656	CTD with Seabird SBE911+							X
1RK005	244	2023-08-09	01:59:00	78 56.5044	12 1.8288	CTD with Seabird SBE911+							X
1RK004A	351	2023-08-09	02:52:00	78 57.0912	11 55.9164	CTD with Seabird SBE911+							X
1RK004	288	2023-08-09	04:35:00	78 58.0308	11 48.1188	CTD with Seabird SBE911+							X
1RKKB2	318	2023-08-09	05:41:00	78 58.626	11 42.0126	CTD with Seabird SBE911+							X
1RK003	234	2023-08-09	06:42:00	78 59.7516	11 34.1364	CTD with Seabird SBE911+							X

1RKKB1	309	2023-08-09	07:52:00	79 0.8046	11 25.9956	CTD with Seabird SBE911+							X
Kchla1	43	2023-08-09	11:03:00	78 58.4394	11 14.6502	CTD with Seabird SBE911+							X
2RK001	242	2023-08-09	11:39:00	78 59.0202	11 23.6484	CTD with Seabird SBE911+							X
2RK002	327	2023-08-09	12:15:00	78 59.7564	11 26.0004	CTD with Seabird SBE911+							X
2RK003	338	2023-08-09	12:52:00	79 0.516	11 28.4424	CTD with Seabird SBE911+							X
2RK004	237	2023-08-09	13:33:00	79 1.602	11 32.1528	CTD with Seabird SBE911+							X
2RK005	136	2023-08-09	14:08:00	79 2.4192	11 34.4928	CTD with Seabird SBE911+							X
2RK006	68	2023-08-10	14:56:00	79 2.8932	11 35.8926	CTD with Seabird SBE911+; DROP CAMERA	X						X
2RK007	28	2023-08-10	16:09:00	79 3.2694	11 37.1376	CTD with Seabird SBE911+; DROP CAMERA	X						X
MA_OC_AR 23_4	72	2023-08-10	22:32:00	79 34.7832	10 43.4796	CTD with Seabird SBE911+; DROP CAMERA;GEMAX	X						X
MA_OC_AR 23_3	77	2023-08-10	23:51:00	79 33.7596	10 56.9784	CTD with Seabird SBE911+; DROP CAMERA;GEMAX	X						X
MA_OC_AR 23_1	27	2023-08-10	01:14:00	79 33.654	11 9.0942	CTD with Seabird SBE911+; DROP CAMERA;GEMAX	X						X
M7	36	2023-08-10	12:13:00	79 34.3092	10 51.4764	CTD with Seabird SBE911+; 2x net WP-2/180						X	X
M6	49	2023-08-11	14:38:00	79 37.5696	10 24.6744	CTD with Seabird SBE911+; net WP-2/180						X	X
M5	140	2023-08-11	17:21:00	79 43.7316	10 9.072	CTD with Seabird SBE911+; net WP-2/180						X	X
M3	425	2023-08-11	19:48:00	79 48.9108	9 47.8788	CTD with Seabird SBE911+; net WP-2/180						X	X
M1	472	2023-08-11	23:15:00	79 56.1096	9 17.7546	CTD with Seabird SBE911+; net WP-2/180						X	X
M9	478	2023-08-11	01:01:00	79 59.9868	9 41.73	CTD with Seabird SBE911+; net WP-2/180						X	X
M8	449	2023-08-12	02:51:00	79 55.2396	10 5.9322	CTD with Seabird SBE911+; net WP-2/180						X	X
M10	380	2023-08-13	04:31:00	79 49.74	10 18.2088	CTD with Seabird SBE911+; net WP-2/180						X	X
M2	432	2023-08-14	06:41:00	79 48.7284	9 6.1032	CTD with Seabird SBE911+; net WP-2/180						X	X
M4	379	2023-08-14	08:58:00	79 43.0584	9 36.0852	CTD with Seabird SBE911+; net WP-2/180						X	X

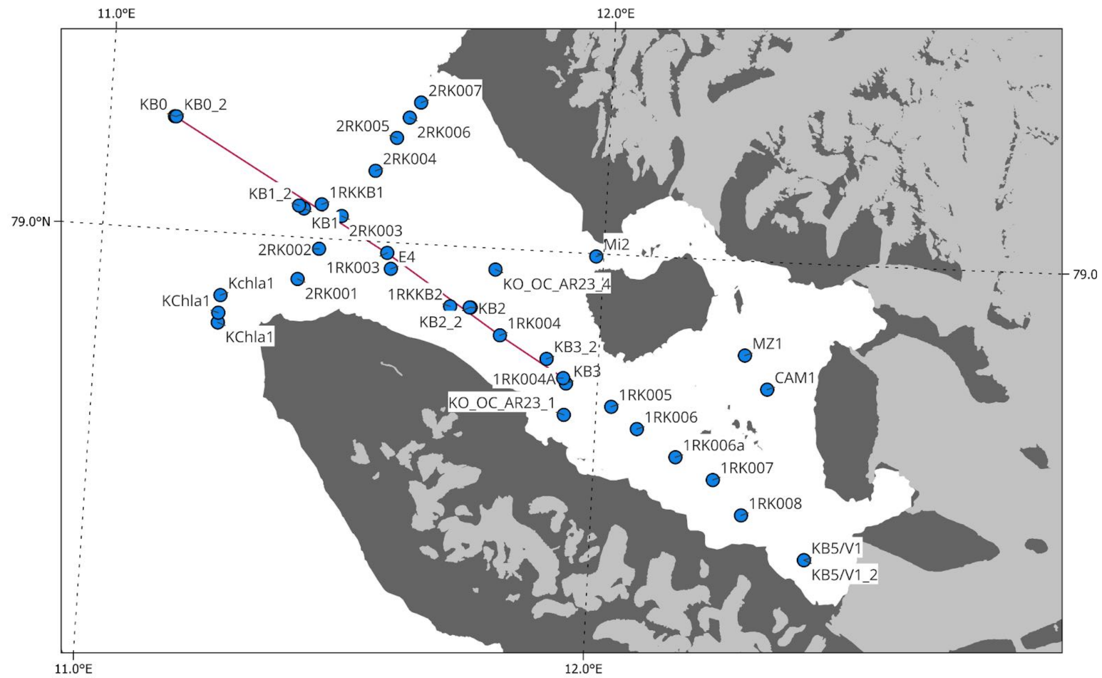

Figure 8.1 Map of stations in Kongsfjorden during the AREX2023 Leg IVb.
Continuous measurement transects using LOPC–CTD–F–O–T are marked with a purple line.

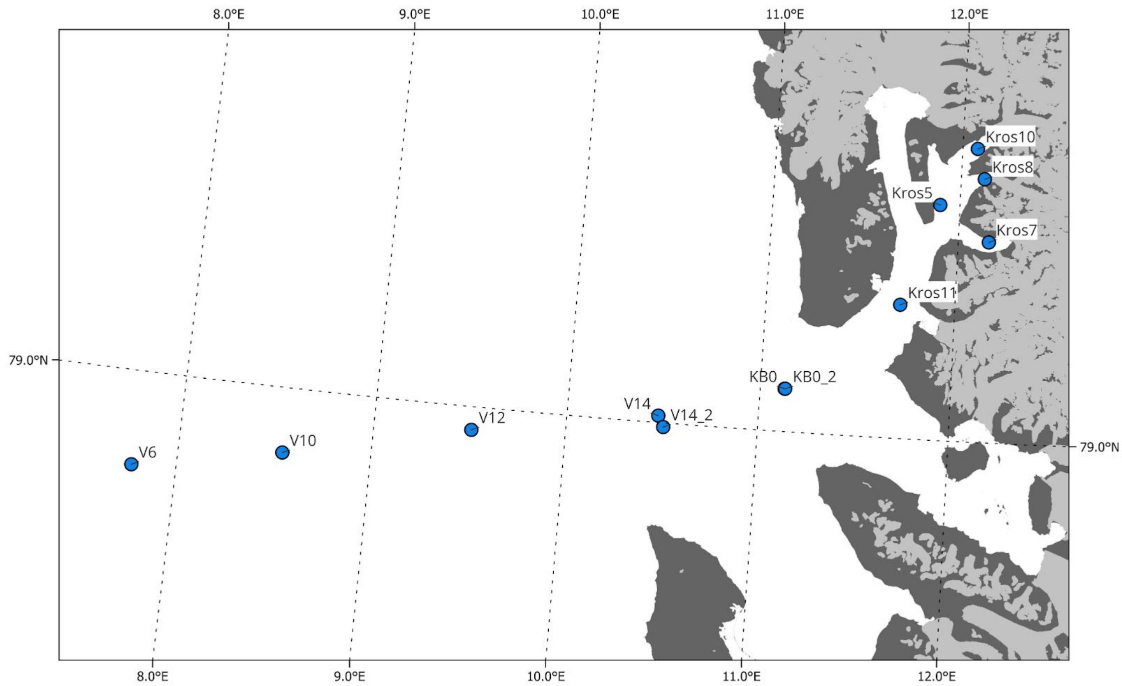

Figure 8.2 Map of stations at the Kongsfjorden forefield during the AREX2023 Leg IVb.

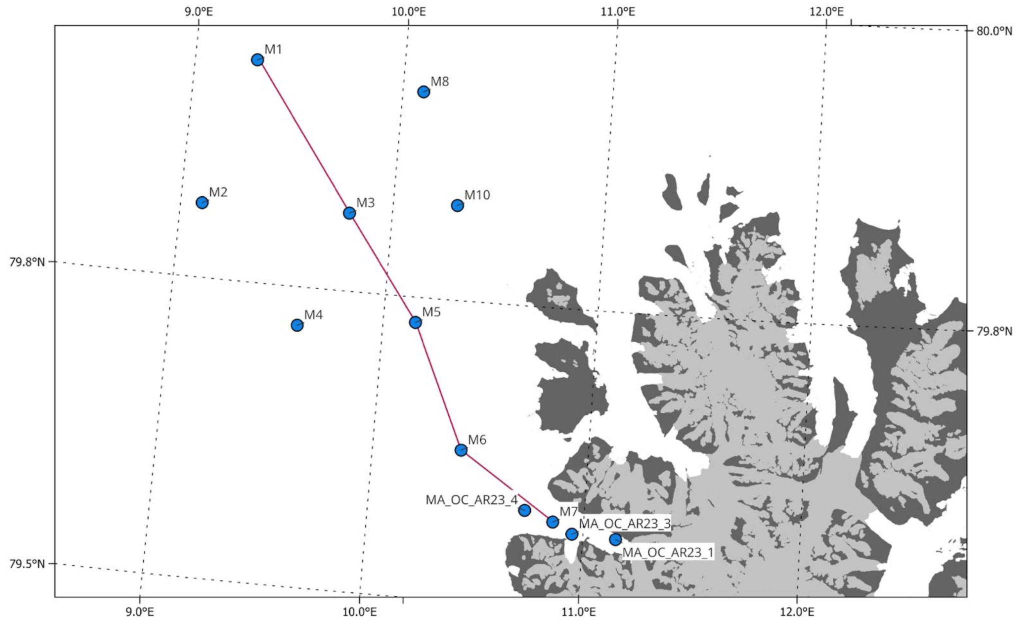

Figure 8.3 Map of stations in Magdalenefjorden and its forefield during the AREX2023 Leg IVb.

8.2 Detailed description of biological measurements – plankton (PEP)

Description of methods and measurement equipment

Studies aimed at determining the qualitative and quantitative composition of zooplankton and its distribution patterns in relation to environmental conditions in Hornsund and its foreland, as well as in Kongsfjorden, and to assess zooplankton availability at the little auk foraging grounds in front of Hornsund, were conducted during the fjord legs IVa and IVb based on recommended methods used in marine zooplankton ecological research, employing procedures and tools adapted to the study objectives. According to the theoretical plan, zooplankton sampling was to be conducted at fixed research stations selected as long-term zooplankton monitoring sites.

At each station, zooplankton samples were collected while the vessel drifted or, when possible, while anchored. Sampling was planned as vertical hauls, from near-bottom depths to the surface, performed in layers defined based on the temperature–salinity structure of the water column at each station. Based on previous hydrographic observations, sampling in typical conditions is carried out in five layers. The thickness of the layers is determined at each station from the temperature and salinity profiles.

The primary sampling gear was a MultiNet type Midi plankton net with a mesh size of 0.180 mm. The MultiNet is equipped with sensors for pressure, conductivity, temperature, and fluorescence. The opening and closing of individual nets at designated depths are controlled remotely from the vessel. In the event of Multinet failure, samples can be collected using a WP-2 plankton net with a 0.180 mm mesh and a mechanical closing system activated by a Nansen-type messenger device. Additional tasks employed a WP-3 plankton net with a 1.0 mm mesh and a Juday-type net with a 0.064 mm mesh.

For the HIMERO project, samples were collected using the above-mentioned Juday net from the entire water column and, when possible, also as three depth-stratified samples, with the layers defined based on the presence of a halocline at each station. Additionally, ~1 L seawater samples were collected at each station for filtration through a set of two filters to determine chlorophyll-a concentration (sampling depths were determined based on real-time fluorescence maxima and depth structure, including the halocline). Filtered samples were wrapped in aluminium foil and frozen at –80°C.

For the HIDEA project, zooplankton samples were collected using a WP-2 net (0.180 mm mesh, 50–0 m layer) and seawater samples (~1 L from three depths: 0, 25, and 50 m) for bacterioplankton and protist plankton studies intended for genetic analyses. Half of the zooplankton samples were preserved in ethanol, and the remainder in buffered formalin with borax. Water samples were filtered through two filters of different porosity, wrapped in aluminium foil, and frozen at –80°C.

Description of measured parameters and collected samples

Zooplankton samples collected for the main research objective—i.e., to determine the qualitative and quantitative composition and distribution patterns of zooplankton in the fjords and in front of the fjords of Spitsbergen—were faunistic zooplankton samples obtained from depth-stratified hauls using a MultiNet type Midi with a 0.180 mm mesh (or, in the case of Multinet failure, a WP-2 net with a 0.180 mm mesh). In the foreland of Hornsund, faunistic zooplankton samples were collected using a WP-2 net with a 0.500 mm mesh.

After retrieval, zooplankton samples were transferred from the net's cod-end into sample containers (bottles) and immediately preserved in a 4% buffered formaldehyde solution prepared in seawater and buffered with borax. The containers were labelled on the outside using a waterproof marker with an individual sample number and a set of basic metadata (station name, water-layer name and extent, sampling date, and net type). In addition, an internal label made of tracing paper, inscribed in pencil with the same individual number and metadata set, was placed inside each container. The containers (bottles) were stored in dedicated collective transport boxes.

In total, during Leg IVb, 49 faunistic samples were collected along the Kongsfjorden transect, as well as 32 faunistic samples for the HIMERO project and 4 samples for the HIDEA project.

List of measurement/sampling stations

MultiNet stations in the fjord and foreland: V6 / continental slope, V10 / continental slope, V12 / shelf, V14 / shelf, KB0 / fjord mouth, KB1 / fjord centre, KB2 / fjord centre, KB3 / inner fjord, KB5 / glacial basin.

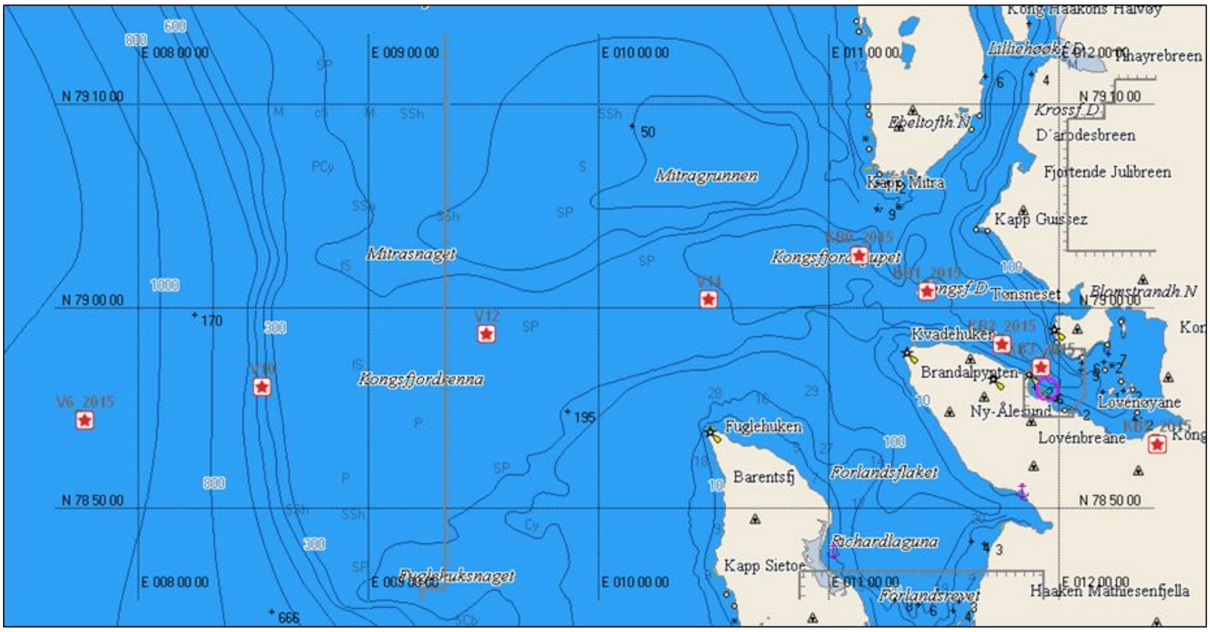

Figure 8.4 Map of stations measured by PEP in Kongsfjorden and at its forefield.

Further processing of data/samples collected during the cruise

No preliminary analytical results were obtained during the cruise due to the specific nature of the methods required for analysing the collected samples, in particular the impossibility of conducting microscopic analyses onboard.

Analytical work on the zooplankton samples collected for faunistic studies—including qualitative and quantitative analysis of zooplankton composition—will be carried out after the cruise in the laboratory, using optical microscopes and relevant taxonomic literature, following established procedures for laboratory analysis of zooplankton. The results of microscopic laboratory analyses, including information on the species composition and abundance of zooplankton organisms in the samples, will serve as the basis for calculating zooplankton composition and abundance in a standardised framework.

In the subsequent stages, the standardised data on zooplankton composition and abundance, together with the collected environmental data, will be used for analyses of zooplankton occurrence patterns according to the specific needs of individual research tasks.

8.3 Detailed description of biological measurements – plankton (PFBP)

Description of methods and measurement equipment

The composition and distribution of zooplankton are studied using both traditional methods (plankton nets) and automated optical methods (laser optical plankton counter — LOPC and underwater camera — UVP). In addition, the LOPC platform is equipped with several supplementary sensors: CTD, fluorometer, oxygen probe, and a turbidity meter. The non-invasive optical methods are carried out in high–spatial-resolution mode — vertical profiles and transects operated in oscillating mode.

Description of measured parameters and collected samples

Pigments: chlorophyll *a*, carotenoids (Niskin bottle) — seawater filtered through Whatman glass fiber filters (GF/F, nominal pore size 0.7 µm). The material retained on the filter was stored in a freezer (–80°C).

Nano- and microplankton samples (Niskin bottle) — samples preserved with Lugol's solution.

Mesozooplankton samples (WP2 net) — samples preserved in 4% formalin in seawater buffered with borax, or in ethanol, or frozen.

Abundance, distribution, and composition of plankton and marine aggregates: LOPC–CTD–F–O–T, UVP.

List of sampling/measurement stations

Stations: V6, V10, V12, V14, KB3, KB2, KB1, KB0, KB5, M7, M6, M5, M3, M1, M8, M10, M2, M4

Sections: the LOPC–CTD–F–O–T platform performed continuous measurements along transects in oscillating mode between 50 m and the surface, plus UVP vertical profiles between stations KB5-V6, M1-M7.

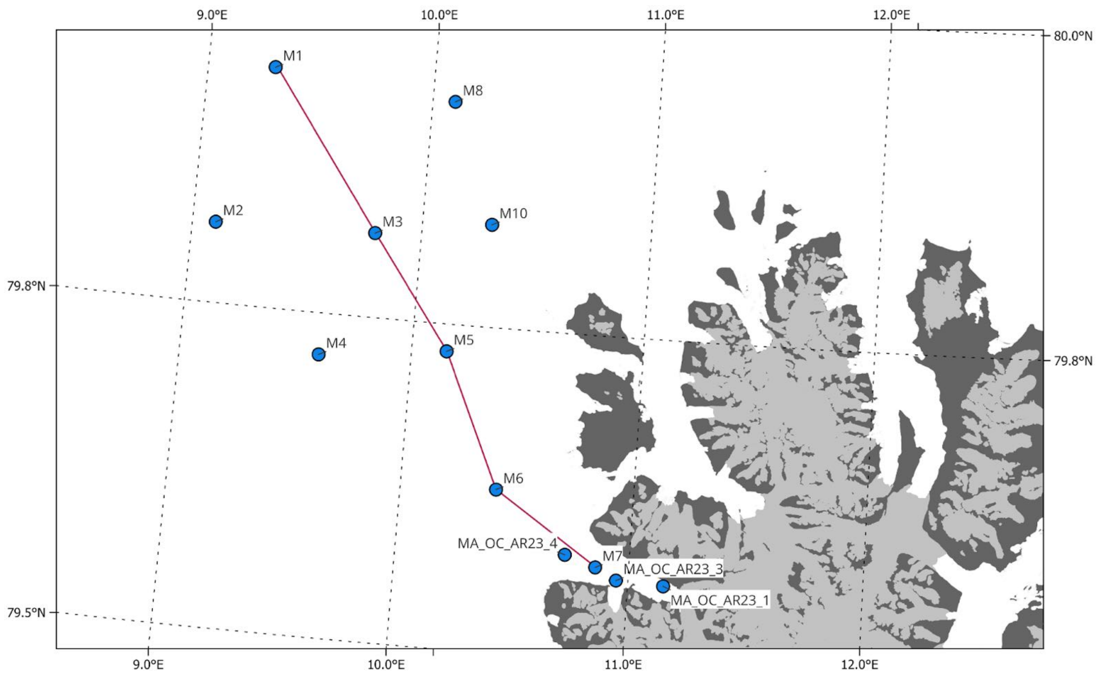

Figure 8.5 LOPC sections at the Magdalenefjorden forefield during the AREX2023 cruise leg IVb.

Preliminary results from LOPC sections

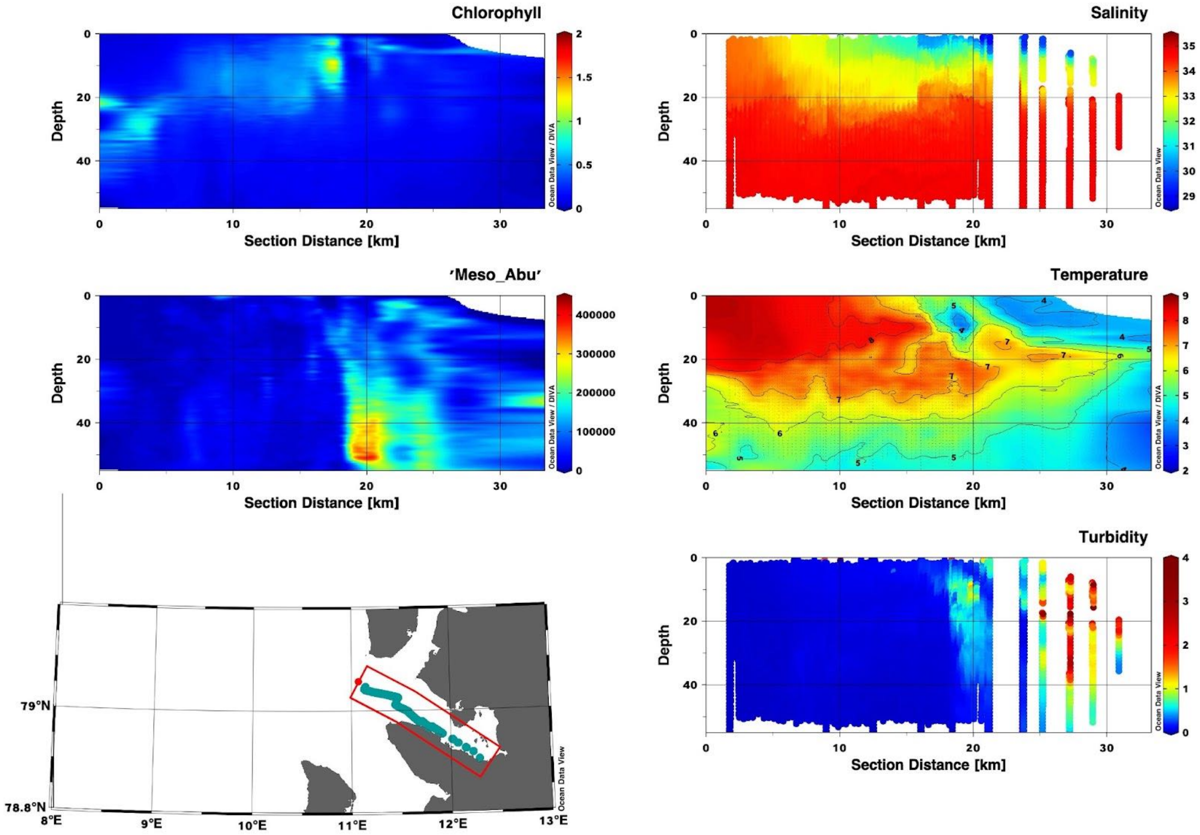

Figure 8.6 Preliminary LOPC measurement results from Kongsfjorden.

Further processing of samples/data collected during the cruise

The samples will be subjected to qualitative and quantitative analysis at IOPAN. Measurements from the LOPC and UVP were stored on an external hard drive. Further analysis of the measurements will be carried out at IOPAN.

8.4 Detailed description of biological measurements – benthos (PEB)

Description of methods and measurement equipment

Soft-bottom sediments were collected using a van Veen grab and a box-corer. Additionally, 10-minute underwater videos of the seafloor were recorded using a DROP CAMERA system. The filming setup consisted of a metal frame, cable, two lasers, two cameras, two lamps with batteries, and a shipboard computer used for recording/monitoring the camera feed and the distance to the bottom.

Description of measured parameters and collected samples

To isolate macrofauna from the sediments collected with the van Veen grab, the material was sieved through a 500 µm mesh. For the extraction of Kinorhyncha from sediments collected with the van Veen grab, the samples were processed onboard using the *bubble and blot* method. From the sediments collected with the box corer, sediment cores were taken for grain-size analysis, carbon and nitrogen content, pigment concentration, and meiofauna studies. Additionally, surface sediments were collected with a sterile spatula for eDNA analyses. Scallops of the genus *Chlamys*, collected with a bottom dredge, were selected and sorted onboard. Underwater video recordings will be used to analyse the traces left on the seafloor by benthic organisms during their movement, as well as to characterise the seabed and the benthic macrofauna present at each station.

List of sampling/measurement stations

Samples were collected at stations E4, Mi2, V1 (soft-bottom sediments), KChla1 (hard-bottom samples), and CAM1, Mi2, KROS7, KROS5, KROS10, KROS9, KROS8, KB5/V1, 2RK006, 2RK007, MA_OC_AR23_4, MA_OC_AR23_3, MA_OC_AR23_1 (underwater camera recordings) (Table 8.1; Figure 8.1).

Further processing of samples/data collected during the cruise

The macrofauna samples obtained after sieving the sediments through a 500 µm mesh were placed in containers and preserved in a 10% formalin solution prepared in seawater. The remaining sediment samples were frozen at –20°C (for grain-size analysis, carbon content, eDNA) or at –80°C (for pigment analysis), or preserved in formalin (for meiofauna). Kinorhyncha extracted using the *bubble and blot* method were preliminarily identified under a stereomicroscope onboard; some specimens were preserved in a 10% formalin solution in seawater, while others were preserved in ethanol.

Scallops of the genus *Chlamys*, collected with a bottom dredge—approximately 50 biofouled individuals and 30 clean individuals—were preserved in 70% ethanol. More than 300 remaining scallops were placed in seawater containers and delivered to Ny-Ålesund to researchers from the University of Gdańsk and the Medical University of Gdańsk as part of the PHARMARINE project collaboration.

The underwater video footage was preliminarily reviewed and described in terms of seafloor characteristics and dominant macrofauna, and has been passed on for further analysis.

8.5 Detailed description of chemical measurements (ZChiBM WZEM/PBM)

Description of methods and measurement equipment

Sediment samples were collected using a GEMAX corer and a van Veen grab. Seawater samples were collected with a rosette or a water sampler from specified depths. Basic seawater parameters were measured using the CTD probe.

Description of measured parameters and collected samples

Basic seawater parameters included temperature and salinity. Seawater samples will be analysed for total mercury content. Sediment samples will be analysed for total mercury concentration, methylmercury concentration, and the concentrations of individual labile and stable mercury fractions.

List of measurement/sampling stations

BI_OC_AR23_1; BI_OC_AR23_2; BI_OC_AR23_3; BI_OC_AR23_4; BI_OC_AR23_5; BI_OC_AR23_6; BI_OC_AR23_7; KO_OC_AR23_1; KO_OC_AR23_2; KO_OC_AR23_3; KO_OC_AR23_4; MA_OC_AR23_1; MA_OC_AR23_2; MA_OC_AR23_3; MA_OC_AR23_4

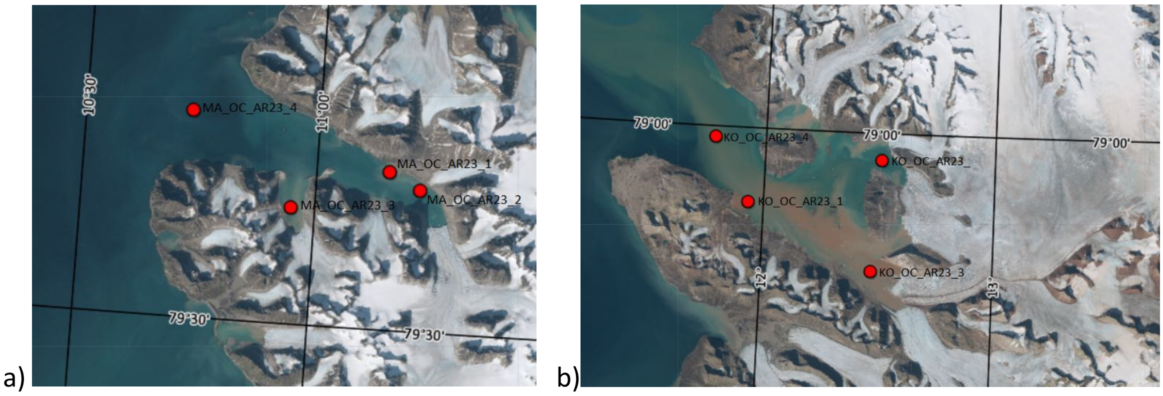

Figure 8.7 Map of stations measured by ZChiBM WZEM/PBM (a) in Magdalenafjorden and (b) in Kongsfjorden.

Further processing of data/samples collected during the cruise

Seawater samples were collected into bottles and preserved for transport. Sediment samples were sectioned into 1 cm layers, placed in zip-lock bags, and frozen onboard at –20ºC until delivery to the laboratory. Further analyses will be carried out in the laboratories of IO PAN.

8.6 Detailed description of optical measurements (ZFM)

Description of methods and measurement equipment

During Leg IVb of the AREX 2023 expedition, as part of the tasks of the Marine Remote Sensing Laboratory (Task II.5), the Marine and Atmospheric Optics Laboratory (Task I.1), and the DOMinEA project, measurements were carried out at selected stations using the same equipment as during Leg IVa, described in Section 7.6.

List of measurement/sampling stations

Table 8.2. Station list of optical measurements by ZFM during the AREX2023 cruise leg IVb with measured parameters

No	Date	Time	Station	Depth	latitude degrees N	longitude degrees E	CDOM	FDOM	DOC	lignin	Chla	HPLC	fik	fractions	SPM	apl
		[UTC]		[m]	°	°	-	-	-	-	-	-	-	-	-	-
1	05.08.2023	19:35	V14	0	79.01	10.48	X	X	X	X	X	X	-	-	-	-
				20			X	X	X	X	X	X	-	-	-	-
				50			X	X	X	X	X	X	-	-	-	-
				258			X	X	-	-	-	-	-	-	-	-
2	05.08.2023	16:30	MZ1	0	78.96	12.29	X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				20			X	X	-	-	X	X	-	-	-	-
				35			X	X	X	X	X	X	-	-	-	-
				78			X	X	X	X	X	X	-	-	-	-
3	05.08.2023	23:00	KB3	0-wiadro	78.95	11.94	-	-	-	-	-	-	-	X	X	X
				0			X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				50			X	X	-	-	-	-	-	-	-	-
				344			X	X	-	-	-	-	-	-	-	-
4	06.08.2023	01:30	KB2	0-wiadro	78.98	11.74	-	-	-	-	-	-	-	X	X	X

				0			X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				35			X	X	X	X	X	X	-	-	-	-
				50			X	X	X	X	X	X	-	-	-	-
				259			X	X	-	-	X	X	-	-	-	-
5	06.08.2023	16:50	KB1	0-wiadro	79.01	11.40	-	-	-	-	-	-	-	-	-	-
				0			X	X	X	X	X	X	-	-	-	-
				7			X	X	X	X	X	X	-	-	-	-
				40			X	X	X	X	-	X	-	-	-	-
				60			X	X	-	-	-	-	-	-	-	-
				250			X	X	-	-	-	-	-	-	-	-
				373			X	X	-	-	-	-	-	-	-	-
6	06.08.2023	23:50	KB0	0-wiadro	79.04	11.13	-	-	-	-	-	-	-	X	X	X
				0			X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				30			X	X	X	X	X	X	-	-	-	-
				100			X	X	X	X	X	X	-	-	-	-
				230			X	X	-	-	-	-	-	-	-	-
				311			X	X	-	-	-	-	-	-	-	-
7	07.08.2023	10:20	Kros11	0	79.13	11.71	X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				15			X	X	-	-	X	X	-	-	-	-
				48			X	X	X	X	X	X	-	-	-	-
				240			X	X	-	-	-	-	-	-	-	-
				325			X	X	-	-	-	-	-	-	-	-
8	07.08.2023	14:30	Kros7	0	79.20	12.16	X	X	X	X	X	X	-	-	-	-
				30			X	X	-	-	X	X	-	-	-	-
				60			X	X	-	-	X	X	-	-	-	-
9	07.08.2023	16:45	Kros5	0	79.24	11.89	X	X	X	X	X	X	-	-	-	-
				30			X	X	-	-	X	X	-	-	-	-
				72			X	X	-	-	-	-	-	-	-	-
				168			X	X	-	-	-	-	-	-	-	-
10	07.08.2023	18:50	Kros10	0	79.29	12.08	X	X	X	X	X	X	-	-	-	-
				7			X	X	-	-	-	-	-	-	-	-
				20			X	X	-	-	X	X	-	-	-	-
				49			X	X	-	-	-	-	-	-	-	-
11	07.08.2023	23:20	Kros9	0	79.26	11.86	X	X	X	X	X	X	-	-	-	-
				30			X	-	-	-	X	X	-	-	-	-
							X	X	-	-	-	-	-	-	-	-
							X	-	-	-	-	-	-	-	-	-
12	08.08.2023	08:45	Kros8	0	79.26	12.13	X	X	X	X	X	X	-	-	-	-
				10			X	-	-	-	X	X	-	-	-	-
							-	-	-	-	-	-	-	-	-	-
13	08.08.2023		KB5	0	78.89	12.42	X	X	X	X	X	X	-	-	-	-
				10			X	X	X	X	X	X	-	-	-	-
				25			X	-	-	-	X	X	-	-	-	-
				35			X	-	-	-	X	X	-	-	-	-
				76			X	-	-	-	-	-	-	-	-	-

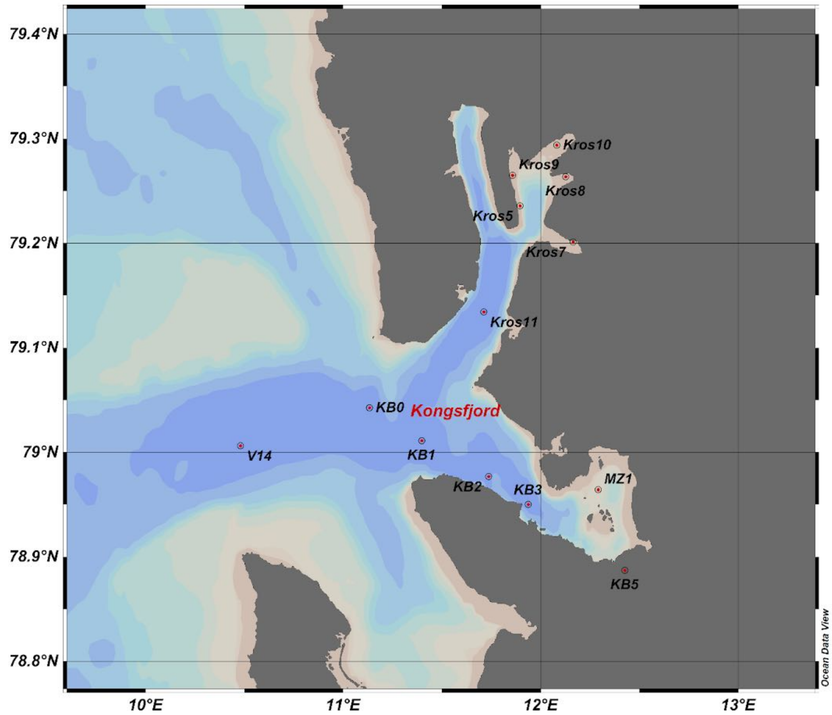

Figure 8.8 Optical measurements stations in Kongsfjorden during the AREX2023 leg IVb.

Further processing of data/samples collected during the cruise

$a_{CDOM}(\lambda)$ – measured spectrophotometrically using a dual-beam spectrophotometer (Lambda 650, Perkin Elmer) in a 10-cm quartz cuvette over the spectral range 240–700 nm. MQ water was used as a reference.

EEM – measured spectrophotometrically using a HORIBA Aqualog spectrofluorometer over an excitation range of 240–600 nm (3 nm step) and an emission range of 246.65–829.44 nm (2.33 nm step). The signal integration time was 8 s.

Lignin phenols – samples for determining lignin concentration in seawater will be transported in March 2024 to the AQUA Laboratory at the Technical University of Denmark in Copenhagen. There, they will be oxidised using CuO and subsequently analysed by HPLC.

The aCDOM(λ) and EEM data will be used to perform multivariate analysis (PARAFAC model). The results of this analysis, together with the measured concentrations of phenolic compounds, will be used for quantitative and qualitative studies of dissolved organic matter in the fjords of western Spitsbergen.

Chl-a – after extraction in ethanol (24 h), the samples were measured spectrophotometrically using a dual-beam spectrophotometer (Lambda 650, Perkin Elmer) in a 2-cm quartz cuvette over the spectral range 250–700 nm.

SPM – will be determined gravimetrically.

HPLC – samples for pigment analysis will be measured using high-performance liquid chromatography.

a_{pl} – measured spectrophotometrically using a dual-beam spectrophotometer (Lambda 650, Perkin Elmer). Measurements were performed on filters.

DOC – measurements will be carried out in the ZChiBM laboratory using a TOC-L analyser (Shimadzu).

Particle size distribution – measured using a Coulter counter.

The samples collected during the cruise will form an important part of the dataset gathered within the DOMinEA project (2022–2025). The data collected during the cruise will be presented at an international conference and described in a scientific publication.

8.7 Szczegółowy opis pomiarów oceanograficznych (ZDM POO)

The Observational Oceanography Laboratory of the Department of Physical Oceanography conducted measurements in Kongsfjorden at long-term monitoring stations as part of Task I.4 (glacial bays, central and lateral basins of the fjord). Transects (spatially dense vertical profiles) were carried out along and across the fjord axis to investigate the distribution of water masses and fjord water dynamics.

Additionally, CTD measurements were conducted at most stations occupied by other research groups in Kongsfjorden, Krossfjorden, Magdalenefjord, and on the shelf and slope of northwestern Spitsbergen (geographical coverage up to 80°N). As in Hornsund, at a subset of stations (34 profiles) measured with the SBE 9/11+, water samples were collected using a Niskin rosette at predefined depths for various projects.

During the casts, problems were encountered with data transmission from the SBE 9/11+, which required repairing a leaking cable. As a result, that station (Krossfjorden, KROS9) was carried out using the SBE SeaCAT system available onboard. The cable issue may also have contributed to earlier transmission errors in the Idronaut probe (measurements with this device were discontinued starting from station Mi2 in Kongsfjorden).

In total, 57 CTD casts were completed with the SBE 9/11+ system (files AR23_262–318), two unsuccessful casts with the Idronaut (files fiords006–007), and one cast with the vessel's SBE 19.

Table 1. CTD stations measured with SBE9/11+ CTD during the AREX2023 cruise leg IVb.

CTD file	Station	Depth (m)	Start				Bottles depths (m)	Bottles numbers
			Data	Czas UTC	Lat (deg min N)	Lon (deg min E)		
AR23_262	V6	1127	04.08.23	10:07	78 54.456	7 45.8868	52, 52, 41, 41, 35, 35, 24, 25, 14, 14, 4	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_263	V10	347	04.08.23	14:45	78 56.13	8 32.052	341, 241, 241, 100, 101, 34, 34, 2, 1	1, 2, 3, 4, 5, 6, 8, 9, 10
AR23_264	V12	222	04.08.23	19:20	78 58.6944	9 30.7128	213, 149, 101, 60, 1	1, 2, 3, 4, 5
AR23_265	V14	269	04.08.23	22:44	79 0.3972	10 28.7028	260, 260, 50, 50, 20, 20, 2, 2, 1	1, 2, 3, 4, 5, 6, 8, 9, 10
AR23_266	V14_2	280	05.08.23	00:17	78 59.7792	10 30.465	272, 272, 130, 75, 50, 40, 36, 25, 15, 5, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_267	KO_OC _AR23_1	162	05.08.23	07:22	78 56.2656	11 56.232	156, 156	1, 2
AR23_268	KO_OC _AR23_4	310	05.08.23	09:52	78 59.502	11 47.1462	304, 305	1, 2
AR23_269	MZ1	83	05.08.23	14:22	78 57.8484	12 17.4234	78, 78, 35, 35, 20, 20, 10, 10, 1, 1, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_270	KB3	350	05.08.23	19:50	78 57.0078	11 56.25	344, 241, 90, 51, 41, 35, 25, 15, 7, 5, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_271	KB3_2	57	05.08.23	20:52	78 57.5412	11 53.8284	51, 51, 10, 10, 1, 1	1, 2, 3, 4, 5, 6
AR23_272	KB2	265	06.08.23	00:13	78 58.6116	11 44.4876	260, 260, 50, 50, 35, 35, 10, 10, 7, 2, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_273	KB2_2	276	06.08.23	01:17	78 58.6248	11 44.358	270, 160, 100, 50, 40, 34, 25, 20, 15, 5, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_274	Mi2	73	06.08.23	07:01	78 59.9316	11 59.0754	69, 69, 40, 41, 20, 20, 7, 7	1, 2, 3, 4, 5, 6, 8, 9
AR23_275	ER4	289	06.08.23	10:14	78 59.4246	11 34.6956	284, 40, 20, 6	1, 2, 3, 4

AR23_276	KB1	370	06.08.23	14:50	79 0.6366	11 23.8848	366, 251, 100, 50, 40, 35, 25, 15, 7, 5, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_277	KB1_2	67	06.08.23	16:18	79 0.7428	11 23.28	61, 61, 41, 41, 6, 6, 1, 1	1, 2, 3, 4, 5, 6, 8, 9
AR23_278	KB0	315	06.08.23	20:26	79 2.5812	11 7.7628	311, 230, 110, 50, 40, 35, 25, 15, 7, 5, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_279	KB0_2	142	06.08.23	21:34	79 2.5764	11 7.9416	100, 100, 30, 30, 10, 10, 1, 1, 1, 1, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_280	Kros11	330	07.08.23	08:00	79 8.046	11 42.6504	326, 326, 240, 240, 48, 48, 15, 15, 10, 10, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_281	Kros7	66	07.08.23	12:00	79 12.0606	12 9.8472	62, 62, 30, 30, 1, 1	1, 2, 3, 4, 5, 6
AR23_282	Kros5	167	07.08.23	14:27	79 14.1576	11 53.682	166, 166, 72, 72, 30, 30, 1, 1	1, 2, 3, 4, 5, 6, 8, 9
AR23_283	Kros10	54	07.08.23	16:43	79 17.634	12 4.8492	50, 50, 20, 20, 7, 7, 2, 2	1, 2, 3, 4, 5, 6, 8, 9
AR23_284	Kros8	90	08.08.23	08:17	79 15.8286	12 7.5846	90, 50, 1	1, 2, 3
AR23_285	KB5	81	08.08.23	12:49	78 53.2128	12 25.5072	76, 51, 40, 35, 25, 15, 7, 5, 1, 1, 1	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12
AR23_286	KB5_2	83	08.08.23	13:50	78 53.22	12 25.5096	10, 10, 10	1, 2, 3
AR23_287	1RK008	46	08.08.23	23:28	78 54.1812	12 17.7936	xx	xx
AR23_288	1RK007	106	09.08.23	00:07	78 54.9546	12 14.2602	xx	xx
AR23_289	1RK006a	101	09.08.23	00:46	78 55.4316	12 9.7272	xx	xx
AR23_290	1RK006	169	09.08.23	01:22	78 56.0148	12 4.9656	xx	xx
AR23_291	1RK005	244	09.08.23	01:59	78 56.5044	12 1.8288	xx	xx
AR23_292	1RK004A	351	09.08.23	02:52	78 57.0912	11 55.9164	xx	xx
AR23_293	1RK004	288	09.08.23	04:35	78 58.0308	11 48.1188	xx	xx
AR23_294	1RKKB2	318	09.08.23	05:41	78 58.626	11 42.0126	xx	xx
AR23_295	1RK003	234	09.08.23	06:42	78 59.7516	11 34.1364	xx	xx
AR23_296	1RKKB1	309	09.08.23	07:52	79 0.8046	11 25.9956	xx	xx
AR23_297	Kchla1	43	09.08.23	11:03	78 58.4394	11 14.6502	xx	xx
AR23_298	2RK001	242	09.08.23	11:39	78 59.0202	11 23.6484	xx	xx
AR23_299	2RK002	327	09.08.23	12:15	78 59.7564	11 26.0004	xx	xx
AR23_300	2RK003	338	09.08.23	12:52	79 0.516	11 28.4424	xx	xx
AR23_301	2RK004	237	09.08.23	13:33	79 1.602	11 32.1528	xx	xx
AR23_302	2RK005	136	09.08.23	14:08	79 2.4192	11 34.4928	xx	xx
AR23_303	2RK006	68	09.08.23	14:56	79 2.8932	11 35.8926	xx	xx
AR23_304	2RK007	28	09.08.23	16:09	79 3.2694	11 37.1376	xx	xx
AR23_305	MA_OC _AR23_4	72	09.08.23	22:32	79 34.7832	10 43.4796	67, 67	1, 2
AR23_306	MA_OC _AR23_3	77	09.08.23	23:51	79 33.7596	10 56.9784	72, 72, 72	1, 2, 3
AR23_307	MA_OC _AR23_1	27	10.08.23	01:14	79 33.654	11 9.0942	22, 22	1, 2
AR23_308	M7	36	10.08.23	12:13	79 34.3092	10 51.4764	33, 32, 24, 24, 16, 16, 4, 4	1, 2, 3, 4, 5, 6, 8, 9
AR23_309	M6	49	10.08.23	14:38	79 37.5696	10 24.6744	35, 35, 25, 25, 15, 15, 5, 5	1, 2, 3, 4, 5, 6, 8, 9
AR23_310	M5	140	10.08.23	17:21	79 43.7316	10 9.072	50, 50, 34, 34, 25, 25, 14, 14, 5, 5	1, 2, 3, 4, 5, 6, 8, 9, 10, 11
AR23_311	M3	425	10.08.23	19:48	79 48.9108	9 47.8788	xx	xx
AR23_312	M1	472	10.08.23	23:15	79 56.1096	9 17.7546	50, 51, 35, 35, 25, 26, 15, 16, 5, 5	1, 2, 3, 4, 5, 6, 8, 9, 10, 11
AR23_313	M9	478	11.08.23	01:01	79 59.9868	9 41.73	2, 1	1, 2
AR23_314	M8	449	11.08.23	02:51	79 55.2396	10 5.9322	xx	xx
AR23_315	M10	380	11.08.23	04:31	79 49.74	10 18.2088	xx	xx
AR23_316	M2	432	11.08.23	06:41	79 48.7284	9 6.1032	xx	xx
AR23_317	M4	379	11.08.23	08:58	79 43.0584	9 36.0852	xx	xx
AR23_318	Moni1	253	12.08.23	00:35	78 4.308	11 35.634	247, 247, 175, 175, 101, 100, 21, 21, 2, 2, 2	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12

8.8 Detailed description of biological measurements (PFE)

Description of methods and measurement equipment

As part of the ANALOG project, water column samples were collected at selected stations using a rosette sampler. In addition, CTD data were used to precisely determine the depths from which the samples were taken for subsequent analyses. On board the vessel, the samples were filtered and preserved appropriately before being delivered for chemical analysis.

Description of measured parameters and collected samples

Seawater samples were collected within the main research task aimed at characterising the chemical composition of seawater in Hornsund. The study focuses on the availability of nutrients essential for the development of kelp forests, as well as identifying potential factors limiting their growth. Samples were collected from various depths in the water column using the rosette, guided by CTD station data.

The seawater samples were taken for the determination of selected metals, ions, and dissolved organic carbon. The collected material was preserved on board using hydrochloric acid, nitric acid, or mercuric chloride, depending on the planned chemical analyses. Samples were stored on the vessel in properly labelled and identified containers.

The preserved seawater samples were transported under +4°C conditions to the Institute of Oceanology, Polish Academy of Sciences.

List of measurement/sampling stations

KB0, KB1, KB2, KB3, KB5, Mi2

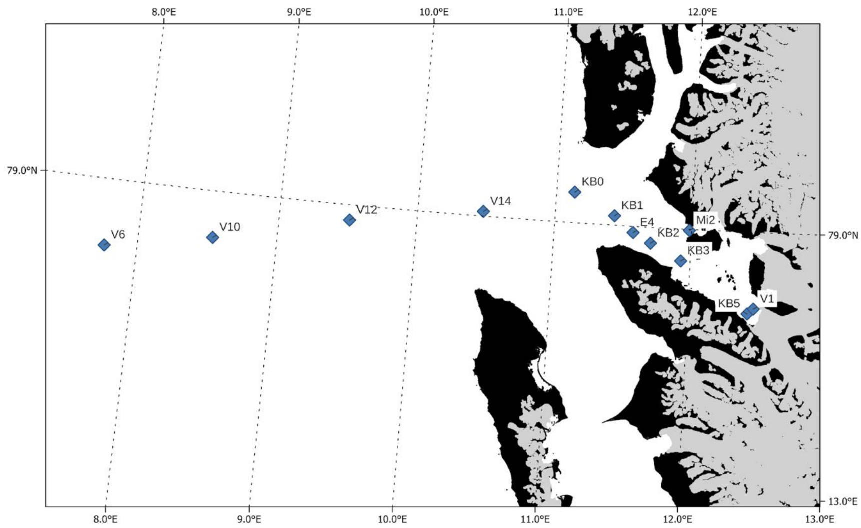

Figure 8.9 Stations occupied by ZEM PFE in Kongsfjorden and at its forefield during the Leg IVb.

Preliminary results

The seawater samples collected during the cruise are currently being analysed by researchers at the University of Silesia in Katowice and Adam Mickiewicz University in Poznań as part of an established scientific collaboration. These research institutions are equipped with specialised analytical instruments and are analysing the collected samples using ion chromatography (for ion determination) and inductively coupled plasma mass spectrometry (for metal analysis).

Further processing of data/samples collected during the cruise

The results obtained from the analyses of the samples collected during the cruise will form an important part of the dataset gathered within the ANALOG project. The findings will be published in high-impact scientific journals indexed in the Philadelphia list and presented at national and international conferences.

8.9 Comments of the Leg IVb cruise leader

The same as for Leg IVa.

9 Mesurements and sampling program during Leg IVc

9.1 General information about Leg IVc

Leg IVc covered research in the area of Isfjorden and its branches. It began and ended in Longyearbyen. At the start of the leg, a group of several people led by Tomek Jankowski was transported to the Eidembukta area and picked up again at the end of the leg. Midway through the leg, the team of divers disembarked from the vessel. Weather conditions were generally good, although on several occasions the ship encountered the sudden onset of very strong winds, which required temporary adjustments to the plans, such as moving to another station more sheltered from the wind.

Table 9.1. List of stations during leg IVcof the AREX2023 crusise with measurements and responsible groups.

Station	Water depth (m)	Date	Time UTC	Lat (deg min N)	Lon (deg min E)	Measuremet	ZEM bentos	ZEM PFE	ZChiBM WZEM/PBM	ZFM Optyka	ZEM PEP	ZEM PFBP	ZDM OOLab
Moni1	253	2023-08-14	00:35:00	78 4.308	11 35.634	CTD with Seabird SBE911+;acs, C-OPs,Trios				X			X
Moni2	251	2023-08-14	19:50:45	78 07.22	012 47.06	CTD Seabird SBE 911+;acs, C-OPs,Trios				X			X
PRO_02	21	2023-08-14	04:31:03	78 48.60	015 19.79	CTD Seabird SBE 911+, pump-CTD, sampling river water, 3X GEMAX							X
Moni13	48	2023-08-14	08:33:25	78 46.14	015 19.07	CTD Seabird SBE 911+;acs, C-OPs,Trios				X			X
PRO_09	86	2023-08-14	10:18:16	78 43.63	015 16.24	CTD Seabird SBE 911+							X
PRO_10	108	2023-08-15	11:36:43	78 38.81	015 17.99	CTD Seabird SBE 911+							X
S2	191	2023-08-15	15:20:16	78 11.71	015 05.58	CTD Seabird SBE 911+; DROP CAMERA	X	X					X
Moni4/PRO_KKM2	181	2023-08-15	18:58:34	78 14.60	014 51.14	CTD Seabird SBE 911+, GEMAX,acs, C-OPs,Trios; DROP CAMERA	X			X			X
SGD19/HIMERO1	290	2023-08-15	23:30:30	78 11.81	013 49.89	CTD Seabird SBE 911+,							X
GF	115	2023-08-15	07:25:14	78 04.72	014 05.01	CTD Seabird SBE 911+; DROP CAMERA	X	X					X
MONI3	267	2023-08-16	11:14:40	78 09.62	014 01.49	CTD Seabird SBE 911+acs,Trios				X			X
MONI5/PRO_KKM3	222	2023-08-16	16:12:28	78 23.12	015 11.37	CTD Seabird SBE 911+, GEMAX;acs, C-OPs,Trios; DROP CAMERA	X						X
MONI6	146	2023-08-16	19:33:02	78 31.09	014 56.28	CTD Seabird SBE 911+;acs, C-OPs,Trios; DROP CAMERA	X			X			X
MONI12	35	2023-08-16	22:13:43	78 36.79	014 40.01	CTD Seabird SBE 911+;acs, C-OPs,Trios; DROP CAMERA	X			X			X
S1	197	2023-08-16	07:02:23	78 13.08	015 11.47	CTD Seabird SBE 911+		X					X

ISA	146	2023-08-16	08:06:17	78 14.58	015 16.59	CTD Seabird SBE 911+; net WP-2/180; 3x net WP-2/100; UVP; LOPC; DROP CAMERA	X						X
MONI10	36	2023-08-16	12:02:43	78 22.76	016 30.31	CTD Seabird SBE 911+;acs, C-OPs,Trios; DROP CAMERA	X			X			X
MONI14	95	2023-08-16	14:22:49	78 23.08	016 56.03	CTD Seabird SBE 911+;acs, C-OPs,Trios; DROP CAMERA	X			X			X
IT3	60	2023-08-17	16:22:06	78 24.95	017 09.79	CTD Seabird SBE 911+; DROP CAMERA	X						X
IT3	60	2023-08-17	16:48:01	78 24.94	017 09.80	CTD Seabird SBE 911+; net WP-2/180; 2x net WP-2/100; UVP; LOPC							X
R5/IT2	49	2023-08-17	18:14:50	78 25.80	017 16.28	CTD Seabird SBE 911+;acs, C-OPs,Trios; DROP CAMERA	X			X			X
IT1	38	2023-08-17	19:55:41	78 26.47	017 21.46	CTD Seabird SBE 911+; net WP-2/180; 2x net WP-2/100; UVP; LOPC; DROP CAMERA	X						X
S1	196	2023-08-17	05:45:00	78 13.325	015 12.564	DROP CAMERA	X	X					
IA1	46	2023-08-17	08:07:19	78 14.10	015 39.76	CTD Seabird SBE 911+; net WP-2/180; 3x net WP-2/100; UVP; LOPC							X
IA2/H	71	2023-08-17	11:55:58	78 15.10	015 35.99	CTD Seabird SBE 911+; net WP-2/180; 3x net WP-2/100; UVP; LOPC							X
IA3	94	2023-08-18	13:30:37	78 15.96	015 30.30	CTD Seabird SBE 911+; net WP-2/180; 3x net WP-2/100; UVP; LOPC							X
ISA2/HIMERO 4	255	2023-08-18	15:09:22	78 15.93	015 07.72	CTD Seabird SBE 911+, 1x net Juday/5		X			X		X
PRO_KKM4	165	2023-08-18	17:14:17	78 24.52	015 43.03	CTD Seabird SBE 911+, GEMAX							X
Moni7	58	2023-08-18	18:51:30	78 25.51	016 10.36	CTD Seabird SBE 911+;acs, C-OPs,Trios; DROP CAMERA	X			X			
BI_OC_AR23_ 7	62	2023-08-18	20:57:52	78 28.16	016 08.25	CTD Seabird SBE 911+;GEMAX							X
MONI8/PRO_ 06	169	2023-08-18	06:06:33	78 31.16	016 11.20	CTD Seabird SBE 911+;acs, C-OPs,Trios; DROP CAMERA	X			X			X
MONI9/SGD9 /HIMERO3/P RO_05/BI_OC _AR23_6	155	2023-08-18	08:50:51	78 36.30	016 30.51	CTD Seabird SBE 911+;acs, C-OPs,Trios;GEMAX; DROP CAMERA, 1x net Juday/5	X			X	X		X
MONI9/SGD9 /HIMERO3/P RO_05/BI_OC _AR23_6	155	2023-08-18	09:53:49	78 36.29	016 30.44	CTD Seabird SBE 911+;GEMAX	X						X
BI_OC_AR23_ 5	44	2023-08-19	11:39:36	78 39.16	016 32.68	CTD Seabird SBE 911+;GEMAX; DROP CAMERA	X						X
BI_OC_AR23_ 4	27	2023-08-19	12:46:17	78 41.35	016 32.59	CTD Seabird SBE 911+;GEMAX; DROP CAMERA	X						X
PRO_03/BI_O C_AR23_1	33	2023-08-19	13:37:31	78 42.07	016 32.59	CTD Seabird SBE 911+;3X GEMAX,, pump-CTD, sampling	X						X

						river water; DROP CAMERA							
IB1	57	2023-08-20	17:18:56	78 39.10	016 51.70	CTD Seabird SBE 911+; net WP-2/180; 2x net WP-2/100; UVP; LOPC							X
IB2/BI_OC_AR23_2	76	2023-08-18	18:45:18	78 39.25	016 50.19	CTD Seabird SBE 911+;GEMAX; net WP-2/180; 3x net WP-2/100; UVP; LOPC							X
BAB/PRO_04/BI_OC_AR23_3	186	2023-08-19	06:01:03	78 39.73	016 44.15	CTD Seabird SBE 911+;GEMAX; net WP-2/180; 4x net WP-2/100; UVP; LOPC; DROP CAMERA	X						X
ISF3/HIMERO2	85	2023-08-19	16:41:27	78 26.84	016 05.48	CTD Seabird SBE 911+; net WP-2/180; 3x net WP-2/100; UVP; LOPC; DROP CAMERA, 1x net Juday/5	X	X			X		X
ISF3/HIMERO2	85	2023-08-19	17:17:18	78 26.85	016 05.36	CTD Seabird SBE 911+							X
SGD19/HIMERO1	303	2023-08-20	05:58:55	78 11.64	013 48.91	CTD Seabird SBE 911+; DROP CAMERA, 1x net Juday/5	X	X			X		X

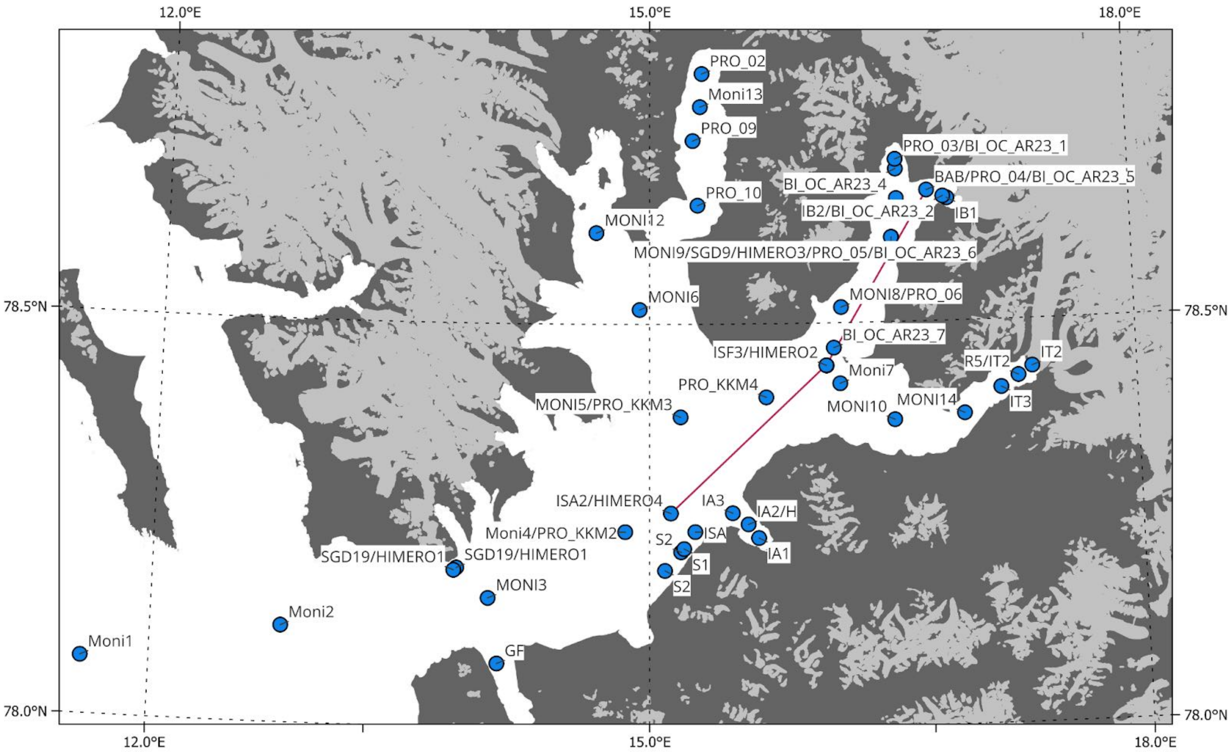

Figure 9.1 Map of stations in Hornsund during Leg IVc.
Continuous measurement transects using LOPC–CTD–F–O–T are marked with a purple line.

9.2 Detailed description of biological measurements – plankton (PEP)

Description of methods and measurement equipment

For the HIMERO project, samples were collected using the above-mentioned Juday plankton net from the entire water column. In addition, at each station, water samples (approximately 1 L) were collected for filtration through a set of two filters to measure chlorophyll-a content (the sampling depths were determined based on real-time fluorescence peaks). The filtered water samples were wrapped in aluminium foil and frozen at –80°C.

Description of measured parameters and collected samples

Zooplankton samples collected for the HIMERO project—aimed at determining the qualitative and quantitative composition and distribution patterns of zooplankton, in particular meroplankton, in the fjords—were faunistic samples obtained from the entire water column using a Juday-type net with a 0.064 mm mesh. After collection, zooplankton samples were transferred from the cod end into sample containers (bottles) and immediately preserved in 95% ethanol. The containers were labelled externally with an individual sample number and a set of basic metadata (station name, water-layer name and depth range, date of collection, and net type) using a waterproof marker. Additionally, an internal tracing-paper label with the same individual number and metadata written in pencil was placed inside each container. The sample bottles were stored in dedicated transport boxes.

In total, during Leg IVc, 4 faunistic samples were collected for the HIMERO project, along with water samples filtered through two filter sets, wrapped in aluminium foil, and frozen at –80°C. After returning from the vessel, the preserved samples will be analysed in the laboratories of ZEM.

List of measurement/sampling stations

Stations Himero1 (SGD19), Himero2 (ISF3), Himero3 (SGD9), Himero4 (ISA2).

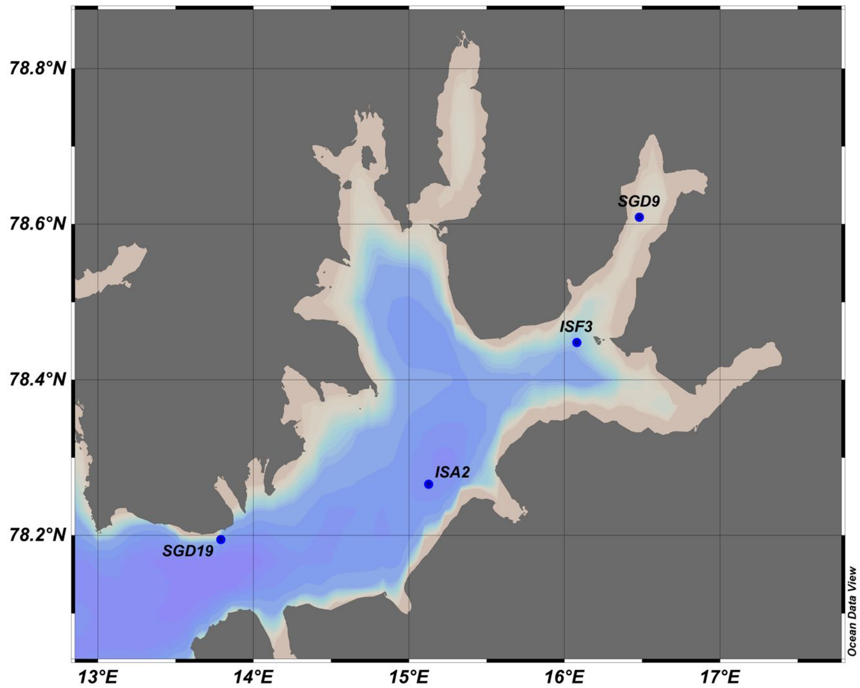

Figure 9.2 Stations for the HIMERO project measured in Isfjorden during the AREX2023 leg IVc.

9.3 Detailed description of biological measurements – plankton (PFBP)

Description of methods and measurement equipment

The composition and distribution of zooplankton are studied using both traditional methods (plankton nets) and automated optical methods (laser optical plankton counter — LOPC and underwater camera — UVP). In addition, the LOPC platform is equipped with several supplementary sensors: CTD, fluorometer, oxygen probe, and a turbidity meter. The non-invasive optical methods are carried out in high–spatial-resolution mode — vertical profiles and transects operated in oscillating mode.

Description of measured parameters and collected samples

Pigments: chlorophyll *a*, carotenoids (Niskin bottle) — seawater filtered through Whatman glass fiber filters (GF/F, nominal pore size 0.7 µm). The material retained on the filter was stored in a freezer (–80°C).

Nano- and microplankton samples (Niskin bottle) — samples preserved with Lugol's solution.

Mesozooplankton samples (WP2 net) — samples preserved in 4% formalin in seawater buffered with borax, or in ethanol, or frozen.

Abundance, distribution, and composition of plankton and marine aggregates: LOPC–CTD–F–O–T, UVP.

List of sampling/measurement stations

Stations: IA1, IA2, IA3, ISA, ISF3, BAB, IB2, IB1, IT1, IT2, IT3,

Sections: the LOPC–CTD–F–O–T platform performed continuous measurements along transects in oscillating mode between 50 m and the surface, plus UVP vertical profiles between stations ISA-BAB.

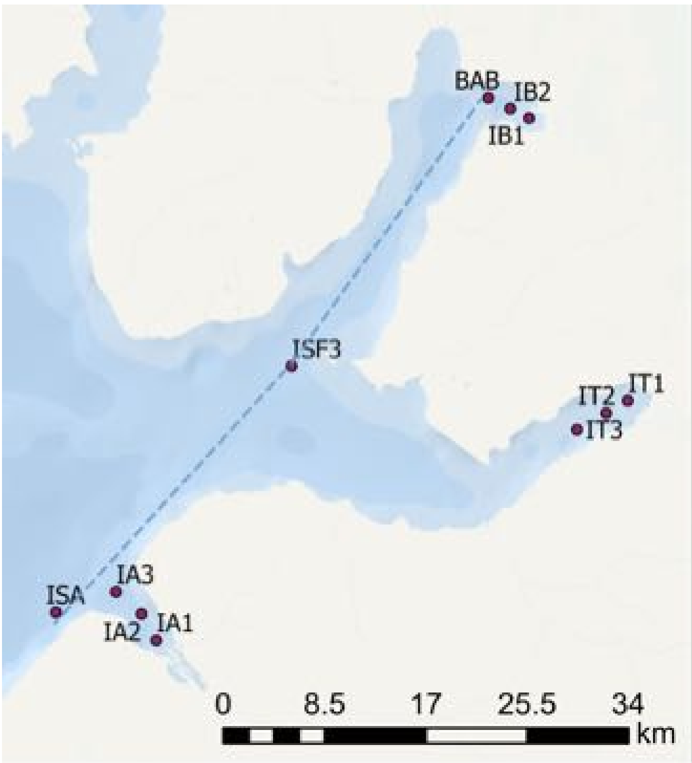

Figure 9.3 LOPC stations and sections in Isfjorden during the AREX2023 cruise leg IVc (PFBP).

Further processing of samples/data collected during the cruise

The samples will be subjected to qualitative and quantitative analysis at IOPAN. Measurements from the LOPC and UVP were stored on an external hard drive. Further analysis of the measurements will be carried out at IOPAN.

9.4 Detailed description of chemical measurements (ZChiBM WZEM/PBM)

Description of methods and measurement equipment

As part of the PROSPECTOR project (*Permafrost-Released OrganicS amPlify ocean aCidification in the aRctic?*), surface water samples were collected at two different river outlets (PRO_02 and PRO_03), as well as water-column samples from the river–fjord transition zone using a pump-CTD system. The pump-CTD was able to deliver water from various depths of the water column directly to the onboard laboratories of R/V *Oceania*. The pump-CTD measured in situ temperature, depth, and salinity, while in the laboratories pH was determined spectrophotometrically; pCO_2 and CH_4 were measured using a cavity ring-down spectrometer (CRDS) G2101-i (Picarro) connected to a bubble-type equilibrator; pO_2 and temperature in the headspace of the equilibrator were measured using a Fibox 4 system with an optical sensor (PreSens GmbH, Germany). Sediments were also collected using the GEMAX corer. Sediment cores were preserved for long-term incubation in controlled temperature and light conditions to investigate biogeochemical interactions between the water column and sediments that may influence inorganic carbon storage in fjords.

Using the same bubble equilibrator system described above, but connected to the ship's seawater intake located at 2.5 m depth, continuous measurements of pCO_2, pH, pO_2, temperature, salinity, and CH_4 were carried out throughout the cruise at a frequency of one measurement per minute.

Surface river samples collected at stations PRO_02 and PRO_03 were equilibrated with air and mixed in different proportions with seawater collected at the bottom of the same stations using the CTD-rosette. Samples were preserved at different time intervals (t0h, t48h, t96h) and stored for transport.

Water-column samples were collected at stations PRO_01, PRO_02, PRO_03, PRO_04, PRO_05, PRO_06, PRO_09, PRO_10, GF, S2, S1, and H to investigate the biogeochemical composition of the water column, including changes in inorganic carbon content in deep fjord waters. Water samples collected at stations GF, S2, S1, and H were additionally used for cross-calibration of biogeochemical sensors deployed at different depths at these locations.

Oceanic water from 2.5 m depth was collected at station Moni2 from the intake of the ship's seawater pump supplying the laboratory's online CO_2 system. Water was stored in 20-L containers (up to 160 L total) for studies of carbon transfer during sea-ice formation. These analyses will be carried out at IO PAN. Sediment samples were collected at PRO_KKM2, PRO_KKM3, and PRO_KKM4 using the GEMAX corer to investigate the distribution of organic matter in the sediments.

All biogeochemical samples collected at all stations were transferred for further analysis at IO PAN.

As part of the work carried out by Narwojsz, sediment samples were collected using a GEMAX corer and a van Veen grab, and seawater samples were taken with a rosette or a water sampler from specified depths.

Description of measured parameters and collected samples

The biogeochemical samples included measurements of total alkalinity, dissolved inorganic carbon, dissolved organic carbon, particulate organic carbon, and coloured dissolved organic matter. Surface sediment samples were also collected. Online measurements of pCO_2, pO_2, temperature, salinity, CH_4, and pH were conducted at a frequency of one minute (pH at a 30-minute frequency).

As part of the work carried out by Narwojsz, basic seawater parameters (temperature and salinity) were measured. Seawater samples will be analysed for total mercury content. Sediment samples will be analysed for total mercury concentration, methylmercury concentration, and the concentrations of individual labile and stable mercury fractions.

List of measurement/sampling stations

PRO_01, PRO_02, PRO_03, PRO_04, PRO_05, PRO_06, PRO_09, PRO_10,GF, S2, S1, H, PRO_KKM2, PRO_KKM3 and PRO_KKM4.

BI_OC_AR23_1; BI_OC_AR23_2; BI_OC_AR23_3; BI_OC_AR23_4; BI_OC_AR23_5; BI_OC_AR23_6; BI_OC_AR23_7;

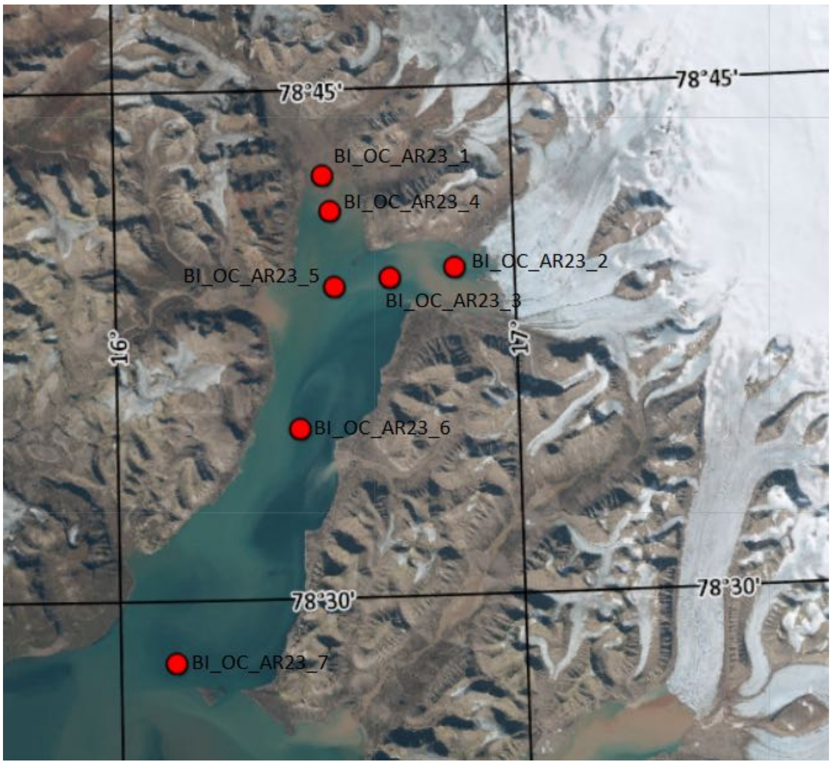

Figure 9.4 Maps of stations with samples collected for Najworsz.

Further processing of data/samples collected during the cruise

The samples collected during the cruise are currently being analysed in the laboratories of the Department of Marine Chemistry and Biochemistry at IO PAN. The samples collected during the cruise will constitute an important part of the dataset acquired within the PROSPECTOR project (carried out in 2021–2024). The data collected during the cruise will be presented in a manuscript forming part of the PhD dissertation of MSc Fernando Aguado Gonzalo, doctoral candidate at the International

Environmental Doctoral School, conducted at the Institute of Oceanology PAS in Sopot. In addition, the results will be presented at the Ocean Sciences Meeting 2024.

For the samples collected by Narwojsz, seawater samples were taken into bottles and preserved for transport. Sediment samples were sectioned into 1 cm layers, placed in zip-lock bags, and frozen onboard at –20°C until delivery to the laboratory. Further analyses will be carried out in the IOPAN laboratories.

9.5 Detailed description of optical measurements (ZFM)

Description of methods and measurement equipment

The composition and distribution of zooplankton are studied using both traditional methods (plankton nets) and automated optical methods (the laser optical plankton counter – LOPC, and an underwater camera – UVP). In addition, the LOPC platform is equipped with auxiliary sensors: CTD, a fluorometer, an oxygen probe, and a turbidity meter. The non-invasive optical methods are conducted in a high-resolution spatial mode, including vertical profiles and transects performed in an oscillatory mode.

Description of measured parameters and collected samples

Pigments: chlorophyll a – seawater was filtered through Whatman glass fiber filters (GF/F, nominal pore size 0.7 µm). The material retained on the filter was stored in a freezer (–80°C).

Nano- and microplankton samples (Niskin bottle) – samples were preserved with Lugol's solution.

Mesozooplankton samples (WP2 net) – samples were preserved in a 4% formalin solution in seawater buffered with borax, or in ethanol, or were frozen.

Abundance, distribution, and composition of plankton and marine aggregates: LOPC-CTD-F-O-T, UVP

List of measurement/sampling stations

Stations: IA1, IA2, IA3, ISA, ISF3, BAB, IB2, IB1, IT1, IT2, IT3,

Sections: the LOPC–CTD–F–O–T platform performed continuous measurements along transects in oscillating mode between 50 m and the surface between stations ISA-BAB

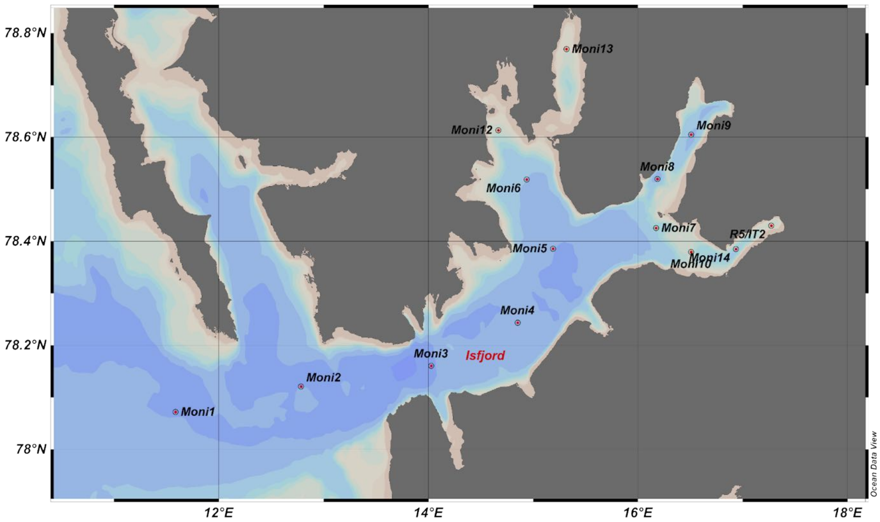

Figure 9.5 Map of stations in Isfjorden during the AREX2023 cruise leg IVc (ZFM).

Further processing of samples/data collected during the cruise

The samples will be subjected to qualitative and quantitative analysis at IOPAN. Measurements from the LOPC and UVP were stored on an external hard drive. Further analysis of the measurements will be carried out at IOPAN

9.6 Detailed description of biological measurements (PFE)

Description of methods and measurement equipment

As part of the ANALOG project, water column samples were collected at selected stations using a rosette sampler. In addition, CTD data were used to precisely determine the depths from which the samples were taken for subsequent analyses. On board the vessel, the samples were filtered and preserved appropriately before being delivered for chemical analysis.

In addition, in Isfjorden seawater samples and brown algae samples were collected from selected nearshore locations (S1, S2, GF, H). The material was collected by divers as part of the ANALOG project, then appropriately preserved onboard and transported together with the other samples to IOPAN.

Description of measured parameters and collected samples

Seawater samples and brown algae samples were collected as part of the main research task aimed at determining the chemical composition of seawater in Isfjorden and assessing the potential of kelp forests to uptake and bioaccumulate selected chemical compounds, primarily metals. The seawater studies focus on the availability of nutrients essential for the development of kelp forests, as well as on identifying potential factors limiting their growth.

Seawater sampling from the vessel was carried out at various depths using a rosette sampler, guided by CTD station data. The seawater samples were collected for the determination of selected metals, ions, and dissolved organic carbon. Seawater and brown algae samples from nearshore locations were collected manually by divers. The material was preserved onboard using hydrochloric acid, nitric acid, or mercuric chloride, depending on the planned chemical analyses. Both the water samples and the brown algae samples were stored onboard in appropriately labelled and documented containers. The preserved samples were transported at +4°C to the Institute of Oceanology PAN.

List of measurement/sampling stations

GF, S1, S2, H, SGD19/HIMERO1, ISA2/HIMERO4, ISF3/HIMERO2, SGD9/HIMERO3

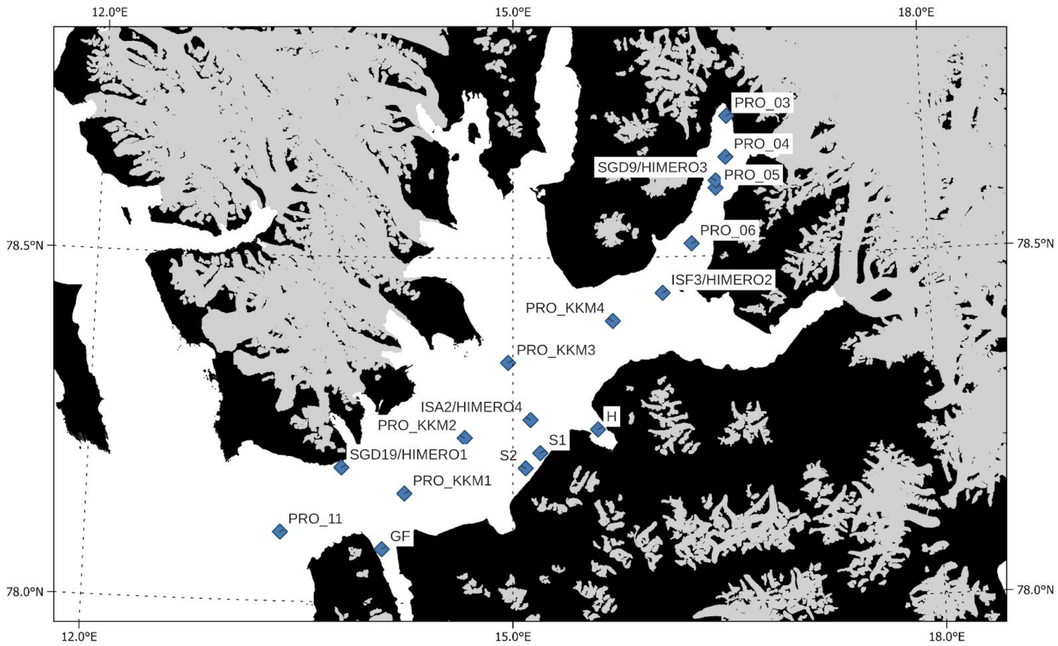

Figure 9.6 Stations occupied by ZEM PFE in Isfjorden during the Leg IVc.

Preliminary results

The seawater samples collected during the cruise were partially analysed by researchers at the University of Silesia in Katowice and Adam Mickiewicz University in Poznań as part of an established scientific collaboration. The brown algae samples were sent separately to the Department of Chemical and Environmental Analytics at Adam Mickiewicz University in Poznań. These research institutions are equipped with specialised analytical instruments and analyse the collected samples using ion chromatography (for ion determination) and inductively coupled plasma mass spectrometry (for metal determination).

The first results obtained from the analyses of seawater samples for selected ions and dissolved organic carbon were presented at the Svalbard Science Conference in Oslo in late October–early November 2023, and are shown on Figure 9.7.

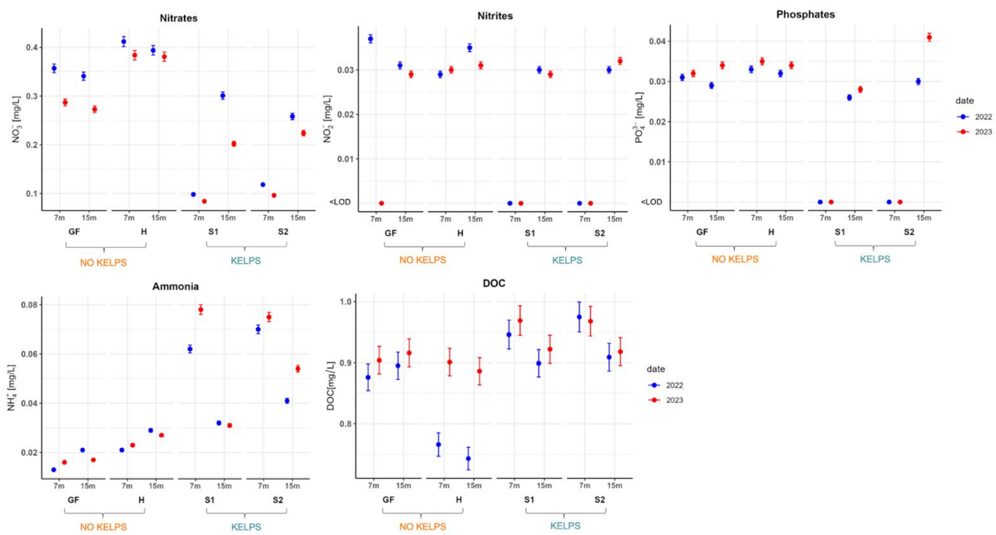

Figure 9.7 Preliminary results of seawater sample analyses obtained by PFE from sampling conducted in Isfjorden during the AREX2023 Leg IVc.

Further processing of data/samples collected during the cruise

The results obtained from the analyses of the samples collected during the cruise will form an important part of the dataset gathered within the ANALOG project. The findings will be published in high-impact scientific journals indexed in the Philadelphia list and presented at national and international conferences. Furthermore, the results and future publications on this topic are planned to be used in the habilitation application of Dr Eng. Klaudia Kosek.

9.7 Detailed description of biological measurements – benthos (PEB)

Description of methods and measurement equipment

Using a DROP CAMERA system, 10-minute underwater video recordings of the seafloor were made. The filming setup consisted of a metal frame, a cable line, two lasers, two cameras, two battery-powered lights, and an onboard computer used to record/monitor the camera footage and the distance to the seabed.

Description of measured parameters and collected samples

The underwater videos will be used to analyse the traces left on the seafloor by benthic organisms during their movement, as well as to characterise the seabed and the benthic macrofauna present at each station.

List of sampling/measurement stations

Samples collected on stations S2, Moni4/PRO_KKM2, GF, Moni5/PRO_KKM3, Moni6, Moni12, ISA, Moni10, Moni14, IT3, R5/IT2, IT1, S1, Moni7, Moni8/PRO_06, Moni9/Himero3/PRO_05/BI_OC_AR23_6, BI_OC_AR23_5, BI_OC_AR23_4, BI_OC_AR23_1/PRO_3, BI_OC_AR23_3/BAB/PRO_04, ISF3/Himero2, SGD19/Himero1 (nagrania z kamery)(Leg IVc covered research in the area of Isfjorden and its branches. It began and ended in Longyearbyen. At the start of the leg, a group of several people led by Tomek Jankowski was transported to the Eidembukta area and picked up again at the end of the leg. Midway through the leg, the team of divers disembarked from the vessel. Weather conditions were generally good, although on several occasions the ship encountered the sudden onset of very strong winds, which required temporary adjustments to the plans, such as moving to another station more sheltered from the wind.

Table ; Error! Reference source not found.).

Further processing of samples/data collected during the cruise

Filmy podwodne zostały wstępnie przejrzane i opisane pod względem charakteru dna oraz makrofauny dominującej. Zostały przekazane do dalszych analiz.

9.8 Comments of the Leg IVb cruise leader

The same as for Leg IVa.

10 Mesurements and sampling program during Leg V

10.1 General information about Leg V

The leg V of the AREX2023 cruise began on 25 August 2023 with almost a 24-hour delay relative to the original schedule due to adverse weather conditions that prevented the vessel from leaving Isfjorden and sailing to Kongsfjorden. Work in Kongsfjorden ultimately began on 26 August 2023 at 23:00 and continued uninterrupted until 27 August 2023 around 16:00. Samples were collected at five stations located along the fjord axis; in total, three marine sediment cores of approximately 1.5 m length, six short sediment cores of approximately 20 cm length, and surface water and sediment samples were obtained. CTD measurements were carried out at each station. At every station, samples for microplastic analysis were also collected.

During the cruise, microplastics were sampled from the surface layer of the water using dedicated devices. A comparative flow-measurement experiment (using two different methods) was also conducted, enabling a quantitative assessment of the volume of filtered water and the microplastic content. Shipboard contamination control samples were collected and secured.

An attempt was also made to recover a long sediment core on the shelf in the Kongsfjordrenna region; however, due to the stony substrate, the corer penetrated only about 20 cm. The sediment was preserved for microplastic analysis in seafloor deposits.

On 28 August 2023 at 21:00, work began in the Storfjordrenna region. Under good weather conditions, a marine sediment core of approximately 3 m length was successfully collected, along with CTD measurements and material for microplastic analysis.

The next station was located in the Kveithola Trough, where only a CTD measurement was performed.

Work at the final research stations in the Bjørnøyrenna region began on 30 August 2023 at 08:00 and continued until 18:30. Favourable weather allowed efficient recovery of marine sediment cores at two stations, each 1.2 m long. CTD and microplastic measurements were conducted at both stations. At one station, the gravitational corer barrel disconnected, resulting in one 1.5-m section remaining in the water; however, this did not impede the continuation of scientific operations.

Sediment coring was also planned in the Vøring Plateau area, at the eastern termination of the Jan Mayen Fracture Zone at 1200 m depth. However, deteriorating weather conditions prevented work in this region, and it was decided to proceed directly to Tromsø.

On 31 August 2023, *Oceania* entered the port of Tromsø, where it remained until 1 September 2023. During this time, two marine sediment cores from the University of Tromsø repository were transported aboard. These cores will be used within the NCN POLONEZ BIS grant: *"Multiproxy reconstruction of the variability of the East Greenland Current during the last 150,000 years (REHEAT)"*.

10.2 Detailed description of paleooceanographic measurements

Description of methods and measurement equipment

1.5-m gravity corer. Box corer. Van Veen grab. 30-liter water sampler and CTD.

Microplastic sampling devices equipped with woven chrome–nickel sieves (with pore sizes of 18–25 µm and 100 µm, each with a 300 µm protective pre-filter).

Manta-type net. Overboard pumps with a 100 µm metal filter.

Description of measured parameters and collected samples

Marine sediment cores will be used for paleoceanographic analyses (sedimentological, micropaleontological, geochemical, and paleogenomic) to reconstruct oceanographic and environmental changes in the Svalbard region during the Holocene. The cores collected in Kongsfjorden will be used to describe environmental changes occurring in the fjord over the last ~150 years, i.e., during the period of strong anthropogenic influence.

Surface sediment samples, short sediment cores, and water samples will be used for microscopic analyses and metabarcoding of contemporary eukaryotic communities.

Microplastic samples will be used for open-ocean monitoring along the Spitsbergen–Gdańsk transect to compare several sampling methods for marine microplastics; for microbiological studies of the plastisphere and the presence of fungi associated with macro- and microplastic surfaces; and for characterising the ageing process of primary microplastic particles in seawater and marine sediments.

List of measurement/sampling stations

Table 10.1. List of stations occupied during the AREX2023 leg V.

Station	Latitude	Longitude	Water depth [m]
Kb4	78°54,731'N	12°11,527'E	109
Kb3	78°57,388'N	11°55,834'E	350
Kb2	78°58,618'N	11°44,580'E	290
Kb1	79°00,707'N	11°24,895'E	370
Kb0	79°02,829'N	11°08,460'E	320
KON1	78°49,963'N	9°05,565'E	300
ST1	76°19,417'N	19°39,982'E	261
BJN01	73°05,553'N	16°39,629'E	460
BJN02	72°54,916'N	16°22,450'E	382

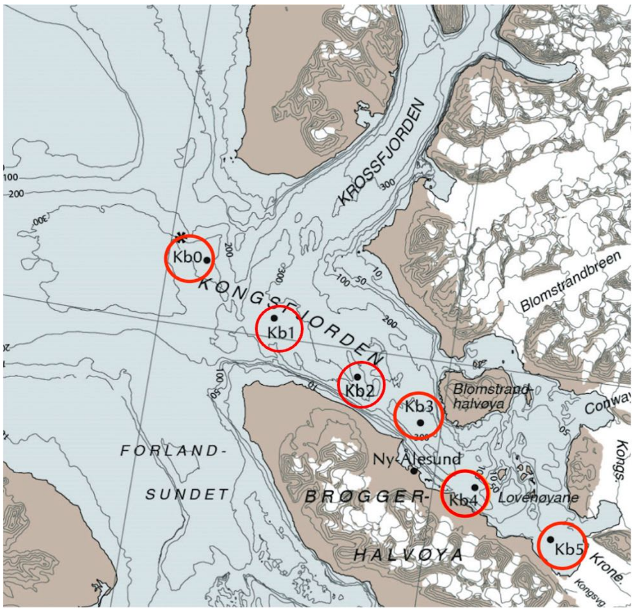

Figure 10.1 Sampling station in Kongsfjorden during the AREX2023 leg V.

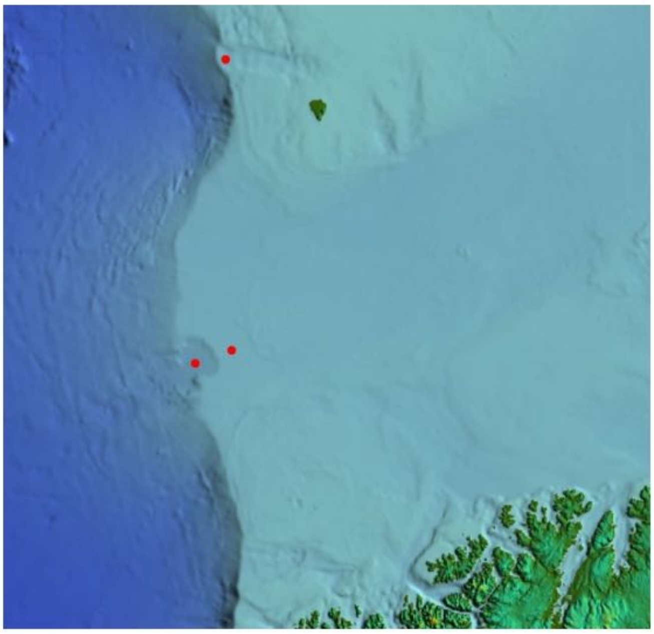

Figure 10.2 Sampling station in the Barents Sea during the AREX2023 leg V.

Further processing of samples/data collected during the cruise

Analyses of the collected material will continue until the end of 2024. The sediment cores from the Storfjordrenna and Bjørnøyrenna regions, the short sediment cores, and the surface sediment and water samples were transported to the Paleoceanography Department of IOPAN for further analysis. The microplastic samples were transported to the Laboratory of Spectroscopy and Intermolecular Interactions at the Faculty of Chemistry, University of Warsaw. The marine sediment cores collected in Kongsfjorden were left in Tromsø and later transported to NORCE in Bergen.

11 Summary of the AREX 2023 cruise

The AREX2023 cruise of the IOPAN research vessel *Oceania* took place between June 15 and September 9, 2023, covering the eastern part of the Nordic Seas (Norwegian and Greenland Sea), the eastern and central Fram Strait, the open ocean region north of Svalbard, and selected West Spitsbergen fjords (Hornsund, Kongsfjorden, Korssfjorden, Magdalenefjorden, and Isfjorden).

During Leg I of the AREX2023 cruise, aerosol, meteorological, and chemical measurements were conducted continuously along the Gdańsk–Tromsø transit. The measured parameters included aerosol particle-size distribution in the near-surface atmosphere, the concentration of marine aerosols, atmospheric CO_2 and H_2O concentrations, the concentration of black carbon particles in the near-surface atmosphere, and basic meteorological variables (wind speed and direction, air temperature and humidity). In the surface layer of the ocean, continuous measurements of sea-surface temperature and salinity (SST and SSS) and the partial pressure of dissolved gases (pCO_2 and pO_2) were conducted. At three stations, CTD measurements were taken and zooplankton samples were collected. Optical measurements were carried out at stations and during short periods of the vessel drift. During Leg I, optimisation of the vessel's data acquisition system was also performed, based on the Starlink satellite communication system.

The first oceanic part of the AREX2023 cruise, Leg II, covered the area between northern Norway and Sørkapp. Due to the limited ship time during this part, no measurements were carried out along the standard V1 section in the Barents Sea Opening. Measurements were conducted along the standard H, K, V2, and S sections, totalling 79 CTD/LADCP stations. During Leg II, two CoreArgo profiling floats were deployed along the K section.

The second oceanic part, Leg III, included sections from Sørkapp to the region north of Svalbard. Measurements were conducted at 127 stations along the N, Z, WB, Y, EB2, and EX sections. Due to ice conditions north of Svalbard, no measurements were carried out along the NB section, while the WB section was completed only partially (to the ice edge), then continued along the ice edge and back toward the shelf. Throughout both oceanic legs, aerosol, meteorological, and chemical measurements were conducted continuously. A total of 193 zooplankton samples were collected at 53 stations during Legs II and III. For long-term zooplankton monitoring, samples were collected at all 53 stations. Additional zooplankton samples were collected at selected stations for the HIMERO (14 stations) and HIDEA (13 stations) projects. At 14 stations, Garrett net samples were collected from the sea-surface microlayer and subsurface water for surfactant analysis.

The fjord spart of the AREX2023 cruise consisted of four sub-legs covering the West Spitsbergen fjords: Hornsund and its forefielde (Leg IVa), Kongsfjorden, Krossfjorden, and Magdalenefjorden (Leg IVb), Isfjorden (Leg IVc), and selected coastal bays within Isfjorden (Leg IVd). In all fjords, an extensive programme of biological, chemical, and bio-optical sampling was conducted, as well as CTD measurements along standard transects in Hornsund and Kongsfjorden. Continuous aerosol and meteorological measurements were also carried out during all fjord legs.

During Leg IVa, measurements and sampling were conducted at 48 stations in Hornsund and 19 stations in its forefield on the shelf and upper slope. CTD profiles of the full water column were carried out at all stations. In total, 32 faunistic zooplankton samples were collected along the Hornsund transect, 16 samples in the foreland region, 16 samples for the HIMERO project, and 4–8 samples for the HIDEA project. At 19 stations, water samples were collected for chlorophyll-a, SPM, carotenoids, and nano- and microplankton analyses, as well as net samples of nano-, micro-, and mesozooplankton for the CoastDark, ORANGE, and SeaPop2 projects. Three LOPC-CTD-F-T transects were conducted. At three stations in Hornsund, soft-bottom sediment samples were taken, and at 13 stations underwater camera recordings were made. Chemical measurements and water sampling were carried out at three stations. At 11 stations in Hornsund and its foreland, bio-optical measurements were performed using an optical–hydrological probe, an optical profiling system, and a radiance float. At the same stations, water samples were collected for optical parameter determinations. Primary production measurements were conducted at two stations.

Leg IVb included measurements and sampling at a total of 55 stations in Kongsfjorden (34 stations), Krossfjorden (5 stations), their forelands (4 stations), Magdalenefjorden (4 stations), and its forefield (8 stations). CTD profiles in the full water column were carried out at all stations. At selected stations, zooplankton, meroplankton, and water samples were collected for long-term monitoring and for the HIMERO and HIDEA projects. A total of 49 faunistic samples were collected along the Kongsfjorden transect, as well as 32 samples for HIMERO and 4 samples for HIDEA. At 18 stations, LOPC vertical profiling was conducted (and continuous LOPC measurements on one transect), and water samples were collected for chlorophyll-a, SPM, carotenoids, nano- and microplankton analyses, as well as net samples of nano-, micro-, and mesozooplankton. For benthic monitoring, soft-bottom sediment samples were taken at 3 stations, hard-bottom samples at 1 station, and underwater camera recordings were made at 13 stations. At 8 stations, water and surface sediment samples were taken for mercury analysis. At 13 stations, optical measurements and water sampling were conducted.

During Leg IVc in Isfjorden, measurements and sampling were conducted at 42 stations. At four stations, meroplankton and water samples were collected for the HIMERO project. At 11 stations, vertical LOPC and UVP measurements were performed (and continuous LOPC measurements on one transect), and water samples were collected for chlorophyll-a, nano- and microplankton, and mesozooplankton analyses. Chemical sampling included surface samples at two river outlets and the river–fjord transition zone. At 12 stations, water-column samples were collected for biogeochemical analyses. At 3 stations, sediment samples were taken to study organic matter distribution. At 8 stations, seawater and brown algae samples were collected for the ANALOG project to study kelp forests. At 22 stations, underwater video recordings were made to document seafloor characteristics and dominant benthic macrofauna.

During Leg V, carried out during the vessel's return transit, sediment coring and CTD measurements were conducted for paleoceanographic studies at a total of 9 stations in the Kongsfjorden area (5 stations), Storfjordrenna (1 station), Kveithola Trough (CTD only), and Bjørnøyrenna (2 stations). At each station, samples for microplastic analysis were also taken. Sediment cores were collected for paleoceanographic analyses (sedimentological, micropaleontological, geochemical, and paleogenomic) to reconstruct oceanographic and environmental variability in the Svalbard region during the Holocene.

During AREX2023, nearly all planned measurements were successfully completed (with the exception of stations in ice-covered areas during the oceanic legs, a small number of stations in Hornsund due to delayed departure from port, and sediment coring at the Vøring Plateau due to poor weather). The successful execution of this extensive and demanding multidisciplinary measurement programme was made possible by the efficient organisation of work during all legs and the excellent cooperation between the research team and the Captain and crew of RV *Oceania*.