6. ECOSYSTEM SCIENCE

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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)

Background

High-latitude ecosystems, which use sea ice as a substrate, habitat, and foraging ground, are characterized by strong spatial heterogeneity and pronounced seasonal dynamics relative to their physio-chemical environment. The coupled interactions between sea ice, biology, and chemistry of the ocean-atmosphere system are, however, generally understudied. As a consequence, biological and ecological impacts on the Arctic climate coupled system are not well represented in regional and global climate models of the Arctic climate system. However, biological activities drive transformations of organic matter and elements, and can control the cycling of climate-active gases (i.e. CO_2, CH_4, N_2O, and dimethyl sulfide [DMS]) across atmosphere-ice-ocean interfaces. Therefore, biological activities mediated by microbes and small animals are important feedback mechanisms in the processing of key elements and gases in the Arctic climate. With MOSAiC, a more complete accounting of inventories and fluxes of essential elements and compounds (C, N, O, P, S) between the atmosphere, ice, and ocean

systems will be gained through a broad appraisal of ecosystem properties and processes across sea ice and the underlying ocean.

Rapid changes to sea ice and upper ocean properties will alter Arctic ecosystem functions. At present, our knowledge of these alterations is primarily from Arctic shelf regions. We know little about how shifts from a predominantly MYI seascape to seasonally driven FYI regime in the CAO will affect the cascade of ecological processes associated with sea ice. Moreover, we possess few field observations and scant experimental data from the CAO beyond the summer season. Summertime snapshots have already alerted us to major changes in the CAO, and the potential impact thinning ice may have on ecosystem processes. However, to better evaluate future changes to the CAO, we require observations of and experimentation with natural Arctic microbial and faunal communities over the annual cycle. These types of measurements, geared towards elucidating mechanistic underpinnings of biological processes and interactions, will foster significant advances in our knowledge of CAO ecosystem services and functions, and how they may change in light of continued global warming.

MOSAiC offers the unique opportunity to study biogeochemistry and ecology in the framework of processes thought to exert strong controls on Arctic biota and related carbon and nutrient cycles. Critical processes to consider include sea ice formation and melting, lead dynamics, melt pond formation, ocean mixed layer dynamics, and wind-induced upwelling of nutrients. Improved understanding of the biologically-mediated fluxes of energy and materials between ocean, sea ice, and atmosphere also requires the investigation of underlying ecosystem dynamics in the context of these processes, at temporal scales not previously resolved.

Biological and biogeochemical processes are spatially heterogeneous due to patchiness in ice structure, microbial communities, and biophysical interactions within the ocean. Moreover, both the magnitude and direction of biogeochemical fluxes appear to evolve with season and with the advance of ice age. Multiple, spatially distributed measurements will be made within the local domain (<2 km) throughout the annual cycle to characterize the biology and biogeochemistry of the ice-dominated CAO ecosystem.

Objectives

MOSAiC Ecosystem objectives are:

1. Quantify components of the inorganic and organic carbon system, primarily in sea ice and the underlying ocean. Produce an annual mass budget of organic and inorganic carbon and alkalinity from FYI and SYI. These measurements will address recent and longstanding questions related to the net air-ice flux of CO_2 in addition to the potential for organic carbon trapping and dark period respiration to CO_2.
1. 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.
2. Establish several semi-autonomous measurement nodes on the main floe to measure oxygen and nitrate concentrations, and optical properties in the upper ocean. Together these measurements could establish whether the sea ice zone is a net producer of O_2 (net autotrophy) or a net producer of CO_2 (net heterotrophy). Sensor packages enable more highly time-resolved fluctuations in the proportion of O_2 versus CO_2 production from sea ice and the upper ocean over the annual cycle than can be captured by discrete sample collections.

3. Quantify primary and bacterial production in sea ice and the upper ocean. Compare estimates of net community production and net primary production from O_2/Ar ratios and ^{14}C-tracer assays to relate rates of organic matter fluxes to inventories of carbon and nutrients.
4. Assess particle fluxes including optical imaging instruments, including a LISST, UVP, and LOKI. Deploy a variety of sediment trap arrays to address different temporal scales of particle flux over the annual cycle. Couple particle flux estimates derived from imaging tools to discrete measurements of material fluxes generated from suspended POM and sediment trap collections of sinking POM to identify processes, which result in high flux events.
5. Measure the cycling of DOC and DOM, and characterize the composition of DOM derived from sea ice and the upper ocean. Assess which biological activities influence changes in the distribution and quality of DOC and POC.
6. Measure the temporal evolution of organismal distributions in sea ice and the ocean. Measure the spatial distribution of sympagic and planktonic biomass (e.g., ice algae, phytoplankton, microbes, micro- and meso-zooplankton) and determine their biodiversity.
7. Quantify biological rate processes that determine the inventories of elements and compounds across different trophic levels. Organic matter remineralization, microbial respiration, micro-zooplankton feeding and growth, and meso-zooplankton feeding, respiration, growth, and reproduction will be measured.
8. Determine standing stocks and distributions of microorganisms and animals to evaluate the physical-biological interactions that impact production, pelagic retention and vertical export below the halocline.
9. Evaluate impact of behavioral (e.g. vertical depth preferences and diel or ontogenic vertical migration) and life history (e.g. reproductive timing and overwintering strategies) patterns on nutrient fluxes, organismal abundance, and biomass in the ecosystem.

Work at sea

Ship-based and on-floe observations and activities were conducted to support core objectives and provide essential information to project-specific goals. Ecological properties were mainly derived from discrete physical sampling of the Arctic environment (air, snow, ice, and water). We also supplemented discrete measurements with [semi]-autonomous measurement packages, which provide higher temporal resolution of key properties from distinct positions on the primary ice floe. A small number of sensor packages and hydrographic buoy systems were deployed thru the ice to provide basic chemical and physical data at the atmosphere-ice-water interface. Ecosystem discrete sampling of snow, ice, and seawater occurred within 1 - 2km of the *Polarstern*.

Water column discrete sampling

NOT AVAILABLE

Tab.6.1: Ecosystem coordinated core variables.

Ecosystem Core Variables	**Environments & Resolution**	**Method**	**Location: Polarstern and coring sites**	**Leg 4 Summary**
Macronutrients (nitrate, nitrite, ammonium, phosphate, silicic acid, DON, DOP)	Water: 10 – 20 depth horizons Sea ice: every 5 cm	SEAL AA3 Auto-analyzer Onboard *Polarstern* TN/TP (frozen, onshore only)		
Dissolved Oxygen (DO)	*Water: 6 – 10 depth horizons* *Sea ice: none (sensor-based)*	*Winkler titration*		
Carbonate chemistry (TA, DIC)	Water: 10 -16 depth horizons Sea ice: every 10 cm	Coulometry & VINDTA		
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		
Oceanic particle size spectra and distributions;	Water column only; Sensor mounted on CTD-rosette package	Optical - Underwater Vision Profiler (UVP): *Polarstern* rosette only		
Sinking Particulate carbon, nitrogen phosphorus, and biogenic silica (POC, PON, POP, BSi)	Single Depth horizon for HydroBios 6-cup trap, deployment duration 4-8 weeks; PIT traps, depth horizons tbd, Deployment time 1-3 days	In situ traps C/N elemental analyzer Spectrophotometry Wet-alkaline method		

Chlorophyll a	6 depth horizons; total onto GF/F filter 1 horizon, size-fractionated	Fluorometry Onboard *Polarstern*		
Pigment Biomarkers	6 depth horizons; total onto GF/F filter	High Performance Liquid Chromatography (HPLC)		
Prokaryotes (Bacteria and Archaea)	8- 10 depth horiozons 6 – 10 depth horizons	Flow cytometry (FCM) DNA/RNA sequencing Eco-Omics suite		
Eukaryotic microbes (protists)	6 depth horizons	Flow cytometry (FCM) DNA/RNA sequencing Eco-Omics suite Light microscopy		
Meiofauna / Microzooplankton	Water: 6 horizons Ice: bottom 10 cm section only	Water sampling DNA sequencing ROV Net		
Meso/Macro zooplankton Fish (polar cod)	5 horizons Multinet: [2000-1000-500-200-50-0 m] Ring nets: integrated 0-100m and 0-1000m	Multinet Midi LOKI ROV Net		
Primary productivity (NPP) Dark carbon fixation	Water: 6 depth horizons Ice: 1 horizon, 2 ice types [bottom only]	14C-bicarbonate tracer 24hr incubation		
Net community production (NCP)	Seawater intake ~10 m depth horizon	MIMS; O2/Ar measurements		

Bacterial productivity (BP)	Water: 10 depth horizons Ice: 4 horizons	3H-leucine tracer 24 hr incubation		

Tab. 6.2: Ecosystem project-specific process rate measurements.

Project-specific rate measurements	**Environments & Resolution**	**Method**	**Location: Polarstern and coring sites**	**Leg 4 Notes**
Nitrogen assimilation rates measurements:	Water: 3 depth horizons (alternating)	15N-Nxx tracer - nitrate, ammonium, N2, urea, AAs		
Community respiration L and D incubations	Water: 6 depth horizons Ice: not conducted	Optodes (Presens); 6-12 hr incubations		
Respiration, grazing, reproductive rates/indices	Water: tbd Ice: none	Grazing rates, reproductive indices		

Tab.6.3: Summary of number of samples and seawater volumes processed per CTD-rosette cast.

Date	**Cast depth (m)**	**# samples**	**Total volume of water (L)**

Sea ice discrete sampling

NOT AVAILABLE

Tab. 6.4: Summary of number of ecosystem coordinated samples collected from sea ice per sampling event.

Date	**Number of samples for Eco properties**	**Number of nutrient samples**	**Totals**

Under ice light measurements

During Leg 4, we performed under ice hyperspectral measurements with the aim of characterizing the under ice light field available for primary production in the surface ocean and at the bottom of the sea ice. Moreover, corresponding ice cores have been extracted to develop relationships between spectral shape and in-ice chl *a* content (Melbourne-Thomas et al., 2015; Lange et al., 2016; Castellani et al., 2020). Such relationships can then be applied to other under-ice light measurements conducted during MOSAiC (e.g., radiation stations, ROV) to upscale in time and space the amount of in-ice chl *a*. Incoming light and under ice light measurements have been taken with Ramses spectral radiometers (Trios GmbH, Rastede, Germany). The sensor for under ice light measurement was mounted on a metal arm with an "L" shape that allows sampling of an undisturbed area 1 m away from the observer. Table 6.5 lists the measurements taken with the Larm during Leg 4. In some cases, Larm measurements coincided with the Monday coring effort at either the FYI or SYI coring site. On these occasions, Larm measurements have been conducted under the location of the ECO core for HPLC and chl *a* analyses. When the Larm was deployed on non-coring days, a core for in-ice chl *a* and HPLC analysis was extracted. Larm measurements have also been taken under the location of the optics core and, on one occasion, under a core extracted for sediment analysis. During week 47 we performed a snow removal experiment in collaboration with team ICE (Section 4.2): we removed the snow layer by layer, made a description of the snow layer, and took under-ice light measurements. During week 48 we conducted a similar experiment: we removed the snow from a square of 2x2 m and let the scattering and snow layer reform. During that time, we took under-ice light measurements. The last set of measurements and the core for HPLC and chl *a* analysis could not be taken because the MOSAiC floe broke.

Tab. 6.5: Summary of the Larm measurements conducted during Leg 4.

Date	Station ID	Station description	No. cores extracted for chl *a*/HPLC analysis	Coring Station ID	Comments
22.06.2020	44-276	FYI coring site	1	44-134	-
26.05.2020	44-275	FYI sediment trap hole	1	44-278	-
29.06.2020	45-214	SYI albedo transect next to radiation station	2	45-215	Extracted core for optics
14.07.2020	47-254	FYI coring site snow removal experiment	1	47-256	-
18.07.2020	47-255	Pond destruction experiment	1	47-137	Extracted core for optics
20.07.2020	48-291	SYI coring site	1	48-25	Extracted core for sediment
21.07.2020	48-292	Snow manipulation at ECO lodge	-	-	-
24.07.2020	48-293	Snow manipulation at ECO lodge	-	-	-
27.07	49-136	FYI coring site	1	49-34	-

Preliminary (expected) results

The majority of Ecosystem properties are based on physical samples, which require further processing at shore-based laboratories. At present, physical samples are stored at respectively appropriate temperatures until further analysis. Specific results per project can be found in the following sections. We anticipate generating a number of datasets with temporal and spatial continuity during MOSAiC. For example, daily Chlorophyll a (Chl) samples taken from the ship's underway system will generate a year-round highly resolved proxy for the biomass of primary producers in surface waters along the drift track. These properties should provide synoptic weekly and/or daily snapshots of the physical and chemical environment, and provide insight into biological responses to these conditions.

Given that there are multiple Principal Investigators behind the science of specific samples and that nearly all of the ECO Team work onboard focused on sample collection, the availability of results and data resides with the responsible PIs. 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 still need to be done. In some other cases, when results derived from biological assays, availability also resides with the responsible PIs.

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 for further processing have been stored in the respective event folders within the MCS. For samples to be analysed at the respective home laboratories, they will be processed and stored in the MCS approximately after analysis. Processed data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science, www.pangaea.de) or other public data repositories that have an agreement with the MOSAiC Project leadership. In the latter case, DOIs will be communicated to PANGAEA for later access via the future MOSAiC Data Portal.

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6.1 ECOSYSTEM SCIENCE: ZOOPLANKTON ECOLOGY AND BIOLOGY

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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 meso-zooplankton 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

This report covers the period of Leg 4 that started on 6 June 2020. Zooplankton sampling took place starting in week 44. No zooplankton net tows were performed from 6-15 June, while the *Polarstern* was in transit to the MOSAiC floe. Zooplankton sampling was conducted primarily from the *Polarstern*, using open water next to the ship. Unlike in previous legs, on this leg the ship was able to maintain space for CTD and net deployment while keeping the gangway on the ice most of the time. Occasionally, water column work was not possible due to ice pressure, drift, or ship position. On two occasions the ROV hole was used to hand deploy the 60 cm ring nets when water column access was limited.

Sampling Schedule:

R/V Polarstern: The original plan was to conduct all of the team ECO CTD and zooplankton tows on Thursday and Friday of each week, with an additional net tow and CTD on Monday morning to collect water and animals for zooplankton grazing experiments. The zooplankton sampling schedule then was expanded to take place on three days (Wednesday-Friday), with the tow and CTD for grazing remaining on Monday. Both Legs 2 and 3 had to adjust constantly to weather and temperature conditions. On Leg 4, we also found it important to start with a plan but remain very flexible to the ever-changing conditions, not just for nets, but for the rest of the team activities. See tables 6.1.1, 6.1.2, 6.1.3, and 6.1.4 for a summary of net deployments.

We appreciate the willingness of the ship's crew and our team ECO teammates to be flexible so that we could achieve as many sampling activities as possible.

The following net and LOKI operations were identified as standard core and project requirements:

1. LOKI, 1000-0 m
2. Multinet, 150-µm, 2000-0 m – for abundances (no picking)
3. Ring Net 150-µm, 200-0 m – for picking of animals for biogeochemical and genetic analyses and experiments
4. Ring Net 150-µm, 2000-200 m – for picking
5. Ring Net 1000-µm, 1000-0 m – for both picking and abundances
6. Ring Net 53-µm, 200-0 m – for abundances (no picking)
7. Additional Ring Net 150 µm, 100 m or less, for additional experimental animals
8. ROV nets 150 µm, under ice and 10 m depth – for both picking and abundances

ROV Oasis: For most of the leg, zooplankton sampling at the ROV Oasis was done on Saturday morning. During two weeks (47 and 48), sampling could not be done on Saturday but was shifted to Sunday. There was also a 24-hour sampling period with 5 ROV sampling events (every 6 hours). In week 49, ROV sampling was made possible by moving the ROV hut and hole when the initial placement became unstable. Sampling ended when the floe was no longer stable enough to leave the ROV and hut at the new location.

Tab. 6.1.1: Summary of zooplankton sampling during Leg 4 by week. MN150 = Multinet-Midi (150 µm mesh); RN53 = 0.25 m^2 Ring Net (53 µm mesh); RN150 = 1 m^2 Ring Net (150 µm mesh); RN1000 = 1 m^2 Ring Net (1000µm mesh); RN150_60 = 0.25 m^2 (60 cm dia.) Ring Net (150 µmm mesh); RN150_closing = 1 m^2 Ring net (150 µm mesh), closing mechanism deployed at 200 m; LOKI= Lightframe On-sight Key species Investigation; ROVnet = 150 µm mesh net mounted on ROV.

Week	Date Day 1	Sampling Gear Deployed							
		MN150	LOKI	RN53	RN1000	RN150	RN150_60	RN150_closing	ROVnet
44	16-Jun	2x	2x	x (hand haul)	x	2x	-	-	x
45	29-Jun	x	x	x	x	2x	-	x (800-200)	x
46	6-Jul	x	5x	x	x	2x	-	x (800-200)	5x

47	13-Jul	x	-	x (hand haul)	-	-	2x (hand haul)	-	x
48	20-Jul	x	x	x	x	2x	-	x (2000-200)	x
49	27-Jul	x	x	x	x	2x	-	-	x

Sampling limitations:

Weather did not limit sampling during Leg 4. Surface drift limited net deployment in week 47 due to risk of snagging on the ice during deployment or retrieval. On two occasions, ring nets were attempted and aborted due to the fast drift. During that week, hand nets were deployed from the ROV hole to obtain animals for core and project picking. Other limitations included ice pressure and ship movement, making it hard to maintain the sampling space between the ship and the ice. If the ship position was not stable, the bridge determined it was too risky to deploy equipment. Schedules were also sometimes changed to accommodate other operations. For example, optical studies or sediment trap deployments altered the schedule at ROV Oasis, and long-line work needed to be organized around shipboard deployments due to entanglement concerns.

Tab. 6.1.2: Detailed daily sampling pattern for each week of this leg.

Week	**Date (M)**	**Sampling Gear Deployed by Day of Week**						
		M	T	W	R	F	S	S
44	**16-Jun**		MN150, RN150(16-Jun), LOKI			RN53 (26-Jun), hand haul at ROV	MN150, RN 1000, LOKI, ROVNet (under ice, 10m, 50m) (27-Jun)	
45	**29-Jun**	RN150		RN150x2, MN150, RN53, RN1000, LOKI	RN150 (595-100m)		ROVNet (under ice, 10m)	
46	**6-Jul**	RN150		RN 1000, MN150, RN150 (800-200m)	LOKI, RN53, RN150	LOKIx3, ROVNet (under ice, 10m, 100m) x2	LOKI, ROVNet (under ice, 10m, 100m) x2 + (under ice, 10m)	

47	**13-Jul**				RN150, MN150	RN53, RN150(60cm) x2, hand haul at ROV		ROVNet (under ice, 10m)
48	**20-Jul**		LOKI, RN1000	RN150x2, RN53	MN150	RN150 (2000-200m)	RN 150	ROVNet (under ice, 10m)
49	**27-Jul**	RN53, MN150	LOKI, RN1000		RN150			

Sampling Gear:

General: Upon arrival to the floe, the ship was positioned with the starboard side next to the ice. Team ECO and OCEAN led a hole cutting effort, supported by people from many teams, but ice pressure and shifting ship position moved the hole out of reach and then crushed it. Eventually, this movement created a small bay that could be used for water column work. Zooplankton sampling gear was deployed with the *Polarstern's* crane and winches into this open water on the starboard side of the ship, next to the gangway. The space and ship position in the ice were maintained using the ship's thrusters. During week 47, there were periods in which a large enough space was not available. Water column sampling, including nets was limited that week.

All sampling gear were lowered from the surface and raised vertically from the designated sampling depth at a speed of 0.5m/s, unless otherwise noted. Upon reaching the surface, nets were rinsed on the outside with seawater from the shipboard underway hose while they were being lifted into the air, to ensure the nets were clean and all organisms were collected in the cod-ends. For non-quantitative experimental nets, the nets were not rinsed to avoid net damage to the animals.

Cod-ends from nets for fixation were brought to the lab in buckets with underway seawater surrounding the cod-ends and immediately fixed. Contents of the cod-ends that were to be used for picking and experiments were diluted with underway seawater (surface tow) or cold filtered seawater (deep tow) into 4 L jars and placed into a cooler. For gut DNA samples (150-µm ring nets), a portion of the sample from a non-quantitative tow was poured through a small 150-µm mesh and the mesh rinsed into a sample container with 96% ETOH before the catch transfer to the large dilution jars.

Multinet Midi (5 nets, 150-µm, 0.25 m^2, 2000-1000-500-200-50-0 meter sample depths): Multinet samples were collected every week from 5 depths to determine the meso-/macro-zooplankton abundance, community composition, and vertical distribution. The samples were preserved in 4% formaldehyde for later analysis. During weeks 44-46 the ship drifted across the Yermak plateau, where the bottom depth was near 800 m, and the pre-established depths were modified to Bottom-500, 500-200, 200-100, 100-50, and 50-0 m.

Ring Nets (53-µm, 0.25 m^2; 150-µm, 1m^2; 1000-µm, 1m^2; and 150-µm, 0.25 m^2): Four different ring nets were deployed on Leg 4.

The smaller 53-µm mesh net collected large micro-zooplankton and small meso-zooplankton in the upper 200 meters. This net was also deployed using the tripod and block at the ROV hole in week 44, to test that approach, before a hole near the ship was available, and again during week 47 when water shipboard water column access was limited.

The larger 150-µm net was used to collect meso- and micro-zooplankton in two separate depth intervals, 200-0 m and 2000-200 m (or bottom-200 m in shallow areas) using a mechanical closing mechanism. The deeper interval could only be sampled during weeks 45, 46, and 48 due to the need for a DYNEEMA to fit the closing mechanism. This line was lighter and more subject to drift into the ice edge. Because of this, a series of blocks were used on the line, and a larger deck crew was required. Additionally, this deployment was run at 0.2 m/s due to the weights, lines, and the winch system involved.

The smaller 60cm 150-*µm* ring net was hand hauled at the ROV hole in week 47.

The 1000-µm net was used to collect large meso- and macro-zooplankton from the upper 1000 m.

Ring nets were deployed with a temperature-depth recorder (TDR) attached to assess the actual depth reached for each tow.

Target species were sorted from both the 150- and 1000-µm nets for biochemical and genetic analysis, and subsamples were occasionally taken from the 150-µm nets for gut DNA analysis. Animals were also picked for other project and experimental work. The remainder of the sample from the 150-µm ring net was frozen at -80 °C. Samples from the 53 µm and 1000-µm ring nets were preserved in 4% formaldehyde for later enumeration at home laboratories.

LOKI (Lightframe On-sight Key species Investigation): The LOKI, an optical plankton recorder, was deployed ten times during Leg 4, including five deployments during the 24-hour sampling period in week 46. 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 photos 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 environmental conditions. The original LOKI computer, used in previous legs was replaced by the back-up computer (alias: THOR) before the 24-hour sampling event and was used for the remainder of Leg 4. Overheating of the LOKI computer during data download was mitigated using ice packs to cool the underwater case; data from all tows were successfully downloaded and archived in the MCS.

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. During the 24-hour sampling event, CTD casts and associated UVP profiles were carried out every 8 hours. During week 44, the ocean team carried out a yo-yo CTD study over 24 hours. Every 4 hours water was sampled with the rosette for biological and biogeochemical analysis. During the first 8 hours we collected UVP profiles at each cast. The time needed to recharge the battery, though, did not allow to collect each profile over the 24 hours so for the remaining period we collected UVP profiles only for those CTD casts from which water was sampled.

ROV Net (150- and 10-µm nets; 0, 10, and 50-100 m sample depths): The under-ice zooplankton community was studied in cooperation with the ROV team of the ICE group (see ROV section 4.6). The ROV net consisted of a large rectangular 150-µm mesh net. During the 24-hour sampling event in week 46, a small phytoplankton/gypsum net (10-µm mesh size) was also included inside of the 150-*µm net*. The smaller gypsum net was caught in the ROV thruster during event 46-174, and was irreparably ripped. Plastic lamellas on top of the net frame were used to scrape organisms off of the underside of the sea ice. In addition, a third tow was added into the sampling scheme (between 50-100 m) in some weeks. The initial impression has been that the 10 m layers were primarily *C. hyperboreus* and *C. glacialis/finmarchicus*, and the surface layer was dominated by the phytoplankton *Melosira* sp. in a fresh-water lens under the ice. In the last half of the leg, amphipods, specifically *Apherusa glacialis*, were captured from the surface layer. Samples were retained in 1-L Kautex plastic jars or diluted into 4-L plastic jars that were kept in a cooler until returned to the ship. Leg 4 experienced a thick fresh water lens under the ice for several weeks. To keep the samples in prime condition we hauled filtered seawater to the ROV oasis to use for pre-filling the cod end, rinsing, and diluting the animals. Additionally, the contents of the cod end were quickly emptied into a jar of filtered seawater before replacing the cod end and rinsing the net thoroughly in the hole. This second pour of animals from the washed net was retained in a separate jar, but the animals were not used for experiments. After picking, all jars from one net were recombined before preservation for abundance. Once on board, samples were immediately transferred to a laboratory container maintained at cold temperatures. Samples were preserved in 4% formaldehyde after sorting target organisms for core sampling and experimental animals; all removals were noted on station protocol sheets. Occasional extra net samples were taken for gut DNA. Alternatively, aliquots were taken. For aliquot sampling, the entire sample was placed in a 2-L beaker, the total volume noted, the sample re-suspended, and a subsample (250-500 ml) taken using a 250 ml beaker. The aliquot volume was recorded and the subsample was passed through a 150 µm mesh sieve and rinsed into a sample jar using 96% EtOH.

Tab. 6.1.3: Zooplankton sampling gear, targeted depth horizons, and number of hauls for each piece of sampling gear during Leg 4. MN150 = Multinet-Midi (150 µm mesh); RN53 = 0.25 m^2 Ring Net (53 µm mesh); RN150 = 1 m^2 Ring Net (150 µm mesh); RN1000 = 1 m^2 Ring Net (1000µm mesh); RN150_60 = 0.25 m^2 (60 cm dia.) Ring Net (150 µmm mesh); RN150_closing = 1 m^2 Ring net (150 µm mesh), closing mechanism deployed at 200 m; LOKI150= Lightframe On-sight Key species Investigation with 150µm net; BEAST = ROV Net (150 µm mesh net).

Sampling Device	Depth Sampled	Number of Hauls
MN150	2000-0	3
MN150	<800-0	4
RN150	200-0	5
RN150	<100-0	5
RN150_60	<100-0	2
RN150_closing	2000-200	1
RN150_closing	<1000-200	2
RN1000	1000-0	2
RN1000	<850-0	3

RN53	200-0	4
RN53	67-0	1
ROV Net	0	9
ROV Net	10	9
ROV Net	50	1
ROV Net	100	4
LOKI	1000-0	7
LOKI	<800-0	3
UVP	Same as CTD casts	47

Tab. 6.1.4: Date, activity number, and position (latitude, longitude) for each zooplankton device operation. MN150=Multinet-Midi, 150-µm mesh nets; RN150=150-µm, 1m^2 Ring Net; RN1000= 1000-µm, 1m^2 Ring Net; RN53=53-µm, 0.25 m^2 Ring Net; RN150_60=150-µm, 0.25 m^2 Ring Net; LOKI150= Lightframe On-sight Key species Investigation with 150-µm net; BEAST=ROV with 150-µm net. *Net was deployed and aborted at the surface due to high drift.

Date	Activity Number	Device	Latitude	Longitude
16-Jun-20	44-69	MN150	82° 12,490' N	008° 19,168' E
16-Jun-20	44-74	LOKI	82° 11,964' N	008° 18,999' E
16-Jun-20	44-75	RN150	82° 11,617' N	008° 18,843' E
26-Jun-20	44-170	RN53	82° 02,572' N	010° 12,592' E
27-Jun-20	44-185	MN150	81° 56,727' N	009° 52,499' E
27-Jun-20	44-186	RN1000	81° 56,180' N	009° 50,761' E
27-Jun-20	44-188	LOKI	81° 55,238' N	009° 46,895' E
27-Jun-20	44-191	BEAST	81° 57,917' N	009° 54,688' E
29-Jun-20	45-5	RN150	81° 49,602' N	009° 10,134' E
1-Jul-20	45-32	RN150	81° 46,056' N	008° 52,976' E
1-Jul-20	45-39	RN150	81° 46,030' N	008° 52,834' E
1-Jul-20	45-40	MN150	81° 45,997' N	008° 52,603' E
1-Jul-20	45-44	RN53	81° 45,970' N	008° 52,370' E
1-Jul-20	45-45	RN1000	81° 45,950' N	008° 52,183' E
1-Jul-20	45-47	LOKI	81° 45,906' N	008° 51,937' E
2-Jul-20	45-55	RN150	81° 44,011' N	008° 32,772' E
4-Jul-20	45-149	BEAST	81° 42,473' N	006° 53,960' E
6-Jul-20	46-4	RN150	81° 41,828' N	005° 35,461' E
8-Jul-20	46-41	RN1000	81° 36,828' N	003° 25,704' E
8-Jul-20	46-43	MN150	81° 36,384' N	003° 21,757' E
8-Jul-20	46-49	RN150	81° 35,826' N	003° 15,429' E

9-Jul-20	46-64	LOKI	81° 32,912' N	002° 35,696' E
9-Jul-20	46-65	RN53	81° 32,678' N	002° 35,232' E
9-Jul-20	46-66	RN150	81° 32,570' N	002° 34,992' E
10-Jul-20	46-80	LOKI	81° 30,323' N	002° 21,884' E
10-Jul-20	46-84	LOKI	81° 29,138' N	002° 12,756' E
10-Jul-20	46-89	LOKI	81° 28,507' N	001° 58,465' E
11-Jul-20	46-90	LOKI	81° 27,847' N	001° 47,329' E
10-Jul-20	46-172	BEAST	81° 31,316' N	002° 24,502' E
10-Jul-20	46-174	BEAST	81° 29,174' N	002° 13,326' E
11-Jul-20	46-175	BEAST	81° 28,513' N	001° 58,629' E
11-Jul-20	46-176	BEAST	81° 27,873' N	001° 47,577' E
11-Jul-20	46-177	BEAST	81° 26,827' N	001° 35,393' E
16-Jul-20	47-67	RN150*	81° 13,529' N	000° 16,993' E
16-Jul-20	47-68	MN150	81° 13,310' N	000° 16,621' E
17-Jul-20	47-86	RN53	81° 08,395' N	000° 21,202' E
17-Jul-20	47-163	RN150_60	81° 08,647' N	000° 21,324' E
19-Jul-20	47-135	BEAST	80° 53,433' N	000° 09,158' W
21-Jul-20	48-17	LOKI	80° 37,873' N	000° 31,891' W
21-Jul-20	48-27	RN1000	80° 37,296' N	000° 32,338' W
22-Jul-20	48-54	RN150	80° 28,503' N	000° 33,840' W
22-Jul-20	48-55	RN150	80° 28,425' N	000° 34,015' W
23-Jul-20	48-73	RN53	80° 20,337' N	000° 41,791' W
23-Jul-20	48-80	MN150	80° 20,153' N	000° 43,936' W
24-Jul-20	48-99	RN150	80° 12,857' N	000° 34,134' W
25-Jul-20	48-136	RN150	79° 56,313' N	000° 47,479' W
26-Jul-20	48-213	BEAST	79° 49,724' N	001° 40,264' W
27-Jul-20	49-3	RN53	79° 37,375' N	002° 15,056' W
27-Jul-20	49-6	MN150	79° 35,602' N	002° 17,162' W
28-Jul-20	49-16	LOKI	79° 23,136' N	002° 42,555' W
28-Jul-20	49-21	RN1000	79° 21,907' N	002° 41,466' W
30-Jul-20	49-39	RN150	79° 06,919' N	002° 31,004' W

Shipboard Laboratory Work

Biochemical and Genetic Variables:
Prior to preservation/freezing, some of the 150-µm, 1000-µm, and ROV net tow collections were sorted for biochemical and genetic specimens of target zooplankton species following protocols provided by the project PIs. Animals were sorted from a portion of the total catch in the environmental room for live rate process measurements (grazing, egg production, and/or respiration rates). A separate portion of the catch was sorted in the zooplankton dry lab from a

tray kept on ice for additional core and project requirements. 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, transcriptomics, and microplastics. 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 150- µm ring net tows and 10 m ROV nets and preserved immediately in 96% EtOH for gut DNA content of target zooplankton species.

Tab. 6.1.5: 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	1491	2213
Trophic Biomarkers	Core/Project	96	669
Energy Content	Project	113	321
Enzymes	Project	15	137
Gut Content	Project	20	72
Transcriptomics	Project	23	23
Microplastics	Project	9	49
Photographs	Core/Project	1864	
Community Measurements			
Abundance/Taxonomy	Core	68	
Gut DNA	Project	23	
LOKI	Core	10 hauls	
UVP	Core	47 hauls	

Rate Process Studies (Respiration, Reproduction, and Feeding):

Most rate process studies were conducted under dim, constant light during this 24-hour day-light summer cruise. Leads and ponding increased the penetration of light into the upper ocean. The set-up and selection of experimental animals were done under red light, in the cold room, on ice.

Respiration rates were determined for target zooplankton species/life stages collected from different depth horizons with a Presens optode oxygen measurement system. Measurements were taken every 6 hours for the first 24 hours and every 12 hours for an additional 1 to 2 days. Eight experiments were conducted with groups of 2-4 target organisms each measured in triplicate along with controls. At the termination of the experiment, all animals were photographed and saved for CN determination. The Optode system was calibrated during Leg 3 by measuring the oxygen concentration of water for which the oxygen had been driven out (zero) and of water that was nearly simultaneously collected for standard determination of oxygen concentration by Winkler titration.

Leg 4 coincided with the reproductive season of the copepod *C. glacialis*. Egg production rates were determined for adult female *C. glacialis* at least weekly through Leg 4, totaling 7 experiments. Egg production rates were monitored daily for individual females and a subsample of the eggs produced each day were followed for egg hatching success. At the termination of the experiments, the females were photographed and saved for CN measurements. The observation period was extended several days after observing continued egg production. Two additional experiments comparing light and dark egg production rates were also performed.

One *C. hyperboreus* egg production experiment was ongoing from Leg 3 at the start of Leg 4, and observations continued until the females ceased egg production. An additional carry-over from Leg 3 was an experiment incubating 20 individual *C. glacialis* females to see if *C. glacialis* without food but with lipid would develop eggs. One *C. glacialis* experiment with 20 females will be continued into Leg 5, to look at egg production rates in relation to food availability.

Zooplankton feeding rates were determined in eight experiments using standard bottle incubation techniques. The incubations were conducted on a plankton wheel in the environmental chamber (1 °C) in low light for 24 – 48 hours. Groups of 1-3 separate target species/stages were incubated in triplicate along with controls. Dilutions were also done for 4 of the experiments to determine micro-zooplankton feeding rates in these experiments. At the start and end of the incubations, samples were taken for chlorophyll and micro-zooplankton analysis. At the termination, all copepods were photographed and saved for CN determination.

Tab. 6.1.6: Zooplankton rate processes. The number of experiments and the total number of samples/bottles incubated for each type of process measurement are shown. For reproduction experiments, some incubations were carried over from Leg 3.

Experiments	Number	Incubations
Respiration	8	106
Reproduction	11	350
Grazing	8	135

Preliminary (expected) Results

All samples will be processed and analyzed 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 6.1.4, 6.1.5, and 6.1.6.

Overall, the zooplankton communities sampled during Leg 4 appeared to be typical of late spring and summer. We observed possible responses to phytoplankton blooms, and reproduction rates occurring for species such as *C. glacialis* that require food availability for egg production. When chlorophyll levels increased, many eggs, nauplii and some younger copepedites were observed in both the nets and grazing water collected at the chlorophyll maximum depth (based on the CTD fluorometer trace).

Water column chlorophyll concentration was fairly low when the *Polarstern* reached the floe at the start of Leg 4. Over the next several weeks, the top few meters changed dramatically. Initially, a fresh water lens with a shallow chlorophyll peak (~10 m) was observed. Then a thick green layer appeared in the leads between the freshwater lens and saltwater (described further in the Lead Sampling Section 8.4). A few days later, the chlorophyll levels in the upper water column peaked, with a broad chlorophyll maximum and often multiple peaks between 10-50 m visible in the CTD fluorometer traces. As the drift speed increased and the floe moved south and southwest, the chlorophyll levels dropped.

The drift south through different water masses resulted in dramatic shifts in animal condition and egg production rates. The first stations of the leg were conducted north of 82°N and the last station at 79°N, a change of more than 3° of latitude. At the last Leg 3 station, over the Yermak Plateau on May 30, late copepodite and adult female stages of multiple *Calanus* species were present. Leg 4 arrived back at the floe approximately three weeks later, with initial net deployments on 16 June, still over the relatively shallow, Yermak Plateau. The 16 June nets included a similar distribution of Calanus species and stages. The stations on the Yermak Plateau were characterized by a low abundance of macrozooplankton.

Almost all upper water column (200-0 m) net hauls through Leg 4 included *C. hyperboreus* and *C. glacialis*, adult females and copepodite stage C5, with shifts in abundance and relative biomass. *Metridia longa*, younger *Calanus* spp. stages, and smaller species were also all present throughout the cruise, though in varying proportions. *C. finmarchicus* females were observed at higher abundance at the start of Leg 4 over the Yermak Plateau, and less abundant later. Qualitative observation suggests *C. hyperboreus* were utilizing the bloom. They appeared to be the dominantly abundant animal by biomass in the upper water column, with noticeably green guts and possibly increasing lipid levels.

The most abundant macrozooplankton were chaetognaths and the amphipod *Themisto abyssorum.* Other species found consistently were *Tyssanoessa longicaudata* and *Apherusa glacialis.* The latter was the primary animal in ROV net tows conducted directly under the ice, very often being the only species present (visible to the eye). During week 48 we encountered a large number of appendicularians in both the ROV nets and the shallow (200-0 m) Ring net.

The temporal and spatial changes of the drift complicate the questions of seasonal progression. Understanding the patterns and characteristics of the zooplankton communities and summer phenology will require careful consideration of the zooplankton data together with physical, chemical and biological data from many of the other MOSAIC core and project measurements.

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). Some data will be stored at the PANGAEA data repository (World Data

Center PANGAEA Data Publisher for Earth & Environmental Science www.pangaea.de <http://www.pangaea.de/>.

Some data will be stored at the Arctic Data Center (ADC) following the agreement between ADC and the MOSAiC Project lead. DOIs will be communicated to PANGAEA for later access via the future MOSAiC Data Portal.

6.2 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 4 of MOSAiC Giulia Castellani was on board *Polarstern* and followed the sampling routines established during the previous legs. Official Leg 4 work at sea started on 6 June. The exchange between Leg 3 and Leg 4 happened in the Isfjord of Svalbard on 6 June. On 8 June *Polarstern* departed from Isfjord in the late morning and exited the Norwegian 12 nm in the evening. Between 12-13 June *Polarstern* has been stuck in the ice for more than a day. On 17

June *Polarstern* reached the MOSAiC ice floe and the exploration activities began. On 19 June the ship parked at the floe and the installation activities started, in parallel with some science activities. The official regular sampling started on 29 June. During Leg 4 the ship was located North-West of Svalbard. In this area we encountered several polar bears that delayed the work on ice. Sometimes poor visibility would also cause delays/cancellations of the work on ice. On 31 July the MOSAiC ice floe disintegrated and so the Leg 4 sampling ended.

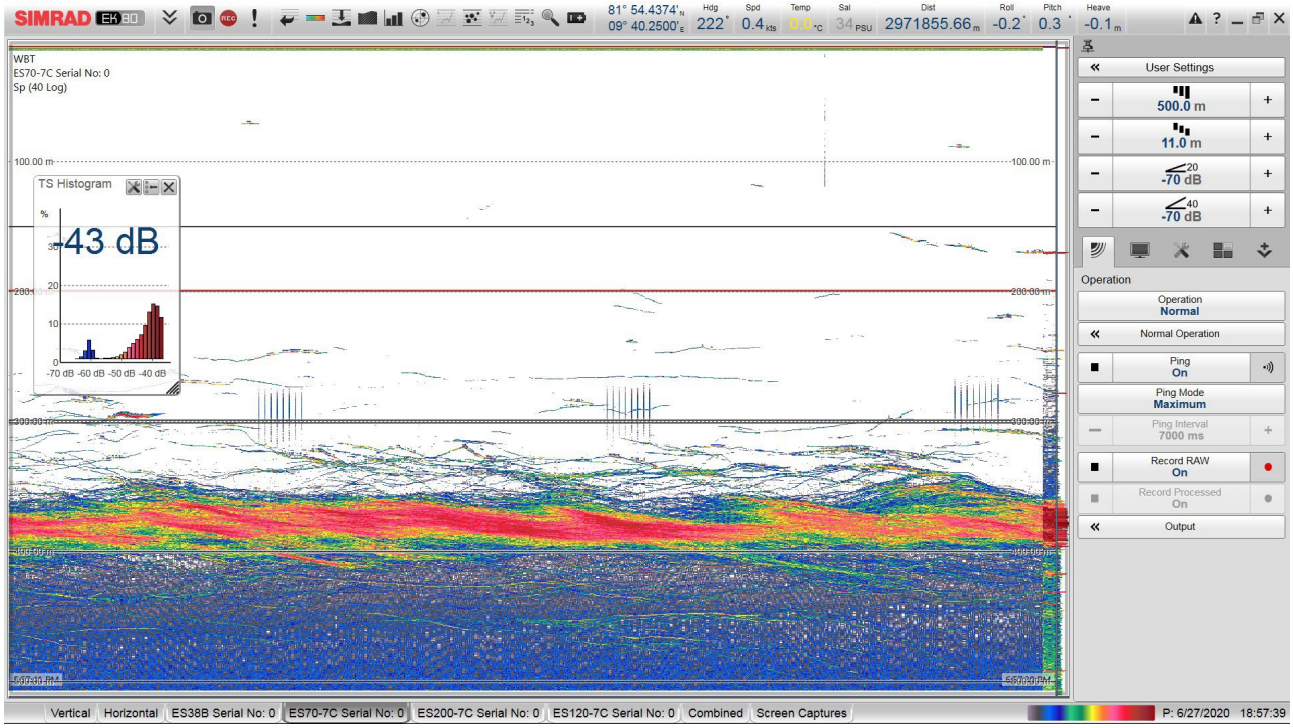
Hydroacoustics

During Leg 4 of MOSAiC the EK80 and EK60 settings were the same as for the end of Leg 3, so the instruments ran with frequencies of 38 kHz (GPT, CW mode), 70 kHz (WBT, FM and CW mode), 120kHz (WBT, FM and CW mode), and 200 kHz (GPT, CW mode) for the EK80, and 18 kHz for the EK60 (GPT, CW mode). The mode of the 70 kHz and of the 120 kHz transducers of the EK80 was manually swopped between FM and CV mode every 24 hours.

During Leg 4 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 a connection problem between the EK80 software and the disk for data storage. An example of the disturbance due to the ADCP installed from an ice hole is shown in Figure 6.2.1. The ADCP pings 8 times every 20 minutes, so this signal can be identified in the data as 8 vertical lines grouped together at a depth of ca. 300 m. When positioning the ship at the ice floe, the two AZFPs previously installed on the ice during Leg 2 were kept at ca. 500 m of distance from the ship in order to avoid any disturbance with the EK80 and EK60 recordings. After relocation of the ship at the floe we conducted an inspection to make sure that the EK60 and EK80 were not affected by other disturbances: With an ROV deployed from the ship's moonpool we checked that no ice blocks were stuck under the ship creating an obstacle for the hydroacoustic signal. We also checked all cables. During the transit the EK60 presented a problem with the ping interval, the settings were changed so that 10 pings (previously 15) from the EK80 were followed by 1 ping with the EK60. This means a change in ping time from 53 sec (EK80) and 7 sec (EK60) to 35 sec (EK80) and 7 sec (EK60).

At the end of Leg 4 we performed a calibration of the 18kHz. Data have been stored and brought home for further analysis.

Figure 6.2.1 Example of the interference caused by the ADCP installed on ice. The interference can be recognized as 8 vertical lines grouped together at a depth of ca. 300m.



Fish sampling

During Leg 4 the procedure defined as standard during previous legs was followed through the entire period, with some exceptions. Long lines have been deployed every week targeting the mesopelagic area (i.e., between 200 and 400 m depth or between 300 and 500 m, according to the EK80 signal). During week 44 we took advantage of the ship being stuck in ice to deploy one long line from the ship's stern. During the residence time at the ice floe long lines were deployed from the ROV hole or from the sediment trap hole. The strong currents under the ice caused the long line to entangle with the CTD during station 45-130. From that time we had to coordinate everything that was deployed at a certain depth from the ice and from the ship. During week 44 we deployed the long lines between 200 and 400 m depth, starting from week 45 we changed the depth to 300 m and 500 m because the fishes were present in high concentration around 400 m depth (Figure 6.2.2, right panel). During week 47 we could deploy only one long line because the persistent presence of ice bears for 3 days in a row prevented the work on ice. During week 48 we focused on ice fishing for juvenile polar cods, thus we deployed only one long line. During week 49 the MOSAiC floe broke and the work ended before any long line deployment was possible.

The citizen science (i.e., fishing with fishing rods) was not possible from the moonpool because the ship's propellers were on the entire time to ensure the ship's position at the ice floe. Fishing was possible from the ice, but only during working hours, so it was not possible for people or crew members to fish.

Visual observations

The deep-sea camera system (FishCam) was recovered during Leg 3 and no further deployment was possible during Leg 4 because of the unstable conditions of the ice floe, and because the data cable with optic fiber to transfer the video files could not be installed.

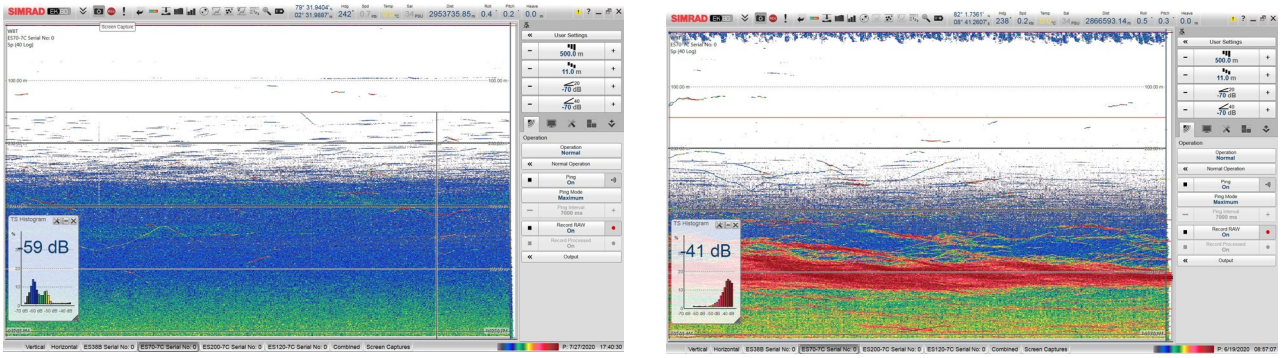
Environmental DNA

During the entire Leg 4, 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. 2.5 TB of hydroacoustic data were collected during Leg 4 of MOSAiC. A scattering layer of living organisms was always observed in the mesopelagic, the organisms in the fish size range (>-45 dB) had extremely high densities. A comparison between a high abundance and low abundance of fish in the EK80 signal at 70kHz is presented in Figure 6.2.2.

Figure 6.2.2. Example of a profile with a very low presence of fishes (left panel) and with a very high presence of fishes (right panel) recognizable by the red horizontal stripes at ca. 400 m.



The fishing activities from the ice during Leg 4 of MOSAiC started on 12 June. In the period 12 June - 31 July we deployed 8 long lines, we performed one surface fishing event with fishing rods and pilkor techniques, and we had 3 ice sampling events (Table 6.1.1). The fishing rods event and the ice sampling events were aiming to collect polar cods from ice holes and small cracks. The fishing rods technique did not prove successful. The best way to catch polar cods was to disturb them with a stick so that they would swim to the surface, and then use hands or small nets to catch them. In total, we collected 53 fishes during Leg 4 by means of these techniques. The species included Atlantic cod, Polar cod, Haddock, and Sebastes. The data taken from the fishes were total length, standard length, and total weight. Most of the Atlantic cods and polar cods were dissected to sample stomach, hind gut, gonads, fin clip for genetic analysis, leaver and muscle for biomarkers. Moreover, otoliths were extracted. The rest of the fishes has been frozen at -20°C for further analyses at home.

Tab. 6.2.1: Overview of sampling efforts and fish samples taken during Leg 4 of MOSAiC.

Event number	Deployment and Retrieval date	Sampling method	Number of fish	Number of dissections*
PS122/4_44-91	12.06.2020-13.06.2020	Long line	0	-
PS122/4_44-144	21.06.2020-23.06.2020	Long line	0	-
PS122/4_44-203	25.06.2020-26.06.2020	Long line	0	-
PS122/4_45-130	04.07.2020-05.07.2020	Long line	13	3
PS122/4_46-16	06.07.2020-07.07.2020	Long line	3	1
PS122/4_46-137	11.07.2020-12.07.2020	Long line	14	0
PS122/4_47-34	14.07.2020-15.07.2020	Long line	4	0
PS122/4_48-57	21.07.2020-22.07.2020	Long line	8	0
PS122/4_	22.07.2020	Fishing rods	0	-
PS122/4_48-278	24.07.2020	General fish sampler	1**	0
PS122/4_48-279	25.07.2020	General fish sampler	9	9
PS122/4_49-128	27.07.2020	General fish sampler	1	1
Total number of fish			**53**	

* we refer here to complete dissection, some fishes have been sampled only partially

** this fish was collected already dead

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.

6.3 Ridges – Safe havens for ice-associated flora and fauna in a seasonally ice-covered Arctic Ocean (HAVOC)

Oliver Müller [4] (Onboard for Team ECO), Jessie Gardner[3] (Onboard for Team ECO), Benjamin Lange[1] (Onboard for Team ICE), Evgenii Salganik[1] (Onboard for Team ICE), Morven Muilwijk (Onboard for Team OCEAN).

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], Lasse M. Olsen[4], Dimitry V. Divine[1]

[1]Norwegian Polar Institute (NPI) [2]Norwegian University of Science and Technology (NTNU) [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 the number of 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 refuge 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 provide 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 6.3.1). 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.

The SIRO utilises state-of-the-art platforms and methods with the aim that all aspects of the ridge evolution can be followed throughout the annual cycle. Field sampling was 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 enables the improvement of coupled physical-biogeochemical sea-ice models. The overall objective of MOSAiC is centred 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.

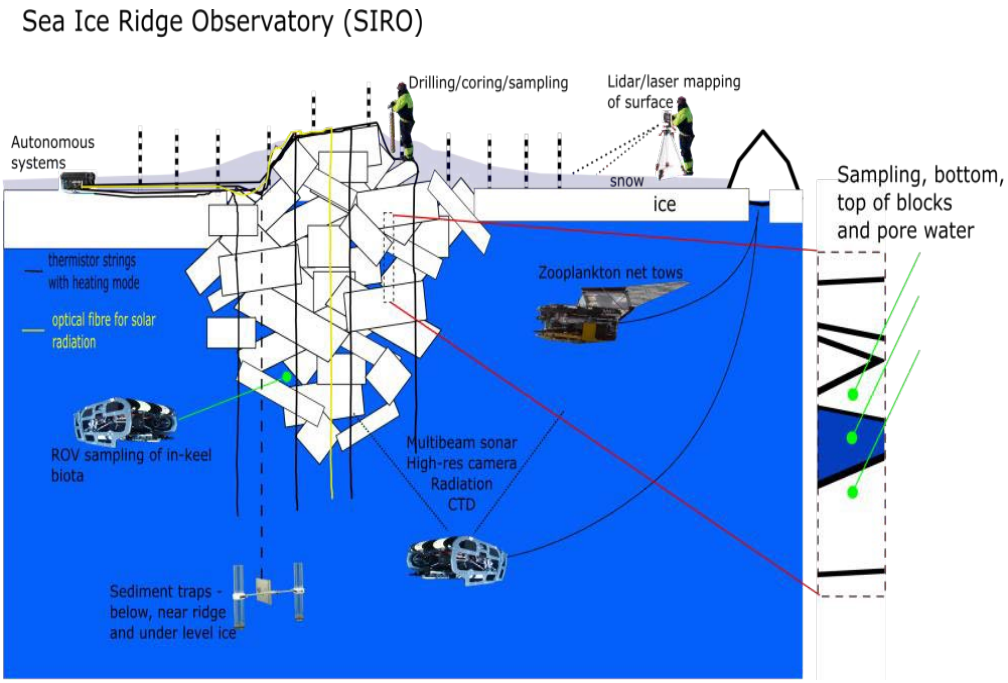

Fig. 6.3.1: Schematic of the core components of the ridge observatory component of the MOSAiC campaign.

The central objectives of HAVOC aim to:

1. Characterize the habitat structure and physical environment in Arctic sea-ice ridges over an annual cycle to understand their ecosystem function
2. Assess processes that cause differences in the diversity of ice associated biota between ridges and level sea ice
3. Determine how food web and biogeochemical processes at the ice-ocean interface and the underlying water column differ between ridges and level sea ice
4. Extend findings to regional and pan-arctic scales and assess performance and improve representation of ridges in coupled ice-ocean-ecosystem models

Work at sea

1.1. Ridge identification

A suitable ridge site ("Jaridge") was located approximately 200 m from *Polarstern* and 10 m from the ROV (Remotely Operated Vehicle) deployment site. Subsequently, the sea ice ridge observatory (SIRO) was established.

1.2. Field sampling logistics

All of the ECO ice cores, gap water and under ridge water samples were collected in the morning session (9 am to ~12:30pm) on Friday, except when there were logistical restraints (e.g. fog, polar bears or infrastructure issues). Typically the measurements taken by the ICE team (see the ridge studies section (4.9) within the Team ICE for more details) were collected the previous day or during the afternoon session. Sediment traps and *in-situ* incubations were then deployed in the afternoon session. The ICE team would deploy the sediment traps under the ridge using the ROV while the ECO team would deploy the sediment traps at the FYI site as well as collecting under ice water (either from the sediment trap hole or at ECO lodge). Sediment traps were recovered by the same teams after 24-48 hours.

Sediment traps: HAVOC

Ice-tethered sediment traps were deployed under the ridge and FYI to quantify the vertical export (biogeochemistry, community and particles) (Figure 6.3.2). At Jaridge on the 27.06.2020, a rope with a weighted loop was deployed from the surface, close to the ridge keel at 1.5 m under the ice. Subsequently, sediment traps were hung onto the loop with a hook via the ROV, operated by the ROV team (Team ICE). Each sediment trap consisted of a wooden hook and another weighted loop at its base to allow for another trap to be attached below. Due to load limitations by the ROV, extra weights and keels were removed from sediment traps, and only two cups were attached per trap depth.

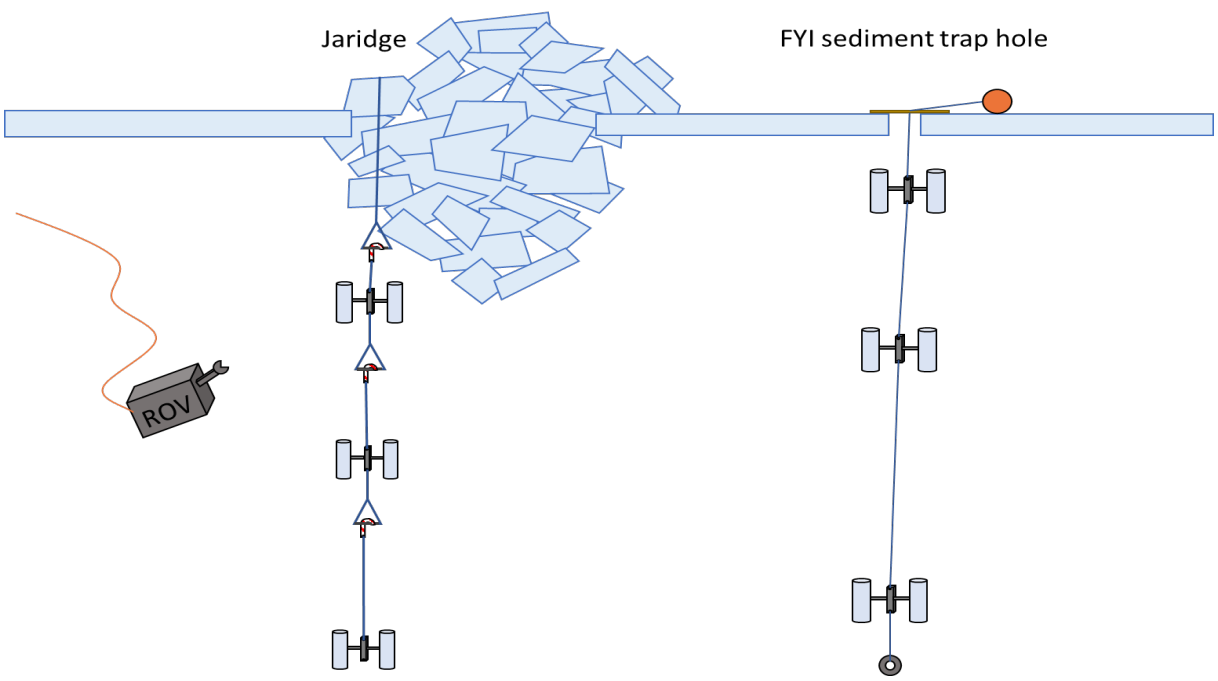

Figure 6.3.2. Schematic of sediment trap moorings for the comparison of vertical export beneath a ridge ("Jaridge") and First Year Ice (FYI sediment trap hole). Sediment traps were deployed at 5, 15 and 50 m beneath the sea ice bottom for 24- 48 hours between 26.06.2020 and 21.07.2020 by the HAVOC project.

In parallel to the ridge sediment traps, a mooring line was also deployed through a hole in the FYI around 100 m from the ROV hole and 50- 70 m from the FYI coring site. This hole was created by the ECO team using a 14” ice corer, ice saws and slush removal equipment. The mooring was secured using ice screws, buoys and wooden crossbars at the surface and weighted at the base with a 10 kg weight.

Traps were deployed at 5, 15 and 50 m below the ice bottom, except during the initial under-ridge deployment where no trap was deployed at 50 m due to logistical restraints. The 1st sediment trap deployment was only under the FYI since the ROV hole had not been established. The subsequent deployments were under the FYI and the ridge in parallel. All deployments were for 24 hours, except for the last deployment which ran for 48 hours due to delays (from polar bear visits to the ROV site) and then conflicts with the ECO core programme.

The FYI sediment trap hole was initially ~40 x 140 cm and the ice was ~130 cm thick (Figure 6.3.3a). One week after establishing the sediment trap hole a nearby melt pond started to drain through it and the hole enlarged significantly thereafter (Figure 6.3.3b). We aimed to establish a second hole, in collaboration with team BGC, on the 9 July for the deployment of gel traps situated 5 m away from the sediment trap hole. Unfortunately there was a rafted piece of ice 1-2 m below the ice bottom making this hole non-functional. A frozen layer of fresh water was observed at the bottom of the hole before all deployments except on 19 July. From 19 July algal aggregates were observed within the hole, particularly degraded white (Melosira?) fragments. Using a GoPro, under ice surfaces were observed to change substantially. Large strands of Melosira were present during the first sediment trap deployment (04.07.2020) but these strands disappeared by the second deployment (11.07.2020), potentially due to the drainage of the melt pond. The final observation (18.07.2020) revealed that extensive melting had occurred, the Melosira was no longer present and an accumulation of algae and organic matter formed on large ledges (Figure 6.3.4).

On retrieval of the sediment trap the cup contents were pooled into a carboy and transported back to *Polarstern* in the dark. The water samples were then processed for Chl a, POC/PON, faecal pellets, light microscopy, FCM, BP, DNA and XRF. Table 6.3.1 gives an overview of the sediment trap events and the parameters collected from each depth. Table 6.3.2 gives the deployment date, time, DSHIP device operation number and deployment details of each trap.

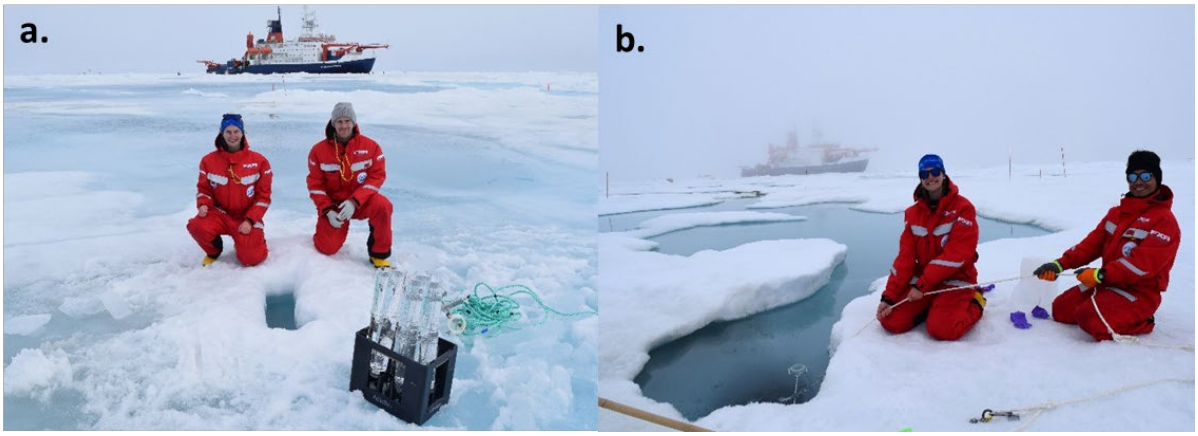

Figure 6.3.3 a) The first year ice sediment trap hole on the 26.06.2020, during the first sediment trap deployment with ECO HAVOC members Jessie Gardner (left) and Oliver Müller (right). b) shows the hole on the final deployment day (19.07.2020) with a melt pond draining into the hole (Image a. was taken by J.P. Balmonte and b. by O. Müller).

Figure 6.3.4. Under ice images taken through the sediment trap hole on a) 04.07.2020, b) 11.07.2020 and c) 18.07.2020.

Tab. 6.3.1: Sediment trap deployment dates, depths and parameters sampled from beneath a ridge ("Jaridge") and First Year Ice (FYI). Chl a and POC/PON were sampled in triplicates.

		Parameter									
Deployment date	**Site**	**Chl a**	**FCM**	**Faecal pellets**	**POC/PON**	**Nutrients**	**Flow Cam**	**Microscope**	**BP**	**XRF**	**DNA**
26.06.2020 14:10 – 27.06.2020 15:30	FYI 5 m	✓	✓	✓	✓			✓		✓	✓
	FYI 15 m	✓	✓	✓	✓			✓		✓	✓
	FYI 50 m	✓	✓	✓	✓			✓		✓	✓
	Ridge 5 m										
	Ridge 15 m										
	Ridge 50 m										
03.07.2020 14:45 – 04.07.2020 14:10	FYI 5 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	FYI 15 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	FYI 50m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Ridge 5 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Ridge 15 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Ridge 50 m										
10.07.2020 11:00 – 10.07.2020 11:30	FYI 5 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	FYI 15 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	FYI 50 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Ridge 5 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Ridge 15 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Ridge 50 m	✓	✓	✓	✓	✓		✓	✓	✓	✓
19.07.2020 14:30 – 21.07.2020 14:30	FYI 5 m	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	FYI 15 m	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	FYI 50 m	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ridge 5 m	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ridge 15 m	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ridge 50 m	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Tab. 6.3.2. Deployment date and time, DSHIP device operations and deployment details of sediment traps beneath a ridge ("Jaridge") and under First Year Ice (FYI).

Deployment date & time	DSHIP device operation	Deployment details
26.06.2020 14:10	PS122/4_44-257 shortterm_sedtrap_lice	Sediment trap mooring deployment for 24 hours. 3 depths at 5, 15 and 50 m under the ice. 2 sediment trap cups per depth. Sediment trap deployment under FYI through hole in the ice. 100 m ish to ROV and next to the FYI coring site.
27.06.2020 14:30	PS122/4_44-204 shortterm_sedtrap_lice	FYI sediment trap recovery. 3 depth horizons, 2 traps each depth, deployed through the ice, in area adjacent to FYI coring, approximately 50-70 m from active coring sites.
03.07.2020 14:45	PS122/4_45-187 shortterm_sedtrap_lice	Sediment trap mooring deployment under FYI at sediment trap hole 100 m from ROV and 50- 70 m from the FYI coring site. Three depths of 5, 15 and 50 m under the ice with 2 cups at each depth. For comparison to HAVOC ridge sediment trap deployment at Jaridge.
03.07.2020 15:00	PS122/4_45-191 shortterm_sedtrap_ridge	Sediment trap deployed under Jaridge for comparison to FYI mooring. Traps were deployed at 5 and 15 m under the ice with 2x cups per trap using the ROV onto a sling using a wooded hook
04.07.2020 14:10	PS122/4_45-188 shortterm_sedtrap_lice	Sediment trap mooring deployment under FYI at sediment trap hole 100m from ROV and 50- 70 m from the FYI coring site. 3 depths of 5, 15 and 50 m under the ice with 2 cups at each depth. For comparison to HAVOC ridge sediment trap deployment at Jaridge.
04.07.2020 14:30	PS122/4_45-192 shortterm_sedtrap_ridge	Sediment trap recovered under Jaridge for comparison to FYI mooring. Traps were deployed at 5 and 15m under the ice with 2x cups per trap using the ROV onto a sling using a wooden hook
10.07.2020 11:00	PS122/4_46-207 shortterm_sedtrap_lice	Sediment trap deployed for 24 hours under FYI to be compared to one deployed under Jaridge over the same time period. Trap was also deployed in parallel to other traps at a shorter timescales. trap consisted of three depths, one deployed at 5m, one at 15m and one at 50m. Two cups were deployed at each depth.
10.07.2020 11:30	PS122/4_46-209 shortterm_sedtrap_ridge	Sediment trap deployed under Jaridge (HAVOC) with the ROV onto a sling. Traps deployed at 5, 15 and 50m under the ridge (captain candy cane). Two cups deployed at each depth. 24 HOURS
11.07.2020 12:30	PS122/4_46-210 shortterm_sedtrap_ridge	Sediment trap recovered from under Jaridge (HAVOC) with the ROV onto a sling. Traps deployed at 5, 15 and 50m under the ridge (captain candy cane). Two cups deployed at each depth. 24 HOURS
11.07.2020 11:30	PS122/4_46-208 shortterm_sedtrap_lice	Sediment trap recovered after 24 hours under FYI to be compared to one deployed under Jaridge over the same time period. Trap was also deployed in parallel to other traps at a shorter timescales. The trap consisted of three depths (5, 15 and 50 m). Two cups were deployed at each depth.
19.07.2020	PS122/4_47-201	Sediment trap array mooring deployed through the

14:30	shortterm_sedtrap_lice	FYI sediment trap hole for 48 hours. Three depths at 5, 15 and 50 m under the ice with two sediment cups per depth. 100 m ish to ROV and 50-70m from the FYI coring site. 48 hours due to inability to collect on Monday (clashes with coring). Was delayed to Sunday deployment due to numerous polar bear visits.
19.07.2020 15:00	PS122/4_47-203 shortterm_sedtrap_ridge	Sediment trap array deployed under Jaridge HAVOC for 48 hours using the ROV with 2 cups at 3 depths: 5, 15 and 50 m.
21.07.2020 14:30	PS122/4_48-228 shortterm_sedtrap_lice	Sediment trap array mooring recovered through the FYI sediment trap hole for 48 hours. 3 depths at 5, 15 and 50 m under the ice. Two sediment cups per depth. 100m ish to ROV and 50-70 m from the FYI coring site
21.07.2020 14:30	PS122/4_48-232 shortterm_sedtrap_ridge	Sediment trap array recovered under Jaridge HAVOC for 48 hours using the ROV with 2 cups at 3 depths: 5, 15 and 50 m.

Sediment traps: Diurnal sampling event

In addition to the FYI and ridge mooring deployments, short term sediment traps were deployed for 4- 8 hours during the cross-cutting diurnal cycling sampling effort. The Team ECO HAVOC members worked alongside Team BGC in order to coordinate vertical flux measurements with other parameters of interest (see the Team BGC section for further details) during diurnal cycling. Details of the deployment and recovery of these short term sediment trap deployments are given in Table 6.3.3. An overview of the parameters sampled from each of these sediment traps is given in Table 6.3.4.

Tab. 6.3.3: Deployment date and time, DSHIP device operations and deployment details of sediment traps deployed under First Year Ice (FYI) during the diurnal cycling sampling event

Deployment date & time	DSHIP device operation	Deployment details
10.07.2020 11:00:00	PS122/4_46-211 shortterm_sedtrap_ lice	Part of 24 hour time series. Deployed at 13:00 ship (11:00 UTC) through hole next to sediment trap hole. Sat on rafted ice. Recovered at 20:00 ship (18:00 UTC) during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Traps are 5m below the ice and consist of 2 cups. Sediment trap deployment diurnal sampling FYI 11:00 to 18:00 Note: carboys (and thus lab books) marked 20:00 (local time of recovery)
10.07.2020 18:00:00	PS122/4_46-212 shortterm_sedtrap_ lice	Part of 24 hour time series. Recovery. Deployed at 13:00 ship (11:00 UTC) through hole next to sediment trap hole. Sat on rafted ice. Recovered at 20:00 ship (18:00 UTC) during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Another sediment trap was deployed strait after this recovery in the sediment trap hole (since this one hit rafted ice). Trap was 5m below the ice and consisted of 2 cups
10.07.2020 18:00	PS122/4_46-214 shortterm_sedtrap_	Part of 24 hour time series. Deployment. Deployed at 18:00 UTC through sediment trap hole since other

	lice	hole had rafted ice. Recovered at 22:00 UTC during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Trap was 5m below the ice and consisted of 2 cups. Sediment trap deployment diurnal sampling FYI 18:00 to 22:00 Note: carboys (and thus lab books) marked 00:00 (local time of recovery)
10.07.2020 22:00	PS122/4_46-215 shortterm_sedtrap_ lice	Part of 24 hour time series. Recovery. Deployed at 18:00 UTC through sediment trap hole since other hole had rafted ice. Recovered at 22:00 UTC during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Trap was 5m below the ice and consisted of 2 cups. Sediment trap recovery diurnal sampling FYI 18:00 to 22:00 Note: carboys (and thus lab books) marked 00:00 (local time of recovery)
10.07.2020 22:00	PS122/4_46-216 shortterm_sedtrap_ lice	Part of 24 hour time series. Deployed at 22:00 UTC through sediment trap hole since other hole had rafted ice. Recovered at 06:00 UTC during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Trap was 5m below the ice and consisted of 2 cups Sediment trap deployment diurnal sampling FYI 22:00 to 06:00 Note: carboys (and thus lab books) marked 08:00 (local time of recovery)
11.07.2020 06:00	PS122/4_46-217 shortterm_sedtrap_ lice	Part of 24 hour time series. Recovery. Deployed at 22:00 UTC through sediment trap hole since other hole had rafted ice. Recovered at 06:00 UTC during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Trap was 5m below the ice and consisted of 2 cups Sediment trap recovery diurnal sampling FYI 22:00 to 06:00 Note: carboys (and thus lab books) marked 08:00 (local time of recovery)
11.07.2020 06:00	PS122/4_46-218 shortterm_sedtrap_ lice	Part of 24 hour time series. Deployed. Deployed at 06:00 UTC through sediment trap hole since other hole had rafted ice. Recovered at 11:30:00 UTC during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Trap was 5m below the ice and consisted of 2 cups sediment trap deployment diurnal sampling FYI 06:00 to 11:30:00 Note: carboys (and thus lab books) marked 12:00 (local time of recovery)
11.07.2020 11:30	PS122/4_46-219 shortterm_sedtrap_ lice	Part of 24 hour time series. Recovered. Deployed at 06:00 UTC through sediment trap hole since other hole had rafted ice. Recovered at 11:30:00 UTC during the 24 hour cycle. See parallel measurements by BGC and ECO during the 24 hour sampling event. Trap was 5 m below the ice and consisted of 2 cups. Sediment trap recovery diurnal sampling FYI 06:00 to

		11:30 Note: carboys (and thus lab books) marked 12:00 (local time of recovery)

Tab. 6.3.4: Sediment trap deployment dates, depths and parameters sampled from beneath First Year Ice (FYI) during the diurnal sampling event

Deployment date	Site	Chl a	FCM	Faecal pellets	POC/PON	Nutrients	Microscope
10.07.2020 11:00 – 10.07.2020 18:00	FYI 5 m	✓	✓	✓	✓	✓	✓
10.07.2020 18:00 – 10.07.2020 22:00	FYI 5 m	✓	✓	✓	✓	✓	✓
10.07.2020 22:00 – 11.07.2020 06:00	FYI 5 m	✓	✓	✓	✓	✓	✓
11.07.2020 06:00 - 11.07.2020 11:30	FYI 5 m	✓	✓	✓	✓	✓	✓

Ice coring for ECO parameters

Fig. 6.3.5: HAVOC team members Benjamin Lange and Evgenii Salganik on Team ICE alongside Oliver Müller and Jessie Gardner from Team ECO coring "Jaridge"

1. HAVOC ridge coring at the new ridge site – JARIDGE (03.07.2020)

3 replicate ice cores were collected for ECO parameters. Following sections were taken (Figure 6.3.6): 30-20cm, 20-10cm and 10-0cm above the first gap layer, 0-10 cm, 10-20cm, 20-30cm below the first gap layer. 30-20 cm, 20-10cm and 10-0cm above the second gap layer, 0-10 cm, 10-20cm, 20-30cm below the second gap layer, 2 additionally core sections from replicate core 3 were taken, one 0-10cm below the third gap layer and one 10 cm ridge bottom section. Core sections were processed once the ice was melted for following parameters: chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi and XRF.

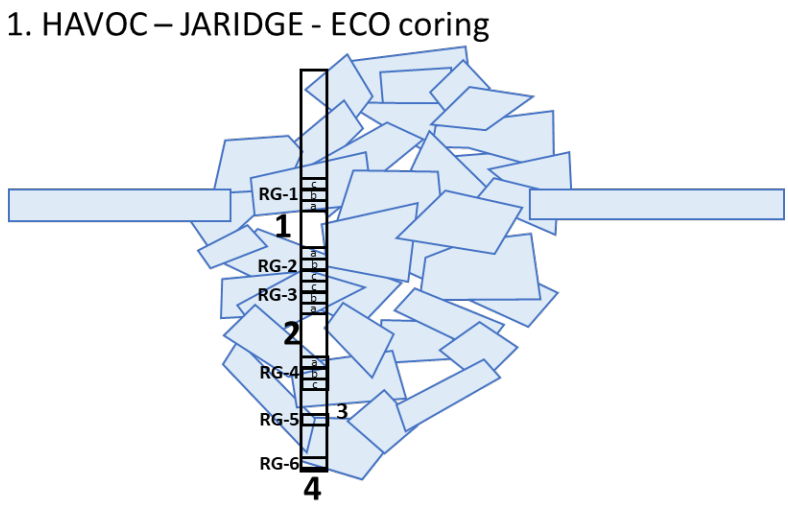

Figure 6.3.6: *Illustration of the samples taken during the first ECO-coring at Jaridge. Numbers (1-4) indicate where a water sample was taken and core sections processed for different ECO parameters are indicated as boxes and labelled as RG-1 to RG-6 with subsections (a-c).*

2. HAVOC – JARIDGE - ECO coring (10.07.2020)

Again 3 replicate ice cores were collected for ECO parameters, however this time the gap layers identified the week before were frozen, so no gap water was collected and instead an ice core section collected where the gap layer has been before. Therefore following sections were taken (Figure 6.3.7): 10-0cm above the first gap layer, 10 cm of refrozen gap layer (clear ice), and 0-10 cm below the first gap layer, 0-10 cm of the bottom of the ridge and two additionally pieces with visible phytoplankton inclusions. Core sections were processed once the ice was melted for following parameters: chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi and XRF.

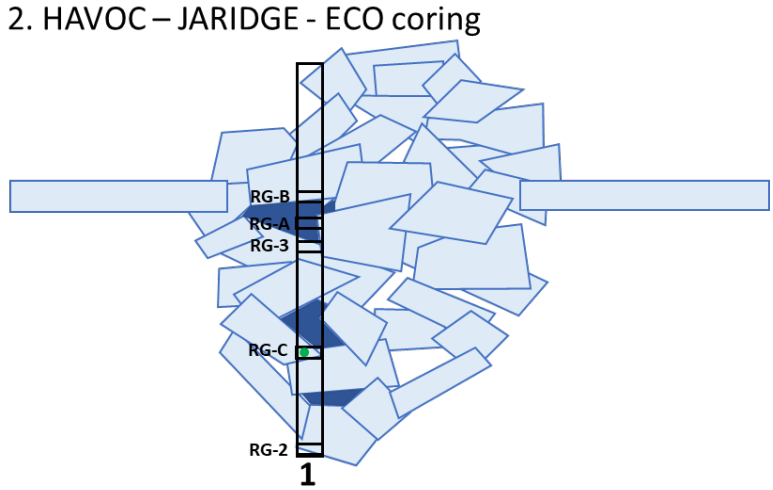

Fig. 6.3.7: *Illustration of the samples taken during the second ECO-coring at Jaridge. Number 1 indicates where the under ice water sample was taken and core sections processed for different ECO parameters are indicated as boxes and labelled as RG-B, A, C and RG-3; RG-2. Dark blue shapes indicate refrozen gap layers.*

3. HAVOC – JARIDGE - ECO coring (18.07.2020 - delayed due to several polar bear visits)

Again 3 replicate ice cores were collected for ECO parameters, the gap layers identified during the first week were still frozen, so no gap water was collected and instead an ice core section collected where the gap layer has been before. Therefore following sections were taken (Figure 6.3.8): 10-0cm above the first gap layer, 10 cm of the refrozen gap layer (clear ice), and 0-10 cm below the first gap layer, 0-10 cm of the bottom of the ridge and one additional piece with visible phytoplankton inclusions. Core sections were processed once the ice was melted for following parameters: chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi and XRF.

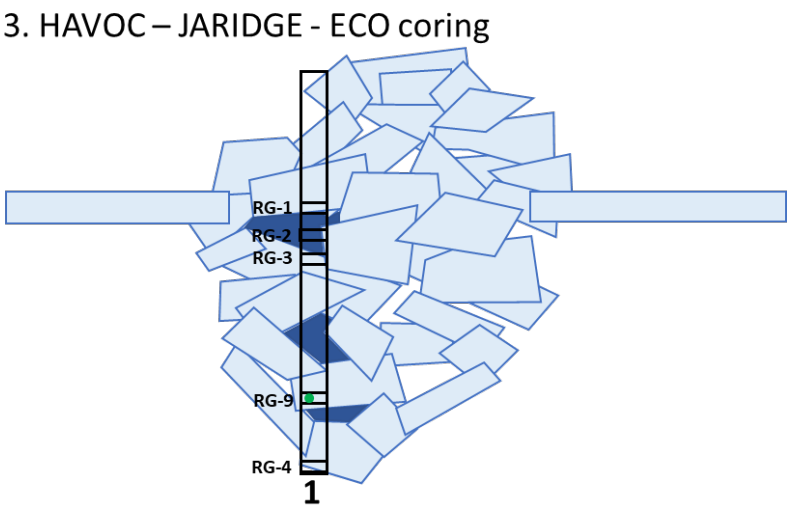

Figure 6.3.8: *Illustration of samples taken during the third ECO-coring at Jaridge. Number 1 indicates where the under ice water sample was taken and core sections processed for different ECO parameters are indicated as boxes and labelled as RG-1-4 and RG-9. Dark blue shapes indicate refrozen gap layers.*

4. HAVOC – JARIDGE - ECO coring (24.07.2020 - delayed due to several polar bear visits)

Again 3 replicate ice cores were collected for ECO parameters, the gap layers identified during the first week were still frozen, so no gap water was collected and instead an ice core section collected where the gap layer has been before. Therefore following sections were taken (Figure 6.3.9): 10-0 cm above the first gap layer, 10 cm of an intermediate part of the refrozen gap layer, 10 cm of refrozen gap layer (clear ice), and 0-10 cm below the first gap layer, 0-10 cm of the bottom of the ridge. In addition, a second site 5 m to the side from the top of the ridge two replicate cores were taken as Ben and Evgenii identified a gap layer that was not frozen the day before. Following sections were taken: 10-0 cm above the first gap layer, 0-10 cm below the first gap layer, 0-10 cm of the bottom of the ridge. Core sections were processed once the ice was melted for following parameters: chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi and XRF.

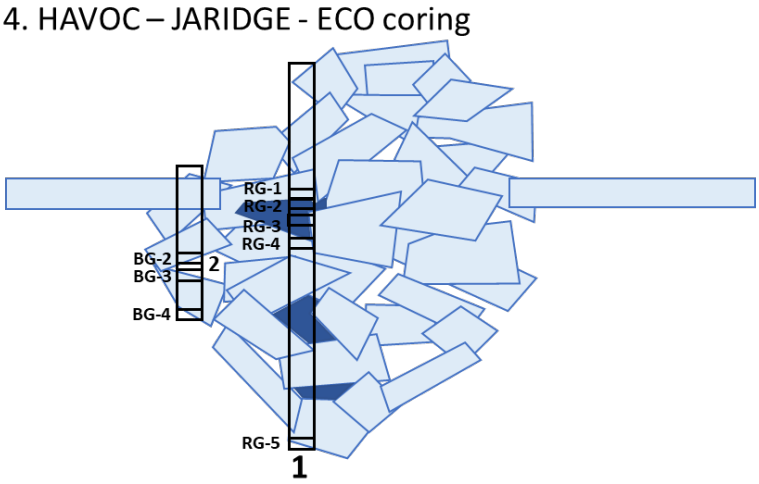

Fig. 6.3.9: *Illustration of samples taken during the fourth ECO-coring at Jaridge. Numbers 1 and 2 indicate where the under ice water and gap water were taken and core sections processed for different ECO parameters are indicated as boxes and* ***labelled as RG-1-5 an the sections from the second core BG-2-4. Dark blue shapes indicate refrozen gap layers.***

Tab. 6.3.5: Ridge ECO - coring dates and time, DSHIP device operations.

Date and time	DSHIP device operation	Details
03.07.2020 08:10	PS122.4_45-131 SI_corer_9cm	Jaridge HAVOC ice core sampling
10.07.2020 08:15:00	PS122.4_46-178 SI_corer_9cm	Ice coring gap layers at Jaridge (3 ECO cores and 1 times Sal.O18). Connected with 7 cm Density core (taken in the afternoon).
18.07.2020 10:00	PS122.4_47-199 SI_corer_9cm	Jaridge ice core sampling. 3x ECO cores
24.07.2020 08:00	PS122.4_48-229 SI_corer_9cm	Ridge coring Jaridge HAVOC eco samples

Tab. 6.3.6: Ice coring dates, sections taken and parameters processed from melted sea ice sections

		Parameter – Ice sampling													
Coring date		ID	Total vol.	Chl a	FCM	POC. PON	BSi	Nutrients	Lipids	Flow Cam	Micro-scope	BP	XRF	DNA (Sterivex)	DNA (Durapore)
03.07.2020	30-20cm above gap layer 1	RG1-C	3200	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	20-10cm above gap layer 1	RG1-B	3200	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	10 cm above gap layer 1	RG1-A	3300	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	10 cm below gap layer 1	RG2-A	3420	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	10-20cm below gap layer 1	RG2-B	3160	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	20-30cm below gap layer 1	RG2-C	3100	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	30-20cm above gap layer 2	RG3-C	3260	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	20-10cm above gap layer 2	RG3-B	3180	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	10 cm above gap layer 2	RG3-A	3200	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	10 cm below gap layer 2	RG4-A	2720	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
	10-20cm below gap layer 2	RG4-B	2000	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
	20-30cm below gap layer 2	RG4-C	2020	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
	10 cm above gap layer 3	RG5	2490	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
	10 cm bottom of ridge	RG6*	1000	✓	✓	✓	✓	✓	✓		✓	✓			✓
10.07.2020	10 cm above gap layer 1	RG-B	3045	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

	10 cm refrozen gap layer 1	RG-A	3120	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	10 cm below gap layer 1	RG-3	3120	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Phytoplankton inclusion (core 1)	RG-C*	800	✓	✓	✓		✓			✓	✓			✓
	Corresponding piece to RG-C but no phytoplankton inclusion (core 2)	RG-1*	840	✓	✓	✓		✓			✓	✓			✓
	10 cm bottom of ridge	RG-2	3195	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Phytoplankton inclusion close to bottom (core 3)	RG-D	240	✓	✓			✓			✓	✓			✓
18.07.2020	10 cm above gap layer 1	RG-1	2960	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm refrozen gap layer 1	RG-2	3150	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm below gap layer 1	RG-3	3160	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm bottom of ridge	RG-4	2980	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Phytoplankton inclusion at 275-280 (core 3)	RG-9*	570	✓	✓			✓		✓	✓	✓			
24.07.2020	10 cm above gap layer 1	RG-1	3670	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm transition into refrozen gap	RG-2	3100	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm refrozen	RG-3	3070	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	gap layer 1														
	10 cm below gap layer 1	RG-4	3160	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm bottom of ridge	RG-5	3250	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm bottom of ridge	BG-1*	1140	✓	✓	✓		✓	✓		✓	✓			
	10 cm above gap layer 1	BG-2	2400	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm below gap layer 1	BG-3	2150	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	10 cm bottom of ridge	BG-4	2000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
*Section originated only from one replicate core															

Water sampling

1. HAVOC – JARIDGE - ECO coring (03.07.2020)

When coring the ridge, two water filled gaps were identified and water was collected from both gaps using the hand pump. Additionally, water from underneath the ridge was collected. Water from the gaps and underneath the ridge was processed for following parameters: chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi and XRF as well as additional NPP reference and in situ assays under the ridge and under first year ice.

2. HAVOC – JARIDGE - ECO coring (10.07.2020)

Water from underneath the ridge and from the FYI sediment trap site was collected using the hand pump and processed for following parameters chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi, XRF, NPP (reference conditions) and Virus diversity.

3. HAVOC – JARIDGE - ECO coring (18.07.2020)

Water from underneath the ridge and from the FYI sediment site was collected using the hand pump and processed for following parameters chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi, XRF, NPP (reference conditions) and Virus diversity.

4. HAVOC – JARIDGE - ECO coring (21.07.2020)

Water from the gap layer, from underneath the ridge and from the FYI ECO-lodge site was collected using the hand pump and processed for following parameters chl a, DNA, FCM, BP, nutrients, POC.PON, lipids, flow cam, light microscopy, BSi, XRF, NPP (reference conditions) and Virus diversity.

Tab. 6.3.7: Ridge and level ice ECO – water sampling dates and time, DSHIP device operations.

Date and time	DSHIP device operation	Details
03.07.2020 09:00:00	PS122.4_45-137 hand_pump	Water sampling of under ridge and gap water. Grazing experiment water collected from here
10.07.2020 08:30:00	PS122.4_46-160 hand_pump	FYI water to compare to under ridge water HAVOC. Collected at the sediment trap hole 100m from the ROV and 50-70m from the FYI coring site. Used CN project hand pump. Sediment trap deployed after water samples collected. Water filled gaps in the ridge were frozen, so water comparison is only between FYI and under ridge
10.07.2020 11:00	PS122.4_46-220 hand_pump	FYI water collected from sediment trap hole for comparison to ridge. During the diurnal cycling event.
18.07.2020 11:10	PS122.4_47-192 hand_pump	this was the FYI under ice water used for comparison to the ridge. Water filled gaps in the ridge were frozen, so water comparison is only between FYI and under ridge. Note this is not Oliver's grazing exp
18.07.2020 10:47	PS122.4_47-200 hand_pump	Water filled gaps in the ridge were frozen, so water comparison is only between FYI and under ridge
24.07.2020 14:30	PS122.4_48-230 hand_pump	Note: FYI water was collected the next day due to heli ops moving the ROV hut
25.07.2020 09:00	PS122.4_48-231 hand_pump	For comparison to gap and ridge water done the day before. Also BP was done here.

Tab. 6.3.8: Water sample deployment dates, depths and parameters sampled from beneath First Year Ice (FYI) and “Jaridge”

		Parameter – water sampling												
Water sampling date		Chl a	FCM	POC /PON	BSi	Nutrients	Lipids	Flow Cam	Microscope	BP	XRF	DNA (Sterivex)	Virus diversity	
03.07.2020	Ridge Gap 1	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		
	Ridge Gap 2	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		
	Ridge UiW	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		
10.07.2020	Ridge UiW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	FYI UiW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
18.07.2020	Ridge UiW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	FYI UiW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
24.07.2020 / 25.07.2020	Ridge Gap	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Ridge UiW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	FYI UiW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

Grazer exclusion experiment of ridge associated microenvironments
Question: How is the microbial food web structured and controlled in ridge associated microenvironments?
Background: This experiment aims to investigate the structure of and interactions within the microbial food web in microenvironments (gap layers) of the ridge compared to under ice surface water (figure 6.3.10). The size fractionation allows to distinguish between processes based on bacterial activities without grazing pressure (<0.8µm), grazing by heterotrophic nanoflagellates (<10µm) and grazing by larger grazers (<90µm) (e.g. Ciliates) potentially reducing the grazing pressure on the bacteria.
Experimental set-up: In order to investigate grazing effects, grazers of different size fractions were removed and then water samples incubated. Water was manipulated using a reverse filtration set-up with 90µm, 10µm and 0.8µm screens to remove predators of different sizes. The three fractions were as following:

1. without meso-zooplankton (<90µm)
2. without meso- and micro-zooplankton (<10µm)
3. bacteria only (<0.8µm)

With two locations (Figure 6.3.10 x and y), three treatments and three replicates there was a total of 18 1L PC-bottles. The bottles were incubated in the incubation container (F2) on board with light and temperature set to close to *in-situ* conditions (reference light conditions for NPP-assays and 2°C). Subsamples (FCM, BP, DNA) were taken throughout the incubation period.

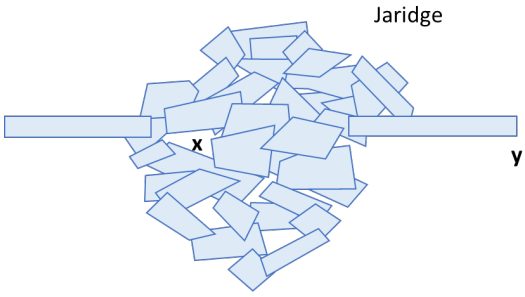

Fig. 6.3.10: *Illustration of Jaridge with x (gap layer) and y (2m depth from CTD) indicating where water was taken for the grazer exclusion experiment.*

Implementation:
The grazer exclusion experiment was set up with water sampled during the first HAVOC ridge coring at Jaridge on the 03.07.2020. The water for the experiment was collected from the first gap layer using a manual hand pump and water from 2 m from the CTD. The experiment was set up in the evening and bottles were incubated for 9 days until the 12.07.2020. The table below shows the parameters that were taken throughout the incubation period.

Tab. 6.3.9: Subsamples taken during grazer exclusion experiment.

Parameter	Start	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
FCM	✓		✓	✓	✓		✓	✓	✓	✓
BP	✓			✓			✓			✓
DNA	✓			✓			✓			✓
Microscopy	✓									✓

Preliminary (expected) results

Tab. 6.3.10: The total numbers of samples for the different variables collected.

Parameter	# samples
Chl a	135
PCPN	132
BSi	56
Nutrients	65
Flow cam	30
Light microscopy	71
Lipids	61
FCM	255
Bacterial Production	223
XRF	100
Ridge sample DNA	59
Experiment DNA	53
Viral diversity	16

Acknowledgments

This work would have been impossible without the amazing team of willing volunteers from the MOSAiC participants. Despite their intense workload and limited time, the following people aided the HAVOC team both in the field and the laboratories; JP, Alli, Emelia, Ale, Debby, Celia, Katy, Lisa, Giulia, Matt S, Saga, Jesper, Laura, Lianna, Ilkka, Julia, Sandra.

Data management

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

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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 measure microbial C and N uptake in experimental incubations 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 investigate the seasonal succession of microbial community composition (DNA - metagenomics) and expressed metabolic functions (RNA - metatranscriptomics) in the field during a full seasonal cycle, in collaboration with a large group of international scientists (see chapter sub-section on the MOSAiC ECO Core Programme).

Work at sea

During Leg 4 of MOSAiC, the CN experiments were carried out by John Paul Balmonte following the protocols established by Pauline Snoeijs Leijonmalm and Allison Fong during Leg 1. For each experiment, we sampled 140-150 L of seawater that were spiked with different stable isotopes and incubated at ca. 1 °C on board, both in light and dark conditions (Figure 6.4.1). Our program focuses 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).

Rationales for chosen experimental water

Throughout Leg 4 (six science weeks, 44-49), six full CN experiments were carried out: two using temperature maximum water (experiments 29 and 34), two using chlorophyll *a* maximum water (experiments 30 and 33), and two using sub-ice water (experiments 31 and 32). Several priorities justified the order of the experiments. Temperature maximum water was the highest priority as no such experiments were carried out on Leg 3 and was therefore

used for experiment 29. Chlorophyll *a* maximum water was used for the following experiment (experiment 30) as a conveniently-located ice hole had not yet been created nor identified.

On 9 July 2020, the ECO Lodge ice holes (one inside the tent, and one outside the tent) were created. The outside ECO Lodge ice hole became the access point for CN sub-ice experimental water, and thus the third CN experiment on Leg 4 (experiment 31) was conducted with sub-ice water. Sub-ice water was also prioritized for this experiment to link CN experimental results with the cross-cutting 24-hr ice work conducted from 10-11 July 2020. While the target was direct sub-ice water – which at this point had been identified as fresh water (0.9 PSU) perched atop brackish water, with a steep transition to marine water (PSU 33) – the hand pump had drawn the marine water. This was only identified after experimental setup had been completed, and water from the mixing tank was measured for salinity (PSU 33). Nevertheless, water from experiment 31 contained biomass which featured a yellow-green hue, similar to biomass collected from other ECO Lodge sampling events during the 24-hr ice program. Widespread interest in the freshwater layer among the MOSAiC team warranted another attempt at a CN experiment with sub-ice fresh-to-brackish water, justifying the decision for experiment 32 (sub-ice, PSU 3.2-3.3) from the outside ECO Lodge hole. A brownish-green hue characterized isotope filters for experiment 32, indicating different sources or degradation state of the biomass in the brackish experimental water – a notable contrast to the yellowish-green hue on filters from experiment 31.

Experiments 33 and 34 were conducted using chlorophyll *a* maximum and temperature maximum waters, respectively, and the rationale were as follows. In the middle of week 48, the ROV and CTD teams identified a dense bloom in the upper water column, visible down to the subsurface chlorophyll *a* maximum. This feature prompted the decision to conduct a second CN experiment for week 48 (experiment 33) to target the dense biomass in the subsurface chlorophyll *a* maximum. While the dense bloom was likely not captured during the CTD operation, the isotope filters from experiment 33 nevertheless showed a tinge of yellow-green. During week 49, the MOSAiC floe had drifted towards the ice edge, near the gateway of the Atlantic water into the Arctic, which rationalized the decision to conduct another experiment with temperature maximum water (experiment 34). The CTD team encountered a challenge unique to this region: as the MOSAiC floe was located at the boundary of the Atlantic water inflow, temperature profiles during the downcast and upcast were sometimes incongruent, depending on drift speed and direction. In particular, on 27 July 2020, a prominent temperature maximum at ca. 210 m was identified (ca. 1.7-1.8°C) during the downcast, but which was not detected during the upcast. A second CTD attempt to target the prominent temperature maximum water indicated that the ship had drifted away from this feature; thus, experiment 34 water was conducted with the local temperature maximum water (ca. 0.7-0.8°C). A greenish hue could be observed on the isotope filters from this experiment.

Several more CN experiments were planned for the remainder of Leg 4, but the breakup of the MOSAiC floe in the evening of 30 July 2020 and into the morning of 31 July 2020 led to the coordination team's decision to leave the floe and begin instrument recovery. Possibilities to do another CN experiment using sub-ice water were dashed due to the discovery of the breakup of the distributed network floes. CTD time was also limited due to transit and instrument recovery time. Finally, the rapid transit of the *Akademik Tryoshnikov* to the *Polarstern* led to the prioritization of end-of-leg record keeping, lab cleaning, and planning for handover procedures. No further experiments were carried out.

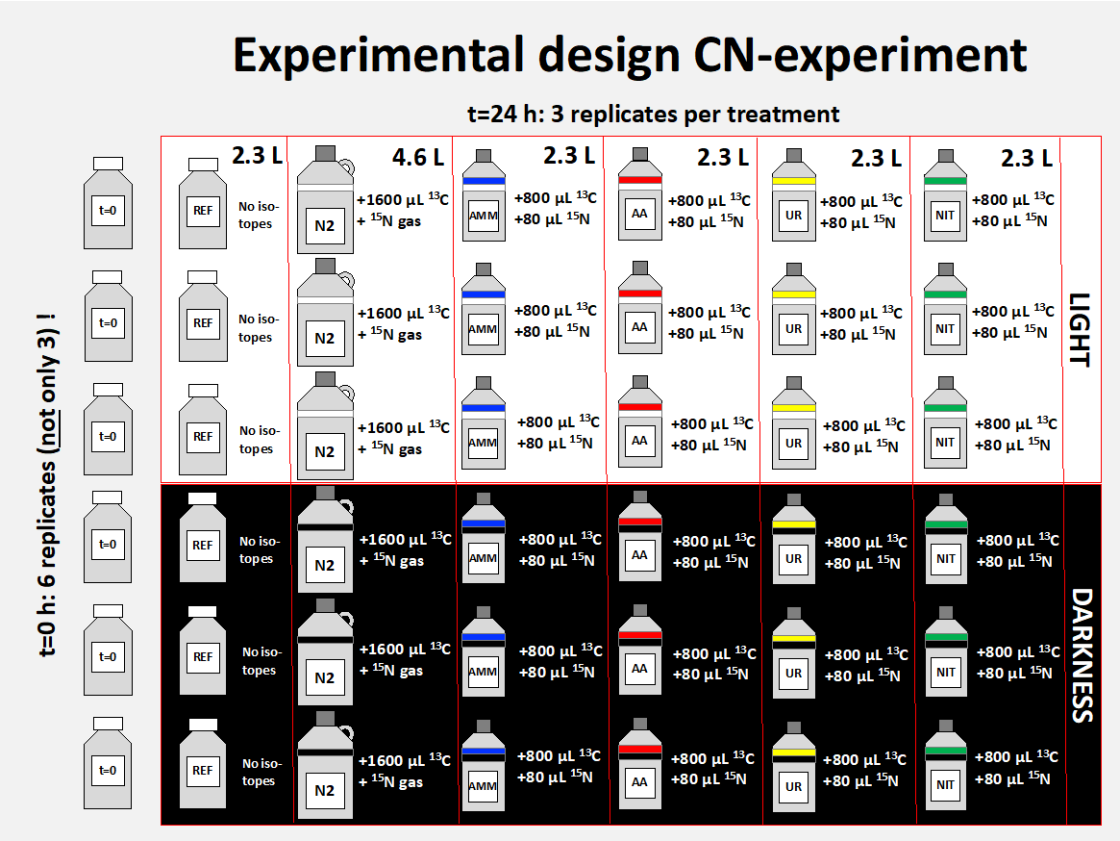

Fig. 6.4.1: Experimental design of the CN-experiment as performed during MOSAiC.

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 4, six 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 4

File no.	Date	Sampling time	Device	Path to MCS	Sensor Web Action-ID	Type of experiment	Device Operation ID
1	27.06.2020	17:30	AWI CTD (200 m)	platforms/ vessel/polarstern/ctd_sbe 9plus_321/PS122-4_44-187	39847	CN-experiment 29	PS122/4_44-187
2	05.07.2020	13:00	AWI CTD (25 m)	platforms/ vessel/polarstern/ctd_sbe 9plus_321/PS122-4_45-121	39882	CN-experiment 30	PS122/4_45-121
3	20.03.2020	9:20	Hand pump, sub-ice seawater (ECO Lodge)	platforms/pack_ice/ice_ps /hand_pump/exdata/PS12 2-4_47-205	39589	CN-experiment 31	PS122/4_47-205
4	20.07.2020	10:50	Hand pump, sub-ice seawater (ECO Lodge)	platforms/pack_ice/ice_ps /hand_pump/exdata/PS12 2-4_48-235	39590	CN-experiment 32	PS122/4_48-235
5	24.07.2020	09:00	AWI CTD (13 m)	platforms/ vessel/polarstern/ctd_sbe 9plus_321/PS122-4_48-96	39904	CN-experiment 33	PS122/4_48-96
6	27.07.2020	12:30	AWI CTD (222 m)	platforms/ vessel/polarstern/ctd_sbe 9plus_321/PS122-4_49-5	39909	CN-experiment 34	PS122/4_49-5

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 metabolisms, 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.

No samples were analyzed on board. Inorganic nutrients, which were analyzed on board during previous legs, could not be analyzed during leg 4 as no nutrient analyst was present. 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 chapter sub-section on the MOSAiC ECO Core Programme).

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). Data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science www.pangaea.de <http://www.pangaea.de/>.

References

Fernández-Gómez B, Díez B, Polz M, Ignacio Arroyo J, Alfaro F, Marchandon G, Sanhueza C, Farías L, Trefault N, Marquet P, Molina-Montenegro M, Sylvander P, Snoeijs-Leijonmalm P (2019) Bacterial community structure in a sympagic habitat expanding with global warming: brackish ice brine at 85-90 ºN. The ISME Journal, 13, 316-333. [https://doi.org/10.1038/s41396-018-0268-9]