6. ECOSYSTEM LEG 2

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A comprehensive summary of the ecosystem measurements during all 5 cruise legs will be published in the *Special Feature: The Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC)* of the scientific journal *Elementa: Science of the Anthropocene* (https://online.ucpress.edu/elementa/collection/269/Special-Feature-The-Multidisciplinary-Drifting)

Objectives

The objectives of the Ecosystem Consortium Group are stated in the respective chapter, under the “Background” section of the Cruise Report Leg 1.

Work at sea

In order to achieve the goals of the Ecosystem Consortium Group, including project specific research, the participants of Leg 2 took over the activities established by Team Eco during Leg 1 and implemented further sample collection and project specific work.

Weekly program

Initially, the weekly work program set out during leg 1 was followed during leg 2 as well. Briefly, this started with coring field work on Monday, followed by ice core sample processing and analysis (as required) on Tuesday and Wednesday. Thursday and Friday were dedicated to water column work, Nets and CTD deployments. Saturday was dedicated to carry out nets towed by the ROV, to complete work that was not achieved during the previous two days and also for project specific work. Finally, Sunday was taken for rest till noon, with the remaining of the day occupied in closing the work of the week and preparations for the week ahead. The weekly work included maintenance of the CTD ice hole, which required 3-5 hours (as needed), 4 times per week (Monday, Tuesday, Wednesday and Saturday), and 3-5 persons (as required and/or as available) from the Eco and Ocean Teams. At the time, the CTD hole was covered by a wooden lid, which required crew and crane time to remove it from the hole, and an in situ circulating water pump to keep water moving in the hole and prevent freezing on the surface. This lid and pump however, were not enough to keep the hole from partially freezing from one day to the next, therefore needing regular maintenance.

As it was, this weekly program was not found efficient for our 6 team member configuration, with 5 members also being responsible for delivering project specific work, due to: 1) the time invested by the crew for swapping cables for CTD and Nets; 2) preparation of the CTD shelter also as a shelter for net catch retrieval (1 and 2 resulted in a heavy work load for the crew); 3) not having enough time to process net catches in between net deployments, 4) the time spent maintaining the CTD hole open prior to water column work and 5) timing not suitable for the implementation of project specific work.

Starting as a “preventive” measure due to forecast on week 4 of Leg 2 (week of 19 MOSAiC) indicating temperatures being lower than -30°C, under which crane operations cannot be conducted, work with nets was moved to the Tuesday and Wednesday. As the week progressed, team members responsible for Net tows, found this to be a more convenient and efficient way to achieve the Net’s sampling program, since focus could be given to working with the catch over Thursday and Friday and there was no longer a conflict with ROV net sampling on Saturday. If and when required, extra net deployments were then possible on either Thursday, Friday or Saturday. This also allowed more flexible time for project specific work.

Almost in parallel and with the initiative taken by the Eco and Ocean Teams, with help from Team BGC, the lid covering the CTD ice hole was replaced by a tent (similar to that in Ocean City and ROV hut). The use of the tent and a heater inside to keep the interior only few degrees above 0, in combination with the water pump used to keep water from freezing ‘only’ when the hole was left uncovered during CTD and Net deployments, provided a more efficient way to keep the ice hole open. We discovered that keeping the pump on when the tent and heater were in place appeared to remove heat from the water’s surface causing freezing on the edges of the hole. From then on, maintenance was required only once per week (typically Mondays) and it could be done by 2 persons working for 2 hours. More thorough maintenance was carried out, but just once per month, thus allowing more time to focus on the science. The use of the tent did not require crew and crane time, allowing us an earlier start of the water column work (both, CTD and Nets). Additionally, the tent functioned as a shelter for retrieving net catches, thus avoiding the need of the CTD-Shelter and crew time to prepare it for work with nets. The tent was also then used by other scientists who required to pump large amount of water from surface or deeper in the water column, without them, their equipment and their samples being exposed to the extreme cold. In **Figure 6.1**, we present images to illustrate the difference between using a wooden lid to cover the CTD ice hole and the tent.

The changes described above yielded a more efficient and convenient way to achieving the weekly program, not only for scientific work, but also for the ship's crew. Therefore, from then onwards, this weekly program was adopted.

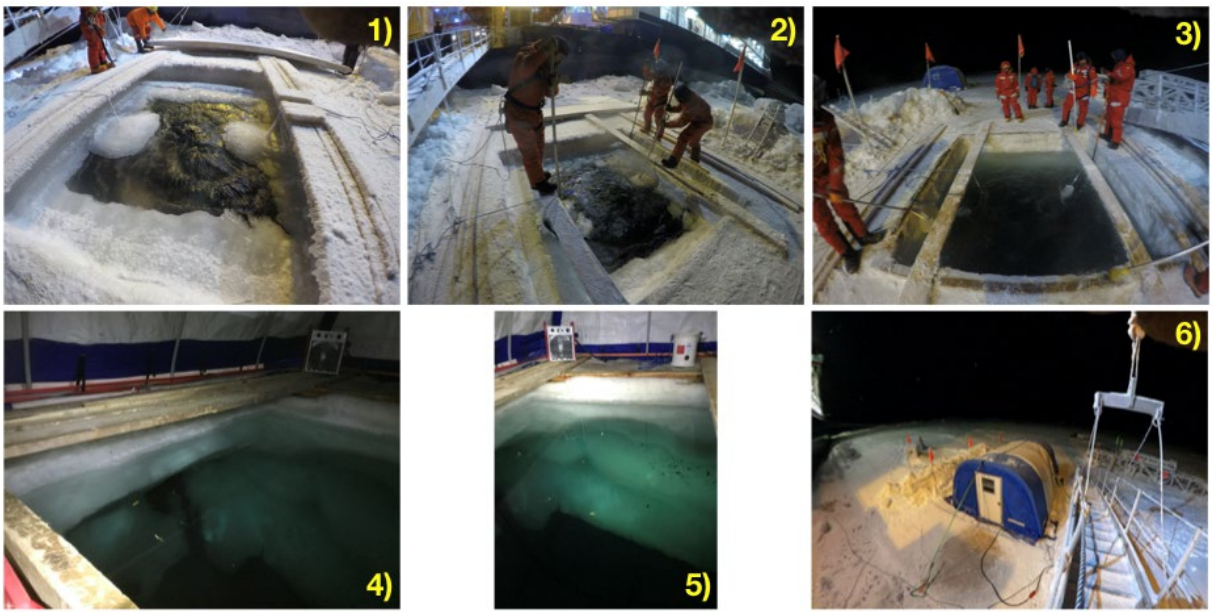

Figure 6.1. Photos showing: 1) the wooden lid used to cover the CTD ice hole and the typical ice cover growth of 2-3 days, it also shows the effect of the submergible pump used to keep the ice from growing; 2) scientist maintaining the hole; 3) the ice hole cleared after 50 man-hours; 4 and 5) the ice hole covered by a weatherhaven tent with a heater inside; 6) CTD tent view from the Polarstern deck.

Water column and sea ice discrete sampling

Sample collection, sample processing and analysis, from ice coring, CTD and Net deployments was distributed among team members according to expertise. Each member was responsible for preparations of the respective sample collection and also for keeping logs associated with such samples/variables. A master sample log was created for ice coring and CTD related work. This log has been sent to the Eco Team coordinators for distribution to other members and it was also placed in the respective Event ID folders within the MOSAiC Central Storage (MCS). Nets derived log sheets were scanned and also placed in the respective Event ID folders within the MCS.

A total of 8 visits to the coring site were done, with only one visit (on the second week of leg 2) not being possible due to the opening of a lead which rendered the site inaccessible. Planning of Polarstern CTD casts and actual deployments were done in coordination with Team Ocean, with only occasional help from BGC Team members. Net deployments were planned and executed by the two Team Eco zooplankton experts. CTD deployments and associated sample collections summarised in **Table 6.1**. Given crane operations are not possible when ambient temperatures are lower -30°C, some casts had to be postponed, modified or cancelled, as indicated in Table 6.1.

Following from the report of Team Eco Leg 1, **Table 6.2** summarises the so called "core parameters" collected by the Eco Team on Leg 2. To avoid repetition, further details regarding water column and sea ice coring sampling details, please refer to the respective sections of the Team Eco Leg 1 cruise report.

For further detailed concerning water column and sea ice work, please refer to Chapters/sections 5 and 7.4 of Leg 1 Cruise Report.

Table 6.1. CTD deployments and samples collected during Leg 2. Symbols are as follows: (•) Cast from the depth of the temperature maximum 'T_{max}' (~250 m) up to the surface (~2 m) for Total DNA and Total RNA; (◊) Deep Cast, from 10 m (~4300 m) above the sea floor up to the surface for DIC, nutrients, nitrate isotopes, DOC, CDOM, Chl-a, HPLC, DNA, FCM, light microscopy, BBP and DMSP; (⊗) Cast from the T_{max} to the surface for projects μARC and CN; (∅) Cast from 1000 m to the surface for POC, PON, BSi, CSIA and some cases for the HAVOC project and grazing experiments.

Date	Cast 1	Device Operation	Cast 2	Device Operation
26.12.2019	•	PS122/2_17-39 CTD_SBE9plus_321	◊	PS122/2_17-41 CTD SBE9plus_321
27.12.2019	⊗	PS122/2_17-64 CTD_SBE9plus_321	∅	PS122/2_17-68 CTD_SBE9plus_321
02.01.2020	•	PS122/2_18-32 CTD_SBE9plus_321	◊	PS122/2_18-34 CTD SBE9plus_321
03.01.2020	⊗	PS122/2_18-57 CTD_SBE9plus_321	∅	PS122/2_18-74 CTD_SBE9plus_321
09.01.2020	•	PS122/2_19-55 CTD_SBE9plus_321	◊	PS122/2_19-56 CTD SBE9plus_321
10.01.2020	⊗	PS122/2_19-76 CTD_SBE9plus_321	∅	PS122/2_19-77 CTD_SBE9plus_321
16.01.2020	•	PS122/2_20-45 CTD_SBE9plus_321	◊	PS122/2_20-46 CTD SBE9plus_321
17.01.2020	⊗	PS122/2_20-71 CTD_SBE9plus_321	∅	PS122/2_20-73 CTD_SBE9plus_321
23.01.2020	•	PS122/2_21-64 CTD_SBE9plus_321	◊	PS122/2_21-65 CTD SBE9plus_321
24.01.2020	⊗∅ Casts not possible due to temperatures being lower than -30°C.			
30.01.2020	•	PS122/2_22-42 CTD_SBE9plus_321	◊	PS122/2_22-47 CTD_SBE9plus_321
31.01.2020	⊗∅ Combined cast at lower vertical resolution implemented because crane operations were restricted due to temperatures being lower than -30°C. PS122/2_22-63 CTD_SBE9plus_321			
06.02.2020	•	PS122/2_23-46 CTD_SBE9plus_321	◊ Postponed due to winch problems.	
07.02.2020	----------	----------	◊	PS122/2_22-63 CTD_SBE9plus_321
10.02.2020	⊗	PS122/2_24-2 CTD_SBE9plus_321	∅	PS122/2_24-4 CTD_SBE9plus_321
20.02.2020	•	PS122/2_25-52 CTD_SBE9plus_321	◊	PS122/2_25-54 CTD_SBE9plus_321
21.02.2020	⊗	PS122/2_25-71 CTD_SBE9plus_321	∅	PS122/2_25-73 CTD_SBE9plus_321

Final notes

- During Leg 2, Team Eco helped setting up equipment that was not fully assembled during Leg 1. During the last stages of Leg 2, including during the hand over/transition to Leg 3, we completed the assemblage of the glass filtration units needed to process DOC/DON, CDOM, POC Isotopes and DOM solid phase extraction (SPE).
- We also installed the new titration system for dissolved oxygen Winkler determinations that Team Eco Leg 3 brought onboard and together with one member of Leg 3, we helped setting up the method.

- Primary production measurements during Leg 2 were limited due to the time involved for sample processing in combination with other duties of specific personnel to conduct the assays in the radioisotope container.
- Running of the AUTO-FIM was limited during leg 2 because of system malfunctions partially due to much lower temperatures as previously experienced in the bow thruster room.
- Onboard analysis of chlorophyll-*a* was planned, but not possible to execute during leg 2 due to the lack of calibration standards for calibrating on board fluorometers.
- Thanks to the help of Mario Hoppmann (Team Ocean), a sensor package prepared by Daniel Scholz (Eco Team), was deployed at the dark site as part of FRAM (Frontiers in Arctic Marine Monitoring) activities and in support of Ecosystems science (i.e., ice coring site under ice waters). This sensor package consisted of one ISUS nitrate sensor, a SAMI pH sensor, a SAMI pCO2 sensor, and Eco-PAR sensor, an Eco-Triplet (chl-fluorescence, backscatter and CDOM) and a SBE37-ODO CTD-O2 sensor, with a battery pack to last for one year, all assembled in a custom-made frame. This sensor package was deployed at 5 m under the ice with the aim to generate high temporal resolution measurements. The package deployment was reinforced to sustain moderate pressure, it was anchored into the surrounding ice and it also had flotation spheres. The original plan was to retrieve data once per week during ice coring activities. However, data retrieval did not take place during leg 1. During the transition between Leg 1 and Leg 2, we were informed the package was close to a forming lead and a ridge, and access was to the site was limited then. Once Leg 2 started, the location of the sensor package was unknown. During Leg 2 and thanks to the help and interest of Team Ocean, two missions to locate the package were launched. Although the coordinates and potential new location were estimated, by the time the search party arrived on site, heavy snow fall covered the whole area and searching for the package under dark conditions was not straightforward. Several hours on two separate occasions were spent looking for the package. Unfortunately, due to lack of time, no further search trips to locate the package were possible. If the package anchors, floating spheres and strengthened rope hold, it may become visible and/or easier to locate once the Polar day starts later on the drift campaign.

Table 6.2. Ecosystem coordinated core variables.

Ecosystem Core Variables	**Environments & Resolution**	**Method**	**Location: Polarstern and coring sites**	**Leg 2 Summary**
Macronutrients (nitrate, nitrite, ammonium, phosphate, silicic acid, DON, DOP)	Water: 17 depth horizons Sea ice: every 5 cm	Colorimetric using a SEAL-Analytical AA3 Auto-analyzer TN/TP (frozen, onshore only)	Weekly, with additional shallow casts from Ocean City.	Collected from the deep cast (17 depths; from 10 m above the seafloor to surface). Samples from Ocean City were collected by Team Ocean and Ellen Damm (BGC).
Dissolved Oxygen (DO)	Water	Winkler titration	Weekly	*Not collected due to broken equipment.*
Carbonate chemistry (TA, DIC)	Water: 14 -17 depth horizons Sea ice: every 10 cm	Coulometry & TA titration using a VINDTA	Weekly	Collected from the deep cast.

DOC/DOM concentration and characterization; CDOM	Water: 6 - 10 depth horizons Sea ice: 0-5, 5-10, then every 10 cm	Solid phase extraction (onboard) FT-ICR-MS	Weekly	GF/F pre-filtered DOC and CDOM samples collected from full depth cast; 0.2 micron PES pre-filtered DOC samples collected from FYI and SYI samples; DOM SPE not conducted.
Oceanic particle size spectra and distributions;	Water column only; Sensor mounted on CTD-rosette package	Optical - Underwater Vision Profiler (UVP): Polarstern rosette only	Weekly	Activated on all CTD casts
Particulate carbon, nitrogen, and biogenic silica (POC, PON, BSi)	Water column only	elemental analyzer Spectrophotometry Wet-alkaline method	Weekly	Collected from 1000 m cast; 10 depths for POC/N, 7 depths for BSi, 1 depth for CSIA.
Chlorophyll a	Water: 6 depth horizons Sea ice: 0-5, 5-10, then every 10 cm	Fluorometry	Weekly	Collected, but unable to process onboard during Leg 2 due to missing standard for fluorometer calibration. Samples stored frozen at -80°C.
Pigment Biomarkers	6 depth horizons; total onto GF/F filter	High Performance Liquid Chromatography (HPLC)	Weekly	Collected and stored; standard depths.
Prokaryotes (Bacteria and Archaea)	6 – 11 depth horizons	Flow cytometry (FCM) DNA/RNA sequencing Eco-Omics suite	Weekly	FCM samples collected and preserved; not run onboard DNA and RNA samples collected from standard depths in upper 300 m and additional collections at 4 depths ≥ 500 m
Eukaryotic microbes (protists)	6-11 depth horizons	Flow cytometry (FCM) DNA/RNA sequencing Eco-Omics suite Light microscopy	Weekly	FCM samples collected and preserved; not run onboard DNA and RNA samples collected from standard depths in upper 300 m and additional collections at 4 depths ≥ 500 m. Additionally hand-net tows integrated upper 20 m, near weekly from Ocean City.
Meso/Macrozooplankton	Multinet: [2000-1000-500-200-50-0 m] Ring nets: 53µm (0-200m), 150µm (:0-200m, 200-2000m) and 1000 µm,(0-1000m) ROV nets (0,10, and 50m_	Multinet Midi LOKI ROV Net Ring nets	Weekly	Refer to section 6.x for details
Primary productivity (NPP) Dark carbon fixation	Water: 3 depth horizons Ice: 1 horizon, 2 ice types [bottom only]	14C-bicarbonate tracer 24 hr incubation		Irregularly conducted on leg 2; 3 depths for column casts, and 1-2 bottom sections of FYI and SYI.
Net community production (NCP)	Seawater intake ~10 m depth horizon	MIMS; O2/Ar measurements	Continuously	During Leg 2, the MIMS was looked after by Ellen Damm (Team BGC).
Bacterial productivity (BP)	Water: 10 depth horizons Ice: 4 horizons	3H-leucine tracer 24 hr incubation	Weekly	Conducted from Thursday cast and ice cores, FYI and SYI.

Preliminary (expected) results

Given the fact that there are multiple Principal Investigators behind the science concerning specific samples and given the fact that nearly all of the Eco Team work onboard focused on sample collection, the availability of results and data resides with the PIs responsible. In cases where analyses were done onboard (e.g., inorganic nutrient measurement), final data sets will be available upon completion of the expedition, since data quality controls need to be assessed globally. In some other cases, when results derived from biological assays, their availability also resides on the PIs responsible.

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). All sample collection and raw data from analyses were logged in the MCS in accordance with MOSAiC data management requirements. Similarly, once available, participants will submit data sets to the PANGAEA data repository as agreed by signing the data management policy document.

6.1 ECOSYSTEM SCIENCE: ZOOPLANKTON ECOLOGY AND BIOLOGY

Objectives

The objectives for the zooplankton studies are included in the following overall Ecosystem Team objectives:

1. Characterize the spatial distribution of sympagic and planktonic biomass (e.g., ice algae, phytoplankton, microbes, micro-, meso- and macro-zooplankton) and determine their biodiversity. Quantify the energy flow and elemental (C, N, O, P) and compound specific (e.g. amino acids, fatty acids) cycles in the ice/ocean ecosystem. Special focus will be on the energy flow and the elemental and compound-specific cycles within the sea ice and pelagic communities, and the linkages between the two communities through the quantification of important biological rate processes. Important processes include primary production (new and regenerated), microbial respiration and remineralization, micro-zooplankton feeding and growth, and mesozooplankton feeding, respiration, growth, and reproduction.
2. Determine standing stocks and distributions of microorganisms and animals in relation to physical conditions (ice, stratification, water masses, etc.) to evaluate the physical-biological interactions that impact production, pelagic retention and vertical export.
3. Determine nutrient fluxes, organismal abundance and biomass of important components of the ecosystem (e.g. ice algae, phytoplankton, zooplankton). Relate these properties to behavioral (e.g. vertical depth preferences and diel or ontogenic vertical migration) and life history (e.g. reproductive timing and overwintering strategies) patterns.

Work at Sea

Sampling Schedule:

We began zooplankton sampling for Leg 2 on January 19, 2020 and for the first three weeks we continued on the same schedule as Leg 1 - conducting net hauls in conjunction with CTD sampling on Thursday, Friday, and Saturday. The Saturday sampling proved difficult because it conflicted with the ROV net sampling and so we needed to split our efforts

between the ship and the ROV site to complete the work. At the beginning of week 4, there were predictions that cold weather would limit sampling from the ship later in the week and so the Captain suggested we move the water column sampling earlier in the week. We moved the net sampling to Tuesday/Wednesday, but there were conflicts with the CTD sampling and so the CTD sampling could not be changed. The new schedule allowed us to complete the zooplankton sampling at the ship in two, instead of three days, gave us additional time to process the nets on Thursday and Friday, and we no longer had a conflict with the ROV net sampling on Saturdays. In addition, the crew was much happier with new arrangement as it reduced the need to move the CTD shelter on and off the ice between net and CTD casts and also reduced the 12-hour day on Thursdays to a normal workday for them. And most importantly, this gave us more flexibility to complete our work when equipment malfunctioned, cold weather cancelled operations, or an extra net haul was needed for experiments. As a result, we were able to complete the full suite of measurements in each of the remaining weeks.

Weather:
Upon arrival on the Dranitsyn, we learned for the first time that the Polarstern's crane, which was being used for deployment of the CTD and nets from the ship, could not be used when temperatures fell below -30 °C. We were worried that this could severely hamper our sampling as some instruments could only be used from the ship and net sampling from Ocean City had not been tested and would be greatly restricted because of scheduling. In the end, we did loose several days to cold weather, but because of the flexibility in the schedule we were able to complete the cancelled casts later in the week and completed the full suite of measurements for each week.

Sampling Gear:
General: Zooplankton sampling gear were deployed with the Polarstern's crane and winches through a hole in the ice on the starboard side of the ship. The maintenance of the CTD/net hole is described earlier in this section. Prior to the start of water column sampling for the day, the heater was removed and the tent was lifted by 4 to 6 scientists and moved off the hole away from the ship with the tent door about 2 to 3 meters away facing the hole. The heater was replaced in the tent and the pump turned on in the hole to circulate water. The pump remained on for the entire period that the tent was removed, except for short periods when gear was being deployed or recovered. At the end of the day, the tent was moved over the hole and the heater placed back inside on a low setting and the tent left until the next sampling day.

All sampling gear were lowered from the surface and raised vertically from the designated sampling depth at a speed of 0.5m/s. Upon reaching the surface, nets were rinsed with buckets of surface water from the hole while they were being lifted into the air to make sure the nets were clean and all organisms were collected in the cod-ends. The cod-ends were quickly pulled into the heated tent while still attached to the nets to prevent freezing and processed. For samples that were to be preserved immediately without pre-sorting (Multinet and 53-µm ring net), the cod-ends were removed and rinsed into small 1-L Kautex jars and placed into a cooler. For samples to be processed for biochemical or genetic variables, the cod-end was diluted in 3 or 4, 4-L jars that were half-filled with surface seawater and then placed in the cooler. If a gut DNA subsample was to be taken (150-µm ring nets), the cod-end was first rinsed into a large beaker and subsampled with a small 150-µm mesh and the mesh rinsed into a sample container with 96% ETOH. The remainder of the sample was then distributed between the large jars. The cooler was then brought onto the ship for further processing. Sample processing in the tent was done with the aid of a headlamp; only red light was used if a portion of the catch was to be used for rate processes measurements.

Multinet Midi (5 nets, 150-µm, 0.25 m^2, 2000-1000-500-200-50-0 meter sample depths): Multinet samples were collected from the 5 depth strata at weekly intervals to determine the meso/macrozooplankton abundance, community composition, and vertical distribution. The samples were preserved in 4% formaldehyde for later analysis. In Addition, samples for total mesozooplankton biomass were taken on two occasions with the Multinet. The contents of each of the five nets was size-fractionated (>1000 µm, 1000-500 µm, <500 µm), filtered onto pre-weighted GFF filters and frozen at -20°C.

Ring Nets (53-µm, 0.25 m^2; 150-µm, 1m^2; and 1000-µm, 1m^2): Three different ring nets were deployed during Leg 2: The smaller 53-µm mesh net collected large microzooplankton and small mesozooplankton in the upper 200 meters; the large 150-µm net collected meso- and macrozooplankton in primarily two separate intervals (2000-200 and 200-0 m); and the 1000-µm net was used to collect large meso- and macrozooplankton from the upper 1000 m. An opening/closing mechanism with mechanical messenger was used to close the net at 200 m for the 2000-200 m net haul. The 53- and 1000-µm nets were preserved in 4% formaldehyde for later enumeration at home laboratories, and the 150-µm net frozen at -80 °C, so samples could be used for later biochemical and genetic analysis. Target species were presorted from both the 150- and 1000-µm nets for biochemical and genetic analysis, and subsamples were occasionally taken from the 150-µm net for gut DNA analysis.

ROV Net (150- and 10-µm nets; 0, 10, and 50 m sample depths): The under-ice zooplankton community was studied in cooperation with the ROV team of the ICE group (see ROV section 4.5). The ROV net consisted of a large 150-µm net bag and a small phytoplankton/gypsum net (10-µm mesh size). Plastic lamellas on top of the net frame were used to scrape organisms off of the underside of the sea ice. During leg 2, we observed the presence of platelet ice at the bottom of the ice. Collecting platelets together with the zooplankton catch resulted in damaging the organisms. We thus decided to dive close to the ice, but without scraping the bottom of the ice in order to preserve the catch in better condition. Samples were preserved in 4% formaldehyde after pre-sorting target organisms for biochemical and genetic variables. Occasional extra net samples were taken for gut DNA.

LOKI (Lightframe On-sight Key species Investigation): The LOKI, an optical plankton recorder, was deployed on a weekly basis to 1000 m. The LOKI was equipped with a 150-µm net to concentrate the plankton and a high-resolution camera taking up to 19 pictures sec^{-1}. The underwater computer unit of the LOKI system immediately detected zooplankton organisms and particles in the pictures and saved clippings of these objects. In addition, a set of sensors measured depth, water temperature, conductivity, oxygen and fluorescence, which will allow us to relate zooplankton distributions to the environmental conditions. The LOKI was used to perform a 24-hour study during week 22. The original plan was to have a LOKI at 9am, 3pm 9pm and 3am. Unfortunately weather conditions were not favourables, with temperatures oscillating above and below -30°C, so we could conduct only one measurement at 3pm and one 12 hours later, at 3am. The LOKI started having some problems during week 22. Overheating of the LOKI computer during data download caused a connection failure thus impeding the complete download of the data. At the end of the leg 2, together with the electrician on board we opened the LOKI computer and dowloaded the data while keeping the temperature low with the aid of a ventilator. The LOKI now has enough free memory to accommodate leg 3 and leg 4 data.

UVP (Underwater Vision Profiler): The UVP, a second optical device, was mounted on the AWI CTD Rosette. During the casts, the UVP took pictures at a frequency of 20 Hz. In those pictures, objects >2px were automatically counted and measured by the UVP system, while particles and organisms >80px were saved as vignettes to be analysed taxonomically.

Biochemical and Genetic Variables:
Prior to preservation/freezing, the 150-µm, 1000-µm, and ROV net tow collections were pre-sorted for biochemical and genetic variables of target zooplankton species following protocols provided by the project PIs. After sorting out a portion of the collection for rate process measurements (egg production and/or respiration rates) in the environmental room, if needed, the catch was brought to the zooplankton lab where it was concentrated and poured into a sample tray that was kept over ice. Large animals (e.g. Amphipods, gelatinous zooplankton, chaetognaths) were sorted to species by eye, while smaller zooplankton (e.g. copepods) were sorted to species/life stage under a dissecting microscope. The Core project variables included trophic biomarkers (lipid class composition, fatty acid composition, bulk stable isotope composition, compound-specific stable isotope composition of fatty acids, highly branched isoprenoids) and carbon and nitrogen (CN) content. Target animals were also sorted for project variables including: energy content, gut content, digestive enzymes, microplastics, and transcriptomics. All animals sorted for trophic biomarkers, CN content, digestive enzymes, and transcriptomics were photographed prior to transferring to sample containers. All other animals were transferred directly to the sample containers without photographs. All samples were processed, preserved or frozen following the sampling protocol for the given variable. In addition, subsamples were taken from the surface, and on occasion the deep 150-µm ring net, and a dedicated ROV net, and preserved immediately in 96% ETOH for gut DNA content of target zooplankton species.

Rate Process Studies (respiration, reproduction, and feeding):
All rate process studies were conducted in the dark, between 0.5 and 1 °C in the environmental chamber. The set-up, termination, and all manipulations were done under red light.

Respiration rates were determined for target zooplankton species/life stages collected from different depth horizons with an Optode oxygen measurement system. Measurements were taken every 12 hours for 2 to 3 days. Eleven experiments were conducted with groups of three or four target organisms each measured in triplicate along with controls. At the termination of the experiment, all animals were photographed and saved for CN determination.

Egg production rates were determined for adult females of the copepod *Calanus hyperboreus* in long-term incubations. A series of 5 experiments with 9 to 30 females were conducted during Leg 2, with one experiment still ongoing for 68 days and handed over to Leg 3 to continue. Egg production rates were monitored daily for individual females and a subsample of the eggs produced each day was taken to monitor for egg hatching success. At the termination of the experiments the females were or will be photographed and saved for CN measurements. Four experiments were still ongoing and handed off to Leg 3 when we departed Polarstern.

Zooplankton Feeding Rates were determined in a single experiment using standard bottle incubation techniques. The incubation was conducted on a plankton wheel in the environmental chamber (1 °C) in the dark for 24 hours. Groups of four separate target species were incubated in triplicate along with controls. At the start and end of the incubations samples were taken for chlorophyll and microplankton analysis so that feeding rates on chlorophyll and microzooplankton could be determined. At the termination, all animals were photographed and saved for CN determination.

Preliminary (expected) Results
All samples will be processed and analysed at the home laboratories. The number of deployments for each sampling gear, the number of samples taken for each variable, and the

total number of rate process measurements have been summarized in Tables 6.1.1, 6.1.2, and 6.1.3.

Table 6.1.1. Zooplankton sampling gear, targeted depth horizons, and number of hauls for each piece of sampling gear during Leg 2.

Sampling Device	Depth Sampled	Number of Hauls
MultiNet	2000-0	11
RN150	200-0	10
RN150	2000-200	7
RN150	1000-0	1
RN150	1000-200	1
RN1000	1000-0	8
RN53	200-0	8
ROV Net	0	9
ROV Net	10	8
ROV Net	0-50	1
LOKI	1000-0	10
UVP	Same as CTD casts	30

Table 6.1.2. Summary of the core and project sample variables collected for individual species and zooplankton community measurements.

Variable	Core/Project	Samples	Number of Animals
Individual Species/Stage Measurements			
Carbon and Nitrogen	Core	1226	3780
Trophic Biomarkers	Core/Project	207	1300
Energy Content	Project	167	656
Enzymes	Project	62	622
Gut Content	Project	26	61
Transcriptomics	Project	57	57
Microplastics	Project	5	11
Photographs	Core/Project	2189	
Community Measurements			
Abundance/Taxonomy	Core	75	

Gut DNA	Project	11
Biomass	Project	30
LOKI	Core	10 hauls
UVP	Core	30 hauls

Table 6.1.3. Zooplankton rate processes. The number of experiments and the total number of samples/bottles incubated for each type of process measurement are shown.

Experiments	Number	Incubations
Respiration	12	132
Reproduction	5	81
Feeding	1	18

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). All data will be subject to the MOSAiC data policy, and therefore, deposited in the MCS and relevant public open access data repositories upon publication.

6.2 ECOSYSTEM SCIENCE: NUTRIENT BIOGEOCHEMISTRY

Objectives

As stated in the respective section of the Team Eco Leg 1 cruise report:
"Produce an annual mass balance of the cycling of macro and micronutrients across the sea ice-water interface. Characterize vertical fluxes of nutrients in combination with nutrient tracer assays to understand carbon and nitrogen recycling pathways by microbes in sea ice and seawater. We aim to measure the progressive concentration of nutrients, including iron, in sea ice over the ice formation season."

Work at sea

During Leg 2, samples for the analysis of inorganic nutrients (nitrate+nitrite, nitrite, phosphate, silicate and ammonium) were collected from: 1) sea ice, snow and brine from the coring sites, FYI and SYI, in coordination with Team Ice (Chapter 4, section 4.2); 4.5 2) sea ice, sludge, frost flowers, brine and seawater, from leads and BGC sites in coordination with Team BGC (Chapter 7, section 3); 3) seawater collected from CTD-Rosette deployments from Polarstern and from Ocean City in coordination with Team Ocean (Chapter 5: CTD/Rosette Casts in Ocean City) and Team BGC; 4) seawater collected using Niskin bottles at sites of the distributed Network coordinated by Team Ocean (Chapter 5: Operation of a small CTD at different locations on the ice floe); 5) seawater from incubations with stable

isotopes provided by Lena Eggers (CN project, see section 6.4); and 6) from ridge cavities and ice cores as requested by Lasse Olsen (HAVOC project). Additionally, samples were collected for later analysis of total nitrogen (TN) and total phosphorus (TP) from CTD deployments from Poalrstern and Ocean City in coordination and with help with/from Team Ocean and Team BGC.

As during Leg 1, analyses onboard were performed using a 5-Channel Seal Analytical AA3 segmented flow autoanalyser. Certified reference materials (CRMs) from KANSO, LTD, Japan, were measured on each analysis run. These CRMs will be crucial to assess the accuracy and quality of the MOSAiC-long nutrient data set. Two different batches of CRMs were used, CD and CJ. The former is a mid-nutrient-concentration-range CRM, consistent with typical nutrient concentrations in Arctic waters. The latter is a high-nutrient-concentration-range CRM, with phosphate and silicate above the calibration range selected for the MOSAiC expedition. In order to test the linearity of the calibration curve above the highest calibration standard, the CJ CRM (mostly) and the CD CRM (few times) were also measured diluted at 50%.

Samples from seawater were collected unfiltered. Due to the sediment content in sea ice, samples from ice cores were filtered through 25 mm (0.2 micron) Advantec cellulose filters using a syringe inline filtration unit. Samples from CTD deployments and sea ice cores were all analysed in duplicate, with random samples (minimum of 4 per event) analysed in triplicate. Brine, sludge and frost flower samples were measured in triplicate (typically) twice per run, with the second time being diluted either at 50% or 5:25 mL in Milli-Q water (as required), given these were mostly off the pre-expedition selected calibration ranges. This was particularly true for ammonium and phosphate, and in some cases for nitrite and silicate too.

Effort was made in coordination with Team BGC to obtain samples which can provide further insight concerning the redistribution of nutrients (and other compounds) within the sea ice matrix during the sea ice formation process. Hence, whenever possible, seawater, sludge, frost flowers and brine were sample from recently open leads. Effort was also made in collaboration with Team Ocean and Team BGC to increase the temporal resolution in the upper 250 m of the water column over a week period, given the time scales of physical processes (e.g., advection of different water masses, mixing due to ice drift, eddies, tides and brine release) affecting the distribution of nutrients in the upper ocean layers and in the ocean-sea ice interface, where only one CTD deployment per week at coarse vertical resolution (from Polarstern) is simply not enough to capture such processes. Moreover, sampling from both CTD-Rosette sets will provide the data required to calibrate the two nitrate-SUNA sensors attached to both frames. The sensor in Ocean City will in turn yield better vertical resolution data, which can then be combined with microstructure profiling to compute nitrate vertical fluxes. Given the current gap in scientific knowledge concerning the processes that condition the upper layers in the central Arctic Ocean during winter time prior to the onset of the productive season, we concurred that this effort was granted. This did not incur extra time from Team Eco, thanks to the willingness of Team Ocean and Team BGC to work together for a common purpose. **Table 6.2.1** lists events additional to those listed in Table 6.1, from which samples were collected and/or analysed. A, B and C indicate: samples measured onboard (A), samples collected and stored frozen for TN and TP (B), samples collected as back up for inorganic nutrient analysis (C, only from PS CTD).

Table 6.2.1. Events (device operations) sampled during Leg 2 in addition to those taken from the main CTD on Polarstern. Events associated with analysis of sludge, frost flowers and brine obtained from Team BGC sampling, are logged by Team BGC.

Date	Device Operation	Device	Sample type
19.12.2019	PS122/2_16-21 CTD_SBE9plus_321	CTD AWI-OZE	A
21.12.2019	PS122/2_16-54 CTD_SBE9plus_935	Ocean City CTD	A

23.12.2019	PS122/2_17-8 CTD_SBE9plus_935	Ocean City CTD	A
23.12.2019	20191223-PS_122-2_17_FYI-salo18	Ice Corer Kovacs Mark II	A
23.12.2019	20191223-PS_122-2_17-SYI-salo18	Ice Corer Kovacs Mark II	A
28.12.2019	PS122/2_17-78 CTD_SBE9plus_935	Ocean City CTD	A, B
30.12.2019	PS122/2_18-5 CTD_SBE9plus_935	Ocean City CTD	A, B
31.12.2019	PS122/2_18-16 CTD_SBE9plus_935	Ocean City CTD	A
04.01.2020	PS122/2_18-81 CTD_SBE9plus_935	Ocean City CTD	A, B
06.01.2020	PS122/2_19-4 CTD_SBE9plus_935	Ocean City CTD	A, B
06.01.2020	20200106-PS122-2_19-FYI-SALO18	Ice Corer Kovacs Mark II	A
11.01.2020	PS122/2_19-89 CTD_SBE9plus_935	Ocean City CTD	A, B
13.01.2020	PS122/2_20-2 CTD_SBE9plus_935	Ocean City CTD	A, B
13.01.2020	Ice Corer Kovacs Mark II	Ice Corer Kovacs Mark II	A
14.01.2020	PS122/2_20-17 CTD_SBE9plus_935	Ocean City CTD	A, B
16.01.2020	PS122/2_20-157	Niskin (5L) L2, N2	A
16.01.2020	PS122/2_20-151	Niskin (5L) L2, N5	A
16.01.2020	PS122/2_20-153	Niskin (5L) L2, N3	A
16.01.2020	PS122/2_20-154	Niskin (5L) L2, N6	A
18.01.2020	PS122/2_20-156	Niskin (5L) L3, N5	A
18.01.2020	PS122/2_20-159	Niskin (5L) L1, N2	A
18.01.2020	PS122/2_20-155	Niskin (5L) L1, N3	A
19.01.2020	PS122/2_20-109 CTD_SBE9plus_935	Ocean City CTD	A, B
20.01.2020	PS122/2_21-1 CTD_SBE9plus_935	Ocean City CTD	A, B
20.01.2020	20200120-PS122-2_21-FYI-SALO18	Ice Corer Kovacs Mark II	A
21.01.2020	PS122/2_21-26 CTD_SBE9plus_935	Ocean City CTD	A
23.01.2020	PS122/2_21-152 NISK5L_5	Niskin (5L) 5, Lead	A
23.01.2020	PS122/2_21-153 NISK5L_3	Niskin (5 L) 3, Lead	A
23.01.2020	PS122/2_21-154 NISK5L_2	Niskin (5 L) 2, Lead	A
23.01.2020	PS122/2_21-155 NISK5L_6	Niskin (5 L) 6, Lead	A
24.01.2020	PS122/2_21-101CTD_SBE9plus_935	Ocean City CTD	A
25.01.2020	PS122/2_21-114 CTD_SBE9plus_935	Ocean City CTD	A, B
26.01.2020	PS122/2_21-128 CTD_SBE9plus_935	Ocean City CTD	A
27.01.2020	PS122/2_22-3 CTD_SBE9plus_935	Ocean City CTD	A, B
27.01.2020	20200127-PS122-2_22-SYI-SALO18	Ice Corer Kovacs Mark II	A
28.01.2020	PS122/2_22-18 CTD_SBE9plus_935	Ocean City CTD	A
31.01.2020	PS122/2_22-71 CTD_SBE9plus_935	Ocean City CTD	A, B
03.02.2020	PS122/2_23-4 CTD_SBE9plus_935	Ocean City CTD	A, B
03.02.2020	20200203-PS122-2_22-SYI-SALO18	Ice Corer Kovacs Mark II	A
04.02.2020	PS122/2_23-17 CTD_SBE9plus_935	Ocean City CTD	A, B
08.02.2020	PS122/2_23-97 CTD_SBE9plus_935	Ocean City CTD	A
10.02.2020	20200210-PS122-2_23-115-FYI-Salo18	Ice Corer Kovacs Mark II	A
14.02.2020	PS122/2_24-47 CTD_SBE9plus_935	Ocean City CTD	A
15.02.2020	PS122/2_25-4 CTD_SBE9plus_935	Ocean City CTD	A, B
17.02.2020	20200217/PS122/2_25-15-SYI-Salo 18	Ice Corer Kovacs Mark II	A
17.02.2020	PS122/2_25-26 CTD_SBE9plus_935	Ocean City CTD	A, B

Preliminary (expected) results

Due to the work load during Leg 2, there was not enough time to process data from the analyses onboard. Data will be partially processed during transit time back to land. However, a final data set will only be possible once the expedition-long data set is evaluated as a single continuous time series.

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). In the case where analyses were done onboard, raw data files, from which further processing is possible, have been stored in the respective event folders within the MCS. In the case where samples were collected and stored frozen, these will be analysed at the home laboratory (AWI) approximately within 6 months of arrival. All data set produced are subjected to the MOSAiC data policy and will be or have been stored in the MCS.

Eventually, data sets will be submitted to PANGAEA in agreement with the MOSAiC data Policy.

6.3 UNDERSTANDING THE LINKS BETWEEN PELAGIC MICROBIAL ECOSYSTEMS AND ORGANIC MATTER CYCLING IN THE CHANGING ARCTIC (*μ*ARC)

J. Grosse[1]

Not onboard: A. Engel[1], M. Cunliffe[2], B. Zaencker[2], E. M. Noethig[3], B. Ward[4], M. Schartau[1]

[1]GEOMAR

[2]MBA

[3]AWI

[4]University of Southampton

Objectives

The bio-reactivity of particulate and dissolved organic matter is determined by its biochemical composition and diagenetic state. The loss of organic matter within and below the euphotic zone is mainly mediated by the degradation activity of heterotrophic bacteria, colonizing sinking particles and their surroundings. Hence, bacterial activity co-determines the efficiency of carbon export to the deep ocean. Furthermore, bacterioplankton plays a fundamental role at the basis of microbial foodwebs. Dissolved organic matter is almost exclusively accesible for bacterial cells that make it available for higher trophic levels by the production of bacterial biomass. Bacterial communities and their activity are thereby of outstanding importance, but yet hardly considered. Spring and summer studies conducted in the Arctic Ocean over the past decades revealed strong physiological responses of marine bacteria to changing temperature and pH, but their relevance for biogeochemical cycles in the Arctic winter is only poorly investigated.

The *μ*ARC project has the overarching aim to improve our understanding of how short-term (e.g. seasonal-scale) and long-term (e.g. climate-driven) changes in the physical environment of the Arctic Ocean are impacting pelagic microbial ecosystems, including bacterio-, myco-, phyto- and micro-zooplankton, and how these affect current and future organic matter (OM) biogeochemistry. Our activities focus on developing a quantified understanding of the structure and functioning of Arctic ecosystems. The sampling on MOSAiC leg2 provided the unique opportunity to study the rarely sampled winter.

Work at sea

During Leg 2 of MOSAiC, Julia Grosse took weekly samples of the water column for various components of the organic matter pool (See table **Table 6.3.1**). Seawater was taken weekly from 6 standard depths (2 m, 10 m, 20 m, 50 m, 75 m, 100 m, Atlantic Water ~250 m) at CTD casts on Friday. Additional water was collected opportunistically from deep CTD casts (3-4 depths >1000 m from CTD casts on Thursday as well as Ocean City CTD casts to obtain higher resolution on the upper 75 m (**Table 6.3.2**).

Additional sampling of Eco-CORE parameters (POC, Chl a, Bacterial and Phytoplankton abundance and activity) will be used for data interpretation.

Table 6.3.1. Sample overview of the *μ*ARC project and institute responsible for sample analysis on land

Parameter	Abbreviation	Total # of samples	Institute
Dissolved organic carbon	DOC	73	GEOMAR
Dissolved amino acids	DAA	73	GEOMAR
Dissolved carbohydrates	DCHO	73	GEOMAR
Particulate amino acids	PAA	30	GEOMAR
Particulate carbohydrates	PCHO	30	GEOMAR
Phospho-lipid derived Fatty Acids	PLFA	6	MBA
transparent exopolymer particles	TEP	67+48	GEOMAR
Coomassie stainable particles	CSP	67+48	GEOMAR
TEP sequencing	TEP seq	67	MBA
MesoLens	-	67	MBA
Confocal Laser Scanning Microscope	cLSM	38	GEOMAR

Samples for DOC were filtered over 0.45 µm GMF syringe filters into combusted glass ampules and stored at 4°C. DAA and DCHO were filtered over 0.45 µm Acrodisc filters into combusted glass vials, samples for PAA and PCHO samples were filtered onto combusted GF/F filters. TEP and CSP samples were filtered onto 0.4 µm PC filters, stained and stored for analysis by photometry and microscopy. MesoLens and cLSM samples were filtered on black PC filters for 1) Enumerating Bacterial abundance on gel particles via Mesolens and 2) Identification of organic compound composition of particles (polysaccharide, protein, nucleic acid, chlorophyll containing) via cLSM. All samples were stored at -20°C. TEPseq samples were taken the same way as TEP samples but stored at -80°C for molecular determination of TEP inhabiting bacteria.

Tab. 6.3.2. Overview of sampling events during Leg 2

date	ActionLog_ID	Device	depths sampled
23.12.2019	PS122/2_17-7 CTD_SBE9plus_935	Ocean City	5m, 35m, 50m, 75m, 100m, 200m
27.12.2019	PS122/2_17-64 CTD_SBE9plus_321	Polarstern	2m, 10m, 20m, 50m, 75m, 100m
3.1.2020	PS122/2_18-57 CTD_SBE9plus_321	Polarstern	2m, 10m, 20m, 50m, 75m, 100m, 260m
2.1.2020	PS122/2_18-34 CTD_SBE9plus_321	Polarstern	1000m, 2000m, bottom
7.1.2020	PS122/2_19-18 CTD_SBE9plus_935	Ocean City	2m, 20m, 40m, 50m, 75m, 90m
10.1.2020	PS122/2_19-76 CTD_SBE9plus_321	Polarstern	2m, 10m, 20m, 50m, 75m, 100m
17.1.2020	PS122/2_20-71 CTD_SBE9plus_321	Polarstern	2m, 10m, 20m, 50m, 75m, 100m, 260m
23.1.2020	PS122/2_21-65 CTD_SBE9plus_321	Polarstern	1000m, 2000m, 25000m, 3500m, 4444m
31.1.2020	PS122/2_22-75 hand_pump	hand pump	under ice water
31.1.2020	PS122/2_22-63 CTD_SBE9plus_321	Polarstern	2m, 10m, 20m, 50m, 75m, 100m, 252m
8.2.2020	PS122/2_23-97 CTD_SBE9plus_935	Ocean City	2m, 20m, 30m, 35m, 45m, 55m
10.2.2020	PS122/2_24-2 CTD_SBE9plus_321	Polarstern	2m, 10m, 20m, 50m, 75m, 100m
21.2.2020	PS122/2_25-71 CTD_SBE9plus_321	Polarstern	2m, 10m, 20m, 50m, 75m, 100m, 270m

Preliminary (expected) results

We expect to obtain winter data to quantify organic matter concentration, composition and production rates during the polar night. Estimates of organic matter bioavailability through molecular analysis of major biochemical compounds will be obtained during a critical time of the year, when production of these compounds by primary producers in not expected. Concurrently, we will assess the microbial community structure and function associated with microgel particles, microbial abundance total and associated with microgel particles during leg 2.

Except for measuring bacterial and primary production rates (as part of Eco-CORE program) no samples were analysed on board. All samples will be send back to GEOMAR and MBA via AWI for analysis.

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). All data will be subject to the MOSAiC data policy, and therefore, deposited in the MCS and relevant public open access data repositories upon publication.

References

No references.

6.4 UNCOVERING THE SEASONALITY OF SYMPAGIC AND PELAGIC MICROBIOMES AND THEIR METABOLIC FUNCTIONS IN THE CENTRAL ARCTIC OCEAN WITH EMPHASIS ON CARBON AND NITROGEN CYCLING

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Objectives

The CN-Project complements existing knowledge on the global marine microbiome with data from the Earth's least known large marine ecosystem, the permanently ice-covered Central Arctic Ocean (CAO). This includes not only metagenomic mapping of the full collection of genes in the microbial communities (archaea, bacteria, fungi, eukaryotes) living in the sympagic and pelagic microhabitats of the CAO, but also exploring gene expression, both in

the field and during incubation experiments, and to relate the results to biogeochemical cycling and modelling. The participants of the CN-Project will - in experimental incubations - measure microbial C and N uptake by using stable isotope tracers in combination with single-cell transcriptomics and metatranscriptomics. To be able to relate the experimental results to natural conditions, we will - in collaboration with a large group of international scientists - reveal the seasonal succession of microbial community composition (DNA - metagenomics) and expressed metabolic functions (RNA - metatranscriptomics) in the field during a full seasonal cycle, see the part of this chapter dealing with the MOSAiC ECO Core Programme.

Work at sea

During Leg 2 of MOSAiC, the CN-experiments were carried out by S. Lena Eggers following the practical routines that were established by Pauline Snoeijs Leijonmalm and Allison Fong during Leg 1. During the coming three legs, the experiments will be carried out by Anders Torstensson (Leg 3), Allison Fong (Leg 4), and John Paul Balmonte (Leg 5). We sample 140-150 L of seawater that, spiked with different stable isotopes, is incubated at ca. 1 °C on board, both in light and dark conditions (**Figure 6.4.1**). We focus on two pelagic habitats (sampled from the large CTD), the chlorophyll maximum in the surface layer (or, if absent, 20 m of depth) and the temperature maximum in the Atlantic layer (or, if absent 300 m of depth), and one sympagic habitat, the immediate sub-ice seawater (sampled from the ice with a hand pump). If no samples can be taken from any of these habitats for safety or logistic reasons, the water for the experiment is supposed to be taken from the Polarstern seawater tap in Container F4 at the F-deck.

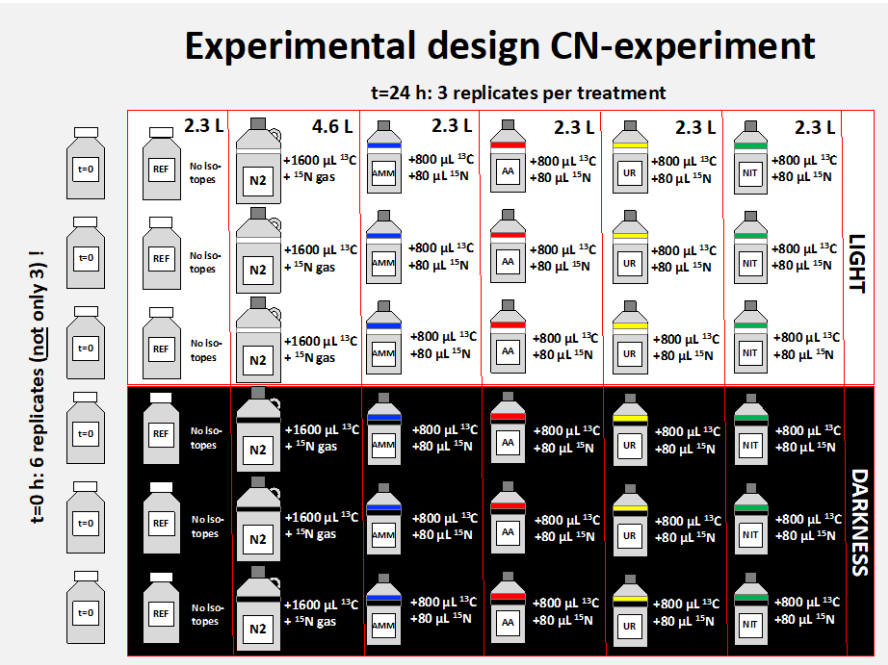

Fig. 6.4.1. Experimental design of the CN-experiment as performed during MOSAiC.

In the course of one experiment, 118 sub-samples are taken for single-cell genomics, metatranscriptomics, mass spectrometry of stable isotopes, flow cytometry for cellular abundance and composition, as well as for inorganic and organic nutrients (Table 6.4.1). During MOSAiC Leg 2, ten full experiments were carried out (Table 6.4.2).

Tab. 6.4.1. Overview of the 118 sub-samples taken during one CN-experiment

Working order	Sample type	DAY 1	DAY 2						Total
		t = 0	REF	N2	AMM	AA	UREA	NIT	
1	Single Cell genomics	3		6					9
2	MIMS			6					6
3	Nitrification				6				6
Make the Pajamas bottles									
4	Flow cytometry	4	4	4	4	4	4	4	28
5	Sterivex filters RNA	2	2	2	2	2	2	2	14
Rest of each experimental bottle									
6	Advantec filters	6	6	6	6	6	6	6	42
Samples taken from Carboy with the rest of the mixed water									
7	Inorganic nutrients	3							3
8	Organic nutrients	6							6
9	Sterivex filter DNA	1							1
Samples taken from extra Carboy(s) = has not been in mixing tank									
9	Sterivex filters DNA	3							3

Tab. 6.4.2. Overview of the experiments performed during Leg 1

File no.	Date	Sampling time	Device	Path to MCS	Type of experiment	Device Operation ID
12	191221	10:30	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122-2_16-74	CN-experiment 9	PS122/2_16-74
13	191227	Morning	CTD, shallow cast, Chlmax	platforms/vessel/polarstern/ctd_sbe9plus_321/exdata/PS122-2_17-64	CN-experiment 10	PS122/2_17-64
14	200103	Morning	CTD, shallow cast, Tempmax	platforms/vessel/polarstern/ctd_sbe9plus_321/exdata/PS122-2_18-57	CN-experiment 11	PS122/2_18-57
15	200106	9:30	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122-2_19-140	CN-experiment 12	PS122/2_19-140
16	200110	Morning	CTD, shallow cast, Chlmax	platforms/vessel/polarstern/ctd_sbe9plus_321/exdata/ PS122-2_19-76	CN-experiment 13	PS122/2_19-76
17	200117	Morning	CTD, shallow cast, Tempmax	platforms/vessel/polarstern/ctd_sbe9plus_321/exdata/PS122-2_20-71	CN-experiment 14	PS122/2_20-71
18	200120	9:30	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122-2_21-55	CN-experiment 15	PS122/2_21-55
19	200131	9:30	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122-2_22-75	CN-experiment 16	PS122/2_22-75

20	200210	Morning	CTD, shallow cast, Chlmax	platforms/vessel/polarstern/ctd_sbe9plus_321/exdata/PS122-2_24-2	CN-experiment 17	PS122/2_24-2
21	200221	Morning	CTD, shallow cast, Tempmax	platforms/vessel/polarstern/ctd_sbe9plus_321/exdata/PS122-2_25-71	CN-experiment 18	PS122/2_25-71

For the field samples of DNA and RNA, with many scientists involved in sampling, analyses and bioinformatics, including all participants in the CN-Project, see the part of this chapter dealing with the MOSAiC ECO Core Programme. The CN-Project sponsors a significant part of the field sampling programme in the form of berths, consumables (Sterivex filters, GF/F filters) and equipment (peristaltic pumps, etc.).

Preliminary (expected) results

We expect to uncover microbial processes that take place during the half-year long polar night. In summer the focus is on processes related to the melting of sea ice which is increasing dramatically in the CAO as a result of global warming, e.g. the expansion of brackish and fresh water alters microbial community composition (Fernández-Gómez et al. 2019). We particularly target C and N metabolism in general, and will specifically test three specific hypotheses: (a) that diazotrophy (biological N_2-fixation) is a significant source of new nitrogen to the oligotrophic CAO marine ecosystem throughout the year, (b) that urea is an alternative substrate for ammonium oxidation and chemoautotrophic CO_2 fixation in the CAO, especially in winter and at low ammonium availability, and (3) that amino acids (AA) can be used as a nutrient source by microbial communities.

Except for the analyses of inorganic nutrients, no samples were analyzed on board. All samples from the experiments will be sent to Stockholm University and from there distributed for analyses at other laboratories. The molecular and bioinformatics analyses will use the resources of the Swedish National Genomics Infrastructure (NGI) and the SciLifeLab Stockholm-Uppsala for the experiments. For the field samples, sequencing will take place at JGI (DOE) as granted for the joint MOSAiC genomics application (Mock et al., 2019), see the part of this chapter dealing with the MOSAiC ECO Core Programme.

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). The molecular data will be stored in specialized open international genomics databases. All other data will be submitted to the MOSAiC Central Data Storage (MCS) when analyses have been performed. When publishing, all original data will be submitted to the journal data base.

References

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6.5 UNCOVERING THE LARGEST BLIND SPOT ON THE MAP OF THE WORLD'S FISH STOCKS: MESOPELAGIC FISH AND THEIR ROLE IN THE CENTRAL ARCTIC OCEAN FOOD WEB

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Objectives

No scientific data exists for pelagic fish populations in the Central Arctic Ocean (CAO), i.e. the deep basins outside the continental shelves. In the EFICA (European Fisheries Inventory in the Central Arctic Ocean) project we target fish in the water column from the surface down to ca. 800 m of depth. Our goal is to answer the following research questions: (1) Do pelagic fish occur in the CAO?, (2) To which species and populations do they belong?, (3) What are their numbers and biomass along the MOSAiC drift transect?, (4) What is their role in the CAO pelagic food web?, (5) What are their migration patterns?, and (6) How are the existing populations expected to change with further climate warming? Since the *Polarstern* is drifting with the ice, MOSAiC offers the possibility to collect a unique acoustic data set with one year of measurements targeting fish while crossing the CAO. Such data collection is impossible to achieve when an ice-breaker is moving through the ice because of the noise. Normally, fish studies combine acoustics with trawling, but trawling is impossible in an area covered by thick sea ice. Therefore, we collect fish samples with fishing gear deployed from the ice as well as through "citizen science" on board by fishing from the *Polarstern*'s moon pool. We also use a deep-sea camera system for visual under-water observations and will mine the MOSAiC genomic data sets for fish genes to answer the EFICA project's research questions.

Work at sea

General

During Leg 2 of MOSAiC Giulia Castellani was on board *Polarstern* and followed the sampling routines established during Leg 1. Official Leg 2 work at sea started on December 15th.

Hydroacoustics

During Leg 2 of MOSAiC the EK80 and EK60 settings were the same as for the end of Leg 1, so the instruments ran with frequencies of 38 kHz (GPT, CW mode), 70 kHz (WBT, FM and CW mode, 200 kHz (GPT, CW mode) for the EK80 and 18 kHz and 120 kHz for the EK60 (GPT, CW mode). The mode of the 70 kHz transducer of the EK80 was manually swopped between FM and CY mode every 24 hours.

During Leg 2 few events have caused a disturbance in the data, but to a minimum level, so the data can still be used to detect fishes. These events were the discharge of gray water, which is documented by the ship so it can be easily identified in the data; the two ADCP's (one on the ship and one on the ice), and the deployment of fishing rods from the moon pool. Durign Leg 2 two AZFPs have been installed on the ice as a joint effort between team ECO

and team ICE. The AZFP buys have been placed at ca. 1 km of distance from the ship in order to avoid any disturbance with the EK80 and EK60 recordings.

During Leg 2 we conducted a preliminary interference test, but the data have not been analyzed and the test has to repeated since unexpected signals were present in the recordings (i.e., the ROV diving in water). The test will be completed by the participant of Leg 3.

Fish sampling

During Leg 2 the procedure defined as standard during Leg 1 was followed through the entire period, with few exceptions. Two long lines have been deployed every week targeting the mesopelagic area (i.e., between 200 and 400 m depth). Until week 18 included the deployment took place from a hole made in the ice. During week 18 the ROV hut has been relocated in the fishing area and since week 19 we could use the ROV hole and hut for the long lines deployments. This was a substantial improvement of our working conditions and allowed us to have deployments every week despite the harsh weather conditions. During week XXX we tested a horizontal long line deployed between the ROV hut and the Ocean City tent. During week 21 the bad weather caused the formation of big leads and the effort of all teams on board has been directed towards the sampling of the lead as soon as the weather allowed. That week we did not deploy any long line but we focused on surface fishing with the fishing rods. Week 24 was used to clean up and prepare the handover with Leg 3 so no long lines has been deployed.

Visual observations

The deep-sea camera system (FishCam) was deployed by Leg 1 participants on 12 December at 214 m of depth. On December 21, however, a problem occurred with the settings of the Portvis software used to record the videos. With the support of the manufacturing company we were able to solve the issues and start the recordings, unfortunately this took few days because it was the period of Christmas vacation. This problem resulted in 6 days of no recordings. After the problem with the settings has been solved on 27 December, the fishcam has been recording for an entire day. However, on December 28 we received the visit of several polar foxes that chewed the data cable connecting Met city to Polarstern, causing the data stream failure. The problem was solved on 5 January and the settings have been put back to the same as Leg 1 i.e., 55 minutes of recordings and 5 minutes of idle. Since 15 January, we alternated daily the settings from 55 minutes recording and 5 minutes idle to 15 minutes recording and 15 minutes idle. A problem with the power cable on 29 January caused many instruments to be out of power at MET city, the problem was solved on 3 February.

Environmental DNA

During the entire Leg 2, we used the large CTD rosette to take water samples for DNA and RNA metagenomics analyses, see the part of this chapter dealing with the MOSAiC ECO Core Program. Within the EFICA project, we will mine the large metagenomic data sets that will be created by the MOSAiC Eco-omics group for fish and zooplankton genes.

Preliminary (expected) results

Altogether, ca. 2 TB of hydroacoustic data were collected during Leg 2 of MOSAiC. A scattering layer of living organisms was always observed in the Atlantic water layer of the CAO, but with varying density and varying vertical distribution. The organisms in the fish size range (>-45 dB) had extremely low densities.

The fishing activities from the ice during Leg 2 of MOSAiC started on 21 December 2019. In the period 21 December - 28 February we deployed 17 long lines, we performed one surface fishing event with fishing rods and pilkor techniques, and we had 3 “citizen science” events. In total, we collected no fish during Leg 2 by means of these techniques. Only one fish was collected with a ring net with 150µ mesh at a depth between 2000 and 200 m. This low number of fish samples collected confirms the low fish abundance in the area as observed from the hydroacoustic data. The data taken from the fish were total length, standard length, and total weight. Otoliths have been extracted and the rest of the fish has been frozen at -80° for further analyses at home.

Altogether, we collected ca 840 hours of video film for each of the two cameras in the weeks the FishCam was operational (Table 6.5.2). The video films will be analyzed at home.

Tab. 6.5.1. Overview of sampling efforts and fish samples taken during Leg 2 of MOSAiC, including the results of “Citizen science”.

Event number	Deployment and Retrieval date	Sampling method	Number of fish
PS122/2_16-65	21.12.2019-22.12.2019	Long line	0
PS122/2_16-91	16.12.2019	Citizen science	0
PS122/2_16-92	17.12.2019	Citizen science	0
PS122/2_16-93	20.12.2019	Citizen science	0
PS122/2_17-34	24.12.2019-25.12.2019	Long line	0
PS122/2_17-87	28.12.2019-29.12.2019	Long line	0
PS122/2_18-63	03.01.2020-04.01.2020	Long line	0
PS122/2_18-106	04.01.2020-05.01.2020	Long line horizontal	0
PS122/2_19-94	08.02.2020-09.02.2020	Long line	0
PS122/2_19-62	09.01.2020-10.01.2020	Long line	0
PS122/2_19-79	10.01.2020-11.01.2020	Long line	0
PS122/2_20-51	16.01.2020-17.01.2020	Long line	0
PS122/2_20-77	17.01.2020-18.01.2020	Long line	0
PS122/2_21-164	23.01.2020	Fishing rods	0
PS122/2_22-62	30.01.2020-01.02.2020	Long line	0
PS122/2_22-122	01.02.2020-02.02.2020	Long line	0
PS122/2_23-10	04.02.2020	RN 150µ	1
PS122/2_23-50	06.02.2020-07.02.2020	Long line	0
PS122/2_23-68	07.02.2020-08.02.2020	Long line	0
PS122/2_25-58	20.02.2020-21.02.2020	Long line	0
PS122/2_25-99	21.02.2020-22.02.2020	Long line	0
PS122/2_29-40	27.02.2020-28.02.2020	Long line	0
Total number of fish			**1**

Tab. 6.5.2 Overview of the video recordings taken within the EFICA project in the periods 15 December – 24 February. In the number of files we include both cameras.

Number of video files	Minutes recording	Idle	Min/hour	Total hours
1337	55	5	55	1226
1433	15	15	30	358
491	5	55	5	41
75	Various length	Various length	Various length	ca. 48
3336				**ca. 1673**

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). The data have been submitted to the MOSAiC Central Data Storage (MCS).

References

No references.

6.6 RIDGES – SAFE HAVENS FOR ICE-ASSOCIATED FLORA AND FAUNA IN A SEASONALLY ICE-COVERED ARCTIC OCEAN (HAVOC)

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Partners not onboard: Mats Granskog[1], Nicole Aberle-Malzahn[2], Philipp Assmy[1], Jørgen Berge[3], Gunnar Bratbak[4], Pedro Duarte[1], Torbjørn Eltoft[3], Sebastian Gerland[1], Rolf Gradinger[3], Knut Høyland[2], Aud Larsen[5], Eva Leu[6], Cecilie von Quillfeldt[1], Marit Reigstad[3], Arild Sundfjord[1], Janne Søreide[7], Anna Vader[7], Oliver Müller[4]

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[3]UiT – The Arctic University of Nor-way (UiT)
[4]University of Bergen (UiB)
[5]UNI Research (UNI)
[6]Akvaplan-Niva (APN)
[7]The University Centre in Svalbard (UNIS)

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Objectives

As a complement to the level-ice studies during MOSAiC the HAVOC project provides a detailed interdisciplinary year round study on the unique role of first year ice (FYI) pressure ridges. With a more dynamic Arctic ice cover (Spreen et al. 2011; Itkin et al. 2017), the probability of pressure ridge formation increases under the new Arctic sea ice regime and FYI ridges are predicted to increase in the future (Wadhams and Toberg, 2012). An understanding of how ridges develop differently to level ice is thus important from a geophysical and marine biogeochemical perspective. For navigation in ice the existence of ridges is a critical factor, and mapping of ridges on larger scales will become increasingly important with the expected increase in Arctic ship traffic. Pressure ridges constitute an important pillar stone for the Arctic sea-ice system and the functioning of the ice-associated ecosystem in the Arctic, from microbes to polar cod to polar bears (Melnikov 1997; Hop et al. 2000; Gradinger and Bluhm 2004; Hop and Pavlova 2008; Gradinger et al. 2010). Ridges have also been recently identified as hotspots of ice-algal biomass accumulation using under-water remotely operated vehicles (ROVs) (Lange et al. 2017). With the dramatic loss of thick old ice, FYI ridges might become the only ref-uge for ice-associated flora and fauna during the summer melt season (Gradinger et al. 2010), being critical for species conservation and ecosystem services.

Hypotheses, approach and choice of method

Overarching hypothesis: Ridges harbor key ecosystem functions in terms of habitat and food web components for sea ice, under-ice and pelagic flora and fauna in the central Arctic. Pressure ridges will become an increasingly important component of the new Arctic sea ice regime dominated by FYI where the largest portion of the level ice melts completely in summer.

Our core approach is to establish a “Sea Ice Ridge Observatory (SIRO)” in coordination with the MOSAiC consortium. The SIRO will be part of the core observational program throughout MOSAiC and make use of autonomous systems and a new ROV platform for interdisciplinary observations under sea ice (Katlein et al. 2017) for continuous monitoring of background data, combined with regular sampling of sea ice ridges (**Figure 6.6.1**). This work is deeply integrated within and across three MOSAIC teams: sea ice, ecosystem and remote sensing. In addition to the project specific tasks, HAVOC will contribute to the collection of the full set of level sea ice and pelagic data as identified as core parameters in the MOSAiC teams. HAVOC strengthens the observational program to the mutual benefit of MOSAiC and will be engaged in further developing the MOSAiC Implementation Plan together with international collaborators at a workshop in St. Petersburg, Russia 13-16 November 2017.

The SIRO will utilize state-of-the-art platforms (**Fig. 6.6.1**) and methods with the aim that all aspects of the ridge evolution can be followed throughout the annual cycle. Field sampling will be augmented by process studies and experimental work to understand the mechanisms underlying the observed dynamics. This much-needed process-based understanding of the role of ridges will lead to improvement of coupled physical-biogeochemical sea-ice models. The overall objective of MOSAiC is centered on causes and consequences of an evolving and diminished Arctic sea ice cover and HAVOC will contribute especially to the question of how sea ice formation, drift, and deformation is coupled to atmospheric, oceanic and ecosystem processes. Parameters collected will follow the core MOSAiC guidelines. The central objectives of the proposed project are to:

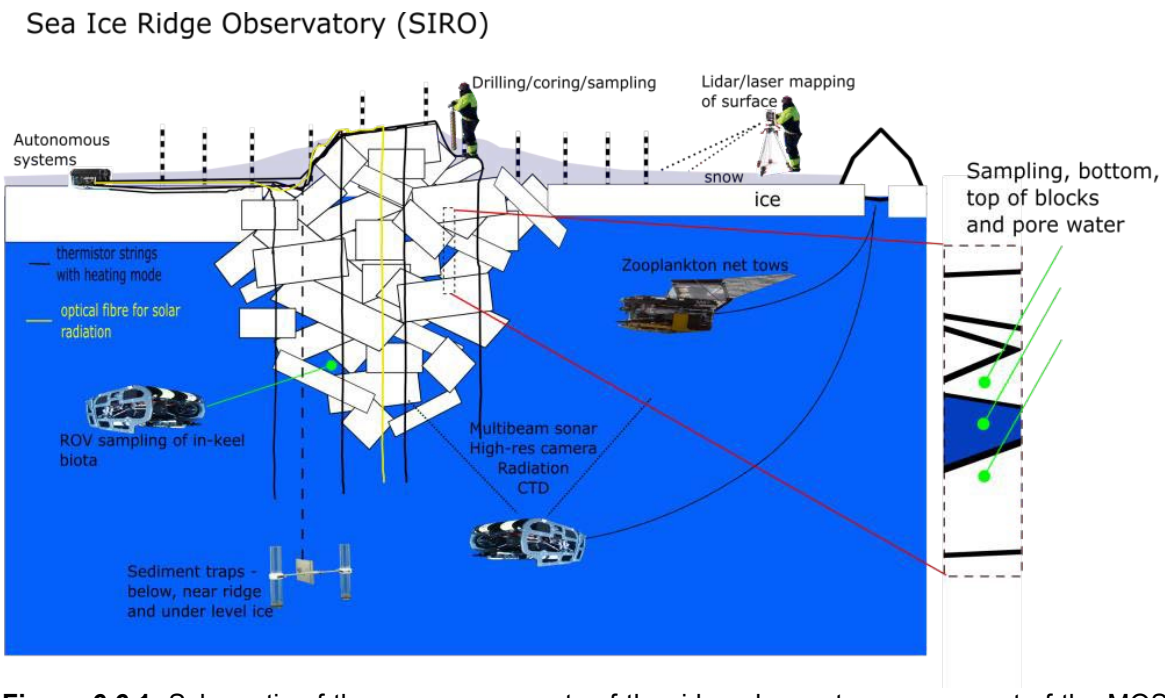

Figure 6.6.1: Schematic of the core components of the ridge observatory component of the MOSAiC campaign.

- Characterize the habitat structure and physical environment in Arctic sea-ice ridges over an annual cycle to understand their ecosystem function (WP1)
- Assess processes that cause differences in the diversity of ice associated biota between ridges and level sea ice (WP2)

- Determine how food web and biogeochemical processes at the ice-ocean interface and the underlying water column differ between ridges and level sea ice (WP3)
- Extend findings to regional and pan-arctic scales and assess performance and improve representation of ridges in coupled ice-ocean-ecosystem models (WP4)

Work at sea

A suitable ridge site was localized about 300 m from Polarstern and approximately 150 m from the ROV (Remotely operated vehicle) deployment site, i.e. within reach of the ROV. Subsequently, the sea ice ridge observatory (SIRO) was established with deployment of ADCPs and CTDs on each side of the ridge keel and several automatic measuring systems deployed in the ridge. These deployments and ridge thickness drilling transects were performed by the ICE team. See the ICE team section of the cruise report for more details.

In cooperation with the ROV team (Team ICE) we deployed sediment traps under the ridge and level ice by using the ROV. A rope with a loop was deployed through the ice from the surface and the trap was hung onto the loop with the ROV (**Fig. 6.6.2**). One trap site was close to the ridge keel and another site close to level ice at the side of the ridge. In addition a mooring with traps was deployed from the ROV deployment site.

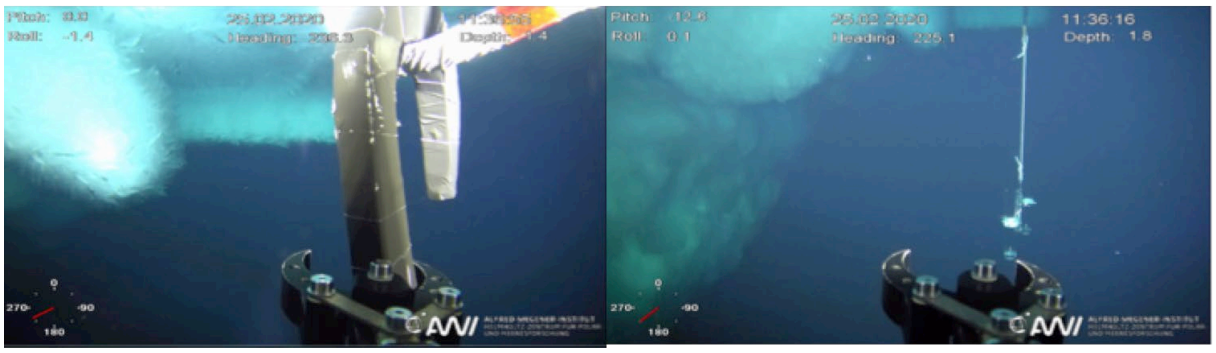

Figure 6.6.2: Deployment of sediment trap under the ridge with ROV. Left: closeup of hook and loop during deployment, Right: trap hanging after deployment at the site close to level ice.

The first HAVOC ice coring sampling was from the level ice on both sides of the ridge. Subsequently two coring sessions were performed in the ridge at a site slightly at the side of the keel where the thickness was approximately 5 m. We detected several water filled voids when coring through the ridge. By the use of a hand pump we could take water sample from such voids. Ice cores were collected from directly below and above the ridge void. These samples were used for subsampling for the various variables in the HAVOC sampling plan.

Preliminary (expected) results

The total numbers of samples for the different variables collected were: 70 fixed protist samples, 82 chlorophyll a samples (Chl-a), 273 flow cytometry samples (FCM), 51 samples for particulate carbon and nitrogen (PCPN), 52 duropore filters for molecular analysis, 14 fecal pellet (FP) samples from sediment traps, 6 Sterivex filters for genetic analysis, 2 Virus diversity samples, 1 lipid/POM sample, 6 PDMPO samples, 23 samples for element analysis

of particles (XRF). Bacterial production measurements and approximately 60 nutrient samples were analysed onboard. Grazer exclusion experiments were performed with water from ridge void sampled on 24 January and seawater from 20 m depth sampled on 22 January. The experiments were run for 8 days. In table 1 are listed the sampling events for HAVOC during leg 2.

Table 6.6.1: HAVOC sampling events during MOSAiC leg 2

Date	ActionLog_ID	Device	Description
03.01.20	PS122/2_18-61	Ice Corer Kovacs Mark II	Level ice at both sides of ridge
10.01.20	PS122/2_19-116	Ice Corer Kovacs Mark II + Hand pump	1st ridge coring and water sampling
13.01.20	PS122/2_20-5	Ice Corer Kovacs Mark II	SYI core for reference
14.01.20	PS122/2_20-172 - PS122/2_20-176	Sediment traps	Sediment traps, ridge and mooring
18.01.20	PS122/2_20-101	ROV suction pump	Suction sample under ridge and level ice
22.01.20	Ship coordinates	CTD	Ocean city CTD 20 m, GE exp
24.01.20	PS122/2_21-124	Ice Corer Kovacs Mark II + Hand pump	2nd ridge core and water, GE exp
31.01.20	PS122/2_22-63	CTD	Ship CTD water
02.02.20	PS122/2_22-107	ROV net	ROV net
02.02.20	PS122/2_21-125	ROV net	ROV net under ridge
03.02.20	PS122/2_23-3	Ice Corer Kovacs Mark II	FYI core for reference
04.02.20	PS122/2_23-148 - PS122/2_23-151	Sediment traps	Sediment traps, ridge and mooring
08.02.20	PS122/2_23-116	ROV net	ROV net
25.02.20	PS122/3_29-15 - PS122/3_29-19	Sediment traps	Sediment traps, ridge and mooring

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX).

References

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5.7 MEASUREMENTS OF SUSPENDED PARTICULATE MATTER AND DYNAMICS

Measurements of suspended particulate material were done via deployments of a LISST (Laser *In-Situ* Scattering and Transmissometry) probe. LISST deployments, continued from Leg 1, were carried out by Team Ocean (Hailong Liu) and Team Eco (Lasse M. Olsen) during Leg 2. The report is presented in the Team Ocean cruise report (Chapter 4).