6. ECOSYSTEM

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Objectives

The scientific background and the objectives of the Ecosystem Consortium Group are stated in the respective sections of the Leg 1 Cruise Report.

Work at sea

In order to achieve the goals of the Ecosystem Consortium Group, including project specific research, the participants of Leg 3 continued the activities established by Team Eco during Legs 1 and 2, modified plans where needed and implemented further sample collection and project specific work. 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 sampling of the Arctic environment (mainly sea ice and water) which occurred within 1 - 2km of the *Polarstern*.

We continued the previously established time-series sampling of ecological, biogeochemical, and biological properties and processes using a coordinated effort across teams to capture a suite of properties once per week. For 10 weeks, we conducted cooperative sampling with

teams ICE and OCEAN to measure changes in biological components in relation to the physical and chemical properties of snow, ice, and seawater whenever weather, temperatures and ice dynamics allowed. Core variables coordinated by Team ECO were primarily collected from the CTD-rosette water sampler and different zooplankton nets deployed in Ocean City, in addition to a few sampling instances from Polarstern thru an ice hole alongside the ship. Core sea ice variables were sampled at the two large ice coring sites established during Leg 1, approximately 1.2 km from Polarstern, to track the development of first year ice (FYI) that formed in autumn 2019, and second year ice (SYI) that had survived summer melt. (For further details, see section 6 of the leg 1 cruise report). Common coring activities and approaches are further described in Section 6.4.1. Other regular activities included e.g. continuous underway measurements of O2/Ar for the determination of Net Community production via Membrane Inlet Mass Spectrometry (MIMS), continuous hydroacoustics measurements with the EK80/60 system, daily underway sampling for Chl, DNA and INPs, and weekly deployments of the Laser In-situ Scatter Transmission meter (LISST) in addition to a few deployments of the Underwater Vision Profiler (UVP), both being used for highly depth-resolved particle distribution and characteristics.

In terms of the weekly routines, we largely followed the program planned by the MOSAiC consortium prior to the start of the campaign with some adjustments to a) accommodate all needed work and b) react to the dynamic ice situation, extreme weather conditions and the loss of the large CTD hole next to the ship on March 15th. In short, FYI and SYI coring was conducted on Mondays whenever the sites were accessible and on other weekdays in a few instances. Processing of the differently treated cores was done over the following 3 days. Water sampling with the large ship-based CTD rosette as well as zooplankton sampling with different nets (including the ROV net) was initially planned to be conducted on 4 days of the week to accommodate core and project-specific work (see tables 6.1. and 6.2.). After the loss of the ship's CTD hole, nets (including the ROV net) and the small OC CTD rosette were deployed on three days each.

Newly established or optimized instrumentation and methods

In terms of newly established instrumentation and methods, the leg 3 team successfully integrated a few missing core parameters into the MOSAiC ECO work routines. Soon after our arrival, the filtration setup for solid phase extraction (SPE) samples was finalised, tested and optimized, allowing for regular sampling over the duration of the cruise.

Similarly, the routines to use newly set-up Winkler titration system for dissolved oxygen (DO) measurements were tested and optimised using samples from the first deep CTD cast as well as from the underway system. Unfortunately, only one high-quality set of measurements could be conducted as the CTD hole was lost on March 15th. In Ocean City, these measurements were initially not possible due to the low outside temperatures. Once these rose above -20°C, trial sampling in OC was successful, and these measurements were successfully conducted in OC on the weekly deep casts (as well as the last deep cast with the ships rosette before leaving the floe on May 16th).

Chorophyll a (Chl) extractions and measurements were established as part of the weekly routine after successfully calibrating the fluorometers (10AU, Turner). The procedure entailed extraction of Chl in 90% acetone over night after a bead-beating step using a Precellys (2 cycles of 5000 rpm for15 seconds) at 4°C, centrifugation (5000 rpm, 10 min) and subsequent fluorescence measurements before and after the addition of 3 drops of 1M HCl. A set of inter-calibration samples was collected from the under-way system, half of the samples were measured while the other half was frozen for later measurements after the next set of calibrations to be done on leg 4.

Partway through the leg, the centrifuge unfortunately developed some misbalance that could not be fixed by the on-board personnel, causing sample vials to break in the centrifuge. Therefore, the routine analysis of chlorophyll samples had to be stopped, and from week 36

onwards, only one replicate of the daily underway samples was extracted and measured, while the other samples were stored at -80°C for later analysis.

Other than reported by leg 2, both the Fast Repetition Rate Fluorometer (FRRF) and the Auto-FIM were working well at the beginning of leg 3. At the end of leg 3, however, the FRRF stopped connecting to the computer, and the second backup instrument was set-up and tested to be operational for the leg 4 team.

Regarding the work in the radioisotope lab, measurement frequencies for 14-C based Net Primary Production (NPP) measurements and Photosynthesis-Irradiance (PI) curves were greatly increased for both sea water and ice samples compared to leg 2. Similarly, 3-H based bacterial production (BP) assays for sea ice samples were optimized and efforts were strongly enhanced. Parallel microcentrifuge and filtration assays were performed for the first sea-ice sampling during leg 3 (PS122/3_32-63) to evaluate the two methods. The large-volume filtration method was abandoned after this comparison, due to incompatible filters for the assay (a problem already identified during leg 2) and acceptable results from the microcentrifuge method (1.5 ml). The microcentrifuge method was therefore used both for seawater and for sea ice samples for the entire duration of leg 3. The switch to smaller volumes also resulted in the capacity to analyse sea-ice samples at a higher depth-resolution, so that all sections from FYI and every second depth for SYI usually were analysed, with more frequent SYI measurements (i.e. approximately once a month). Saturation curves (12.5–200 nM leucine) were performed once for seawater (PS122/3_36-81) and once for sea ice (PS122/3_36-21) during leg 3. Additional tests to evaluate the melting procedure for upper sea ice was also performed using isohaline melting and comparisons with brine communities collected via sackholes. Sea-ice brine was incubated at a range of temperatures (from +10 to –20°C) during two time points during leg 3 to evaluate the temperature discrepancy between our normal incubation temperature (0°C) and *in situ* conditions.

Respiration experiments using a PyroScience FireSting GO2 and sensor spots were carried out at several points during Leg 3. In situ O_2 concentrations were near and occasionally above saturation, and the F-deck incubator was set at approximately 1 °C, roughly 2.8 ° above the *in situ* temperature. This temperature difference was sufficient to achieve supersaturation in all cases, with the resulting drop on O_2 due to solubility change masking any biological signal. As a result, Leg 3 efforts focused on developing a strategy for mitigating bubble formation to enable the collection of useable data on Legs 4 and 5.

Two strategies were tested. First, samples were allowed to reach thermal equilibrium in a 4 °C incubator for 24 hours prior to the start of the respiration experiment at 1 °C. It was determined that 24 hours was insufficient for the DO concentration to reach equilibrium, however, and longer incubations at 4 °C were undesirable due to concerns about impact on the microbial community. Second, samples were allowed to reach equilibrium at the incubation temperature with an iterative, daily removal of bubbles until there was no new bubble formation. Though tedious this procedure seemed to work. After roughly 10 days no new bubbles formed and a true T_0 value could be taken. Given the low levels of biomass we presume it will take some weeks for the biological signal to emerge once equilibrium is reached. A new protocol was developed for Legs 4 and 5 taking this into consideration, and a set of 5 m incubations was established and left for measurement by Leg 4 personnel.

Additionally, we collected 40 DNA and RNA samples from one large volume well-mixed sample from the underway system as a first set of inter-calibration samples for the different labs involved in MOSAiC DNA and RNA extractions.

Lastly, and after some technical issues with the software, we also managed to collect one set of L-arm based hyperspectral under-ice light climate measurements with associated collection of ice cores to derive a relationship between light absorption and Chl-based biomass development.

Tab. 6.1: *Description and collected total samples numbers of ECO coordinated core variables sampled during leg 3. For details on zooplankton-related parameters, see section 6.1.*

Ecosystem Core Variables	Environments	Method	Temp. resolution	Leg 3 Summary
Macronutrients (nitrate, nitrite, ammonium, phosphate, silicic acid, DON, DOP)	Water: 17 depth horizons Sea ice: every 5 cm	Colorimetric using a SEAL-Analytical AA3 Auto-analyzer TN/TP (frozen, onshore only)	Weekly, with additional shallow casts from Ocean City.	Collected from the PS deep cast (17 depths) in three instances. After the loss of the CTD hole, samples were collected from OC deep casts (1200m depth) as well as ECO shallow casts (380m). Additional samples from OC were collected by Team BGC. Total number of samples: 1344
Dissolved Oxygen (DO)	Water	Winkler titration	Weekly	Collected and measured from PS deep casts before loss of the PS CTD hole, and OC deep casts once temperature were >-20°C. Total number of samples: 58
Carbonate chemistry (TA, DIC)	Water: 14 -17 depth horizons Sea ice: every 10 cm	Coulometry & TA titration using a VINDTA	Weekly	Collected from the PS deep cast (17 depths; from 10 m above the seafloor to surface) in three instances. After the loss of the CTD hole, samples were collected from OC deep casts (1200m depth) as well as ECO shallow casts (380m). Sea-ice was sampled in 10cm section from FYI and SYI. Total number of samples: 389
DOC/DOM concentration and characterization; CDOM	Water: 6 - 10 depth horizons Sea ice: 0-5, 5-10, then every 10 cm	Solid phase extraction (onboard), FT-ICR-MS	Weekly	GF/F pre-filtered DOC and CDOM samples collected from 2-6 depths of the water column, as well as 0.2µm PES pre-filtered from FYI and occasionally SYI; DOM SPE 2L from two and 20L from one depth. Total number of samples: 41
Oceanic particle size spectra and distribution	Water column only; Sensor mounted on PS CTD-rosette	Optical - Underwater Vision Profiler (UVP)	Weekly	Activated on all PS CTD casts. Total number of casts: 7
Particulate carbon, nitrogen, and biogenic silica (POC, PON, bSi)	Water column only	elemental analyzer Spectrophotometry Wet-alkaline method	Weekly	Collected from 1000 m PS cast; after loss of PS hole 2 depths per weeks for POC/N and BSi, 1 depth for CSIA. Sea ice: 5-10cm sections FYI&SYI, isoPOM only bottom samples Total number of samples: 259 POC/N, 164 bSi, 9 CSIA, 8 isoPOM
Chlorophyll a	Water: 6 depth horizons Sea ice: 0-5, 5-10, then every 10 cm	Fluorometry	Weekly	6 prio depths from PS casts, 4 prio depths from OC cast after loss of PS CTD hole, one depth size-fractioned per week. 1-2 samples per day from underway system. Sea ice: 5-10cm sections FYI&SYI and lead ice. Extractions and on-board measurements established and performed until centrifuge failure. Total number of samples: 462, measured: 217
Pigment Biomarkers	6 depth horizons; Sea ice: 0-5, 5-10, then every 10 cm total onto GF/F filter;	High Performance Liquid Chromatography (HPLC)	Weekly	6 prio depths from PS casts, 4 prio depths from OC cast after loss of PS CTD hole. Sea ice: 5-10cm sections FYI&SYI. Total number of samples: 201
Prokaryotic and eukaryotic microbes (Bacteria and Archaea)	6 – 11 depth horizons	Flow cytometry (FCM) DNA/RNA sequencing Eco-Omics suite	Weekly	FCM samples from 4-12 depths of the water column and 5-10cm sectioned full cores of FYI, SYI and leads collected and preserved; instrument not operational. Total number of samples: 1065 DNA and RNA samples collected from 6 prio depths from PS casts, 2 depths from OC cast after loss of PS CTD hole, one depth size-fractioned per week. Auto-FIM samples were collected daily. Sea ice: 5-10cm sections FYI&SYI. Sea ice DNA from 5-10cm sections, mostly FYI and some SYI cores. Sea ice RNA from bottom FYI in 2 and brine in 1 instance. Total number of samples: 334 DNA and 135 RNA.

				Light microscopy samples collected from 6 prio depths from PS casts, and from 4 prio depths from OC cast after loss of PS CTD hole. Additionally hand-net tows integrated upper 20 m, weekly from PS hole or Ocean City. Total number of samples: 269
Meso/Macrozooplankton	Different tows between 0 and 2000m	Multinet Midi LOKI ROV net Ring nets	Weekly	Refer to section 6.1. for details
Primary productivity (NPP), incl. dark carbon fixation	Water: 3 depth horizons Ice: 1 horizon, 2 ice types [bottom only]	14C-bicarbonate tracer 24 hr incubation	Weekly	In the first two weeks 2, thereafter 4 water column depths incubated for NPP and dark fixation measurements. On FYI bottom sections from sea ice. Total number of samples:41 t0m 44 dark and 88 reference samples. In-situ incubations not done due to logistical challanges
Photosynthesis-irradiance curves	Water: 2 depth horizons Ice: 1 horizon, 2 ice types [bottom only]	14C-bicarbonate tracer , 24 hr incubation; FRRF-based	Weekly	Weekly 14C- and FRRF-based PI curves from 1 water column depth and FYI bottom samples. Total number of samples: 17 14C-based and 5 FRRF-based PI curves.
Net community production (NCP)	Seawater intake ~10 m depth horizon	MIMS; O2/Ar measurements	Continuously	Ran continuously, except for several software failures. Additionally, project-specific bottle samples collected.
Bacterial productivity (BP)	Water: 4–12 depth horizons Ice: 4–25 horizons	3H-leucine tracer 24 hr incubation	Weekly	Weekly measurements from 4-12 depths of the water column and 10cm sectioned full cores of FYI, SYI and leads; additional saturation curves, temperature and salinity test applied. Total number of samples: 1239 (triplicated incubation with one killed control from 310 ice and water samples)

Tab. 6.2: *Description and total samples numbers of ECO coordinated project-specific variables sampled during leg 3 without own contribution/berth. For details on zooplankton-related parameters, see section 6.1*

Ecosystem Core Variables	**Environments**	**PI / Group**	**Temp. resolution**	**Leg 3 Summary**
Laser In-situ Scatter Transmission meter (LISST) profiles	Water column down to 1000m depths	J. Ren, H. Jin (SIO)	Weekly	LISST deployments were done once per week in OC down to 700-1000m water depth as a joint effort of teams ECO and OCEAN (for details, see OCEAN report). Total number of deployments: 10
Ice nucleating particles (INPs) I	Water: 10 depths closest to surface Sea ice: all sections	J. Creamean, Colorado State University	Weekly	6 prio depths from PS casts, 4 prio depths from OC cast after loss of PS CTD hole. One sample per day from underway system. Sea ice: 5-10cm sections from FYI&SYI. Total number of samples: 375
Ice nucleating particles (INPs) II	Water: surface, Sea ice: all sections	M. Van Pinxteren, S. Zeppenfeld (TROPOS)	Weekly for water column, few ice cores per leg	Collected from surface sample at one cast per week, and several SYI and FYI ice cores. Total number of samples: 71
Neutral Sugars	Water: surface, Sea ice: all sections	M. Van Pinxteren, S. Zeppenfeld (TROPOS)	Weekly for water column, few ice cores per leg	Collected from surface sample at one cast per week, and several SYI and FYI ice cores. Total number of samples: 71
Nitrate Isotopes	Water: full profiles (as nutrients). Sea ice: all sections	F. Fripant (MPI)	Weekly	6 prio depths from PS casts, 4 prio depths from OC cast after loss of PS CTD hole. Sea ice: 10cm sections from FYI&SYI. Total number of samples: 284
14C-DIC	6-10 depths of deep cast	G: Mollenhauer (AWI)	Once to twice per leg	Two PS deep casts. Total number of samples: 28
Hyperspectral under-ice light measurements	Set of 5 measurements and 5 full ice cores	G. Castellani (AWI)	Weekly once sun returned	No capacity during the first phase of the leg, software issues afterwards. Total number of samples 1x5 measurements

Water column discrete sampling

The ECO leg 3 team followed the prioritization scheme developed by the ECO consortium in January 2020 to allow for increased capacity to implement those tasks that had not (or not sufficiently) been implemented on legs 1 and 2, e.g. SPE filtrations, NPP and FRRF measurements, as well as Winkler DO titrations. This entailed reducing the depth resolution for work-intensive parameters (i.e. especially those that require filtrations) to 4 to 6 depths. We also adapted the weekly schedule for operations at the CTD hole next to the ship in order to allow for enough time to collect and properly process all net tows, and to allow for experimental work (see chapter .1. for details). In terms of CTD operation, we followed the routines established on legs 1 and 2 regarding moving the tent and using the rosette shelter to prevent freezing of the sensors. Unfortunately, we were only able to execute our water sampling schedule for two weeks, as ice dynamics and pressure caused the ship to lose some of its ice anchors and move backwards, making the hole inaccessible to the ship's crane and winches and with the ship's gangway damaging the tent covering the CTD (Figure 6.1. A-C). In the following weeks, it was not possible to establish a new CTD hole because the ship did not keep a stable position relative to the floe, and because the movements (e.g. Figure 6.1. D-F; also visible on the daily 380°C camera images on the MOSAiC logbook) and the strong ice pressure caused the ice along the starboard side of the ship to raft and ridge, making the ice unusable for such an operation. As a solution, a relocation of the ship to the other side of the central floe was discussed and planned. Increased ice pressure and ridge formation did not allow for that operation on the planned day, and the plan was discarded by the cruise leader in the next week due to the high risk to destroy measurement fields on the way.

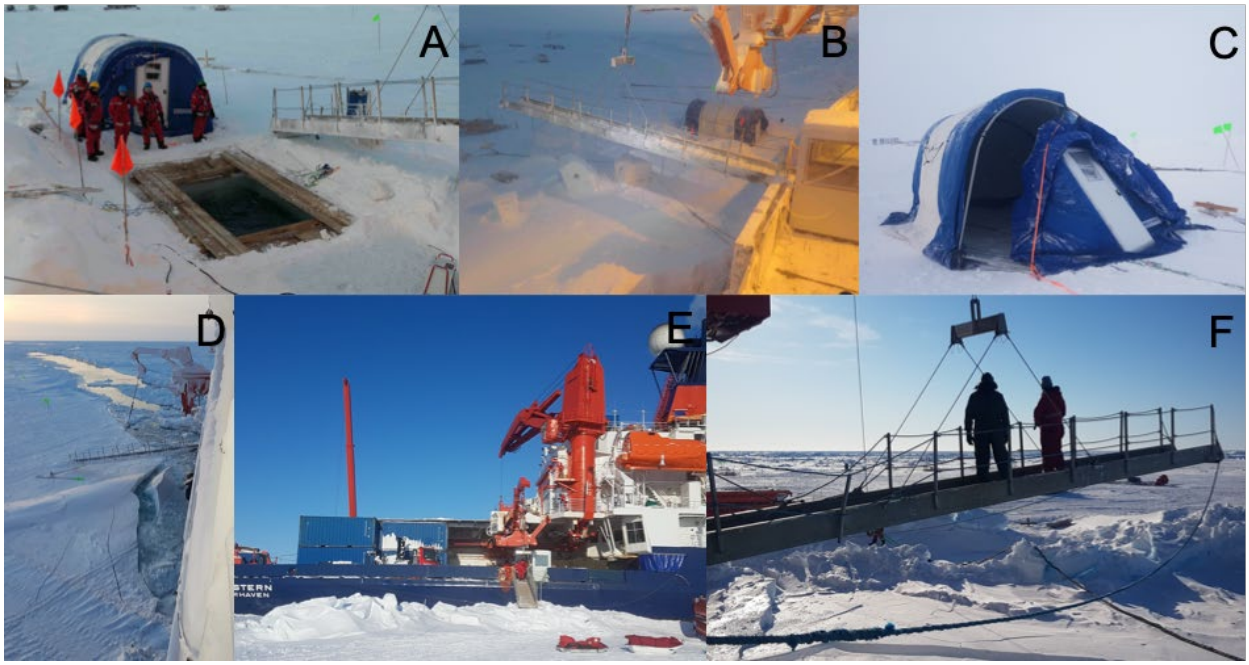

Fig. 6.1: *Position of the CTD hole relative to the gangway before (A) and after the ships movement (B) on March 15th, as well as the damaged tent (C). Regular movements of the ship relative to the floe as well as the formation of rafted and ridged ice along the starboard side (e.g. on March 20th (D), April 23rd (E) and April 27th (F)) of the ship did not allow for the construction of a new CTD hole.*

Water sampling with the large ship-based CTD rosette as well as zooplankton sampling with different nets was initially planned to be conducted on Mondays (for grazing experiments), Thursdays (mainly for core parameters), Fridays (mainly for project-specific parameters) and Saturdays (ROV nets only), with additional opportunities for net sampling on Wednesday. After the loss of the ship's CTD hole, the scientific program planned for both ice holes needed to fit into the busy schedule of just one. Also the much smaller volume of the OC rosette compared to the PS rosette (60 and 288L, respectively) resulted in a strongly reduced depth resolution and sample number for ECO core and project-specific parameters. After discussions with teams OCEAN and BGD, the newly established weekly program entailed Nansen and ring nets deployed in the Ocean City hole on Wednesdays and Thursdays, and ECO-sampling CTD casts on Thursdays (one cast to 380m and two shallow dips to 2m and 20m; full ECO casts) and Fridays (deep cast to 1200m by team OCEAN; sampled by team ECO for DIC, nutrients and partially BP and DO). All CTD casts that were sampled for ECO parameters are summarized in table 6.3.

During each cast with the ship-based CTD rosette, the UVP (Underwater Vision Profiler) was also operated. The UVP takes pictures at a frequency of 20 Hz, in which objects >2px are automatically counted, while particles and organisms >80px are saved as vignettes to be analyzed taxonomically.

Due to the limited possibilities to collect samples with the CTD rosettes, additional samples were collected from the moon pool by deploying an electrical pump (Mega Typhoon, Environmental Industries) at 20m water depth. Visual filter inspection, light microscopy and Chl extractions indicated enhanced particle content relative to the surrounding seawater, so that this approach was discarded for sampling of core parameters.

In addition to the weekly water sampling schedule, additional samples were collected. These comprised of 20µm Apstein hand net tows for light microscopy conducted once to twice per week, and daily samples for Chl, DNA and ice nucleating particles (INPs; see chapter 6.3, MethOx project, for details) from the ships underway water system. Also, daily DNA samples were automatically filtered by the Auto-FIM system from the seawater supply from the 'Bugstrahlruder – Tunnel' at a depth of approx. 10m. The instrument was maintained and filters were collected every 5th day over the entire period of leg 3, including the transit time to Svalbard. Other than leg 2, we had no major issues with operating the Auto-FIM and samples were collected daily with a few lost samples due to filter breakage.

Tab. 6.3: *CTD rosette casts by the ship's rosette (CTD AWI-OZE) and the rosette in Ocean City (Ocean City CTD) sampled during leg 3 for ECO core and project specific parameters. Letters indicate sample sets taken per event: large volume samples (totDNA, RNA, POC, bSi, 2L SPE) at one depth (A), small volume samples (e.g. nutrients, FCM, Chl, DIC, O_2, NPP, BP, INPs) at several depths (B), project-specific sampling (C), deep casts by team OCEAN subsampled by team ECO for DIC, nutrients, MIMS and O_2 (D), additional large volume samples (20L SPE, reverse filtration, CSIA) at 20m depth (E), and nutrients only (F)*

Science week	Date	ActionLog_ID	Device	Depths (m)	Cast type	# of ECO samples	Comment
30	05.03.20	PS122/3_30-40 CTD_SBE9plus_935	Ocean City CTD	2	A	8	temperatures too low for ship-based CTD operations
30	05.03.20	PS122/3_30-41 CTD_SBE9plus_935	Ocean City CTD	2	B	20	
30	07.03.20	PS122/3_30-53 CTD_SBE9plus_321	CTD AWI-OZE	bottom	B	176	
31	12.03.20	PS122/3_31-39 CTD_SBE9plus_321	CTD AWI-OZE	380	A+B	93	
31	14.03.20	PS122/3_31-59 CTD_SBE9plus_321	CTD AWI-OZE	bottom	A	202	
31	14.03.20	PS122/3_31-63 CTD_SBE9plus_321	CTD AWI-OZE	380	C	16	loss of ship's CTD hole after this cast
32	22.03.20	PS122/3_32-75 CTD_SBE9plus_935	Ocean City CTD	380	B	93	

32	22.03.20	PS122/3_32-76 CTD_SBE9plus_935	Ocean City CTD	2	A	11	
33	27.03.20	PS122/3_33-69 CTD_SBE9plus_935	Ocean City CTD	380	B	97	
33	27.03.20	PS122/3_33-70 CTD_SBE9plus_935	Ocean City CTD	2	A	15	
33	27.03.20	PS122/3_33-71 CTD_SBE9plus_935	Ocean City CTD	20	A	15	
34	03.04.20	PS122/3_34-97 typhoon_sn1479	Typhoon pump	20	A+B	25	
34	04.04.20	PS122/3_34-65 CTD_SBE9plus_935	Ocean City CTD	20	A	25	
34	04.04.20	PS122/3_34-66 CTD_SBE9plus_935	Ocean City CTD	2	A	11	
34	04.04.20	PS122/3_34-67 CTD_SBE9plus_935	Ocean City CTD	380	D	45	
34	05.04.20	PS122/3_34-77 CTD_SBE9plus_935	Ocean City CTD	380	B	80	
35	09.04.20	PS122/3_35-60 CTD_SBE9plus_935	Ocean City CTD	20	A	83	full set of parameters; 20m depth from moon pool
35	09.04.20	PS122/3_35-61 CTD_SBE9plus_935	Ocean City CTD	2	A	14	
35	09.04.20	PS122/3_35-62 CTD_SBE9plus_935	Ocean City CTD	20	E	3	
35	09.04.20	PS122/3_35-63 CTD_SBE9plus_935	Ocean City CTD	500	B	53	
35	10.04.20	PS122/3_35-77 CTD_SBE9plus_935	Ocean City CTD	1200	D	48	
36	16.04.20	PS122/3_36-59 CTD_SBE9plus_935	Ocean City CTD	1200	D	100	
36	17.04.20	PS122/3_36-81 CTD_SBE9plus_935	Ocean City CTD	380	B	71	
36	17.04.20	PS122/3_36-83 CTD_SBE9plus_935	Ocean City CTD	20	A	11	
36	17.04.20	PS122/3_36-84 CTD_SBE9plus_935	Ocean City CTD	2	A	11	
36	17.04.20	PS122/3_36-85 CTD_SBE9plus_935	Ocean City CTD	20	E	3	
37	23.04.20	PS122/3_37-45 CTD_SBE9plus_935	Ocean City CTD	75	B	99	
37	23.04.20	PS122/3_37-46 CTD_SBE9plus_935	Ocean City CTD	20	A	16	
37	23.04.20	PS122/3_37-47 CTD_SBE9plus_935	Ocean City CTD	2	A	15	
37	25.04.20	PS122/3_37-88 CTD_SBE9plus_935	Ocean City CTD	1200	D	52	
37	25.04.20	PS122/3_37-99 CTD_SBE9plus_935	Ocean City CTD	20	A	2	
38	27.04.20	PS122/3_38-5 CTD_SBE9plus_935	Ocean City CTD	110	B	75	
38	30.04.20	PS122/3_38-54 CTD_SBE9plus_935	Ocean City CTD	380	B	64	
38	30.04.20	PS122/3_38-55 CTD_SBE9plus_935	Ocean City CTD	20	A	15	
38	30.04.20	PS122/3_38-56 CTD_SBE9plus_935	Ocean City CTD	2	A	15	
38	01.05.20	PS122/3_38-69 CTD_SBE9plus_935	Ocean City CTD	1200	D	79	
39	07.05.20	PS122/3_39-51 CTD_SBE9plus_935	Ocean City CTD	360	B	135	
39	07.05.20	PS122/3_39-52 CTD_SBE9plus_935	Ocean City CTD	20	A	15	
39	07.05.20	PS122/3_39-53 CTD_SBE9plus_935	Ocean City CTD	2	A	15	
39	07.05.20	PS122/3_39-54 CTD_SBE9plus_935	Ocean City CTD	20	E	3	
40	16.05.20	PS122/3_40-36 CTD_SBE9plus_321	CTD AWI-OZE	bottom	A+B	190	
42	30.05.20	PS122/3_42-32 CTD_SBE9plus_321	CTD AWI-OZE	bottom	F	17	

Sea ice discrete sampling

Due to ice thickness and correspondingly large number of core sections (and pools) to process, leg 2 team only went to one site per week (alternating between FYI and SYI). Following the ECO prioritization scheme, we attempted to sample both sites each week and rather reduced the number of pools and subsamples taken per site. Team ECO always contributed three team members to FYI coring, and one team member to SYI coring. On leg 3, FYI and SYI coring was conducted on Mondays whenever the sites were accessible, and on other weekdays in a few instances. The main limitation to this approach was accessibility. In several instances (weeks 31, 32, 33, and 37) either both or one of the sites was inaccessible due to ice dynamics (open cracks and leads, ridges) and/or weather (temperatures below -40°C, 10 bft winds). In one instance, a helicopter was used to access the SYI site. All coring events are summarized in table 6.4.

Ice thickness of SYI varied between 1.67 and 2.32m, while ice thickness of FYI was between 1.44 and 3.29m, both without a clear temporal trend. This variability was partially due to rafting events in the coring sites. Scouting trips were performed prior to coring in some weeks to identify non-rafted coring plots, with varying success. At the end of the leg (PS122/3_38-24), the FYI team identified and once sampled a seemingly undisturbed area of the FYI coring site, which should be used if coring in this area is continued during leg 4. It is located approximately 50 m beyond the old coring plots (from the road), and marked by bamboo sticks from two coring events. More details on the coring sites can be found in section 4.1.

For each sampling event, 1 to 15 ECO cores were collected in addition to the cores required by teams ICE and BGC. For main coring events, the following prioritization scheme of ECO cores was followed: 1) ECO pool A (at least one core for Chl, if possible up to three cores for Chl, INPs (Creamean), microscopy, FCM, BP, POC, as well as less regularly isoPOM, HPLC, bSi, neutral sugars and INPs (TROPOS)); 10cm sections plus two 5cm bottom sections), 2) Nutrients (combined with ICE parameters salinity and deltaO18, and nitrate isotopes from week 39; 5 cm sections), 3) DIC (combined with nitrate isotopes until week 38, 10 cm sections), 4) Primary Production pool (including Chl and BP; rapid melt; 3 times 5 cm bottom sections), 5) meiofauna (10 cm bottom section), 6) ECO pool B (1 to 3 cores for DNA, DOC, CDOM; 10 cm sections plus two 5 cm bottom sections), 7) RNA (5 cm bottom sections, mainly skeletal layer; rapid melt). Cores were sectioned (and pooled where applicable) in the field, except for event PS122/3_34-4, where sectioning was performed using the band saw in the sea ice physics container. Core processing of the differently treated cores (rapid melt of skeletal layer, 5 cm sectioned, 10 cm sectioned, pooled 10 cm sections; see section 6 of the leg 1 cruise report for details) was done over the next 3 days depending on the core and sample type.

During two coring events (week 34 and 39), the FYI team also for the first time during MOSAiC sampled for RNA to study the metabolic activity and regulation of in-ice prokaryotes and eukaryotic protists. As these samples should ideally be process within 60 minutes, it is a challenging parameter to sample for in sea-ice. While the sampling and processing of bottom sections including crushing of ice and melting it under regular shaking in the dark at room temperature still took three to four hours from collection to flash-freezing, sampling of brine from sack holes prove to be a more promising approach. The sackholes were covered by a lid and snow, and the brine was draining for 3–5 h before collection. The processing took 60 min from brine collection to freezing the sample, but has the limitation that is mainly covers prokaryotic RNA from a bulk sample of the upper ice, as eukaryotic biomass in the collected brine was not detectable (FRRF, light microscopy). However, this microbial community may show some very interesting features as it appears to have been actively degrading the autumn algal biomass in the upper ice during winter and spring.

Tab. 6.4: *ECO coring events in first year ice (FYI), second year ice (SYI), ridges and re-frozen leads during leg 3. Letters indicate sample sets taken per event: Nutrients (A), DIC (B), ECO pool A (C), ECO pool B (D), NPP pool (E), RNA pool (F), Chl, FCM and microscopy only (G), ridge sampling for HAVOC project (H), meiofauna (I)*

Science week	Date	ActionLog_ID	Ice Type	ECO cores sampled	Total sample #	Comment
30	-	-	-	-	-	handover
31	-	-	-	-	-	Bad weather -40°C (-60°C windchill)
32	21.03.20	PS122/3_32-63 SI_corer_9cm	FYI	B,C	256	SYI not accessible, FYI accessible later in the week; FYI rafted (3.2m)
33	24.03.20	PS122/3_33-18 SI_corer_9cm	SYI	A,B,C,D	377	Both sites not accessible via snowmobile, SYI accessed via helicopter
34	30.03.20	PS122/3_34-4 SI_corer_9cm	FYI	B,C,E,F	125	planned ship-relocation; afterwards only short trip to FYI possible
35	06.04.20	PS122/3_35-11 SI_corer_9cm	FYI	A,B,C,D,E,I	326	
35	06.04.20	PS122/3_35-4 SI_corer_9cm	SYI	A,B,C,I	244	
36	13.04.20	PS122/3_36-4 SI_corer_9cm	SYI	A,B,C	383	
36	14.04.20	PS122/3_36-21 SI_corer_9cm	FYI	A,B,C,D,E,I	205	rafted
37	22.04.20	PS122/3_37-32 SI_corer_9cm	ridge	H	40	
38	26.04.20	PS122/3_37-155 SI_corer_9cm	lead	G	55	
38	27.04.20	PS122/3_38-16 SI_corer_9cm	SYI	A,B,C,D,I	80	
38	27.04.20	PS122/3_38-24 SI_corer_9cm	FYI	A,B,C,D,E,I	265	
38	02.05.20	PS122/3_38-104 SI_corer_9cm	lead	G	273	
39	04.05.20	PS122/3_39-18 SI_corer_9cm	SYI	A,B,C,I	347	
39	04.05.20	PS122/3_39-7 SI_corer_9cm	FYI	A,B,C,D,E,F,I	317	
39	05.05.20	PS122/3_39-104 SI_corer_9cm	ridge	H	20	
39	06.05.20	PS122/3_39-39 SI_corer_9cm	lead	G	40	

Measurements from the underway system

To estimate high resolution data on Net Community production in the surface ocean over the full annual cycle from continuous underway measurements of O2/Ar, the AWIs self-built Membrane Inlet Mass Spectrometer (MIMS) was operated in continuous measurement mode throughout leg 3. Briefly, seawater from the ship's underway system is pumped through a cylinder where seawater is subsampled via a cuvette with water flowing across a silicon membrane. The extracted gas from the water is transferred to a quadrupole mass spectrometer for continuous elemental O_2/Ar ratio measurements. The ion current ratio was calibrated daily by subsampling two other cuvettes which were bubbled with pure nitrogen gas (no oxygen, no argon) and an artificial mixture of air (21% nitrogen, 1% argon) for at least 35 min, respectively. From the O_2/Ar supersaturation, a gas exchange rate, and the oxygen concentration at saturation, the net biological oxygen flux across the ocean surface will be estimated. The quasi-continuous measurements were frequently interrupted by scheduled maintenance, e.g., daily calibrations and defrosting of the Pulse Tube Cooler. Longer interruptions were associated with cleaning of the flow-through cylinder and sampling cuvettes. A catastrophic computer failure occurred on 12 March. After extensive troubleshooting and switching to a new backup computer, the MIMS was up and continuously running again on 16 March. A new LabView software update was successfully installed on 21 May.

Furthermore, daily sampling from the underway seawater system was conducted for Chl (core parameter), INPs (project-specific; PI Creamean) and DNA (project-specific, PI Bowman; see section 6.3 for details) to achieve a higher temporal resolution of these parameters in surface waters (table 6.5.). Chl and DNA samples were filtered and frozen at -80°C, while INP samples were directly frozen at -20°C. For Chl, one subsample per day was extracted every few days for near real time measurements of phytoplankton dynamics in the surface ocean (See figure 6.2. for results), while a second subsample was stored for later analysis from week 37 onwards. Underway sampling was continued during the transit to Svalbard and the handover with the leg 4 team.

Tab. 6.5: *Daily device operations and associated sampling from the underways seawater system*

Date	ActionLog_ID	Samples taken
29.02.20	PS122/3_29-78 seawatertap_ps	Chl, totDNA
01.03.20	PS122/3_29-89 seawatertap_ps	Chl, totDNA
02.03.20	PS122/3_30-15 seawatertap_ps	Chl, totDNA
03.03.20	PS122/3_30-51 seawatertap_ps	Chl, totDNA, INPs
04.03.20	PS122/3_30-63 seawatertap_ps	Chl, totDNA, INPs
05.03.20	PS122/3_30-49 seawatertap_ps	Chl, totDNA, INPs
06.03.20	PS122/3_30-50 seawatertap_ps	Chl, totDNA, INPs
07.03.20	PS122/3_30-80 seawatertap_ps	Chl, totDNA, INPs
08.03.20	PS122/3_30-93 seawatertap_ps	Chl, totDNA, INPs
09.03.20	PS122/3_31-14 seawatertap_ps	Chl, totDNA, INPs
10.03.20	PS122/3_31-27 seawatertap_ps	Chl, totDNA, INPs
11.03.20	PS122/3_31-40 seawatertap_ps	Chl, totDNA, INPs
12.03.20	PS122/3_31-48 seawatertap_ps	Chl, totDNA, INPs
13.03.20	PS122/3_31-58 seawatertap_ps	Chl, totDNA, INPs
14.03.20	PS122/3_31-74 seawatertap_ps	Chl, totDNA, INPs
15.03.20	PS122/3_31-83 seawatertap_ps	Chl, totDNA, INPs
16.03.20	PS122/3_32-4 seawatertap_ps	Chl, totDNA, INPs
17.03.20	PS122/3_32-20 seawatertap_ps	Chl, totDNA, INPs
18.03.20	PS122/3_32-35 seawatertap_ps	Chl, totDNA, INPs
19.03.20	PS122/3_32-47 seawatertap_ps	Chl, totDNA, INPs
20.03.20	PS122/3_32-49 seawatertap_ps	Chl, totDNA, INPs
21.03.20	PS122/3_32-69 seawatertap_ps	Chl, totDNA, INPs
22.03.20	PS122/3_32-87 seawatertap_ps	Chl, totDNA, INPs
23.03.20	PS122/3_33-6 seawatertap_ps	Chl, totDNA, INPs
24.03.20	PS122/3_33-16 seawatertap_ps	Chl, totDNA, INPs
25.03.20	PS122/3_33-49 seawatertap_ps	Chl, totDNA, INPs
26.03.20	PS122/3_33-54 seawatertap_ps	Chl, totDNA, INPs
27.03.20	PS122/3_33-77 seawatertap_ps	Chl, totDNA, INPs
28.03.20	PS122/3_33-94 seawatertap_ps	Chl, totDNA, INPs
29.03.20	PS122/3_33-95 seawatertap_ps	Chl, totDNA, INPs
30.03.20	PS122/3_34-6 seawatertap_ps	Chl, totDNA, INPs
31.03.20	PS122/3_34-17 seawatertap_ps	Chl, totDNA, INPs

01.04.20	PS122/3_34-33 seawatertap_ps	Chl, totDNA, INPs
02.04.20	PS122/3_34-44 seawatertap_ps	Chl, totDNA, INPs
03.04.20	PS122/3_34-48 seawatertap_ps	Chl, totDNA, INPs
04.04.20	PS122/3_34-73 seawatertap_ps	Chl, totDNA, INPs
05.04.20	PS122/3_34-82 seawatertap_ps	Chl, totDNA, INPs
06.04.20	PS122/3_35-6 seawatertap_ps	Chl, totDNA, INPs
07.04.20	PS122/3_35-25 seawatertap_ps	Chl, totDNA, INPs
08.04.20	PS122/3_35-45 seawatertap_ps	Chl, totDNA, INPs
09.04.20	PS122/3_35-68 seawatertap_ps	Chl, totDNA, INPs
10.04.20	PS122/3_35-86 seawatertap_ps	Chl, totDNA, INPs
11.04.20	PS122/3_35-101 seawatertap_ps	Chl, totDNA, INPs
12.04.20	PS122/3_35-109 seawatertap_ps	Chl, totDNA, INPs
13.04.20	PS122/3_36-7 seawatertap_ps	Chl, totDNA, INPs
14.04.20	PS122/3_36-33 seawatertap_ps	Chl, totDNA, INPs
15.04.20	PS122/3_36-36 seawatertap_ps	Chl, totDNA, INPs
16.04.20	PS122/3_36-71 seawatertap_ps	Chl, totDNA, INPs
17.04.20	PS122/3_36-100 seawatertap_ps	Chl, totDNA, INPs
18.04.20	PS122/3_36-126 seawatertap_ps	Chl, totDNA, INPs
19.04.20	PS122/3_36-136 seawatertap_ps	Chl, totDNA, INPs
20.04.20	PS122/3_37-10 seawatertap_ps	Chl, totDNA, INPs
21.04.20	PS122/3_37-13 seawatertap_ps	Chl, totDNA, INPs
22.04.20	PS122/3_37-43 seawatertap_ps	Chl (2x), totDNA, INPs
23.04.20	PS122/3_37-54 seawatertap_ps	Chl (2x), totDNA, INPs
24.04.20	PS122/3_37-106 seawatertap_ps	Chl (2x), totDNA, INPs
25.04.20	PS122/3_37-107 seawatertap_ps	Chl (2x), totDNA, INPs
26.04.20	PS122/3_37-113 seawatertap_ps	Chl (2x), totDNA, INPs
27.04.20	PS122/3_38-23 seawatertap_ps	Chl (2x), totDNA, INPs
28.04.20	PS122/3_38-29 seawatertap_ps	Chl (2x), totDNA, INPs
29.04.20	PS122/3_38-153 seawatertap_ps	Chl (2x), totDNA, INPs
30.04.20	PS122/3_38-154 seawatertap_ps	Chl (2x), totDNA, INPs
01.05.20	PS122/3_38-73 seawatertap_ps	Chl (2x), totDNA, INPs
02.05.20	PS122/3_38-156 seawatertap_ps	Chl (2x), totDNA, INPs
03.05.20	PS122/3_38-157 seawatertap_ps	Chl (2x), totDNA, INPs
04.05.20	PS122/3_39-118 seawatertap_ps	Chl (2x), totDNA, INPs
05.05.20	PS122/3_39-119 seawatertap_ps	Chl (2x), totDNA, INPs
06.05.20	PS122/3_39-120 seawatertap_ps	Chl (2x), totDNA, INPs
07.05.20	PS122/3_39-121 seawatertap_ps	Chl (2x), totDNA, INPs
08.05.20	PS122/3_39-122 seawatertap_ps	Chl (2x), totDNA, INPs
09.05.20	PS122/3_39-123 seawatertap_ps	Chl (2x), totDNA, INPs
10.05.20	PS122/3_39-124 seawatertap_ps	Chl (2x), totDNA, INPs
11.05.20	PS122/3_40-23 seawatertap_ps	Chl (2x), totDNA, INPs
12.05.20	PS122/3_40-24 seawatertap_ps	Chl (2x), totDNA, INPs

13.05.20	PS122/3_40-25 seawatertap_ps	Chl (2x), totDNA, INPs
14.05.20	PS122/3_40-56 seawatertap_ps	Chl (2x), totDNA, INPs
15.05.20	PS122/3_40-57 seawatertap_ps	Chl (2x), totDNA, INPs
16.05.20	PS122/3_40-58 seawatertap_ps	Chl (2x), totDNA, INPs
17.05.20	PS122/3_41-32 seawatertap_ps	Chl (2x), totDNA, INPs
18.05.20	PS122/3_41-31 seawatertap_ps	Chl (2x), totDNA, INPs
19.05.20	PS122/3_41-30 seawatertap_ps	Chl (2x), totDNA, INPs
20.05.20	PS122/3_41-29 seawatertap_ps	Chl (2x), totDNA, INPs
21.05.20	PS122/3_41-28 seawatertap_ps	Chl (2x), totDNA, INPs
22.05.20	PS122/3_41-39 seawatertap_ps	Chl (2x), totDNA, INPs
23.05.20	PS122/3_41-43 seawatertap_ps	Chl (2x), totDNA, INPs
24.05.20	PS122/3_41-49 seawatertap_ps	Chl (2x), totDNA, INPs
25.05.20	PS122/3_42-2 seawatertap_ps	Chl (2x), totDNA, INPs
26.05.20	PS122/3_42-7 seawatertap_ps	Chl (2x), totDNA, INPs
27.05.20	PS122/3_42-15 seawatertap_ps	Chl (2x), totDNA, INPs
28.05.20	PS122/3_42-22 seawatertap_ps	Chl (2x), totDNA, INPs
29.05.20	PS122/3_42-36 seawatertap_ps	Chl (2x), totDNA, INPs
30.05.20	PS122/3_42-37 seawatertap_ps	Chl (2x), totDNA, INPs
31.05.20	PS122/3_42-46 seawatertap_ps	Chl (2x), totDNA, INPs
01.06.20	PS122/3_42-54 seawatertap_ps	Chl (2x), totDNA, INPs
20.06.20	PS122/3_42-59 seawatertap_ps	Chl (2x), totDNA, INPs

On ice installations

No new ECO in-ice installations were established on leg 3. Aside from checking their locations, no work was done on the existing installations, being 1) the SIO-owned McLane sediment trap deployed in the SYI dark site during leg 1 (see Leg 1 cruise report, chapter 6.6) and 2) two Acoustic Zooplankton and Fish Profilers (AZFP POPE buoys, HAVOC project) deployed next the Northern Transect and in the SYI dark site on leg 2 by team ICE (see Leg 2 cruise report chapter 4.9).

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. Exemplarily, the development during leg 3, including the effect of water mass changes after drifting over the Gakkel Ridge at the beginning of April and the initiation of biomass build-up in mid/end April is shown in figure 6.2. 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.

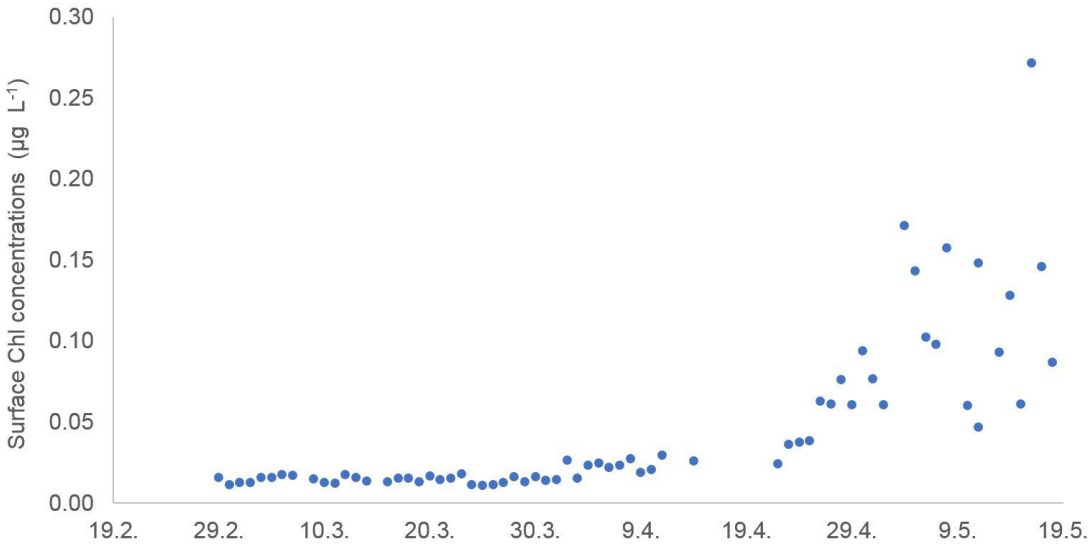

Fig. 6.2: *Daily surface chlorophyll a (Chl) concentrations sampled from the ship's underway system over the course of the leg 3 drift.*

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.

References

No references

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 mesozooplankton feeding, respiration, growth, and reproduction.
2. Determine standing stocks and distributions of microorganisms and animals in relation to physical conditions (ice, stratification, water masses, etc.) to evaluate the physical-biological interactions that impact production, pelagic retention and vertical export.
3. Determine nutrient fluxes, organismal abundance and biomass of important components of the ecosystem (e.g. ice algae, phytoplankton, zooplankton). Relate these properties to behavioral (e.g. vertical depth preferences and diel or ontogenic vertical migration) and life history (e.g. reproductive timing and overwintering strategies) patterns.

Work at Sea

This report covers the period of Leg 3 that started on February 24. Zooplankton sampling took place starting in week 30 (first date March 2). No zooplankton sampling took place from February 20 – March 3. Zooplankton sampling was conducted both from the *Polarstern*, through a hole in the sea ice located next to the ship (as was done for Legs 1 and 2), and, after the ship moved relative to the ice floe making the hole inaccessible to the handling gear, from Ocean City. Sampling from the *Polarstern* was conducted during weeks 30, 31, and, using limited gear, 40 and 42. Sampling from Ocean City was done during weeks 32-29. The loss of use of the ship-based sampling gear significantly compromised the zooplankton program since we were unable to use two of our primary instruments, the Multinet (depth stratified sampling) and the LOKI (Lightframe On-sight Key species Investigation; high resolution vertical distributions in the upper 1000 m). Furthermore, the nets deployed at Ocean City have smaller mouth areas (60 cm diameter) than the larger nets (1 m^2 mouth area) that we are able to use from *Polarstern* and the winch can only deploy gear to 800 m, both of which limited the quantity and type of zooplankton we could collect for core and project assays and for experiments. Sampling also was done from the ROV City working together with team ICE to tow a net mounted on the ROV.

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. It quickly became clear that conducting all of the required evolutions plus removing and reinstalling the tent covering the sampling hole on the ice was not possible within that two-day period. The zooplankton sampling schedule then was expanded to take place on three days (Wed-Friday), with the tow and CTD for grazing still on Monday. In practice, we never achieved the planned schedule due primarily to weather limitations. The Polarstern's cranes are limited to operations at temperatures greater than -30°C. Several days had very cold temperatures so that we were unable to work (either nets or CTD). As a result, only a few tows could be done during week 30 (Table 6.6.1). In addition, high winds during week 31 precluded our deployment of the large and light ring nets on Thursday so sampling was done using only the much heavier LOKI and the Multinet, with additional tows on Saturday. We appreciated the willingness of the ship 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 -0m – for abundances (no picking)

Ocean City: Operations moved to Ocean City during week 32 and were conducted with two (RN53, Nansen150) rather than four (RN53, RN150, RN1000, MN150) types of nets and without the LOKI. Working together with team OCEAN, we arrived at a schedule in which net sampling would take place on Wednesday afternoon (1300-1530) and Thursday afternoon (1300-1730) (Table 6.6.1). We by and large followed this schedule with only occasional adjustments to accommodate different timing for CTDs and microstructure measurements by team OCEAN.

The following net operations were identified to approach standard core and project requirements:

1. Ring Net 53-µm, 200 -0m – for abundances (no picking)
2. Nansen Net 150-µm, 50-0 m – for abundances (no picking)
3. Nansen Net 150-µm, 200-50 m – for abundances (no picking)
4. Nansen Net 150-µm, 500-200 m – for abundances (some picking)
5. Nansen Net 150-µm, 200-0 m – for picking (usually 2 per day)
6. Nansen Net 150-µm, 800-500 m – for abundances (some picking)

ROV City: For most of the leg, zooplankton sampling at ROV City was done on Saturday morning. During one week (week 34), sampling could not be done on Saturday and so two sets of tows were conducted during week 35, one on Tuesday and one on Saturday (Table 6.6.1). High floe drift speed precluded sampling during week 33.

***Tab. 6.1.1**: Dates of zooplankton sampling during Leg 3. MN150 = Multinet-Midi with 150 µm mesh; RN53=Ring Net with 53 µm mesh; RN150=Ring Net with 150 µm mesh; RN1000 = Ring net with 1000µm mesh; Nansen150=Nansen net with 150 µm meshl LOKI= Lightframe On-sight Key species Investigation; ROVNet=150 µm mesh net mounted on ROV.*

Week	Date Day 1	Sampling Location		Sampling Gear Deployed by Day of Week					
			M	T	W	R	F	S	S
30	2-Mar	PS		MN150, RN150				ROVNet	
31	9-Mar	PS				MN150x2, LOKI		RN1000, RN150, RN53	
32	16-Mar	OC			RN53 x 4			ROVNet	
33	23-Mar	OC				RN53, Nansen150x4		ROVNet	
34	30-Mar	OC					RN53, Nansen150 x 4		
35	6-Apr	OC		ROVNet	RN53, Nansen150x2	Nansen150x3		ROVNet	
36	13-Apr	OC			RN53, Nansen150x2	Nansen150x5		ROVNet	
37	20-Apr	OC			RN53, Nansen150x3	Nansen150x4	RN53	ROVNet	Nansen150x4
38	27-Apr	OC			Nansen150x5			ROVNet	
39	4-May	OC			Nansen150x5	RN53x2, Nansen150x2		ROVNet	
40	16-May	PS						MN150, LOKI	
42	30-May	PS						MN150x2, LOKI	

Weather:

Cold weather (air temperature less than -30°C) precluded sampling for several days during weeks 30 and 31. Weather did not limit sampling to a significant extent at Ocean City and with the ROV, although there were some days on which drift was too fast to deploy the ROV. On high drift days, care was taken to pull the wire away from the ice edge in Ocean City. For this, a small block attached to a line was used. (The block reduces the friction over the wire while pulling it towards the center of the hole.)

Sampling Gear:

Polarstern:

General: For weeks 30 and 31, zooplankton sampling gear were deployed with the Polarstern's crane and winches through a hole in the ice on the starboard side of the ship that sheltered by a heated tent when not in use. Prior to the start of water column sampling for the day, the heater was removed and the tent was lifted by 4 to 6 scientists and moved off the hole away from the ship with the tent door about 2 to 3 meters away facing the hole. The heater was replaced in the tent and the pump turned on in the hole to circulate water. The pump remained on for the entire period that the tent was removed, except for short periods when gear was being deployed or recovered. At the end of the day, the tent was moved over the hole and the heater placed back inside on a low setting and the tent left until the next sampling day. During weeks 40 and 42, sampling also was conducted from the Polarstern through an opening in the sea ice that had been cleared and was maintained using the ship's thrusters.

All sampling gear were lowered from the surface and raised vertically from the designated sampling depth at a speed of 0.5m/s. Upon reaching the surface, nets were rinsed with

buckets of surface water from the hole while they were being lifted into the air to make sure the nets were clean and all organisms were collected in the cod-ends. The cod-ends were quickly pulled into the heated tent while still attached to the nets to prevent freezing and processed. Contents of the cod-ends were rinsed into small 1-L Kautex jars and placed into a cooler. For some samples that were to be used for experiments, the contents of the cod-end were diluted in 3 or 4, 4-L jars that were half-filled with surface seawater and then placed in the cooler. For gut DNA samples (150-µm ring nets), a portion of the sample from a non-quantitative tow was passed retained on a small 150-µm mesh and the mesh rinsed into a sample container with 96% ETOH. The remainder of the sample was then distributed between the large jars. The cooler was then brought onto the ship for further processing. Sample processing in the tent was done with the aid of a headlamp.

Multinet Midi (5 nets, 150-µm, 0.25 m^2, 2000-1000-500-200-50-0 meter sample depths): Multinet samples were collected during weeks 30, 31, and 40 from 5 pre-established depth strata to determine the meso/macrozooplankton abundance, community composition, and vertical distribution. The samples were preserved in 4% formaldehyde for later analysis. During week 31, two Multinet tows were conducted on Thursday because that net was heavy enough to be used during the high winds experienced that day. One of the tows was preserved for later quantitative analysis; the second was used to select animals for biogeochemical or genetic analyses. During week 42, a second Multinet tow was conducted using only a single net to collect animals from the upper 200 m.

Ring Nets (53-µm, 0.25 m^2; 150-µm, 1m^2; and 1000-µm, 1m^2): Three different ring nets were deployed. The smaller 53-µm mesh net collected large microzooplankton and small mesozooplankton in the upper 200 meters. The large 150-µm net was to collect meso- and microzooplankton in two separate intervals (2000-200 and 200-0 m) using a mechanical closing mechanism, but the deeper interval could not be sampled given the weather limitations of weeks 30 and 31 (and the loss of the hole after that). The 1000-µm net was used to collect large meso- and macrozooplankton from the upper 1000 m and, again due to weather, could only be used during week 31. Target species were presorted from both the 150- and 1000-µm nets for biochemical and genetic analysis, and subsamples were occasionally taken from the 150-µm net for gut DNA analysis. The remainder of the sample from the 150-µm net was frozen at -80 °C for later biochemical and genetic analysis. Samples from the 53- and the remainder of the 1000-µm 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 to 1000 m three times during Leg 3 (Weeks 31, 40, and 42). The LOKI was equipped with a 150-µm net to concentrate the plankton and a high-resolution camera taking up to 19 pictures sec^{-1}. The underwater computer unit of the LOKI system immediately detected zooplankton organisms and particles in the pictures and saved clippings of these objects. In addition, a set of sensors measured depth, water temperature, conductivity, oxygen and fluorescence, which will allow us to relate zooplankton distributions to the environmental conditions. Overheating of the LOKI computer during data download was mitigated using ice packs to cool the underwater cases; data from both tows were successfully downloaded and archived in the MCS.

ROV City

ROV Net (150- and 10-µm nets; 0, 10, and 50-95 m sample depths): The under-ice zooplankton community was studied in cooperation with the ROV team of the ICE group (see ROV section 4.5). The ROV net consisted of a large 150-µm net bag and a small phytoplankton/gypsum net (10-µm mesh size); for most sampling dates, only the large net was

used. Plastic lamellas on top of the net frame were used to scrape organisms off of the underside of the sea ice. In addition, based on the zooplankton-like characteristics of some scattering layers observed on EK80, a third tow was added into sampling scheme (changing between *50-95 m)*. The initial impression has been that the layers were primarily composed either of *C. glacialis* or *M. longa*.
Samples were preserved in 4% formaldehyde after pre-sorting target organisms for biochemical and genetic variables. Occasional extra net samples were taken for gut DNA. For this, the entire sample was placed in a 2-L beaker, the total volume noted, and a subsample (250-500 ml) taken using a 250 ml beaker. This subsample then was passed through a 150 µm mesh sieve and rinsed into a sample jar using 96% EtOH.

Ocean City

General: Net tows at Ocean City were done with two different nets: the 53-µm, 0.25 m^2 ring net and a 150-µm, 0.25 m^2 Nansen Net. Tows were done using a small oceanographic winch (KC Denmark or Blue or NPI winch; all names used) together with the A-frame stand and wire payout control system used for the CTD. The set-up was the same as used for the LISST during both Legs 2 and 3. Deployment required locating the A-frame so that the wire from the winch had the longest lead between winch and the first wheel on the A-frame as possible. For this, the CTD had to be moved from its normal resting spot further away from the hole so that the back legs of the A-frame could be positioned as closely to the back wall of the tent as possible. The angle of the A-frame relative to the winch and the centering of the top bar of the A-frame relative to the center of the winch drum were optimized to provide as straight a lead as possible for the winch wire from drum to top of the A-frame. This arrangement provided usually satisfactory conditions in which the small wheel on the top of the A-frame turned readily throughout the period of the tow. Other less optimal configurations and geometry would put excessive tension on the wheel so that it stopped turning, essentially dragging the wire across the small wheel without the wheel turning. This was dangerous and potentially harmful to the equipment so care was taken to mitigate this circumstance as much as possible.

Sampling with the 53-µm Ring Net (200-0 m) and 150-µm Nansen Net (50-0; 200-50; 500-200; 800-500; 200-0 m sample depths): Both nets were deployed and recovered nominally at 0.5 m/sec speeds. Speed was estimated using the wire-out display that is part of the CTD deployment package. Both nets were deployed with weights attached to the net frame. The 53-µm Ring Net utilized a weight carried out from the Polarstern; the Nansen net is equipped with a heavy cod-end basket that functioned as a weight. Both nets were equipped with one-way flow meters (either General Oceanics (GO) or Hydrobios). Both types were observed to be not turning during retrieval of tows and both yielded estimates of the distance traveled that were far less than the theoretical distance traveled based on the length of wire deployed. This could have resulted from a) back pressure from the net preventing water from entering or b) malfunction of the flow meter. The GO flowmeter was clearly malfunctioning initially, since the tail would catch and not turn. However, changing the ball bearing in the one-way turning mechanism and adjusting the tail position rectified this problem. It was not clear why the Hydrobios flowmeter was malfunctioning. A brand-new flowmeter was installed partway through the leg with no improvement. This led to likely underestimates of the volume of water filtered through the net.

A closing mechanism was used with the Nansen net to obtain samples from discrete depth intervals. The large termination was removed from the winch wire using a small wrench and the closing mechanism secured to the loop in the end of the wire. A messenger was used to close the nets. Messengers were put on the wire and sent while the net was being hauled back, without stopping the winch. The messenger was sent when the wire payout was 4 meters for every 50 meters of depth.

Samples were retained in 1-L Kautex plastic jars that were kept against the wall of the tent, where it was coolest, until returned to the ship in a cooler. Once on board, samples were immediately transferred to a laboratory container maintained at cold temperatures. Sampling for gut DNA was conducted from non-quantitative net tows (200-0 m) as described for the Ring Net sampling on the Polarstern.

***Tab. 6.1.2**. Zooplankton sampling gear, targeted depth horizons, and number of hauls for each piece of sampling gear during Leg 3. MN150=Multinet-Midi, 150-µm mesh nets; RN150=150-µm, 1m² Ring Net; RN1000= 1000-µm, 1m² Ring Net; RN53=53-µm, 0.25 m² ; NaN150=150-µm, 0.25 m² Nansen Net; LOKI150= Lightframe On-sight Key species Investigation with 150-µm net; BEAST=ROV with 150-µm net*

Sampling Device	Depth Sampled	Number of Hauls
MN150	2000-0	3
MN150	200-0	1
NANSEN150	50-0	7
NANSEN150	200-0	16
NANSEN150	200-50	4
NANSEN150	500-0	1
NANSEN150	500-200	7
NANSEN150	800-200	2
RN150	200-0	2
RN150	2000-200	0
RN150	1000-200	0
RN1000	1000-0	1
RN53	200-0	10
RN53	50-0	10
RN53	20-0	10
ROV Net	0	8
ROV Net	10	9
ROV Net	0-50	0
ROV Net	Scattering Depth (60-90)	6
LOKI	1000-0	2
UVP	Same as CTD casts	7

Tab. 6.1.3. *Date, activity number, and position (latitude, longitude) for each zooplankton device operation. MN150=Multinet-Midi, 150-µm mesh nets; RN150=150-µm, 1m² Ring Net; RN1000= 1000-µm, 1m² Ring Net; RN53=53-µm, 0.25 m² ; NaN150=150-µm, 0.25 m² Nansen Net; LOKI150= Lightframe On-sight Key species Investigation with 150-µm net; BEAST=ROV with 150-µm net*

Date	Activity Number	Device	Latitude (°N)	Longitude (°E)
7.Mar 20	30-65	MN150	88.071	26.909
7-Mar-20	30-67	RN150	88.069	26.839
7-Mar-20	30-69	BEAST	88.078	27.318
12-Mar-20	31-42	LOKI 150	87.545	21.767
12.Mar 20	31-45	MN150	87.523	21.391
12.Mar 20	31-47	MN150	87.499	20.979
14-Mar-20	31-62	RN150	87.136	17.203
14-Mar-20	31-67	RN1000	87.125	17.022
14-Mar-20	31-68	RN53	87.142	17.013
18-Mar-20	32-25	RN53	86.682	12.128
18-Mar-20	32-26	RN53	86.682	12.128
18-Mar-20	32-27	RN53	86.682	12.128
18-Mar-20	32-28	RN53	86.682	12.128
22-Mar-20	32-78	BEAST	86.230	15.677
26-Mar-20	33-55	Nansen150	85.998	13.088
26-Mar-20	33-56	Nansen150	85.996	13.088
26-Mar-20	33-57	Nansen150	85.993	13.087
26-Mar-20	33-58	Nansen150	85.989	13.086
26-Mar-20	33-59	RN53	85.984	13.088
28-Mar-20	33-83	BEAST	85.626	13.340
3-Apr-20	34-56	Nansen150	84.783	13.413
3-Apr-20	34-57	Nansen150	84.782	13.398
3-Apr-20	34-58	Nansen150	84.779	13.346
3-Apr-20	34-59	Nansen150	84.776	13.307
7-Apr-20	35-32	BEAST	84.503	14.535
8-Apr-20	35-38	RN53	84.479	14.704
8-Apr-20	35-39	Nansen150	84.478	14.699
8-Apr-20	35-40	Nansen150	84.478	14.703
9-Apr-20	35-64	Nansen150	84.428	14.794
9-Apr-20	35-65	Nansen150	84.426	14.786
9-Apr-20	35-66	Nansen150	84.424	14.777
11-Apr-20	35-95	BEAST	84.334	14.747
15-Apr-20	36-40	RN53	84.453	13.835
15-Apr-20	36-41	Nansen150	84.492	13.835
15-Apr-20	36-42	Nansen150	84.325	13.835
17-Apr-20	36-76	Nansen150	84.325	13.689
17-Apr-20	36-77	Nansen150	84.416	13.690
17-Apr-20	36-78	Nansen150	84.417	13.701
17-Apr-20	36-79	Nansen150	84.419	13.702
17-Apr-20	36-80	Nansen150	84.419	13.774
18-Apr-20	36-112	BEAST	84.422	13.816
22-Apr-20	37-24	RN53	84.020	15.934

22-Apr-20	37-25	Nansen150	84.121	15.934
22-Apr-20	37-26	Nansen150	84.121	15.946
22-Apr-20	37-27	Nansen150	84.119	15.955
23-Apr-20	37-50	Nansen150	84.117	16.030
23-Apr-20	37-51	Nansen150	84.072	16.028
23-Apr-20	37-52	Nansen150	84.072	16.029
23-Apr-20	37-53	Nansen150	84.071	16.034
24-Apr-20	37-108	BEAST	84.070	15.652
9-May-20	38-91	BEAST	83.885	17.643
3-May-20	38-123	RN53	83.886	17.938
3-May-20	38-124	Nansen150	83.886	17.965
3-May-20	38-125	Nansen150	83.886	17.973
3-May-20	38-126	Nansen150	83.886	17.988
3-May-20	38-127	Nansen150	83.922	18.016
6-May-20	39-34	Nansen150	83.921	17.682
6-May-20	39-35	Nansen150	83.921	17.675
6-May-20	39-36	Nansen150	83.923	17.659
6-May-20	39-37	Nansen150	83.924	17.637
6-May-20	39-38	Nansen150	83.925	17.628
7-May-20	39-55	RN53	83.936	16.681
7-May-20	39-56	Nansen150	83.932	16.612
7-May-20	39-57	RN53	83.932	16.610
5-May-20	39-77	BEAST	83.919	18.059
16-May-20	40-39	MN150	83.388	9.107
16-May-20	40-44	LOKI 150	83.387	9.107
30-May-20	42-34	LOKI 150	81.870	9.446
30-May-20	42-35	MN150	81.933	9.470
30-May-20	42-38	MN150	81.933	9.467

Shipboard Laboratory Work

Biochemical and Genetic Variables:
Prior to preservation/freezing, some of the 150-µm, 1000-µm, Nansen, 53-µm, and ROV net tow collections were pre-sorted for biochemical and genetic variables of target zooplankton species following protocols provided by the project PIs. After sorting out a portion of the collection for rate process measurements (egg production and/or respiration rates) in the environmental room, if needed, additional animals were sorted out either in the environmental room or in the zooplankton dry lab. For the latter, the catch was brought to the zooplankton lab where it was poured into a sample tray that was kept over ice. Large animals (e.g. Amphipods, gelatinous zooplankton, chaetognaths) were sorted to species by eye, while smaller zooplankton (e.g. copepods) were sorted to species/life stage under a dissecting microscope. The Core project variables included trophic biomarkers (lipid class composition, fatty acid composition, bulk stable isotope composition, compound-specific stable isotope composition of fatty acids, highly branched isoprenoids) and carbon and nitrogen (CN) content. Target animals were also sorted for project variables including: energy content, gut content, and digestive enzymes. A paucity of macrofaunal and gelatinous forms precluded collection of samples for microplastics or transcriptomics (see Leg 2 report). 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 ring, Nansen, and ROV nets and preserved immediately in 96% EtOH for gut DNA content of target zooplankton species.

***Tab. 6.1.4**. 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	1310	3218
Trophic Biomarkers	Core/Project	141	1306
Energy Content	Project	31	176
Enzymes	Project	29	268
Gut Content	Project	3	18
Transcriptomics	Project	0	0
Microplastics	Project	0	0
Photographs	Core/Project	788	
Community Measurements			
Abundance/Taxonomy	Core	90	
Gut DNA	Project	13	
Biomass	Project	0	
LOKI	Core	3 hauls	

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

Most rate process studies were conducted in the dark, between 0.5 and 1 °C, in the environmental chamber. One grazing experiment was conducted under dim, constant light as the natural light cycle evolved to 24 hours of daylight and leads increased the penetration of light into the upper ocean. The set-up and all manipulations were done under red light.

Respiration rates were determined for target zooplankton species/life stages collected from different depth horizons with an Optode oxygen measurement system. Measurements were taken ~every 12 hours for 2 to 3 days. Fourteen 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” 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.

Egg production rates were determined for adult females of the copepod *Calanus hyperboreus* in long-term incubations. Four experiments with 53 females total were still ongoing from Leg 2 at the start of Leg 3 and were continued until the females had ceased egg production rates. An additional experiment was initiated during Leg 3, despite the difficulty in collecting ovigerous females with the more limited sampling capability at Ocean City. Egg production rates were

monitored daily for individual females and a subsample of the eggs produced each day was taken to monitor for egg hatching success. At the termination of the experiments the females were or will be photographed and saved for CN measurements. One experiment was still ongoing at the end of Leg 3 and will be handed off to Leg 4. In addition, an experiment incubating 20 individual females of the copepod *Calanus glacialis* was initiated to see if *C. glacialis* without food but with lipid could develop eggs.

Zooplankton feeding rates were determined in six experiments using standard bottle incubation techniques. The incubations were conducted on a plankton wheel in the environmental chamber (1 °C) in the dark for 24 hours except for one experiment that was conducted under low light. Groups of 1-2 separate target species were incubated usually in triplicate along with controls. At the start and end of the incubations samples were taken for chlorophyll and microplankton analysis so that feeding rates on chlorophyll and microzooplankton could be determined. At the termination, all animals were photographed and saved for CN determination. The last experiment measured the feeding rates of the copepod *Metridia longa* on *C. hyperboreus* eggs rather than on chlorophyll and microzooplankton.

Tab. 6.1.5. *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 2*

Experiments	Number	Incubations
Respiration	14	141
Reproduction	4	82*
Feeding	6	53

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 6.1.3, 6.1.4, and 6.1.5.

Overall, the zooplankton communities sampled during Leg 3 appeared to be typical of early spring, prior to the onset of the spring ice and water column blooms, with reproduction occurring for species such as *C. hyperboreus* that depend on stored lipid reserves but not for other species requiring greater food availability. The impression is that few younger stages (e.g., copepodites) of mesozooplankton were observed with the exception of C. *hyperboreus* eggs and nauplii. Water column chlorophyll was very low for much of the period of Leg 3 but was increasing as the sampling period came to an end, suggesting that the inception and development of the spring bloom and the mesozooplankton response to the increased food availability likely would occur during the sampling gap between Legs 3 and 4.

The southward drift of Leg 3 was very extensive which further complicates consideration of the seasonal progression of the ecosystem. The first stations of the leg were conducted to at ~ 88°N and the last station was conducted at ~83.4°N, a change of 4.6° latitude, corresponding to 276 nm/511 km (an average drift to the south of 51 km/week) (Fig. 6.1). The drift path ran from the Amundsen Basin to the north across Gakkel Ridge and terminated in the Nansen Basin. Along with the changing geographic location came changes in hydrography, with increasing “Atlantification” to the south and especially to the south of Gakkel Ridge. These hydrographic changes also should be associated with changes in the zooplankton community composition and relative abundances (and thus importance) of arctic vs. subarctic species.

The more southern locations also could have experienced further seasonal development of plankton communities as seasonal environmental changes such as snow melt and lead formation are more advanced relative to northern locations. The shift from sampling from the Polarstern, using large nets, the Multinet, and the LOKI, to sampling at Ocean City with smaller nets, no LOKI, and reduced depth capability further complicates the situation.

Qualitatively speaking, it appears that different zooplankton communities were observed as the station drifted to the south, with fewer of the large *C. hyperboreus* collected and increasing occurrences of smaller *Calanus* spp. that likely include the Atlantic species *C. finmarchicus* in addition to smaller populations of the arctic *C. glacialis* that may have originated in the more southern waters. The last occupied station, over the Yermak Plateau on May 30, had noticeably greater abundances of zooplankton with late copepodite stages of all Calanus species present in addition to adult females. However, the temporal, spatial, and sampling biases are inextricably intertwined. Understanding of the patterns and characteristics of the zooplankton communities and spring phenology will require careful consideration of the zooplankton data together with hydrographic and other physical characteristics.

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.

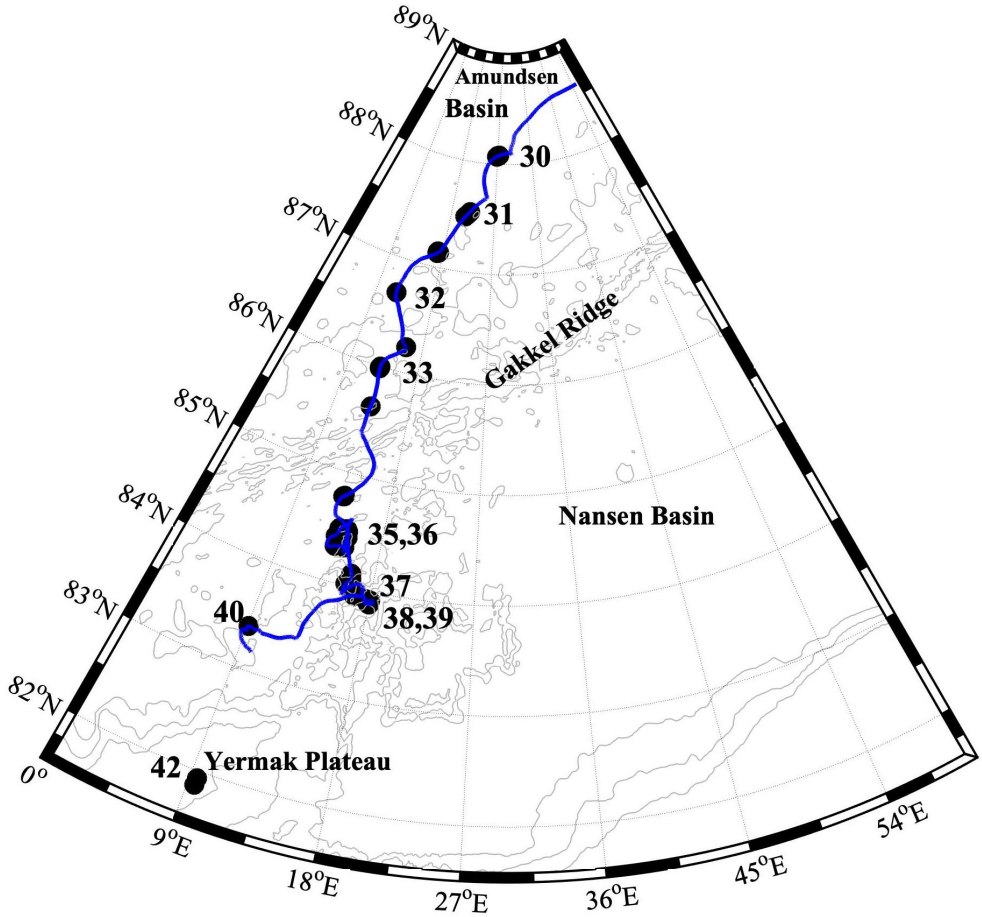

Fig. 6.1.1: *Drift track (blue), station locations (black symbols), and sampling week (numbers) for Leg 3 zooplankton sampling. The first sampling event within each week is shown by the numbers; subsequent sampling events during each week not labeled. Note that for some weeks, sampling events taking place later in the week could be quite far from those during early in the week (e.g., week 31). Bottom topography shows location of Gakkel Ridge. Bottom topography from the IBCAO 3.0 bathymetric data set (Jakobsson et al., 2012).*

References

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

6.2 Ecosystem Science: Nutrient Biogeochemistry

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Objectives

As stated in the respective section of the Team Eco Leg 1 and 2 cruise report:
"Produce an annual mass balance of the cycling of macro and micronutrients across the sea ice-water interface. Characterize vertical fluxes of nutrients in combination with nutrient tracer assays to understand carbon and nitrogen recycling pathways by microbes in sea ice and seawater. We aim to measure the progressive concentration of nutrients, including iron, in sea ice over the ice formation season."

Work at sea

During Leg 3, samples for the analysis of inorganic nutrients (nitrate+nitrite, nitrite, phosphate, silicate and ammonium) were collected from: 1) sea ice, from the FYI and SYI coring sites, and once from BGC1; 2) seawater collected from CTD-Rosette deployments from Polarstern and from Ocean City (the latter partially in coordination with Team Ocean and Team BGC); 3) seawater from incubations with stable isotopes provided by Anders Torstensson (CN project, see section 6.4), as well as from incubations provided by Clara Hoppe (DarktoLight project, see section 6.5.) ; and 4) from ridge cavities for HAVOC (HAVOC project, see section 6.7.). Additionally, samples were collected for later analysis of total nitrogen (TN) and total phosphorus (TP) from CTD deployments from Polarstern and Ocean City in coordination from and with help with Team Ocean and Team BGC.

As during Leg 1 and 2, analyses onboard were performed using a 5-Channel Seal Analytical AA3 segmented flow autoanalyser. Certified reference materials (CRMs) from KANSO, LTD, Japan, were measured on each analysis run. These CRMs will be crucial to assess the accuracy and quality of the MOSAiC-long nutrient data set. Two different batches of CRMs were used, CD and CJ. The former is a mid-nutrient-concentration-range CRM, consistent with typical nutrient concentrations in Arctic waters. The latter is a high-nutrient- concentration-range CRM, with phosphate and silicate above the calibration range.
Samples from seawater were collected unfiltered. Due to the sediment content in sea ice, samples from ice cores were filtered through 25 mm (0.2 micron) Advantec cellulose filters using a syringe inline filtration unit. Samples from CTD deployments and sea ice cores were all analysed in duplicate.

Preliminary (expected) results

In total, 30 CTD casts were realized, using the small portable winch at OC 25 times, while only five casts were done from the Polarstern CTD due to the loss of the CTD hole next to the ship on March 15th. In total, approximately 300 unfiltered seawater samples were taken and analyzed with additional approximately 50 samples frozen for later analysis.
A second set of seawater samples from these same CTD casts were also collected (and immediately frozen) for total nitrogen (TN) and total phosphorus (TP) analysis. Analysis of these samples will be performed at the Alfred Wegener Institute in Bremerhaven, Germany in the coming months. A frozen sample for nutrient analysis will occur alongside the TN/TP measurements to validate the results that were determined at sea.

Over 360 sea ice nutrient samples, were collected and measured during leg 3 of the MOSAiC campaign. These samples were collected at both the first year (FYI) and second year ice (SYI) sites that were established by both the sea ICE and ECO teams in late September 2019 during leg 1, and once from BGC1 collected by Team BGC. The SYI location was visited 5 times and FYI location was visited 4 times during leg 3; nutrient samples were collected during each except one visit. Samples were collected in 5-cm intervals and were taken from the subsection allocated for salinity and oxygen isotope analysis. Samples were set to thaw immediately after returning from the field. The following morning, the samples were immediately syringe filtered through 25 mm (0.2 micron) Advantec cellulose filters. Samples were analyzed the same day using the same protocol as was used for the seawater samples. Opportunistic sampling for brine occurred at the FYI site in two instances. Brine samples were collected by drilling a series of sack holes approximately 1-2 meters apart to a depth of ~30-50 cm and allowing the brine to accumulate in the hole for 3–5 h prior to drawing the sample into a syringe through a piece of Tygon tubing.

Tab. 6.2.1: *lists events additional to those listed in Table 6.1, from which samples were collected and/or analysed. A, B and C indicate: samples for inorganic nutrient analysis (A), samples for TN and TP (B)*

Date	Device Operation	Device	Sample type
08.03.2020	PS122/3_30-53	CTD AWI-OZE	A,B
12.03.2020	PS122/3_31-19	Ocean City CTD	A,B
12.03.2020	**PS122/3_31-5**	**Ice Corer Kovacs Mark II**	A
12.03.2020	PS122/3_31-39	CTD AWI-OZE	A,B
15.03.2020	PS122/3_31-59	CTD AWI-OZE	A,B
15.03.2020	PS122/3_31-81	Ocean City CTD	A, B
22.03.2020	PS122/3_32-77	Ocean City CTD	A, B
22.03.2020	PS122/3_32-75	Ocean City CTD	A, B
25.03.2020	**PS122/3_33-18**	**Ice Corer Kovacs Mark II**	A
28.03.2020	PS122/3_33-69	Ocean City CTD	A,B
28.03.2020	PS122/3_33-80	Ocean City CTD	A,B
04.04.2020	PS122/3_34-17	Ocean City CTD	A,B
04.04.2020	PS122/3_34-65	Ocean City CTD	A,B
04.04.2020	PS122/3_34-67	Ocean City CTD	A,B
07.04.2020	PS122/3_34-77	Ocean City CTD	A,B
07.04.2020	**PS122/3_35-4**	**Ice Corer Kovacs Mark II**	A
07.04.2020	**PS122/3_35-11**	**Ice Corer Kovacs Mark II**	A
07.04.2020	PS122/3_35-25	Ocean City CTD	A,B
07.04.2020	PS122/3_35-63	Ocean City CTD	A,B
10.04.2020	PS122/3_35-77	Ocean City CTD	A,B
14.04.2020	**PS122/3_36-4**	**Ice Corer Kovacs Mark II**	A
15.04.2020	**PS122/3_36-21**	**Ice Corer Kovacs Mark II**	A,
14.04.2020	PS122/3_36-19	Ocean City CTD	A,B
17.04.2020	PS122/3_36-59	Ocean City CTD	A,B
17.04.2020	PS122/3_36-81	Ocean City CTD	A,B
23.04.2020	PS122/3_36-115	Ocean City CTD	A,B
23.04.2020	PS122/3_37-45	Ocean City CTD	A,B
26.04.2020	PS122/3_37-88 CTD	Ocean City CTD	A,B
26.04.2020	PS122/3_37-116	Ocean City CTD	A,B
28.04.2020	**PS122/3_38-16**	**Ice Corer Kovacs Mark II**	A
28.04.2020	**PS122/3_38-24**	**Ice Corer Kovacs Mark II**	A
28.04.2020	PS122/3_38-31	Ocean City CTD	A,B
30.04.2020	PS122/3_38-54	Ocean City CTD	A,B
01.05.2020	PS122/3_38-54	Ocean City CTD	A,B

02.05.2020	PS122/3_38-100	Ocean City CTD	A,B
05.05.2020	**PS122/3_39-7**	**Ice Corer Kovacs Mark II**	A
05.05.2020	**PS122/3_39-18**	**Ice Corer Kovacs Mark II**	A
07.05.2020	PS122/3_39-51 CTD	Ocean City CTD	A,B
16.05.2020	PS122/3_40-36	CTD AWI-OZE	A,B
30.05.2020	PS122/3_42-32	CTD AWI-OZE	A,B

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). In the case where analyses were done onboard, raw data files, from which further processing is possible, have been stored in the respective event folders within the MCS. In the case where samples were collected and stored frozen, these will be analysed at the home laboratory (AWI) approximately within 6 months of arrival. Processed data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science, www.pangaea.de).

6.3. Drivers of anthropogenic Changes in Carbon Storage and Ocean Acidification in the new Arctic Ocean (DRACO2)

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Objectives

Biological activity and production in the ice covered central Arctic Ocean is generally considered to be low, but with large inter-basin variability. When the sea ice melts during summer, the uppermost layer freshens and helps in forming a strong stratification, separating the shallow summer mixed layer from the winter mixed layer and the underlying warm Atlantic water. The increasing coverage of melt ponds during summer allows more solar radiation to reach the water column. Due to the strong stratification, the supply of nutrients to the summer mixed layer is very low and relies mainly on advection. Despite this, the shallow well-mixed layer and the availability of light and nutrients is enough to sustain biological production in the uppermost water column, just below the sea ice, and in the sea ice itself. With the onset of freeze-up conditions, brine release by sea ice formation triggers convection which leads to a homogeneous winter mixed layer. During winter, the homogenization of the upper water column contributes to nutrient availability at the beginning of the next productive season. The sea ice concentration and its thickness, the depths of the summer and winter mixed layers, the nutrient supply and light availability, all differ and vary between the deep basins. Hence, also the biological activity and primary production vary and, subsequently, the CO_2 fluxes and net community production. These can be constrained on a larger scale by conventional sampling from ship-based surveys transecting the deep basins employing discrete and underway methods. However, the large-scale estimates rely on assumptions such as a well-mixed layer in steady state with respect to air-sea gas exchange, convection, advection, and diurnal cycles

at the time of observation. This is not necessarily the case in practice and a more detailed study of the variability of small-scale processes such as mixing, air-sea exchange, and biological activity over time is warranted. In addition, the Arctic Ocean is experiencing rapid anthropogenic changes in carbon storage and ocean acidification in the intermediate layers [*Ulfsbo et al.*, 2018]. The acidification in the upper surface layer is more dynamic and varies with, e.g., season, source waters, sea-ice cover and melt/freezing, wind fields, ocean circulation, and freshwater input. All these processes and factors need to be better understood to map the current state of Arctic acidification for future projections. This background leads up to the following overarching research questions:

1) What are the present fluxes and controls of carbon with respect to CO_2 and net community production in the central Arctic Ocean?

2) What environmental and seasonal drivers affect the carbon cycle of the central Arctic Ocean with respect to net community production, ocean acidification, and anthropogenic CO_2?

In addition to discrete samples of dissolved inorganic carbon (DIC) and total alkalinity (TA), the project was responsible for discrete and underway measurements of O_2/Ar and discrete samples for dissolved oxygen during Leg 3.

Work at sea

Seawater samples for DIC and TA were drawn from the Niskin bottles of the CTD/Rosette systems of Polarstern (24x12 L; URN: vessel:polarstern:ctd_sbe9plus_321) and Ocean City (12x5 L; URN: pack_ice:ice_ps:ctd_sbe9plus_935) according to Table 6.3.1. In total 160 samples for DIC and TA, including 59 duplicate samples, were drawn into 250 ml borosilicate glass bottles with ground glass stoppers, fixed with mercuric chloride (100 µl) and sealed with Apiezon L grease according to Dickson et al. (2007). The samples are stored dark and cold (+4°C) until analysis post-cruise. In total 11 sea ice cores for DIC/TA were processed from the first-year ice and second-year ice sites according to Table 6.3.2. The DIC/TA core is bagged in the field and processed onboard into 10 cm sections from the top in the -15°C ice physics lab container. In total, 230 core sections were immediately placed within gas-tight bags and evacuated of air using a small motorized vacuum pump. Processing of the DIC core in the ice physics lab container occurs under white light. All core sections are melted onboard in the dark at room temperature (18 - 22°C) until the last piece of ice disappears. The melting time varies, but on average was between 24-48 hours. Upon melting, the bulk ice melt was carefully transferred to 200 ml borosilicate serum bottles using Tygon tubing, fixed with mercuric chloride (100 µl), closed with thick butyl rubber stoppers and crimped-sealed with an aluminum ring.

Tab. 6.3.1: *Device operations for DIC/TA seawater samples from CTD casts during Leg 3*

Date	Device operation	No. of samples
2020-03-05	PS122/3_30-41 CTD_SBE9plus_935	2
2020-03-06	PS122/3_30-53 CTD_SBE9plus_321	6
2020-03-14	PS122/3_31-59 CTD_SBE9plus_321	16
2020-03-22	PS122/3_32-75 CTD_SBE9plus_935	2
2020-03-27	PS122/3_33-69 CTD_SBE9plus_935	8
2020-04-04	PS122/3_34-67 CTD_SBE9plus_935	12
2020-04-05	PS122/3_34-77 CTD_SBE9plus_935	8
2020-04-09	PS122/3_35-63 CTD_SBE9plus_935	8
2020-04-10	PS122/3_35-77 CTD_SBE9plus_935	12
2020-04-16	PS122/3_36-59 CTD_SBE9plus_935	12
2020-04-17	PS122/3_36-81 CTD_SBE9plus_935	8
2020-04-23	PS122/3_37-45 CTD_SBE9plus_935	8
2020-04-25	PS122/3_37-88 CTD_SBE9plus_935	12
2020-04-30	PS122/3_38-54 CTD_SBE9plus_935	8
2020-05-01	PS122/3_38-69 CTD_SBE9plus_935	12
2020-05-07	PS122/3_39-51 CTD_SBE9plus_935	8
2020-05-16	PS122/3_40-36 CTD_SBE9plus_321	18

Tab. 6.3.2: *Device operations for the 11 DIC/TA sea ice cores*

Device operation	No. of core sections
PS122/3_32-61 SI_corer_9cm Group 2020-03-21	30
PS122/3_33-18 SI_corer_9cm Group 2020-03-24	20
PS122/3_34-4 SI_corer_9cm Group 2020-03-30	14
PS122/3_35-11 SI_corer_9cm Group 2020-04-06	16
PS122/3_35-4 SI_corer_9cm Group 2020-04-06	22
PS122/3_36-21 SI_corer_9cm Group 2020-04-14	22
PS122/3_36-4 SI_corer_9cm Group 2020-04-13	18
PS122/3_38-16 SI_corer_9cm Group 2020-04-27	17
PS122/3_38-24 SI_corer_9cm Group 2020-04-27	16
PS122/3_39-18 SI_corer_9cm Group 2020-05-04	24
PS122/3_39-7 SI_corer_9cm Group 2020-05-04	16

The partial pressure of carbon dioxide (pCO_2) was measured underway from the bow surface seawater intake by two permanently installed systems: 1) General Oceanics system (GO8050) with a nondispersive infrared CO_2 sensor (LI-COR 7000), and 2) SubCTech OceanPack Sea-Air-Exchange (SAE) system with nondispersive infrared CO_2 sensors for air (LI-COR LI-7200x) and water (LI-COR LI-840x). Because the measured pCO_2 is strongly dependent on temperature, the temperature difference between the water at the intake and in the equilibrium chamber of the GO system was recorded. Two thermosalinographs (Sea-Bird SBE4) in the bow (6m) and the keel (11 m) thruster tunnels provided temperatures; note that the bow system was not employed during icebreaking and that both intakes were closed on occasion due to clogging of ice. Calibration was performed several times per day against a series of four standard gases. The pCO_2 data will be processed according to Pierrot et al. (2009) and Surface Ocean CO_2 Atlas (SOCAT)-approved methods (Pfeil et al., 2013).

Biological oxygen supersaturation ($\Delta(O_2/Ar)$) was measured continuously by Membrane Inlet Mass Spectrometry (MIMS), provided by Sebastian Rokitta (AWI) as part of the ECO core program (see section 6 for details). In addition to the continuous operation mode of the MIMS, a total of 132 discrete bottle samples from CTD casts were analyzed according to Table 6.3.3. The MIMS was operated onboard together with Jeff Bowman (Team BGC).

Tab. 6.3.3: *Device operations from which discrete seawater samples for O_2/Ar were taken and analyzed by MIMS*

Date	Device operation	Device
2020-03-14	PS122/3_31-63	CTD_SPE9plus_321
2020-03-17	PS122/3_32-12	CTD_SBE9plus_935
2020-03-19	PS122/3_32-38	CTD_SBE9plus_935
2020-03-22	PS122/3_32-77	CTD_SBE9plus_935
2020-03-28	PS122/3_33-80	CTD_SBE9plus_935
2020-03-28	PS122/3_33-82	CTD_SBE9plus_935
2020-04-04	PS122/3_34-64	CTD_SBE9plus_935
2020-04-04	PS122/3_34-67	CTD_SBE9plus_935
2020-04-05	PS122/3_34-76	CTD_SBE9plus_935
2020-04-07	PS122/3_35-25	CTD_SBE9plus_935
2020-04-10	PS122/3_35-77	CTD_SBE9plus_935
2020-04-11	PS122/3_35-92	CTD_SBE9plus_935
2020-04-18	PS122/3_36-115	CTD_SBE9plus_935
2020-04-14	PS122/3_36-17	CTD_SBE9plus_935
2020-04-14	PS122/3_36-19	CTD_SBE9plus_935
2020-04-16	PS122/3_36-59	CTD_SBE9plus_935
2020-04-26	PS122/3_37-116	CTD_SBE9plus_935
2020-04-21	PS122/3_37-15	CTD_SBE9plus_935
2020-04-25	PS122/3_37-88	CTD_SBE9plus_935
2020-05-02	PS122/3_38-100	CTD_SBE9plus_935
2020-04-28	PS122/3_38-31	CTD_SBE9plus_935
2020-05-01	PS122/3_38-69	CTD_SBE9plus_935
2020-05-05	PS122/3_39-16	CTD_SBE9plus_935
2020-05-09	PS122/3_39-82	CTD_SBE9plus_935

Dissolved oxygen in seawater was determined by potentiometric titrations (Metrohm Titrino Plus 848) with thiosulfate following standard GO-SHIP protocols (Langdon et al., 2010). The thiosulfate (~0.2 N) was regularly standardized (n = 4) against an iodate standard (OSIL 0.01 N) and blanks (n =4) were determined before each batch of samples. Duplicate samples were taken at all depths according to Table 6.3.4.

Tab. 6.3.4: *Device operations from which discrete seawater samples for dissolved oxygen were analyzed*

Date	Device operation	Device	Depths (m)
2020-03-06	PS122/3_30-53	ctd_sbe9plus_321	3500, 2500, 1000, 500, 10
2020-03-14	PS122/3_31-59	ctd_sbe9plus_321	4000, 3000, 1000, 500, 10
2020-04-16	PS122/3_36-59	ctd_sbe9plus_935	1200, 1000, 500, 200, 20
2020-04-25	PS122/3_37-88	ctd_sbe9plus_935	1200, 1000, 500, 200, 20
2020-05-02	PS122/3_38-69	ctd_sbe9plus_935	1200, 1000, 500, 200, 20
2020-05-16	PS122/3_40-36	ctd_sbe9plus_321	4000, 3000, 1000, 500, 20

Preliminary (expected) results

We expect to obtain high-quality, multi-seasonal observations of DIC and TA along the drift track across the Amundsen and Nansen basins, areas that previously have been covered during the summer months, e.g., during the two Trans-Arctic surveys of the Arctic Ocean in transition in 2011 (PS78; ARK-XXVI/3) and 2015 (PS94; ARK-XXIX/3). We expect to obtain a better understanding of the shelf-basin interactions with respect to the distribution of the marine carbonate system, anthropogenic CO_2, and ocean acidification. This includes the strength and variability of the transpolar drift in the upper layers, as well as deeper shelf-basin interactions and export between the Laptev and East Siberian shelves and the central, deep basins. Export of $CaCO_3$-corrosive waters influenced by remineralization of organic matter, freshwater (river runoff and sea-ice melt), sea ice concentration (and air-sea gas exchange) are of particular interest, including the extent and variability of the shelf-Atlantic-Pacific water fronts. The drift across the Amundsen and Nansen basins are exceptionally interesting in view of recent studies of increasing anthropogenic CO_2 and ocean acidification in the intermediate layers of the Eurasian Basin. The seasonal variability of the return flows of the boundary current and the fronts of Pacific and Atlantic source waters are key processes to further look into, as well as the possibly strong or weak signal of ocean acidification in the summer and winter mixed layers. The year-round variability in the vertical distribution of the CO_2 system parameters, transient tracers, and ancillary biogeochemical parameters are key for future estimates of anthropogenic carbon storage and uptake in the central Arctic Ocean. All DIC/TA seawater and sea ice samples were fixed onboard and will be analyzed post-cruise.

We also expect a better understanding of how net community production based on high-resolution O_2/Ar measurements relate to community structure, sea ice and light conditions, and nutrient supply, as well as the variability in physical and biological controls of CO_2 and O_2 (and its biological and physical components) across the Eurasian Basin. Preliminary results of underway surface seawater pCO_2 observations during Leg 3 are shown in Figure 6.3.1. The Nansen Basin is particularly interesting with respect to the biological ($\Delta(O_2/Ar)$) and physical (ΔAr) components of the total dissolved oxygen: i) how they vary in time and space; ii) whether they reflect the biological production/remineralization processes; iii) whether they relate to physical processes, such as net sea-ice freeze/melt and air-sea gas exchange (residence times); iv) how the biological oxygen supersaturation (or NCP) compare to more traditional incubation approaches; v) how the NCP is related to the community structure in time and space.

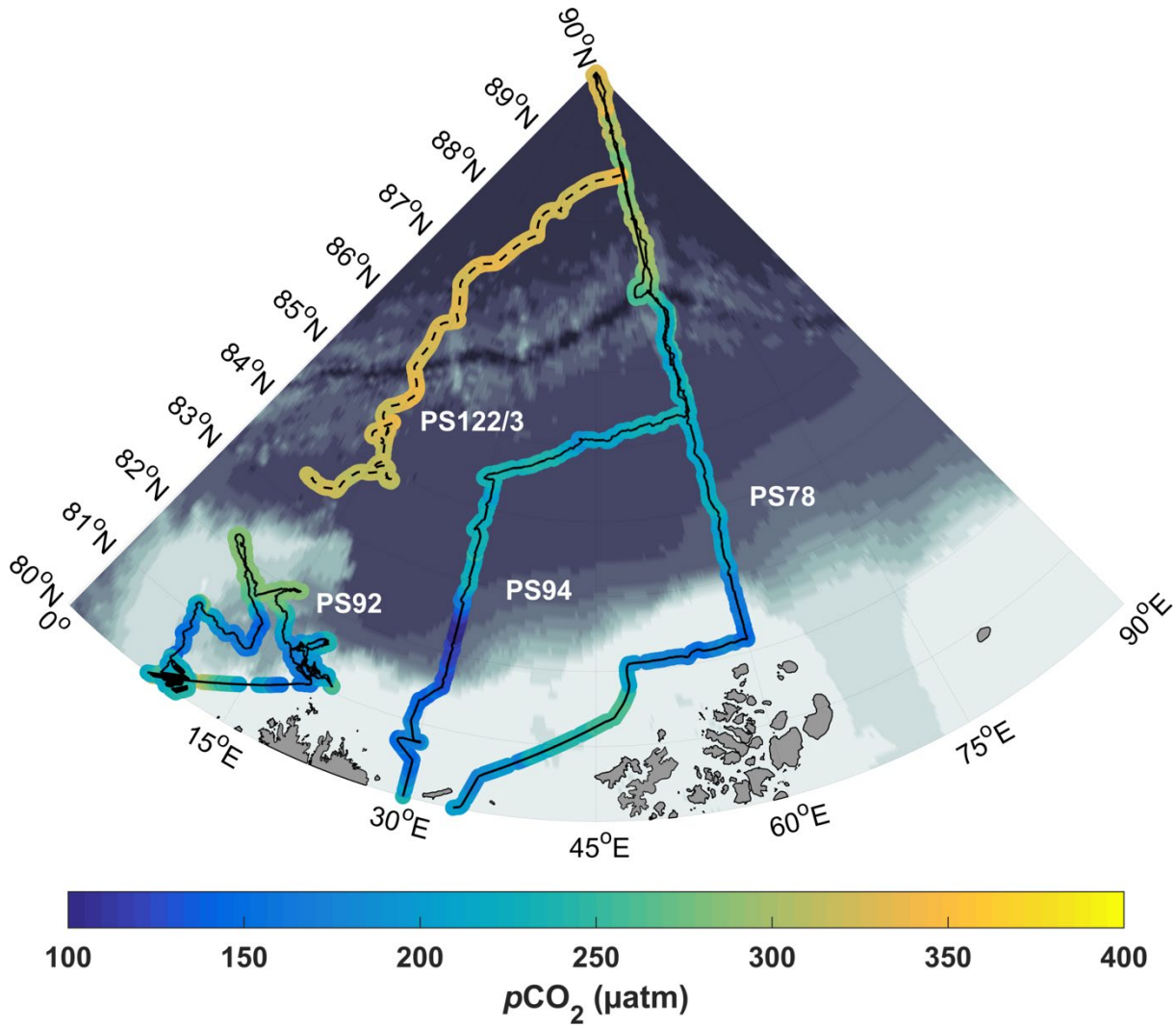

Fig. 6.3.1: *Preliminary underway surface measurements of pCO_2 during Leg 3 (PS122/3). Shown for reference are also summer underway surface pCO_2 observations from PS78 (2011), PS92 (2015), and PS94 (2015) across the Amundsen and Nansen Basins, as well as the Yermak Plateu (Bakker et al., 2016).*

The dissolved oxygen titrations will be used for post-cruise calibration of the dissolved oxygen sensors that were mounted on the small (pack_ice:ice_ps:ctd_sbe9plus_935) and large (vessel:polarstern:ctd_sbe9plus_321) CTD/rosette systems. Figure 6.3.2. shows a preliminary comparison between Winkler titrations and the CTD sensors from PS122/3_31-59.

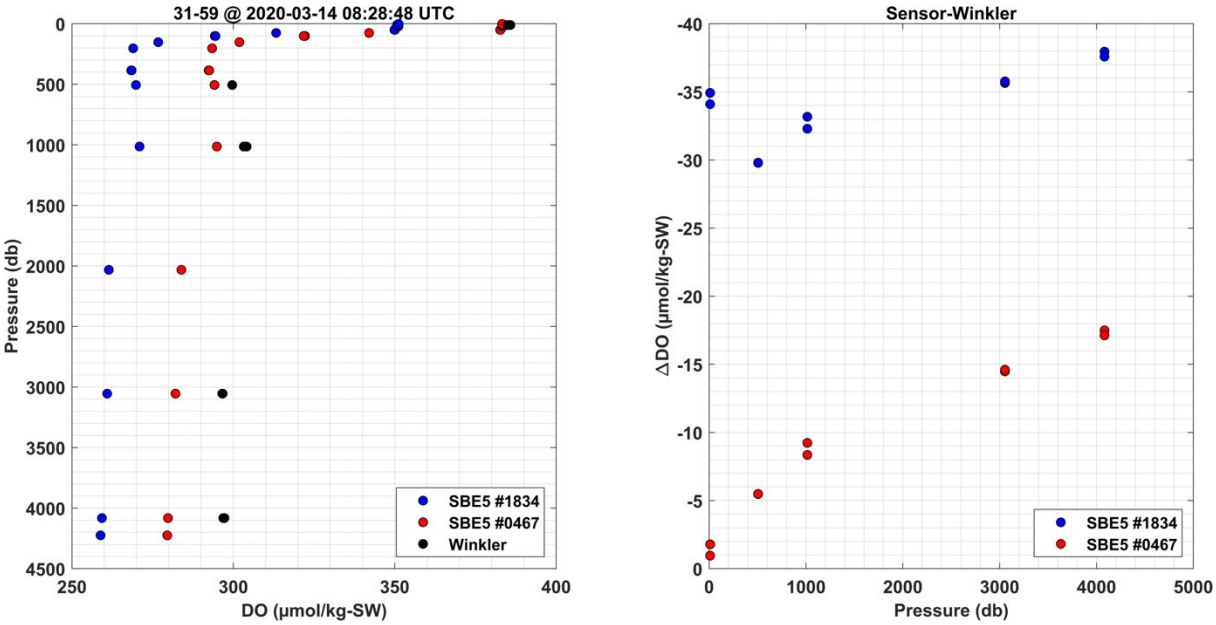

Fig. 6.3.2. *Comparison between Winkler titrations and two CTD sensors on the CTD AWI-OZE (CTD_SBE9plus_321) from PS122/3_31-59.*

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/>.

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

Work at sea

During Leg 3 of MOSAiC, the CN experiments were carried out by Anders Torstensson following the practical routines that were established by Pauline Snoeijs Leijonmalm and Allison Fong during Leg 1. For each experiment, we sampled 140-150 L of seawater that, spiked with different stable isotopes, is incubated at ca. 1 °C on board, both in light and dark conditions (Figure 6.4.1). 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). However, due to the loss of the CTD hole during leg 3, no experiments could be performed using the ship's CTD. Instead, experiments were alternated using seawater that was either pumped from the sub-ice habitat or from 20 m depth. No experiments from the Atlantic layer could be carried out during leg 3 due to the large volumes needed for the experiments. Attempts to deploy 30L Niskin bottles to the temperature maximum from the ROV site were unsuccessful due to a malfunctioning winch.

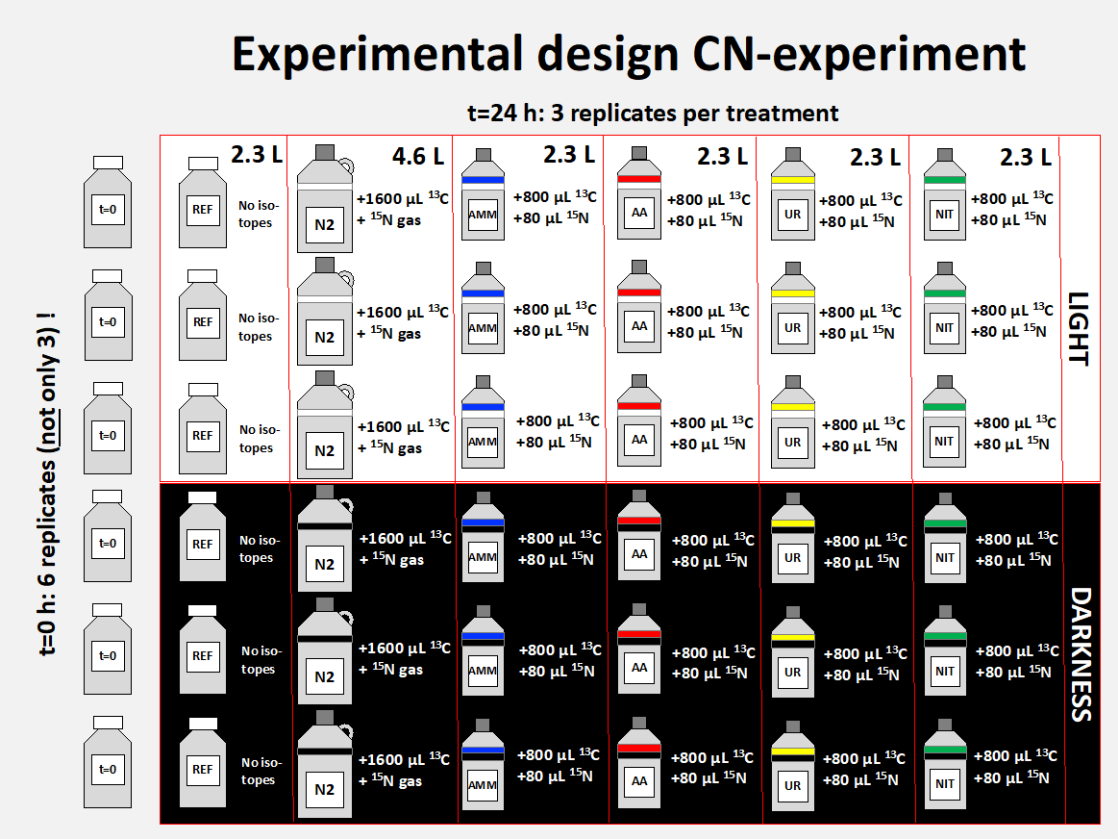

Fig. 6.4.1: *Experimental design of the CN-experiment as performed during MOSAiC.*

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 3, ten full experiments were carried out (Table 6.4.2).

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

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

Tab. 6.4.2: *Overview of the experiments performed during Leg 3*

File no.	Date	Sampling time	Device	Path to MCS	Sensor Web-ID	Type of experiment	Device Operation ID
1	04.03.2020	10:00	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122/3_30-102	27635	CN-experiment 19	PS122/3_30-102
2	13.03.2020	09:00	Moonpool pumping (20 m)	platforms/pack_ice/ice_ps/typhoon_sn1479/exdata/PS122/3_31-98	33991	CN-experiment 20	PS122/3_31-98
3	20.03.2020	10:00	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122/3_32-89	33999	CN-experiment 21	PS122/3_32-89
4	27.03.2020	09:00	Moonpool pumping (20 m)	platforms/pack_ice/ice_ps/typhoon_sn1479/exdata/PS122/3_33-111	33990	CN-experiment 22	PS122/3_33-111
5	03.04.2020	09:00	Moonpool pumping (20 m)	platforms/pack_ice/ice_ps/typhoon_sn1479/exdata/PS122/3_34-104	33989	CN-experiment 23	PS122/3_34-104
6	10.04.2020	09:30	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122/3_35-76	33987	CN-experiment 24	PS122/3_35-76
7	17.04.2020	12:00	ROV site pumping (20 m)	platforms/pack_ice/ice_ps/typhoon_sn1479/exdata/PS122/3_36-111	33988	CN-experiment 25	PS122/3_36-111
8	24.04.2020	09:30	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122/3_37-87	33992	CN-experiment 26	PS122/3_37-87
9	01.05.2020	09:00	Moonpool pumping (20 m)	platforms/pack_ice/ice_ps/typhoon_sn1479/exdata/PS122/3_38-90	33285	CN-experiment 27	PS122/3_38-90
10	08.05.2020	09:00	Hand pump, sub-ice seawater	platforms/pack_ice/ice_ps/hand_pump/exdata/PS122/3_39-71	33995	CN-experiment 28	PS122/3_39-71

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

Preliminary (expected) results

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

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

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). 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 °N. The ISME Journal, 13, 316-333. [https://doi.org/10.1038/s41396-018-0268-9]

6.5. Dark to Light: Phototrophic Activity during the Arctic Winter-Spring Transition

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Eva Leu[2], Björn Rost[1] (not on board)

Objectives

The high Arctic ecosystem is characterised by its extreme seasonality, with several months of complete darkness and a short intense growing season of phototrophic organisms in sea ice and water column. It is currently not well understood how phototrophic organisms overwinter in this environment, nor under which conditions phototrophic growth resumes. The overarching objective of this project is to understand how high Arctic (planktonic) phototrophs transition from polar night to the return of light in spring. In this framework, we study the physiological status of winter communities, and how it changes with the return of sunlight. Furthermore, we aim to investigate the relative importance of different potential seeding populations (ice, under-ice and Atlantic water) for the spring bloom.

Work at sea

This project only collected data and samples on leg 3. Work at sea consisted of two main components: 1) the physiological and taxonomic characterization of in-situ protist communities from the pelagic under-ice environment and 2) a long-term germination experiment with potential seeding populations from different environments.

Regarding the physiological and taxonomic characterization of in-situ protist communities, 20-40L water samples were collected without any light contamination, i.e. in the dark (in the tent of the CTD hole next to Polarstern) or/and using dark tubing, cloth and bottles during sampling. Sample handling was conducted in the F2 container in the dark under dim red light only. Here, samples were concentrated via gravitational filtration using a custom-build reverse-filtration unit with 90mm polycarbonate filters (0.8 µm pore-size). Depending on the sample volume (10-40L), the final sample was concentrated 500 to 2000 times, with a final volume of 5-20 mL. This sample was used to investigate photophysiogical parameters via Fast Repetition Rate Fluorometry (FRRF; FastActII, Chelsea Technologies). Next to characterization of the dark-acclimated state, photosynthesis-irradiance curves and short-term (30 min) wake up assays at 10 µmol photons m^{-3} s^{-1} were performed. The remaining samples was fixed with lugols solution for light microscopic analysis of taxonomic composition.
In three instances, additional ^{14}C-based Net primary Production incubations were conducted for 48h instead of the usual 24h to verify the fast induction of carbon fixation observed in Svalbard (Kvernvik et al. 2018).
To investigate the role of different seeding populations and light environments for the composition and biogeochemical characteristics of the high Arctic spring bloom, a long-term germination experiment was conducted with under-ice water, bottom ice cores melted in 0.8µm filtered surface seawater, and water from the temperature maximum of the core Atlantic water at 380m depth.

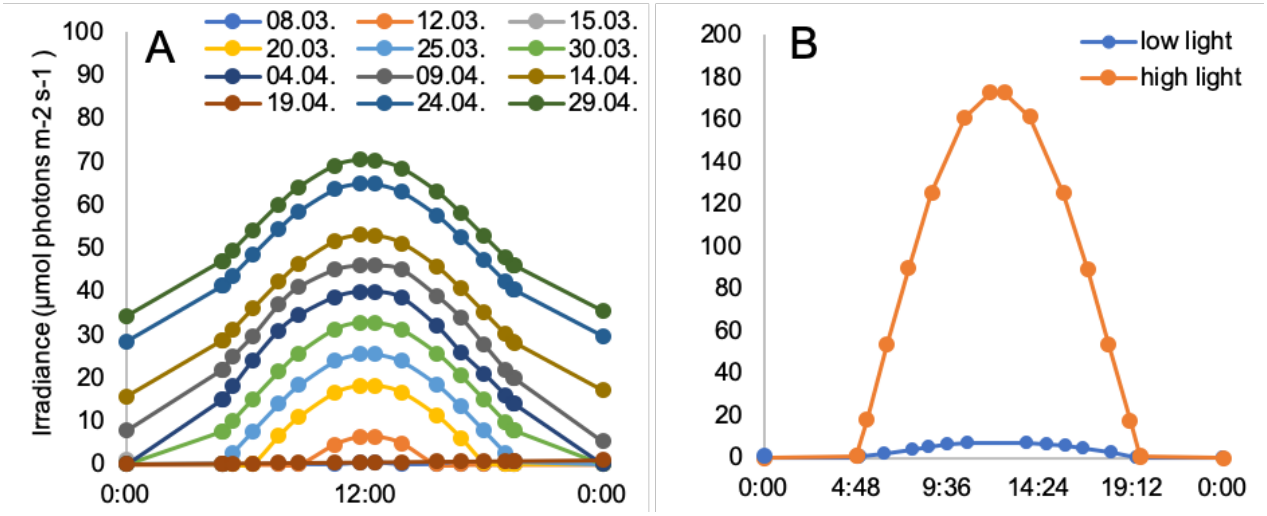

Fig. 6.5.1: *Light fields applied in the increasing dynamic (A) as well as stable dynamic low and high light (B) treatments of the long-term germination experiment*

From each of the environment 10L subsamples were incubated in triplicate under irradiances designed to mimic ice-covered Arctic surface waters. Light levels were calculated based on incident irradiances at 85°N using the suncycle.m matlab function and incrementally increased every 5 days (Figure 1A). For the under-ice water habitat, two additional treatments were applied to triplicate samples each, representing fixed diurnal daily light cycles for the same location on March 25th with and without ice cover (Figure 1B). Incubations were sampled for taxonomic composition (via light microscopy, SEM and DNA), photophysiology (HPLC, FRRF and 14-C), nutrient drawdown and biomass composition (Chl, POC, PON, bSi) at the beginning and the end of the experiment. Bottles were incubated for 27 to 70 days (the latter being the last day of possible laboratory work), as the aim was to let them grown until nutrients were depleted.

Preliminary and expected results

In total, 16 samples for photo-physiological analysis were collected, which needed to be concentrated due to very low biomass levels. After reverse filtration, 13 of these samples had sufficient biomass to perform FRRF measurements. During the first weeks of the leg, samples were too dark acclimated to perform meaningful PI curves, so that only dark yield measurements and short-term wake up assays were conducted. From March 9th onwards, PI curves (also core parameter) were performed when biomass was sufficient. Over the duration of leg 3, initial analysis indicates a gradual increase in the photo-physiological performance of surface water assemblages. Further detailed data processing is needed to verify this trend. From 11 of these samples, live microscopy was performed and/or samples were fixed for later light microscopic analysis. Initial analysis indicates no strong change in the taxonomic composition over time. More detailed analysis will be performed in the home laboratory (AWI).

Regarding the long-term germination experiment, biomass development and nutrient drawdown were slower than expected and greatly varied between experimental bottles (27 to 70 days of incubation), even within one treatment. From all 15 incubation bottles (3 per treatment), samples for stoichiometry, nutrient drawdown and taxonomic composition at the end of the experiment were taken. Due to time limitations, 14C-NPP measurements and FRRF assays were only performed from 12 out of 15 bottles. Initial light microscopic analysis indicates differences in species composition between, and partially even within, seeding sources and light treatments.

Please note that problems with temperature stability in the container may impact experimental results.
Overall, the measurements and experiment conducted for this project may help to better understand the mechanisms and dynamics of re-initiation of photosynthetic biomass development after the polar night, as well as about the relative importance of different overwintering habitats for the spring bloom.

Tab. 6.5.1: *Overview of all device operations during which samples were collected for different sample types, i.e. reverse-filtration and FRRF (A), 48h PP incubations with 14-C (B), light microscopy of concentrated samples (C) and the long-term germination experiment with different seeding sources (D). Asterix indicate that biomass in the concentrated sample was not sufficient to perform any further analysis*

Date	Device Operation	Habitat	Sample type
28.02.20	PS122/3_29-91 BUCKET_PS	under-ice water	A
01.03.20	PS122/3_30-105 BUCKET_PS	under-ice water	A, B
05.03.20	PS122/3_30-41 CTD_SBE9plus_935	under-ice water	C
09.03.20	PS122/3_31-95 typhoon_sn1479	mixed layer water	A, B, C, D
10.03.20	PS122/3_31-101 BUCKET_PS	under-ice water	A*
11.03.20	PS122/3_31-102 BUCKET_PS	under-ice water	A*
14.03.20	PS122/3_31-63 CTD_SBE9plus_321	Atlantic temperature maximum	D
14.03.20	PS122/3_31-63 CTD_SBE9plus_321	under-ice water	A
16.03.20	PS122/3_32-6 SI_corer_9cm	bottom SYI ice	A, D
20.03.20	PS122/3_32-89 hand_pump	under-ice water	A
22.03.20	PS122/3_32-76 CTD_SBE9plus_935	under-ice water	C
28.03.20	PS122/3_33-111 typhoon_sn1479	mixed layer water	A, B
03.04.20	PS122/3_34-97 typhoon_sn1479	mixed layer water	A, B
04.04.20	PS122/3_34-67 CTD_SBE9plus_935	under-ice water	A, B
09.04.20	PS122/3_35-62 CTD_SBE9plus_935	mixed layer water	A, B
17.04.20	PS122/3_36-85 CTD_SBE9plus_935	mixed layer water	A, B
24.04.20	PS122/3_37-87 hand_pump	ridge gap layer water	A, B
25.04.20	PS122/3_37-99 CTD_SBE9plus_935	mixed layer water	A, B
27.04.20	PS122/3_38-5 CTD_SBE9plus_935	under-ice water	A*
07.05.20	PS122/3_39-54 CTD_SBE9plus_935	mixed layer water	A, B

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 home laboratory (AWI), they will be processed and stored in the MCS approximately within 8 months after arrival. Processed data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science, www.pangaea.de).

References

Kvernvik, A.-C., Hoppe, C.J.M., Prásil, O., Lawrence, E., Greenacre, M., Wiktor, J., Leu, E. (2018): Fast reactivation of photosynthesis in Arctic phytoplankton during the Polar night. Journal of Phycology, 54, 461-470, doi:10.1111/jpy.12750

6.6 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 underwater observations and will mine the MOSAiC genomic data sets for fish genes to answer the EFICA project's research questions.

General Note

Leg 3 of MOSAiC officially started on February 24th, one week earlier than the arrival of the Leg 3 team. After the hand-over activities, which took place on Mach 2nd and 3rd, Serdar Sakinan started Leg 3 work on 4th of March 2020. Therefore, the contents of this report focus on the period starting from march 4th, as the earlier part has already been included in the Leg 2 report.

Work at sea

During Leg 3 of MOSAiC Serdar Sakinan continued the data collection according to the established the practical routines and Standard Operation Protocols (SOPs).

Hydroacoustics

Sampling routines established during Leg 1 and continued during Leg 2 were correspondingly followed during the Leg 3. In addition, some noise tests and calibrations were performed which resulted a slight change in the echo-sounder configuration. Before the exchange between Leg 3 and Leg 4, a new configuration file was generated for the new team, involving the new settings and a detailed explanation. In addition, although a full suite of calibration was performed for the echosounders during Leg 3, a detail description of the calibration procedures was transferred to the Leg 4 team so that additional calibrations can be performed by the Leg 4 team when necessary.

EK80 Noise Tests and solutions

The echo-sounders, and particularly the 38 kHz, had been influenced by an elevated background noise since the beginning of the MOSAIC expedition. Initially it was assumed that the 120 kHz WBT (the EK80 transceiver unit) could have been the source of the problem. For this reason, during Leg 1 on November 15, 2019, this frequency was separated from the EK80 system which since then was running with the EK60 set-up. Although this change reduced the background noise in the 38 kHz to some extent, the problem persisted at a level affecting the recordings below ca. 400 m. In order to understand this problem, some noise tests had been conducted during Leg 2, however, the analysis of the test data was pending. Furthermore, the data acquisition during this test coincided with a multibeam survey of the ROV, which introduced additional noise and caused confusion about the potential source.

The test data collected during Leg 2 was analyzed during the first week of Leg 3, and an additional series of tests were conducted by fully isolating the 38 kHz and checking the progression of the noise (additional tests were performed on March 9, between 06:50 and 12:00 am UTC). As a result, the problem was found to be related to the power connection of the WBTs. i.e., the background noise when the WBTs are connected to the power outlets inside the box containing the transceivers. Other potential noise candidates, such as the connection of the transducer cables, ethernet cables or grounding wire did not show any effect. In addition, it was observed that the problem was exactly the same for the either of the WBTs.

The solution for this electrical problem was use of external power connection for the WBTs which eliminated the noise. A series of additional tests were done by running the 38 kHz in first active and then passive mode, and running both 70 and 120 kHz in CW mode and then FM mode in

each respective 38 kHz configuration. The results of these additional tests confirmed that the noise problem was solved

After the tests on March 9, the echo-sounders switched back to the original setup (i.e. 120 kHz connected back to the GPT and reconfigured under the EK60). By March 13th, 2020 07:30 am, the 120 kHz transferred to the WBT and started running in parallel to the 70 kHz.

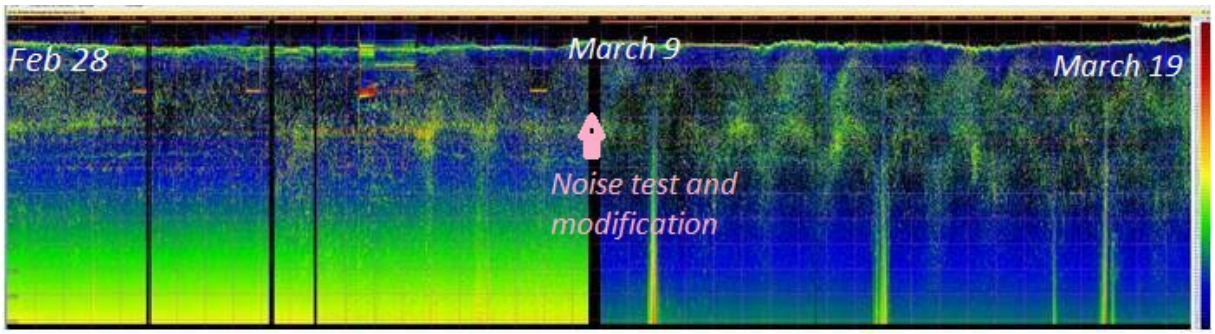

Fig. 6.6.1: *Plot showing a general overview of the 10 days before and the 10 days after the background noise level improvements. The improvement of the signal to noise ratio below 350 m is noticeable.*

Calibration

Although an echo-sounder calibration was planned for the end of the expedition, the changed exchange plans between Leg 3 and Leg 4 caused uncertainties regarding a calibration operation at the later stages of the expedition. As an alternative, a series of calibration trials were carried out on the ship from the moon pool. On April 27, from 9:00 to 15:30 UTC and on May 05, from 07:15 - 11:40 UTC. These trials enabled the successful calibration of 38, 70, 120 and 200 kHz in CW mode, and 70 and 120 kHz echo-sounders in FM mode. The successful results ensure that no further calibration are needed unless some substantial changes are observed on the performance of the echo-sounders.

Calibration was performed using a 38.1 tungsten carbide sphere at the depth of approximately 26 m below the transducer. The calibration sphere was lowered from the moon pool by a fishing line, with one end attached to the moon pool and the other end attached to the ROV. Handling of the ROV was carried out by Olaf Hüttebräucker and Andreas Winter. Software handling was carried out by Serdar Sakinan.

Two sets of calibrations were performed for clean electrical connection and noisy electrical connection. Since the beginning of the expedition, the 38 kHz was being impacted by an electrical background noise. Based on the test conducted at the beginning of Leg 3, it was found that the source of the noise was due to WBT power connections inside the metal transceiver box of the Polarstern. The noise was then eliminated by powering the WBTs from an outside power source. Therefore, the two sets of calibration were considered to represent the conditions before and after.

However, the repeated calibration on 38 kHz produced almost identical results in terms of estimated gain and Sa correction, suggesting that the transducer efficiency is not affected by this electrical interference.

The preliminary results for the CW calibration are provided in table 6.6.1. Results of the calibration trials for all channels (38 kHz, 70 kHz,120 kHz and 200 kHz) are satisfactory in terms of RMS error score and total beam coverage. Furthermore, the determined gain offsets relative to the factory defaults are not notably large. Further details of the calibration will be provided in a separate document after the expedition.

Tab. 6.6.1: *Calibration results. The term "noisy" in the first and second columns indicate that these trials were performed in the conditions where the background noise in the 38 kHz exist in the same way as in the data collected during Leg 1 and Leg 2. The clean refers to a condition where the electrical connections has been modified, thus where the background noise was eliminated. Nevertheless, the results are very similar whether there is background noise or not.*

PARAMETER	ES38B NOISY	ES38B CLEAN	ES200 7C NOISY	ES200-7C CLEAN	ES70-7C	ES120-7C
FREQUENCY	38000	38000	200000	200000	70000	120000
GAIN	24.30	24.32	24.43	24.43	24.86	25.98
SACORRECTION	-0.4745	-0.4286	-0.2668	-0.3370	0.0256	-0.0268
BEAMWIDTHALONGSHIP	6.84	6.86	6.95	6.93	6.49	6.00
BEAMWIDTHATHWARTSHIP	6.80	6.76	7.02	6.94	6.45	5.95
TSRMSERROR	0.0459	0.0518	0.0668	0.0691	0.0698	0.1170
PULSE LENGTH	1.024	1.024	1.024	1.024	1.024	1.024
NO OF HITS	1050	1751	611	1356	1914	2018
DATE	April 27, 2020	April 27, 2020	April 27, 2020	April 27, 2020	May 05, 2020	May 05, 2020

Routine Data collection

Until March 13, 2020 the EK80 and EK60 settings were the same as for the end of Leg 2, so the instruments ran with frequencies of 38 kHz (GPT, CW mode), 70 kHz (WBT, FM and CW mode, 200 kHz (GPT, CW mode) for the EK80 and 18 kHz and 120 kHz for the EK60 (GPT, CW mode). By March 13, the 120 kHz connected back to the WBT and integrated back into the EK80 configuration. Due to the concerns that the background noise level was high in CW mode in 120 kHz, this frequency predominantly kept running in FM mode until April 27, 2020. After the confidence gained by the successful calibration results, this frequency switched back to a routine same as the 70 kHz i.e., manually swopping between FM and CW mode every ca 24 hours. I addition, daily screen captures were produced from the echosounder recordings according to the SOP. In order to ensure that the screen captures are representative of the exact same time period of the day, screenshots were taken from the replay of the data on a separate computer (the PC used for the post-processing).

False Bottom effects

During the southward drift to south of Leg 3, rapid changes in bathymetry were observed particularly around the Gakkel Ridge. This led to the generation of false bottom layers on the 38 kHz. This problem did not exist in the earlier legs as the drift was mainly within the flat – deep section of the Amundsen basin. As the MOSAIC drift proceeded past the Gakkel Ridge, and reached to the Nansen basin, where the bottom topography flattened and deepened again, the problem disappeared. This problem may, however, arise again when the drift continues further south and approaches the continental slopes.

The false bottom is generated simply because of the ping rate settings. The EK80 is pinging at a rate of 3.5 seconds. This means that every subsequent sound pulse is sent before the first pulse hits the bottom and its echoes completes its travel back to the surface. For example, assuming an average sound speed of 1450 m/s in an area where the bottom depth is 3500m, the journey of the pulse to the seabed and back is 7000 m in total. This would take ca. 4.8 seconds. This means that the echo of the first ping from the bottom will reach the transducer ca 1.3 seconds

after the succeeding pulse is sent. In the echosounder data this will appear at around 960 m. Since the maximum recording range is 800m at 38 kHz, this is not a problem. But if the depth is 3100 m then the false bottom will show up around 560 m and this overlaps with the recorded region.

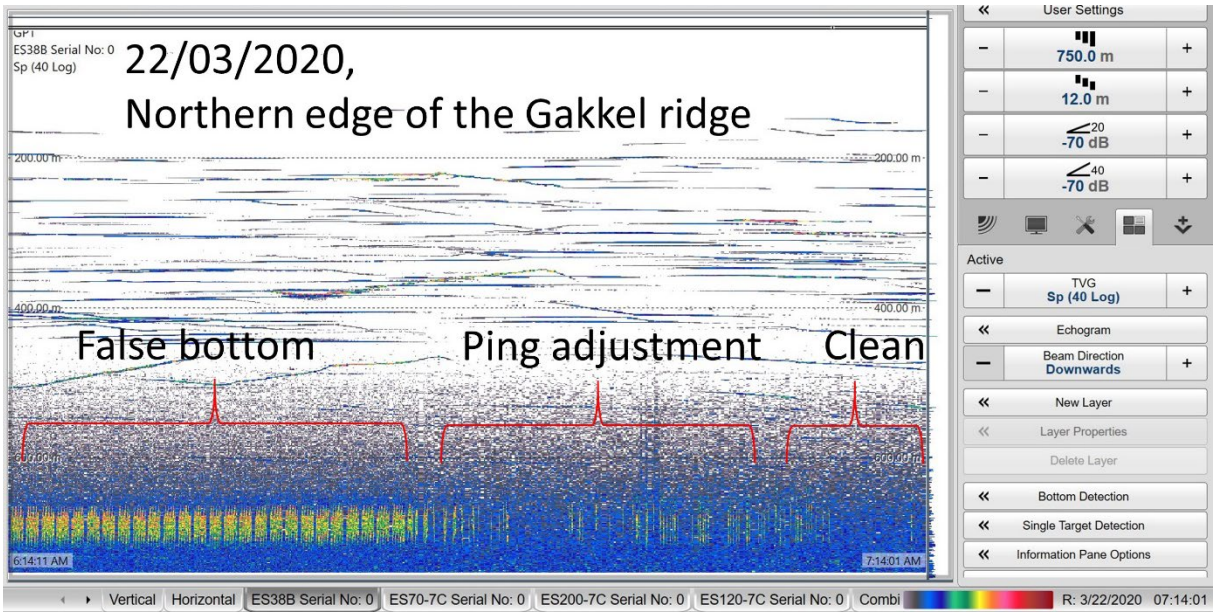

Fig. 6.6.2: *Example of the appearance of a false bottom in a region where the bathymetry is changing rapidly. A strong band of echo appears below 600m and rises up gradually. This bottom associated echo is caused by the ping interval setting, and it can be eliminated by changing the ping rate (i.e. from 3.5 to 7 second intervals)*

Therefore, the false bottom may start to show up when the bottom depth drops below ca 3300 m and pollute the 38 kHz echogram between 600 m and 800 m (**Figure 7.6.2**). The location of this layer on the echogram will start to rise as the water depth gets shallower. This may have severe effect on the quality of the fish detections if it rises further up and contaminates the range around 400 m where high fish density was observed towards the end of Leg 3. The solution for this is that, in region where false bottom is observed due to sharp bathymetric change, the ping rate should be changed on EK 80. It should be switched from “maximum” to “interval” and the intervals should set to 7 seconds.

Grey Water discharge

Grey water discharge was one of the main source of disturbances during the earlier legs and it continued during the Leg 3. From March 3, 2020 to May 14, 2020, a total of 28 grey water discharge disturbances were observed. During Leg 3, a discharge operation lasted could last between 6 hours and 24 hours, with an average of 8.3 hours (Tab.). This adds up to approximately 234 hours of greywater related disturbance in total, which corresponds to approximately 13 % of the data collected during this period. The main undesirable effect of the greywater disturbance is that the strong backscatter from the hose and the attached metal parts

on the hose masks the region within 150 m. However the masking effect is strongest at points where metal collars are attached and the hose itself may or may not cause disturbance depending on the tilt. Therefore a careful cleaning during the postprocessing may render some of the data usable particularly in the higher frequencies. The effect of the grey water discharge also depends on the drift speed and direction (e.g. when the hose is tilted outwards relative to the beam then the effect is much less pronounced). No significant backscatter remnants were observed during the period after the grey water hose have been lifted up.

Tab. 6.6.2: *Record of grey water discharge events*

Start	End	Duration (h)	Latitude	Longitude
03/03/2020 05:04	03/03/2020 13:41	8.60	88.148	30.588
03/05/2020 05:09	03/06/2020 05:38	24.50	88.09	30.795
03/08/2020 06:07	03/08/2020 13:42	7.60	88.029	25.349
03/10/2020 05:46	03/10/2020 12:28	6.70	87.778	24.4
03/15/2020 06:13	03/15/2020 12:57	6.70	87.096	16.167
03/17/2020 06:26	03/17/2020 13:15	6.80	86.802	12.403
03/20/2020 07:07	03/20/2020 15:17	8.20	86.365	14.674
03/22/2020 08:54	03/22/2020 16:53	8.00	86.229	15.692
03/24/2020 21:48	03/25/2020 06:49	9.00	86.171	15.087
03/29/2020 05:57	03/29/2020 13:20	7.40	85.46	13.24
04/04/2020 09:08	04/04/2020 16:24	7.30	84.675	12.89
04/07/2020 07:41	04/07/2020 20:22	12.70	84.503	14.535
04/10/2020 06:19	04/10/2020 20:06	13.80	84.394	14.655
04/12/2020 06:54	04/12/2020 13:05	6.20	84.294	14.729
04/14/2020 06:06	04/14/2020 13:45	7.70	84.325	14.87
04/16/2020 06:10	04/16/2020 13:12	7.00	84.309	13.189
04/18/2020 06:07	04/18/2020 12:19	6.20	84.449	13.807
04/20/2020 05:53	04/20/2020 12:09	6.30	84.584	14.659
04/22/2020 06:00	04/22/2020 12:59	7.00	84.151	15.846
04/24/2020 06:18	04/24/2020 14:38	8.30	84.062	15.981
04/26/2020 06:07	04/26/2020 11:54	5.80	83.941	15.516
04/30/2020 06:26	04/30/2020 13:41	7.20	83.943	17.384
05/02/2020 05:50	05/02/2020 13:49	8.00	83.912	17.556
05/04/2020 06:29	05/04/2020 13:41	7.20	83.895	18.308
05/08/2020 05:52	05/08/2020 12:32	6.70	83.878	15.642
05/10/2020 05:50	05/10/2020 12:30	6.70	83.695	13.638
05/12/2020 05:49	05/12/2020 13:11	7.40	83.421	12.914
05/13/2020 21:48	05/14/2020 06:20	8.50	83.373	10.13

Fish sampling

The long line sampling was carried out by following the routines established during Leg 1 and as practiced during Leg 2. Due to very low density of the fish back scatter on the echo-sounder data, the longline deployments were only performed once per week using the standard long lines with 150 hooks of three different sizes. Trials were done by changing the combinations of the type and size of the baits (e.g. shrimp vs. squid and small pieces vs. big pieces) and the attachment of flashing lights. This did not change the result and no fish was caught until the last days of the Leg 3. Multiple trials were also performed with the gill nets. The first trial was performed in the third week (March 24th) in a frozen crack. A 50 m long cut was opened with an ice saw along which a dynema line was put through and maintained under the water. The two holes at the end of this line were used to deploy and recover the net. A second deployment was performed from the same location the day after. Similar trials were performed in April and May (table 6.6.4). Despite that no fish was captured with the gill nets, the several ctenophores and one sea angle (*Clione limacina*) that were captured confirmed that the nets were working (e.g. laid out and opened properly under the ice). A deep-water deployment (300 m) was carried out on April 29, 2020, but did not provide any catch. Constant movement and breakup of the ice prevented the increase of the deployment frequency. All longline and gill net deployments are summarized in table 6.6.4. On May 16, the backscatter intensity elevated at the layer between the depths 280 m and 420 m. Therefore, additional fishing efforts continued from the ship while the distance to the MOSAiC Floe was still short (May 18,19, 24 and 27) and 11 fish were caught in total. Of these fish 5 were caught with the longline, 1 with a fishing rod and another 5 were caught by the Polarstern crew usingtheir own fishing rods.

Visual observations

The deep-sea camera system (FishCam) was running continuously during Leg 2 and operated according to the protocol until March 11th during Leg 3: daily alternating 15 minutes on, 15 minutes off; 55 minutes on, 5 minutes off. The power was disconnected on March 11th after a crack had opened on the ice floe. On March 14th , a new crack opened and progressed towards the fishcam cable bundle. All cable and wooden crate were pulled back to a safer place. However, the mobility of the ice floe continued further in the following days and new cracks and leads started to open, endangering the fish-cam installation. With the help of the entire Team Eco and the Logistics team, the FishCam was recovered after a 2-day operation (17/18 March). Unfortunately, damage was inflicted on the FishCam cable during the recovery, which made the system inoperative. Later in April, some tests and repairs were done, the cable was shortened and the system became operational again. However, redeployment was postponed to Leg 4. During Leg 3 altogether 324 hours of video were recorded (Table 6.6.3). 112 hours of these videos were recorded between February 25 and March 3. Of the files recorded from the two differed cameras from March 3, 2020, onwards, the duration of 110 files are 5 minutes, 420 files are 15 minutes and 96 files are 55 minutes each. According to the initial check, there is a lot of footage of small organisms such as chaetognaths, hydromedusae, siphonophores, copepods, euphausiids and copepods. However no larger individuals, such as fish or squid, were observed.

Tab. 6.6.3: *Duration of the videos recorded by the two separate cameras of the fish cam*

	Camera1 (Hours)	Camera2 (Hours)
Feb 25 to March 03	37	85
March 03 to March 11	101	101
Total Hour	138	186

Environmental DNA

Sampling carried out as part of the MOSAiC ECO Core Program.

Preliminary (expected) results

During the Leg 3, altogether, ca. 4.5 TB of hydroacoustic data were collected between February 24 and June 5, 2020. 252 GB of this data was collected between February 24 and March 3, 2020. Since Leg 3 encompassed the dark to light transition, a long drift causing geographical change (Figure 6.6.2 and 6.6.5), and changes in under-ice light levels due to large lead openings ,drastic changes in the characteristics of the backscatter were observed at different frequencies (e.g. the DVM of zooplankton observed on 200 kHz during March Figure 6.6.3). In line with the later phases of Leg 2, backscattering intensity associated with the larger targets (e.g. fish) continued to drop until beginning of April and remained low until beginning of May (Figure 6.6.4). Furthermore, the average depth of the scattering layer deepened steadily (Figure 6.6.6). While its average depth was around 200 m at the beginning of March, it gradually went down reaching to 400m during mid-April. The DVM of the zooplankton layer started to become apparent above the halocline. While this surface zone was occupied with plankton–like scatters during the dark period, empty patches started to become observable and followed regular but evolving cycles for a period approximately three weeks during March (Figure 6.6.3.). In addition, the 200 kHz backscatter showed development of a relatively strong scattering layer building up at the mixed layer depth and immediately below this depth. The existence of such zooplankton concentration was qualitatively confirmed with initial ROV and Ring net tows. Observations of changes in the vertical migration of zooplankton are very valuable for the understanding of the Arctic food web in relation to light availability, sea-ice properties and water column properties, to gain knowledge on the potential availability of food for e.g. fish species such as polar cod, and to explain potential differences in net catches.

Despite that the time series for the longline deployments were kept continuous without interruption, the low backscatter observed throughout Leg 3 may potentially explain the lack of catch. Fish samples were only obtained at the very last phase of Leg 3, coinciding with highly elevated backscatter levels between 280 and 420 m depth. Measurements taken from each fish include total length, standard length, total weight, and eviscerated weight. From each fish, the stomach, hindgut, gonads, liver, muscle tissue, otoliths and afin clip were taken for further analyses at home. Apart from information on the distribution of fish species, collected samples will give information on the biology of the fish and their role in the ecosystem. As the productivity in the surface is increasing and the drift of the ship is expected to come closer to the sea-ice margins, the distribution of fish is expected to increase in the under-ice surface water, as was shown for polar cod. Therefore, an increased effort in under-ice fishing during the coming legs of MOSAiC is desirable.

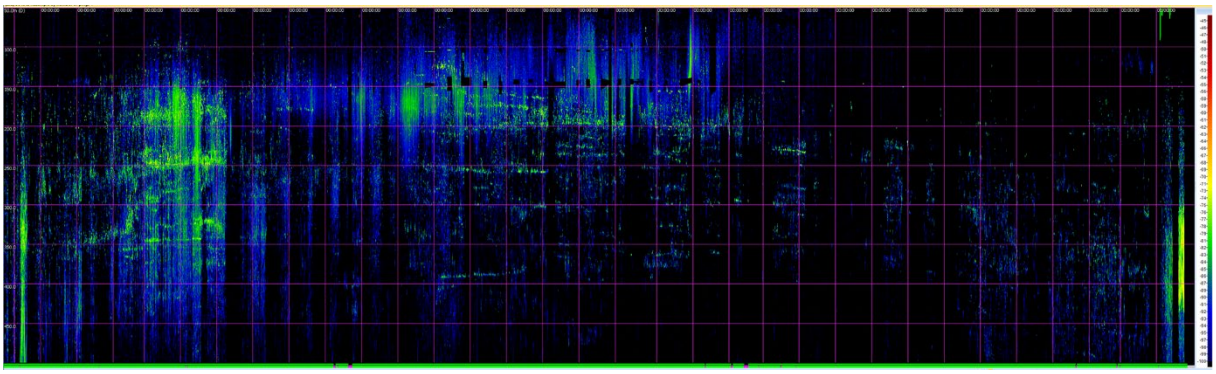

Fig. 6.6.3: *A full overview of the 38 kHz data collected from 1st of October 2019 until 25th of May 2020*

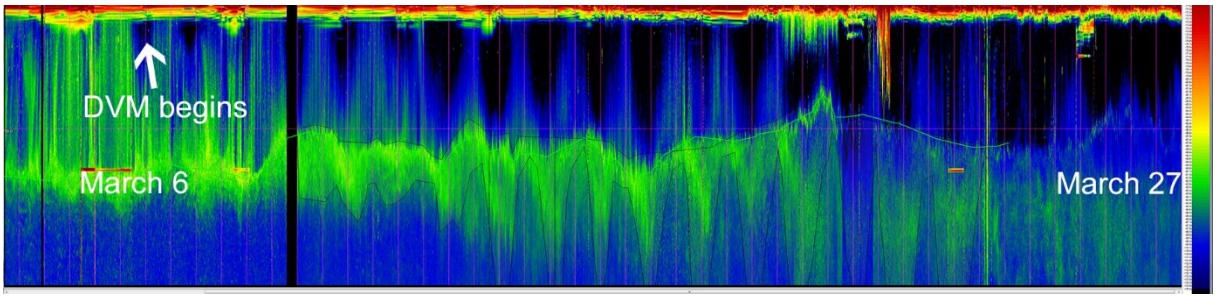

Fig. 6.6.4: *Initiation and evolution of the DVM during March 2020, during Leg 3. It will be pronounced on 6th of March in the surface layers and lasts 3 week until end of March.*

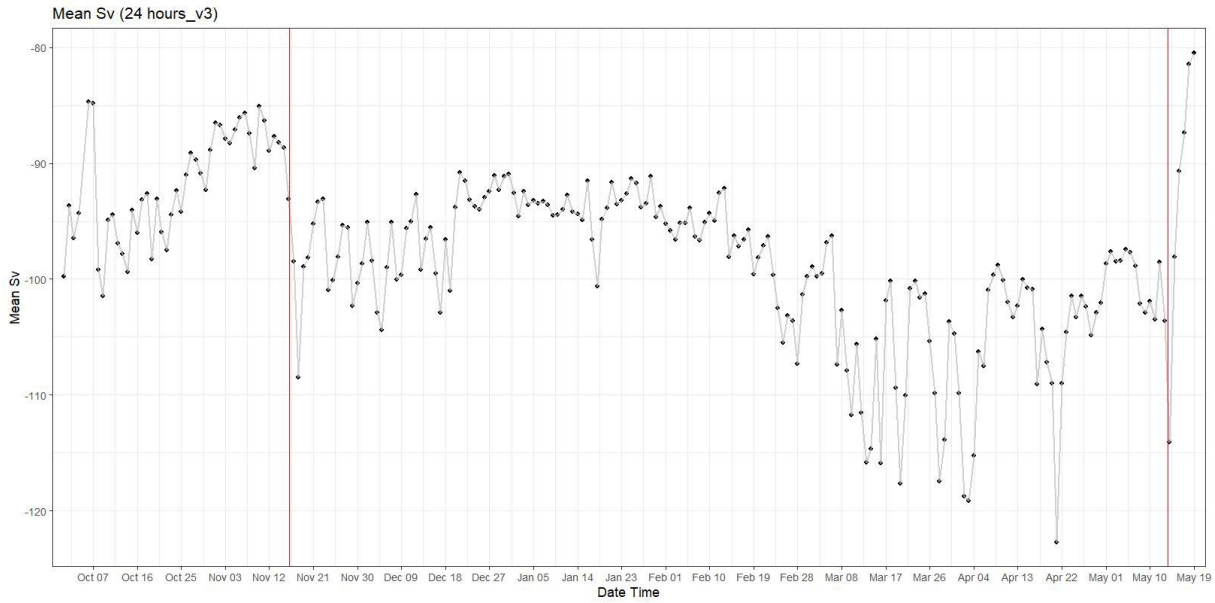

Fig. 6.6.5*: A full overview of the integrated 38 khz data (Daily intervals) collected from 1st of October 2019 until 20th of May 2020. The vertical red lines show the timing of the two major storms*

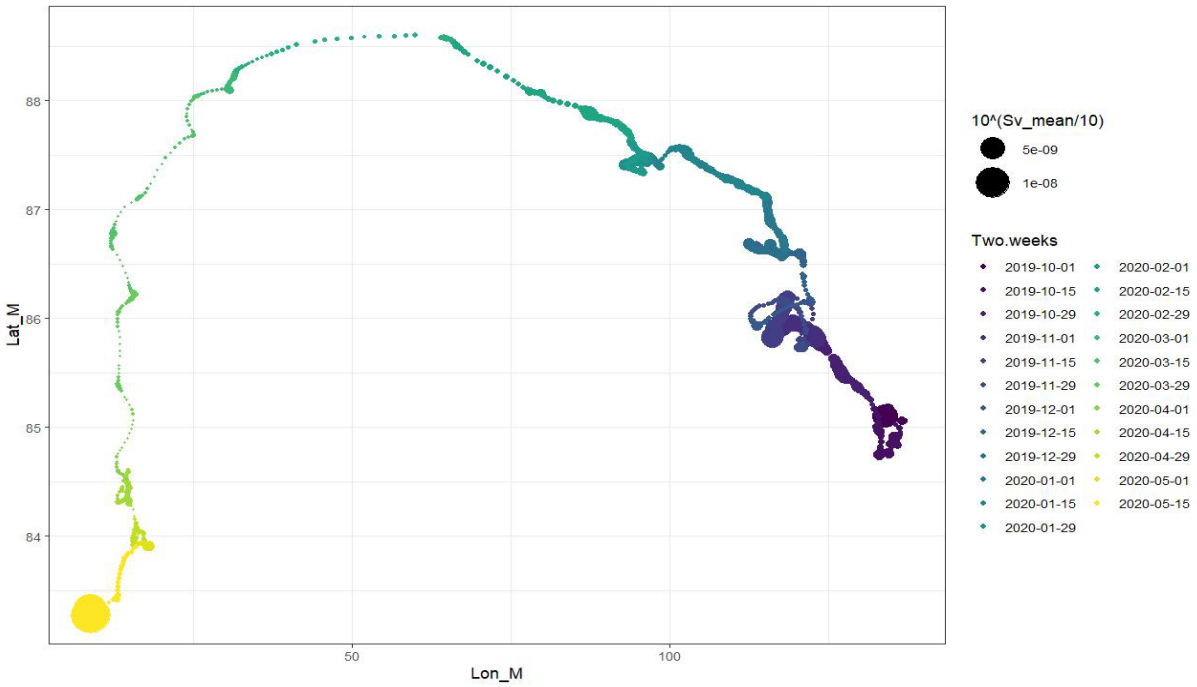

Fig. 6.6.6: *A spatial overview of the integrated 38 khz data (with 6 hours interval) collected from 1st of October 2019 until 20th of May 2020*

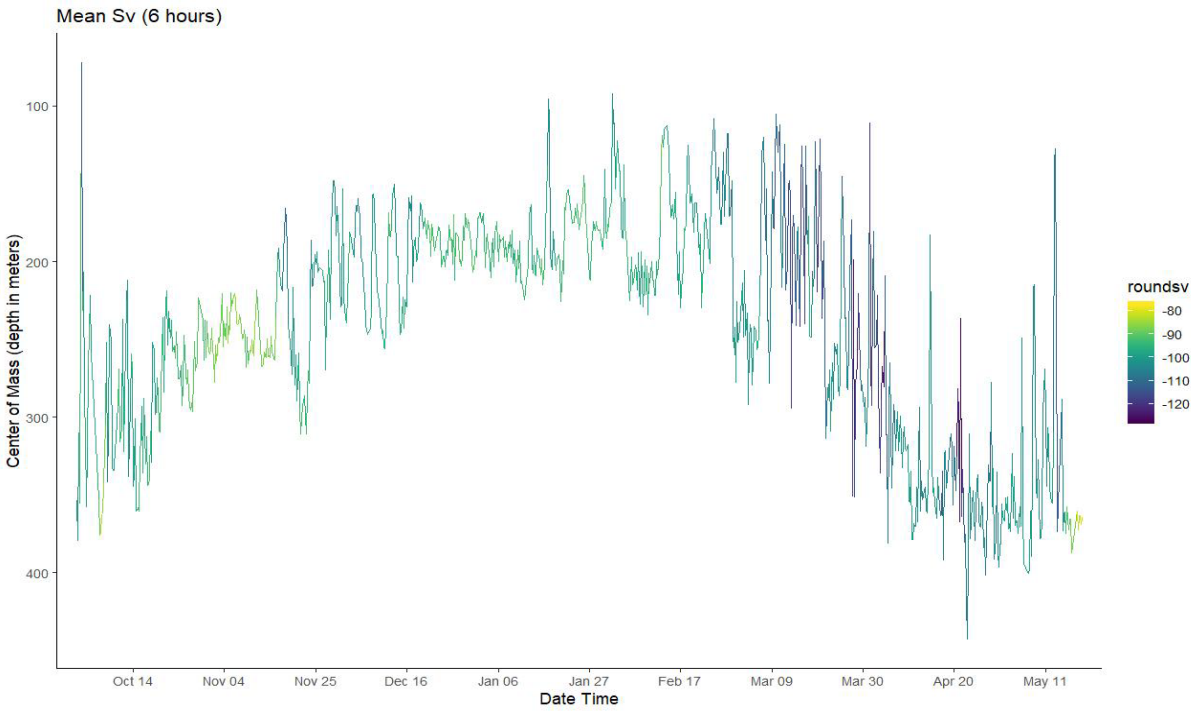

Fig. 6.6.7: *An overview of the concentration depth of the fish-like targets from the first week of Leg 1 until the last week ofLeg 3 on the MOSAiC Floe.*

Tab.. 6.6.4: *Overview of sampling efforts and fish samples taken during Leg 3 of MOSAiC, including long lines and gill nets*

Station - Device Operation	Date Time	Device	Comment
PS122/3_30-104	04.03.2020 07:30	Long line	200 - 400 m (ROV)
PS122/3_31-25	10.03.2020 15:15	Long line	Long line deployment 200 - 400 m (ROV)
PS122/3_32-3	16.03.2020 09:15	Long line	Long line : ROV hut 200 _400 m deployed
PS122/3_33-2	23.03.2020 08:49	Long line	Long line 1: ROV site deployed to 200 - 400 m
PS122/3_33-23	24.03.2020 12:45	Gill net	Gill net (40 m long) deployed under ice in a frozen lead
PS122/3_33-39	25.03.2020 08:52	Gill net	Gill net deployment: re-deployment
PS122/3_34-5	30.03.2020 16:39	Long line	Long line week 34: long line deployment at ROV site 200 - 400 m.
PS122/3_34-68	04.04.2020 14:56	Long line	Long line: deployment at ROV
PS122/3_35-67	09.04.2020 08:51	Gill net	Gill net week 35: deployment at balloon tow lead 40 m net to under ice
PS122/3_36-38	15.04.2020 09:20	Long line	Long line: longline deployment at ROV site 200 - 400 m
PS122/3_37-31	22.04.2020 08:51	Long line	Long line ROV deployment: long line deployment a at ROV 200 - 400 m
PS122/3_38-143	29.04.2020 16:30	Gill net	40 m gill net with 20 kg weight (300 m). Deployment from the logistic crack (300 m) 2 X 10 kg weights
PS122/3_38-144	01.05.2020 15:15	Long line	Deployed from the logistic crack: long line deployed from the logistic crack 200 - 400 m
PS122/3_39-61	06.05.2020 11:25	Gill net	40 m gill net deployed under ice (surface) in the logistic crack
PS122/3_39-61	07.05.2020 15:00	Gill net	40 m gill net deployed, again under ice from the logistic crack
PS122/3_39-61	08.05.2020 13:30	Gill net	40 m gill net deployment under ice from the logistic crack
PS122/3_39-61	09.05.2020 15:00	Gill net	40 m gill net deployment under ice, deployed from the logistic crack
PS122/3_39-125	10.05.2020 13:00	Gill net	Logistic crack gill net deployment, the 25 mm mesh gill net (New package)
PS122/3_39-125	11.05.2020 08:45	Gill net	Logistic crack gill net deployment, the 25 mm mesh gill net (New package) deployed with 2X5kg weight at each end
PS122/3_39-125	11.05.2020 15:15	Gill net	Logistic crack gill net deployment, the 25 mm mesh gill net (New package) redeployed
PS122/3_39-125	12.05.2020 15:09	Gill net	Logistic crack gill net deployment, the 25 mm mesh gill net (New package)redeployed with the weights

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 analyzed at the home laboratory (AWI), they will be processed and stored in the MCS approximately within 8 months after arrival. Processed data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science, www.pangaea.de).

6.7 The Role of Sea Ice in the Life Cycle of Polar Cod (*Boreogadus saida*) and its Prey (PC&P)

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Objectives

Zooplankton and sea-ice fauna constitute an important link in the cycling of organic matter, nutrient and trace elements between the sea ice, the water column and the sea floor. Some zooplankton species spend part of their life cycle associated with sea-ice, while others complete their entire life cycle within it. These life cycles are often adapted to water column and/or sea-ice primary production cycles. Ice-associated zooplankton species such as the copepod *Calanus glacialis* and the amphipod *Apherusa glacialis* are an important food source for young polar cod (*Boreogadus saida*), which in turn provide an important food source for e.g. sea birds and seals. The aim of this project is to investigate the role of sea ice for the survival, life cycles and energy budgets of polar cod and/or its prey, such as *Calanus* spp. and *A. glacialis*. We aim to investigate the diet of these key species to understand how the sea ice is used as a food source, how this changes seasonally and how this is related to sea-ice parameters. For this purpose we aim to investigate the gut content of polar cod, and to study the gut content and the energy content of a variety of zooplankton species that are known prey. Diet and energy studies of key species will complement the work of the MOSAiC Ecosystems Working Group partners who are analysing e.g. fatty acids and stable isotopes, isoprenoids, elemental compositions and water column or sea ice protist and metazoan communities.

Work at sea

For the aim of the project, sampling is conducted year-round by members of the ECO team. As the project's own berth/contribution was made during Leg 3, a more detailed description of the work is presented in this cruise report. General descriptions of biological sampling during the other legs, including sampling for projects, can be found in the respective cruise reports.

The sampling of fish and zooplankton was done using:

- Picking from several zooplankton nets
- Opportunistic collection of amphipods
- Fish traps
- Gill net deployments

Zooplankton for energy (Table 6.7.1) and gut content measurements were picked from several nets, such as the Nansen net, Multinet and ROV net, operated from Ocean City, ROV city or Polarstern. Gut content samples consisted of *Themisto abyssorum* and *Calanus hyperboreus*. A detailed description of all network conducted can be found in chapter 6.1: Ecosystem science: zooplankton ecology and biology.

Tab. 6.7.1: *Overview of samples collected for energy content measurements.*

Species	*n*	Sample numbers
Chaetognaths	24	FR01856 - FR01868, FR01889 - FR01898
Apherusa glacialis	7	FR1781, FR1792, FR1800, FR1801, FR1809
Eusirus ssp.	10	FR1796 - FR1799, FR01803, FR1784, FR1785, FR01870 - FR01872
Onisimus nanseni	1	FR1783
Onisimus sp.	1	FR01802
Themisto abyssorum	14	FR01854, FR01855, FR01790, FR01876, FR01833
Themisto libellula	1	FR01791
Thysanoessa longicaudata	5	FR01886, FR01796, FR01805
Calanus hyperboreus	132	FR1789, FR0302, FR01880, FR01884, FR01900
Copepods	2	FR01877

Amphipods could be collected opportunistically from the holes in the ice at both Ocean city and ROV city by colleagues working at these sites, and was quite successful (Table 6.7.2). The amphipod *Eusirus holmii* was caught mostly (Figure 6.7.1). This amphipod may be the dominant species under ice during this time, suggested from the fact that they were so prevalent. This could be due to a lack of predator, for example, the polar cod.

The fish trap was suggested as an idea to fish under ice, as gill net deployment was not possible at the time of arrival. For that purpose, several different fish traps were build and deployed from the CTD hole and ROV hole during March. This did not result in any successful fish or amphipod catch. As there were always amphipods swimming around, but none of them going inside the trap, this method was not considered really effective and efforts were not continued after March. An improvised way to deploy the gill nets from the frozen leads was tried and several trials immediately under ice were attempted. Unfortunately, this also did not result in any catch. The sampling period probably coincided with the poorest time of the year for the region in terms of under-ice biological activity. Algal growth only started to develop towards May. The ROV tows under ice resulted with very few animals, and no fish were observed in the footage of the gopro or ROV camera. A more detailed description of the gill net trials and further fish sampling efforts can be found in chapter 6.6: 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.

Preliminary (expected) results

We expect to gain knowledge on the food web of the ice-covered Arctic Ocean and the life-history traits of several species, and to contribute to answering the question on what the effect of changes in the Arctic sea ice on its ecosystems will be.

Data management

All data are handled, documented, archived and published following the MOSAiC data policy (see APPENDIX). After analysis at the home laboratory, data will be stored at the PANGAEA data repository (World Data Center PANGAEA Data Publisher for Earth & Environmental Science www.pangaea.de) and the Netherlands Polar Data Center (www.npdc,nl).

Tab. 6.7.2: *Numbers of opportunistic catch of amphipods.*

	Location	
Date	Ocean	ROV
20200305		8
20200308	1	
20200309	1	2
20200310	3	1
20200318	7	
20200320	1	
20200321	3	
20200322		1
20200323		1
20200327	3	
20200329	4	
20200331	4	
20200404	6	
20200405	4	1
20200407	4	1
20200408	1	1
20200409	13	1
20200410	1	
20200411	4	3
20200414	3	
20200415	3	
20200416		2
20200417	1	1
20200418	1	
20200420	2	
20200421	1	
20200423	11	
20200425	2	
20200427	4	
20200430	6	
20200429	4	
20200504	11	
20200507	2	
Total	111	23

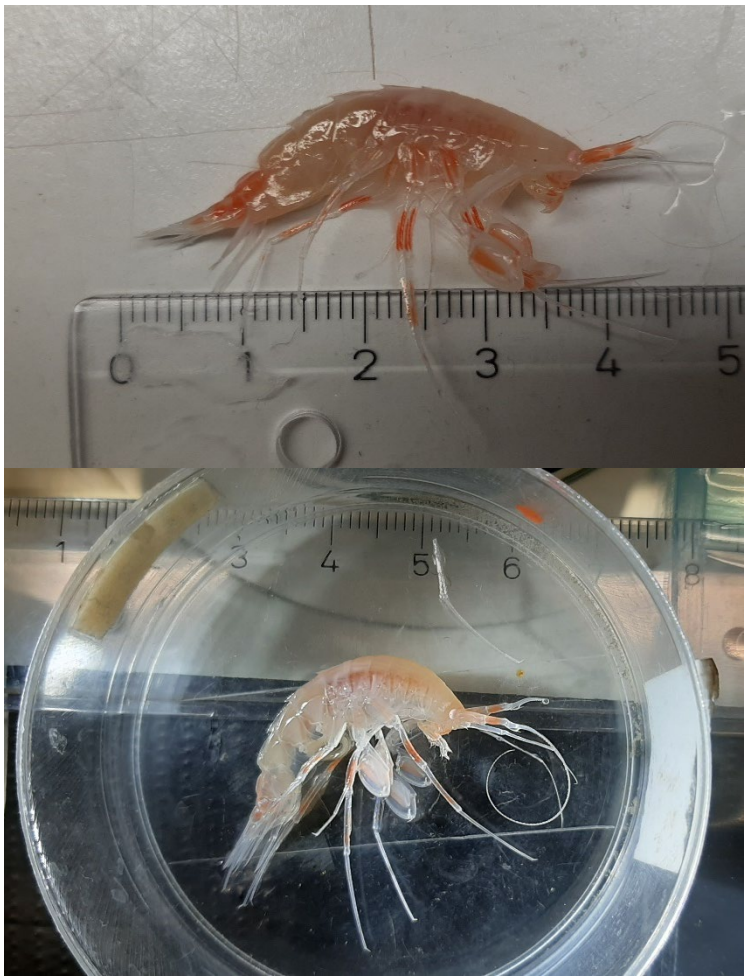

Fig. 6.7.1: *Examples of specimens of Eusirus holmii (© Serdar Sakinan)*

6.8 Ridges – Safe Havens for ice-associated Flora and Fauna in a seasonally ice-covered Arctic Ocean (HAVOC)

Clara J. M. Hoppe[1], Anders Torstensson[2] (for the HAVOC consortium), Mats Granskog[1], Nicole Aberle-Malzahn[2], Philipp Assmy[1], Jørgen Berge[3], Gunnar Bratbak[4], Lasse M. Olsen[4], Dimitry V. Divine[1], Pedro Duarte[1], Torbjørn Eltoft[3], Sebastian Gerland[1], Rolf Gradinger[3], Knut Høyland[2], Aud Larsen[5], Eva Leu[6], Cecilie von Quillfeldt[1], Marit Reigstad[3], Arild Sundfjord[1], Janne Søreide[7], Anna Vader[7], Oliver Müller[4] (not on board)

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[8]NO.APN

Funded by the Norwegian Research Council

Objectives

The objectives of the HAVOC project are stated in the respective section of the Leg 2 Cruise Report.

Work at sea

In this section of the cruise report, only the discrete sampling conducted by the ECO team is reported. For more information on the work done by team ICE, see section 4 of this cruise report.

As the HAVOC ridge sites had either collapsed ('Fort Ridge') or were not accessible ('Alli's Ridge'), a smaller ridge (which was approximately 1m high) at the outer edge of the accessible area (in the old 'Stakes 1' area) was selected for coring. The main part of the ridge had formed in November 2019, while another part closer to the (by the time of sampling mostly refrozen) lead formed and/or were modified in March 2020.

Both ice coring events conducted for the HAVOC project were performed about 2/3 to the sail of the ridge. By ice thickness drilling, we searched for and selected sites on the ridge that contained water filled voids/gap layers. Ice thickness in the selected sites was 2.5 to 3.1m. By the use of a hand pump, 40L water samples were collected from the gap layer. Subsequently, ice cores for ECO parameters were collected from directly below and above the gap layer. In addition, two cores for team ICE (SALO18, density) were collected from the full depth of the ridge. These samples were used for subsampling for the various variables in the HAVOC sampling plan.

Preliminary results

The sampling events for HAVOC during leg 3 are listed in table 6.6.1. The total numbers of samples for the different variables collected were: 16 fixed protist samples, 4 nutrient samples, 10 chlorophyll a samples (Chl), 6 (sterivex) DNA samples, 24 flow cytometry samples (FCM), 8 samples for particulate carbon and nitrogen (POC/PON), 2 bSi samples, 6 lipid/POM samples. In addition, 14-C based primary production assays (4 samples each) and photosynthesis-irradiance curves were performed with water from both gap layer sampling events. From both sampling events, bacterial production measurements were performed both with gap layer water samples as well as melted ice cores sections from above and below the gap layer (24 samples in total).

Tab. 6.8.1: *HAVOC sampling events during MOSAiC leg 3*

Date	ActionLog_ID	Device	Description
22.04.20	PS122/3_37-149 hand_pump	Hand pump	Water sampling from gap layer
22.04.20	PS122/3_37-32 SI_corer_9cm	Ice Corer Kovacs Mark II	Ice core samples taken from below and above gap layer
24.04.20	PS122/3_37-46 CTD_SBE9plus_935	Ocean City CTD	Under-ice water lipid samples; core parameters can be used as further reference for gap layer
05.05.20	PS122/3_39-105 hand_pump	Hand pump	Ice core samples taken from below and above gap layer
05.05.20	PS122/3_39-104 SI_corer_9cm	Ice Corer Kovacs Mark II	Water sampling from gap layer
07.05.20	PS122/3_39-51 CTD_SBE9plus_935	Ocean City CTD	Under-ice water lipid samples; core parameters can be used as further reference for gap layer

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.

References

No references