Ecosystem mapping in the Central Arctic Ocean (CAO) during the SAS-Oden expedition

Final Report

15 January 2022

Pauline Snoeijs-Leijonmalm, Hauke Flores, Nicole Hildebrandt, Serdar Sakinan, Julek Chawarski, Baldvin Thorvaldsson, Frank Menger, Prune Leroy, Clara Pérez Martínez, Claudia Morys, Javier Vargas Calle, Julia Muchowski

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Contact: CINEA EMFAF CONTRACTS

E-mail: cinea-emfaf-contracts@ec.europa.eu

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B-1049 Brussels

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LIST OF ABBREVIATIONS

Term	Description
AWI	Alfred-Wegener-Institut (Bremerhaven, Germany)
Bio CTD	A CTD taken for obtaining water samples for biological parameters, down to 1000 m of depth
CAO	Central Arctic Ocean
ChlMax	The chlorophyll maximum in the water column (around 15-30 m of depth)
CINEA	European Climate, Infrastructure and Environment Executive Agency (successor of EASME)
CTD	Conductivity, temperature, and density measuring device
Deep CTD	A CTD taken for obtaining water samples for chemical parameters, down to the seafloor
DG MARE	Directorate-General for Maritime Affairs and Fisheries
DSL	Deep scattering layer, a layer of living organisms (zooplankton, small fishes) at mesopelagic oceanic depths detected as acoustic backscatter by an echosounder
EASME	Executive Agency for Small and Medium-sized Enterprises (predecessor of CINEA)
EC	European Commission
eDNA	Environmental DNA, i.e., genetic material obtained directly from environmental samples without any obvious signs of biological source material
EEZ	Exclusive Economic Zone
EFICA	European Fisheries Inventory in the Central Arctic Ocean Consortium
EMFF	European Maritime and Fisheries Fund
EU	European Union
EU CFP	EU Common Fisheries Policy
FishCam	Deep-sea camera system deployed by the EFICA scientists during MOSAiC
FWC	Framework Contract
Heli	Helicopter
IB	Icebreaker
ICES	International Council for the Exploration of the Sea
LOKI	Light frame On-site Key species Investigation
MIK net	Midwater Ringnet, ICES standard gear for the sampling of fish larvae
Mini FishCam	Deep-sea camera system deployed by the EFICA scientists during SAS-Oden
MOSAiC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
Omics	The joint collaboration on-board the SAS-Oden expedition on metagenomics and metatranscriptomics, including sampling for eDNA
Omics CTD	A CTD taken for obtaining water samples for eDNA filtrations, down to 1000 m of depth
PSCG	Provisional Scientific Coordinating Group of the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean
SAS	Synoptic Arctic Survey (a scientist-driven initiative aiming at collecting primary ecosystem data in the Arctic Ocean 2020-2022)
SAS-Oden	Swedish Synoptic Arctic Survey expedition with IB Oden
SAS-Oden WP	SAS-Oden Work Package (executing one of the 16 SAS-Oden projects)
SC	Specific Contract
SC03	Specific Contract 3 (MOSAiC expedition 2019-2020)
SC06	Specific Contract 6 (SAS-Oden expedition 2021)
SC07	Specific Contract 7 (Sample elaborations, data analyses, results and conclusions from the sea-going MOSAiC and SAS expeditions in the Central Arctic Ocean), for the period 2022-12-20 until 2023-04-20
SFPs	Standard Fish Protocol Sheets
Shallow CTD	A CTD taken for obtaining water samples for chemical parameters in surface waters, usually down to ca. 200 m of depth
SLU	Swedish Agricultural University, Department of Aquatic Resources (Lysekil, Sweden)
SND	Swedish National Data Service (https://snd.gu.se/en)
SOPs	Standard Operation Protocols
SPRS	Swedish Polar Research Secretariat
SU	Stockholm University (Sweden)
TempMax	The temperature maximum in the water column (around 300 m of depth)
UVP	Underwater Vision Profiler
VACAO	Ventilation and Anthropogenic Carbon, a research project on-board the SAS-Oden expedition
WBAT	Wideband Autonomous Transceiver
WBAT CTD	A CTD taken for obtaining acoustic measurements with the EFICA WBAT, down to 1000 m of depth
WMR	Wageningen Marine Research (The Netherlands)

ABSTRACT

Ecosystem mapping in the Central Arctic Ocean (CAO) during the SAS-Oden expedition

As a result of global warming, the marine ecosystem around the North Pole, the Central Arctic Ocean (CAO), is in fast transition from a permanently to a seasonally ice-covered ocean. The sea-ice loss is expected to enable summer access to the CAO for non-icebreaking ships, including fishery vessels, in the near future[1]. However, the lack of knowledge on the CAO ecosystem impedes any assessment of the sustainability of potential future fisheries in the CAO. Taking a precautionary approach, the EU and nine countries in October 2018 signed the *Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean*. This agreement entered into force in June 2021 and a.o. requires the establishment of a joint scientific program to improve the understanding of the CAO ecosystem, including mapping and monitoring. To reduce the existing lack of knowledge, 12 scientists from the EFICA Consortium participated, together with 26 other on-board scientists, in sampling and data collection of ecosystem data during the Swedish SAS-Oden expedition in summer 2021. This report describes the field work performed by the EFICA scientists using water-column acoustics, deep-sea optical observations, and fish, zooplankton, sediment otolith and eDNA sampling for targeting fish, zooplankton and mammals. Further ecosystem data (physical, chemical and biological) were collected by the EFICA scientists in collaboration with other scientists on-board. Together with this report, a metadata database containing lists of all collected samples and data that are relevant for future fish-stock modelling and assessment studies was delivered to the European Commission.

Cartographie de l’Ecosystème de l’Océan Central Arctique (OCA) au cours de l’expédition SAS-Oden

L’écosystème marin des régions du Pôle Nord, l’océan central arctique (OCA), historiquement couvert de glace de façon permanente, subit actuellement une transition rapide vers une glaciation saisonnière du fait du réchauffement climatique. Il est attendu que cette diminution de la banquise entraînera dans un futur proche l’accès estival pour les navires, dont les bateaux de pêche, à l’océan central arctique, sans besoin de recourir à des brises glaces[1]. Cependant, l’absence de connaissances suffisantes sur l’écosystème de l’OCA empêche toute évaluation de la durabilité de futures pêcheries potentielles en son sein. Partant du principe de précaution, neuf états ainsi que l’Union Européenne ont signé en octobre 2018 le *Traité pour la prévention de pêcheries non régulées en haute mer dans l’océan central arctique*. Ce traité est entré en vigueur en juin 2021 et requiert la mise en place d’un programme scientifique commun pour améliorer la compréhension de l’écosystème de l’OCA, à travers en autres une cartographie et un monitoring. Afin de pallier à l’actuel manque de connaissances, 12 chercheurs du consortium EFICA ont participé à la collecte d’échantillons et de données sur l’écosystème durant l’été 2021 avec les 26 autres chercheurs présents à bord au cours de l’expédition SAS-Oden.
Le rapport ci- joint décrit le travail de terrain des scientifiques du groupe EFICA, réalisé à l’aide de mesures acoustiques sous-marines, d’enregistrements vidéos à basse profondeur, ainsi que de prélèvements de poissons et d’échantillons pour l’analyse d’ADN environnemental (eDNA) provenant des poissons, du zooplancton et des mammifères. Par ailleurs, la collaboration entre l’équipe EFICA et les chercheurs à bord a permis de collecter des données physiques, chimiques et biologiques pour une meilleure description de l’écosystème. En complément de ce rapport, un registre de données répertoriant l´ensemble des échantillons et des données collectés ayant une importance pour les études concernant une pêcherie future dans l’OCA a été fourni à la Commission Européenne.

[1] Kwok R (2018) Arctic sea ice thickness, volume, and multiyear ice coverage: losses and coupled variability (1958–2018). *Environ. Res. Lett.* **13**, 105005

EXECUTIVE SUMMARY

Within the Framework Contract (FWC: EASME/EMFF/2018/003) "Provision of Scientific Support to the High Seas Fisheries in the Central Arctic Ocean (CAO)", the Contractor (the EFICA Consortium) has collected ecosystem data in the CAO to support the Joint Program of Scientific Research and Monitoring (JPSRM) of the "Agreement to prevent unregulated High Seas fisheries in the Central Arctic Ocean"[2] that entered into force on 25 June 2021.

The work reported here was carried out within Specific Contract 6 (SC06: EASME/EMFF/2019/1.3.2.1/03/SI2.840508 under the FWC) "Ecosystem mapping in the Central Arctic Ocean (CAO) during the SAS-Oden expedition". The Swedish SAS-Oden expedition with icebreaker Oden, took place 25 July – 19 September 2021. The expedition track crossed the Nansen Basin, the Gakkel Ridge, the Amundsen Basin, the North Pole, the Lomonosov Ridge and a small corner of the Makarov Basin, the western Amundsen Basin, and then back over the Gakkel Ridge to the end station on the Yermak Plateau (**Figure 1**). Together, the MOSAiC expedition 2019-2020 (SC03 under the FWC) and the SAS-Oden expedition (SC06 under the FWC), cover a large portion of the Eurasian Basin and part of the Lomonosov Ridge (**Figure 1**). Most of this area is situated within the High Seas portion of the CAO.

The SAS-Oden expedition participates in the international scientist-driven initiative "Synoptic Arctic Survey" (SAS)[3] as one of twelve research expeditions that collect empirical data from the Arctic Ocean in 2020-2022 from (ice-breaking) research vessels. The goal of SAS is to generate a comprehensive dataset that allows for an improved characterization of the Arctic Ocean with respect to its (1) physical oceanography, (2) marine ecosystems and (3) carbon cycle and acidification. The complete SAS dataset will provide a unique baseline that will allow for tracking climate change and its impacts as they unfold in the Arctic region over the coming years, decades and centuries.

Since IB Oden is a very strong icebreaker[4] with research facilities, the SAS-Oden expedition was within the international SAS framework tasked to investigate an area of the CAO with the thickest Arctic sea-ice cover. Other SAS expeditions that cover part of the High Seas of the CAO are Araon in 2020, 2021 (South-Korea, Chukchi Plateau), Mirai in 2020, 2021 (Japan, Chukchi Plateau), IB Louis S St. Laurent 2020, 2021 (Canada, Beaufort Gyre, Canada Basin), Kronprins Haakon 2021 (Norway, Nansen and Amundsen basins), and the planned Healy expedition in 2022 (USA, Canada and Makarov Basins, up to the North Pole). The Chukchi Plateau is part of the High Seas, but does not fall within the CAO. Other ships participating in SAS (Denmark, Italy, Norway, Russia) have operated in the shelf seas of the Arctic Ocean outside the CAO in 2020 and 2021.

The objective of SC06 was to collect new field data for addressing the four questions proposed for the mapping phase of the JPSRM by the Fifth FiSCAO Meeting[5], and further developed in the First PSCG Meeting[6], by expert groups appointed by the Signatories of the Agreement. These four questions are:

(1) What are the distributions of species with a potential for future commercial harvests in the High Seas portion of the CAO?
(2) What fish species are currently present in the High Seas portion of the CAO?

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[2] EU (2019) Agreement to prevent unregulated High Seas fisheries in the Central Arctic Ocean. *Official Journal of the European Union* L 73, 3–8.

[3] Synoptic Arctic Survey – a pan-Arctic Research Program – Science and Implementation Plan (https://synopticarcticsurvey.w.uib.no/science-plan)

[4] https://www.polar.se/en/research-support/icebreaker-oden/

[5] FiSCAO (2018) Final Report of the Fifth Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean. FiSCAO. 45 pp.

[6] PSCG (2020) Report of the 1st meeting of the Provisional Scientific Coordinating Group (PSCG) of the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean. PSCG. 63 pp.

(3) What are the trophic linkages among fishes and between fishes and other taxonomic groups?
(4) What are the likely key ecological linkages between potentially harvestable fish stocks of the High Seas portion of the CAO and adjacent shelf ecosystems?

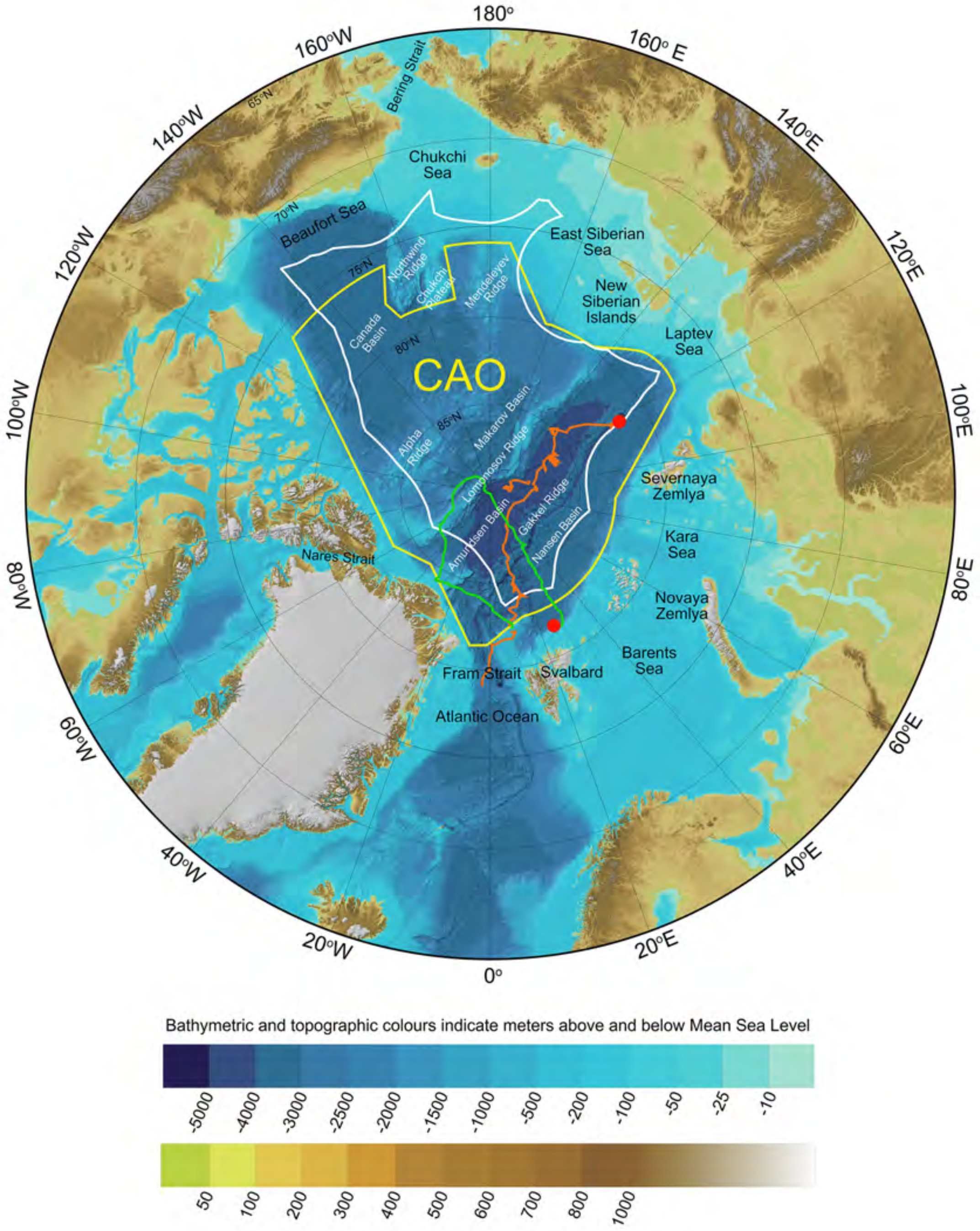

Figure 1: The SAS-Oden expedition (green) and MOSAiC expedition (orange) cruise tracks in relation to the Central Arctic Ocean Large Marine Ecosystem (CAO, yellow line) and the High Seas portion of the CAO (white line). Red dots indicate the starting point of the expedition tracks. The background map was extracted from IBCAO[7].

[7] Jakobsson M, et al. (2012) The International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3.0. Geophysical Research Letters 39:L12609 [http://doi.org/10.1029/2012GL052219]

For addressing the four questions proposed for the mapping phase of the JPSRM, the EFICA Consortium has collected water-column acoustic and optical data, and samples of fish, zooplankton, sedimentary otoliths and environmental DNA (eDNA) for targeting fish, zooplankton (fish prey) and mammals (fish predators). The deliverables of SC06 consist of metadata, i.e., a compilation of data and samples collected during the expedition, but no further data or sample analyses. These metadata were compiled in 9 EXCEL files that together constitute the "SC06 Metadata Database", which is built up in the same way as the "SC03 Metadata Database" from the MOSAiC expedition[8].

During the SAS-Oden expedition, the EFICA field scientists contributed to collecting the SAS Core Parameters, and the EFICA Consortium has therefore access to EFICA-relevant physical, chemical and biological ecosystem data that – in combination with the EFICA-specific data – allow for food-web analyses and fish-stock modelling and assessment to address the four research questions proposed for the mapping phase of the JPSRM (see page 2 of this Report).

Some tentative results and conclusions based on the observations made during the SAS-Oden expedition fieldwork are presented below (1-7). However, these results and conclusions are only preliminary and not quantitative at this stage. They must be confirmed by detailed studies of the SAS-Oden data and samples before they are scientifically validated.

(1) Routine fisheries assessments are normally based on trawling and hydroacoustics in combination, but logistical difficulties prevent such activities in the CAO. While trawled nets cannot be applied in the CAO today due to its thick ice cover, also acoustic data collection is problematic because hydroacoustic backscatter from organisms is distorted by noise from ice-breaking. Similar to the results from the MOSAiC expedition, fish sampling remained a challenge. Only four fish individuals could be sampled during the entire expedition despite numerous efforts. Hydroacoustic data of good quality were collected at discrete measuring stations along the expedition track when the ship's engines were turned off and it was drifting with the sea ice.

(2) Preliminary observations of the hydroacoustic dataset collected by the EFICA Consortium during SAS-Oden suggest that low abundances of fish occur in a deep scattering layer (DSL) in the "warm" Atlantic water layer of the Amundsen and Nansen basins (**Figure 1**) at ca. 200-500 m of depth. This confirms the results from a previous study carried out in summer 2016 with the Swedish icebreaker Oden at 13 discrete hydroacoustic stations along a transect from 83.2 °N in the Nansen Basin, across the Eurasian Basin, the North Pole and the Lomonosov Ridge, to 82.4 °C in the Canada Basin[9], as well as by the results from the MOSAiC expedition[10].

(3) Similar to the 2016 study and the MOSAiC expedition (2019-2020), the hydroacoustic signals received during the SAS-Oden expedition suggested that the Central Arctic DSL contains low abundances of zooplankton and small fish (roughly <15 cm long).

(4) In contrast to the MOSAiC expedition, we did not detect high abundances of Atlantic fish species in the DSL at the inflow of Atlantic water to the CAO near the Yermak Plateau north of Svalbard during the SAS-Oden expedition.

(5) The beam net allowed us to abundantly sample macrozooplankton, and our data provide the first comprehensive macrozooplankton dataset for the CAO. This is an

[8] Snoeijs-Leijonmalm P. et al. (2021) Ecosystem mapping in the Central Arctic Ocean (CAO) during the MOSAiC expedition. Publications Office of the European Union, 2021 [https://data.europa.eu/doi/10.2926/714618]

[9] Snoeijs-Leijonmalm P. et al. (2021) A deep scattering layer under the North Pole pack ice. Progress in Oceanography 194:102560. [https://doi.org/10.1016/j.pocean.2021.102560]

[10] Snoeijs-Leijonmalm P. et al. (2022) Unexpected fish and squid in the central Arctic deep scattering layer. Science Advances (in press)

under-studied part of the food web in the CAO because catches of macrozooplankton have been very rare in the multinet samples that have been deployed in the area. Analyses of these data will provide new insights in the roles of macrozooplankton in the CAO ecosystem and their possible relevance for fish populations.

(6) During the SAS-Oden expedition >300 well-preserved fish otoliths were discovered in the upper sediment layer that presumably represents the current geological epoch, the Holocene, that started ca. 11,700 years ago. The otoliths were preliminary identified as belonging to polar cod (*Boreogadus saida*) and ice cod (*Arctogadus glacialis*). These were not only otoliths from juvenile fish and may provide us with proof of the occurrence of adults of these species in the CAO today (on the sediment surface) and in the past (in the 10-20 cm "Holocene" layer below the sediment surface).

(7) Since no fish samples were collected in the DSL of the CAO, despite numerous attempts with vertical nets, traps and lines, the eDNA samples have become all the more important for the EFICA studies in assessing fish diversity and distribution in the CAO. The SAS-Oden genomic sample collection constitutes of thorough systematic sampling the water-column (4-7 depths, depending on seafloor depth), eight ice habitats and sediment cores for the purpose of finding evidence of the occurrence of fish, zooplankton and mammals.

(8) Future sustainable commercial fisheries in the deep Eurasian Basins do not seem feasible given the extremely low fish biomass and the fact that the productivity of the CAO ecosystem is expected to remain very low for a long time[11].

The work reported from the SAS-Oden expedition in this report, as well as that performed during the MOSAiC expedition[12], and the Standard Operation Protocols (SOPs) and Standard Fish Protocol Sheets (SFPs) delivered to CINEA / DG MARE from both expeditions, may be used as sources of information to the Provisional Scientific Coordinating Group (PSCG) of the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean in developing the data sharing protocol and the joint monitoring program of the JPSRM. This especially concerns the further development of methods for fish sampling under a 2-m thick ice cover when fish abundance in the DSL is very low.

Future analyses of the data and samples collected during the SAS-Oden and MOSAiC expeditions can provide information on the identity, size, density and biomass of pelagic living organisms from the surface down to 1000 m of depth, the ecological living conditions for fish, food availability, food quality for juvenile and adult fish, and the potential for fish production in the CAO ecosystem. The collected data from the two expeditions include the deep Eurasian Basin of the CAO, part of the Lomonosov Ridge, a small corner of the Makarov Basin, and the inflow area of Atlantic water to the CAO.

This SC06 Final Report summarises the deliverables of SC06 (**Chapter 2**), the organisation and conditions for the execution of SC06 (**Chapters 3-4**), detailed records of the fieldwork carried out during the SAS-Oden expedition (**Chapters 5-6**), the relevance of the collected data for fish-stock modelling and assessment (**Chapter 7**), data issues (**Chapter 8**), the SC06 Media Archive (**Chapter 9**), and the SC06 Metadata Database Manual (**Chapter 10**).

[11] Nöthig S, et al. (2020) Summertime chlorophyll *a* and particulate organic carbon standing stocks in surface waters of the Fram Strait and the Arctic Ocean (1991–2015). Frontiers in Marine Science 7, 350

[12] Snoeijs-Leijonmalm P. et al. (2021) Ecosystem mapping in the Central Arctic Ocean (CAO) during the MOSAiC expedition. Publications Office of the European Union, 2021 [https://data.europa.eu/doi/10.2926/714618]

1 INTRODUCTION

The marine ecosystems of the Arctic Ocean are experiencing rapid change. This includes the Central Arctic Ocean (CAO), i.e., the deep basins and ridges around the North Pole (**Figure 1**) that until recently were permanently covered by thick sea ice. In the past two decades, up to 40 % of the CAO has been ice-free during summer. This reduction in sea-ice coverage in the CAO is transforming a basically inaccessible marine ecosystem into a new type of ecosystem with seasonal changes in sea ice cover.

In response to the increasing accessibility of the CAO, the "*Agreement to prevent unregulated High Seas fisheries in the CAO*" between the European Union and nine countries (Canada, the People's Republic of China, the Kingdom of Denmark in respect of the Faroe Islands and Greenland, Iceland, Japan, the Republic of Korea, the Kingdom of Norway, the Russian Federation, the United States of America) was signed in October 2018. The Agreement entered into force on 25 June 2021 after it had been ratified by all ten Signatories. The Agreement takes a precautionary approach by essentially preventing any fishery in the Arctic High Seas until a sound scientific knowledge base is available about the present fish stocks, the ecosystems sustaining them, and their expected fate in a changing Arctic Ocean.

There is almost no knowledge on the presence and distribution of fish populations in the rapidly changing CAO ecosystem. The objectives of SC03 (MOSAiC Expedition 2019-2020) and SC06 (SAS-Oden Expedition 2021) were to collect new field data for addressing the four questions proposed for the mapping phase of the JPSRM by the Fifth FiSCAO Meeting[13], and further developed in the First PSCG Meeting[14], by expert groups appointed by the Signatories of the Agreement. These four questions are:

(1) What are the distributions of species with a potential for future commercial harvests in the High Seas portion of the CAO?
(2) What fish species are currently present in the High Seas portion of the CAO?
(3) What are the trophic linkages among fishes and between fishes and other taxonomic groups?
(4) What are the likely key ecological linkages between potentially harvestable fish stocks of the High Seas portion of the CAO and adjacent shelf ecosystems?

Critical gap analyses performed by the EFICA Consortium within a previous Specific Contract (SC02)[15] highlighted that the knowledge gaps for the CAO are enormous and obstruct any quantitative analyses of its fish stocks (**Figure 2**). This was in agreement with the conclusions from the Fifth FiSCAO Report[4]. While data for the physical environment in the CAO (oceanography, bottom topography and ice-cover dynamics) would be sufficient, it is the massive lack of biological and ecological data that makes fish-stock modelling and assessment impossible.

The work performed under specific Contract SC06 constituted the second systematic effort (SC03, the MOSAiC Expedition being the first one) to map fish populations present on the Eurasian side of the CAO and provides information for future mapping and monitoring surveys as envisioned in the Agreement. SC06 enabled the EFICA Consortium to take part in the Swedish SAS-Oden expedition in order to collect primary data on the marine ecosystem, focusing on fish stocks and associated parameters in the CAO. The EFICA Consortium prepared the expedition during the EFICA SC04 Workshop in Brussels

[13] FiSCAO (2018) Final Report of the Fifth Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean. FiSCAO. 45 pp.
[14] PSCG (2020) Report of the 1st meeting of the Provisional Scientific Coordinating Group (PSCG) of the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean. PSCG. 63 pp.
[15] Snoeijs-Leijonmalm P, et al. (2020) Review of the research knowledge and gaps on fish populations, fisheries and linked ecosystems in the Central Arctic Ocean (CAO). Publications Office of the European Union, 2020. [https://data.europa.eu/doi/10.2826/387890]

on 17-18 June 2019[16] and builds on experiences from the MOSAiC expedition (2019-2020).

For addressing the four questions proposed for the mapping phase of the JPSRM, and knowing the gaps in the scientific knowledge about the CAO ecosystem, relevant ecosystem parameters for fish-stock modelling and assessment were selected and included in the planning of the SAS-Oden expedition. The aim of SC06 was to collect these parameters as often as possible during the SAS-Oden expedition.

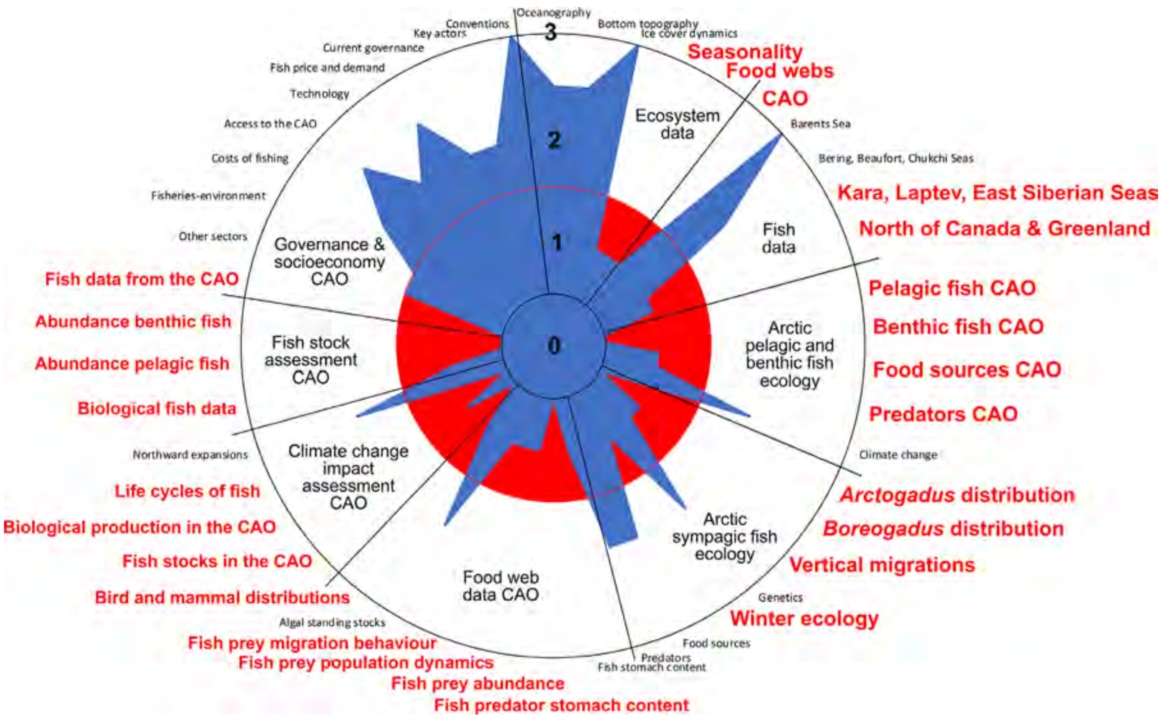

Figure 2: Radar chart summarising knowledge gaps (adapted from Snoeijs-Leijonmalm et al. 2020)[17]. On the axis the estimates of the severity of the knowledge gaps are provided: 0 = no knowledge, 1 = serious lack of knowledge, 2 = insufficient knowledge, 3 = sufficient knowledge available for fish-stock modelling and assessment. The larger the blue area is in the direction of a specific subject, the smaller the relative knowledge gap on this subject. The red circle in combination with the red texts shows where the lack of knowledge is most severe.

[16] EFICA Consortium (2019) EFICA Workshop in preparation for the Polarstern and Oden expeditions for 2019 and 2020. Report to EASME/DG MARE. 32 pp.

[17] Snoeijs-Leijonmalm P, et al. (2020) Review of the research knowledge and gaps on fish populations, fisheries and linked ecosystems in the Central Arctic Ocean (CAO). Publications Office of the European Union, 2020. [https://data.europa.eu/doi/10.2826/387890]

2 SC06 TASKS AND DELIVERABLES

2.1 Tasks and deliverables overview

The SC06 tasks and deliverables fall into three categories: "Preparation", "Fieldwork", and "Delivery". The execution of the tasks and deliverables have been fulfilled according to the SC06 Contract (**Table 1**).

Table 1: The SC06 tasks and deliverables and the dates on which these were concluded or delivered to CINEA / DG MARE.

Task	Task or deliverable	Date concluded / delivered
Task 1 Preparation	Mobilisation of research facilities and most equipment and consumables to Helsingborg (Sweden) before 12 June 2021. Covid19 quarantine in Malmö 16-25 June, safety trainings at IB Oden 25-26 July.	26 July 2020
Task 2 Fieldwork	Data and sample collection during the SAS-Oden expedition	19 September 2021
Task 3 Delivery	Draft Inception Report Kick-off Meeting (on-line due to Covid19) Inception Report Draft Interim Report Interim Meeting (on-line due to COVID19) Interim Report Status Report 1 from the SAS-Oden Expedition Status Report 2 from the SAS-Oden Expedition Status Report 3 from the SAS-Oden Expedition Draft Final Report Final Meeting (on-line due to COVID19) Final Report	15 April 2021 22 April 2021 10 June 2021 30 June 2021 15 July 2021 23 July 2021 12 August 2021 02 September 2021 19 September 2021 01 December 2021 16 December 2021 15 January 2022
	Media archive consisting of press releases and public media outputs related to SC06 (**Chapter 9**)	15 January 2022
	SC06 Metadata Database Manual (**Chapter 10**)	15 January 2022
	SC06 Metadata Database consisting of 9 EXCEL files: *Database File 01 - Logbook 220115.xlsx* *Database File 02 - SHIP data 220115.xlsx* *Database File 03 – SAS CTD metadata 220115.xlsx* *Database File 04 – EFICA ACOUSTIC metadata 220115.xlsx* *Database File 05 – EFICA OPTICAL metadata 220115.xlsx* *Database File 06 – EFICA ZOOPLANKTON metadata 220115.xlsx* *Database File 07 – EFICA FISH metadata 220115.xlsx* *Database File 08 – EFICA OTOLITH metadata 220115.xlsx* *Database File 09 – SAS OMICS metadata 220115.xlsx*	15 January 2022

2.2 Standardisation of EFICA methods

The "EFICA Standard Operation Protocols for MOSAiC" (SOPs) and the "EFICA Standard Fish Protocol Sheets for MOSAiC" (SFPs) developed during the MOSAiC expedition were discussed and adapted for the SAS-Oden expedition to ensure continuity in the fundamental data collection methods throughout the expedition even if different people carry out the tasks. The resulting standardised methodologies are described in this report and can be used as a start for producing standard operational protocols (SOPs) for use in the Joint Program for Scientific Research and Monitoring (JPSRM) of the Agreement.

2.3 Expedition Logbook

All scientific sampling operations, named "device operations", carried out during the SAS-Oden expedition, were recorded in a Logbook on the bridge. This Logbook is delivered with this report as "Database File 1 – Logbook.xlsx". Each device operation has a number consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation at the same station), thus providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition. A device operation is either a winch operation from the ship or an ice station. In the Logbook, the device operation is coupled to date, time, geographical position and ocean depth. Ice stations next to the ship are in the Logbook classified as sampling operations at the ship station while ice stations reached by helicopter each have their own station number. Single sampling activities within the ice stations (e.g., ice coring, long-line deployment) were not recorded in the Logbook; their sampling details are recorded in the respective metadata files. With the help of the time of each device operation, the ship's exact position, speed and wind conditions can be extracted from the ship data. During the SAS-Oden expedition, 260 successful device operations were carried out, 9 failed and 2 were short test CTD casts. The latter 11 operations are also included in the Logbook, which in total contains 271 device operations.

2.4 Data and sample types collected

During the SAS-Oden fieldwork, the EFICA scientists collected the following six types of data and samples:

(1) Hydroacoustics using the EK80 echo sounder of IB Oden (frequency 18 kHz) and a Wide-Band Autonomous Transceiver (WBAT, frequencies 38 and 333 kHz) on the CTD rosette for later data analyses (within SC07) of fish and fish prey distributions and biomass, and their physical environment (e.g., stratification).

(2) Optical recordings using a deep-sea camera system (FishCam), an Underwater Vision Profiler (UVP6) and a Lightframe On-sight Key species Investigation (LOKI) for later analyses (within SC07) to identify fish, squid, siphonophores (zooplankton colonies some of which can produce acoustic backscatter) and fish prey species at mesopelagic depths (ca. 200-500 m).

(3) Fish and zooplankton samples for later laboratory analyses (within SC07) of fish age, condition (indices, chemical analyses), prey (stomach and hindgut contents), the stock origin (population genetics), and the previous living conditions of the fish (otolith stable isotope analyses), as well as zooplankton composition and biomass.

(4) Sediment otolith samples for later laboratory analyses (within SC07) of fish age and the previous living conditions (otolith stable isotope analyses).

(5) E-DNA samples for later bioinformatic analyses of the SAS-Oden Metagenomic Dataset including barcoding of fish and zooplankton (within SC07) to identify fish, squid, siphonophores, fish prey species (zooplankton) and fish predator species (mammals).

(6) Other ecosystem data: EFICA will need to relate its fish and food-web data to physical, chemical and biological data (within SC07). The EFICA field scientists have contributed to collecting EFICA-relevant SAS-Oden Core Parameters during the expedition, which therefore are available for the analyses in SC07.

3 SC06 TIME SCHEDULE

The EFICA Consortium has followed the original time schedule according to the SC06 contract. The timing and duration of the different tasks and subtasks within SC06 is visualised in a Gantt chart for the time period between 1 April 2021 (the start of SC06 according to the contract) and 15 January 2022 (delivery of the Final Report) (**Table 2**). The SC06 Contract ended on 31 January 2022.

Table 2: Gantt chart showing the timing and duration of the different tasks and subtasks within SC06, as well as the responsible EFICA partners and experts for each subtask.

	Responsible EFICA scientist(s)	EFICA partner	2021 (1 April - 31 December)																		2022 (Jan)	
			4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10 a	10 b	11 a	11 b	12 a	12 b	1a	1b
Task 1: Preparation and mobilisation of research facilities and equipment (16 December 2020 - 25 July 2021)																						
Preparing the field work	Pauline	SU	■	■	■	■	■	■	■													
Safeguarding ship facilities	Pauline	SU	■	■	■	■	■	■	■													
EFICA equipment SLU	Baldvin	SLU	■	■	■	■	■	■	■													
EFICA equipment AWI	Hauke, Nicole	AWI	■	■	■	■	■	■	■													
EFICA equipment SU	Pauline	SU	■	■	■	■	■	■	■													
Task 2. Expedition (25 July - 19 September 2021)																						
Coordinating the field work	Pauline	SU								■	■	■	■									
Acoustic data collection	Serdar, Julek, Julia	WMR/SU								■	■	■	■									
FishCam data collection	Pauline, Hauke	AWI/SU								■	■	■	■									
UVP data collection	Julek	SU								■	■	■	■									
Pelagic fish sampling	Baldvin, Frank, Serdar, Julek	SLU/SU/ WMR								■	■	■	■									
Ice fish sampling	Hauke	AWI								■	■	■	■									
Zooplankton sampling	Nicole, Hauke	AWI								■	■	■	■									
Sediment otolith sampling	Julek, Claudia, Pauline, Hauke	SU/SLU/ AWI								■	■	■	■									
eDNA sampling	Prune, Javier, Clara, Claudia	SU/SLU								■	■	■	■									
Task 3. Delivery of the project results to CINEA / DG MARE (20 September 2021 - 15 January 2022)																						
Draft Inception Report	Pauline	SU	■																			
Kick-off Meeting	Pauline	SU		■																		
Inception Report	Pauline	SU					■															
Draft Interim Report	Pauline	SU						■														
Interim Meeting	Pauline	SU							■													
Interim Report	Pauline	SU								■												
Status Report 1 to CINEA	Pauline	SU									■											
Status Report 2 to CINEA	Pauline	SU											■									
Status Report 3 to CINEA	Pauline	SU												■								
Draft Final Report	Pauline	SU																	■			
Draft Metadata Database	Pauline	SU																	■			
Final Meeting	Pauline	SU																		■		
Final Report	Pauline	SU																			■	
Final Metadata Database	Pauline	SU																			■	

4 SC06 SCIENTISTS AND THEIR TASKS

4.1 SC06 Executive Committee

The Executive Committee for SC06 consisted of the twelve scientists from four EFICA Consortium partner institutes (SU, SLU, AWI, WMR) (**Figure 3**). Together, they carried out the fieldwork during the SAS-Oden expedition.

Figure 3: The EFICA Team of the SAS-Oden expedition gathered at the North Pole. Back row from left to right: Prune Leroy (SU), Nicole Hildebrandt (AWI), Clara Pérez Martínez (SU), Hauke Flores (AWI), Pauline Snoeijs-Leijonmalm (SU), Frank Menger (SLU), Serdar Sakinan (WMR), Baldvin Thorvaldsson (SLU), Julek Chawarski (SU), Front row from left to right: Javier Vargas Calle (SLU), Julia Muchowski (SU), Claudia Morys (SU). © Alexandra Padilla

4.2 SC06 on-board tasks

The responsibilities of the respective EFICA scientists during the expedition are summarised in **Table 3**. The SC06 Project Manager, Pauline Snoeijs-Leijonmalm, was also Chief Scientist on the expedition, and was a member of the Expedition Leader Team together with Mattias Petersson (Captain of IB Oden, Swedish Maritime Administration) and Maria Samuelsson (Logistics Coordinator, SPRS).

Table 3: List of the twelve EFICA scientists in the EFICA Team during the SAS-Oden expedition with their tasks and responsibilities on-board and the percentage of their time they performed EFICA-specific work.

EFICA scientist (name and affiliation)	Role on board and field of expertise	Main tasks within SC06 (with help from the others)	Main responsibility for EFICA metadata (with help from the others)	Time spent on EFICA-specific work on-board
Pauline Snoeijs-Leijonmalm (SU)	SC06 Project Manager, marine ecologist	Organisation of the fieldwork Safeguarding ship facilities Status Reports to CINEA / DG MARE Made labels for all EFICA+SAS samples FishCam maintenance Deployment EFICA FishCam on the CTD	SC06 Metadata Database compilation Expedition Logbook metadata Ship metadata CTD metadata FishCam metadata SAS Core Parameters metadata	50 % EFICA 50 % Chief Scientist for whole expedition
Serdar Sakinan (WMR)	Acoustician, fish biologist	Acoustics (EK80, WBAT) Pelagic fish and macrozooplankton sampling from ship (beam net) and ice	EK80 metadata WBAT metadata	100 % EFICA
Julek Chawarski (SU)	Acoustician, fish biologist	Acoustics (EK80, WBAT) Pelagic fish and macrozooplankton sampling from ship (beam net) and ice UVP and TDR-Mk9-404A tag light tag (on the "Shallow" and "Deep" CTD casts) Otolith sampling	UVP metadata Otolith samples metadata	100 % EFICA
Julia Muchowski (SU)	Acoustician, physical oceanographer	Acoustics (EK80, WBAT)	EK80 metadata	10 % EFICA 90 % SAS-Oden WP14 project
Baldvin Thorvaldsson (SLU)	Sampling of organisms, Fish biologist	Deployment EFICA beam and MIK nets Pelagic fish and macrozooplankton sampling from ship and ice	Beam and MIK nets deployment data EFICA ice station metadata Longline metadata Trapline metadata	100 % EFICA
Frank Menger (SLU)	Sampling of organisms, Environmental chemist	Pelagic fish and macrozooplankton sampling from ship (beam) and ice	EFICA ice station data Longline metadata Trapline metadata	90 % EFICA 10 % environmental chemistry
Hauke Flores (AWI)	Sea-ice / pelagic ecologist	SAS ice station coordination Fish sample collection Macrozooplankton sample collection Deployment EFICA FishCam from the ice	SAS ice station data Fish samples metadata Macrozooplankton samples metadata	100 % EFICA
Nicole Hildebrandt (AWI)	Zooplankton ecologist	Deployment SAS multinet Deployment SAS bongo net Deployment EFICA LOKI Mesozooplankton sample collection (together with SAS-Oden WP8)	Net and LOKI deployment data LOKI metadata Mesozooplankton samples metadata	100 % EFICA
Prune Leroy (SLU)	Molecular biologist	Water sampling from CTD Water, ice and snow sampling from ice eDNA filtrations	eDNA samples metadata	25 % EFICA 75 % SAS-Oden WP2 project
Clara Pérez Martínez (SU)	Molecular biologist	Water sampling from CTD Water, ice and snow sampling from ice eDNA filtrations	eDNA samples metadata	25 % EFICA 75 % SAS-Oden WP2 project
Javier Vargas Calle (SLU)	Molecular biologist	Water sampling from CTD Water, ice and snow sampling from ice eDNA filtrations	eDNA samples metadata	25 % EFICA 75 % SAS-Oden WP7 project
Claudia Morys (SU)	Benthic ecologist	Deployment SAS box corer Water sampling from CTD Water, ice and snow sampling from ice eDNA filtrations	Box core deployment data eDNA samples metadata	25 % EFICA 75% SAS-Oden WP7 project

5 SAS-ODEN EXPEDITION SUMMARY

5.1 Expedition participants

The 75 SAS-Oden expedition participants comprised 38 scientists, 14 employees from the Swedish Polar Secretariat (coordinator, technicians, bear guards, meteorologist, helicopter team, medical team), and 23 IB Oden captain and crew from the Swedish Maritime Administration. General information about the SAS-Oden expedition in 2021 is available at https://www.polar.se.

5.2 Quarantine in Malmö (Sweden)

Strict quarantine measures were necessary because an outbreak of Covid19 on-board could adventure the whole expedition. From 16 until 24 July all expedition participants endured a strict eight-day quarantine in the Scandic Malmö City Hotel. Nobody was allowed to leave the hotel room. The quarantine time was mainly used for organisational meetings for all participants, and smaller meetings within the different SAS-Oden Work Packages (executing the SAS-Oden projects). The EFICA Team had several meetings during which the coming field work was discussed. On 17 July, Pauline Snoeijs-Leijonmalm presented the SC06 project for all expedition participants (on-line). All 75 people tested negative for Covid19 infection twice and were on 24 July transported by bus from the hotel in Malmö to IB Oden.

5.3 Transit to the marginal ice zone

During the transit from Malmö to the marginal ice zone north of Svalbard, the EFICA Team continued discussing the coming field work, including discussing the SOPs and SFPs from MOSAiC, and started up the practical preparations. In the first place this involved packing up the ca. four tonnes of EFICA equipment sent to IB Oden during the expedition mobilization in the beginning of June and installing the equipment in containers and labs. The largest EFICA equipment remained on deck. This concerned the "beam net", a newly designed net for sampling pelagic fish and macrozooplankton (i.e., zooplankton larger than 0.5 cm) under the sea ice, consisting of a 10 m steel beam and a 30 m long fishing net, as well as the "Giant Box Corer" that was used for taking deep sea-bottom samples.

On the ship, EFICA disposed of two 20-foot deck containers, one for the fish sampling gear and one for the zooplankton sampling gear. Fish and zooplankton sample processing took place on deck immediately after sampling and microscopy in the "Triple Lab" on Deck 4. The eDNA sample processing took place in the laboratory containers 14, 22 and 23 and the "Main Lab". The EK80 acoustics were programmed from the bridge. Further deck space and labs were shared with other WPs.

5.4 Expedition track and sampling stations

The SAS-Oden expedition lasted 56 days (26 July - 19 September 2021). The transit from Malmö (Sweden) to the marginal ice zone took 7 days. The first sampling station with winch operations from the ship was performed on 2 August (Station 1, **Figure 4**). The last winch operation from the ship was performed on 12 September (Station 60, **Figure 4**). The 60 stations include 36 ship stations and 24 helicopter stations (**Table 4**). By order of the captain of IB Oden the transit home to Helsingborg (Sweden) started in the evening of 12 September. This timing was based on the weather forecast for the

North Atlantic; in this way IB Oden could get back two Sweden in-between two fronts with bad weather with high waves.

The expedition crossed the Nansen Basin, the Gakkel Ridge, the Amundsen Basin, the North Pole, the Lomonosov Ridge and a small corner of the Makarov Basin, the western Amundsen Basin, and then back over the Gakkel Ridge to the end station on the Yermak Plateau (**Figure 4**). The originally planned expedition track was followed as much as possible, but since the pack ice west and east of the track between Stations 42 and 50 (**Figure 4 inset**) was too thick to be forced by IB Oden, the route needed to be adapted.

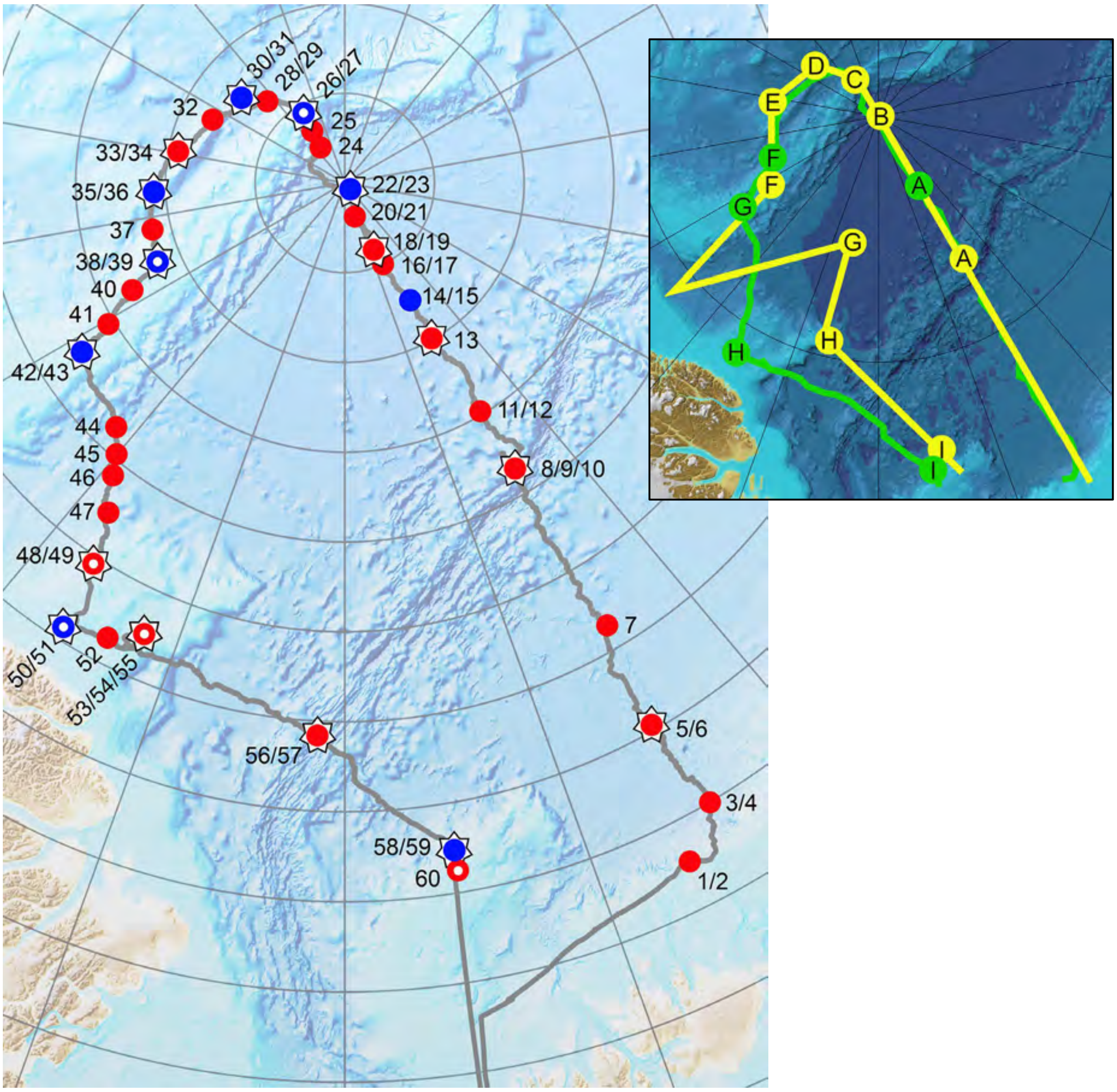

Figure 4: The large map shows the realized expedition track with the station numbers. Red and blue circles indicate CTD stations, white stars indicate ice stations, and small white dots indicate box core stations. The first station number is always a ship station, the second and third station numbers are helicopter stations. The blue stations are the nine EFICA Master stations where fishing activities took place with the beam net. The inset map shows the preliminary planned (yellow) and realized (green) EFICA Master stations A-I. Station A was north of the planned position because of strong winds when IB Oden passed the Gakkel Ridge. Stations G and H needed to be adapted due to the heavy ice situation around the original positions (see Figure 6), in combination with the time schedule of the expedition. Background map: bathymetric map of the Arctic Ocean[18].

[18] Jakobsson M, et al. (2012) The International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3.0. Geophysical Research Letters 39:L12609 [http://doi.org/10.1029/2012GL052219]

Table 4: Summary of the 60 sampling stations (Stations 1-60, 36 ship stations and 24 helicopter stations) visited during the SAS-Oden expedition with IB Oden and the sampling activities that took place at these stations. Heli station = sampling station reached by helicopter in the vicinity of the ship (within a radius of ca. 1 nautical mile). The description codes for the sampling devices are explained in Chapter 6.

Sampling device	Description	Ship	0	1	3	5	7	8	11	13	14	16	18	20	22	24	25	26	28	30	32	33	35	37	38	40	41	42	44	45	46	47	48	50	52	53	56	58	60	Number of stations	Number of device operations
		Heli		2	4	6		9	12		15	17	19	21	23			27	29	31		34	36		39			43					49	51		54	57	59			
		Heli					10																												55					
CTD 1000m	Bio	SAS			1		1	1		1		1	1		1			1		1		1	1		1			1					1	1		1	1	1		18	18
CTD 1000m	Omics	SAS			1		1	1		1		1	1		1			1		1		1	1		1			1					1	1		1	1	1		18	18
CTD 1000m	WBAT	EFICA									1				1			1		2			1		1			1						1		3	1	1		11	14
CTD deep	Bottom	SAS		1		1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		32	32
CTD deep	Bottom	VACAO				1		1				1		1					1											1								6	6
CTD shallow	Calib EK80	SAS	1																																				1	1
CTD shallow	Surface	SAS				1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1		1											1	1	1		20	20
CTD shallow	ChlMax	PICO						1								1																					1			3	3
Multinet	150 µm	SAS			1			1		1		1			2			1		1		1	1		1			1					1	1		1	1	1		16	17
Multinet	50 µm	FORAM																1				1			1			1					1	1		1		1		8	8
Bongo net	200m	SAS						1							1			1		1			1		1			1						2		1	1	2		11	13
Bongo net	1000m	FORAM					1						1					1																					3	3
Beam net	800m	EFICA									4				2			4		5			7		7			7						5				4		9	45
MIK net	800m	EFICA																																		2		3		2	5
LOKI	Optics	EFICA						1							1			1		1		1	1		1			1						1		1		1		11	11
Box corer	Bottom	SAS																1							1								1	2		1			2	5	8
Ice station	Ship	SAS+proj						1		1			1		1			1		2			1		1			1						1		1	1	1		13	14
Ice station	Heli	SAS				1																1											1						3	3
Ice station	Heli	EFICA		1	1			2			1		1		1			1		1			1		1			1						1		1	1	1		15	16
Ice station	Heli	ACAS							1			1		1					1																		1				5	5
Total number of sampling events			1	2	4	4	5	12	2	6	6	7	7	4	13	3	2	17	4	17	1	8	17	1	19	1	1	17	1	1	2	1	7	18	1	17	10	19	2	210	260

5.5 Sea ice observations

During the SAS-Oden expedition the ice was thick around the North Pole, but we found a surprisingly large area with open water north of Greenland (**Figure 5**). Generally, the ice was highly dynamic over large areas, and changing significantly from day to day (**Figure 6**). Because of this many fast decisions about changes of the expedition track needed to be taken by the Expedition Leader Team so that we would not get stuck in the ice.

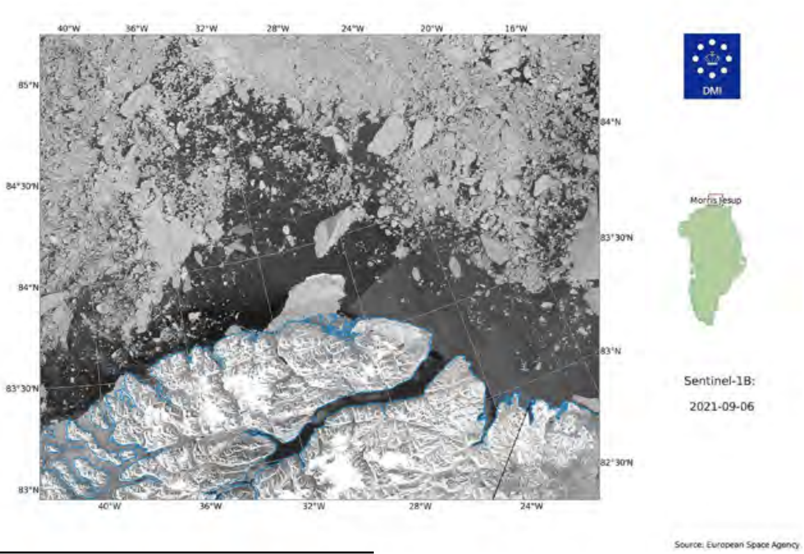

Figure 5: Satellite image showing the large open-water area north of Greenland that we passed during the SAS-Oden expedition. © European Space Agency

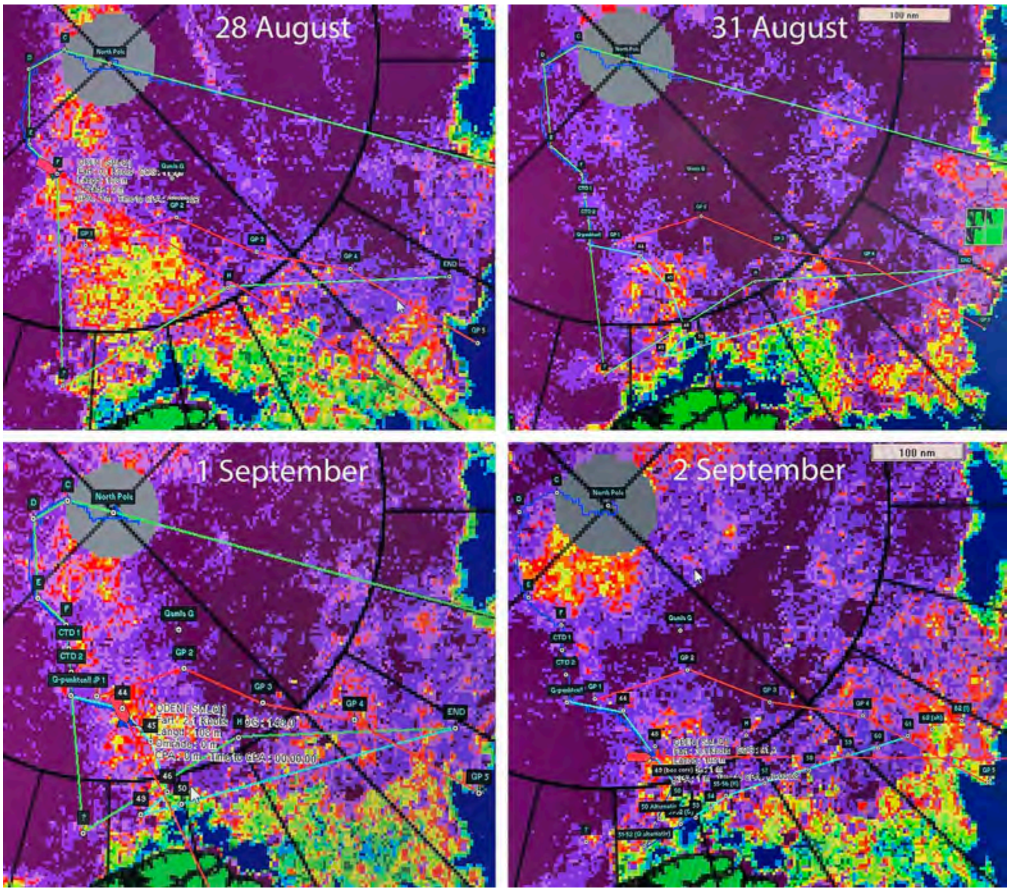

Figure 6: Ice charts on four days close in time. The sea ice was highly dynamic, see e.g., the difference between 28 August when IB Oden was at point "F" with relatively low ice cover (yellow) whereas on 31 August the ice was completely closed in this area (purple). These fast ice dynamics are largely regulated by winds. © ARTIST Sea Ice (ASI), AMSR2 satellite

5.6 Expedition highlights

The SAS-Oden expedition was granted permission to carry out research (including fish research) within the Greenland and Norwegian EEZs under the condition that data would be shared. The expedition reached further west on the Greenland shelf than any other expedition has ever done before. Closest was the geological Lomrog III expedition with IB Oden in 2007, but then they needed the help of the accompanying Russian atomic-driven ice-breaker "50 years of Victory" to get this far west.

Between Stations 42 and 53, the SAS-Oden expedition was in a completely unexplored area. Some outcomes are that the seabed map needs to be revised, in one place it was 900 m deep instead of 300, in another place it was 1200 m shallower than on the map.

Although it was foreseen that biological productivity – including fish – would be extremely low, we now have the first real measurements of bacterial, primary and zooplankton production and many other ecosystem parameters from the area between Stations 30 and 53. The collected Omics samples form the basis for a unique biodiversity dataset, covering water column, ice habitats, and sediments. These samples include the genomes and transcriptomes of viruses, archaea, bacteria, protists, and eDNA of multicellular organisms such as zooplankton, fish and mammals. Altogether, the expedition covered all stipulated physical, chemical and ecosystem SAS parameters[19] except for specific studies on birds and mammals.

[19] Synoptic Arctic Survey – a pan-Arctic Research Program – Science and Implementation Plan [https://synopticarcticsurvey.w.uib.no/science-plan]

6 SAS-ODEN EXPEDITION FIELDWORK

6.1 Acoustic measurements with EK80

6.1.1 EK80 equipment

The ship-mounted echosounder system on IB Oden originally consists of a Simrad EK60 that runs a split-beam Simrad ES18-11 transducer designed to be operated for narrow-band applications. During the SAS-Oden expedition, this transducer was coupled to an EK80 transceiver and used in wideband mode to generate frequency modulated signals. The full bandwidth that can be achieved with this transducer extends from 15 to 28 kHz. However, previous experiences with this special configuration have shown that the signal quality deteriorates towards the higher end of the full bandwidth.

Data were recorded continuously and checked on a daily basis when possible. For biological observation of individual targets at low density and high range (250-600 m), higher echosounder sensitivity is desirable. However, this comes with a trade-off regarding noise sensitivity. To achieve the best signal-to-noise ratio for measurement of living targets, the bandwidth was reduced to 16-19 kHz, thereby preventing the dilution of transmitted energy that would accompany higher bandwidth data requiring noise filtering during post-processing of the data.

6.1.2 EK80 calibration

The ES-18 transducer was calibrated on 1 August 2021 between 11:44 UTC and 15:41 UTC at 81° 14’N, 18° 30’E. XBT 2 was used to calculate the sound speed profile in the calibration site after completing all three calibrations (**Table 5**). Due to different requirements in measuring biological backscatter and physical phenomena, two setting types were used: EFICA and Geophysical

The EFICA EK80 settings were alternated with “Geophysical Mapping” EK80 settings. For the purpose of geophysical mapping, a relatively wider bandwidth (15-25 kHz) was used. This wider bandwidth setting was typically in place during transit when the EK80 was synchronized with the multibeam and the sub-bottom profiler. The ES-18 transducer was calibrated for three unique transmit signals that were used during the expedition (**Table 5**). We followed established calibration procedures described in Demer et al. (2015)[20] and the SWERUS 2014 Cruise Report[21]. The ES-18 was calibrated with a 63 mm copper sphere, providing different beam patterns of the signals for the calibrations with Geophysical Mapping settings and EFICA settings, respectively (**Figure 7A-D**). Additionally, preliminary results of the correction factor, which considers measurement offsets due to electro-mechanical processes from the EK80 wideband transceiver, were produced (**Figure 7E,F**).

Table 5: Calibration information

Transmit signal	EFICA (16-19 kHz)	Geophysical Mapping (15-25 kHz)	CW (18 kHz)
Start Time (UTC)	11:44	13:50	15:07
End Time (UTC)	13:50	15:06	15:42
Pulse Length (ms)	4.096	4.096	1.024
Power (W)	1600	1600	1600
Ramping	Fast	Fast	Fast
Pulse Type	LFM Up	LFM Up	CW

[20] Demer DA, et al. (2015) Calibration of acoustic instruments. ICES Coop. Res. Report, 326:1-132
[21] SWERUS 2014 Cruise Reports Leg 1 and Leg 2 [https://bolin.su.se/data/swerus/reports.php]

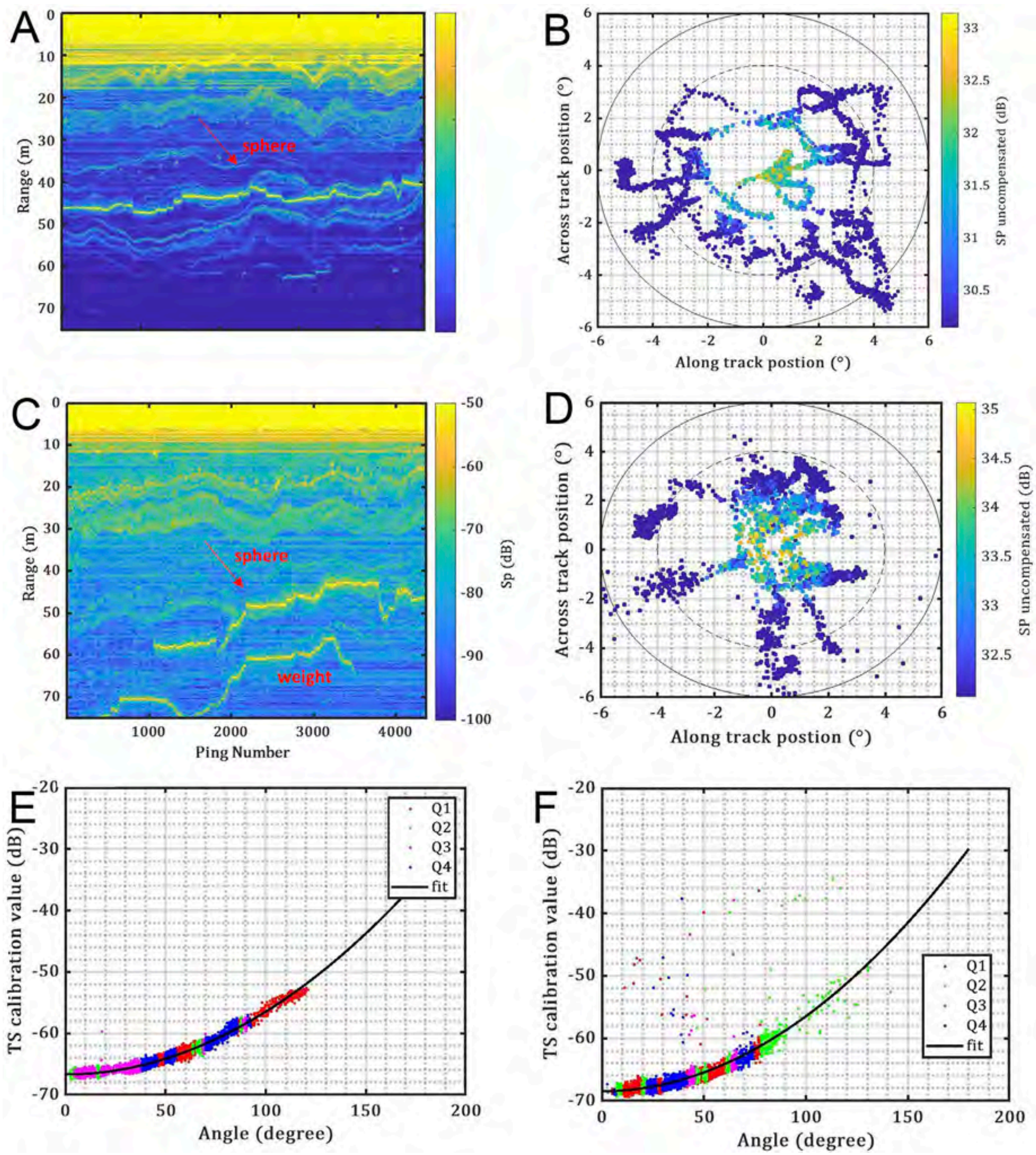

Figure 7: EK80 calibration results. (A) Geophysical Mapping settings - overview echogram of calibration data. (B) Geophysical Mapping settings - position of sphere in beam. (C) EFICA settings - overview echogram of calibration data. (D) EFICA settings - position of sphere in beam. (E) Geophysical Mapping settings - calibration offset as a function of electrical phase angle (equivalent to distance from beam centre). (F) EFICA settings - calibration offset as a function of electrical phase angle (equivalent to distance from beam centre).

6.1.3 EK80 standard settings for EFICA measurements

A series of tests was performed during the transit before arriving at the calibration station close to the marginal ice zone. The tests consisted of systematically changing the settings and assessing the noise levels. The test results showed that the cleanest data for observation of biological targets would be achieved by using a relatively narrow bandwidth and the following pulse parameters:

FrequencyStart	16 kHz
FrequencyEnd	19 kHz
PulseDuration	4.096 milliseconds
SampleInterval	0.256 milliseconds
TransmitPower	1600 Watt

In addition to these adaptations to pulse settings, the multibeam and the sub-bottom profiler were shut off when the ship was drifting with the ice during sampling stations. Then, the EK80 was run in standalone mode which allowed for an increased ping rate, thus improving the temporal resolution of the dataset. During selected operations aiming at quantifying fish, the recording range of the EK80 was reduced to 1200 m to further increase the ping rate of the system.

6.1.4 EK80 metadata summary

EK80 data were collected during the whole expedition: from leaving the Norwegian EEZ (29 July at ca. 18:30) until arrival in Helsingborg after the expedition (19 September). In the CAO, we observed very low target density in the epi- and meso- pelagic portion of the water column (10-600 m). Acoustic observations of water column stratification and possible methane seeps were observed. During the periods when the noise level was low, individual targets were observed in desired detail and from these data individuals can be counted, their target strengths can be estimated reliably and their behaviour can be observed. The EK80 sections overlapping with CTD WBAT casts are suitable for comparison. Hundreds of hits from individual targets were received with the possibility of single target tracking.

6.1.5 EK80 considerations

EK80 Ping rate

Since the density of biological targets was very low throughout the expedition track, the focus was given on detecting the targets individually, which would eventually allow a detailed understanding of the behaviour and size distribution. This requires receival of multiple hits from the same target which then can allow for isolation and tracking of the target. Collecting observations of this quality required a high frequency with which an ultrasonic pulse is sent into the water column by an echo sounder through the transducer (a high ping rate). Multiple factors hindered this objective, such as synchronization of the EK80 pings with the multibeam and the sub-bottom profiler in a sequential mode. Since the synchronization substantially reduced the pinging rate for the EK80, it was decided to switch the multibeam and sub-bottom profiler off during all sampling stations.

A second issue with respect to ping rate was the depth of the Central Arctic basins where seafloor depth extended below 3000-4000 m. A ping adjustment that enabled coverage of this full range required intervals between 6 to 10 seconds. This substantially reduced the pinging rate. Therefore, it was decided to reduce the observation range to 1200 m of depth and to adjust the ping rate accordingly while keeping the aliasing signals from the bottom returns (false bottom) out of the observed range. This adjustment generally allowed for a ping rate of 3 seconds. However, during deep CTD deployments bottom detection was needed and required either expansion of the observation range or switching on the multibeam. Furthermore, during the box core stations a detailed characterization of the seabed was needed that required the multibeam and the EK80 to run in parallel. However, these activities were limited in time and caused only minor loss of temporal resolution or interference issues.

EK80 disturbances

During the SAS-Oden expedition it was difficult to obtain high-quality acoustic EK80 recordings due to disturbances by noise. This observation was similar to experiences with the same EK80 equipment on previous expeditions (e.g., the Ryder expedition with IB Oden in 2019) when the shipborne noise substantially impacted the quality of the data (**Figure 8**).

From a general overview of the data from the entire SAS-Oden expedition, it was estimated that the usable portion of the dataset is ca. 42%. Ice-breaking was the major disturbance and generated almost no usable data. When the engines were turned off and the ship was drifting with the ice there were other sources of noise. A regular noise that significantly disturbed data collection was that from a steam hammer in the ship's fuel heating system. This noise was in the form of irregular stripes becoming stronger with depth that were especially amplified by the time-varied gain. There was also a reoccurring temporary elevated broadband background noise that was potentially caused by power usage. Although continuous communication was sustained with the ship's crew, and generally ad-hoc solutions were found for temporary improvements, noise remained to be a perturbation of the data quality.

In addition to acoustic noise there was a failure in the EK80 software that caused data loss a few times. Our understanding of the origin of this problem was that a bug in the software caused recording failure in a random fashion when user settings had been switched. Normally, there were two main settings that were being alternated (EFICA and Geophysical Mapping). In order to prevent operator-related errors due to alternation of settings (e.g., mistyping parameters, forgotten changes), pre-defined user setting files were generated and used to for importing exact settings. This is an EK80 functionality used commonly for this purpose. However, in a few instances this caused the recording to stop without notice. This was a deceptive problem as the recording alert falsely indicates that recording was ongoing. The data loss caused by this error mostly coincided with transit periods. Furthermore, thanks to generated screen shots of these periods, a detailed representation for the lost section is stored as jpeg images. These cases occurred partially on 14 August, 16-19 August and 28 August. Post-inspection of the images indicated that these data losses would not result in noticeable gaps for the biological observations from the EFICA perspective.

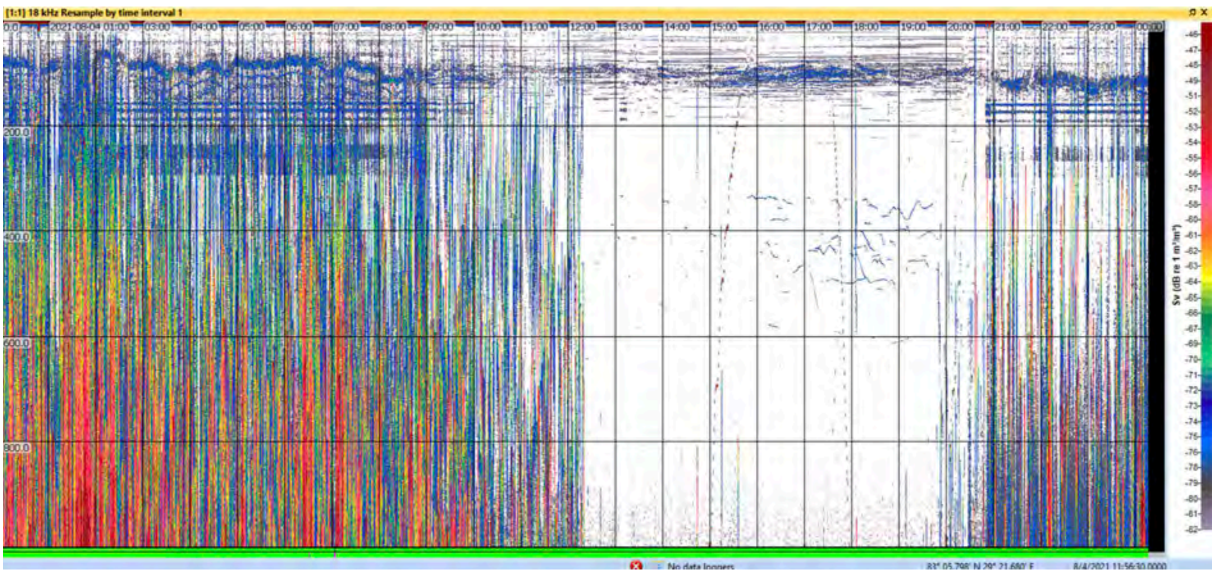

Figure 8: Echogram showing that it was possible to obtain high-quality recordings during the SAS-Oden expedition. Gaps in the data occur due to different sources of noise as shown in this 24-hour echogram from 4 August 2021 when 35% of the data is of usable quality.

EK80 additional EFICA measurements without disturbances

Higher acoustic target density was expected between Stations 50 and 59 when the SAS-Oden expedition crossed the Atlantic water inflow region to the CAO. This expectation was based on the observation of high fish density near the Yermak Plateau during the MOSAiC expedition. A special setting was used to maximize the ping rate during this part of the expedition track by decreasing the recording range to 800 m (instead of 1200 m). This track partially coincided with open water conditions, which enabled collection of usable data. The ship was instructed to stop for 10 minutes every six hours between Stations 50 and 53, every three hours between Stations 53 and 58, and every hour along the slope of the Yermak Plateau (**Figure 9**). During these EFICA stops it was possible to collect relatively clean data to assess the density of the DSL.

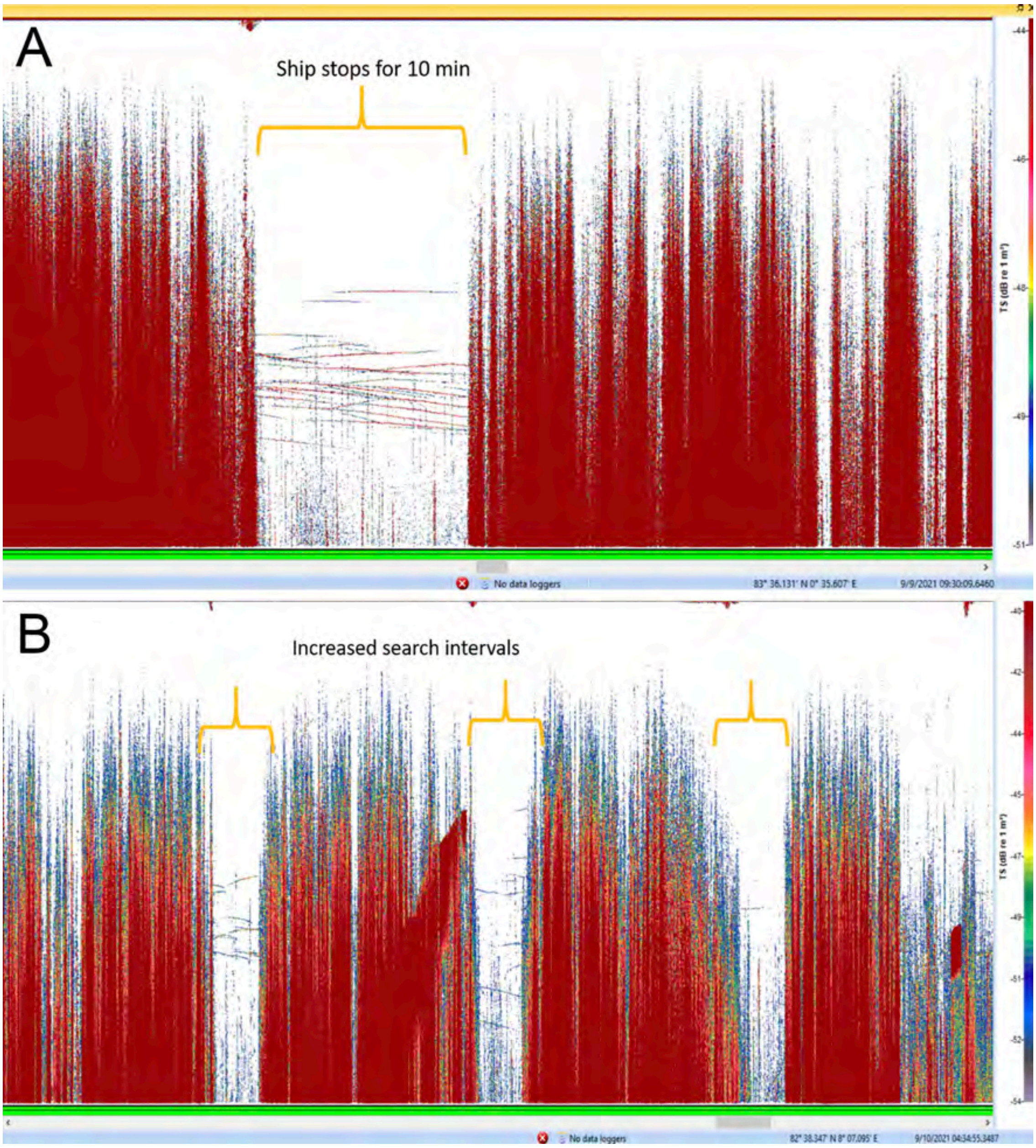

Figure 9: Echograms of the ship's EFICA stops between Stations 50 and 59 (A) A 10-minute stop showing single targets receiving multiple hits as (nearly) horizontal lines. (B) Three 10-minute stops along the slope of the Yermak plateau on 10 September 2021 between 3 am and 6 am UTC (lower panel).

EK80 targets actively avoided sampling devices

Throughout the SAS-Oden expedition we regularly observed that targets resembling fish actively avoided the sampling devices that were lowered into the water column with winches (**Figure 10**). These observations suggest that the targets were actively swimming organisms that were able to change direction very fast.

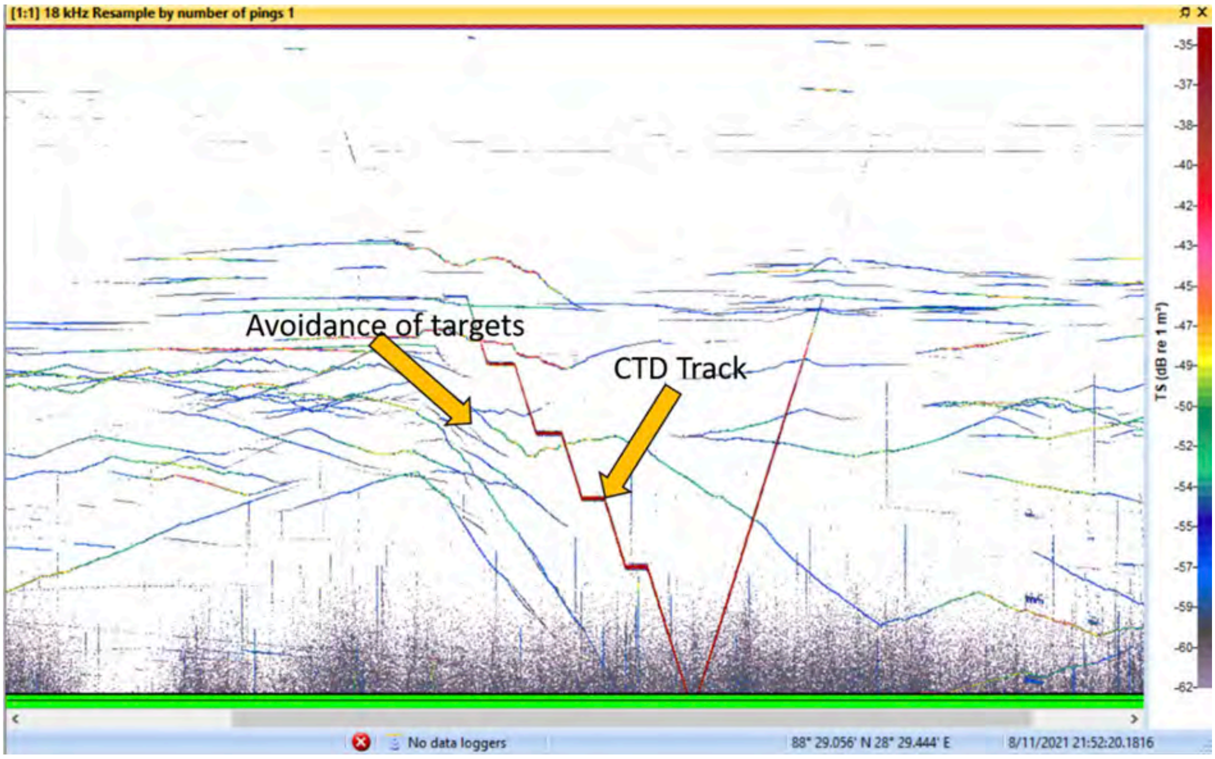

Figure 10: Targets clearly avoiding the CTD rosette.

6.2 Acoustic measurements with WBAT

6.2.1 WBAT equipment

Two of the EFICA Consortium partner institutes (SU and SLU) had each provided a Simrad™ Wideband Autonomous Transceiver (WBAT) system for the EFICA acoustic measurements during the SAS-Oden expedition. Each WBATs was equipped with two split-beam transducers (SU 38 and 333 kHz, SLU 38 and 200 kHz). The SU WBAT was mounted on the CTD rosette operated from the stern for continuously profiling at 0-1000 m depth). The SLU WBAT was designated to opportunistic deployments to collect drifting time series at 24-hour ice stations.

After the first deployment of the SLU WBAT, following an on-ice calibration, the SLU WBAT was severely damaged due to a power surge. Upon visual inspection of the circuit board, significant electrical damage was observed. For the remainder of the expedition, the SU WBAT became the main instrument, and data collection effort were adjusted (doubled) to meet the overall scientific objectives of SC06. This instrument is hereafter referred to as the "CTD WBAT".

The CTD WBAT was equipped with two split-beam transducers with the center frequencies of 38 kHz (ES38-18DK) and 333 kHz (ES333-7CD) (**Figure 11**). Two discrete cast types were used (**Figure 12**) down to a max. depth of 1000 m, typically alternating between each frequency.

First, the downward-facing 38 kHz transducer was configured with an observation range of 200 m. During CTD casts using this transducer, the CTD rosette was stopped at discrete depths to collect approximately 3 minutes of data (180 pings). The 333 kHz transducer was mounted facing sideward and was configured with an observation range of 50 m. These profile types were collected during continuous lowering of the CTD rosette. In both cases, the primary focus of data collection was on the downcast of the CTD rosette. After each sampling station, the WBAT was rinsed with freshwater, carefully dried and all data was copied from the internal memory.

The two frequencies (38 and 333 kHz) were used alternating between the casts with the aim to obtain at least one full profile per frequency per station. Starting with Station 22 (15 August 2021), a video camera with a red light source was coupled with one specific cast at each station (corresponding to 38 kHz). In addition, when sufficient time was available, additional CTD casts were performed opportunistically. These casts with different configurations were identified as follows:

Bio CTD: 38 kHz stops every 100 m for 3 min periods during down cast, a video camera attached for continuous recording.
Omics CTD: 333kHz without any stop during down cast and no video camera
WBAT CTD: Opportunistic 38 kHz with stops similar to Bio CTD but without video camera

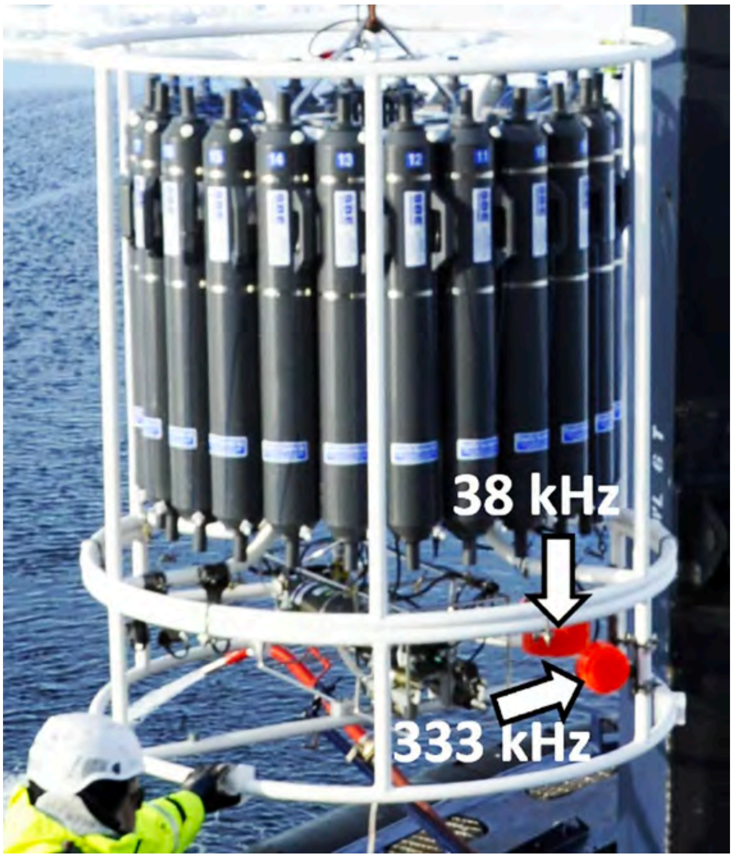

Figure 11: Photograph of the CTD WBAT on the SAS-Oden CTD operated from the stern (max. Depth 1000 m) below the Niskin bottles, with arrows showing the 28 KHz and 333 kHz transducers. © **SPRS**

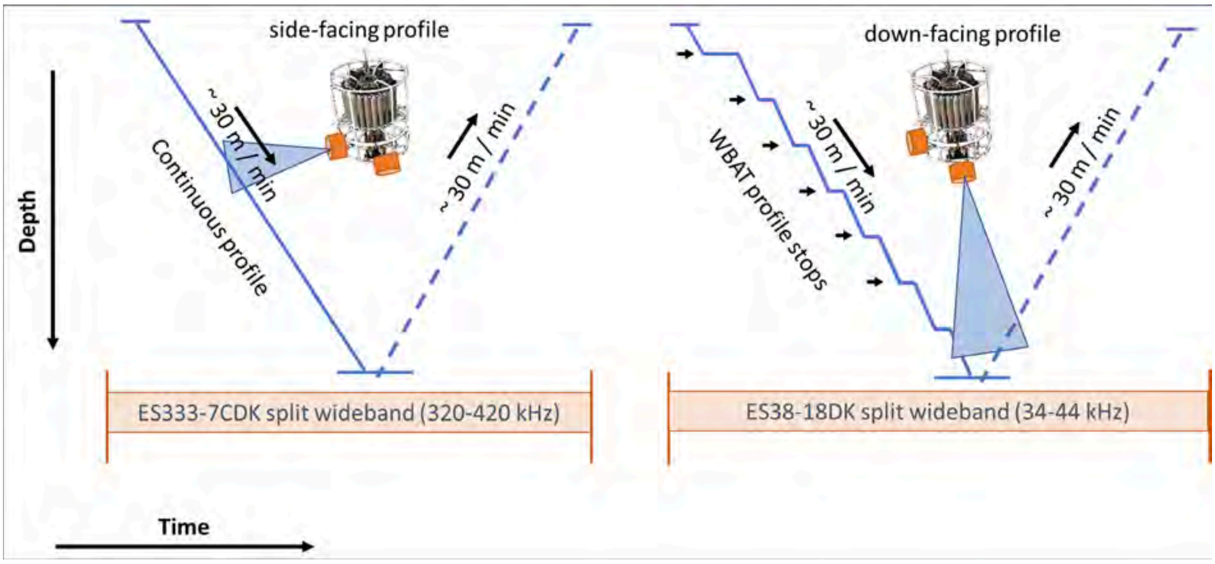

Figure 12: The two CTD WBAT deployment configurations (38 and 333 kHz). Data collection was primarily focused on the downcast, as upcasts (heaving) resulted in some bubble artefacts and occasional stops to fire Niskin bottles for water collection.

6.2.2 WBAT calibration

In order to calibrate the four transducers (two ES38-18CDKsplits, one ES200-7DKsplit, and one ES333-7CD split) of the two WBATs on the expedition, we performed two separate on-ice operations. Conditions on the expedition offered thick (1.5-2 m) and stable ice floe conditions which served as excellent platforms for establishing temporary ice camps for calibration. Prior to departure from the ship, the WBAT was mounted to a "Simrad stand" (**Figure 13**) designed as a stand-alone probe equipped with one WBAT tube and two split-beam transducers. The slim profile of this design was ideal for lowering the echosounder into a narrow 4-bore ice hole.

The calibration of the CTD WBAT was performed for the 38 kHz and 333 kHz transducers of the CTD WBAT at Station 58 on 10 September 2021 (9°14.351'E, 82°27.752'N) over ca. 1000 m water depth (**Figure 13**). The 38 kHz was calibrated in FM mode with the same acquisition parameters used for the regular deployments using a 38.1 mm tungsten carbide sphere that was hanging ca. 12 m below the transducer. Similarly, the calibration of the 333 kHz was performed with a 22 mm tungsten carbide sphere. In both cases a satisfactory coverage of the center axis and 3 dB beam coverage was achieved. The entire operation took 1 hours and 5 minutes between leaving and returning to the ship from the ship.

The calibration of the SLU WBAT took place using helicopter transport to a nearby (~1.5 km) ice floe at Station 4 on 3 August 2021 (30°22.17'E, 82°1.512'N) over 3226 m water depth. The entire operation took 4 hours and 40 mins between helicopter take-off and landing from the ship. The weather was clear and sunny skies, air temperature was ~0 °C, wind was less than 8 m s^{-1} and ice drift speed was below 0.5 nm h^{-1}.

Figure 13: Calibration of the CTD WBAT used during the SAS-Oden expedition. (A) Preparing the WBAT for calibration on the ice at Station 58 (B) Manoeuvring the calibration spheres (A,B) © Serdar Sakinan

6.2.3 WBAT standard settings

Data acquisition of the WBAT was carried out using pre-programmed commands ("mission plans") that were uploaded to the instrument prior to deployment. A Simrad pressure switch was used to automatically initiate these mission plans soon after the WBAT had been submerged (at ca. 4 m depth), which also stops the data acquisition as soon as the WBAT is close to the surface (back to ca. 4 m). After a few tests at the first two stations, a standard mission plan for each frequency (**Table 6**) was used consistently during the rest of the expedition.

Table 6: Mission plans for the two transducers of the CTD WBAT during the SAS-Oden expedition.

Transducer	Ping interval (seconds)	Range (m)	Power	Start frequency (kHz)	End frequency (kHz)	Pulse length (milli seconds)
333 kHz	0.6	50	Max	320	420	2.086
38 kHz	1	200	Max	35	44	2.086

6.2.4 WBAT metadata summary

Out of 49 CTD deployments with the CTD WBAT, 45 were successful. Of these, 32 cast used the 38 kHz transducer and 13 casts used the 333 kHz transducer (**Table 6**).

In general, we observed a high signal-to-noise ratio with both transducers. With the 38 kHz we clearly observed discrete gas-bearing targets on the echograms with an exceptionally high number of target measurements per individual (90-150 pings) (**Figure 14**). With the 333 kHz, we obtained relatively noise-free water column profiles with excellent target resolution.

Table 7: Metadata for the CTD WBAT during the SAS-Oden expedition.

CTD casts	Number of casts	Number of successful casts	Average recording time (minutes)	38 kHz transducer	333 kHz transducer
Bio CTD	18	17	100.7	15	2
Omics CTD	17	15	71.3	4	11
WBAT CTD	14	13	84.7	13	0
Total	**49**	**45**		**32**	**13**

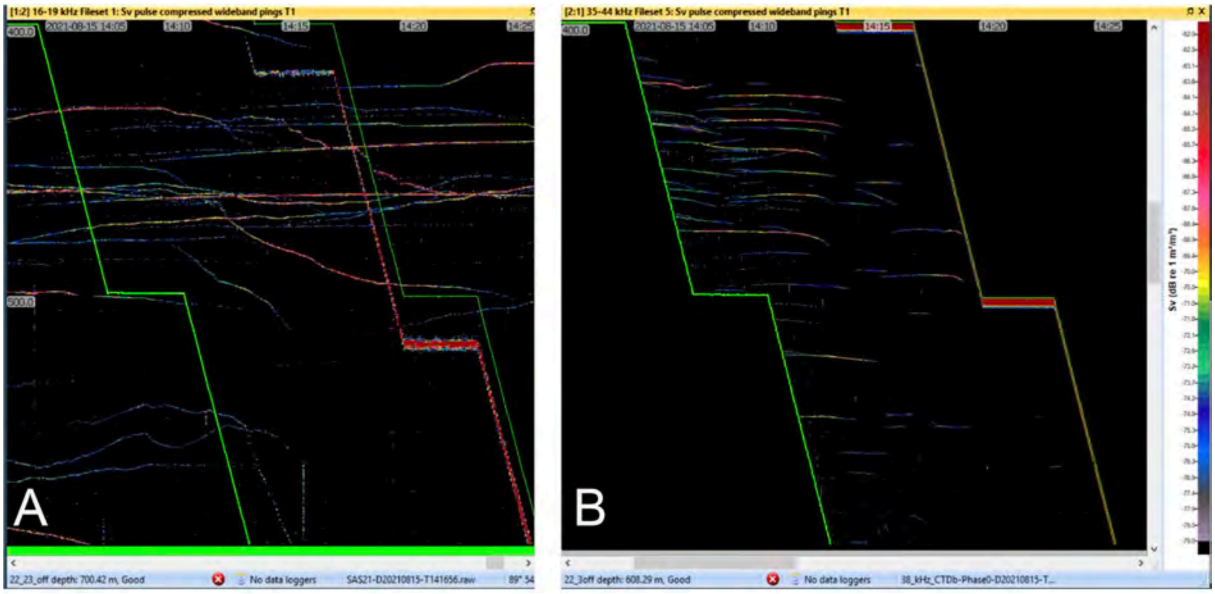

Figure 14: Comparison between the EK80 and the CTD WBAT of overlapping sections over the depth range 400-600 m at Station 22. (A) EK80 recordings. (B) WBAT recordings.

6.2.5 WBAT considerations – CTD WBAT

A few details are worthwhile mentioning regarding data quality issues and challenges. A challenge was interference by the echoes due to reflections from the sea surface/ice in the 38 kHz data. To our understanding, this issue should be related to the lack of proper dampening of the top part of the 38 kHz transducer which caused sound transmission leaks towards the opposite direction of the main beam. This caused perturbed sections in the data at a range equal to the distance between the transducer and the surface (**Figure 15**). The effect of this perturbation was minor in the CTD WBAT and disappeared as soon as the WBAT reached 200 m of depth. However, for similar applications in the future, it is recommended to better insulate the top part of the transducer to prevent such sound leakage and undesirable echoes.

False bottom reflections were noted at a few stations where the seafloor depth was shallower than 2000 m and this affected a small portion of the data. This is an unavoidable problem as there is no possibility to interactively alter the ping rate to prevent false bottom echoes.

Another issue was related to unpredictable movements of the CTD rosette. Since the transducer was attached to the frame of the CTD, it was affected by its motions such as tilt and rotation. This complicates interpretation of individual targets. During the last five casts a magnetometer (IMP) that measures the tilt, acceleration and azimuth was attached to the CTD rosette to understand the CTD motion and to correct single target position data.

Mechanical noise from the ship had some minor effects on the CTD WBAT data when the CTD rosette was close to the surface. This effect was negligible below 200 m of depth. During the deployments, the EK80 was kept pinging with the aim to collect data simultaneously with both instruments. This caused some interference spikes in the WBAT recordings. Some preliminary postprocessing trials shown that these spikes can be cleaned in a relatively straightforward way and the effect on the data quality is very minor.

Some technical issues were experienced in the beginning of the expedition during the four casts that failed to collect WBAT data. The first problem was the consumption of the rechargeable battery much faster than expected. This high battery consumption was probably related to the low water temperature of the Arctic Ocean. To remedy this, the rechargeable battery was replaced with a long-life battery, and the problem never occurred again during the expedition.

The second technical problem that appeared in the beginning of the expedition was related to an extension cable that connects the pressure switch to the WBAT. The pressure switch was used to automatically start and stop a mission plan based on the depth (at ca. 4 m below the surface). For an unexplainable reason, the pressure switch sent stop commands to 38 kHz missions at unpredictable times, which caused loss of data acquisition of two CTD casts. This problem was solved by removing the extension cable and connecting the pressure switch directly to the WBAT.

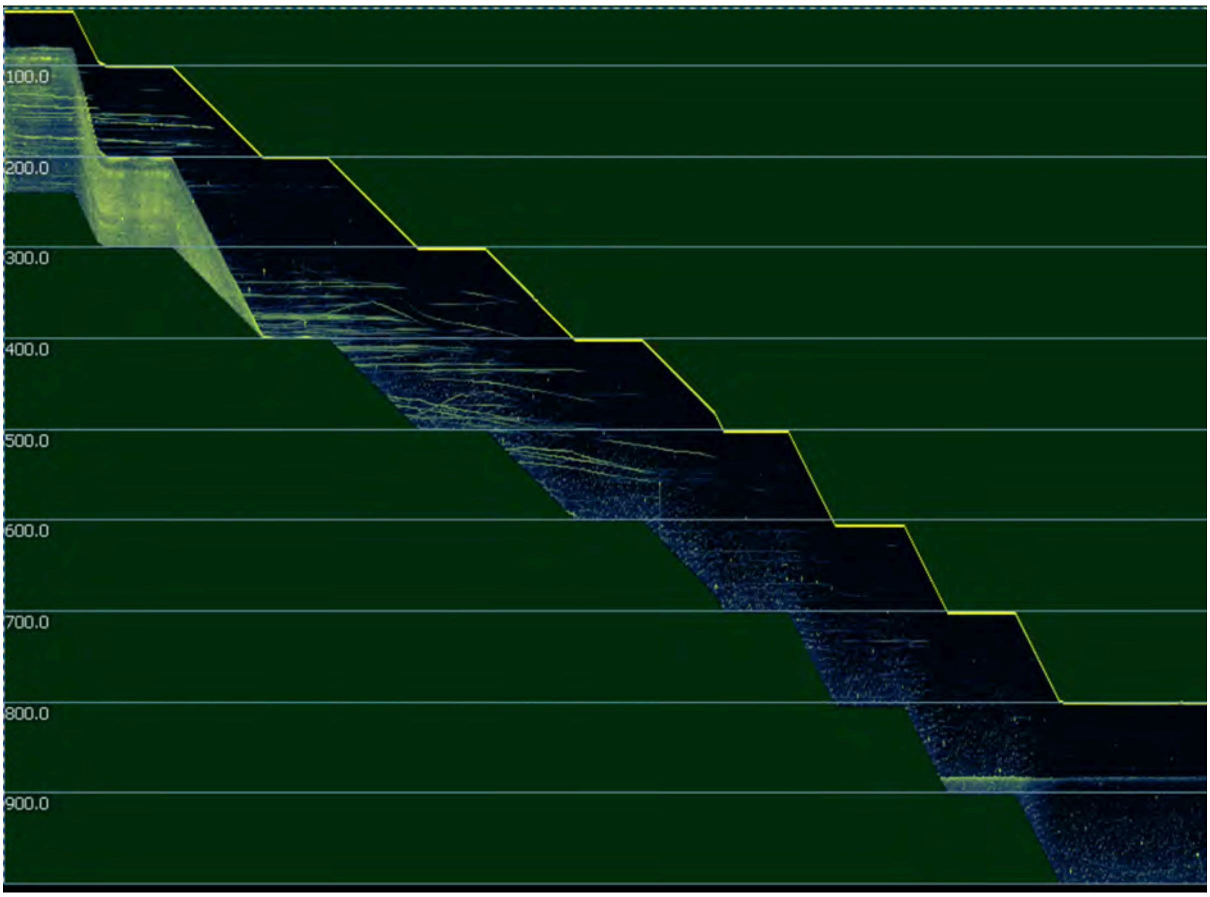

Figure 15: A full downcast profile with the CTD WBAT, 38 kHz. The perturbations due to surface reflection are visible until the WBAT reaches down to 200 m. The zig-zag pattern in the data is due to 3 min stops every 100 m for pinging.

6.2.6 WBAT considerations – SLU WBAT

Although data acquisition with the SLU WBAT, that was intended for deployment from the ice, started with a very successful *in situ* calibration, further data collection could not be carried out as planned due to an early failure of the instrument after a successful deployment from the ice.

The failure occurred when the WBAT was recovered from the ice followed by disconnection of transducer cables for helicopter transport. Once on the ship, we had some trouble communicating with the WBAT, but after several trials we once again established a connection and tried a test mission plan. However, this mission plan generated no .raw files.

The last available file was an empty file generated approximately 20 minutes after ice recovery, presumably while the WBAT was still operating a mission. Unable to receive a mission plan to initialize, we decided to have a look at the internals to possibly identify the problem. On the transceiver portion, we found brown material on the motherboard with 2-3 bulged circuits and one that was visibly broken on one end of the solder. This observation was accompanied by a strong smell of a burned circuity. We very gently touched the black piece of the circuit and it crumbled as if burned. After that, we were unable to communicate with the WBAT and transceiver.

According to the feedback we received from the technical service of the Simrad, the problem was related to the power transistors with its surrounding components in the transmitter of one of the four channels. We were informed that this was one of the most critical parts of the design and there was no way of repairing this in the field. Therefore, we were advised against further use of this instrument until the damaged board has been replaced.

The single ice deployment of the SLU WBAT was at Station 8 on 7-8 August 2021 (**Figure 16**). The total data acquisition time was ca. 26 hours. The WBAT was lowered to 150 m with a rope and recorded a range down to 500 m under the 38 kHz transducer and 300 m under the 200 kHz. The system was used in multiplexing mode allowing for pinging of each set with intervals of ca. 11 seconds. A surface reflection layer appeared for both frequencies at 150 m below the transducer which is the same distance to the surface from the transducer. Within the clean region down to this depth (from 150 m to 300 m of the water column) some clear detections of single targets were observed.

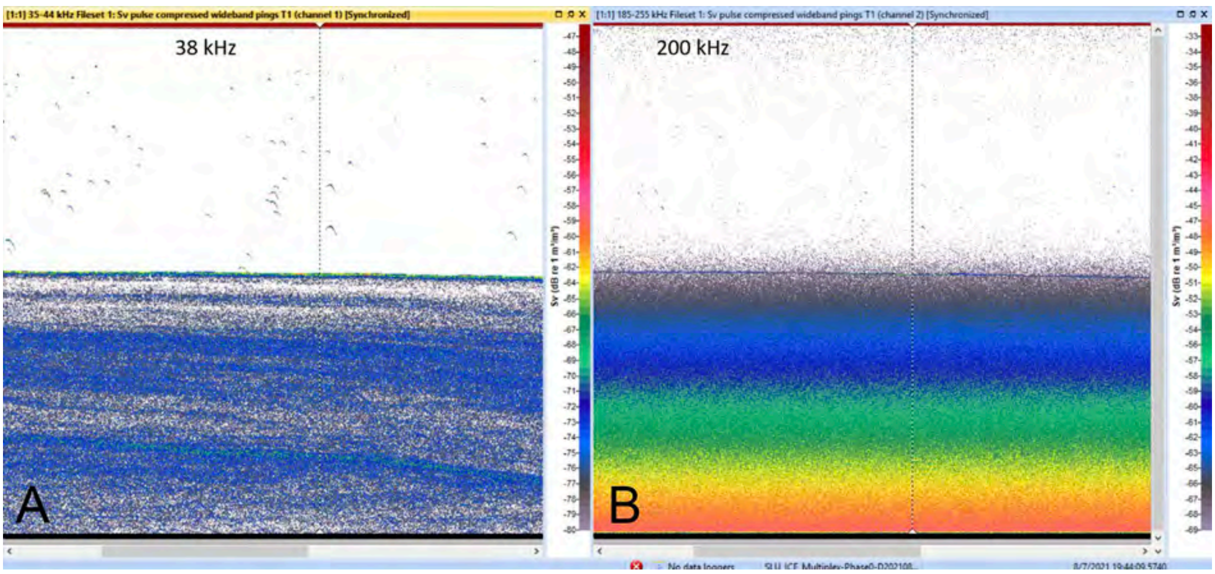

Figure 16: Example of results from the SLU WBAT deployment from the ice at Station 8 of the SAS-Oden expedition. (A) 38 kHz transducer. (B) 200 kHz transducer.

6.3 Video recordings targeting fish and zooplankton

6.3.1 FishCam equipment

During the MOSAiC expedition (SC03), we used a custom-built deep-sea camera system (FishCam) that was installed under the ice for many months and connected by electricity and fibre-optical cables to the ship. This FishCam took several days to deploy and several days to retrieve.

It was not possible to use the MOSAiC FishCam for the SAS-Oden expedition because the ship moved between sampling stations as fast as possible. Therefore, EFICA used three smaller stand-alone camera systems "Mini FishCams" consisting of custom-programmable small camera (go-flo, GitUp 2 action camera) and a custom-programmable LED light (Nautilux, white light, 1500 lumens), each with one 12 V battery. All equipment was mounted in water-tight housing that could be deployed down to 1750 m of depth. For programming and memory card and battery maintenance the system needed to be opened.

One of the Mini FishCam equipments was sideward-facing and used for shallow deployments (0-5 m) under the ice (**Figure 17**). Another one was downward-facing and used for deep deployments (300-400 m) under the ice. The latter system had two battery compartments for the camera and two for the LED light so that 24 hours deployment would be possible. The third Mini FishCam mostly had red light and was mounted on the CTD that stopped every 100 m for 3 minutes when the CTD went down. During continuous CTD deployment (1 m s^{-1}), no living organisms could be distinguished on the video recordings because of the high speed of the winch in relation to the resolution of frames per second of the camera.

Figure 17: The Mini FishCam used during the SAS-Oden expedition. (A) Sideward-facing Mini FishCam on its stainless steel frame with the two battery tubes under the camera and the LED light above the camera. (B) Downward-facing Mini FishCam: camera and programming unit housing below the battery housing tube. (C) Downward-facing Mini FishCam: connection programming unit to the left and connection battery unit to the right. (A,B,C) © Pauline Snoeijs-Leijonmalm

6.3.2 FishCam calibration

On 3, 5 and 6 September a ruler was attached to the camera system, which showed that organisms could be seen in red light within ca. 0.8 m from the camera lens, but not beyond this limit (**Figure 18**).

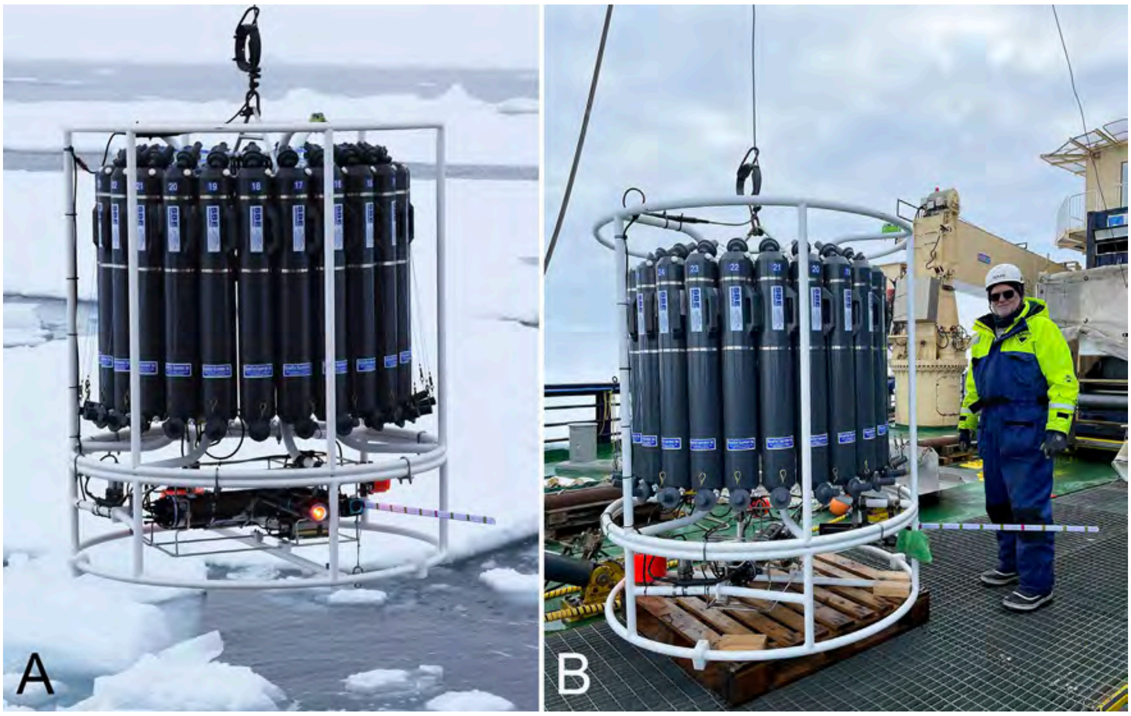

Figure 18: CTD FishCam calibration using a ruler of 100 cm length. (A) Mini FishCam with red light on the CTD (together with the CTD WBAT). (B) Calibration of the Mini FishCam sight field on the CTD with a ruler. (A) © Hans-Jørgen Hansen, (B) © Pauline Snoeijs-Leijonmalm

6.3.3 FishCam standard settings

After each deployment, the Mini FishCam was programmed and prepared with new batteries, a formatted memory card, new tightening rings and silicone grease in a warm room (ca. 20 °C), but needed to be opened in the CTD container and on the ice to connect the batteries (**Figure 17C**). The conditions on the ice were ca. 0 to -5 °C.

6.3.4 FishCam metadata summary

Altogether, we were able to make successful video recordings during 15 CTD deployments from the stern and at three ice stations (ca. 2 m under the ice). The total recording time was 4200 minutes (70 hours) and the data consist of 178 video files of altogether 717 GB (**Table 8**). The images were not of the same high quality as those on the MOSAiC FishCam, but it is possible to recognise zooplankton taxonomic groups by their shapes and behaviour (movements) (**Figure 19**). The community composition observed was similar to that caught by the beam net.

Table 8: Metadata for the FishCam video recordings made during the SAS-Oden expedition.

Date	Station number	FishCam deployment	Light colour	Recording time (minutes)	Number of video files	Total data size (GB)
11-Aug	14	WBAT CTD	red	106	5	18.23
12-Aug	16	Omics CTD	white	133	6	23.33
12-Aug	16	Bio CTD	white	170	7	29.72
13-Aug	18	Bio CTD	red	144	6	24.88
16-Aug	22	Bio CTD	red	133	6	23.38
19-Aug	26	Bio CTD	red	156	7	27.14
23-Aug	30	Bio CTD	red	140	6	24.12
25-Aug	33	Bio CTD	red	125	5	21.45
27-Aug	35	Bio CTD	red	154	7	26.63
29-Aug	38	Bio CTD	red	128	6	22.00
03-Sep	48	Bio CTD	red	132	6	22.87
05-Sep	50	Bio CTD	red	113	5	18.86
06-Sep	53	Bio CTD	red	118	5	20.38
08-Sep	56	Bio CTD	red	146	6	25.32
11-Sep	58	Bio CTD	red	159	7	27.28
13-Aug	18	ca. 2 m under ice	white	351	16	60.30
16-Aug	22	ca. 2 m under ice	white	300	12	51.48
19-Aug	26	ca. 2 m under ice	white	1492	60	250.07
Total				**4200**	**178**	**717.44**

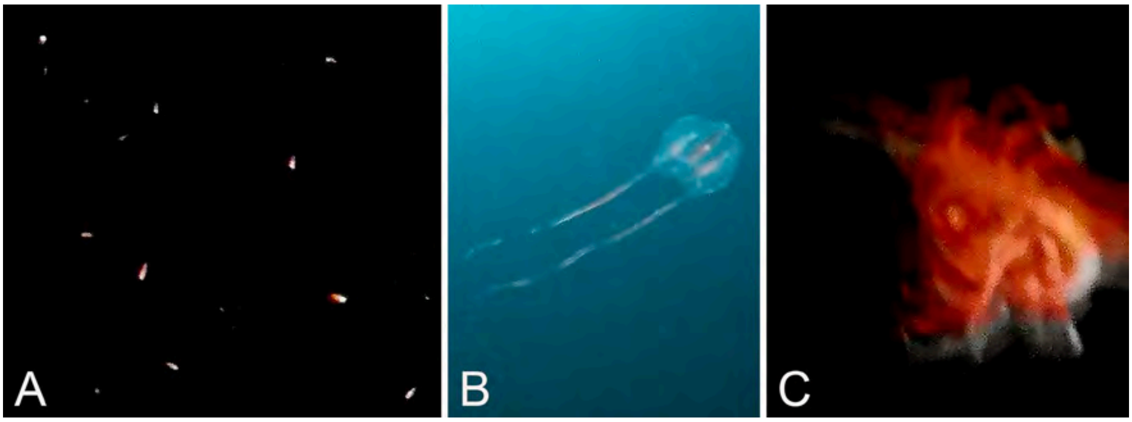

Figure 19: Screen captures from video recordings of macrozooplankton made with the FishCam. (A) Amphipods. (B) *Mertensia* sp. (jellyfish). (C) Jellyfish.

6.3.5 FishCam considerations

Unfortunately, the FishCam that was deployed from the ice in the DSL was destroyed during the first deployment by leakage that was caused by delivery of a too short screw by the manufacturer, which caused loss of data from the DSL that would have complemented the data from the CTD-mounted camera system. The FishCam that was deployed from the ice ca. 2 m under the ice did not work after 19 August because the connection cable between battery and camera was compromised. Using a FishCam immediately under the ice was not planned for the expedition, and the loss of this camera system did not affect the planned data collection within SC06.

The FishCam on the CTD worked well throughout the expedition, but it was not a suitable instrument for practical field use in the Arctic Ocean because it had to be opened under heavy field conditions to connect the batteries. This was a sensitive moment and yielded some failures. There was always the risk of water leakage into the housing. Even if the housing was guaranteed until a depth of 1750 m, it was very difficult (screwing by hand) and time-consuming to prepare the FishCam for being water-tight before deployment.

6.4 UVP optical zooplankton and particle recordings

6.4.1 UVP equipment

The Underwater Vision Profiler 6 (HD)[22], owned by EFICA partner SU (Serial number 00126), is an optical instrument used for capturing images of particles ranging from ~50 to 2000 µm. Particles can include phytodetrital aggregates, suspended sediment, and zooplankton. The instrument was delivered as a prototype by Hydroptic. Due to production setbacks, the instrument was not field tested nor ready for deployment until approximately one week into sampling.

The instrument was installed on the rosette frame of the CTD operated from the bow with the fore-deck winch (operated to full depth, i.e., to max. ca. 4350 m during the SAS-Oden expedition). The UVP was operated autonomously during each of the ship's CTD casts from the bow. To run autonomously, each profile requires a basic "rinsing" sequence, whereby the rosette is lowered to 15 m depth to initiate the instrument and then raised to 2 m depth before conducting a full water column profile. Once the rosette is heaved 30 m, the instrument shuts off to ensure that data is only collected during the down cast. The instrument was maintained alongside other rosette instruments using standard procedures (i.e., rinsing, charging, lubricating connections, etc.).

6.4.2 UVP standard settings

The UVP arrived with an incorrect manual. It did not run unless you exactly follow the UVP6-HF_CTD_user_manual_mini.pdf instructions, which were provided only once we were underway and past our first sampling stations. This means that the UVP is not piloted using the UVPapp, but the OctOS.exe command line software. The UVP was already setup to run in CTD mode and these settings were not changed prior to deployment.

The UVP box did not contain important instructions on how to connect the battery. These instructions arrived only on 7 August 7 2021: "You need to pull the orange thread in order to remove the titanium cap. Then connect the molex connector...". We pulled the orange thread but was not able to push it back in all the way after connecting the molex connector below the titanium cap. I considered this to not be a risk to the battery.

After getting the UVP powered, there were no problems communicating with the instrument. The static IP address on the laptop was set to the same IP address as seen in the manual: 193.49.112.130. Each time the UVP was plugged into the battery via red cable, it flashed three times indicating that it was in stand-by mode. The CTD operators charged the battery in-between each cast. Due to some long back-to-back casts, we lost some data at the end of casts, when presumably the battery died. The battery life is approximately 10 hours.

Upon installation on the rosette, we discovered that the manufacturer made holes in the frame on the wrong plane of the bracket (x *vs* y). We fixed this by drilling new holes in the steel arm. It fitted on the rosette without any interference with the ADCP or Niskin bottles.

[22] Picheral M, et al. (2021) The Underwater Vision Profiler 6: an imaging sensor of particle size spectra and plankton, for autonomous and cabled platforms. Limnol. Oceanogr.: Methods, 15 pp. [http://doi.org/10.1002/lom3.10475]

We followed the instructions to lubricate connections during each connection to the UVP. CTD operators confirmed that they followed these instructions. However, there was some obvious corrosion occurring on the red connector to the UVP. One of the pins was corroding faster than the others. This connector was cleaned as often as possible using Lectra clean solution and the connection was relubricated. Nonetheless, by the end of the expedition, the red connection side of the y-cable appeared heavily corroded. During data processing it was noticed that some of the later casts had power failures with resets in the middle of casts. In order to process these casts, merging of sequences is required to create single samples.

6.4.3 UVP metadata summary

With the exclusion of shallow casts (<50 m), 54 UVP profiles were collected, including shallow CTD casts (50-250 m), deep CTD casts (full water column profiles), and VACAO CTD casts (full water column profiles). Each full water-column profile consists of approximately 50,000-100,000 particle images. Apart from six profiles requiring manual merging, likely caused by power failures, the remainder of profiles were prepared on-board for cruise post-processing using the EcoTaxa software and database.

After the expedition, the data were uploaded to the EcoTaxa software (https://ecotaxa.obs-vlfr.fr) where each image will be measured using a multi-dimensional feature space (~50 image features). Features used for image analysis include object size, perimeter, thickness, elongation, equivalent spherical distance (ESD), entropy, etc. A database file (.tsv) was created for each profile and can be used for subsequent analyses. The images of 47 out of 54 UVP profiles could be uploaded and particle data of the all 54 profiles were imported in EcoPart (**Figure 20**). According to the first preliminary tests, 43 complete and reliable vertical profiles and five time series exist, showing very little detritus but abundant plankton. The images are impressive with a variety of zooplankton organisms (**Figure 21**), strong stratification and very nice images.

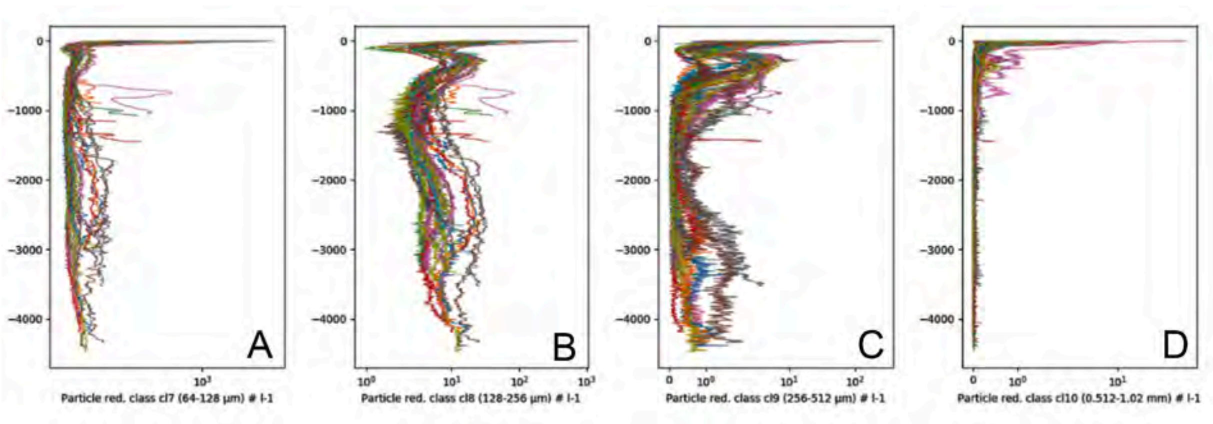

Figure 20: Preliminary UVP particle profiles in four different size classes from the North Pole area measured during the SAS-Oden expedition. (A) 64-128 µm. (B) 128-256 µm. (C) 256-512 µm. (D) 512-1020 µm.

A number of graphical or code-based image classification options for analysis are available, however EcoTaxa hosts a number of publicly available classification models based on previously validated samples in Arctic regions (e.g., GreenEdge expedition in 2016). Individual profiles or entire projects can be predicted using these models. Projects can be predicted and validated repeatedly to improve results. A small number of particles (~1%) will be allocated to custom or pre-defined taxonomic categories such as "copepod-like", "amphipod", "chaetognath", etc.

Particle profiles can be used to measure particle abundance and size distribution across the geographical region of study. These can be customized to select specific particle types and investigate specific portions of the water column (epipelagic, mesopelagic, bathypelagic).

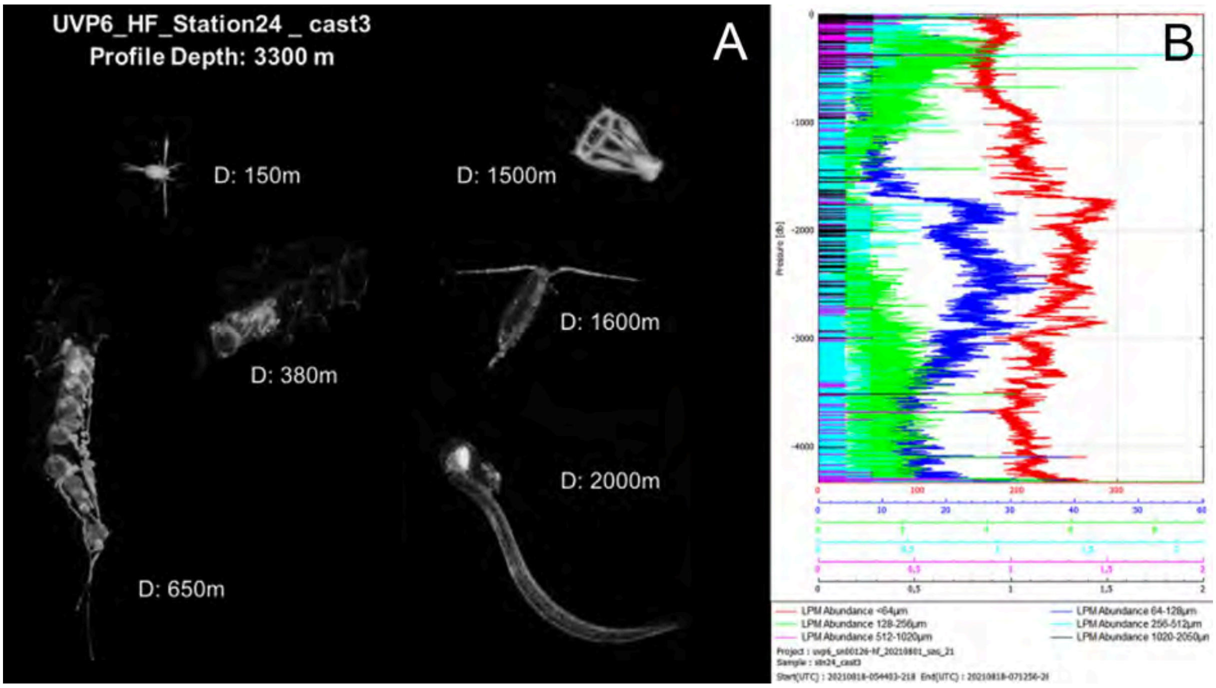

Figure 21: Examples of output from the UVP at Station 24 of the SAS-Oden expedition. (A) Images of zooplankton. (B) Particle profiles.

6.4.4 UVP considerations

Do not send the UVP out on expedition until it has been inspected for corrosion-related problems. During the last eight casts of the SAS-Oden expedition, five had power supply problems on the way down. An inspection is required at the manufacturer of the UVP (Hydroptic), they need to upgrade the firmware and replace the lights. Neither are tested and may not be available until early 2022. Please contact Hydroptic for customs and shipping information.

Have Hydroptic send a spare y-cable and a spare charging cable in case one gets damaged. These types of cables are very complicated to assess for damage and likely impossible to repair on the ship.

Request the proper documentation from Hydroptic to run the UVP. We lost some precious sampling time due to careless packaging and incorrect manuals.

6.5 LOKI optical zooplankton recordings

6.5.1 LOKI equipment

The Lightframe On-sight Key species Investigation system[23] (LOKI), manufactured by iSiTEC, Germany (**Figure 22**), is a plankton recorder that provides high-resolution photographs (6.1 megapixels) of mesozooplankton organisms and particles taken directly in the water column during vertical hauls from 1000 m water depth to the surface (**Figure 23**). The photographs often allow the identification of genera/species or even (in copepods) developmental stages. A built-in image analysis automatically recognizes objects in the pictures and saves the respective vignettes for later analyses. In addition to the camera system, the LOKI carries sensors for measuring depth, salinity, temperature, oxygen concentration and fluorescence. This allows to study the small-scale zooplankton distribution patterns in relation to environmental conditions.

The LOKI was used with a winch speed of 0.5 m s^{-1}, and the standard sampling depth was 1000 m. LOKI was equipped with a 150 µm plankton net with a net opening of 0.28 m^2. A mesh with a mesh size of 1 cm covered the net opening to prevent larger animals from entering and clogging the system. A flow meter with back run stop was used to calculate the amount of filtered water. At the outflow of the net, within a narrow flow-through chamber, a 6.1 mpix digital camera took pictures at a max. frame rate of 19.8 pictures sec^{-1}. A built-in computer unit processed the pictures immediately by scanning them for objects, which were then cut out and stored on the internal hard drive. To simultaneously measure the environmental parameters, we mounted a Sea-Bird SBE19plus V2 SeaCAT Profiler CTD (Sea-Bird Electronics Inc., USA) to the side of the LOKI frame. The CTD was equipped with additional sensors for measuring oxygen and fluorescence. Pictures and environmental data can later be matched via a time stamp.

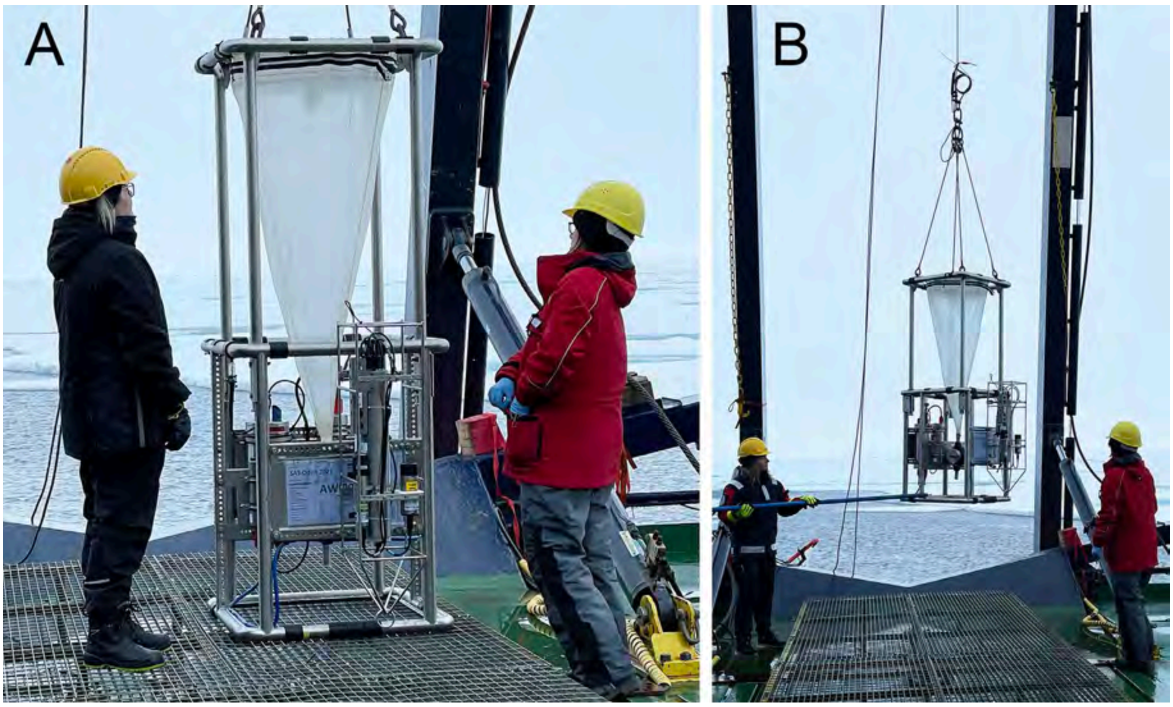

Figure 22: Deployment of the Lightframe On-sight Key species Investigation system (LOKI) during the SAS-Oden expedition. (A) Preparations on deck. (B) Winching the LOKI into the water. (A,B) © Pauline Snoeijs-Leijonmalm

[23] Schulz J, et al. (2009) Lightframe On-sight Key species Investigation (LOKI). IEEE OCEANS 2009-EUROPE [http://doi.org/10.1109/OCEANSE.2009.5278252]

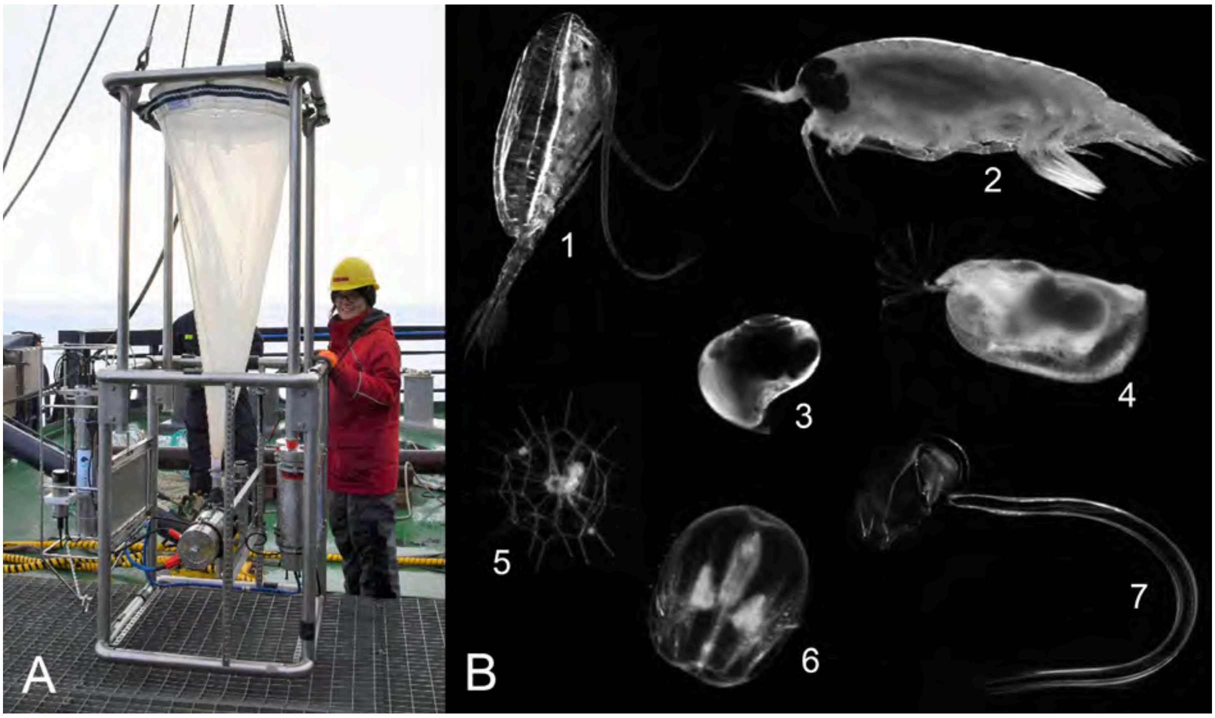

Figure 23: The Lightframe On-sight Key species Investigation system (LOKI) during the SAS-Oden expedition. (A) After retrieval during the SAS-Oden expedition. (B) Zooplankton images recorded with the LOKI. (1) *Calanus glacialis* (Copepoda), (2) *Cyclocaris guilelmi* (Amphipoda), (3) *Limacina helicina* (Gastropoda), (4) Ostracoda, (5) Radiolaria, (6) *Mertensia ovum* (Ctenophora), (7) *Oikopleura* sp. (Appendicularia). Images are not drawn to scale. (A) © Hans-Jørgen Hansen

6.5.2 LOKI metadata summary

The LOKI was deployed 11 times during the SAS-Oden expedition (**Table 9**). During the ca. 1-hour casts, 0-1000 m optical profiles were obtained and altogether 429,488 digital images were produced. At stations shallower than 1000 m the LOKI went to the deepest possible depth (Stations 50 and 53).

Table 9: Metadata for the 11 LOKI optical profiles made during the SAS-Oden expedition.

Device operation	Station number	Area	Date	Time UTC (start)	Time UTC (end)	Time in water (hh:mm)	Max. depth (m)
SO21_08-08	8	Gakkel Ridge	8-Aug	15:51	16:55	01:03	1000
SO21_22-04	22	North Pole	15-Aug	15:37	16:41	01:03	1000
SO21_26-07	26	Lomonosov Ridge	19-Aug	18:50	19:56	01:06	1000
SO21_30-14	30	Makarov Basin	23-Aug	15:54	16:58	01:03	1000
SO21_33-07	33	Makarov Basin	25-Aug	16:59	18:05	01:05	1000
SO21_35-10	35	Lomonosov Ridge	26-Aug	23:38	00:43	01:05	1000
SO21_38-10	38	Lomonosov Ridge	28-Aug	21:04	22:10	01:06	1000
SO21_42-04	42	Lomonosov Ridge	30-Aug	21:45	22:24	00:39	610
SO21_50-08	50	Greenland Shelf	4-Sept	21:16	22:13	00:57	860
SO21_53-02	53	Morris Jesup Plateau	5-Sept	21:22	22:20	00:57	970
SO21_58-14	58	Yermak Shelf Slope	11-Sept	04:50	05:54	01:04	1000

6.6 Mesopelagic longlines and trap lines targeting mesopelagic fish

6.6.1 Longlines and trap lines equipment

Longlines (**Figure 24**) and trap lines (**Figure 25**) targeting fish in the DSL were deployed at ice stations reached by helicopter. Ice thickness ranged between ca. 1 and 2 m. An auger (diameter 25 cm) was used to drill holes for each longline (one hole) and each deep trap line (four holes united, **Figure 25**). The holes for the deep trap line were cut to a rectangular opening with an ice saw. The preferred deployment time for both devices was 24 hours, however, shorter deployments were also performed whenever a time in the water of >4 hours could be realised. The time, date and geographical position were recorded at the start and end of each deployment (fully submerged and out of the water, respectively).

Figure 24: Deployment of longline. (A) Scientist carrying a 25-cm diameter auger used for making holes in the ice for the deployments during the SAS-Oden expedition. (B) A long line is hauled in with the help of a battery-driven winch on a tripod. (C) Hooks on a longline prepared for deployment. (D) Different hook sizes with artificial bait used for longline fishing. (E) The EFICA ice stations were reached by helicopter. (F) Line retrieval by hand-hauling. (A,B,C,D,E) © Frank Menger, (F) © Mats Persson

Figure 25: A deep trap line with six traps and a rectangular hole for deployment made by combining four 25-cm diameter auger holes in the ice. © Frank Menger

6.6.2 Longlines and trap lines standard settings

Longlines standard settings

Longlines were deployed between 300 and 700 m depth to sample fish from the DSL. A 5-kg bottom weight was attached to the long line, and true deployment depth was monitored using one or two Star Oddi TD probes (bottom or bottom and top of the longline, depending on Star Oddi probe availability).

Each longline had 150 hooks with 2.8 m spacing between hooks, and either squid, shrimp, herring or artificial bait was used to attract fish. Hooks were set up in a sequence of 15 defined hooks and the sequence was repeated ten times (**Figure 24, Table 10**). Three hooks with squid were followed by three hooks with shrimp and three hooks with herring as bait, followed by one squid hook and three hooks with different artificial bait, e.g., fluorescence or fly hooks, to test if this might attract the fish (**Figure 24**).

The hooks with natural bait consisted of one small, one medium and one large hook (**Table 10**). Longlines were retrieved either by line hauler or by hand-hauling (**Figure 24 F**) depending on weather conditions. Hand-hauling was the more controlled and, therefore preferred, but also the more strenuous retrieval method.

Table 10: Standard hook sequence for the longlines. S = small, M = medium, L = large.

	1	2	3	4	5	6	7	8	9	10	11-15
Hook	S	M	L	S	M	L	S	M	L	squid	S or M
Bait	squid	squid	squid	shrimp	shrimp	shrimp	herring	herring	herring	-	artificial

Trap lines standard settings

Four to six tubular traps (**Figure 25 and 26**) were attached to a line with 30 m spacing in-between them. After an initial trial phase of five deep trap lines to evaluate different setups during 7-19 August, a setup using six traps from 310 to 460 m was defined and deployed as a standard for the eight trap lines deployed after 19 August for the rest of the expedition.

The final standard trap line contained three traps with mushed bait (squid, shrimp and herring in equal amounts) and a white light source (Proglow superbright white) were deployed at 460, 400 and 340 m. These were alternated with traps with mushed bait and no light at 430, 370 and 310 m. A 5-kg bottom weight and 2.5-kg weights on each trap were used. A Star Oddi TD probe was attached to the lower end of the trap line to monitor its true deployment depth.

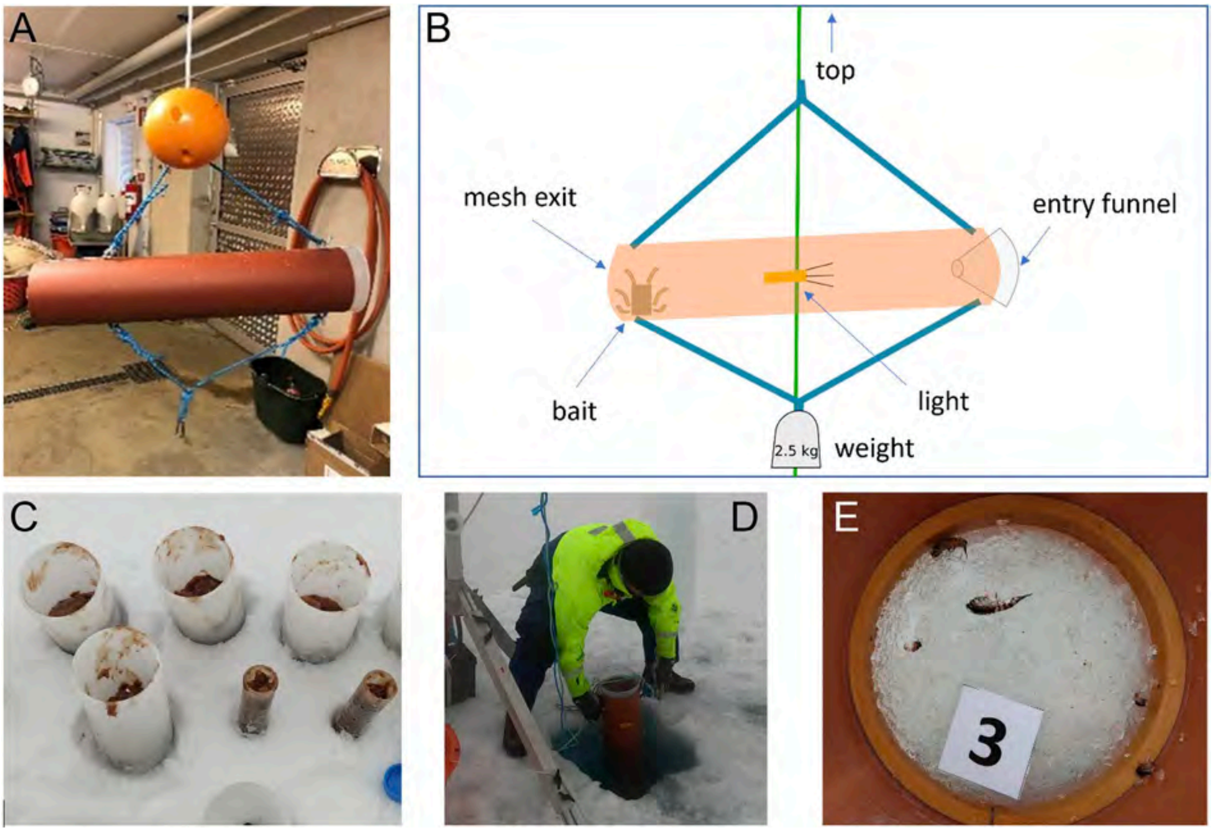

Figure 26: Design of the tube traps. (A) A hanging trap. (B) Schematic sketch of a hanging trap. (C) Filled bait containers for the traps. (D) Trap retrieval from the ice. (E) Example of trap catch. (A,D) © Baldvin Thorvaldsson, (C,E) © Frank Menger

6.6.3 Longlines and trap lines metadata summary

Altogether, 14 longlines (**Table 11**) and 13 trap lines (**Table 12**) were deployed at 14 ice stations. No pelagic fish were caught by using these methods throughout the entire expedition. This confirms the very low abundance of targets that could be fish as recorded by the EK80 and WBAT echosounders.

Deep traps with light sources repeatedly caught different types of zooplankton (amphipods and copepods), while traps without light did not. This confirms that light attracts these animals. Certain species were repeatedly caught at the same depth(s), e.g., *Cyclocaris guilelmi*. was only recorded in the deepest trap with light (at 460 m). The three traps that were aimed at catching fish (only bait, no light) did, like the other three traps with light, catch no fish.

Table 11: Metadata for the longlines deployed during the SAS-Oden expedition.

Device operation	Station number	Date (start)	Time UTC (start)	Date (end)	Time UTC (end)	Time in water (hh:mm)	Max. depth (m)
SO21_02-01	2	2-Aug	10:41	2-Aug	13:05	02:24	520
SO21_09-01	9	7-Aug	13:58	8-Aug	15:30	25:32	730
SO21_09-02	9	7-Aug	14:30	8-Aug	16:15	25:45	730
SO21_15-02	15	11-Aug	12:57	11-Aug	17:15	04:18	730
SO21_23-01	23	15-Aug	11:44	16-Aug	10:04	22:20	610
SO21_27-01	27	19-Aug	09:34	20-Aug	11:35	26:01	730
SO21_31-01	31	22-Aug	09:49	23-Aug	09:41	23:52	730
SO21_36-01	36	26-Aug	10:29	27-Aug	10:08	23:39	730
SO21_39-01	39	28-Aug	10:22	29-Aug	09:25	23:03	730
SO21_43-02	43	30-Aug	20:35	31-Aug	15:34	18:59	730
SO21_51-01	51	4-Sept	09:57	5-Sept	06:15	20:18	730
SO21_54-01	54	5-Sept	20:25	6-Sept	21:23	24:58	730
SO21_56-01	56	8-Sept	14:00	8-Sept	22:54	08:54	730

Table 12: Metadata for the trap lines deployed during the SAS-Oden expedition.

Device Operation	Station number	No of traps	Date (start)	Time UTC (start)	Date (end)	Time UTC (end)	Time in water (hh:mm)	Min. depth (m)	Max. depth (m)
SO21_09-03	9	4	7-Aug	15:00	8-Aug	17:00	26:00	300	390
SO21_15-01	15	4	11-Aug	11:46	11-Aug	16:07	04:21	370	460
SO21_19-02	19	6	13-Aug	11:19	13-Aug	13:50	02:31	310	460
SO21_23-02	23	5	15-Aug	12:24	16-Aug	11:17	22:53	340	460
SO21_27-02	27	6	19-Aug	10:09	20-Aug	12:34	26:25	330	460
SO21_31-02	31	6	22-Aug	10:26	23-Aug	10:41	24:15	310	460
SO21_36-02	36	6	26-Aug	11:25	27-Aug	11:06	23:41	310	460
SO21_39-02	39	6	28-Aug	11:20	29-Aug	10:19	22:59	310	460
SO21_43-01	43	6	30-Aug	19:58	31-Aug	16:02	20:04	310	460
SO21_51-02	51	6	4-Sept	10:03	5-Sept	05:40	19:37	310	460
SO21_54-02	54	6	5-Sept	20:40	6-Sept	22:00	25:20	310	460
SO21_56-02	56	6	8-Sept	14:10	8-Sept	23:27	09:17	310	460

6.6.4 Longlines and trap lines considerations

The Star Oddi TD probe results showed that deployment depth was strongly affected by ice drift / water currents (**Figure 27**). This affected the sampling depth.

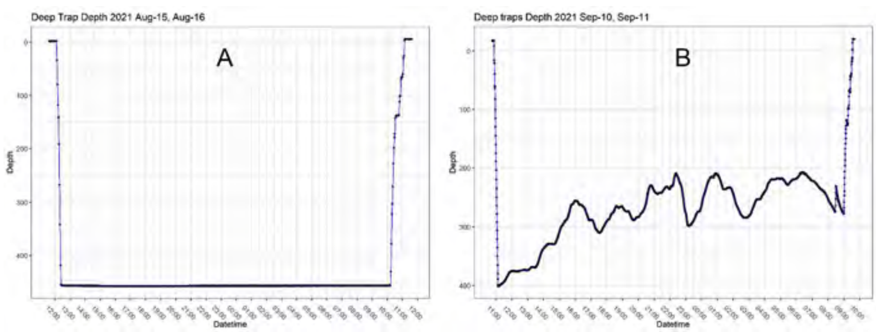

Figure 27: Difference in the effect of ice drift / water currents between two trap lines deployed on different dates as shown by Star Oddi TD probe depth measurements. The indicated depth is the depth of the lower end of the trap line. (A) Hardly any effect. (B) Strong effect.

6.7 Jigging machines and fishing rods targeting mesopelagic fish

6.7.1 Jigging machines and fishing rods equipment

Jigging machines

A jigging machine is automatic fishing gear with hooks that has the capacity to fish very deep and search for fish. Jigging machines are commonly used in fisheries worldwide, mainly for cod, mackerel and squid fishing. A jigging machine consists of a control unit and a winch or drum for the line (**Figure 28**). It is electrically driven by a 12 volt car battery and can fish automatically following a predetermined programme. The two jigging machines brought on the SAS-Oden expedition by EFICA partner SLU were of the brand Belitronic BJ5000 (manufactured in Sweden).

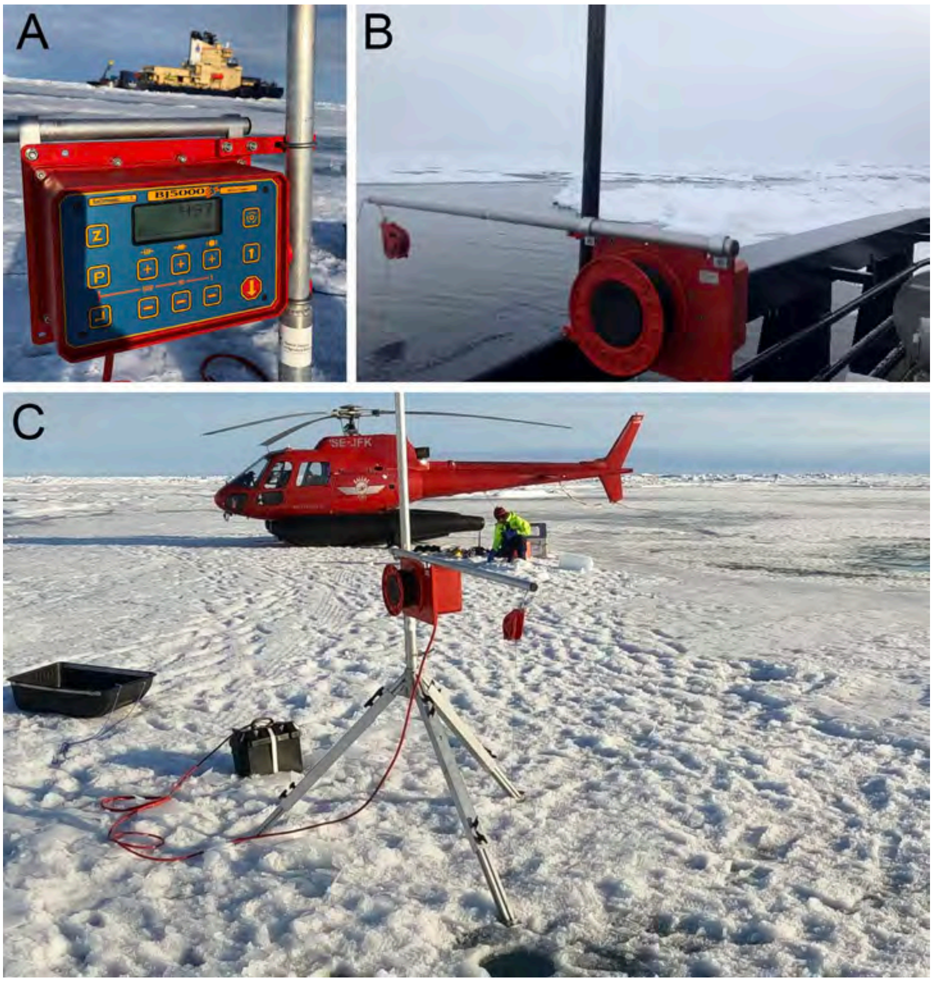

Figure 28: A BelitonicBJ5000 jigging machine used during the SAS-Oden expedition. (A) Control unit. (B) Deployment from the ship. (C) Deployment from the ice with a tripod. (A,B,C) © Baldvin Thorvaldsson

On the winch/drum of the jigging machines we had 1000 m dyneema line (extra strong rope made of High Modulus Polyethylene fibres), 1.4 mm thick, to be able to fish in the DSL. At the end of the line there were five hooks on a nylon line and a weight of tree kilos. Most often we used the program for fish searching. In this program a starting depth is chosen and how many jigs should be performed before changing to the next water depth. In this way, the machine can search for fish as far up as programmed before it restarts from start depth. We fished with the jigging machine both from the ship and from the ice.

Fishing rods

We used two types of fishing rods: (1) rods targeting planktivorous fish such as polar cod and myctophids, equipped with small herring hooks and artificial bait resembling zooplankton, partly fluorescent, and (2) rods for large predatory fish equipped with the same hook types as those used with the longlines, with the option to use artificial, fluorescent and/or organic bait (shrimp and herring).

Fishing with rods was performed on an opportunistic basis and would only be recorded when fish was caught. This activity was called "Citizen science" (**Figure 29**). The equipment for opportunistic fish sampling consisted of rods and reels for angling down to 500 m to be used under cold conditions, such as aluminium reels and special non-freezing rods. Many different artificial baits were brought as well. This equipment could be borrowed by anyone on board in their free time and, in case fish was brought up, the EFICA scientists would get the opportunity to take scientific samples.

Figure 29: The "Citizen science" site during the SAS-Oden expedition. © Pauline Snoeijs-Leijonmalm

6.7.2 Jigging machines and fishing rods metadata summary

Altogether, we performed five deployments of the jigging machine of between 1 and 3.5 hours each (**Table 13**), and numerous (>100) deployments of fishing rods. No fish were caught with the jigging machines or the fishing rods.

Table 13: Metadata for the jigging machine deployments during the SAS-Oden expedition.

Device operation	Station number	Date	Time UTC (start)	Time UTC (end)	Time in water (hh:mm)	Maximum depth (m)
SO21_13-101	13	10-Aug	10:30	11:30	01:00	500
SO21_19-101	19	13-Aug	11:15	12:48	01:33	500
SO21_30-101	30	23-Aug	15:00	16:00	01:00	500
SO21_34-101	34	25-Aug	10:30	13:30	03:00	500
SO21_53-101	53	5-Sept	15:30	17:00	01:30	500

6.8 Under-ice traps targeting sympagic fish

6.8.1 Under-ice traps equipment

For sampling sympagic (ice-associated) polar cod *Boreogadus saida* and invertebrates, we deployed baited traps in the ice-water interface layer. Two types of traps were deployed: tube traps of the same model as used in the mesopelagic sampling (**Figure 26**) and umbrella net traps (**Figure 30**).

Umbrella net traps are fish traps with approximately 1 cm mesh which can be deployed through a narrow hole in the ice or from an ice edge. In catching configuration, the net has a chamber of ~ 50 x 50 x 50 cm size, with a fyke throat as an entrance. To deploy the net, it is compressed to a cylindrical shape in the same way as a folded umbrella. Once the net is under the ice, it can be unfolded with a mechanism triggered with a stick through the ice hole.

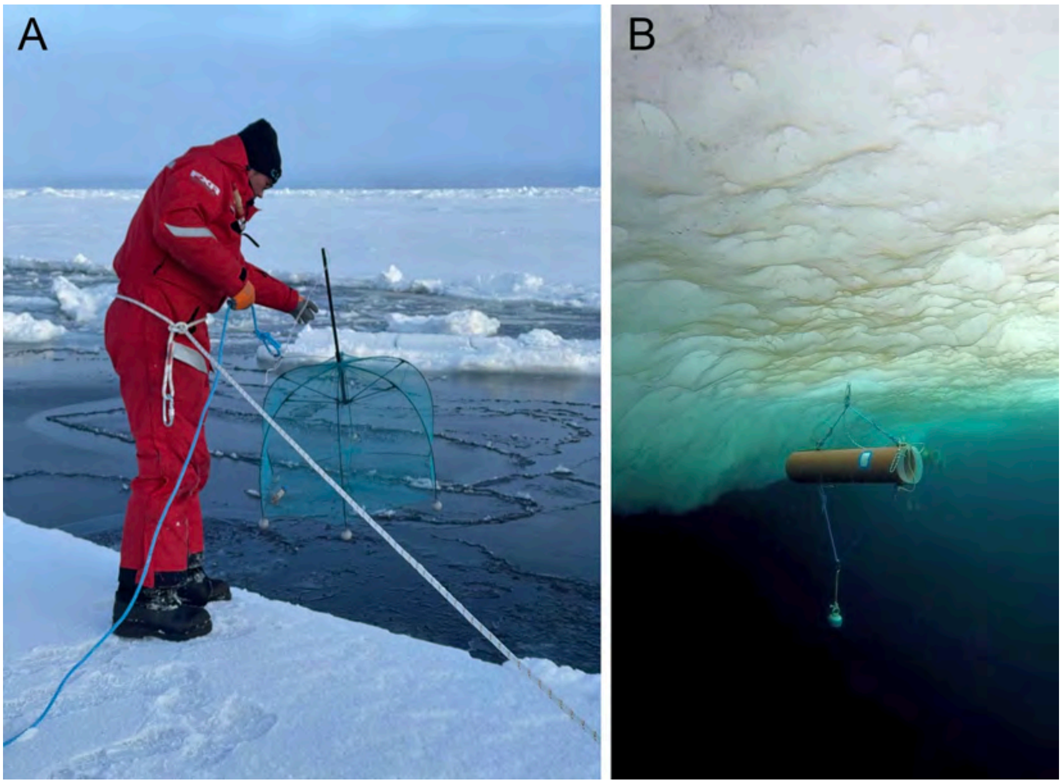

Figure 30: The two types of under-ice traps used for catching juvenile polar cod. (A) Deployment of an umbrella net trap at an ice edge. (B) A tube trap hanging under the ice. (A,B) © Nicole Hildebrandt

6.8.2 Under-ice traps metadata summary

Altogether, we deployed 23 traps, 17 tube traps and 6 umbrella net traps, at the ice-water interface at 11 sampling stations (**Table 14**). Three sympagic polar cod were caught with baited under-ice traps and one at the water surface with the beam net (**Chapter 6.9**). The polar cod were between 107 and 164 mm long (**Figure 31, Table 15**). The largest specimen caught at Station 35 was a gravid female. The fish caught with under-ice traps were dissected and sampled for otoliths, muscle tissue, guts, gonads, livers and tissue for genetic analysis. The remaining carcasses and the fish caught with the beam net were individually frozen (-20°C) for later analysis in the home laboratory.

Table 14: Metadata for the under-ice trap deployments during the SAS-Oden expedition. [1] **at an ice thickness of 1.5 m, the trap would be deployed 50 cm under the ice. All fish caught were *Boreogadus saida* (polar cod).**

Device operation	Station number	No of traps	Type of trap	Date (start)	Time UTC (start)	Date (end)	Time UTC (end)	Time in water (hh:mm)	Depth (m)[1]	Nr of fish
SO21_02-02	2	5	umbrella	2-Aug	11:00	2-Aug	13:45	02:45	2	
SO21_08-10	8	1	tube	7-Aug	14:55	8-Aug	17:15	02:20	2	
SO21_18-06	18	1	tube	13-Aug	10:00	13-Aug	17:00	07:00	2	
SO21_26-16	26	1	tube	19-Aug	13:00	20-Aug	13:55	00:55	2	
SO21_26-16	26	1	umbrella	19-Aug	15:00	20-Aug	16:10	01:10	2	1
SO21_30-17	30	1	tube	13-Aug	10:00	23-Aug	17:00	07:00	2	
SO21_35-16	35	1	tube	26-Aug	10:00	27-Aug	11:30	01:30	2	1
SO21_38-18	38	1	tube	28-Aug	10:00	29-Aug	14:00	04:00	2	1
SO21_42-18	42	5	tube	30-Aug	20:30	31-Aug	17:00	20:30	2	
SO21_50-17	50	1	tube	4-Sept	10:20	5-Sept	06:30	20:10	2	
SO21_50-17	50	1	tube	4-Sept	10:43	5-Sept	06:30	19:47	2	
SO21_53-16	53	1	tube	5-Sept	11:20	6-Sept	10:00	22:40	2	
SO21_58-19	58	3	tube	10-Sept	11:30	11-Sept	10:00	22:30	2	
Total		**23**								

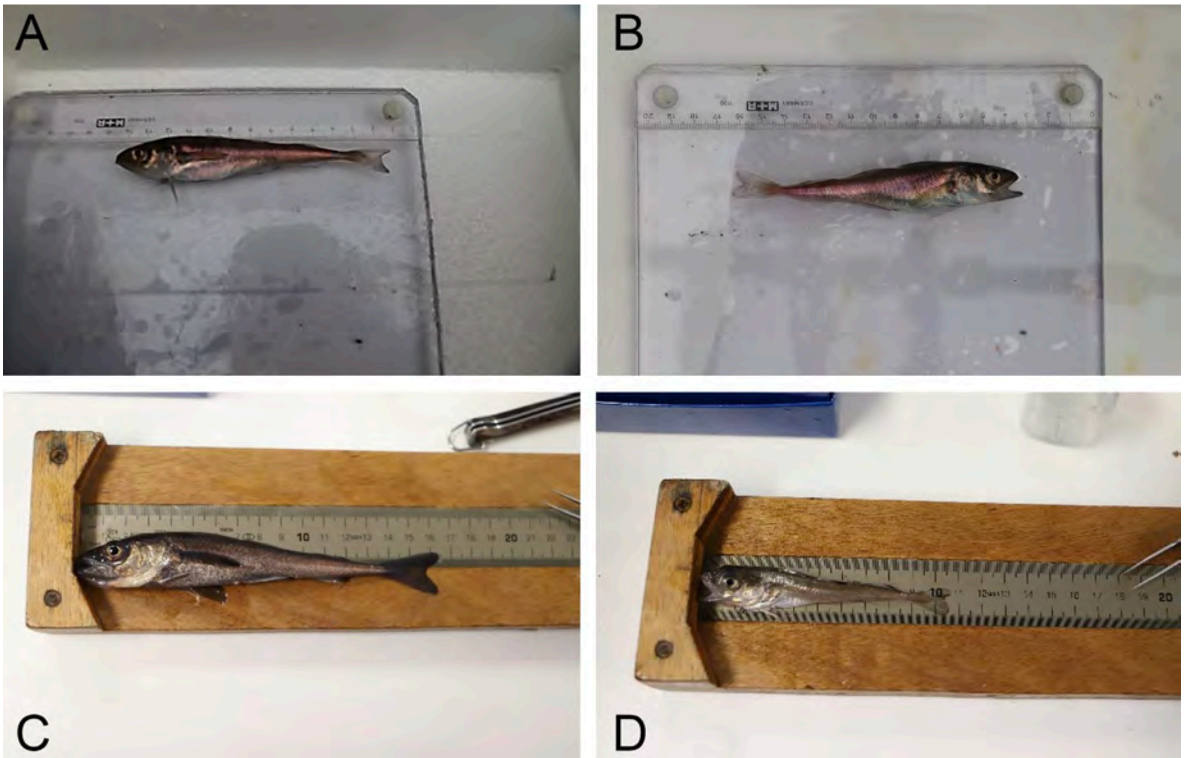

Figure 31: The four *Boreogadus saida* (polar cod) caught during the SAS-Oden expedition. (A) Station 26, beam net. (B) Station 26, under-ice tube trap. (C) Station 35, under-ice tube trap. (D) Station 38, under-ice tube trap.

Table 15: Data for the four polar cod caught during the SAS-Oden expedition. * The entire fish was frozen without dissection.

Device operation	Station number	Sampling device	Species	Total length (mm)	Sex
SO21_26-14	26	Beam net	*Boreogadus saida*	127	n.a.*
SO21_26-16	26	Under-ice trap	*Boreogadus saida*	130	female
SO21_35-16	35	Under-ice trap	*Boreogadus saida*	164	female
SO21_38-18	38	Under-ice trap	*Boreogadus saida*	107	immature

6.9 Nets targeting fish and macrozooplankton

6.9.1 Beam and MIK net equipment

Beam net equipment

The EFICA beam net was designed especially for the SAS-Oden expedition. It is a vertically towed net with a 10 m long steel beam in the middle to achieve maximum opening in the cross-track direction and two aluminium otter boards (trawl doors) of each 1.5 m^2 and kites attached to the headrope to open the net (**Figure 32**).

While the winches were operated by personnel from the SPRS for all winch operations, the beam net required additional assistance on deck from at least four IB Oden crew under the command of the Chief Officer, including bosun, crane operator and two additional seamen.

A 30 meter-long net is attached to the beam in the ends of the steel beam and also to the otter boards (**Figures 32, 33, 34**). On the beam there are four attachment points which are connected to one dyneema line, five meters above the beam. From there it goes another 15 meters and meets the two dyneema lines from the otter boards, where the tree lines are connected to the main winch.

The net is subdivided into three sections. The top section has 35 mm mesh, the middle section 16 mm, and the cod-end 10 mm. The cod-end is equipped with two throats to avoid the escape of fish after capture. To the end of the cod end we attached four weights with a total mass of 70 kg.

Attached to the centre of the beam was a Simrad PX TrawlEye with Simrad TV 80 software with portable hydrophone on board the ship. With this equipment the opening on one side of the beam net could be observed and an echogram, roll and pitch (the rotation of the beam along the transverse and longitudinal axes) and opening height were registered. Attached to the beam was also a Simrad PX Universal sensor that recorded depth and temperature.

The beam net was deployed from the aft deck with the ship crane. There we connected the towing wire from the winch and lifted the beam net from the deck (**Figures 35, 36**). The A-frame was leaned backwards, and then the net was launched with the weights until it was fully stretched. After that we paid out the wire to the desired depth at a speed of 0.3 m s^{-1}

After reaching the target depth (800 m), the net was hauled up at a speed of 1.0 m s^{-1}. This was the optimal speed to get an as large opening as possible. At the surface, we pulled the rope that is attached to the end of the beam net and leads down to the cod-end to lift in and empty it (**Figures 35, 37**). After the first two beam net stations, the motherboard of the Oden's main winch ("North Sea winch") broke. After that, we used the CTD winch for beam net sampling. The latter winch did not have the same capacity as the North sea winch, and we could only haul it up with max. 0.87 m s^{-1} instead of 1.0 m s^{-1}.

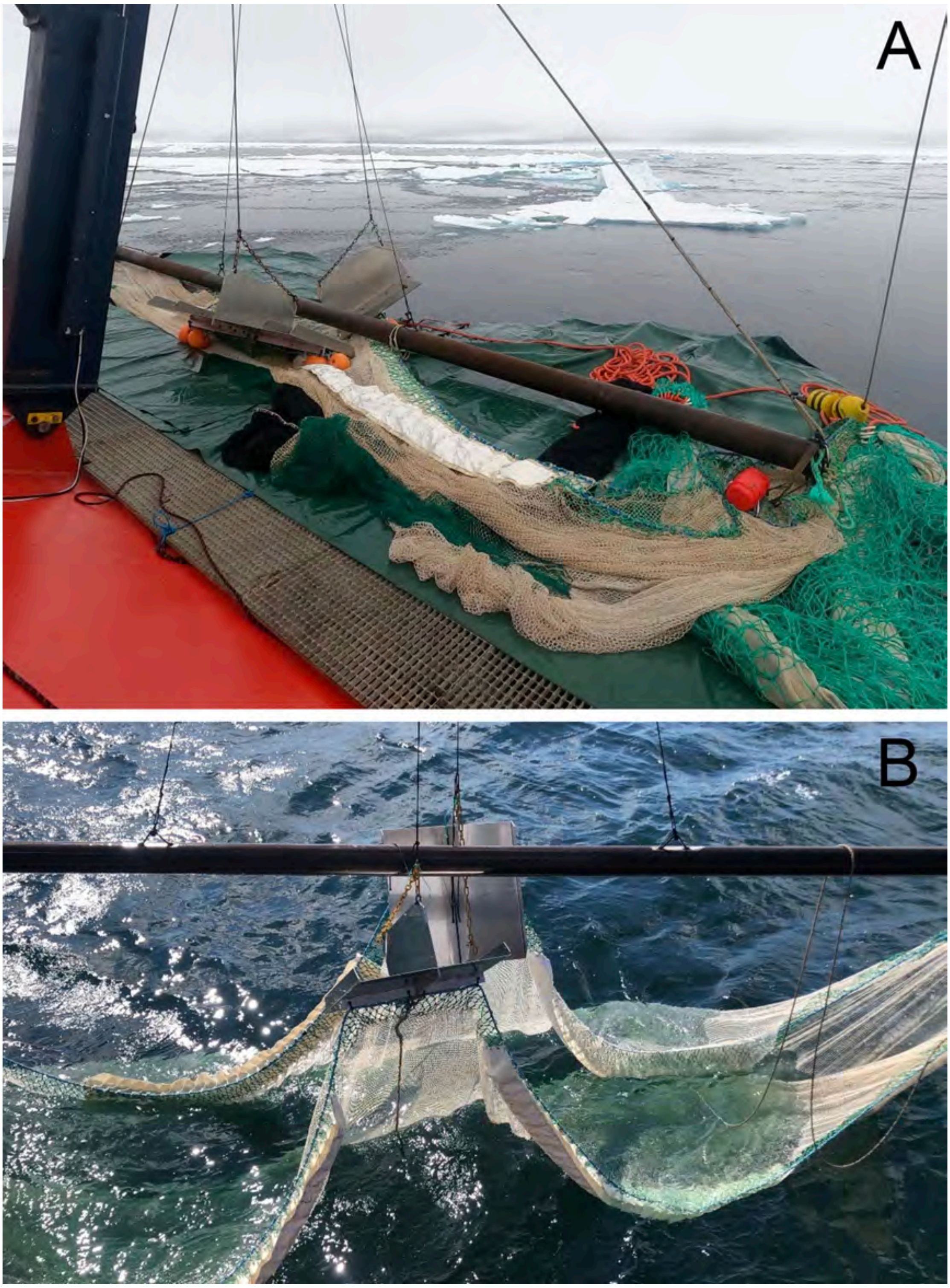

Figure 32: The beam net. (A) On the aft deck during the SAS-Oden expedition. (B) During a test deployment in Swedish waters. (A,B) © Baldvin Thorvaldsson

Figure 33: Attachment of the net. (A) Attachment to the steel beam. (B) Attachment to the otter boards. (A) © Hans Nilsson, (B) © Baldvin Thorvaldsson

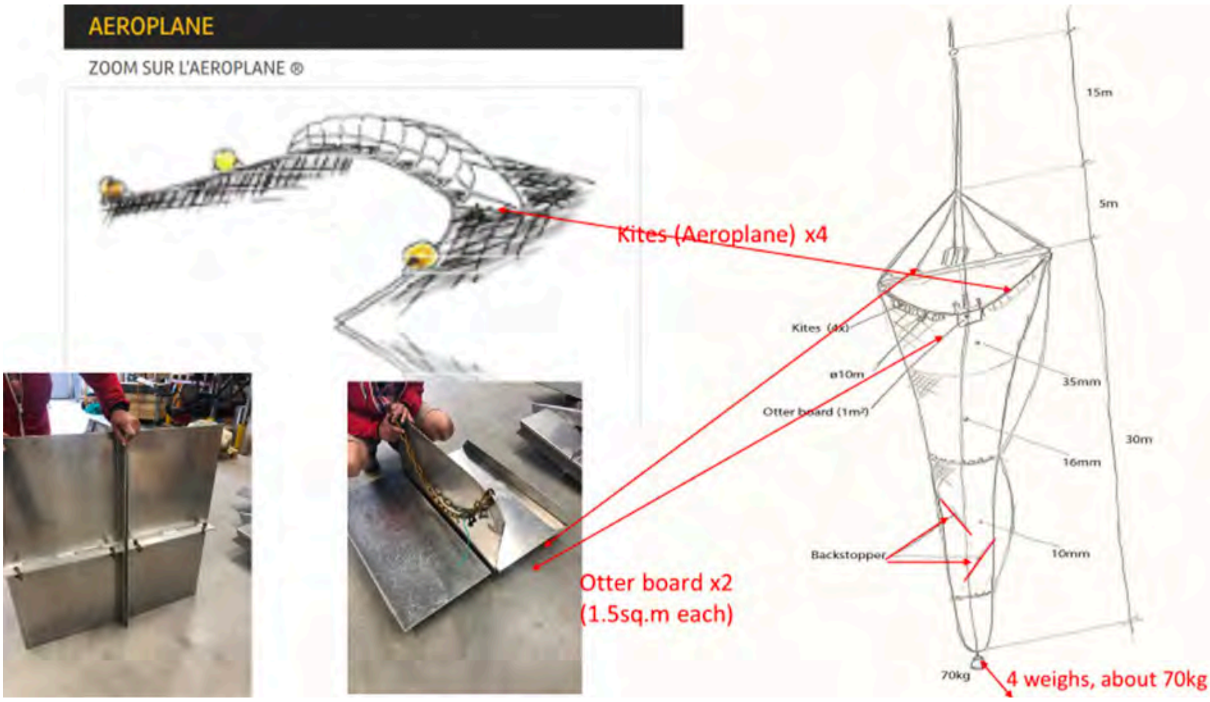

Figure 34: The construction of the beam net. © Baldvin Thorvaldsson

Figure 35: The beam net connected to the towing wire. (A) Before deployment. (B) Retrieval. (A) © Baldvin Thorvaldsson, (B) © Pauline Snoeijs-Leijonmalm

Figure 36: The beam net connected to the towing wire. © Kimberley Bird

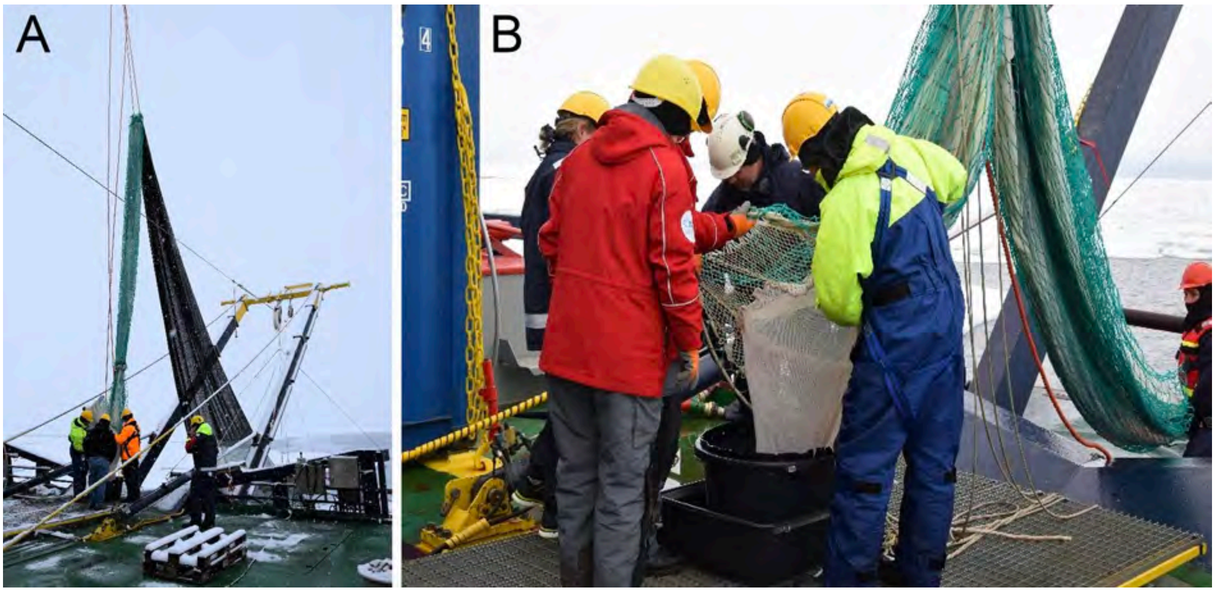

Figure 37: Emptying the cod-end of the beam net. (A) Overview of the aft deck after retrieval of the beam net. (B) Collecting the catch. (A,B) © Hans-Jørgen Hansen

MIK net equipment

Since the beam net opening was much larger, but less precise, than that of a ring net with a fixed opening, we performed net hauls with a MIK net (**Figure 38**) to be able to compare the macrozooplankton catches of the beam and MIK nets quantitatively. The MIK net is the standard gear for the sampling of fish larvae adopted by ICES[24]. It has a strong and robust construction. The MIK net consists of a 2 m diameter ring frame to which the net is attached. The 13-meter long black net has a mesh size of 1.6 mm and is strengthened by canvas straps. The last metre of the MIK net consists of a 500 µm mesh net, and in the bottom we attached a cod-end bucket for sample collection. Underneath, a weight of 30 kg enabled the cod-end to sink fast enough to avoid entanglement during the lowering of the net. We attached a flow meter (Hydrobios) for the determination of the volume of water filtered and a Star Oddi TD probe for monitoring net depth and water temperature.

For deployment, we connected the ring to the winch wire and leaned the A-frame backwards and lifted up the ring as high as possible. Then we launched the weights and net until it was stretched downward in the water (**Figure 38B**). After that, we paid out the wire to the desired depth at speed of 0.3 $m\ s^{-1}$. After reaching the desired depth, we hauled the net upwards at a speed of 0.67 $m\ s^{-1}$. When the MIK net came out of the water, we lifted it out of the water as far as possible with the A-frame and put a strap around the net to lift the cod-end on deck with the ship crane.

[24] ICES (2013) Manual for the Midwater Ring Net sampling during IBTS Q1, Revision 2. Series of ICES Survey Protocols SISP 2-MIK 2. 18 pp.

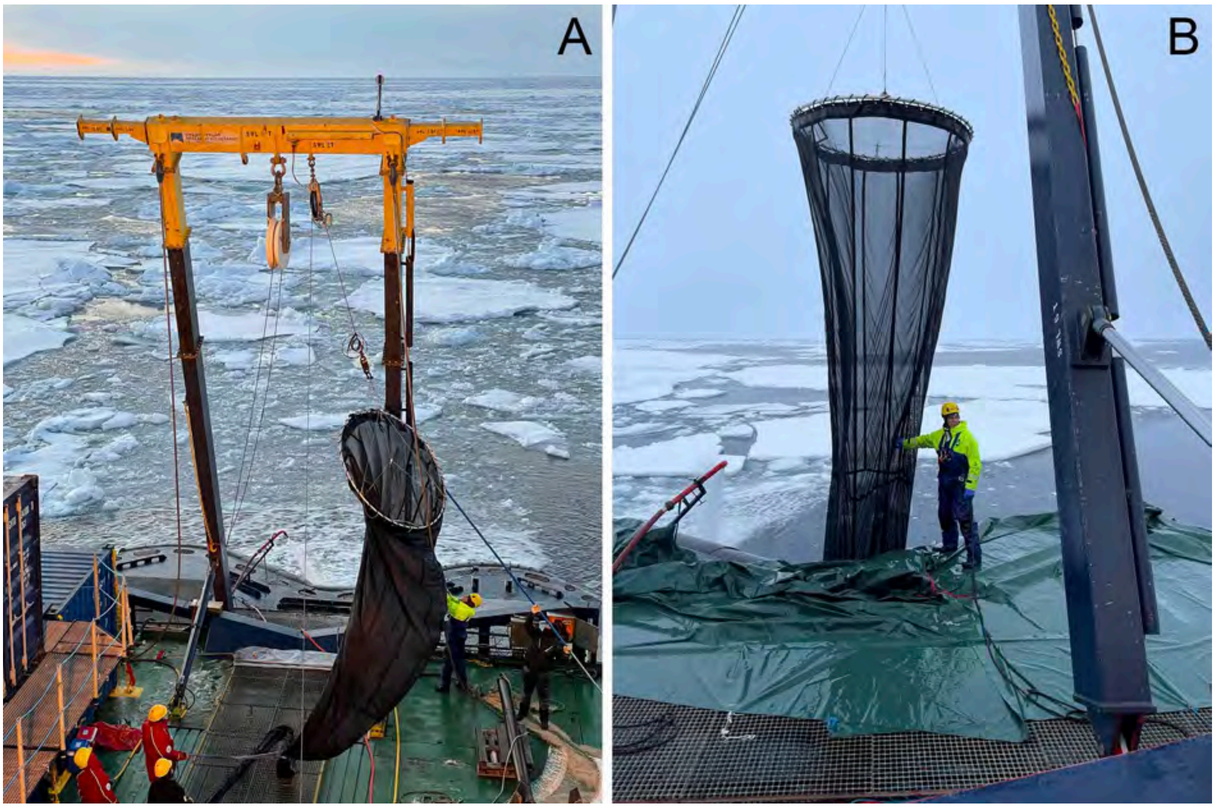

Figure 38: The MIK ring net. (A) Overview of the aft deck before deployment of the MIK net. (B) The weights are launched and the MIK net is stretched downward in the water (A) © Pauline Snoeijs-Leijonmalm, (B) © Nicole Hildebrandt

6.9.2 Beam and MIK net metadata summary

Altogether, we performed 45 successful hauls with the beam net (**Table 15**) and five hauls with the MIK net (**Table 16**). At the first beam net station (Station 14) the aimed haul depth was 700-0 m and at all other stations 800-0 m, except for Station 42 where the bottom depth was 600-700 m and the average haul depth was 634-0 m. At some stations, beam net and MIK net deployments could not be carried out because of strong wind or failed due strong ice drift.

The main target organisms for the beam net on the SAS-Oden expedition were mesopelagic fishes. However, we did not catch any mesopelagic fish during the expedition. From the EK80 acoustic measurements it became clear that the acoustic targets that resembled fish actively avoided the beam net, as well as the other sampling gear lowered from the ship, including thin fishing lines (**Figure 10**). Only one polar cod (*Boreogadus saida*) was caught with the beam net, but this was a sympagic individual, not a mesopelagic one.

The other target organisms for the beam and MIK nets on the SAS-Oden expedition were macrozooplankton to characterize the taxonomic composition of the potential prey field, or competitors (e.g., the comb jelly *Beroe* sp.) of finfish in the CAO. Because of its large opening (10 m), the beam net was highly successful in catching larger-sized macrozooplankton that are rare in multinet samples (**Figure 39**).

Using both taxonomic composition and the size distribution of each taxon in combination with hydroacoustic data from the WBAT and the ship-mounted 18 KHz EK80, we will be able to quantify the prey biomass distribution along the SAS-Oden expedition track.

Table 16: Successful beam net sampling during the SAS-Oden expedition. Samples vary between single specimens for fatty acid or stable isotope analyses to collections of all specimens of the same species or collections of whole communities. All samples were photographed.

Device Operation	Station number	Station number	Date UTC (start)	Time UTC (end)	Time in water (hh:mm)	Maximum depth (m)	Number of formaldehyde-preserved samples
SO21_14-01	14	11-Aug	07:47	09:10	01:05	715	5
SO21_14-02	14	11-Aug	09:45	13:28	03:28	710	6
SO21_14-03	14	11-Aug	14:27	17:18	02:38	707	8
SO21_14-04	14	11-Aug	18:00	19:17	01:10	702	9
SO21_22-01	22	15-Aug	07:16	08:26	00:53	800	29
SO21_22-02	22	15-Aug	09:58	11:05	01:06	800	27
SO21_26-12	26	20-Aug	07:28	09:05	01:37	805	33
SO21_26-13	26	20-Aug	09:26	10:58	01:05	804	10
SO21_26-14	26	20-Aug	11:11	13:00	01:09	815	11
SO21_26-15	26	20-Aug	13:35	15:00	01:04	798	7
SO21_30-04	30	22-Aug	08:48	10:10	01:16	800	25
SO21_30-05	30	22-Aug	10:29	11:53	01:04	796	5
SO21_30-06	30	22-Aug	12:35	13:45	00:54	800	9
SO21_30-07	30	22-Aug	14:05	15:20	01:02	801	10
SO21_30-08	30	22-Aug	16:34	17:50	01:09	820	9
SO21_35-01	35	26-Aug	06:53	08:07	00:57	796	21
SO21_35-02	35	26-Aug	08:25	09:45	01:15	805	17
SO21_35-03	35	26-Aug	10:06	09:50	01:07	800	16
SO21_35-04	35	26-Aug	11:30	12:45	01:04	800	13
SO21_35-05	35	26-Aug	13:15	14:36	00:58	799	10
SO21_35-06	35	26-Aug	15:18	16:40	01:10	802	7
SO21_35-07	35	26-Aug	16:52	18:00	00:53	800	10
SO21_38-01	38	28-Aug	07:03	18:19	01:00	800	26
SO21_38-02	38	28-Aug	08:32	09:37	00:53	805	10
SO21_38-03	38	28-Aug	10:02	11:00	00:47	806	9
SO21_38-04	38	28-Aug	11:20	12:25	00:54	805	11
SO21_38-05	38	28-Aug	12:57	13:42	00:38	807	8
SO21_38-06	38	28-Aug	14:05	15:06	00:52	810	9
SO21_38-07	38	28-Aug	15:26	16:27	00:53	809	8
SO21_42-09	42	31-Aug	07:22	08:22	00:42	615	11
SO21_42-10	42	31-Aug	08:35	09:30	00:44	620	0
SO21_42-11	42	31-Aug	09:36	10:50	00:52	600	0
SO21_42-12	42	31-Aug	10:59	11:49	00:43	647	14
SO21_42-13	42	31-Aug	12:15	13:10	00:55	650	8
SO21_42-14	42	31-Aug	13:35	14:35	00:47	654	0
SO21_42-15	42	31-Aug	14:54	16:00	00:45	651	0
SO21_50-01	50	4-Sept	10:10	11:18	00:49	800	31
SO21_50-02	50	4-Sept	11:32	12:40	00:47	781	0
SO21_50-03	50	4-Sept	12:50	13:55	00:54	780	1
SO21_50-04	50	4-Sept	14:11	15:16	00:58	806	1
SO21_50-05	50	4-Sept	15:35	16:39	01:05	799	0
SO21_58-01	58	10-Sept	08:56	10:01	00:52	802	20
SO21_58-02	58	10-Sept	10:32	11:33	00:52	790	2
SO21_58-03	58	10-Sept	12:15	13:16	01:01	790	1
SO21_58-04	58	10-Sept	13:45	14:57	00:54	771	1
Total							**468**

Table 17: Successful MIK ring net sampling during the SAS-Oden expedition.

Device Operation	Station number	Date UTC (start)	Time UTC (start)	Time UTC (end)	Time in water (hh:mm)	Maximum depth (m)	Number of samples
SO21_53-12	53	6-Sept	18:51	19:53	01:02	800	27
SO21_53-13	53	6-Sept	20:20	21:24	01:04	800	10
SO21_58-06	58	10-Sept	17:20	18:29	01:09	800	17
SO21_58-07	58	10-Sept	18:50	20:01	01:11	800	1
SO21_58-08	58	10-Sept	20:19	21:30	01:11	800	1
Total							**56**

As soon as the cod-end arrived on deck, either from the beam net or the MIK net, the catch was immediately emptied into a tub (about 70 cm diameter). The cod-end was carefully inspected to collect all animals entangled in the mesh of the cod-end. The catch was then transferred to a large sorting tray (ca. 80 x 50 cm), where an overview photo was made with an SLR camera (**Figure 39**). Subsequently, all macrozooplankton organisms were sorted to the lowest possible taxon and enumerated.

Each taxonomic group was photographed with a mm-graded ruler in the picture for documentation and later digital size measurements with an image analysis software. Subsamples of each taxon were sampled for later taxonomic verification (4% formaldehyde solution), lipid biomarker (including fatty acid) analyses (-80°C), and CN content (including ^{13}C and ^{15}N stable isotopes) analyses (-20°C) in the home laboratory. Each animal sampled for lipid biomarker and CN measurements was photographed individually with a Leica stereo microscope connected to a digital imaging system in order to enable size measurements and species verification in the home laboratory.

The remaining zooplankton sample was sorted by taxon and preserved frozen for further analyses, including diet analysis, bulk stable isotope analysis (BSIA) and genetic barcoding (-20°C) as well as for references for the metagenomic eDNA analyses. Altogether, 468 macrofauna samples were collected from the beam net and 56 from the MIK ring net (**Tables 16, 17**).

The same sampling procedure was carried out for macrozooplankton sampled with traps. Some casts were only sorted, counted and photographed. From Station 42 onwards, all animals were collected into one sample per taxon at the end of the day. CN and biomarker samples were taken from 1-2 specific casts. That is why some casts have zero samples (**Table 16**). Ctenophores (comb jellies) that were not sampled for lipid biomarker analyses were discarded after photographic documentation and identification because they would disintegrate in both frozen and formaldehyde-preserved samples.

6.10 Nets targeting mesozooplankton

6.10.1 Multinet and bongo net equipment

A 150 µm mesh multinet (Midi) was used to sample mesozooplankton (0.2-20 mm) for analysing community composition, abundance and depth distribution (**Figure 40, 41**). This work was carried out jointly by EFICA and SAS-Oden WP8. As a standard, the multinet collected five samples per cast from the five depth intervals 2000-1000-500-200-50-0 m, i.e., the standard depths for sampling zooplankton in the CAO as also used during MOSAiC and adopted by SAS. On two occasions (at Stations 22 and 30) the multinet covered the full water column and two casts were made to cover the seven depth intervals bottom-3000-2000-1000-500-200-50-0 m. The multinet had two nets on the side: one "bicycle net" that collected zooplankton for species sorting and a smaller "gypsum net" to collect gypsum for SAS-Oden WP3.

The bongo net consisted of two ring nets, both with an upper diameter of 60 cm (**Figure 42, 43**). One net had a mesh size of 150 µm, and the other one had a mesh size of 53 µm.

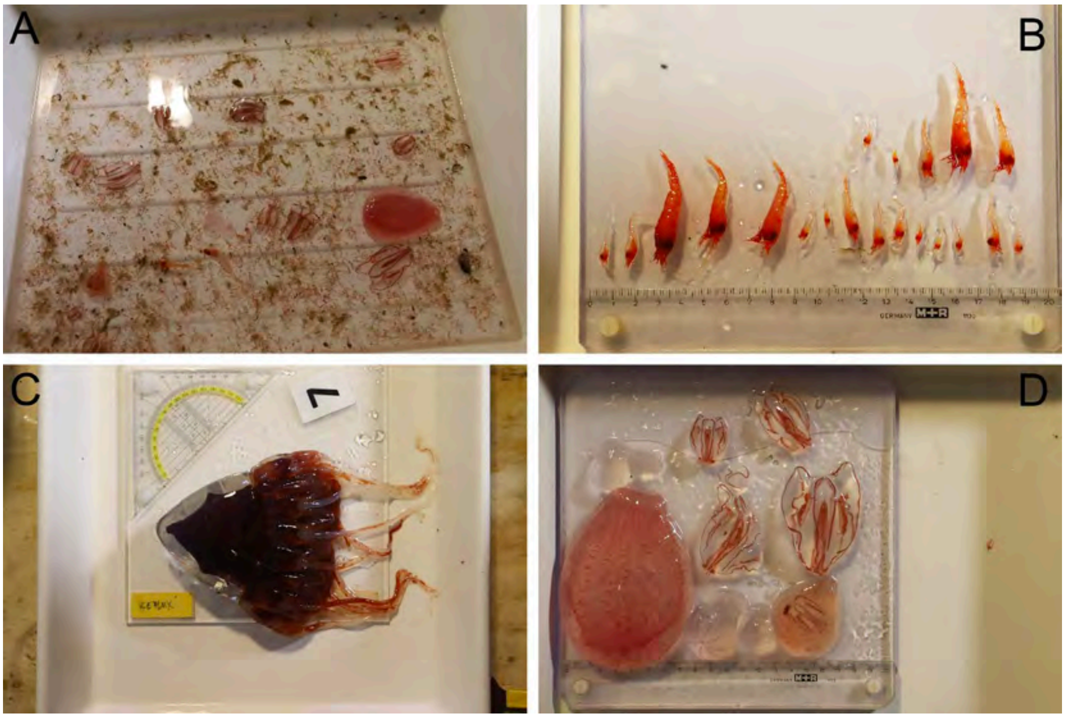

Figure 39: Examples of macrozooplankton collected with the beam net and the MIK net. (A) Overview of entire catch, beam net, (B) Size overview of *Hymenodora glacialis*, beam net. (C) *Periphylla periphylla*, MIK net, (D) Ctenophores *Beroe* sp. and *Mertensia* sp., MIK net.

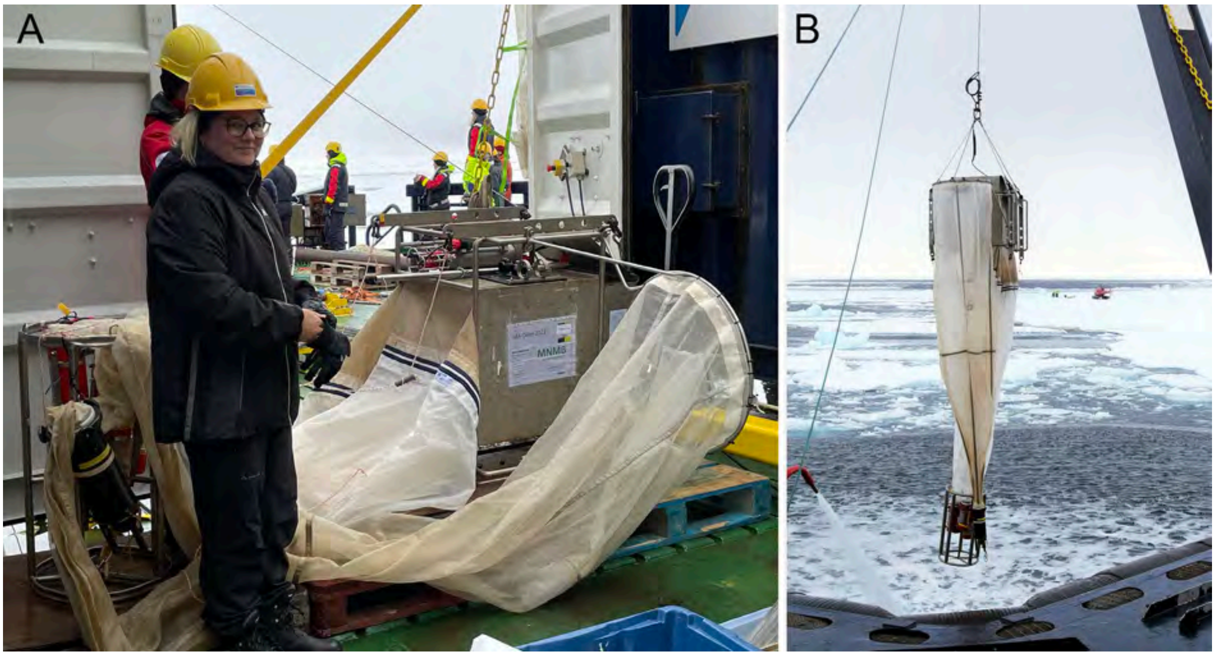

Figure 40: Multinet deployment during the SAS-Oden expedition. (A) Preparations. (B) The net is winched into the water – the water hose is used to keep the ice open. (A) © Pauline Snoeijs-Leijonmalm, (B) © Hans-Jørgen Hansen

6.10.2 Zooplankton species sorting

To investigate the biochemical composition of key mesozooplankton species, individual organisms were sorted from bicycle and Bongo nets both from the SAS and the FORAM project (SAS-Oden WP9) net operations. The sorting took place in the unheated "Triple Lab" (**Figure 41B**). The net catches were carefully poured into large photo trays, and zooplankton organisms were picked out and sorted for species and life stage using glass pipettes or tweezers. Target species included copepods (*Calanus* spp., *Paraeuchaeta* spp., *Metridia* sp., *Scaphocalanus* sp., *Spinocalanus* sp., *Gaetanus* spp., *Heterorhabdus* sp., *Microcalanus* spp., *Oithona* spp., *Aedideopsis* spp., *Mormonilla* sp.), Amphipods (*Themisto* spp., *Cyclocaris* sp., *Eusirus holmi*), gastropods, chaetognaths, appendicularians, hydrozoans, ostracods, polychaetes and decapods.

For analysing the carbon and nitrogen content, including their stable isotopes ^{13}C and ^{15}N, organisms were first photographed with a stereo microscope camera in order to perform length measurements later on. Then they were briefly dipped in MilliQ water to remove salt and placed in pre-weighted tin caps, either individually (large species) or pooled (smaller species). Individuals that were too big for the tin caps were placed in small plastic bags. In very small copepod species, individuals were pooled on a piece of mesh (50 µm), rinsed with MilliQ and then placed in a petri dish. All CN samples were frozen at -20 °C until further processing in the home laboratories.

For analysing the lipid composition, zooplankton organisms were photographed, dipped in MilliQ, briefly dabbed dry on a tissue and then placed in a pre-combusted, pre-weighted glass vial. These lipid vials were then stored at -80°C. Additionally, two bicycle net samples (Stations 22 and 30) and one bongo net sample (Station 56) were preserved in 95% ethanol for genetic barcoding.

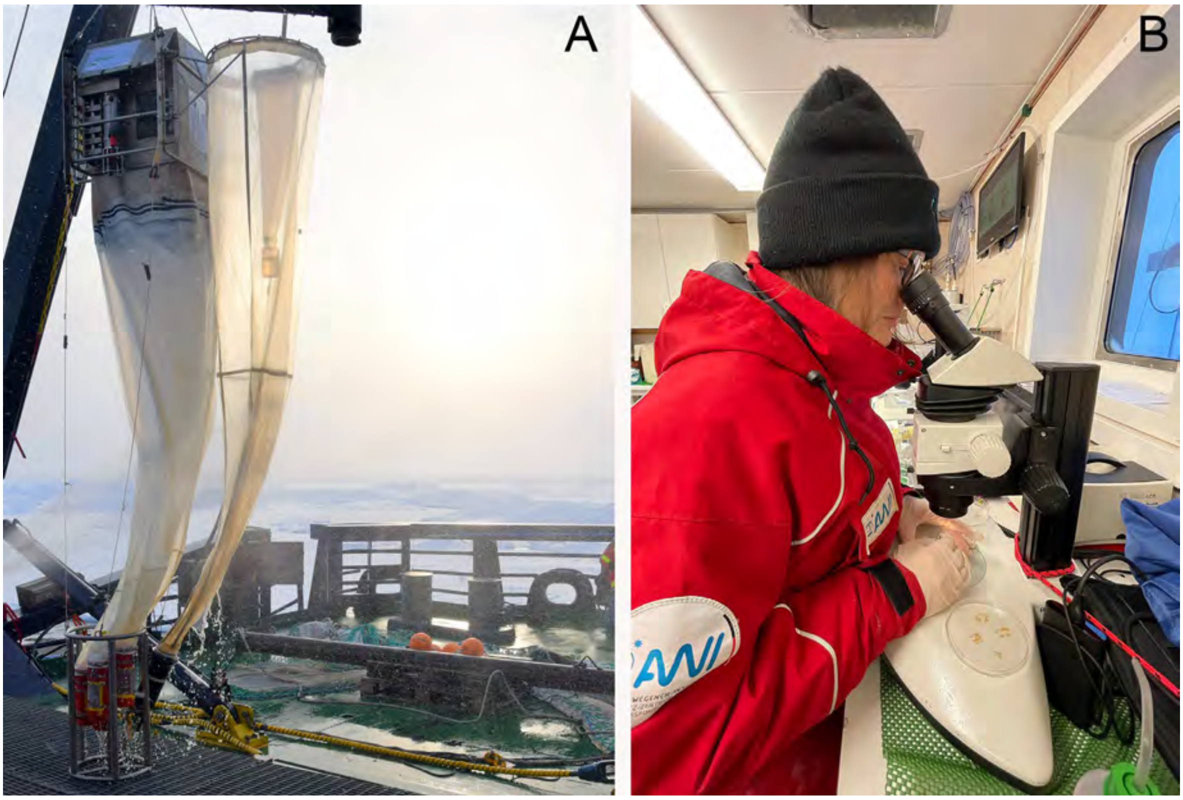

Figure 41: Multinet retrieval and species identification during the SAS-Oden expedition. (A) Retrieval of the multinet, showing the side nets: one "bicycle net" for species sorting and a smaller "gypsum net" for SAS-Oden WP3. (B) Species sorting and identification in the unheated "Triple lab" on board IB Oden. (A) © Hans-Jørgen Hansen, (B) © Pauline Snoeijs-Leijonmalm

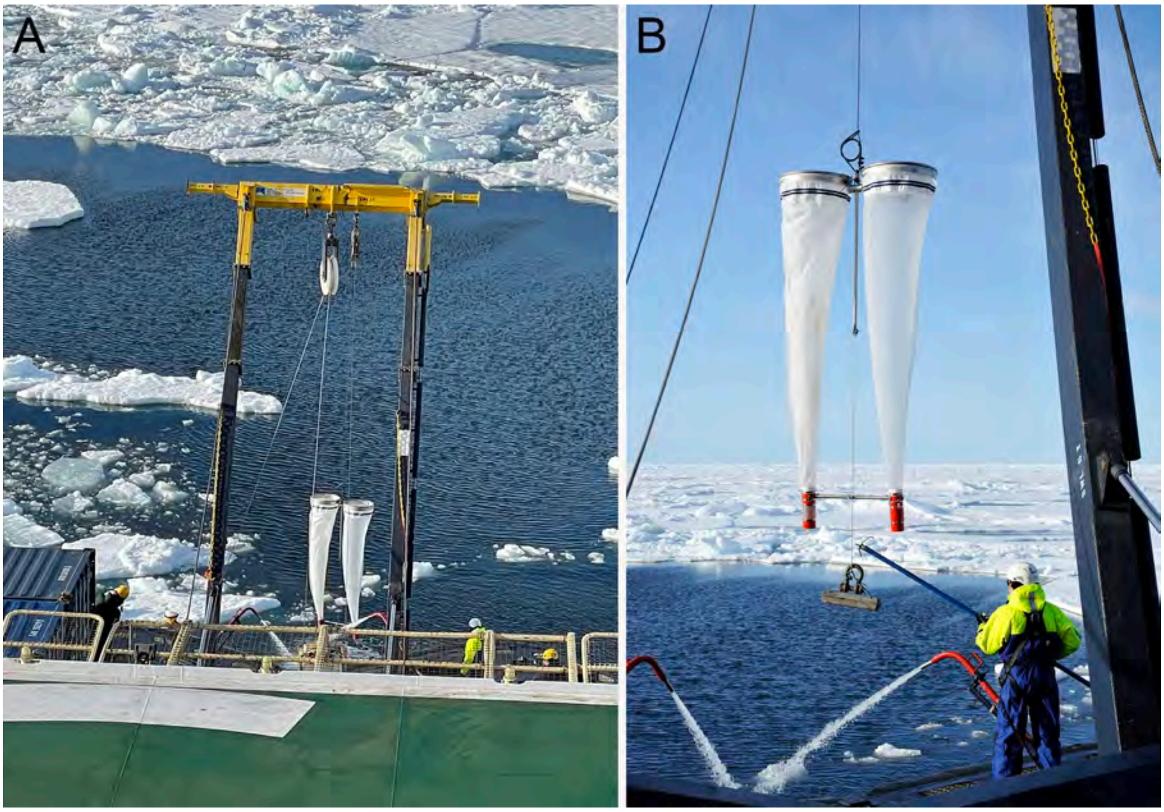

Figure 42: Deployment of the bongo net from which zooplankton organisms were collected for CN and lipid analyses. (A) © Pauline Snoeijs-Leijonmalm, (B) © Flor Vermassen

Figure 43: The bongo net and all other nets were deployed from the stern. © SAS-Oden sea-ice team

6.10.3 Multinet and Bongonet metadata summary

Altogether, 84 mesozooplankton community samples for species composition, abundance and biomass analyses were collected at the 16 multinet stations during the SAS-Oden expedition (**Table 18**). Of these, 66 are relevant for EFICA as they were taken in the upper 1000 m of the water column, i.e., including the DSL. All samples were transferred into 100 ml plastic vials, preserved with a 4 % formaldehyde solution buffered with hexamethylenetetramine and stored at 4 °C.

Additionally, 534 samples of key species for C and N content and 26 samples for trophic biomarker analysis were obtained from the “bicycle net” attached to the multinet (MN-BC) and the bongo net (**Table 19**). These samples were frozen at -20 °C.

Table 18: Successful multinet net (150 µm mesh) sampling during the SAS-Oden expedition. EFICA-relevant samples are those taken in the upper 1000 m of the water column. * = sample can be replaced by Bongo net sample

Device Operation	Station number	Date UTC (start)	Time UTC (start)	Time UTC (end)	Time in water (hh:mm)	Maximum depth (m)	No of samples	EFICA-relevant samples
SO21_03-03	3	3-Aug	18:31	21:10	02:38	2000	5	4
SO21_08-05	8	8-Aug	10:39	12:53	02:13	2000	5	4
SO21_13-02	13	10-Aug	10:27	12:35	02:07	2000	6	4
SO21_16-02	16	12-Aug	10:34	12:51	02:17	2000	4	3
SO21_22-06	22	15-Aug	18:18	22:42	04:24	4136	5	2
SO21_26-04	26	19-Aug	11:11	12:41	01:29	1320	5	4
SO21_30-09	30	22-Aug	19:10	23:44	04:34	3940	4	1
SO21_30-10	30	23-Aug	00:15	00:50	00:34	200	5	5
SO21_33-04	33	25-Aug	10:37	12:45	02:08	2000	5	4
SO21_35-09	35	26-Aug	21:51	23:20	01:28	1450	5	4
SO21_38-09	38	28-Aug	19:32	20:44	01:12	1180	5	4
SO21_42-03	42	30-Aug	20:55	21:30	00:35	600	5	5
SO21_48-03	48	3-Sept	14:24	16:07	01:42	1550	5	4
SO21_50-07	50	4-Sept	20:09	21:04	00:54	900	5	5
SO21_53-01	53	5-Sept	19:59	21:09	01:10	1050	5	5
SO21_56-04	56	8-Sept	17:23	19:40	02:16	2000	5	4
SO21_58-13	58	11-Sept	02:58	04:28	01:29	1300	5	4
Total							**84**	**66**

Table 19: Overview of mesozooplankton samples collected with different nets prepared for CN and lipid analyses. These are integrated samples hauled from the sampling depth to the surface.

Device operation	Station number	Area	Sampling device	Sampling Depth (m)	CN no of samples	CN no of taxa	Lipids no of samples	Lipids no of taxa
SO21_07-02	7	Nansen Basin	Bongo net	1000	153	14	9	5
SO21_13-02	13	Amundsen Basin	Bicycle net	2000	14	7	8	4
SO21_26-04	26	Lomonosov Ridge	Bicycle net	1280	52	9	5	3
SO21_30-09	30	Makarov Basin	Multinet	500	6	4		
SO21_30-15	30	Makarov Basin	Bongo net	200	17	4		
SO21_33-04	33	Makarov Basin	Bicycle net	2000	12	4		
SO21_38-14	38	Lomonosov Ridge	Bongo net	200			4	1
SO21_48-03	48	Lomonosov Ridge	Bicycle net	1530	67	9		
SO21_48-05	48	Lomonosov Ridge	Bicycle net	1000	18	11		
SO21_50-07	50	Greenland Shelf	Bicycle net	860	66	12		
SO21_50-10	50	Greenland Shelf	Bongo net	200	46	3		
SO21_56-02	56	Gakkel Ridge	Bongo net	200	84	16		
SO21_56-04	56	Gakkel Ridge	Bicycle net	2000	6	2		
Total					**541**	**95**	**26**	**13**

6.11 Sedimentary otolith samples

6.11.1 Relevance of sedimentary otoliths for fish-stock assessment

Sagittal otoliths (fish ear stones) are aragonite and protein structures that can provide a wealth of information about historical fish populations, including taxonomy, growth, and environmental conditions. Otoliths can accumulate in surficial sediment and under the right conditions they can be preserved for several millennia. We presume that the darker-coloured sediment layer we found in the CAO represents the current geological epoch, the Holocene, that started ca. 11,700 years ago. This layer seemed quite undisturbed by animal activities; a macrofauna community was only found at the southernmost station of the expedition (Station 60).

Collection of otoliths from sediments was not foreseen in SC06, but when we found that well-preserved otoliths occurred in the box core samples we realized that valuable information about the present and future fish stocks in the CAO, i.e., addressing questions 1 and 2 (see page 6 of this report):

(1) What are the distributions of species with a potential for future commercial harvests in the High Seas portion of the CAO.

Rationale: During the Holocene there have been warmer and colder periods, notably the Holocene thermal maximum from around 9000 to 5000 years before present[25]. By studying the otoliths we collected in the CAO we can estimate the time of their deposition (^{14}C analyses of shells in the same layer) and the ambient temperature the fish experienced when living (^{18}O analyses of otoliths). The number of otoliths in each layer can then be related to temperature and we can predict if fish stocks will increase with climate warming in the future. From the otoliths we can also extract the age of the fish when they died and relate this to temperature to answer the question if they grow older in higher temperature.

(2) What fish species are currently present in the High Seas portion of the CAO?

Rationale: Since we were unable to collect samples of adult *Boreogadus saida* in the DSL of the CAO (both during the MOSAiC and SAS-Oden expedition), the otoliths in the upper cm of the CAO sediment, i.e., otoliths from fish that died recently, could provide evidence that adults of this species occur in the CAO (by age determination). During MOSAiC we caught one *Arctogadus glacialis* in the DSL of the CAO, but this was in the same area as we caught *Gadus morhua* (Atlantic cod), and this fish may also have its origin in Norwegian waters. Co-existence of adult *Boreogadus* saida and *Arctogadus glacialis* along the SAS-Oden track could thus be proven from the otoliths.

6.11.2 Box core equipment

The SAS-Oden expedition borrowed a Giant Box Corer from the AWI[26] (**Figure 44**). This box corer samples a comparatively large area of the sediment surface (50 x 50 cm) with minimal disturbance and collects a large block of sediment up to max. 60 cm below the sea floor. The square box is fixed to a head with a column that is connected to a frame by a cardanic (gimballed) suspension. This allows vertical penetration of the box into the sediment. A crank with spade including rubber sealed plate is attached to the head of the box. The column is filled with lead weights to aid penetration and weighs 900 kg.

[25] Park HS, et al. (2019) Mid-Holocene Northern Hemisphere warming driven by Arctic amplification. Science Advances 5: eaax8203

[26] Giant Box Corer: https://www.awi.de/en/science/geosciences/marine-geology/tools/sea-going-equipment/boxcorer.html

During lowering to the sea floor and sampling, flaps at the top of the head remain open to allow a free flow of water. This prevents pressure build-up and following disturbance of the sediment surface. When the box has reached the sea floor, the box is triggered by a trip as the column passes through its frame. While pulling the corer out of the sediment the flaps at the head are closed and the spade is drawn down into vertical position so that the bottom of the box is closed and the sample is secured. Once the box corer has returned on board the ship and lowered onto the deck, the box with the sample can be detached from the frame for subsampling of the sediment (**Figure 45**). The square boxes are equipped with a removable front plate for access the sediment from the side, to obtain undisturbed subsamples of the near-surface sediments.

Figure 44: Retrieval of the Giant Box Corer during the SAS-Oden expedition. (A) the box corer is lifted on the aft deck with a crane. (B) The box is detached from the frame. (C) Curious scientists inspect the sample. (D) The box with the sediment sample covered by bottom water. (A,B,C,D) © Pauline Snoeijs-Leijonmalm

Once in the desired general area, the specific location of box core stations was considered through dialogue with SAS-Oden WP14, who identified regions of level, soft sediments from multibeam and sub-bottom profiler data: regions of relatively flat topography, or small bathymetric "highs", characterised by coherent acoustic layering should be targeted where possible. Steep slopes and acoustically chaotic sediment piles should be avoided.

Figure 45: The structure of the box core samples taken during the SAS-Oden expedition – macroscopic animal life as almost absent. (A) The box core sample after removing the bottom water with silicone tubing. (B) The vertical structure of the sediment with the darker upper layer presumably representing the Holocene and lighter-coloured glacial sediment below it. (C) Otoliths were observed on the sediment surface. (D) The pencil is pointing at a relatively large otolith. (A,B,C,D) © Pauline Snoeijs-Leijonmalm

6.11.3 Otolith sampling

At each of the six box core stations of the SAS-Oden expedition (**Figure 4**), two sample types were taken to analyse otolith sedimentation. The sediment was sieved over a 300 µm mesh sieve.

(1) Transparent cores (Plexiglas, diameter 8 cm) were used for subsampling to collect one cm vertically stratified sediment subsamples to obtain otoliths and other calcareous structures such as bivalve shells for sediment dating (**Figures 46, 47**). Within 24 hours of sampling, 11-12 subcores (kept at ambient temperature) were sliced into 1-cm sections (**Figure 46G**) and combined into bulk stratified samples (i.e., all 0-1 cm layers of the 12 cores were combined, all 1-2 cm layers of the 12 subsamples were combined, etc.) for the entire darker (presumably Holocene) layer.

(2) After placement of the subsampling cores of all SAS-Oden projects, the remaining sediment from the darker-coloured (presumably Holocene) upper 10-20 cm layer was carefully removed from around each subsampling core as they were removed from the box core and combined into one bulk sample (**Figure 46D-F**).

Figure 46: Subsampling of a box core sample during the SAS-Oden expedition. (A) The subsampling tubes of the different SAS-Oden WPs and the Omics collaboration were gently pushed into the sample. When there was some resistance, this was most easily done with two persons and a piece of wood. (B) Subsampling tubes in the sample. (C) Removal of the front plate. (D) Subsampling tubes with bulk sample in-between. (E) Digging out the cores and saving the bulk sample. (F) Slicing the upper darker (presumably Holocene) layer from each core into 1-cm sections and combining the same sections from the replicate subsamples. (G) Sieving the sediment over a 300 µm sieve for sampling the otoliths. (A,B,C,D,E) © Pauline Snoeijs-Leijonmalm, (F) © Anna Hermanssen, (G) © SPRS

At two stations an extra box core was available for EFICA's otolith studies (**Table 20**) due to obliquely sampled sediment, which was not ideal for the other SAS-Oden WPs. These two extra samples were used for bulk sampling of otoliths *cf.* (2). All samples were sieved on deck with flowing freshwater through a 300 µm mesh sieve (**Figure 46G**). The sieved sediment samples were stored in jars for further analysis, including on-board microphotography.

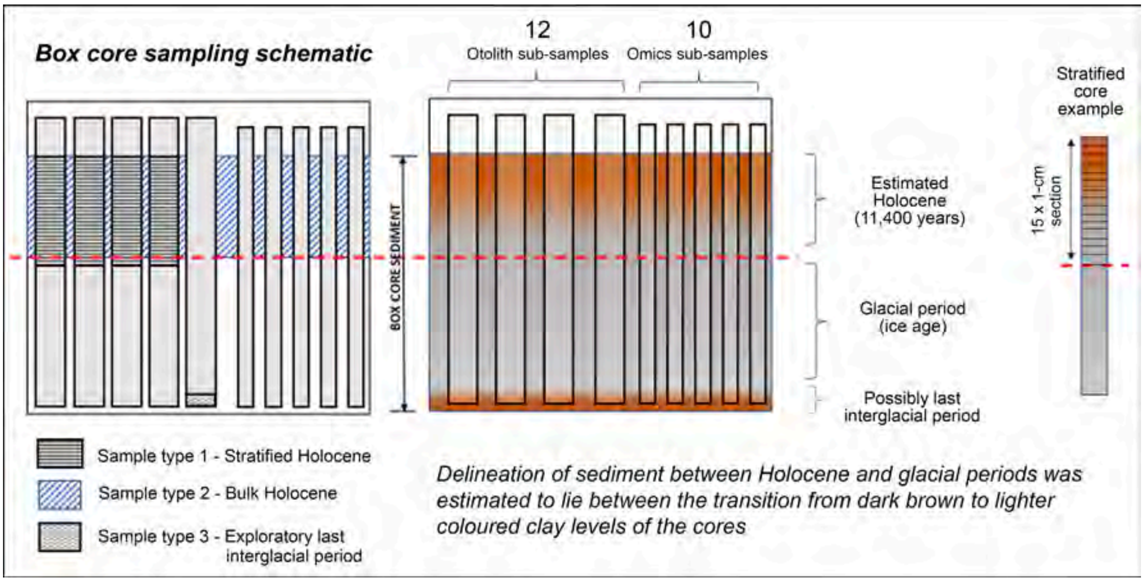

Figure 47: Box core sampling schematic for the three sediment sample types taken at each of the six box core stations of the SAS-Oden expedition. The bulk samples included all material from the dark brown coloured layer (presumably Holocene) in-between all cores, including the eDNA cores.

6.11.4 Otolith metadata summary

Altogether, eight box core samples from six stations were available for otolith sampling (**Table 20**). Six of these samples were shared with other SAS-Oden WPs.

Table 20: Successful box core sampling during the SAS-Oden expedition.

Device Operation	Station	Date UTC (start)	Time UTC (start)	Time UTC (end)	Time in water	Bottom depth (m)	No of samples
SO21_26-06	26	19-Aug	15:55	17:44	01:49	-1319	1
SO21_38-12	38	29-Aug	00:15	01:37	01:21	-1186	1
SO21_48-06	48	3-Sept	20:03	21:05	01:02	-1550	1
SO21_50-14	50	5-Sept	03:45	04:30	00:44	-889	1
SO21_50-15	50	5-Sept	06:03	06:43	00:39	-900	1
SO21_53-11	53	6-Sept	16:56	17:58	01:01	-1364	1
SO21_60-01	60	11-Sept	17:09	17:55	00:45	-719	1
SO21_60-02	60	11-Sept	18:31	19:10	00:38	-713	1
Total							**8**

Altogether, 315 otoliths were sampled from a total of 85 sediment samples, including both stratified and bulk samples. These otoliths seemed to belong to the two Arctic endemic gadoids polar cod (*Boreogadus saida*) and ice cod (*Arctogadus glacialis*) that could be distinguished on the basis of their respective morphologies (**Figure 48**). Further laboratory studies are necessary to confirm this.

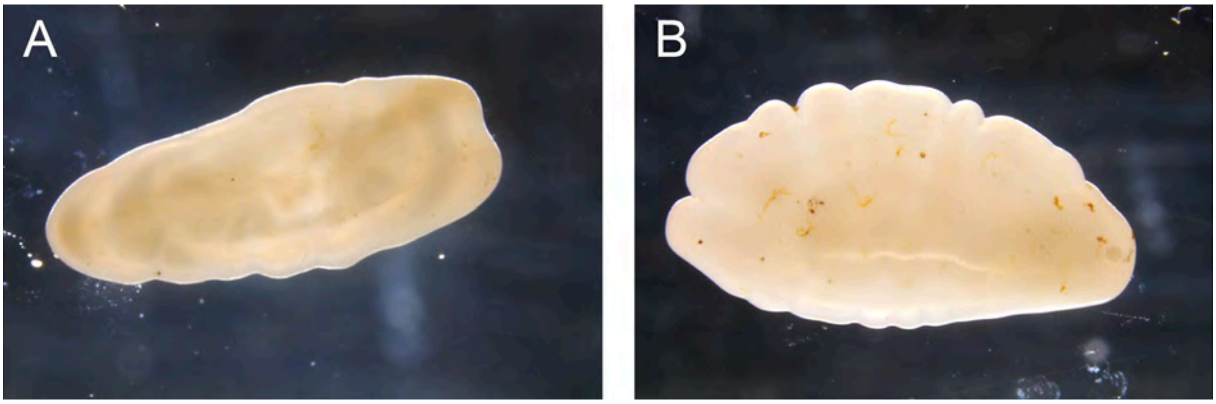

Figure 48: Microscopic images of otoliths with two different morphologies found during the SAS-Oden expedition. They were preliminary identified as belonging to (A) *Boreogadus saida* and (B) *Arctogadus glacialis*.

6.12 eDNA samples

6.12.1 Omics sampling from the SAS CTD rosettes

More than half of the scientists of the SAS-Oden expedition contributed to the sampling and filtering of the Omics water from the CTDs. The Omics CTD, with a rosette carrying 24 Niskin bottles of 12 L each, was deployed from stern (**Figure 49**). The CTD equipment consisted of a standard SeaBird SBE911 plus system with dual sensors to measure temperature, salinity and single sensors measuring pressure and oxygen.

After retrieval of the Omics CTD (**Figure 50**), 16 pre-marked carboys were filled with 12 L of water each (from one Niskin bottle). In this way, the carboys were easy to carry and samples could not get mixed up. Omics water was sampled from four depths while the rosette was coming up: the chlorophyll maximum in the water column around 15-30 m ("ChlMax", measured by a fluorometer on the rosette on € way down), 100 m, the temperature maximum in the water column around 300 m ("TempMax", measured by the CTD on its way down), and 1000 m (**Table 21**). The TempMax is in the Atlantic Water Layer where the DSL is found. In the same way, operating another CTD of the same model from the bow, Omics water was sampled from two additional depths: 2000 m, 3000 m, and 10 m above the seafloor, called "Bottom" (**Table 21**).

Figure 49: Preparations and deployment of the Omics CTD. (A) The blue 20-L carboys for sampling the Omics water are brought to the CTD container on the aft deck. (B) Carboys waiting for sampling the water. (C) The CTD is taken out of the container. (D) CTD prepared for deployment. (E) CTD ready for deployment. (F) CTD being deployed. (A) © Serdar Sakinan, (B,C,D,E,F) © Pauline Snoeijs-Leijonmalm

Figure 50: Retrieval of the Omics CTD. © Yannis Arck

Table 21: Summary of Omics water-column sampling during the SAS-Oden expedition.

Standard Omics depth	CTD	No of Niskin bottles
ChlMax	Stern	4
100 m	Stern	4
TempMax	Stern	4
1000 m	Stern	4
2000 m	Bow	2
3000 m	Bow	2
Bottom	Bow	2

6.12.2 Omics sampling from the SAS ice stations

More than half of the scientists of the SAS-Oden expedition contributed to sampling and filtering of the Omics water from the ice stations. This Omics water was taken from bulk samples that was used for measuring other biological SAS Core Parameters. The ice stations were selected either by observation from the bridge, or from the helicopter. We aimed to select ice floes that were representative of the wider area around the ship observed from the past 3-6 hours of steaming. Another important criterion was whether IB Oden was able to find a station site at which it could hold position in the ice without destroying the ice floe. This implied that thin ice floes (<1.2 m) could generally not be selected for sampling from the ship. From the helicopter, suitable sampling sites were identified from the air. The final selection was made after a polar bear survey, a test landing and local inspection of the potential sampling site. Helicopter ice stations were usually not situated more than 1 nautical mile away from IB Oden. All ship- and helicopter-based ice stations were protected by professional bear guards on the ice and a bear watch on the bridge.

Figure 51: Ice stations during the SAS-Oden expedition. (A) Scientists and polar bear guards on their way to sampling site close to the ship. (B) A crane-operated basket for bringing people from the ship to the ice and back. (C) Overview of an ice station very close to the ship. (D) Ice-coring. (E) Sampling water from ice habitats, i.e., water from melt ponds, brine, and sub-ice seawater. (A) © Hans-Jørgen Hansen, (B) © Julia Muchowski, (C) © Johan Wikner, (D) © Hauke Flores, (E) © Flor Vermassen

The sea ice was accessed from the ship either via the gangway or with a man-basket (**Figure 51**). On the ice, we carefully investigated several potential sampling sites with ice thickness drills. This inspection was necessary to ensure safety, and to choose ice of an appropriate thickness according to scientific criteria and available time to sample ice cores. Other criteria to select sampling sites were accessibility of melt ponds and the potential to sample snow. Sampling sites were also chosen in such a way that the impact from the ship (noise, grey water, thrusters) was minimized, based on distance and direction from the potential sampling site. The maximum distance of a sampling site from the ship largely depended on the visibility determining the ability of bear guards on the ice and on the bridge to detect polar bears soon enough to guarantee the safety of the scientists. Ice stations accessed from the ship were not placed more than 300 m away from IB Oden.

All ice station work for SAS core parameters followed the same design (**Figures 51, 52**). A square 5 x 5 m coring field was identified. Cross-wise walk ways allowed access to the inner area of the coring field. The outer corners of the coring field and the walking path between ship or helicopter and coring field were marked with red poles to ensure recognition in foggy conditions, especially when the floe needed to be temporarily abandoned for safety reasons. After the coring field was established, we selected a suitable site for the sampling of melt pond water. Before the sampling was started, we noted the general condition at the sampling sites in terms of ice coverage, ice type, air temperature, presence of ridges, snow depth, and ice temperature.

For ice coring, we worked in teams of 2-5 people working with 1-3 ice corers in parallel. Ice cores were sampled using 9-cm diameter Kovacs ice corers operated by battery-driven drilling engines. Before coring, we measured the snow depth above each individual ice core. After the ice core was removed, we measured ice thickness and freeboard (the difference between the surface of the ice and the water level in the borehole) using an ice-thickness gauge. Each ice core was placed in a cradle and individually photographed before further processing (**Figure 52**). Two individual ice cores were taken for temperature/salinity and nutrient measurements, respectively. Eight bulk samples, normally from 18 replicate cores, were taken at each SAS ice station from eight ice habitats for later subsampling for Omics and the other biological SAS Core Parameters (**Table 22**). Only at three of the 16 SAS ice stations the bulk samples were made up by less than 18 ice cores due to bad weather or safety concerns.

Ice-habitat water was sampled with a hand-operated membrane pump after the ice coring work was completed (**Figure 51E**). Water from the ice-water interface was sampled through a borehole about 10 cm below the lower ice margin to avoid contamination by brine from the borehole. For sampling brackish brine water, a new borehole was drilled in such a way that about 0.5 m of ice remained at the bottom of the borehole. This hole immediately filled up with brine water. Melt pond water was sampled about 10 cm below the melt-pond surface. To confirm that the sampled water was not contaminated by water from other sources, we constantly monitored the salinity during ice-habitat water sampling. Water samples were transported back to the ship as soon as possible to avoid freezing of the samples.

Snow was sampled close to the coring field by shovelling the rather loose layer into six 20 L plastic buckets with a metal shovel. Care was taken to not compact the snow in the buckets. Snow from all six buckets was pooled and melted in a bigger plastic container onboard the ship.

Table 22: Summary of Omics ice-habitat sampling during the SAS-Oden expedition.

Standard ice habitat	Sample description
Bottom ice	Lower 10 cm of 16 ice cores combined into one bulk sample
Centre-bottom ice	Lower half ice core minus 10 cm bottom ice of 8 ice cores combined into one bulk sample
Centre-top ice	Upper half ice core minus 10 cm top ice of 8 ice cores combined into one bulk sample
Top ice	Upper 10 cm of 16 ice cores combined into one bulk sample
Ice-seawater interface water	Pumped 40 L of water from the ice-seawater interface from boreholes through the ice into two 20-L carboys
Interstitial brackish brine water	Pumped 40 L of brine water from boreholes until 0.5 m above the ice-seawater interface into two 20-L carboys
Melt pond water	Pumped 40 L of melt pond water from 10 cm under the melt pond surface into two 20-L carboys
Snow	120 L of snow taken with a clean shovel into six clean 20-L buckets with lids

Figure 52: Ice coring during the SAS-Oden expedition. (A) A 5 x 5 m coring site has been selected and ice coring has started. (B) Measuring ice thickness through a coring hole. (C) Ice core in cradle with notebook, ice saw and drill. (D) Measuring a temperature profile in an ice core. (E) The longest ice core taken during the SAS-Oden expedition at Station 42, (F) Coring field after the coring had been completed. (A) © Johan Wikner, (B,C,D,E) © SAS-Oden sea-ice team, (F) © Pauline Snoeijs-Leijonmalm

The main challenge to perform successful ice stations was to guarantee safe working situations in unpredictable weather conditions. Fog occurred on almost all days during the SAS-Oden expedition. Even when a station was started in clear weather, upcoming fog often forced us to interrupt or abandon an ice station. The last ice station (Station 58) work was interrupted over-night due to a polar bear inspecting our sampling site (**Figure 53**). The reason why we were able to complete all 16 SAS ice stations at such a high success rate was that we gradually developed a highly flexible schedule, in which ship crew, scientists, bear guards and pilots were ready to perform sea ice work whenever possible, and interrupt whenever needed.

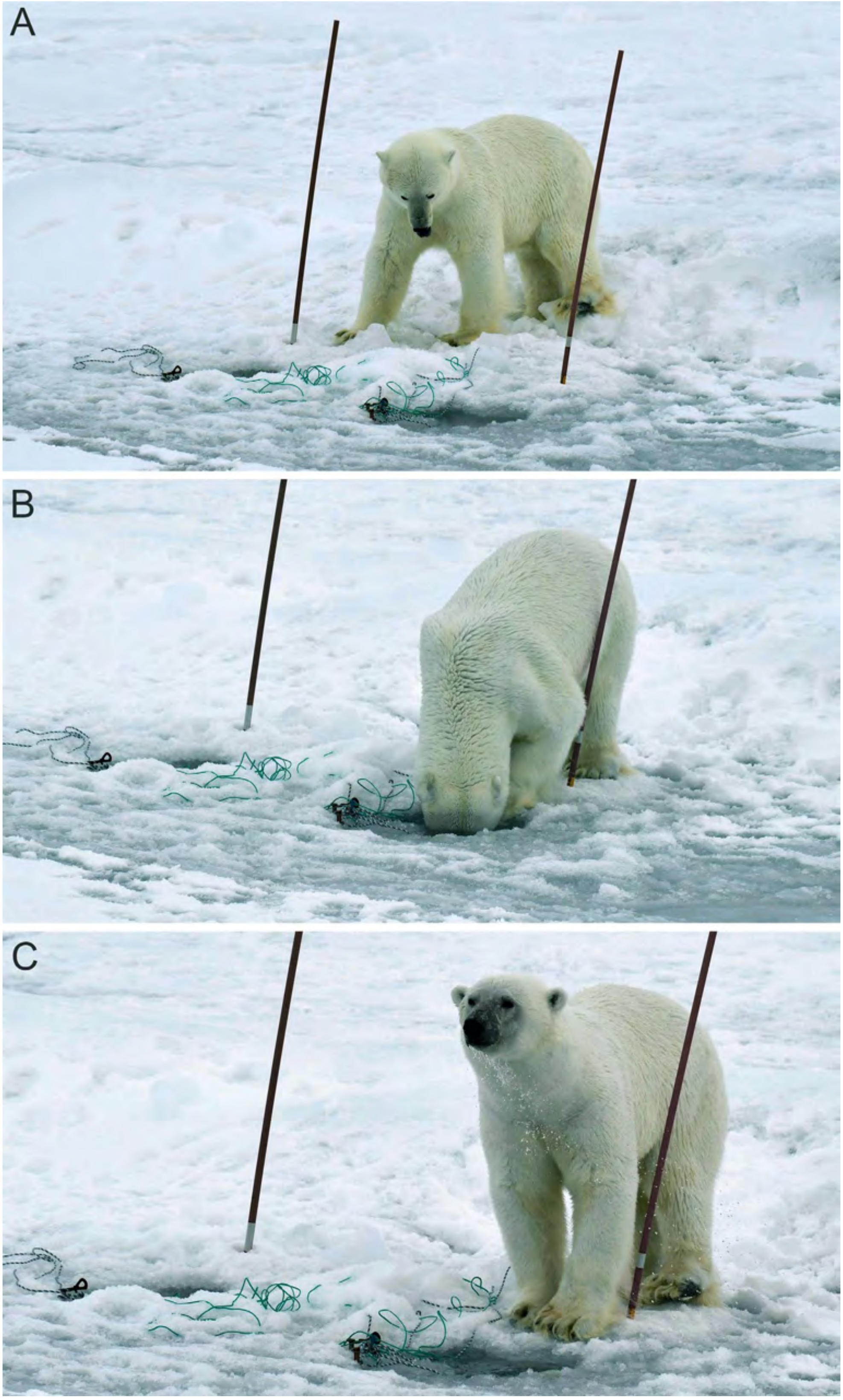

Figure 53: Polar bear inspecting our sampling site on Station 58 of the SAS-Oden expedition. (A,B,C) © Hans-Jørgen Hansen

Altogether, we sampled 1291 ice core sections for SAS core parameter measurements. Most of these sections were pooled to obtain sufficient material for all SAS Core Parameter measurements. The dominating ice type sampled during the SAS-Oden expedition was second-year ice (formed winter 2019/2020). However, it must be noted that the preconditions for selecting ship-based ice stations caused a bias towards thicker ice, which is why first-year ice (formed winter 2020/2021) was probably under-represented by our sampling. Between the Lomonosov Ridge and the north coast of Greenland, the proportion of multi-year ice increased. Overall, the measured mean ice thickness at the coring sites ranged between 112 to 262 cm, whereas the mean core length per station ranged between 106 and 263 cm (**Figure 54A**). The longest core had a length of 305 cm (**Figure 52E**). Station 42 had the thickest ice due to a high proportion of multi-year ice. The thinnest ice was present at Stations 6 and 56, both situated close to the marginal ice zone. Average snow depth ranged between 2 and 13 cm (**Figure 54B**), which is typical for the late summer season in the CAO. The average thickness of sea ice protruding above the water level (freeboard) varied between 9 and 30 cm.

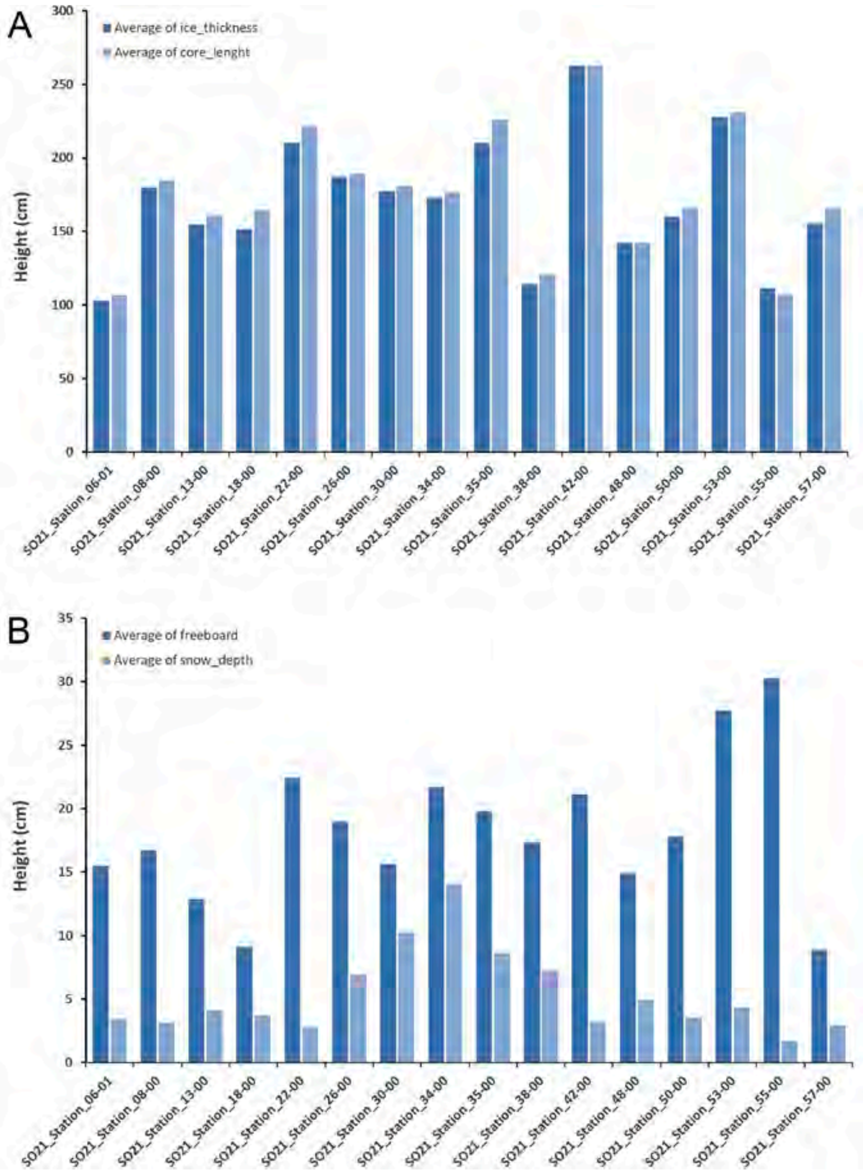

Figure 54: Summary of physical conditions at the 16 SAS ice stations where Omics samples were taken during the SAS-Oden expedition. (A) Average ice thickness measured with an ice-thickness gauge and average length of the sampled ice cores. (B) Freeboard and snow depth.

6.12.3 Omics sampling from the SAS box cores

The box core sampling and subsampling is described in **Chapter 6.11**. The 10 Omics subsamples taken from each box core consisted of sediment cores in white 50-cm long PVC tubes with an inner diameter of 3.8 cm (**Figure 55**). The tubes had been sterilized with 96% ethanol before sampling. Immediately after sampling, the outside of the tubes was cleaned and they were frozen at -80 °C as complete cores. Sub-sectioning of ca. 20 cm of the cores into 1-cm sections for RNA and DNA analyses will take place in the home laboratory.

Figure 55: Subsampling a box core sample for Omics sediment samples during the SAS-Oden expedition. (A) Ten Omics samples were taken from each box core. (B) The Omics samples covered both the darker and lighter-coloured sediment layers (presumably the Holocene and interglacial layers) *cf.* Figure 47. (A,B) © Pauline Snoeijs-Leijonmalm

6.12.4 Omics filtrations

Immediately after sampling, the water-column water (from the CTD) and the ice-habitat water (ice-seawater interface, brine, melt pond) was, as fast as possible, brought to the unheated laboratory containers on-board (**Figure 56**). These labs were unheated and illuminated with red light to not contaminate photosensitive cells by white light. In the labs, other scientists than those sampling from the CTD or on the ice had already prepared the peristaltic pumps with tubing and Sterivex filters with pore size 0.2 µm. This fast procedure was necessary for two reasons: (1) RNA (gene expression) changes very fast when environmental conditions change, and (2) the water in the carboys partly freezes when carboys with water are left outside, which may destroy cells. The ice-seawater interface, brine, and melt pond water were combined into bulk samples in 50-L containers. The RNA samples were filtered for max. 30 minutes and flash-frozen in liquid nitrogen within 45 minutes after sampling. The DNA samples were filtered after the RNA samples for max. 60 minutes and flash-frozen. Lastly, the viral DNA samples were – after iron chloride treatment – filtered from the filtrate of the RNA and DNA filters (still containing viruses) on a 142 mm diameter Omnipore PTFE membrane filter with pore size 1.0 µm filter on a membrane filter with pore size 0.8 µm as a support filter.

The two ice-habitat samples consisting of large volumes of sea ice (the centre-top and centre-bottom parts of the ice cores) were each combined in a 115-L container with taps in the heated "Main lab" (**Figure 56A**). The top and bottom ice-core sections remained in their 5-L containers until melted and were combined into two bulk samples (top and bottom) later before filtration. To each container, an appropriate amount of 0.2 µm filtered seawater was added (50 ml water per cm ice) to prevent cells from bursting and the ice left to melt in the laboratory. The snow from the buckets was also combined in a 115-L container with a tap, but no seawater was added because the organisms in the snow are adapted to freshwater conditions. The melting process took 30-40 hours. From the melted ice and snow only DNA samples (no RNA samples) were taken because RNA (gene expression) changes very fast when environmental conditions change and 36 hours of melting generates an enormous change of environmental conditions, so that analysing RNA would be unrealistic.

Figure 56: Omics filtrations in the red-light laboratory containers. (A) The 115-L containers for ice and snow. The snow was sampled in the white buckets and the top and bottom ice-core sections in the containers with red lids. Filtered seawater was available in the blue containers. (B) The 50-L containers with the ice-seawater interface, brine, and melt pond bulk samples. (C) collecting water from the bulk samples into 10-L bottles with scales to read the volume. (D) The peristaltic pumps used. (E) Filtration on Sterivex filters. (F) After the filtrations the peristaltic-pump tubing was rinsed with MilliQ water (A,B,C,D, F) © Pauline Snoeijs-Leijonmalm, (E) © SPRS

6.12.5 Omics metadata summary

During the SAS-Oden expedition, SAS Omics DNA samples were taken from 18 CTD stations and 16 ice stations (**Table 24**). Mostly, CTD stations and ice stations were located at the same geographical position (ice stations next to the ship) or within one nautical mile from the ship (ice stations by helicopter). In the beginning of the expedition this synchronisation was not possible due to logistical problems (e.g., the CTD winch broke).

Altogether, 896 SAS-Omics DNA filters (**Table 23**) and 598 SAS-Omics RNA filters (**Table 24**) were made during the expedition. From the filtrates of the Sterivex filters of the SAS DNA and RNA, 52 virus DNA filters were made (**Table 25**). These virus filters were treated in a different way to bind smaller particles with iron chloride and could have a higher affinity for small eDNA aggregates in the water. From extra CTD casts and extra ice-habitat samplings, 128 extra DNA and RNA samples were taken during the expedition as well (**Table 26**). Finally, the DNA samples include 60 sediment cores (60 x 20 sample sections of 1 cm).

Table 23: Overview of SAS-Omics DNA samples taken during the SAS-Oden expedition.

Ship station	Ice station	ChlMax	100 m	TempMax	1000 m (Station3=500 m)	2000 m	3000 m	4000 m or Sea bottom	Ice-seawater interface	Brackish brine	Melt pond	Top ice (10 cm)	Centre-top ice	Centre-bottom ice	Bottom ice (10 cm)	Snow	Total samples
3		4	4	4	4												16
	6								4	4	4	4	4	4	4		28
7		4	4	4	4	4	4	4									28
8	8	4	4	4	4	4		4	4	4	4	4	4	4	4	4	56
13	13	4	4	4	4	4	4	4	4	4	4	4	4	4	4		56
16		4	4	4	4	4	4	4									28
18	18	4	4	4	4	4	4	4	4	4	4	4	4	4	4		56
22	22	4	4	4	4	4	4	4	4	4	4	4	2	3	4	4	57
26	26	4	4	4	4			4	4	4	4	4	4	4	4	4	52
30	30	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	60
33	34	4	4	4	4	4		4	4	4	4	4	4	4	4	4	56
35	35	4	4	4	4			4	4	4	4	4	4	4	4	4	52
38	38	4	4	4	4			4	4	4	4	4	4	4	4	4	52
42	42	4	4	4				4	4	4	4	4	4	4	4	4	48
48	49	4	4	4	4			4	4	4	4	4	4	4	4		48
50	50	4	4	4				4	4	4	4	4	4	4	4	3	47
53	53	4	4	4	4			4	4	4	4	4	4	4	4		48
56	56	4	4	4	4	4		4	4	4	4	4	4	4	4	4	56
58	58	4	4	4	4			4	4	4	4	4	4	4	4	4	52
Total		72	72	72	64	36	24	68	64	64	64	64	62	63	64	43	896

Table 24: Overview of SAS-omics RNA samples taken during the SAS-Oden expedition.

Ship station	Ice station	ChlMax	100 m	TempMax	1000 m (Station3=500 m)	2000 m	3000 m	4000 m or Sea bottom	Ice-seawater interface	Brackish brine	Melt pond	Total samples
3		4	4	4	4							16
	6								4	4	4	12
7		4	4	4	4	4	4	4				28
8	8	4	4	4	4	4		4	4	4	4	36
13	13	4	4	4	4	4	4	4	4	4	4	40
16		4	4	4	4	4	4	4				28
18	18	4	4	4	4	4	4	4	4	4	4	40
22	22	4	4	4	4	4	4	4	4	4	4	40
26	26	4	4	4	4			4	4	4	4	32
30	30	4	4	4	4	4	4	4	4	4	4	40
33	34	4	4	4	4	4		4	4	4	4	36
35	35	4	4	4	4			4	4	4	4	32
38	38	4	4	4	4			4	4	4	4	32
42	42	4	4	4				4	4	4	4	28
48	49	4	4	4	4			4	4	4	4	32
50	50	4	4	4				4	4	4	4	28
53	53	4	4	4	4			4	4	4	4	32
56	56	4	4	4	4	4		2	4	4	4	34
58	58	4	4	4	4			4	4	4	4	32
Total		72	72	72	64	36	24	66	64	64	64	598

Table 25: Overview of SAS-Omics virus DNA samples taken during the SAS-Oden expedition.

Ship station	Ice station	ChlMax	TempMax	Ice-seawater interface	Brackish brine	Melt pond	Snow	Total samples
3		1	1					2
	6			1	1	1		3
7								0
8	8	1	1	1	1	1		5
13	13	1	1					2
16								0
18	18	1	1					2
22	22			1	1	1		3
26	26			1	1	1		3
30	30	1	1	1	1	1	1	6
33	34	1	1					2
35	35			1	1	1		3
38	38			1	1	1		3
42	42	1	1					2
48	49	1	1					2
50	50			1	1	1		3
53	53			1	2	2		5
56	56	1	1					2
58	58			2	1	1		4
Total		9	9	11	11	11	1	52

Table 26: Overview of extra DNA and RNA samples taken during the SAS-Oden expedition (from extra CTD casts and extra ice-habitat sampling).

Station number	Station type	ChlMax	TempMax	Ice-seawater interface	Brackish brine	Melt pond	Seawater tap in lab	Total samples
8	Ice					4		4
13	Ice					6		6
20	CTD		6					6
24	CTD	6						6
26	Ice			6				6
30	Ice				6			6
33	CTD		6					6
38	Ice			6				6
44	Tap						6	6
49	Ice				4			4
53	Ice					6		6
56	CTD	34						34
56	Ice					32		32
Total		40	12	12	10	48	6	128

6.13 Other ecosystem data

Many SAS Core parameters were measured or sampled for later analysis during the expedition by EFICA together with the 15 other SAS-Oden WPs or by other WPs alone. The raw data measured on board (e.g., ship data, meteorological data, CTD data, multibeam, sub-bottom profiler) is available at the Swedish National Data Service (SND; https://snd.gu.se/en). The metadata from the whole expedition, collected by all 16 SAS-Oden WPs (all projects, altogether 38 scientists), will be available at the NDS data service latest 30 April 2022, and all analysed data from the whole expedition on 1 November 2023.

The SAS Core Parameter data measured or sampled during the SAS-Oden expedition found relevant or possibly relevant for fish-stock modelling and assessment (**Table 27**) comprises the physical and chemical environment of the CAO fish, their prey and predators, as well as ecosystem productivity for assessing the carrying capacity of the investigated area of the CAO with respect to fish.

Table 27: Overview of the physical, chemical and biological SAS Core Parameters measured or sampled during the SAS-Oden expedition (possibly) found relevant or possibly relevant for fish-stock modelling and assessment.

Relevant SAS physical and (biogeo)chemical data	Relevant SAS biological data
- Seafloor depth	- Chlorophyll fluorescence
- Temperature	- Chlorophyll-a
- Salinity	- HPLC pigment composition
- Insolation (PAR)	- Virus density
- Dissolved oxygen	- Bacterial density
- Inorganic nutrients (NO_3/NO_2, PO_4, SiO_3)	- Microalgal density
- Dissolved Inorganic Carbon (DIC)	- Bacterial production and respiration
- CDOM fluorescence	- Primary production
- Dissolved Organic Carbon (DOC)	- Plankton respiration
- Particulate Organic Carbon (POC)	- Microbial $^{13}C/^{15}N$
- Particulate Organic N and P (PON, POP)	- Phytoplankton
	- Microzooplankton
	- Meiofauna in ice

7 RELEVANCE FOR FISH-STOCK MODELLING AND ASSESSMENT

7.1 Possibilities and limitations of the collected data

The data and samples collected during the SAS-Oden expedition (and the MOSAiC expedition) are intended to build a basis for future fish-stock modelling and assessment, including scenario building and socio-economic analyses, to understand the dynamics of the fish stocks in the changing Arctic environment.

These requirements for data delivery can be met by the EFICA Consortium through analysing the data and samples from both expeditions in the coming year (within SC07). However, it should be realised that appropriate data for performing "traditional" fishery assessment in the CAO cannot be delivered. This would include acoustic data *in combination* with quantitative trawling data on the fish community with fish species composition and fish size distributions, etc. Trawling is not possible under a thick sea-ice cover. Furthermore, we showed both on the MOSAiC (SC03) and the SAS-Oden (SC06) expedition that catching fish with hooks in the CAO is associated with an extremely low success rate. This only seems to work for Atlantic fish in the CAO (as shown during the MOSAiC expedition).

Fish-stock modelling based on the data collected within SC03, SC06 and SC07 would thus need to include an alternative way of modelling, relying on estimates of the potential abundance of fish as estimated by hydroacoustics, the abundance, biomass and quality of available fish prey, the ecology and population genetics of the juvenile polar cod and the Atlantic fish (potentially) entering the CAO, the sedimentary record of fish otoliths in the CAO, and the occurrence and distribution of eDNA.

Furthermore, it will in the future be possible to use, e.g., temperature reconstruction data in combination with modelled temperature fields in the whole Arctic Ocean to assess how likely fish are to spread to the CAO. The zooplankton data from the SAS-Oden expedition could be used to assess how much fish could be supported, given their known diet. Future scenario-building, e.g., using CMIP6 and ecosystem models to predict primary and secondary production in the future, and their impact on the carrying capacity of the CAO could be assessed through the temperature envelopes of the fishes in relation to prey biomass in CMIP6 future scenarios.

7.2 Summary of relevance

During the SAS-Oden expedition, the EFICA field scientists collected the samples and measurements listed in the SC06 Metadata Database (Files 4-9). They also contributed to collecting the SAS Core Parameters, and the EFICA Consortium has therefore access to EFICA-relevant physical, chemical and biological ecosystem data (**Table 27**) that – in combination with the EFICA-specific data (**Table 28**) – will allow for analyses (within SC07) to address the four research questions proposed for the mapping phase of the JPSRM for the Eurasian Basin of the CAO:

(1) What are the distributions of species with a potential for future commercial harvests in the High Seas portion of the CAO?
(2) What fish species are currently present in the High Seas portion of the CAO?
(3) What are the trophic linkages among fishes and between fishes and other taxonomic groups?
(4) What are the likely key ecological linkages between potentially harvestable fish stocks of the High Seas portion of the CAO and adjacent shelf ecosystems?

Since no fish samples were collected in the DSL of the CAO during the SAS-Oden expedition, despite numerous attempts with vertical nets, traps and lines, the eDNA samples have become all the more important for the EFICA studies in assessing fish diversity and distribution in the CAO.

Additionally, SAS Core Parameters for ecosystem productivity measured during the expedition, such as inorganic nutrients (NO_3/NO_2, PO_4, SiO_3), dissolved organic carbon (DOC), particulate organic N and P (PON, POP), chlorophyll-a concentrations, chlorophyll-a fluorescence, and bacterial and microalgal density and production (**Table 27**) can be directly linked to the EFICA fish and zooplankton data for fish-stock modelling and assessment. Similar data are available from the MOSAiC expedition. Measurements and samples for these parameters were taken by other projects of the SAS-Oden 2021 expedition(especially by WP7 and WP10), and the metadata will be available at the NDS data service latest 30 April 2022, and all analysed data from the whole expedition on 1 November 2023.

Table 28: Ecosystem parameters relevant for fish-stock modelling and assessment collected during the SAS-Oden expedition coupled to the SC06 Metadata Database. PELAGIC habitat = water column, SYMPAGIC habitat = ice-associated, nekton = actively swimming organisms (fish and squid). File numbers refer to the appropriate SC06 Metadata Database file.

SC06 Metadata database	Relevance for fish-stock modelling and assessment	Parameters	Data category
Logbook **File 1**	Necessary for data analysis	Date, time, geographical position, deployment times of sampling gear	EFICA-relevant SAS-Oden Core Parameters
SHIP data **File 2**	Necessary for data analysis	Date, time, geographical position, water depth, ship speed, wind speed	EFICA-relevant SAS-Oden Core Parameters
CTD metadata **File 3**	Physical and chemical living conditions for pelagic fish	Temperature, salinity, water depth, PAR, oxygen concentration	EFICA-relevant SAS-Oden Core Parameters
ACOUSTIC metadata **File 4**	Distribution of pelagic fish and zooplankton	Acoustic backscatter from fish and zooplankton	EFICA-specific data
OPTICAL metadata **File 5**	Food availability for pelagic fish indicates the potential for pelagic fish production	Distribution of zooplankton species and biomass	EFICA-specific data
ZOOPLANKTON metadata **File 6**	Food availability for pelagic fish indicates the potential for pelagic fish production	Community composition, biomass and nutritional quality of zooplankton	EFICA-specific data
FISH metadata **File 7**	Presence, distribution and ecology of sympagic fish	Length, weight, age, genetics, stomach contents, food-web structure, nutritional quality	EFICA-specific data
OTOLITH metadata **File 8**	Presence and distribution of fish today and in the past with climate change	Number, species, age, temperature reconstruction from sedimentary otoliths	EFICA-specific data
OMICS metadata **File 9**	Presence and distribution of fish, squid, and their prey and predators	eDNA sequences of fish, squid, zooplankton, and mammal species	EFICA-specific data

8 DATA OWNERSHIP AND STORAGE

8.1 Data ownership

Fieldwork on ship-borne expeditions targeting ecosystem science is highly collaborative by nature. In the case of the SAS-Oden expedition (as well as the MOSAiC expedition), this involved intense on-board collaboration between the EFICA scientists and a large interdisciplinary (physics-chemistry-biology) group of scientists not involved in EFICA. This collaboration is a great advantage because EFICA will have access to ecosystem data that never could have been measured and sampled by the EFICA scientists on the SAS-Oden expedition alone.

This construction has consequences for data ownership, but makes no essential difference for future data and sample analyses or fish-stock modelling and assessment. According to the data policy of the SAS-Oden expedition (**Annex 1**), data collected during the expedition and analysed from samples taken during the expedition must be publicly available latest on 1 November 2023 at the SND (https://snd.gu.se/en). This includes the EFICA-specific data because otherwise we would not have had access to the expedition since only scientists signing the SAS-Oden Research Data Management Policy were allowed to participate in the expedition. This arrangement guaranties that all data will be freely available to the EC for future modelling and assessment of potential fish stocks in the CAO, including the raw data.

For clarity about data ownership, two different data categories from the SAS-Oden expedition are available to EFICA before 1 November 2023 (**Table 28**): (1) "EFICA-specific" data and samples collected as additions to the SAS-Oden expedition by the EFICA scientists, i.e., exclusively within SC06. These (raw) data and samples thereby belong exclusively to the EC. (2) "EFICA-relevant SAS-Oden Core Parameters" collected during the SAS-Oden expedition by the EFICA scientists in collaboration with other scientists on-board.

The second category includes data owned by the Swedish Maritime Administration (e.g., ship position and speed) and the SPRS (data collected by the on-board instruments owned by the SPRS, e.g., the CTD data and the EK80 acoustic data). These data owned by Swedish Governmental authorities are already publicly available at the SND or will be soon (within 2022). Furthermore, the second category includes data and samples collected by EFICA in collaboration with other SAS-Oden WPs, e.g., the zooplankton multinet and bongo net samples and the Omics collaboration that involved sampling carried out by most of the research projects (ca. 25 people) on-board.

Thus, even if the EFICA scientists programmed, recorded data and calibrated the instruments, the EK80 acoustic raw data belong to the SPRS. These instruments are always running during all expeditions. However, through EFICA's participation in the expeditions and the EFICA scientist's programming and attending to the echosounder, EFICA has the exclusive right to analyse the ship's acoustic data for fish, zooplankton and their physical environment. Similarly, EFICA has the exclusive right to use the expedition's metagenomic data set for analysing the occurrence and abundance of fish, fish prey (zooplankton) and mammal predators.

8.2 Data and sample storage

All data collected during the SAS-Oden expedition were backed up on identical hard discs, and each of the four EFICA partner institutes (SU, SLU, AWI, WMR) brought home one copy. The fish, zooplankton and otolith samples were transported to the AWI and are kept there until analysis (within SC07).

9 THE SC06 MEDIA ARCHIVE

The SAS-Oden expedition received attention in public media mainly in Sweden. Altogether, 18 media items with relevance to SC06 were identified, and listed and linked in the SC06 Media Archive (**Table 29**). The media archive was last updated on 13 January 2021.

Table 29: The SC06 Media Archive.

Date	Media type	Medium	Language	Headline	Weblinks
210103	Swedish Radio	P4 Norrbotten	Swedish	Arktis marina ekosystem ska kartläggas	https://sverigesradio.se/artikel/7629789
210526	Governmental web site	Swedish Polar Research Secretariat	English	Synoptic Arctic Survey 2021	https://www.polar.se/expeditioner/synoptic-arctic-survey-2021/
210526	Governmental web site	Swedish Polar Research Secretariat	English	Leads expedition to the Arctic Ocean with icebreaker Oden	https://www.polar.se/en/news/2021/leads-expedition-to-the-arctic-ocean-with-icebreaker-oden/
210601	University website	Stockholm University	Swedish	Outforskat område mål för expedition till Arktis	https://www.su.se/nyheter/outforskat-område-mål-för-expedition-till-arktis-1.558463
210601	University website	Stockholm University	English	Research expedition to unexplored part of the Arctic	https://www.su.se/english/news/research-expedition-to-unexplored-part-of-the-arctic-1.558938
210701	Digital newspaper with focus on the sea	Deep Sea Reporter	Swedish	Hon ska forska på livet under Arktis sista is	https://www.deepseareporter.se/hon-ska-forska-pa-livet-under-arktis-sista-is/
210712	Governmental web site	Swedish Polar Research Secretariat	English	Press release: The icebreaker Oden conducts research in a hard-to-reach area	https://www.polar.se/en/news/2021/press-release-the-icebreaker-oden-conducts-research-in-a-hard-to-reach-area/
210716	Journal Swedish Maritime Administration	Sjörapporten 2021/2	Swedish	Oden till orörd arktisis	https://www.sjofartsverket.se/sv/om-oss/nyheter-och-press/reportage/oden-till-orord-arktisis/
210719	Swedish National TV	TV4 - Nyhetsmorgon	Swedish	Polarexpedition för klimatet: "Vill kartlägga ett helt annat ekosystem"	https://www.tv4.se/klipp/va/13351369/polarexpedition-for-klimatet-vill-kartlagga-ett-helt-annat-ekosystem
210726	Swedish National TV	TV4 - Nyhetsmorgon	Swedish	Nu kastar svenska isbrytaren loss mot Nordpolen: "Väldigt svajigt"	https://www.tv4.se/klipp/va/13352016/nu-kastar-svenska-isbrytaren-loss-mot-nordpolen-valdigt-svajigt
210817	Journal Swedish nautical organisation	Båtliv	Swedish	Isbrytaren Oden når Nordpolen för tionde gången	https://www.batliv.se/2021/08/17/isbrytaren-oden-nar-nordpolen-for-tionde-gangen/
210820	Swedish Radio	P4 Norrbotten	Swedish	Oden har lämnat hemmahamnen i Luleå för Nordpolen	https://sverigesradio.se/artikel/oden-har-lamnat-hemmahamnen-i-lulea-for-nordpolen
210923	Swedish National TV	SVT - Aktuellt	Swedish	Arktis isar smälter	svtplay.se/aktuellt
210924	Swedish National TV	TV4 - Nyhetsmorgon	Swedish	Forskaren tillbaka från Arktisexpedition - har studerat klimatpåverkan	https://www.tv4play.se/program/nyhetsmorgon/forskaren-tillbaka-från-arktisexpedition-har-studerat-klimatpåverkan-måste-ändra-hela-samhället/13364511
210925	Daily national newspaper	Dagens Nyheter	Swedish	Svenska forskare kartlägger Arktis för att undersöka effekter av klimatförändringarna	https://www.dn.se/sverige/svenska-forskare-kartlagger-arktis-for-att-undersoka-effekter-av-klimatforandringarna/
210930	University website	su.se	Swedish	Min slutsats är redan nu att havet i centrala Arktis måste skyddas	https://www.su.se/nyheter/min-slutsats-är-redan-nu-att-havet-i-centrala-arktis-måste-skyddas-1.575032
211001	Governmental web site	Polarnytt Polar.se	Swedish and English	Isbrytaren Oden tillbaka efter framgångsrik forskningsexpedition	https://trk.idrelay.com/2927/arc?q=b6f-91d&c=6af4a3c3a4
220107	Digital newspaper with focus on the sea	Deep Sea Reporter	Swedish	Bevis på fisk under Arktis sista is	https://www.deepseareporter.se/bevis-pa-fisk-under-aktis-sista-is/

10 THE SC06 METADATA DATABASE MANUAL

10.1 SC06 Metadata Database delivery

The SC06 Project Manager Pauline-Snoeijs-Leijonmalm was responsible for compiling the metadata and for producing the SC06 Metadata Database. This Database is delivered together with this SC06 Final Report and comprises nine EXCEL files (Database Files 1-9). The database lists all EFICA samples and measurements made during the SAS-Oden expedition that are thought to be relevant for sample elaboration, evaluation of the CAO fish-stock modelling and assessment, etc. in further SCs. Metadata summarise which data and samples were collected, but do not provide actual measurements or analytical results. Typical metadata from scientific field samples are, e.g., date, time, geographical position, ocean depth, or sampling depth.

The raw data measured on board (e.g., ship data, CTD data, multibeam, sub-bottom profiler) is available at the Swedish National Data Service (SND; https://snd.gu.se/en). The metadata from the whole expedition, collected by all 16 SAS-Oden WPs (all projects, altogether 38 scientists), will be available at this data service latest 30 April 2022, and all analysed data from the whole expedition on 1 November 2023. The data can be located by searching for "Synoptic Arctic Survey" or "Oden" in the SND database.

10.2 SC06 Metadata Database files

Database File 1: Logbook
This is the key file for all other files. It contains a complete record of all stations and device operations (sampling activities) performed during the SAS-Oden expedition 2021. A device operation is either a winch operation from the ship or an ice station. It includes exact date, time, geographical position, ocean depth and sampling device used for each of the 260 successful device operations performed during the expedition. This information is essential to link data from any measurement or sample with corresponding data from other samples and measurements taken at the same time and location.

Database File 2: SHIP data
This file contains date, time, geographical position, ship speed and wind speed measured by IB Oden for every 30 minutes during the entire expedition. The ship speed data can be used to calculate the track length of the expedition and different subsections of the track. This file was extracted from daily files with the same measured parameters for every five seconds since further analyses by EFICA do not need this high resolution.

Database File 3: SAS CTD metadata
This file contains the metadata for all 112 CTD casts performed during the expedition. The CTD measurements provide profiles of water depth, salinity, temperature, photosynthetic active radiation (PAR) and oxygen concentration. Various other sensors were attached to specific CTD casts as well (e.g., chlorophyll-a fluorescence, CDOM fluorescence), and are elaborated within different SAS-Oden projects. EFICA attached its WBAT and FishCam to specific CTD casts (see Database Files 4 and 5).

Database File 4: EFICA ACOUSTIC metadata
This file contains the metadata for the 49 WBAT acoustic profiles (19 stations) made with the CTD-mounted WBAT. Data from the ship-mounted acoustic equipment (EK80) were collected during the whole expedition: from leaving the Norwegian EEZ (29 July at ca. 18:30) until arrival in Helsingborg after the expedition (19 September).

Database File 5: EFICA OPTICAL metadata
This file contains the metadata for the FishCam video recordings from 15 CTD profiles (15 stations), and from 2 m under the sea ice at (3 stations), the 11 LOKI profiles (11 stations) and the 47 UVP profiles (30 stations).

Database File 6: EFICA ZOOPLANKTON metadata
This file contains the metadata for the 1271 zooplankton net samples taken during the expedition.

Database File 7: EFICA FISH metadata
This file contains the metadata for the four fish samples, and the 23 tissue subsamples from these fish, taken during the expedition.

Database File 08: EFICA OTOLITH metadata
This file contains the metadata for the >300 sedimentary otoliths sampled during the expedition.

Database File 9: SAS OMICS metadata
This file contains the metadata for the almost 3000 OMICS samples (DNA and RNA) taken during the expedition.

10.3 SC06 Metadata Database explanations

The detailed explanations of the metadata available in the SC06 Metadata Database are presented in **Table 30** as well as in the first EXCEL sheet of each Database File, named "Explanations".

Table 30: Overview of all parameters occurring in Database files 1-9, and their explanations.

Field	Explanation
General abbreviations	
UTC	Coordinated Universal Time, or UTC, is the primary time standard by which the world regulates clocks and time. It is within about 1 second of mean solar time at 0° longitude and is not adjusted for daylight saving time. It is effectively a successor to Greenwich Mean Time (GMT).
DD	Decimal degrees (DD) express latitude and longitude geographic coordinates as decimal fractions of a degree (on-line converter: e.g. https://www.pgc.umn.edu/apps/convert/)
DM	Degrees Minutes (DM) = Degrees Decimal Minutes (DDM) express latitude and longitude geographic coordinates as degrees and decimal fractions of a minute (on-line converter: e.g. https://www.pgc.umn.edu/apps/convert/)
DMS	Degrees Minutes Seconds (DMS) express latitude and longitude geographic coordinates as degrees, minutes and seconds (on-line converter: e.g. https://www.pgc.umn.edu/apps/convert/)
MB	Multibeam
SBP	Sub-bottom profiler
IBCAO	The International Bathymetric Chart of the Arctic Ocean, Version 4.1 (Jakobsson, M. et al., 2020, Sci Data 7, 176. https://doi.org/10.1038/s41597-020-0520-9). The IBCAO model is used for constructing seabed charts for the Arctic Ocean.
Coordinates for helicopter flights	For most helicopter flights the Logbook shows the geographical position as registered by the helicopter GPS, but in some cases this needed to be adapted with values from the ship's GPS. The helicopter GPS is handled by the pilot manually. Since he was occupied with lifting or landing this was sometimes forgotten and then the ship position when the helicopter lifted or landed was used. Usually, the helicopter landed on the ice very close to the ship (max. distance 1 nm). The scientists on the ice also had their own GPS, but these might show slightly different values. The ship and helicoipter GPS were well synchronized. The original helicopter log files are avialable in the database. For a reliable geographic position it should read in these files "AIS data were: 0 minutes old" above the position given in these helicopter log files (that means that the pilot pressed the button and the GPS value is OK, if it reads more than 0 minutes the GPS value is not OK)
Fail	Indicates that a winch operation went wrong and no data were obtained. Since these were recorded as device operations with a cast number, they are still in the list of device operations in this file. For the CTD (2x), LOKI (1x), and Multinet (1x) this was due to a connector or fuse or unfavourable drift, for the box corer this was due to rocks in the bottom (3x), and for the beam net (1x) and the MIK net (1x) conditions were too windy.
Database file 1 - Logbook	
EXCEL sheet "Summary of device operations"	
This sheet contains two summary tables of all device operations and a map of the sampling stations (**Figure 4** in this Report).	
EXCEL sheet "List of device operations"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition. A device operation is either a winch operation from the ship or an ice

	station. In the Logbook, the device operation is coupled to date, time, geographical position and ocean depth. Ice stations next to the ship are in the Logbook classified as sampling operations at the ship station while ice stations reached by helicopter each have their own station number. Single sampling activities within the ice stations (e.g., ice coring, long-line deployment) were not recorded in the Logbook; their sampling details are recorded in the respective metadata files. With the help of the time of each device operation, the ship's exact position, speed and wind conditions can be extracted from the ship data. During the SAS-Oden expedition, 260 successful device operations were carried out, 9 failed and 2 were short test CTD casts. The latter 11 operations are also included in the Logbook, which in total contains 271 device operations.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). NOTE that the SAS ice station at Station 30 was a "hybrid" station - it started as a helicopter station but ended as a ship station. The helicopter station was abandoned because of fog and the helicopter could not fly anymore that day as the fog remained. To not lose the station we went there with the ship and sampled the rest of the SAS ice cores and ice habitat water. This SAS ice station is classified as a device operation of Station 30 (SO21_30-18), even if the helicopter was involved. There was also an ice station next to the ship for project work at Station 30, which is classified as a separate device operation (SO21_30-17).
Cast	Cast number (1-19), a running number for each device operation performed at one station
Category	A short description of the sampling device (CTD, NET, etc.)
Description	A more informative description of the sampling device
AVER_depth(m)	The average of the measured depth at the start of the device operation and the measured depth at the end of the device operation (since the ship was drifting with the sea ice). The depth was measured with the multibeam and the EK80, but this was not done for each device operation to not disturb acoustic data collection. In the list of device operations in this file, the depth measurement of the nearest point in time is used if a depth measurement from the exact time was missing. There is also a modelled depth (IBCAO model) given in the list of device operations, but this depth could deviate from the measured depth, especially on the Greenland shelf which was not well-covered by the IBCAO model.
TIME_min	The duration of the device operation as logged by Carlos Castro and Caroline Bringensparr on the bridge for winch operations from the ship, by Sara Johansson and Per Lundgren for helicopter stations, and by Pauline Snoeijs-Leijonmalm for ice stations
AVER_lat(DD)	The average of the latitude at the start of a device operation and the latitude at the end of a device operation
AVER_lon(DD)	The average of the longitude at the start of a device operation and the longitude at the end of a device operation
START_date	Start of the device operation, date (yyyy-mm-dd)
START_UTC	Start of the device operation, time (UTC, hh:mm) - for ice stations reached by helicopter when the helicopter landed on the ice
START_lat(DD)	Latitude (DD) at the start of a device operation, for ice stations reached by helicopter when the helicopter landed on the ice
START_lon(DD)	Longitude (DD) at the start of a device operation, for ice stations reached by helicopter when the helicopter landed on the ice
START_lat(DM)	Latitude (DM) at the start of a device operation, for ice stations reached by helicopter when the helicopter landed on the ice
START_lon(DM)	Longitude (DM) at the start of a device operation, for ice stations reached by helicopter when the helicopter landed on the ice
START_m(model)	Modelled depth (m) at the start of a device operation using the IBCAO model (only ship data)
START_m(meas)	Measured depth (m) at the start of a device operation using the multibeam/EK80 (only ship data)
END_date	End of the device operation, date (yyyy-mm-dd)
END_UTC	End of the device operation, time (UTC, hh:mm) - for ice stations reached by helicopter when the helicopter departed from the ice
END_lat(DD)	Latitude (DD) at the end of a device operation, for ice stations reached by helicopter when the helicopter departed from the ice
END_lon(DD)	Longitude (DD) at the end of a device operation, for ice stations reached by helicopter when the helicopter departed from the ice
END_lat(DM)	Latitude (DM) at the end of a device operation, for ice stations reached by helicopter when the helicopter departed from the ice
END_lon(DM)	Longitude (DM) at the end of a device operation, for ice stations reached by helicopter when the helicopter departed from the ice
END_m(model)	Modelled depth (m) at the end of a device operation using the IBCAO model (only ship data)
END_m(meas)	Measured depth (m) at the end of a device operation using the multibeam/EK80 (only ship data)
EXCEL sheet "Details helicopter flights"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number and the cast number. In this tab all device operations are one or two helicopter flights. In the case of two helicopter flights, sampling equipment was deployed with the first flight and harvested with the second flight.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	The station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). NOTE that the SAS ice station at Station 30 was a "hybrid" station - it started as a helicopter station but ended as a ship station. The helicopter station was abandoned because of fog and the helicopter could not fly anymore that day as the fog remained. To not lose the station we went there with the ship and sampled the rest of the SAS ice cores and ice habitat water. This SAS ice station is classified as a device operation of Station 30 (SO21_30-18), even if the helicopter was involved. There was also an ice station next to the ship for project work at Station 30, which is classified as a separate device operation (SO21_30-17).
Cast	Cast number (1-19), a running number for each device operation performed at one station

Project	SAS-Oden project for which the helicopter flight was performed
Description	Purpose of the helicopter flight
Flight nr	Flight number as registered in the expedition helicopter logbook
Heli crew	Pilot (Ted), helicopter technician (Mats)
Scientists	The scientists on-board the helicopter
Date	Date of the helicopter flight
Time_on_ice	Time between landing and departure of the helicopter on the ice
UTC_dept_ship	Time at which the helicopter departed from the ship
Lat_dept_ship	Latitude at which the helicopter departed from the ship - measured by the helicopter GPS
Lon_dept_ship	Longitude at which the helicopter departed from the ship - measured by the helicopter GPS
Lat_dept_IBCAO	Latitude at which the helicopter departed from the ship - measured by the IBCAO GPS on the bridge
Lon_dept_IBCAO	Longitude at which the helicopter departed from the ship - measured by the IBCAO GPS on the bridge
UTC_land_ice	Time at which the helicopter landed on the ice
Lat_land_ice	Latitude at which the helicopter landed on the ice - measured by the helicopter GPS
Lon_land_ice	Longitude at which the helicopter landed on the ice - measured by the helicopter GPS
UTC_dept_ice	Time at which the helicopter departed from the ice
Lat_dept_ice	Latitude at which the helicopter departed from the ice - measured by the helicopter GPS
Lon_depart_ice	Longitude at which the helicopter departed from the ice - measured by the helicopter GPS
UTC_land_ship	Time at which the helicopter landed on the ship
Lat_land_ship	Latitude at which the helicopter landed on the ship - measured by the helicopter GPS
Lon_land_ship	Longitude at which the helicopter landed on the ship - measured by the helicopter GPS
Lat_land_IBCAO	Latitude at which the helicopter landed on the ship - measured by the IBCAO GPS on the bridge
Lon_land_IBCAO	Longitude at which the helicopter landed on the ship - measured by the IBCAO GPS on the bridge
EXCEL sheet "Details SAS ice stations"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number and the cast number. In this tab all device operations are one or two helicopter flights.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	The station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). NOTE that the SAS ice station at Station 30 was a "hybrid" station - it started as a helicopter station but ended as a ship station. The helicopter station was abandoned because of fog and the helicopter could not fly anymore that day as the fog remained. To not lose the station we went there with the ship and sampled the rest of the SAS ice cores and ice habitat water. This SAS ice station is classified as a device operation of Station 30 (SO21_30-18), even if the helicopter was involved. There was also an ice station next to the ship for project work at Station 30, which is classified as a separate device operation (SO21_30-17).
Cast	Cast number (1-19), a running number for each device operation performed at one station
Description	Description of the ice station
START_date	Start date of the ice station - for end date, see "List of device operations"
START_UTC	Start time of the ice station - for end time, see "List of device operations". The time given in this tab is the time noted by the people on the ice and may deviate from that noted on the bridge.
Lat(DD)	Latitude noted by the people on the ice, may deviate from that noted on the bridge
Lon(DD)	Longitude noted by the people on the ice, may deviate from that noted on the bridge
Collector_device	Ice corer, membrane pump operated by hand for water or shovel for snow
Sample	Ice core number or type of ice habitat (brackish brine, ice-seawater interface, melt pond, snow)
EXCEL sheet "Notes for acoustics"	
Date	Date (yyyy-mm-dd)
UTC	Time (hh:mm)
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	The station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations).
Lat(DD)	Latitude in decimal degrees
Lon(DD)	Longitude in decimal degrees
Lat(DM)	Latitude in decimal degrees
Lon(DM)	Longitude in decimal degrees
Depth(m)_IBCAO	Modelled depth according to the IBCAO model: International Bathymetric Chart of the Arctic Ocean, Version 4.1 (Jakobsson, M. et al., 2020, Sci Data 7, 176. https://doi.org/10.1038/s41597-020-0520-9)
Depth(M_MB/EK80	Measured depth (m) at the start of a device operation using the multibeam/EK80
Notes	Notes made on the bridge regarding changes in the settings of the EK80, multibeam and sub-bottom profiler
Database file 2 – SHIP data	
EXCEL sheet "Ship data"	
DateTime	Date and UTC (Coordinated Universal Time)
Oden.Ship.LatitudeDegrees	Decimal degrees (DD) express latitude and longitude geographic coordinates as decimal fractions of a degree
Oden.Ship.LongitudeDegrees	Decimal degrees (DD) express latitude and longitude geographic coordinates as decimal fractions of a degree

Oden.Ship.HDT	Ship heading (degrees)
Oden.Ship.COG	Ship course over ground (degrees)
Oden.Ship.SOG	Ship speed over ground (knots)
Oden.Met.WindSpeedRel	Ship-relative wind speed, from the two wing-mounted ship anemometers (m/s)
Oden.Met.WindDirectionRel	Ship-relative wind direction, from the two wing-mounted ship anemometers (direction FROM, wind on bow is 0)
Oden.Met.WindSpeedTrue	True wind speed, from the two wing-mounted ship anemometers (m/s)
Oden.Met.WindDirectionTrue	True wind direction, from the two wing-mounted ship anemometers (direction FROM, northerly wind is 0)
Database file 3 – SAS CTD metadata	
EXCEL sheet "CTD metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Category	A short description of the CTD (deep = full depth, shallow = upper 20-200 m, 1000 m = 1000 m if the station was deeper than 1000 m and to full depth if the station was shallower than 1000 m)
Description	A more informative descriptor of the CTD
AVER_lat(DD)	The average of the latitude at the start of the CTD cast and the latitude at the end of the CTD cast
AVER_lon(DD)	The average of the longitude at the start of the CTD cast and the longitude at the end of the CTD cast
AVER_depth(m)	The average of the station depth at the start of the CTD cast and the station depth at the end of the CTD cast (in m)
START_date	Start of the CTD cast, date (yyyy-mm-dd)
START_UTC	Start of the CTD cast, time (UTC, hh:mm)
END_date	End of the CTD cast, date (yyyy-mm-dd)
END_UTC	End of the CTD cast, time (UTC, hh:mm)
TIME_min	The duration of the CTD cast (in minutes)
Database file 4 – EFICA ACOUSTIC metadata	
EXCEL sheet "WBAT metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
CTD_type	Code for the main purpose of the CTD
CTD_purpose	Short description of the main purpose of the CTD
START_date	Start of the CTD cast, date (yyyy-mm-dd)
Transducer	38 kHz (targeting fish) or 333 (targeting zooplankton and physics)
START_UTC	Start of the CTD cast, time (UTC, hh:mm)
END_UTC	End of the CTD cast, time (UTC, hh:mm)
START_lat(DD)	Latitude (decimal degrees, DD) at the start of the CTD cast
START_lon(DD)	Longitude (decimal degrees, DD) at the start of the CTD cast
START_lat(DM)	Latitude (degrees minutes, DM) at the end of the CTD cast
START_lon(DM)	Longitude (degrees minutes, DM) at the send of the CTD cast
TIME_CTD_min	The duration of the CTD cast (in minutes)
TIME_WBAT_min	The duration of the WBAT recordings (in minutes)
Ping_interval	The intereval between the ultrasonic pulses sent into the water column by the WBAT through the transducer
Mission	Name of the mnission plan that programs the WBAT
Range_m	Range setting of the WBAT (in m)
Power	Power setting of the WBAT
START_bw_kHz	Bandwith at the start of the mission (in kHz)
END_bw_kHz	Bandwith at the end of the mission (in kHz)
Pulse_msec	Length of the unlrasonic pulse (in milliseconds)
Comments	Any comment written down concerning the operation of the WBAT
Database file 5 – EFICA OPTICAL metadata	
EXCEL sheet "FishCam metadata"	

Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Description	Description of the cast (instrument used)
START_date	Start of the device operation, date (yyyy-mm-dd)
Deployment	How the FishCam was deployed (attached to a CTD or on a rope in an ice hole 2 m under the sea ice)
Light colour	White or red
Rec time (min)	Video recording time (in minutes)
Nr of video files	Number of all video recordings made during one deployment
Total data size (GB)	Gigabytes of data collected during one deployment
EXCEL sheet "LOKI metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Description	Description of the cast (instrument used)
START_date	Start of the device operation, date (yyyy-mm-dd)
START_UTC	Start of the device operation, time (UTC, hh:mm)
END_UTC	End of the device operation, time (UTC, hh:mm)
TIME_min	Duration of the device operation (in minutes)
Max_depth(m)	Maximum depth reached by the LOKI (in m). Maximum deployment depth was 1000 m, but shorter at stations shallower than 1000 m
EXCEL sheet "UVP metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Description	Description of the cast (instrument used)
START_date	Start of the device operation, date (yyyy-mm-dd)
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
PIQv sorted	The PIQv Team of EcoTAXA has finished sorting the data. The new project is called "uvp6_sn00126-hf_20210801_sas_21_PIQv"
EcoTAXA uploaded	The data have been uploaded to EcoTAXA
Need work merging)	These data still need to be merged into one profile
Database file 6 – EFICA ZOOPLANKTON metadata	
EXCEL sheet "ZOOPLANKTON metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
START_date	Start of sampling, date (yyyy-mm-dd)
START_UTC	Start of sampling, time (hh:mm)
START_depth(m)	Depth at which the net started to collect zooplankton or deployment depth of the trap
END_depth(m)	Depth at which the net stopped collecting zooplankton

Category	A short description of the sampling device
Description	A more informative description of the sampling device
Collector	The actual net from which the sample originates (mostly more than one net were attached to the sampling device
Sample_ID	The unique sample number for each sample
Sample_type	The analysis for which the sample was collected: taxonomy (community composition and biomass), CN (including stable isotopes), lipids (including fatty acids)
Sample_content	The species in the sample, zooplankton = community sample
Nr_individuals	Number of individuals in the sample (not indicated for community samples)
Database file 7 – EFICA FISH metadata	
EXCEL sheet "FISH metadata"	
Device_Operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
START_date	Start of sampling, date (yyyy-mm-dd)
START_UTC	Start of sampling, time (UTC)
START_depth(m)	Depth at which the net started to collect zooplankton or deployment depth of the trap
END_depth(m)	Depth at which the net stopped collecting zooplankton
Collector	A short description of the sampling device
Fish_sample_ID	ID number of the fish sample
Sample_type	The actual net from which the sample originates (mostly more than one net were attached to the sampling device
Sample_content	The species in the sample (all were polar cod, *Boregogadus saida*)
Nr_individuals	Number of individuals in the sample (not indicated for community samples)
Length_tot(mm)	Total lengh of the fish = from nose to end of tail fin (in mm)
Length_std(mm)	Standard lengh of the fish = from nose to start of tail fin (in mm)
Tissue_type	Fish tissue type (fin clip, gonad, liver, stomach, muscle, otoliths)
Tissue_sample_ID	ID number of the tissue sample
Database file 8 – EFICA OTOLITH metadata	
EXCEL sheet "OTOLITH metadata - stratified"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Box_core_nr	A running number for each box corer
START_date	Start of the box corer deployment, date (yyyy-mm-dd)
START_UTC	Start of the box corer deployment, time (UTC, hh:mm)
Time_min	Duration of the box corer deployment (in minutes)
DEPTH_m	Depth of the box corer deployment (in m)
Sample_ID	The unique sample number for each sample
Slices_cm	The depth of the slices sampled, starting at the sediment surface (in cm)
Slices_nr	The number of slices combined into one sample per box core
Otolith_preservation	Medium in which the otoliths are kept (water or ethanol)
Sediment_sampled_by	EFICA scientist who sampled the stratified sediment
Otoliths_sampled_by	EFICA scientist who sampled the otoliths
EXCEL sheet "OTOLITH metadata – bulk"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Leg	Leg number (1-7). The SAS-Oden expedition consisted of seven legs, i.e. when the ship's direction was fundamentally changed after a station, a new leg started.
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Box_core_nr	A running number for each box corer
START_date	Start of the box corer deployment, date (yyyy-mm-dd)
START_UTC	Start of the box corer deployment, time (UTC, hh:mm)

TIME_min	Duration of the box corer deployment (in minutes)
DEPTH_m	Depth of the box corer deployment (in m)
Sample_ID	The unique sample number for each sample
Bulk_depth(cm)	The depth of the bulk sediment sampled, starting at the sediment surface (in cm)
Taken_where	Description from where the bulk sediment sample was taken
Note	Note made during sampling
Otolith_preservation	Medium in which the otoliths are kept (water or dry)
Sampled_by	EFICA scientist who sampled the sediment and the otoliths
Database file 9 – SAS OMICS metadata	
EXCEL sheet "Sterivex DNA metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Sample_ID	The unique sample number for each sample
Sampling_date	Sampling date (yyyy-mm-dd)
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Habitat	Depth in the water column (in m) or ice habitat type (see Cruise Report)
Sampling_occasion	CTD or ice station
Filtration_date	Filtration date (yyyy-mm-dd)
Start_vol(mL)	Volume in the water container before filtration (in mL)
End_vol(mL)	Volume in the water container after filtration (in mL)
Volume(mL)	Water volume filtered (in mL)
Start_filtr(UTC)	Start of filtration, time (UTC, hh:mm)
End_filtr(UTC)	End of filtration, time (UTC, hh:mm)
Filtration_time	Duration of filtration (hh:mm)
Filtered_by	Scientist(s) who fitered the sample
Comments	Any comments about the filtration process
EXCEL sheet "Sterivex RNA metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Sample_ID	The unique sample number for each sample
Sampling_date	Sampling date (yyyy-mm-dd)
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Habitat	Depth in the water column (in m) or ice habitat type (see Cruise Report)
Sampling_occasion	CTD or ice station
Filtration_date	Filtration date (yyyy-mm-dd)
Start_vol(mL)	Volume in the water container before filtration (in mL)
End_vol(mL)	Volume in the water container after filtration (in mL)
Volume(mL)	Water volume filtered (in mL)
Start_filtr(UTC)	Start of filtration, time (UTC, hh:mm)
End_filtr(UTC)	End of filtration, time (UTC, hh:mm)
Filtration_time	Duration of filtration (hh:mm)
Filtered_by	Scientist(s) who fitered the sample
Comments	Any comments about the filtration process
EXCEL sheet "Sterivex extra DNA+RNA metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Sample_ID	The unique sample number for each sample
Sampling_date	Sampling date (yyyy-mm-dd)
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Habitat	Depth in the water column (in m) or ice habitat type (see Cruise Report)
Sampling_occasion	CTD or ice station
Start_sampl(UTC)	Start of field sampling, time (UTC, hh:mm)
End_sampl(UTC)	End of field sampling, time (UTC, hh:mm)
Sampling_time	Duration of fieöld sampling (hh:mm)
Filtration_date	Filtration date (yyyy-mm-dd)
Start_vol(mL)	Volume in the water container before filtration (in mL)
End_vol(mL)	Volume in the water container after filtration (in mL)
Volume(mL)	Water volume filtered (in mL)
Start_filtr(UTC)	Start of filtration, time (UTC, hh:mm)

End_filtr(UTC)	End of filtration, time (UTC, hh:mm)
Filtration_time	Duration of filtration (hh:mm)
Filtered_by	Scientist(s) who fitered the sample
Comments	Any comments about the filtration process
EXCEL sheet "Virus DNA metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Sample_ID	The unique sample number for each sample
Sampling_date	Sampling date (yyyy-mm-dd)
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Habitat	Depth in the water column (in m) or ice habitat type (see Cruise Report)
Sampling_occasion	CTD or ice station
Start_sampl(UTC)	Start of field sampling, time (UTC, hh:mm)
End_sampl(UTC)	End of field sampling, time (UTC, hh:mm)
Sampling_time	Duration of field sampling (hh:mm)
Filtration_date	Filtration date (yyyy-mm-dd)
Iron_incub(min)	Minutes of iron incubation
Start_filtr(UTC)	Start of filtration, time (UTC, hh:mm)
End_filtr(UTC)	End of filtration, time (UTC, hh:mm)
Filtration_time	Duration of filtration (hh:mm)
Volume(mL)	Water volume filtered (in mL)
Filtration_speed	End of filtration, time (UTC, hh:mm)
Nr_filters	Number of filters made
Storage_box	Running number of the storage box
Filtered_by	Scientist who fitered the sample
Comments	Any comments about the filtration process
EXCEL sheet "Sediment DNA metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Sample_ID	The unique sample number for each sediment core of 4 cm in diameter
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Box_core_nr	A running number for each box corer
START_date	Start of the box corer deployment, date (yyyy-mm-dd)
START_UTC	Start of the box corer deployment, time (UTC, hh:mm)
TIME_min	Duration of the box corer deployment (in minutes)
DEPTH_m	Depth of the box corer deployment (in m)
Nr_replicates	The number of replicate cores
EXCEL sheet "Aerosol DNA metadata"	
Device_operation	A code consisting of the expedition abbreviation (SO21 = SAS-Oden 2021), the station number (1-60) and the cast number (a running number for each device operation performed at one station), providing a unique code for each scientific sampling operation carried out during the SAS-Oden expedition.
Sample ID	The unique sample number for each sample
Station	Station number (1-60). The SAS-Oden expedition included 60 sampling stations. These stations were reached by ship (36 stations) or by helicopter (24 stations). All stations in this file are ship stations during an ice station longer than 24 hours.
Cast	Cast number (1-19), a running number for each device operation performed at one station
Sampling_occasion	Ice station
Sample_category	Type of sample (here aerosols on filter)
Sample	Aerosol sample or blank (kept in lab)
Start_samp(date)	Start of aerosol sampling (yyyy-mm-dd)
End_samp(date)	Sampling date (yyyy-mm-dd)
Start_pump(UTC)	Start time of the aerosol pump (UTC, hh:mm)
End_pump(UTC)	End time of the aerosol pump (UTC, hh:mm)
Pump_hrs	Number of hours the pump was on
Pump_min	Number of minutes the pump was on
Start_vol(m3)	Start volume of the pump (in m3)
End_vol(m3)	End volume of the pump (in m3)
Volume(m3)	Volume of air pumped over filter (in m3)
Vol/min	Volume of air pumped over filter per minute (in m3/min)
Vol/hr	Volume of air pumped over filter per hour (in m3/hour)
Start_temp_in(oC)	Start temperature in the lab (in oC)

End_temp_in(oC)	End temperature in the lab (in oC)
Start_Rh_in(%)	Start relative humidity in the lab (in %)
End_Rh_in(%)	End relative humidity in the lab (in %)
Start_p_in(mbar)	Start air pressure in the lab (in mbar)
End_p_in(mbar)	End air pressure in the lab (in mbar)
Start_tempout(oC)	Start temperature outside (in oC)
End_temp_out(oC)	End temperature outside (in oC)
Start_Rh_out(%)	Start relative humidity outside (in %)
End_Rh_out(%)	End relative humidity outside (in %)
Start_p_out(mbar)	Start air pressure outside (in mbar)
End_p_out(mbar)	End air pressure outside (in mbar)
Comments	Any comments about the sampling process

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