the Nansen LEGACY

JC3 Winter gaps cruise 2022

Cruise Report

The Nansen Legacy Report Series 33/2022

JC3 Winter gaps cruise

Cruise 2022702

R/V Kronprins Haakon
Tromsø-Longyeabyen
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Summary

The Nansen Legacy (NL) JC3 cruise (19.02.-11.03.2022) aimed to fill regional, temporal and scientific gaps following the earlier NL cruises, in particular during the winter-to-spring transition and in the northern part of the NL transect to the Nansen Basin. Joint physical, chemical, and biological sampling and experiments for new technology addressed aims of RF1, RF2, RF3 and RA-C.

Sampling began in the Atlantic domain with a process station at P1. Afterwards, the cruise focused on the northern Barents Sea around and north of Kvitøya covering process stations at P5, P7 and between Nordaustlandet and Kvitøya. They lasted from 29 to 68 hours to enable observation of at least one daily cycle in the under-ice water layer. Ice conditions varied but consisted mostly of extensive but thin first-year ice, often as small floes that were frozen together. In the northernmost region, the floes were larger, but the ice remained thin. Despite a fair amount of daylight available, preliminary analysis of biological sampling seemed to indicate that the ecosystem was still in winter mode.

In addition to the process stations, the northern part of the NL transect was covered from the shelf north of Kvitøya into the deeper Nansen Basin. This included mainly hydrographic measurements and chemical sampling along the entire transect, biological sampling at P6, and benthic sampling at selected depths from shelf over slope to deep. In the entire region, warm Atlantic water was prominent and close to the surface, potentially explaining the lack of thick sea ice and the late ice formation.

Before and after the main cruise program, several gliders were recovered. One mooring was pinged but could not be located.

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1 Introduction

The Nansen Legacy Joint Cruise 3 (NL JC3) onboard R/V Kronprins Haakon aimed to fill spatial and seasonal gaps in the sampling by the earlier NL cruises to fill our gaps in knowledge around the winter-to-spring transition in the northern Barents Sea and the connectivity between the northern Barents Sea and the Eurasian Basin. The cruise addressed objectives and tasks in the research foci RF1 Physical drivers, RF2 Human impacts, and RF3 The living Barents Sea, as well as in research activity RA-C Technology and method development. More specifically, sampling and experimental work included:

- RF1: hydrographic measurements for better understanding of connectivity between different areas in the study region and interaction between sea ice and ocean; characteristics of the sea ice cover across the domain in winter; advanced ship-based measurements of the 3-D wind vector in the lower atmosphere; recovery of an NL glider;
- RF2: biochemical samples from water and sea ice/snow on ice for ocean acidification and carbon cycle studies; onboard experiments on temperature effects on *Calanus glacialis* and *C. hyperboreus* as well as sampling for future multistress experiments on land; trawling for Atlantic cod, capelin and polar cod to investigate spatiotemporal population structure and potential local adaptations;
- RF3: sampling of lower trophic levels (microbes – virus, prokaryotes, protists; phytoplankton) for biodiversity, abundance, biomass and activity in the water column and sea ice; net hauls for characterization of mesozooplankton communities; experimental work and measurements for mesozooplankton productivity, metabolism and phenology with focus on key species *C. hyperboreus*, *C. glacialis* and *C. finmarchicus*; benthic sampling for biodiversity and abundance/biomass of sediment communities, environmental drivers, and sympagic-pelagic-benthic coupling;
- RA-C: testing of and under-ice surveying with novel ROV setups; under-ice navigation experiments.

Additionally, two gliders were recovered for partner projects.
The science party consisted of both NL veterans and researchers new to NL fieldwork, which allowed for efficient work at the same time as training and teaching of the less experienced scientists. Two highly-experienced safety officers ensured safe operations on the sea ice. In addition to the scientific work, a large focus was put on communication of the activities onboard. A dedicated person created daily updates highlighting science and life on the ship and supported other outreach activities like blog posts. Data management and sample logging were supported by two people from the data management RA in addition to their other scientific tasks.

2 Survey Area

Focus area for the cruise was the region from shelf to deep basin along the NL transect north of Svalbard with 2-3-day ice stations planned on the shelf and in the deep basin, and if time and ice conditions permitted at another location of interest. Additionally, CTD transects were planned to cover water mass exchange pathways between the shelf north of Svalbard and the northern Barents Sea.

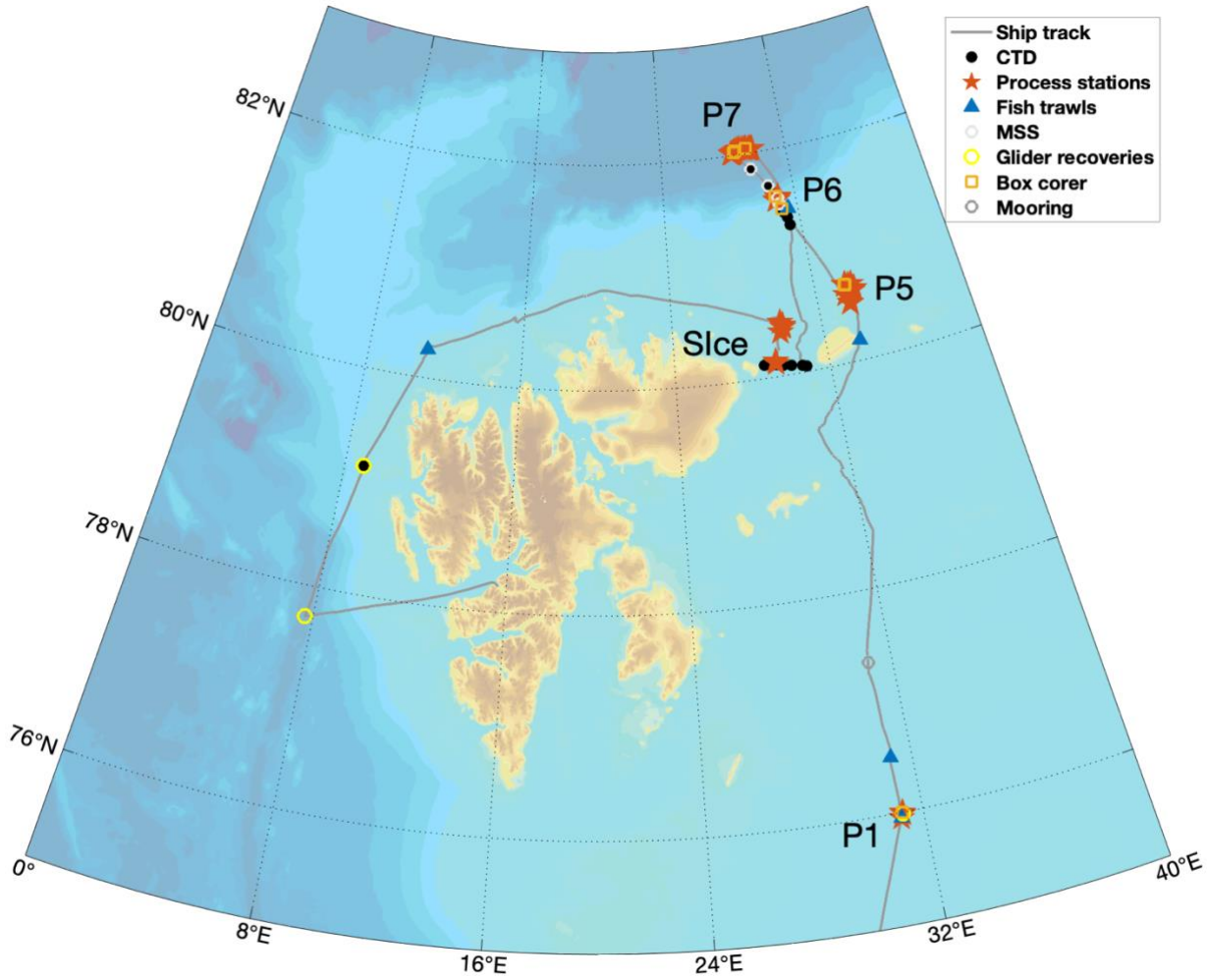

Figure 1: Map of the cruise track and stations. Process stations included full pelagic sampling (CTD with water samples, phyto- and zooplankton nets). P5, P7 and SIce included sea ice work. CTD stations across the continental slope were located at NLEG stations.

As the cruise started in Tromsø on 19. February 2022, we used the transit past P1 to conduct a pelagic station including benthos sampling in the Atlantic domain before entering the sea ice. Progress through the northern Barents Sea was slowed down by heavy ice cover and a winter storm with strong northerly winds. The wind opened a polynya south of Kvitøya, and the location of the first ice station, aimed to be on the shelf, had to be changed from P4 south of Kvitøya to P5 due to unstable ice conditions. P5 was covered by relatively thin first year ice and therefore was moved further north

than the nominal position. Despite this, the floe broke up during day 2 while work was ongoing and had to be evacuated.
Progress to the deep station P7 was fast as ice remained thin, even at 82° N. Along the way, benthos samples (box corer) were taken on the slope. With favourable weather with limited wind and limited ship movement around the ice floe (i.e., not leaving the ice floe at night), a full process station spanning almost three full days could be done at P7. During the transit south, the NLEG stations were covered for selected measurements and extended pelagic sampling at P6.
As weather and ice conditions prevented the coverage of planned CTD transects, we moved back south to attempt the transect between Kvitøya and Nordaustlandet. Heavy ice that was deformed by the strong wind experienced earlier during the cruise limited navigation slightly, but Kvitøya trough could be covered with reasonably high resolution between stations, and an additional sea ice station was done just north of the transect.
The cruise ended in Longyearbyen on the 11. March 2022.

3 Activity Reports

3.1 Along-track measurements

3.1.1 Underway T&S, pCO2

Angelika Renner & Elizabeth Jones (IMR)

The sea-water intake for underway measurements was opened directly after leaving Tromsø, using the intake at 4 m depth. Close to the intake, a SBE38 temperature sensor recorded the temperature before the water became heated as it continued towards the Clean Seawater Lab. There, a SBE21 SeaCAT thermosalinograph monitors temperature, salinity, and fluorescence (WET Labs WET star fluorometer). While in sea ice, the intake had to be switched off. No dedicated log was kept of times of starting and stopping the intake pump, and the record therefore has to be processed carefully.

The underway instrumentation for autonomous high-frequency surface water measurements of partial pressure of CO_2, pCO_2 (General Oceanics), was running in ice-free water from ship's seawater intake at 4 m depth. The instrument was running after the seawater supply had been switched on after leaving coastal waters in the afternoon of 21 February. Raw data are calibrated against a series of reference gases (comprising different CO_2 concentrations) and will be quality controlled in post-cruise processing.

3.1.2 Shipboard-ADCP (SADCP)

Zoe Koenig (NPI)

Two ship-mounted RDI Ocean Surveyor ADCPs (38 kHz and 150 kHz) measured ocean currents during the cruise. Both were installed in "Arctic chamber" windows flush with the ship hull (an additional pair of ADCPs mounted in the drop keel was not used during the cruise). Both ADCPs were configured with a bin size of 8 m, and operated in narrowband mode. Blanking distances were 16 m for the 38 kHz and 8 m for the 150 kHz.

Parameters used for preliminary processing of the 150 kHz ADCP include:

Transducer angle: 46.42 degrees
Transducer depth: 10 m (rounded from the 9.66 m of the 2017 Parker Survey report)
Starboard offset xducer_dx: +1 m
Forward offset xducer_dx: +30 m
Ensemble length 300 m
Maximum depth for bottom search: 400 m.
Position feed / heading feed / heading correction: N1R / N2R / N3R

Parameters used for preliminary processing of the 38 kHz ADCP:

Transducer angle: 46.88 degrees
Transducer depth: 10 m
Starboard offset xducer_dx: +1 m

Forward offset xducer_dx: +27 m
Ensemble length 300 m
Maximum depth for bottom search: 400 m.
Position feed / heading feed / heading correction: N1R / N2R / N3R

The effective depth reach of the 150 kHz after editing was typically from 26 to 250-300 m in sea ice. The range of the 38 kHz was ~40 m to >700 m.

Final processing of the data will be done after the cruise.

3.1.3 EK80

Asgeir Steinsland (IMR)

Acoustic surveying was done throughout the cruise using the Simrad EK80 fisheries echo sounder with the following frequencies: 18 kHz, 38 kHz, 70 kHz, 120 kHz, 200 kHz, 33kHz. All split beam transducers flush mounted in the hull. All frequencies were operated in CW mode with range set to ocean depth. Depth from this echosounder (18kHz) is also the depth measurement used in the cruiselogger. The echosounder was synchronized with the ADCP's to avoid interference between the acoustic systems.

3.1.4 Ship weather station

Asgeir Steinsland (IMR)

Meteorological parameters were recorded continuously throughout the cruise by the Vaisala AWS430 weather station mounted atop the uppermost deck.

The parameters recorded by the weather station are: true Wind speed and direction, Air temperature, Dew point, Relative humidity, air pressure, Solar radiation, and seawater temperature. The weather station logs these parameters every 3 seconds to file.
The weather station is also transmitting data to the Norwegian meteorological institute every 30 minutes to be used for weather forecasts.

3.1.5 Radiosondes

Asgeir Steinsland (IMR)

Weather balloons with radiosondes attached were released daily at 10:30 - 11:00 UTC to record atmospheric properties (e.g. temperature and moisture vs. height). This system belongs to the Deutscher Wetterdienst and data from this system is sent to them via Iridium to be used for weather forecasts after each launch. The data from the system is also logged locally on the vessel and is included in the datasets from the cruise.

3.1.6 Atmospheric work (Task T1-2.3)

Hugo Rubio Hurtado (Fraunhofer IWES), Shokoufeh Malekmohammadi (UiB)

Measurements of the 3D wind vector were provided by means of two vertical profiling Doppler lidars:

- A pulsed lidar device of the type WindCube WLS7 v2 developed by the manufacturer Leosphere. The lidar device has a sampling resolution of 0.7 s per line-of-sight (LoS) measurement, retrieving the radial component of the wind speed at four azimuth directions along a cone with a half cone opening angle of 28°, followed by a fifth vertical beam. The 3-dimensional wind vector is calculated after each LoS measurement using a Doppler beam swinging (DBS) technique. This instrument provides real-time and statistical (10-min averaged) wind data at 12 height levels between 40 m and 290 m above the ground level (AGL),
- A continuous wave lidar of the type ZephIR ZX300, measuring at 10, 20, 30, 40, 100 and 200 meters AGL. This instrument measures the wind vector continuously in conical scan mode with a half cone opening angle of 30.6°. The LoS wind vector is measured at 50 points at each scan (360 degrees) with the sampling resolution of 1s/scan. This device operates in telecommunication near-IR band with the 1.5 micrometers wavelength. ZephIR produces two data sets as 1-sec real-time data as well as averaged 10-min data per day. In addition, ZephIR has recorded the Doppler spectra for each LoS.

In addition to the primary wind sensors, the following extra equipment provided by the Fraunhofer IWES, was installed:

- A combination of an xSEns MTi-G attitude and reference sensor and a Trimble SPS361 satellite compass. These sensors retrieve high-resolution motion information such as ship tilting, position, Course Over Ground (COG) or Speed Over Ground (SOG).
- A weather station from the manufacturer Vaisala to record atmospheric data including, air temperature, humidity, pressure, and precipitation.

The aforementioned equipment has been installed in the helicopter deck, with an average elevation above the sea level of approximately 11 m. Lidars location and setup are shown in Figure 2. The complete system is fixed to the ship structure using strap ties to prevent any possible displacement. Both lidars are oriented to the ship bow and avoiding any possible disturbance of the laser beams caused by the vessel´s structure. However, during the execution of the campaign, it was noticed that when the helicopter hangar door was open, some ZephIR beams were blocked. This situation happened only occasionally and during short periods of time and thus, do not have a relevant influence in the overall retrievals of the device. The complete system started operating on the 20th of February, measuring continuously until the 9th of March (included).

Figure 2: Lidars location and setup on the Helicopter Deck.

3.1.7 ASSIST Sea ice observations (Task T1-1.2)

Adam Steer & Bonnie Raffel (NPI)

Ship-based sea ice observations were done following the ASSIST protocol (https://icewatch.met.no/assist). A roster system was established to conduct observations every few hours during daylight while in sea ice (paused while stationary at sea ice stations). Observations of ice concentration, type, thickness, topography and meteorology were entered directly in a web browser-based form. Sea ice was assessed from the observation deck, and photos were taken pointing port, ahead and starboard. A total of 34 observations were done

3.2 Ship-based measurements/sampling at stations

3.2.1 Physical Oceanography (Tasks T1-1.2, T1-2.1)

3.2.1.1 CTD measurements

Zoe Koenig (NPI), Angelika Renner (IMR)

The hydrographic work was carried out using a CTD-water sampling package from SeaBird Scientific, acquiring data during both down and upcast. The package consisted of a SBE 911plus CTD (underwater unit SBE9plus SN 141612) with sensors listed in Table 1. The Benthos altimeter (200 kHz) allowed profiling close to the bottom. The CTD was equipped with a 24 position SBE 32 Carousel (SN 1222). The rosette was fitted with 24 10-litre bottles. The CTD package was lowered through the moonpool. In total 28 CTD stations were taken, recorded in files sta0001 to sta0028. At all stations, water samples for salinity calibration were collected at the deepest sampling level and at several stations salt samples were taken at various depth in the water column for calibration purpose. Their locations are listed in the full station table in Appendix 2: Cruise diary, full station table. During a CTD cast, the CTD package was lowered into the water for a 1-minute soak before lowering to the bottom. All CTD sensors worked well throughout the cruise. Offset between primary and secondary T and S sensors were in acceptable range. From cast 20 to 26, a SUNA sensor (SN 1618) was mounted on the CTD rosette.

Table 1. Details of sensors installed on the CTD rosette.

Sensor	SN	Calibration/Service date
Temperature	4535	20.02.2020
Conductivity	4386	28.01.2020
Pressure	141612	19.12.2017
Temperature, 2	4306	28.01.2020
Conductivity, 2	2799	28.01.2020
Oxygen, SBE 43	3774 (casts 1-8) 3635 (casts 9-28)	28.02.2020 27.02.2020
Altimeter, Benthos PSA-916	73084	24.12.2017
Fluorometer, Wet Labs ECO-AFL	6506	18.09.2020
Transmissiometer, Wet Labs C-Star	2003 DR	01.10.2019
Fluorometer, Wet Labs ECO CDOM	4885	15.08.2019
PAR/Irradiance, Biospherical/Licor	70736	29.10.2018
SPAR, Biospherical/Licor	20568	27.11.2017
RDI WH300 L-ADCP, downward (master)	24474	
RDI WH300 L-ADCP, upward (slave)	24472	

Data processing - SBEDataProcessing-Win32, standard Seabird Electronics software for Windows (version 7.26.7.114), is used for post-processing of the CTD data. Only data from downcasts are used to avoid turbulence caused by rosette package on the upcast. Raw data (pressure, temperature and conductivity from dual sensors) are converted to physical units using calibration files modified for air pressure and conductivity slope factor (DATCNV). Outliers, differing more than 2 and 20 standard deviations for the first and second pass, respectively, from the mean of 100 scan windows are flagged and excluded from analysis (WILDEDIT). WILDEDIT flags only the bad data point of each parameter, and does not flag the entire scan. The thermal mass effects in the conductivity cell are corrected for (CELLTM, with parameters alpha = 0.03 and 1/beta = 7.0). Pressure is low-pass filtered with a time constant of 0.15 s. Following the SBE recommendation, the conductivity or temperature signals were low-pass filtered. Auxiliary sensors (oxygen, CDOM, flC, Trans) were filtered using a time constant of 0.03 s. Scans when the CTD package moved less than the set minimum fall rate of 0.25 m s^{-1} are flagged to remove pressure reversals due to ship heave (LOOPEDIT). Data are then averaged (BINAVG) into 1-dbar vertical bins and 1-s temporal bins (the latter is for the LADCP data processing). In the final (converted and bin-averaged) data files, temperature is saved using the ITS-90 scale, and salinity on the practical salinity scale (PSS-78). Pressure, temperature, and salinity data are accurate to ±0.5 dbar, $\pm 2\times10^{-3}$ °C, and $\pm 3\times10^{-3}$, respectively.

Conductivity correction from salinity bottle samples (to be done after the cruise) – A total of 52 salinity bottle samples were taken to be analyzed at IMR with a Guildline Portasal 8410 salinometer. Salinity and conductivity values from each bottle are merged with the corresponding CTD data. Bottle conductivity is calculated from bottle salinity and CTD temperature and pressure. Only data within the 95% confidence interval are used to

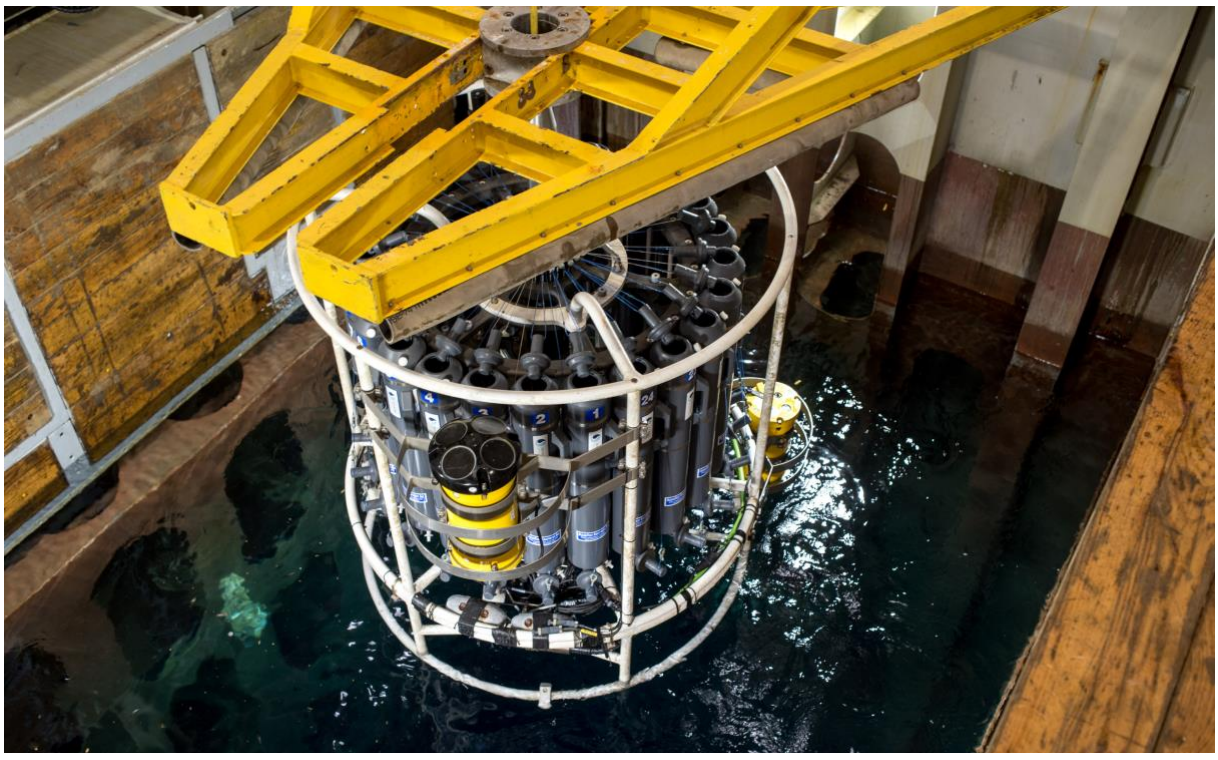

Figure 3: CTD being lowered, with the upward-looking ADCP visibile mounted on the CTD frame.

correct the calibration of the CTD conductivity. Histogram of $\Delta C = C_{CTD} - C_{Bot}$, difference of conductivity measured by CTD and inferred from bottle salinity, is approximately normally distributed. Following the recommendations given by Seabird Electronics, the conductivity values are corrected by the formula, $C_{new} = m\ C_{old}$, where m is the slope calculated by

$$m = \frac{\sum_{i=1}^{n} a_i \times b_i}{\sum_{i=1}^{n} a_i \times a_i}.$$

Here a_i and b_i are the CTD conductivity and the bottle conductivity, respectively and n is the total number of bottles.

3.2.1.2 Current Profiling – Lowered ADCP

Zoe Koenig (NPI)

Two LADCP-profilers (RD Instruments) were mounted on the CTD rosette to obtain vertical profiles of horizontal currents. The ADCPs are 6000 m rated, 300 kHz Sentinel Workhorses. The units received power from an external battery canister with a housing identical to that of the instruments. All three units are installed on the rosette in a balanced distribution to ensure minimum tilt. Each ADCP has the L-ADCP option installed (firmware v16.3). The ADCPs were configured to sample in master and slave mode to ensure synchronization. The master ADCP pointed downward (SN 24474) and the slave ADCP pointed upward (SN 24472). The compass of each instrument was last calibrated in Tromsø, in their respective orientation in 2018. The resulting compass errors were less than 4°. Because the batteries are in an external canister, we expect the compass calibration to be valid.

In total 28 profiles of LADCP were taken. Communication with the instruments, start & stop of data acquisition and data download were done using the BBTalk software. PC time (UTC) was transferred to each instrument before each cast. The vertical bin size (and pulse length) was set to 8 m for each ADCP. Single ping data were recorded in narrow bandwidth (to increase range), in beam coordinates, with blank distance set to zero. The data from the first bin are discarded during post processing. To mitigate a possible influence of previous pinging, especially close to steep slopes, staggered pinging with alternating sampling intervals of 0.8 s and 1.2 s were used. The altimeter worked reliably and no sign of degradation of LADCP data quality was observed.

The LADCP data are processed after the cruise using the LDEO software version IX-13 based on Visbeck (2002). For each master/slave profile data, synchronized time series of CTD and navigation is used. The NMEA GPS stream is automatically stored in the CTD *.hex files with each scan and are post-processed as 1-s bin averages, same as the ADCP ping rate. LADCP-relevant processing of the CTD data included the identical steps in the SBE-Data Processing software. Additionally, 2-minute time averaged profiles from the 150 kHz SADCP are included for constraint on the inversion of the LADCP data. The

SADCP data are obtained from processing of single ping data using CODAS, but before a vigorous editing. The magnetic declination is obtained from https://www.ngdc.noaa.gov/geomag/calculators/ magcalc.shtml, using the WMM (2019-2024) model, at the day and position of the profile.

3.2.1.3 Microstructure Profiling – The MSS

Zoe Koenig (NPI)

Microstructure profiling during the cruise was performed using an MSS (Microstructure Sensor Profiler, Sea&Sun Technology, Germany).
Ocean microstructure measurements were made using the MSS90L profiler (SN 053), a loosely-tethered free-fall instrument equipped with two airfoil probes aligned parallel to each other, a fast-tip thermistor (FP07), an acceleration sensor, conventional CTD sensors for precision measurements and a Chlorophyll a fluorescence sensor. The shear probes used were SN116 (sensitivity 3.59e-04, SHE2) and SN149 (sensitivity 3.52e-4, SHE1). The same sensors were used throughout the cruise and the sensors point downward when the instrument profiles vertically, and all sample at 1024 Hz. The instrument is ballasted for a typical fall speed of 0.6-0.7 m s-1 and is decoupled from operation induced tension by paying out cable at sufficient speed to keep it slack. Data are transmitted in real time to a ship-board data acquisition system. The casts were done using 4 ring weights.
In total 64 casts were done. The profiler is equipped with a sensor protection guard at the leading end.
Two different setups of the MSS were implemented, depending on if it was operated from the ship or from the sea ice.

3.2.1.4 Profiling from the ship

The deployment of the MSS from the ship was done from the starboard side, from the "small" CTD room. A motor-driven winch was mounted on several pallets and an arm was used to extend the cable from the winch to outside. The profiler was lowered in the water and brought back on board by pulling on the data cable transmission by hand. One to two casts were performed at each station.
Because of the keel of the ship, the upper 12 m of each cast were excluded from dissipation estimates.

3.2.1.5 Profiling during the ice station

The MSS was operated from the sea ice during the ice stations. We deployed the MSS through a 0.7 m x 0.7 m hole. The hole was located approximately 200 m away from the ship, ensuring sampling of undisturbed waters. A manual winch was set up by the hole, and a pop-up tent was installed on top of it to protect the electronics (data acquisition unit and a laptop). A heater was added on the second ice station when it got lower than -25. 4 to 5 sets of 3 casts each was performed each day. To avoid freezing of the sensors, the profiler was left in water, at about 2 m depth between the casts.
The MSS temperature data were compared against the thermosalinograph and the ship CTD data. We applied a constant salinity offset of -0.02 to all profiles.

Figure 4: Setup of the MSS on ice.

Table 2: Summary of the MSS data.

Date	Time (UTC)	Station	Latitude	Longitude	Bottom depth (m)	Station type	Casts
2022-02-27	07:15:45	P5	80.6865	33.9812	164.67	ice station	4 cast 1:4
2022-02-27	07:15:45	P5	80.6865	33.9812	164.67	ice station	3 casts 5:7
2022-02-27	07:15:45	P5	80.6865	33.9812	164.67	ice station	3 casts 8:10
2022-02-27	07:15:45	P5	80.6865	33.9812	164.67	ice station	3 casts 11:13
2022-02-27	07:15:45	P5	80.6865	33.9812	164.67	ice station	1 cast 14
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 15:17
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 18:20
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 21:23
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 24:26
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	2 casts 27:28
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 29:31
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 32:34

2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 35:37
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	2 casts 38:39
2022-03-01	14:45:09	P7	82.0386	29.8910	3390.23	ice station	3 casts 40:42
2022-03-04	15:10:22	NLEGX	81.8562	29.6185	3197.73		2 casts 43:44
2022-03-04	22:17:15	NLEG24	81.6829	30.4892	2825.39		2 casts 45:46
2022-03-05	14:50:51	NLEG21	81.5682	30.9409	1132.33		2 casts 47:48
2022-03-05	22:23:04	NLEG20	81.5108	30.9361	735.82		2 casts 49:50
2022-03-07	07:28:32	SIce Kvitøyrenna	80.1205	29.2725	305.92	ice station	3 casts 51:53
2022-03-07	07:28:32	SIce Kvitøyrenna	80.1205	29.2725	305.92	ice station	2 casts 54:55
2022-03-07	07:28:32	SIce Kvitøyrenna	80.1205	29.2725	305.92	ice station	3 casts 56:58
2022-03-07	07:28:32	SIce Kvitøyrenna	80.1205	29.2725	305.92	ice station	3 casts 59:61
2022-03-07	07:28:32	SIce Kvitøyrenna	80.1205	29.2725	305.92	ice station	3 casts 62:64

3.2.1.6 Data processing

Processing of the MSS data was performed using routines developed at the University of Bergen and reported in detail elsewhere. Full-scan (1024 Hz) data from all channels of the MSS profiler are edited for transmission errors and spikes, and then averaged to 256 Hz to reduce noise. Time series are converted into vertical wavenumber space using a smooth fall-speed profile. The fall speed is derived from the time derivative of the (2-Hz low passed) pressure record. The dissipation rate of turbulent kinetic energy per unit mass, e, is estimated from the isotropic relation $\varepsilon = 7.5\nu\left\langle u_z^2 \right\rangle$, where n is the viscosity of seawater (approximated as a function of temperature) u_z is the shear of the horizontal velocity resolved at cm-scales. Shear wavenumber spectra are calculated using half overlapping 256-point (about 0.7 m) Hanning windows. The shear variance is obtained by integrating the shear wavenumber spectrum between 2 cpm and an upper cutoff number depending on the Kolmogorov wavenumber. The upper cutoff is determined by iteration and is set to maximum 30 cpm (a limitation of the probe size) or 14 cpm when 2-14 cpm integrated e < 2 ´ 10^{-8} W kg^{-1}. This range is not affected by the narrowband noise peaks. A small correction is applied for the unresolved variance assuming the Nasmyth's form. A further check is employed by comparing dissipation values from both probes, and anomalous data were discarded prior to averaging at 1 m resolution. The noise level measured in quiet regions is about ~ 10^{-9} W kg^{-1}.

CTD data from the precision sensors are low-passed at 10 Hz. Conductivity and temperature records are aligned by advancing one record over the other in -100 to 100

scan range, with unit increments, and obtaining the best advance giving the minimum salinity spiking (result is typically 35 to 50 scans). CTD data are then averaged at 10-cm intervals prior to calculate salinity. Finally, the 10-cm vertical averaged salinity and density profiles are despiked (detecting only large spikes).

3.2.2 Chemical Oceanography (Task T2-1.1)

Elizabeth Jones (IMR)
PIs: Melissa Chierici (IMR), Agneta Fransson (NPI) – not onboard

The focus of the work onboard was to investigate carbonate and nutrient chemistry for the study of ocean acidification and the carbon cycle, in surface waters, the full water column and the sea ice environment (snow, ice, brine, under-ice water) in regimes and natural gradients in the Barents Sea that are complementary to those studied during the previous Nansen Legacy cruises. This included a higher resolution CTD transect across the northern shelf and slope (Figure 5) and a new CTD transect west of Kvitøya (Figure 6). The water column and sea ice were sampled for carbonate chemistry (total alkalinity, dissolved inorganic carbon), inorganic nutrients (nitrate, nitrite, phosphate, silicate) and the stable oxygen isotope ($\delta^{18}O$) of water. Analyses for the determination of dissolved oxygen were performed onboard.

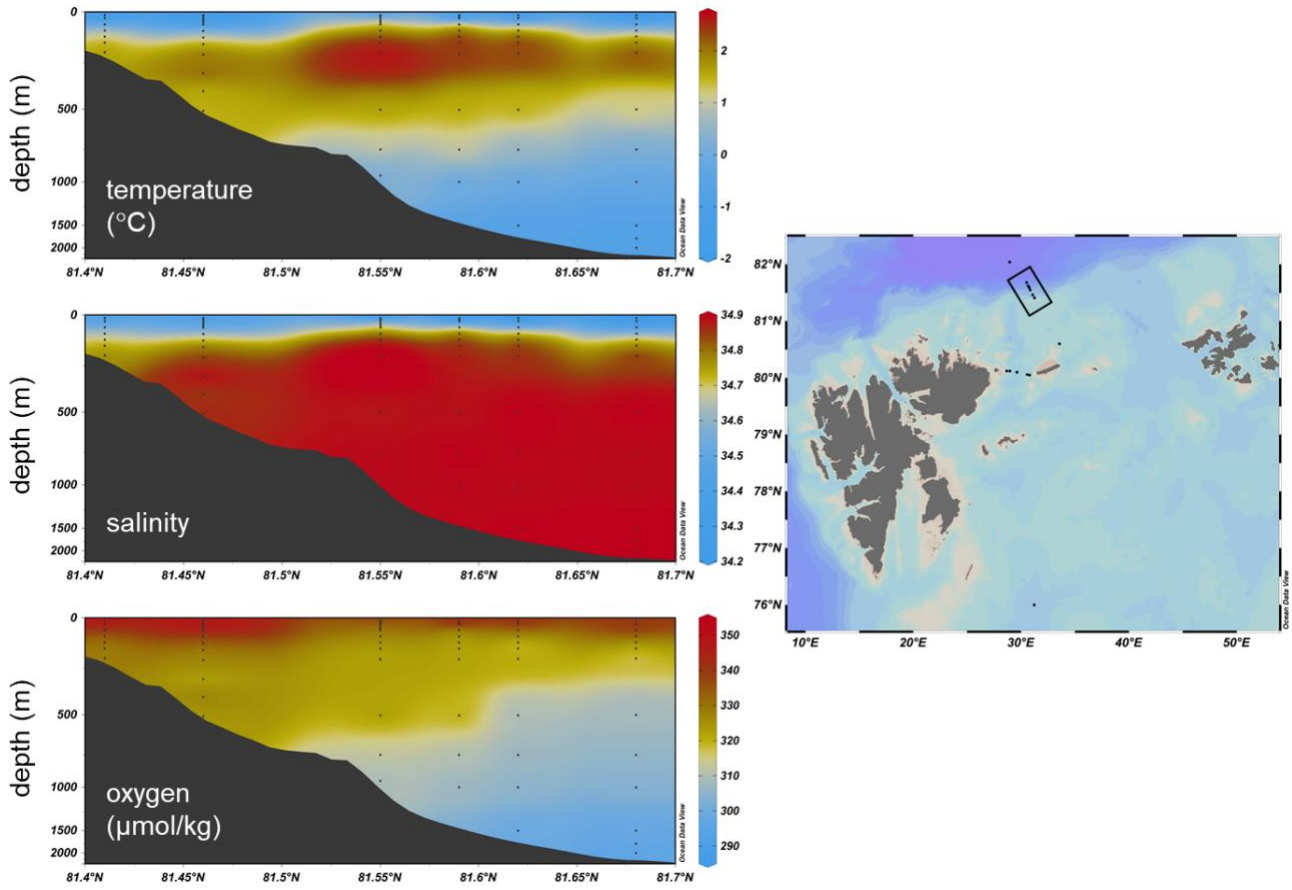

Figure 5: Temperature (upper panel), salinity (middle panel) and dissolved oxygen (lower panel) in the full water column during the northern shelf and slope CTD transect (black box on map).

Seawater was sampled from Niskin bottles mounted onto a 24 bottle CTD-Rosette from a total of 15 stations for post-cruise analyses of carbonate chemistry, nutrients and $\delta^{18}O$ (Table 3). Sampling and future analysis followed the protocol described in *Nansen Legacy Sampling Protocol version 10* and *Dickson et al. (2007)*. The samples for carbonate chemistry were sampled first or directly after those for dissolved oxygen and were stored in the cool and dark for post-cruise analyses at IMR in Tromsø. Samples for inorganic nutrients were preserved with chloroform and stored at 4°C in the dark for post-cruise analyses at IMR in Bergen.

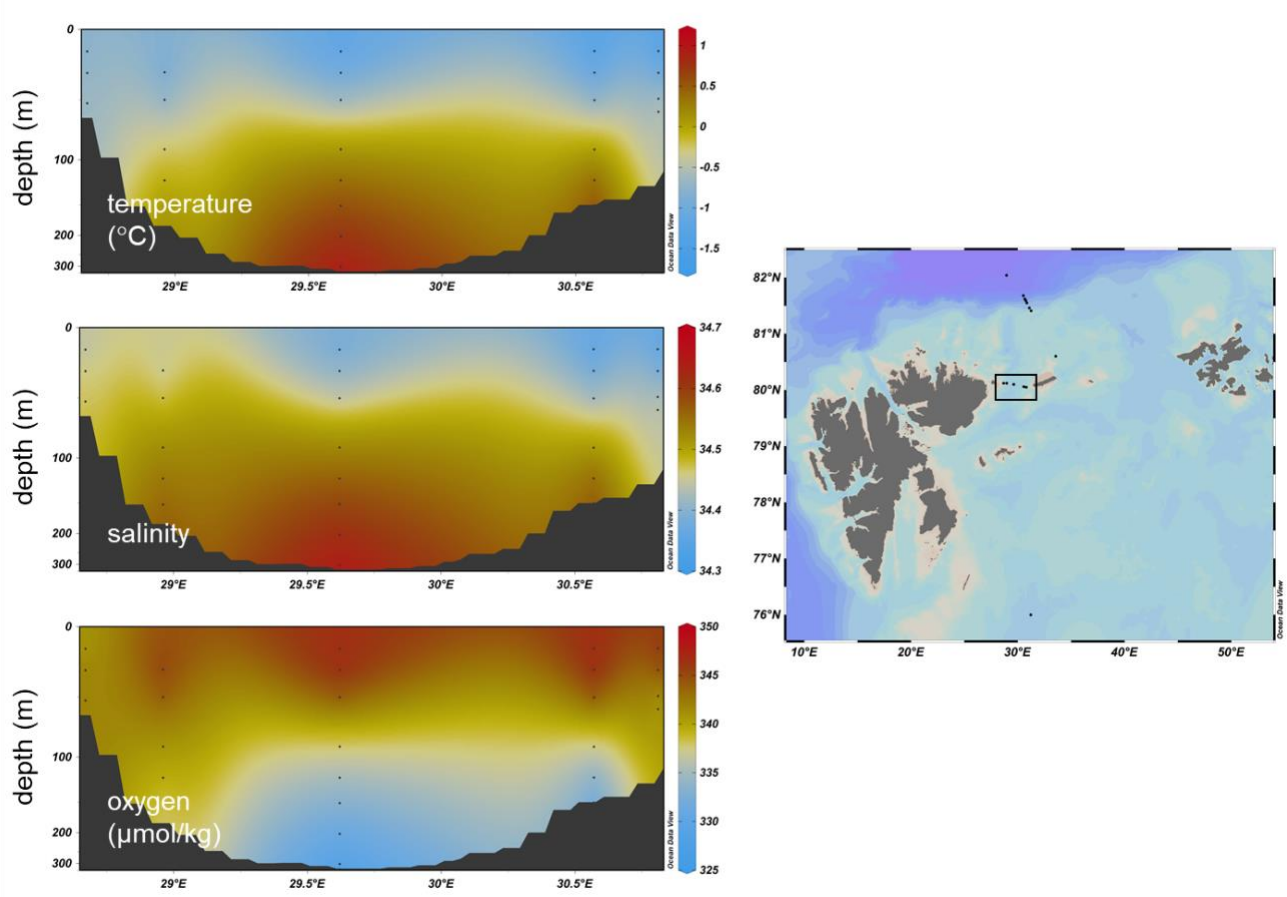

Figure 6: Temperature (upper panel), salinity (middle panel) and dissolved oxygen (lower panel) in the full water column during the west Kvitøya CTD transect (black box on map).

Dissolved oxygen was sampled from 6 CTD stations. On each station replicate sampling was performed at least one depth to ensure that the analytical performance was acceptable. The first oxygen sensor on the CTD was used until cast 9, after which it froze and stopped working and was replaced by a second sensor. Data from the Winkler titration showed that both the first and second oxygen sensors had an average offset of 0.1-0.3 ml/L. The CTD depth profiles indicate that the performance was overall good and that the offset was largely consistent, showing some dependency with depth, which can be corrected for in post-processing. Table 3 summarizes the seawater sampling from the CTD-rosette.

Table 3: Seawater samples from the CTD-Niskin Rosette for chemistry.

Station Name	CTD #	# AT/DIC/pH	# Nutrients	# $\delta^{18}O$	# $DO_{Winkler}$
P1	1	11	11	11	13
P5	3	8	8	8	
P5	4				10
P7	7	17	17	17	12
NLEG24	10	15	15	15	12
NLEG23	11	13	13	13	

NLEG22	12	11	11	11	
P6	13	12	12	12	10
NLEG19	15	13	13	13	
NLEG17	17	7	7	7	
Kvitøyrenna 1	20	4	4	4	
Kvitøyrenna 2	21	7	7	7	
Kvitøyrenna 4	23	9	9	9	10
Kvitøyrenna 6	25	7	7	7	
Kvitøyrenna 7	26	4	4	4	

3.2.3 Microbes (/Lower trophic level): biodiversity, abundance, biomass, distribution and activity (Tasks T3-1, T3-2, T3-3, T3-4)

Miriam Marquardt (UiT), Evan Patrohay (UiT), Lucie Goraguer (NPI), Rosalie McKay (UiT), Megan Lenss (NPI/UiT)

The activity contributes to tasks T3-1 and T3-2 and links to T3-3 and T3-4. Samples for microbial (virus, prokaryotes and protists) community composition, abundance and activity were collected from one open water stations (P1) and four ice-covered stations (P5, P6, P7 and Sice-K). Pelagic samples were collected at all stations, while stations P5, P7 and Sice-K (Kvitøyarenna) also included ice samples (ice-cores and under ice water). Sampling also included phytoplankton nets. Chlorophyll *a* (Chl *a*) concentration and live protist samples were analysed on board, while all other samples were preserved or frozen for later analyses.

List of parameters sampled:

Biodiversity

- Genetic identification of community composition of protists and prokaryotes (Metabarcoding)
- Qualitative analyses of protists >10 µm from net hauls (Net)

Abundance and biomass

- Algal biomass (total and >10 µm chlorophyll a concentration Chl *a*)
- Abundance of bacteria, virus, pico and nano-plankton by flow cytometry (FCM)
- Quantitative analyses of protists from water samples by light microscopy (Microscopy)
- Particulate organic carbon and nitrogen (POC/PON)

Activity

- Bacterial production (only from ice cores)
- Net community production (only from ice cores)
- Primary producer's response to light intensity (P vs I curve) (only from ice cores)

Table 4: water column and ice sampling for microbes (see text above for abbreviations).

Stn	Depth (m)	Metabarcoding	Phytoplankton net	Chl. *a*	FCM	Microscopy	POC/PON	Bacterial production	NCP	P vs. I curve	Nutrients	Ice meiofauna/alage
P1												
	0			x	x	x	x	x				
	15	x		x	x	x	x					
	20			x			x					
	30			x		x	x					
	40			x			x					
	50			x			x					
	60			x		x	x					
	90			x		x	x					
	150			x			x					
	120			x			x					
	200	x		x	x		x					
	bottom			x			x					
	0-50		x									
P5												
	15	x		x	x	x	x					
	20			x		x	x					
	30			x		x	x					
	40			x			x					
	50			x			x					
	60			x		x	x					
	90			x		x	x					
	bottom	x		x			x					
	0-50		x									
P7												
	15	x		x	x	x	x					
	20			x			x					
	30			x		x	x					
	40			x			x					
	50			x			x					
	60			x		x	x					
	90			x		x	x					
	120			x			x					

	200	x		x	x		x					
	500			x			x					
	1000			x			x					
	1500											
	2000						x					
	2500											
	bottom			x			x					
	0-50		x									
P6												
	0			x		x	x					
	15	x		x		x	x					
	20			x		x	x					
	30			x			x					
	40			x			x					
	50			x			x					
	60			x		x	x					
	90			x		x	x					
	120			x			x					
	200	x		x			x					
	500			x			x					
	Bottom-10m			x			x					
	0-50m		x									
Sice-K												
	15	x		x		x	x				x	
	30			x		x	x					
	40			x			x					
	60			x		x	x					
	90			x		x	x					
	120			x			x					
	Bottom-10m	x		x			x				x	
	0-50m		x									
P5ice												
	0-3	x		x	x	x	x	x	x	x	x	x
	3-10	x		x	x	x	x	x	x	x	x	x
	10-20	x		x		x	x				x	x

	20-30	x		x	x	x	x	x	x	x	x	x
	30-50			x		x	x				x	
	50-top			x	x	x	x	x	x	x	x	
2nd	0-3			x								
2nd	3-10			x								
2nd	10-20			x								
2nd	20-30			x								
	2x 0-5		x									
	2x 0-15		x									
	UIW 0.5	x		x		x	x					
	UiW 5			x		x	x					
P7ice												
	0-3	x		x	x	x	x	x	x	x	x	x
	3-10	x		x	x	x	x	x	x	x	x	x
	10-20	x		x	x	x	x	x	x	x	x	x
	20-30	x		x		x	x				x	x
	30-top			x	x	x	x	x	x	x	x	
	2x 0-5		x									
	2x 0-15		x									
	UIW 0.5			x		x	x					
	UIW 05			x		x	x					
Sice-K												
	0-3			x			x	x	x	x	x	x
	3-10			x			x	x	x	x	x	x
	10-20			x			x	x	x	x	x	x
	20-30			x			x				x	x
	30-50/top			x			x	x	x	x	x	
	2x 0-5		x									
	2x 0-15		x									
	UIW 0.5			x		x	x					
	UIW 05			x		x	x					

Phytoplankton net hauls/microscopy/Chl *a* biomass:

Water and ice chlorophyll *a* concentration of the two sice fractions >0.7 µm (total) and >10 µm was measured directly on board with use of a Turner Triology fluorometer. Total chl a concentration was very low at all stations with < 0.03 µg/L (Figure 7).

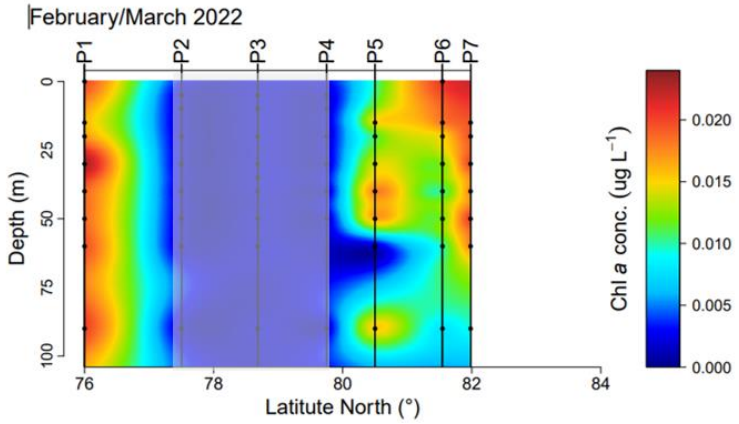

Figure 7: Total chl a concentration (µg/l) in the water column at the main Process station P1, P5, P6 and P7 during the JC3 cruise.

Microscopy was performed from water samples taken from P1, P4, P5, P7 and Sice-K and from ice samples at station P5, P7 and Sice-K. In the pelagic, few cells of diatoms such as *Chaetoceros* spp., dinoflagellates (e.g., *Ceratium* spp.) and ciliates were observed, with the latter in slightly higher abundances. The sea ice flora had low biomass, however a few typical arctic species were observed such as *Nitzschia* spp. (frigida/neofrigida) spp. and *Entomoneis* sp. (Figure 8: Example P5 station).

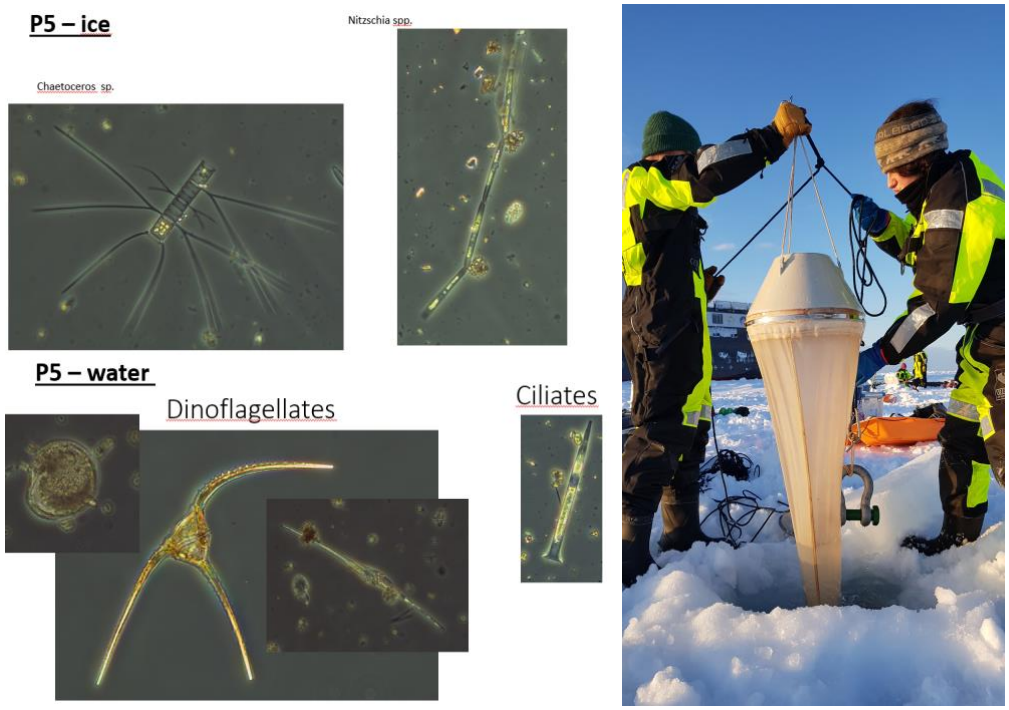

Figure 8: Microscopy pictures from ice (upper panel) and water samples (lower panel) of P5 (sampled 27.-28.2.2022). To the right: Phytoplankton net hauls through the hole at the ice station.

3.2.4 Characterize biological mesozooplankton communities and seasonality in terms of biodiversity, abundance, biomass and distribution patterns (T3-1.1), secondary production (T3-2.1), trophic ecology (T3-4.2), sympagic-pelagic-benthic coupling (T3-4.4)

Anette Wold (NPI), Elisabeth Halvorsen (UiT), Janne E. Søreide (UNIS), Amalie Gravelle (UiO)

The focus on the JC3 cruise was to continue the standard mesozooplankton sampling as done on previous seasonal cruises (1.1), to determine secondary production (2.1) and respiration (metabolism) of some of the key mesozooplankton species with focus on *Calanus* spp. In addition, trophic ecology was targeted by collecting bulk mesozooplankton and selected species (*Calanus* and deep-water species) for later analyses of stable isotopes and fatty acid composition (4.2). Further the phenology of *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus* were studied by comparing ~100 randomly picked *Calanus* from a known sample volume (quantitatively by sub-samples) from South of the Polar front (Stn. P1), interior shelf (Stn. P4) to the high North in the deep Arctic Ocean (Stn. P7). These specimens were photographed for later measurements of body size (prosome length), lipid sac volume as percentage of prosome volume (condition/fitness).

3.2.4.1 Mesozooplankton taxonomy, abundance, biomass and genomics (T3-1.1 & T3-2.1)

Anette Wold (NPI), Elisabeth Halvorsen (UiT) & Janne Søreide (UNIS)

Purpose

The main objective was to describe the mesozooplankton taxonomic composition, abundance and biomass along the transect going from open Atlantic water (P1) to ice covered Arctic water (P7). We expect to see a gradient in the presence of Atlantic and Arctic species.

The data obtained during this cruise (JC3) will supplement the seasonal investigation of zooplankton communities with data collected in Aug 2019 (Q3), December 2019 (Q4), March 2021 (Q1) and April/May (Q2).

Description of work

We have sampled with Multinet Midi (HydroBios, opening: 0.25m^2, net length: 250 cm, 5 nets) and Bongo Nets (HydroBios, opening: 2 x 0.2827m^2, net lengths: 250 cm): For both nets we have been using both 180 µm and 64 µm mesh nets in order to cover all size groups. We refer to the samples from the two mesh sizes as “mesozooplankton” and “small mesozooplankton” respectively.

Taxonomy and abundance were sampled at 5 standard depth intervals using the Multinet. The depth sampled were as follows, P1: bottom-200, 200-100, 100-50, 50-20 and 20-0 m, P5: bottom-100, 100-50, 50-20, 20-0 and P7: bottom-600, 600-200, 200-50, 50-20 and 20-0 m. All samples were preserved in 4 % formaldehyde free from acid. In

addition, we sampled with Multinet Mammoth 180 µm at P7 (HydroBios, opening 1m^2, 9 nets) the following layers: bottom-2000, 2000-1500, 1500-1000, 1000-600, 600-400, 400-200, 200-50, 50-20, 20-0m. These samples were split in two, one part for taxonomy and one part for metabarcoding.
Metabarcoding, taxonomy, total biomass (dry weight) and fatty acid were sampled using Bongo Nets from the bottom-surface at P1 & P5 and from 1000 m to the surface at P7. Each Bongo Net were split in two, net 1 was used for metabarcoding and taxonomy with ½ of the sample for each, the metabarcoding sample was again split in ½ one sample for bulk community and one sample to sort out selected species. Net 2 was used for biomass and fatty acid. The biomass samples were dried and measured onboard. Genetic samples for metabarcoding was preserved in ice cold 96 % ethanol. Taxonomy samples were preserved in 4 % buffered formaldehyde and will be used to support the metabarcoding samples. For more info regarding the method see Nansen Legacy sampling protocol vs 10, chapter 9.2.1.

Table 5: Overview of mesozooplankton sampling.

Purpose	**Gear**	**Station**	**Pcs**
Mesozooplankton taxonomy	Multinet 180 µm	P1, P5, P6, P7, Kvitøyarenna	33
Small mesozooplankton taxonomy	Multinet 64 µm	P1, P5, P6, P7	24
Mesozooplankton taxonomy	Multinet Mammoth 180 µm	P7	9
Mesozooplankton metabarcoding			9
Mesozooplankton taxonomy (1/2)	Bongonet 180 µm	P1, P5, P7, Kvitøyarenna	4
Mesozooplankton barcoding (1/4)			4
Mesozooplankton metabarcoding (1/4)			4
Mesozooplankton biomass (1/2)			4
Mesozooplankton fatty acid (1/2)			4
Small mesozooplankton taxonomy (1/2)	Bongonet 64 µm	P1, P5, P7	4
Small mesozoopl. metabarcoding (1/4)			4
Small mesozoopl. barcoding (1/4)			4
Small mesozooplankton biomass (1/2			4
Small mesozooplankton fatty (1/2)			4

Table 6: Overview of sampling depths, and hauling speed for different zooplankton nets.

Gear	**Sampling depth**		**Hauling speed (m/s)**	
	Shallow	Deep	lowering	heaving
Multinet midi 180 µm	Bot-200-100-50-20-0m	Bot-600-50-20-0m	0.5	0.5
Multinet midi 64 µm	Bot-200-100-50-20-0m	Bot-600-50-20-0m	0.5	0.3
Multinet Mammoth 180	Bot-2000-1500-1000-600-400-200-50-20-0m		0.5	0.5
Bongonet 180 µm	Bottom-0m	1000-0m	0.5	0.5
Bongonet 64 µm	Bottom-0m	1000-0m	0.5	0.3
MIK 1500 µm	Bottom-0m	Bottom-0m	0.3	1.5

3.2.4.2 Macrozooplankton abundance, biomass & species composition (T3-3.1)

Anette Wold (NPI), Elisabeth Halvorsen (UiT) & Janne Søreide (UNIS)

Objective

The aim of the sampling is to provide information on seasonal and regional variation in abundance, biomass, and genetic composition of the microzooplankton community along a North-South gradient in the Barents Sea.

Description of sampling

Biomass was taken with vertical hauls of the MIK net (1500 µm) from the bottom to the surface at all process stations as well as an additional sample from 1000-0 m at P7. Rare taxa and gelatinous zooplankton were isolated from the sample and two subsamples were weighted and taken for (1) for metabarcoding stored in ethanol at -20 degrees C, and (2) for later taxonomic identification of species, stored at room temperature in 4% buffered formaldehyde. Gelatinous zooplankton were picked out from MIK net immediately after sampling. Individuals in good conditions were weighted, photographed and stored individually with ice cold 96 % ethanol for genetic analysis.
For more details regarding the method see "Nansen Legacy sampling protocol vs 10, chapter 9.2.2".
Macrozooplankton trawl and acoustics were not done on this cruise.

Table 7: Overview of macrozooplankton samples from MIK net during Q1.

Station	Depth	Main taxa in the sample
P1	300-0 m	Very little biomass.
P5	170-0 m	*Calanus* spp., *Themisto libelulla, Thyssanoessa* spp.
P7	1000-0 m	*Calanus hyperboreus*, *Themisto abyssorum*, *Cyclocaris guilelmi*
P7	3300-0 m	*Calanus hyperboreus*, *Themisto abyssorum*, *Cyclocaris guilelmi*, *Hymenodora glacialis & Atolla* sp.
Kvitøyarenna	280-0 m	*Calanus* spp., *Thysanoessa* spp. (little biomass)

Table 8: Overview of gelatinous zooplankton samples sampled from the MIK net.

Station	Depth	Taxon
P1	300-0 m	*Aglanta digitale* (71 ind. total, 10 ind. for genetic)
P5	170-0 m	*Mertensia ovum* (2 ind. total/genetics)
P7	1000-0 m	*Aglanta digitale* (6 ind. total/genetics), *Botrynema ellionorae/brucei* (2 ind. total/genetics)
P7	3300-0 m	*Aglanta digitale* (1 ind. total/genetics), *A*tolla sp. (6 ind. total/genetics), *Botrynema ellionorae/brucei* (11 individuals total/genetics) *Beroe sp.* (large yellow/orange, 1 ind. total/genetics)
Kvitøyarenna	280-0 m	Mertenisa ovum (4 ind. total/genetics, Beroe sp. 1 ind total/genetics, Aglanta digitale 45 ind. total, 6 for genetics)

3.2.4.3 Measure how current environmental settings drive the phenology of primary and secondary production (T3-2.2)

Elisabeth Halvorsen (UiT)
PI: Camilla Svensen (UiT) – not onboard

The goal of this task is to characterize how current environmental settings drive the seasonality of copepod production. To meet this goal mesozooplankton productivity was determined experimentally for selected key-species through egg-production/egg-hatching incubations in different seasons, representing species with contrasting life-history traits and reproductive strategies in open and ice-covered waters. Assuming that female copepods allocate their ingested carbon into egg production rather than into growth, the specific egg production rate can be used as an estimate of the production of the population. The data collected during the JC3 (Closing the gap) cruise will be used to supplement the seasonal dataset on copepod production. Egg production experiments of *Calanus hyperboreus* were conducted at two stations, P5 and P7, and for *Oithona similis* only at P7, all experiments run at ~ *in situ* temperature (0˚C).

Egg production and egg hatching experiments

Egg production and egg hatching experiments followed the protocol in Chapter 9.3.3. "Experimental protocol for copepod egg incubations to determine secondary production and grazing experiment" of the Nansen Legacy Sampling Protocol Version 10 and were conducted at P5 and P7 (Table 9: List of copepod egg production experiments and samples for carbon content during JC3 (2022702).).

Table 9: List of copepod egg production experiments and samples for carbon content during JC3 (2022702).

Egg incubation experiments				
Station	Temperature (˚C)	Species	Number of individuals	Comment
P5	0	*Oithona similis*	30	
P5	0	*Calanus hyperboreus*	36	
P7	0	*Calanus hyperboreus*	30	
CHN samples				
Species	type	Number of individuals	Station	Comment
Oithona similis	females	306	P5	100, 103, 103 individuals filtered on pre-combusted GF/Fs

3.2.4.4 Metabolism and phenology of key mesozooplankton

Janne E. Søreide (UNIS)

Respiration is an important estimate of biological activity and is closely connected to the organisms' life history. During the seasonal cruises we have closely followed the metabolism to the three *Calanus* species: *C. hyperboreus*, *C. glacilais* and *C. finmarchicus*. This genus comprises up to 80% of the mesozooplankton biomass in the Svalbard and Barents Sea region. They develop through 6 nauplii (N1-N6) and 5 copepodid stages (I-CV) before they reach adulthood (adult males AM and females AF) and perform extensive seasonal migration. These species are morphological very similar and is primarily determined to species level by their differences in body sizes. For live species presence of red pigmented antennas and gonopores (females) are 90% reliable (Choquet et al. 2018; Daase, unpubl. results). The Arctic oceanic species *C. hyperboreus* is the largest of the three, followed by the Arctic shelf species *C. glacialis* and the smallest boreal *C. finmarchicus* which closely follow the distribution of Atlantic water. Further, measurements with the omnivorous *Metridia longa* were performed to test for differences in metabolism between zooplankton with different life strategy.

Copepods were sampled from different depths by either Bongo 180 µm net or the Multinet/Mammot (180 µm) net. Measurements were taken on individuals of four different species comprising three different life stages: *Calanus finmarchicus* (CV), *C. glacialis* (CIV, CV and adult males and females) *C. hyperboreus* (adult females and males), *Metridia longa* (CV and females). A picture was taken of each individual after respiration incubations. From the pictures morphological measurements of prosome length, prosome area, and lipid sac area, will be conducted. The majority of the individuals were, after the photography, placed in tin cups for later measurements on dry weight and C/N ratio. Incubations to measure feeding and fecal pellet production, by putting one individual in a flask with seawater from max chlorophyll a concentration, was not conducted in March since earlier experience (from Q1) showed that the algal concentrations and feeding activity was too low to be measured by this method in March. There has been criticism of the small incubation volumed used when using the Loligo plate system. During the JC3 cruise we therefore conducted in parallel 100 ml and 250 ml bottle incubations for comparison. This was done for *C. glacialis* females at stn. P5 and *C. hyperboreus* females at Stn. P7. These were run at zero degrees (*in situ* temperatures).

***Calanus* phenology:** As mention above it is challenging to perform correct species identification of *C. finmarchicus* and *C. glacialis* since they largely overlap in body size in regions there *C. glacialis* primarily has a 1-year life cycle an thus do not grow much larger than the North Atlantic *C. finmarchicus* which also have a 1-year life cycle in the northern range of its distribution area. During JC3 we therefore did an effort to quantitatively analyse 100 Calanus from each station which were stage determined an photographed before frozen at -80 °C for later molecular analyses for correct species determination. From these data we can determine average prosome sizes (and ranges) for the three *Calanus* species in the Barents Sea to control that we have used valid size-ranges to separate *C. finmarchicus* and *C. glacialis* to species in our formaldehyde-seawater preserved community analyses.

Vertical distribution: For *C. hyperboreus* we did a high depth resolution investigation of the vertical distribution of adult females and males at Stn. P7. The nine net strata possible to sample with the Mammot net made it possible for more detailed vertical resolution in the Arctic Ocean. Pre-liminary results show that females were mainly found between 2000 to 600 m and males from 1000 to 600m. *C. glacialis* primarily in the upper 500m.
Samples collected during JC3 will be analysed summer and autumn 2022.

3.2.4.5 Other opportunistic samples
Janne E. Søreide (UNIS)

During the cruise opportunistic samples of hyperbenthos and deep-water net samples were taken for barcoding and stable isotope and fatty acid analyses. Especially deep-water specimens from Station P7 were focused upon and representative samples of deep-water amphipod: *Cyclocaris guilelmi*, and deep water decapod *Hymenodora glacialis*, as well as *Paraeuchaeta glacialis* and *P. barbata*. Hyperbenthos was collected by RP sled (named beam trawl in data file since RP sled not included from earlier for gear) at two locations: Station P1 and in northern Kvitøyarenna. This was the first time we were using a hyperbenthic sled on RV Kronprins Haakon, and we collected nematodes by bobble and plot method and mysids. Further, *Periphylla periphylla* from bottom trawl (Campelen trawl) were taken for barcoding. In addition, images and size measurements of snow crab (38 individuals captured in a 20 min trawl haul close to Hopen) were collected.

Under ice net samples taken by suction pump (60 µm) at stations P7 and ice station close to Kvitøya (qualitative samples 30 min to 1 hr). These samples were used for barcoding (picking out harpactoids and other specimens of interest) or preserved whole in ethanol for metabarcoding.
These samples are not high priority to analyse.

3.2.4.6 RF2 Human impacts
Amalie Gravelle (UiO), Janne E. Søreide (UNIS)

RF2 takes a multidisciplinary approach to investigate human activities' impacts on the Barents Sea ecosystem in the past, present and future. The approach includes field observations, experimental work including combined effects, existing models and new innovative model development within and across the main impacts of ocean acidification, contaminations and effect of fisheries.
No multistress experiments were planned for the JC3 cruise, but temperature effects on *Calanus glacialis* and *C. hyperboreus* females were investigated (*in situ* vs. +5°C). Further live females of *C. glacialis* and *C. hyperboreus* were collected and brought back to the cold labs at UiO for later multistress experimental work headed by post doc Khuong Dinh.
Several respiration tests of single individual *Calanus* were conducted on board, at stations P5 and P7. The aim was to do respiration tests for both surface and close-to-bottom depths, at temperatures 0°C and 5°C for females of *Calanus glacialis* and *Calanus*

hyperboreus. We wanted to study both *Calanus* from the deep and those in the surface, as these will have different metabolic rates due to being either in a state of diapause (deep) or more active (surface). The zero temperature is the closest we manage to come to in situ temperatures in the field with the incubators we have on board. The high temperature (+5 °C) is similar to the warming treatment for the long-term laboratory experiments run at UiO during the cruise, based on IPCC scenario of the elevated temperature under climate change. The respiration measurements on board Kronprins Haakon allow for comparison of the response of newly collected females with the females that have been reared in the lab for a long time (since September 2021; JC2 cruise). All data will be complementary to get more knowledge of how *Calanus* responds to warming conditions.

Respiration on board Kronprins Haakon was measured using Loligo MicroResp. In each test, a total of 20 copepods were placed in individual wells on the 24 well plates. The well size used was primarily the 500 μL for *C. glacialis*, while the 1700 μL well plates were used for the much larger *C. hyperboreus*. The tests ran for 4-12 hours, depending on how long it took to get a measurable decrease in oxygen concentrations and thus respiration rate. The tests were ended before the oxygen level dropped below 40-60%. After the respiration test the animals were photographed individually, snap-freezed in liquid nitrogen, and stored at -80°C for later molecular analyses (to detect stress level).

At P5 we ran four respiration tests on *C. glacialis*, two at 0°C and two at 5°C. The samples were collected from the surface (0-100 m). We did not find sufficient numbers of *C. glacialis* at deep depths, nor did we find enough *C. hyperboreus* at any depths to run tests with these at Stn. P5 (interior Barents Sea shelf station with max. depth 200 m only). At both stations 20 individuals (only C. glacialis at P5, both at P7) were directly photographed and snap-frozen as a reference/control.

At P7 we ran ten respiration tests, five with *C. glacialis* and five with *C. hyperboreus*. *Calanus glacialis* was again only found in the surface, so all tests on this species were with samples from the upper 200 meters. Two tests were done for *C. glacialis* at 5°C, and three at 0°C. For *C. hyperboreus* we did two tests with surface samples (upper 200 m), and four tests with samples from the deep (bottom to 1500 m). Of the ones from the surface, we did one test at 0°C, and one at 5°C. Of the ones from the deep, we did two tests at 0°C, and one at 5°C.

Live samples were also collected for laboratory experiments of multiple stressors on Arctic copepods. From P5 we collected ca. 150 *C. glacialis* females. From P7, ca. 100 *C. glacialis* females, and ca. 120 *C. hyperboreus* females. These were brought back to the University of Oslo and stored individually in 0.25 l containers, kept at 0.5°C, prior to experiments.

3.2.5 Fish genetics (T2-3.1)

Marius Filomeno Maurstad (UiO)

T2-3.1. Climate change and fisheries: Spatial environmental variables and genomics

The aim of this task is to investigate the roles of spatiotemporal population structure and possible local adaptations in three key fish species in the northern Barents Sea ecosystem: The Northeast Arctic population of the Atlantic cod (Gadus morhua), capelin (Mallotus villosus) and polar cod (Boreogadus saida). If local adaptations are important for population dynamics and responses to climate change, it may be necessary to revisit the management of fisheries in order to maintain intact spatial and genetic structure. For this purpose, individual samples of these species will be collected at transect cruises in summer and winter for whole-genome sequencing. We will also include samples of the same species collected in associated projects at other locations, such as at their spawning grounds. From these data we aim to characterize the population sub-structure(s) for each of the species, as well as identify signatures of directional selection, for instance as a result of temperature adaptations. In addition to spatial structure, we will assess possible temporal structure, linked to seasonal partitioning of habitat use.
During this cruise we have been collecting tissue samples of the Polar cod, Northeast Arctic cod, and capelin from the process stations: P1, north of P1, Kvitøya close to P4, and North-West Spitsbergen. There was planned for one demersal (Campelen) and one pelagic (Harstad) trawl at each station but due to the difficult weather conditions not all trawls were done, see Table 10 for which trawls were completed at the different process stations. The trawl type going first was decided by echosounder by determining where in the water column the biomass occurred. After a successful pelagic trawl at P4 the demersal trawl was changed to a pelagic trawl due to difficulties in finding suitable bottom conditions for trawling. This second pelagic trawl came up empty. During this cruise we used a modified Harstad trawl. This trawl made it possible to catch pelagic samples in areas with dense sea ice.

Table 10: Number of fish sampled at each of the stations during JC3.

Station/Species	**P1**	**P1 vicinity**	**P4**	**Northwest Svalbard**
Trawl type	Harstad	Campelen	Harstad	Campelen
Polar cod		12	18	
Northeast Arctic cod		4		25
Capelin	25			

For most sampled fish, a total of three tissue samples were taken, one tissue combination to be used for whole-genome DNA sequencing (aprox. 20x coverage). Tissue combinations consist of either liver or fin clip and gill (capelin), spleen and gill or fin clip for polar cod, and spleen and fin clip for Northeast Arctic cod. Gut samples of polar cod and Northeast Arctic cod were taken for metagenomic sequencing. Additionally, otoliths were collected for all fish except capelin to determine age.
Metadata was recorded for all fishes sampled, and includes the following parameters: fork length, total weight, sex, maturation stage and presence of ecto/endoparasites.

3.2.6 Benthos work (T3-1.1, T3-1.2. T3-4.4)

Andreas Altenburger & Birte Schuppe (UiT)

The benthos team worked on the following topics:
T3-1-1: Characterize and quantify biota of the Arctic Basins by sampling sediment communities for biodiversity and abundance/biomass assessments; specifically microbes (PI Lise Øverås, UiB), benthic foraminifera (PIs Elisabeth Alve and Silvia Hess, UiO), multicellular meiofauna (PI Bodil Bluhm, UiT). Characterize biota of the Arctic Basins by collecting voucher material of benthic macro- and megafauna to be archived at the UiT Museum for a legacy of physical material of the project (PIs Bodil Bluhm and Andreas Altenburger, UiT)
T3-1-2: Relate environmental conditions to biological communities by sampling for sediment properties (grain size), indicators of food availability (total organic carbon and nitrogen, sediment pigment amount) and food sources (δ13C/δ15N, pigment composition) (PIs Elisabeth Alve and Silvia Hess, UiO, and Paul Renauld, Akvaplan-niva)
T3-4-4: Sympagic-pelagic-benthic coupling by sampling representative benthic invertebrate taxa for stable carbon and nitrogen stable isotope analysis (PIs Bodil Bluhm, UiT, and Lis Lindal Jørgensen, IMR)

The main tools to reach the goals were the box-corer (BC) and demersal trawls. A total of 14 BC samples (3 replicates per station except at P1) were retrieved from five stations (Table 11) and sampled for sediment properties and biota (Table 12).

Table 11: Overview over box-core stations and physical parameters at each station.

Station / Parameter	**P1**	**P5**	**P7**	**Slope 500**	**Slope 1500**
Date (2022)	23.02.	27.02.	02.03. and 03.03	01.03.	05.03.
Depth (m)	316	186	3535	518	1469
Coordinates	N 75.9997 E 31.2179	N 80.6845 E 33.6606	N 82.0458 E 29.4858	N 81.4601 E 31.0695	N 81.5821 E 30.7973
Salinity at bottom	34.93	34.53	34.93	34.85	34.9
Temperature at bottom (°C)	1.86°C	- 0.10 °C	- 0.70	1.77	0.48
Number of successful box-cores taken	2	3	3	3	3

In addition, demersal trawls (Campelen Super 1800) were taken on the 23rd of February, after P1 (N 76.4994, E 31.1935) and the 9th of March 2022 during transit to Longyearbyen (west of P5, N 80.2524, E 11.0463). Invertebrates from these trawls were used for the Nansen Legacy collection at the Arctic University of Norway (protocol 10.4) and stable carbon and nitrogen isotope analysis of benthic in fauna and epifauna (10.3.13).

Table 12: Overview over protocols followed at each station.

Station / Protocol	P1	P5	P7	Slope 500	Slope 1500
Sediment pigments (protocol 10.3.1)	X	X	X	X	X
Benthic chlorophyll a/phaeopigments (10.3.2)	X	X	X	X	X
Sediment grain size and sediment carbon, nitrogen and stable isotopes (10.3.3)	X	X	X	X	X
Sediment microbes (protocol 10.3.4)				X	X
Foraminiferal community and metazoan meiofauna community (10.3.5)	X	X	X	X	X
Quantitative macrofaunal assemblage (10.3.9) (250 µm mesh size)		X	X[1]	X	X
Stable carbon and nitrogen isotope analysis of benthic in fauna and epifauna (10.3.13)		X	X	X	X
Nansen Legacy collection at the Arctic University of Norway (10.4)		X			
Sediment extraction for trace elements (10.2)			X	X	X
Sediment for eDNA (3 subcores per BC) (10.3.16)	X	X	X	X	X

[1] Sediment was partly altered on the way up for BC 2 and 3 on station P7. Quantitative macrofaunal assemblage could therefore not be retrieved for those two BCs.

For a detailed station overview see Appendix 2: Cruise diary, full station table.

3.3 Sea ice-based measurements

3.3.1 Sea ice physical properties (Tasks T1-1.2, T1-2.2)

Adam Steer & Bonnie Raffel (NPI)

3.3.1.1 Overview

On the Nansen Legacy JC3 'Winter gaps' cruise, a small sea ice physical processes team collected data at three ice stations (see Figure 1). At each location the standard Nansen Legacy parameters were prioritised – ice core collection and a detailed snow pit at the coring site used by most of the other teams on board (see the Nansen Legacy Sampling Protocol, v10). The planned work program also included walked or skie'd surveys of sea ice thickness and snow depth using a towed electromagnetic sounder (Geophex GEM2) and GPS snow probe (snowhydro Magnaprobe); and drone overflights to capture an overview image and relative floe topography. We also collected shipborne sea ice observations using the Arctic Shipborne Sea Ice Standardisation Tool (ASSIST). Finally, the sea ice physical properties team contributed to ice floe safety inspections and assessment at each site.

3.3.1.2 Working style

The sea ice physical processes team has multiple jobs on sea ice, needs to consider battery and equipment care, and also considers the risk of evacuation because of bears or ice breakup. We do not take all our equipment to the ice at once, instead deploying what we need when we need it to the ice on pulks via the gangway. We used a 10 foot

workshop container secured on the working deck to dry, maintain, and stage equipment. This containerized workspace was cramped and not fully sealed from weather, but it was essential to our operations. Future sea ice focused efforts should consider funding a larger (20 foot) replacement.

We split our effort and planning into work blocks – 2.5 hours in the morning and 3 hours in the afternoon, and decide how to arrange tasks in each block. In general the first block of any station is dedicated to basic Nansen Legacy parameters (ice cores, snow pit), and then we spread out from there – to instrument calibrations, drone flights, floe surveys. This helps us coordinate equipment, and also helps coordinate where bear guards need to be.

Over the past few Nansen Legacy voyages we developed a transect style of 'set the furthest point early, and return to the ship from there' when doing snow and ice thickness surveys. This means we can clearly identify our desired operating limits, give bridge teams some certainty about our plans, and shrink our risk envelope as we undertake the survey. One very important aspect to this strategy is that there should always be room to expand an operational envelope again, for example if visibility is awful at survey start and then improves.

On JC3 we invested effort in timing our transect 'lines', and used a time based strategy to help us get a good estimate of how we could cover ground and get back to the ship in time, every time. For an example, on P7 day 3 we skied away from the ship for 20 minutes, then estimated how many transect legs we could do given time available and the distance covered. We then did a 10 minute ski in one direction, then zigzag legs of 20 minutes each. We were cut short by 20 minutes due to a bear arriving, so we missed two 'half lines', but otherwise this strategy was very effective.

Both these strategies – setting far points early, and tracking walk / ski time – are easily adaptable to different teams with different capabilities, and hopefully help avoid some pressure points, for example nervousness about where the team is going, and also feeling a need to do N thousand measurements. Instead we focus on what is possible in the location and time envelope available.

3.3.1.3 P5 general conditions and work done

Ice conditions were highly variable at P5 – a lot of rubble and uneven ice, with substantial flooding in snow loaded regions.

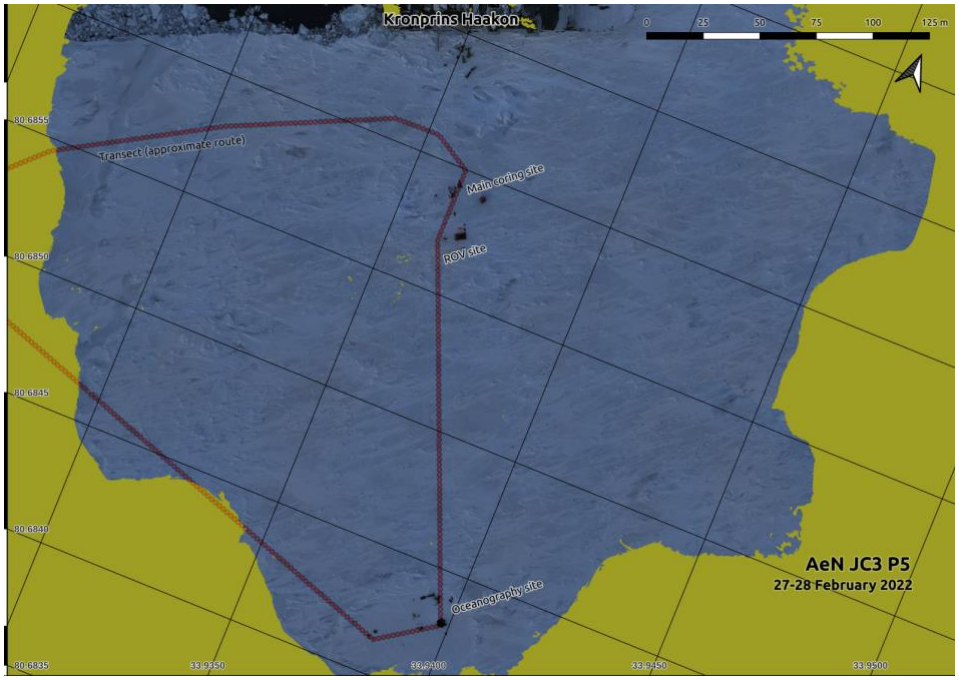

Figure 9: P5 site orthophoto from drone imagery.

At P5, after finalising the main coring site work aerial imagery for floe mapping was collected and a short GEM2 + magnaprobe survey for snow depth and ice thickness was made. A second smaller set of ice cores was also collected on slightly thinner ice on the next patch of level ice away from the ship. We also made a second snowpit in a small dune, containing 40cm of snow on 14cm of ice, and 10cm of negative freeboard.
P5 broke up before a long transect could be performed and was abandoned on the afternoon of the second day.
Here, we encountered our largest technical issue of the voyage – losing settings on the ANAFI USA controller which could not be resolved without internet. No further flights could be made. Post cruise investigation found a hardware failure in the controller.

3.3.1.3.1 Summary of snow and ice thickness

Outside of the main coring site mean snow depth was 0.09 m with a median of 0.06 m and standard deviation of 0.08 m, minimum 0.01 m and maximum 0.57 m. Data from the GEM2 are extremely preliminary, and will likely change in future. Our first cut analysis gives a mean snow + ice combined thickness from the GEM2 survey of 0.61 m, with a median of 0.57 m and standard deviation of 0.21 m, with minimum 0.32 m and maximum 1.74 m.

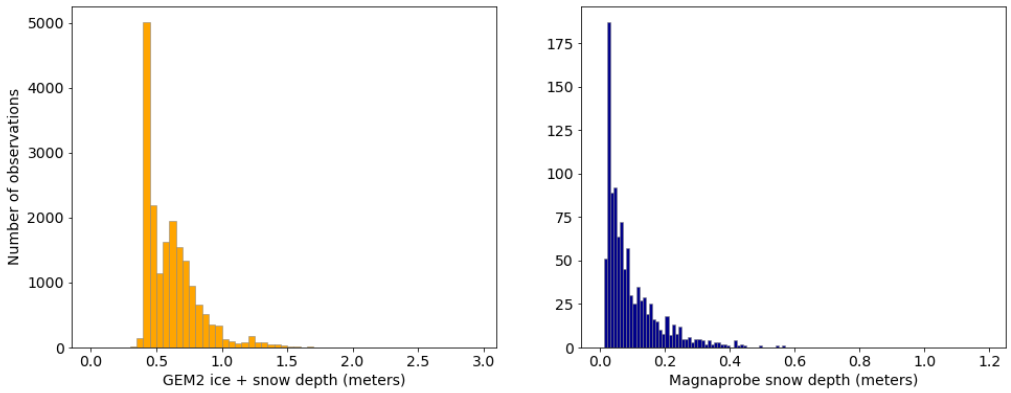

Figure 10: Combined snow + ice thickness (left) and snow depth (right) histograms from transect walks on P5.

3.3.1.4 P7 general conditions and work done

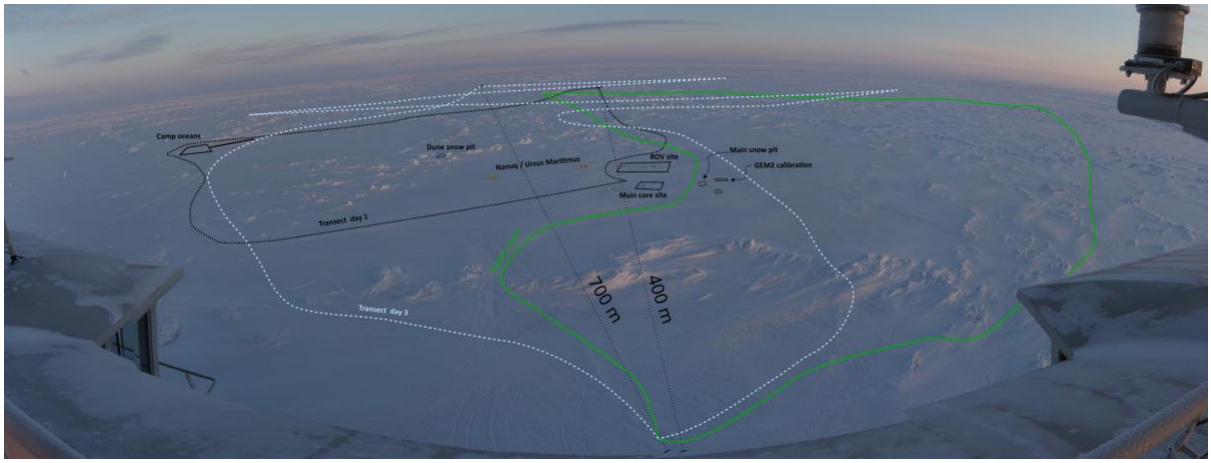

Figure 11: P7 site overview.

At P7 the ice was far more stable, although still quite thin with a relatively deep snow cover. On day 1 we completed the main coring and snow pit program, calibrated the GEM2, and ski'ed approximately 1 km in a rough triangle with GEM2 and Magnaprobe measurements. We also piloted a short ROV mission to help the oceanography team set instrumentation correctly under the sea ice.

On day 2, with bear interruptions we worked locally to the ship on a detailed snowpit in a snow dune before lunch, and after lunch we were able to collect another 1km transect in a rough triangle.
On the final morning (day 3) we focused on a long GEM2 and Magnaprobe transect, collecting approximately 2.5km of data in a zig zag pattern covering approximately 500 x 500 m of ice.

3.3.1.4.1 Summary of snow and ice thickness

Outside of the main coring site, using Magnaprobe data from all three transect walks, mean snow depth was 0.21 m with a median of 0.16 m and standard deviation of 0.15 m, minimum 0.015 m and maximum 1.06 m (N=4652). As for P5, data from the GEM2 are extremely preliminary, and will likely change in future. Our first cut analysis gives a mean snow+ice combined thickness from the day 3 GEM2 survey of 1.05 m, with a median of 0.85 m and standard deviation of 0.53 m. Minimum was 0.38 m, maximum 2.931 m.

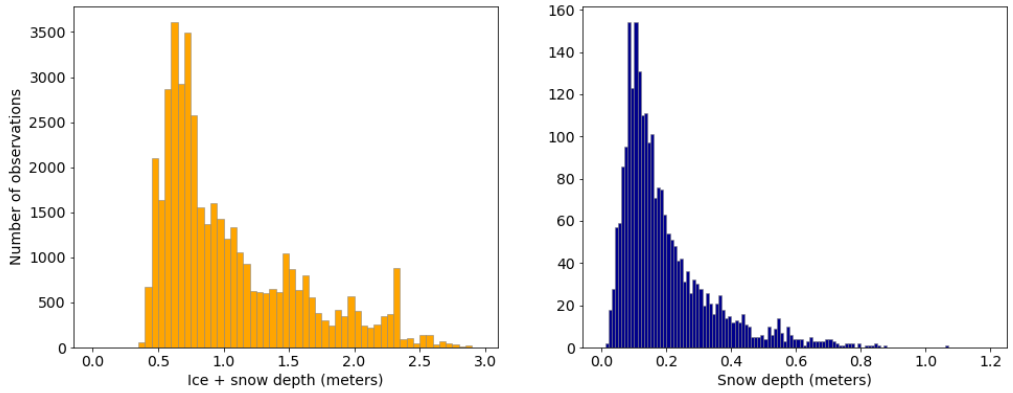

Figure 12: Combined snow and ice thickness (left) and snow depth (right) from transect walks on P7.

3.3.1.5 Kvitøyrenna (Sice-K) general conditions and work done

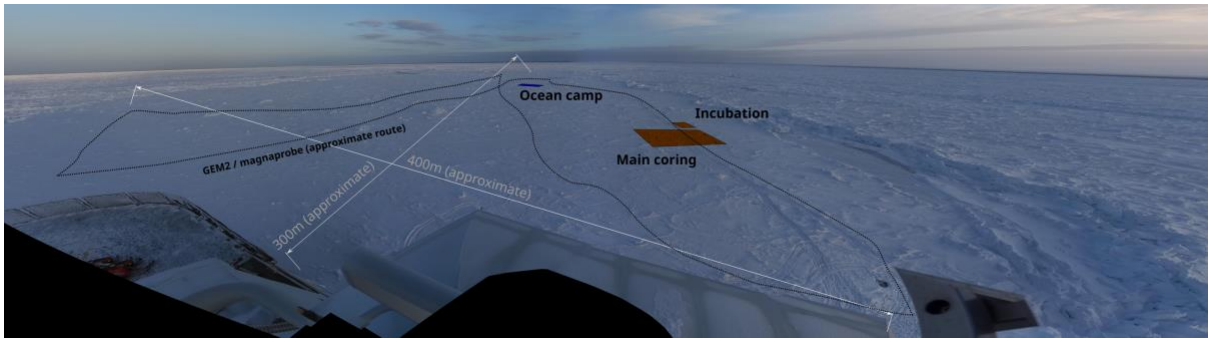

Figure 13: Kvitøyrenna (Sice-K) site overview.

A short 'extra station' was undertaken at the western margin of Kvitøyrenna, with Storøya visible at the start of the station. The ice in the region was quite deformed, but not really consolidated. Some tall (2m+) ridges were present, and a lot of openings and new ice were also prevalent. Very thin ice under snow made walking conditions tricky, especially near the ship.

On the first day we completed the main coring program and a snow pit. Due to polar bear interruption in the afternoon we did not complete any more work on the first day. On day 2, we were able to complete a transect walk, aiming for an irregular butterfly pattern covering main sites on the ice floe, and a broader sample of the ice we worked on.

3.3.1.5.1 Summary of snow and ice thickness

Outside of the main coring site, using Magnaprobe data from all three transect walks, mean snow depth was 0.16 m with a median of 0.16 m and standard deviation of 0.06 m, minimum 0.02 m and maximum 0.44 m (N=1301). As for P5 and P7, data from the GEM2 are extremely preliminary, and will likely change in future. Our first cut analysis gives a mean snow+ice combined thickness from the GEM2 survey of 0.512 m, with a median of 0.86 m and standard deviation of 0.12 m. Minimum was 0.2 m, maximum 2.72 m.

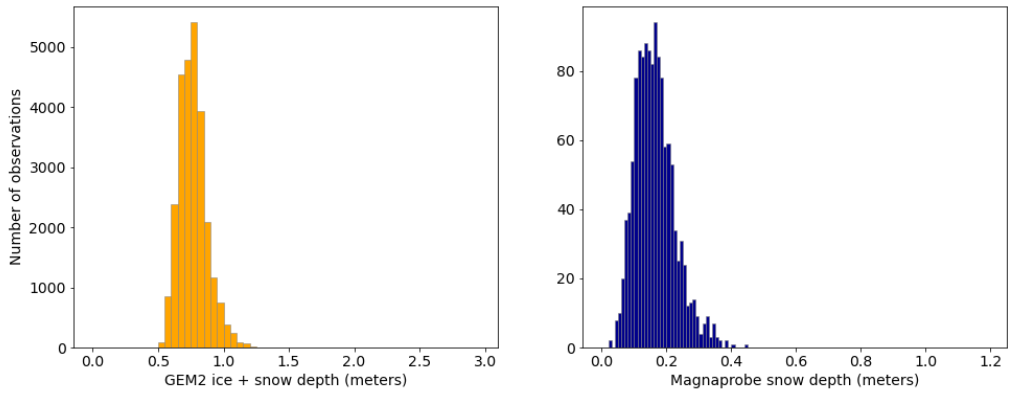

Figure 14: Combined snow and ice thickness (left) and snow depth (right) from transect walks on Kvitøyrenna (Sice_K).

3.3.1.6 Summary of datasets collected:

- Main coring site cores (NL sampling protocol v10) at P5, P7 and Kvitøyrenna (Sice-K)
- Main coring site sea ice temperature and salinity profiles (NL sampling protocol v10)
- Main coring site oxygen isotope ratio samples of sea ice at 5cm resolution for the upper 20 cm (NL sampling protocol v10), plus full cores at 10cm resolution and finally, snow.
- Main coring site detailed snow pits, secondary site detailed snowpits as time permitted
- 277 aerial images over P5, producing a 5cm orthophoto of the work site (approx. 300 x 300 m)
- Approximately 600m of ice thickness and snow depth profile (GEM2, Magnaprobe) at P5, 4.5km at P7 and 1km at Kvitøyrenna
- Detailed snow dune pit at P7, including 67 images for photogrammetric reconstruction
- ASSIST observations while in sea ice, except when stationary at P5, P7 and Kvitøyrenna
- Sentinel 1a and Radarsat sea ice quicklooks for navigation assistance
- Underwater video showing ice bottom conditions using a GoPro camera and BlueEye ROV

3.3.2 Physical Oceanography (Tasks 1-1.2, 1-2.1)

Zoe Koenig (NPI)

During the ice stations, in addition to the MSS that was performed from the sea ice (see Section 3.2.1.5), several sensors were moored in a 20m radius around the MSS hole to study the under-ice ocean dynamics. An AIS was installed at the instrument site to track the instruments in case of any breakup of the sea ice.

During the first ice station, the instruments were deployed after lunch of day 1 on sea ice thickness of about 40cm. The camp was located about 220m away from the ship, on the 3 o'clock. On day 2, a crack/lead opened between the ship and the instrument site. After 3 hours waiting for the system to stabilize, the gear was rescued without any damage.

Figure 15: Cracks appearing between the ship and the instrument site (around the green tent).

The second ice station lasted 3 days. The instruments were deployed on the morning of day 1, and picked up on the morning of day 3, allowing almost 48h of measurements. The instruments were deployed on about 50 cm of sea ice thickness, at about 200 m away from the ship.

Figure 16: Camp setup at the second ice station, with all the moorings in the background and the main tent with MSS profiling in front.

The last ice station lasted 2 days. Instruments were deployed on day 1 just after lunch for Nitrate system, before lunch for the ADCP. They were recovered in the morning of day 2.
In both the second and the third ice station, the Nitrate sensor stopped recording after a few hours (about 7h), most likely because of battery shortage.

3.3.2.1 Nitrate profiling

Figure 17: Nitrate profiling.

A SUNA sensor (SN 1618) was mounted on a frame with a Concerto RBR CTD (SN 66091) equipped with a Chl a and a PAR sensor. The SUNA was setup on continuous mode, and the CTD sampled every 2s. This setup was moored just under the sea ice using a 50-m kevlar rope and a wooden beam across the hole. The mooring was lowered down to 50 m depth and brought back up to be moored under the sea ice 4-5 times a day.

3.3.2.2 ADCP

An ADCP 300kHz from RDI (S/N: 24485) was deployed under the sea ice at both ice stations. The mooring was composed of a wooden beam over a hole. From this wooden

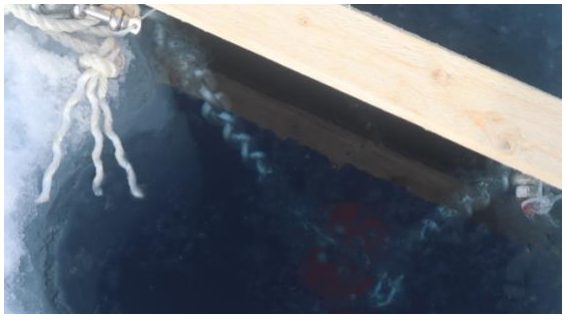

Figure 18: ADCP setup in the sea ice.

beam, two chains were attached to each side of the ADCP frame prevent the latter one from spinning. The ADCP sampled the upper 50 m on average of the water column.

Configuration file of the ADCP during the 3 ice stations:

```
CR1
CF11101
EA0
EB0
ED20
ES35
EX11111
EZ1111101
RN OCS08
WA255
WB0
WC064
WD111100000
WF176
WN50
WP50
WS200
WM1
WV175
TE00:01:00.00
TP00:01.20
CK
CS
;
```

3.3.2.3 ADV (Tasks 3-3.1, 1-1.2, 1-2.1)

Pedro Duarte (NPI)

Introduction

During this cruise it was agreed to carry out current velocity and temperature measurements under the ice with an Acoustic Doppler Velocimeter (ADV) and nitrate measurements with a Satlantic SUNA sensor, in direct relation with sampling that have been carried out in previous cruises and also planned for this one, within the scope of Research focus 1, namely: under ice turbulence measurements with a Micro Structure Profiler (MSS), current velocity measurements with an ADCP and the standard conductivity, temperature and pressure measurements with a CTD. An online document was available to several Nansen Legacy participants for several weeks before the cruise, discussing the possible coordination of all these measurements towards a better understanding/quantification of nitrate exchanges across the pycnocline, the nitracline and the mixing layer and the surface layer (McPhee, 2008), as close as possible to the ice-water interface. In addition to nitrate fluxes the mentioned document suggested also to focus on oxygen fluxes given the plans of colleagues from the Institute of Marine Research to deploy a CTD from the ice with an oxygen probe.

One of the reasons for the proposed work is providing feedback to RF3, Task 3-3, regarding the calculation of primary production and the need to get adequate model parameterizations for nitrate transport across the photic depth and between the ocean and the sea ice. Nitrate is generally seen as the "ultimate" limiting factor to the "new" primary production yield. In part (if not all) of the studied region silicic acid may limit diatom primary production before nitrate but this should not prevent non-diatom algae from keep blooming as long as nitrogen is available (e.g. Duarte et al., 2021. Moreover, most of the processes governing nitrate and silicic acid physical exchanges are the same. Therefore, lessons learnt from the former may be applied to the latter. One crucial aspect when calculating sea ice primary production is how nutrients are supplied across the ice-ocean interface and whether this supply is dominated by inertial forces (turbulence) or viscosity (molecular diffusion) (e.g. Long et al., 2012; Duarte et al., 2022).
Whereas MSS deployments may help resolving turbulence in most of the water column, they are not suitable for "very near" interface measurements, and this is where the ADV may be an important add, measuring the three-dimensional current field in a small sampling volume that, depending on the instrument position, may be located at the ice-ocean interface.
To facilitate ADV deployment under the sea ice, Kristen Fossan (NPI) constructed an aluminum articulated arm that allows regulating the proximity of the sensors to the ice bottom (Figure 19).

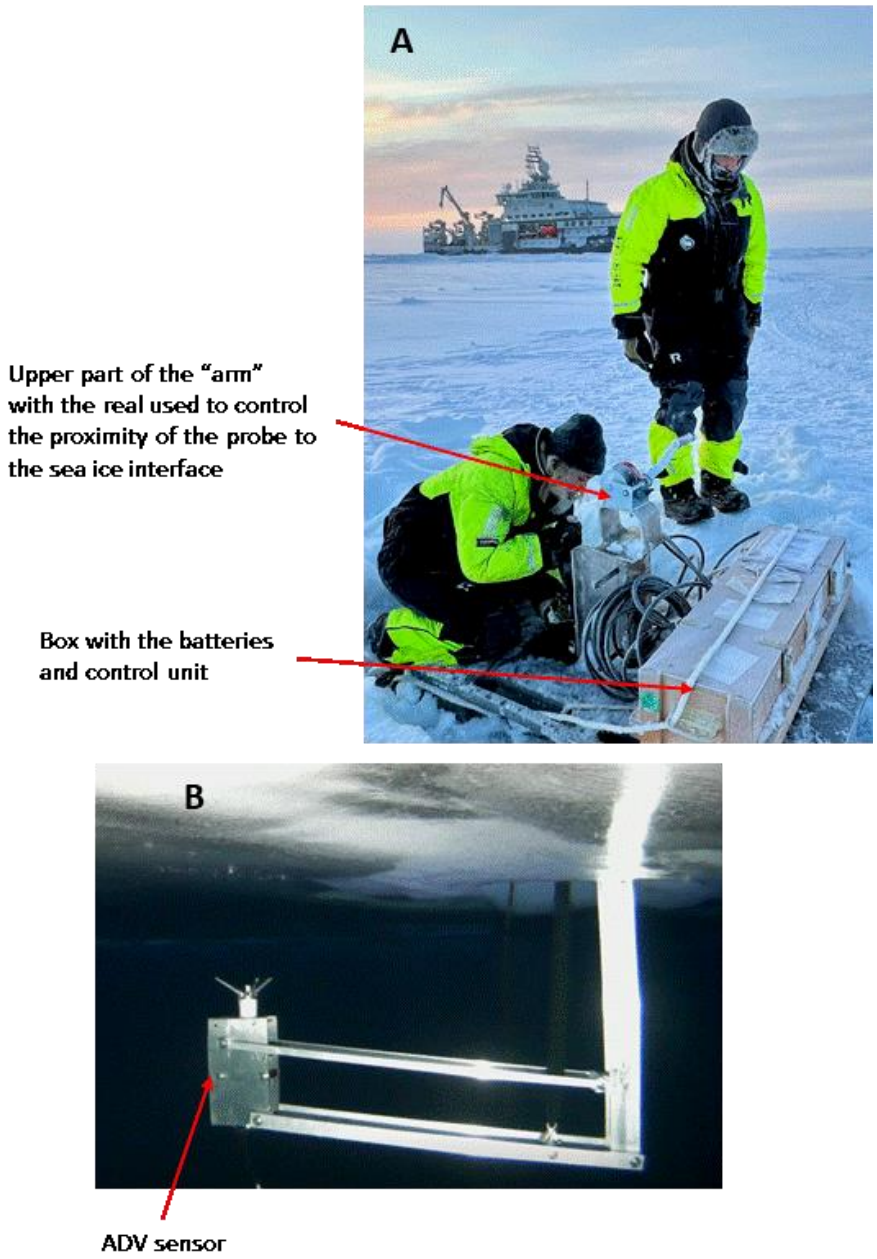

Figure 19: A. The ADV set up and components on the ice (photo: Pernille Amdahl). B. The articulated arm and the sensor placement close to the ice-ocean interface (still from underwater video by Adam Steer and Bonnie Raffel).

3.3.2.3.1 ADV deployments

Deployments under the ice were carried out at stations P5, P7 and Kvitøyarenna. Initial and final dates and times, geographic coordinates and bottom depths of these stations are synthesized in Table 13: Initial and final dates and times, geographic coordinates, and bottom depths of ADV deployments. The initial and the final times correspond to the beginning of the first and the final instrument bursts and each burst lasted for 15 minutes. – for more details see the log file ADV_onice.xlsx. All deployments took place in sea ice < 1 m thick. During the first deployment the sensor was kept at ~1 m from the ice-ocean interface. In the second deployment it started at 60 cm (first 7 measurement

bursts) from the ice-ocean interface but then the distance was lowered to 30 cm (remaining 86 measurement bursts) after checking the instrument vertical position with a ROV operated by Adam Steer. During the third deployment the sensor was kept at between 25 and 30 cm from the boundary. In all deployments a measuring frequency of 25 Hz was employed, leading to 22500 data points for each velocity component and for temperature for each burst of 15 minutes. The burst interval was 30 minutes. A total of 58, 93 and 45 bursts were obtained from deployment at P5, P7 and Kvitøyarenna, respectively. At the end of this section, we present ADV hardware configuration and deployment setup.

Table 13: Initial and final dates and times, geographic coordinates, and bottom depths of ADV deployments. The initial and the final times correspond to the beginning of the first and the final instrument bursts and each burst lasted for 15 minutes.

Deploy-ment #	Station	Initial date	Initial time	Initial latitude	Initial longitude	Initial bottom depth (m)	Final date	Final time	Final latitude	Final longitude	Final bottom depth (m)
1	P5	2022-02-27	09:22:48	80.6913 N	33.9857 E	164.95	2022-02-28	13:52:44	80.5296 N	33.7092 E	161.56
2	P7	2022-03-02	08:47:21	82.0457 N	29.4629 E	3440.1	2022-03-04	06:47:18	82.0150 N	28.5088 E	3505.09
3	Kvitøy-renna	2022-03-07	09:14:04	80.1251 N	29.2692 E	313.09	2022-03-08	07:14:01	80.3843 N	29.7611 E	183.99

The added value of these deployments depends on their combination with data obtained from other instruments (cf. – Introduction) and on results from samples collected for nitrate analysis at the sea-ice interface with an electric pump and from the bottom 3 cm of ice cores collected in the vicinity of the deployment place (see log files AeN_nitrate_from_ice_hole_Pedro_Duarte.xlsx and AeN_nitrate_from_bottom_ice_Pedro_Duarte.xlsx).

A preliminary analysis of the data obtained during these three deployments reveals some limitations mostly due to the low signal-to-noise ratio of many measurements. This seems to result from the extremely low particle concentrations in the water column (e.g., chlorophyll concentrations during the cruise were < 0.1 mg m^{-3}), since the instrument response depends on the signal reflected by suspended particles. Therefore, it will be necessary to screen the data before any in-depth analysis is carried out.

Some examples of the data processing are given below. In Figure 20 we show power spectra of the fluctuations of the three velocity components as a function of sampling frequency. These graphs suggest that most of the variability of the velocity components around their mean values, which may be seen as turbulence, occurs at frequencies smaller than 5 seconds. Right graphs show the autocorrelation of each velocity component as a function of the time lag. Autocorrelations are very high for small time lags, as expected, since values are being correlated with temporarily very close values, decreasing rapidly as the time lag increases but reaching significantly negative values for the w component roughly between 200 and 300 seconds (which correspond to measuring frequencies < 1 Hz, with highest values in the power spectrum of left figures). In Figure 21 we show the power co-spectrum of the product of vertical velocity (w) and

temperature deviations from the corresponding averages. Middle graph shows the autocorrelation of heat fluxes as a function of time lag. The bottom graph shows the heat fluxes over time. Here we may see some small differences from the patterns mentioned above for velocity alone, with small increases in the power co-spectrum for 2 Hz and some high positive autocorrelations for time lags < 50 seconds. The product of the velocity and temperature deviations from their means by the density and specific heat of seawater results in the heat fluxes shown at the bottom figure with an average close to zero. The calculation of nitrate fluxes is analogous to the approach used for heat fluxes and based on the products of velocity and nitrate concentration deviations from their mean values. However, before any such attempt is made it is necessary to confirm which are the relevant time scales and whether nitrate measurements carried out near the surface have the necessary temporal resolution. It is also necessary to confirm whether viscous or inertial forces were dominant during the measuring periods. Accumulated evidence so far suggests that there were periods dominated by turbulence and, therefore, adequate for calculating fluxes from covarying velocity and tracer deviations. In these periods we could see that most of the heat transfer took place in time scales > 0.5 – 1 second.

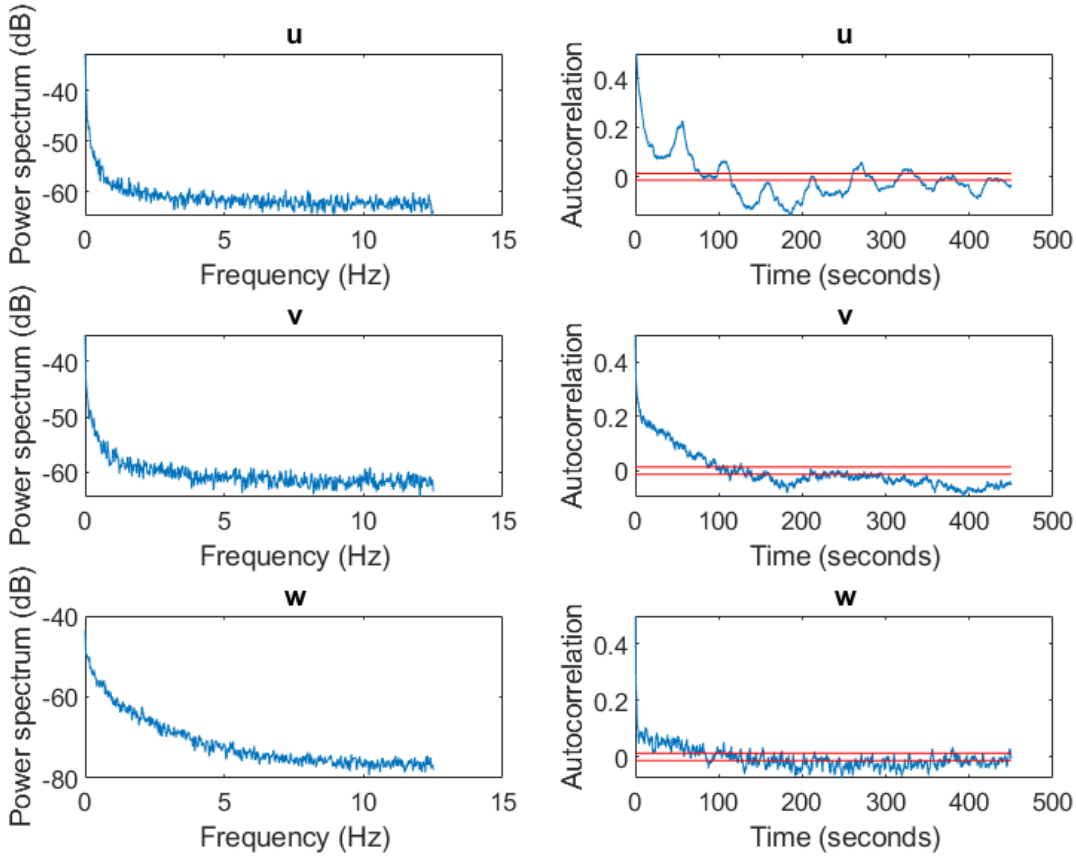

Figure 20: Results from burst #44 of the deployment in Kvitøyrenna. Left: power spectra for the three velocity components (based on velocity fluctuations around the mean) as function of sampling frequency. Right: autocorrelation of each velocity component as function of the time lag. Horizontal red lines represent the upper and lower thresholds for significant positive (above the upper red line) or negative (below the lower red line) correlations.

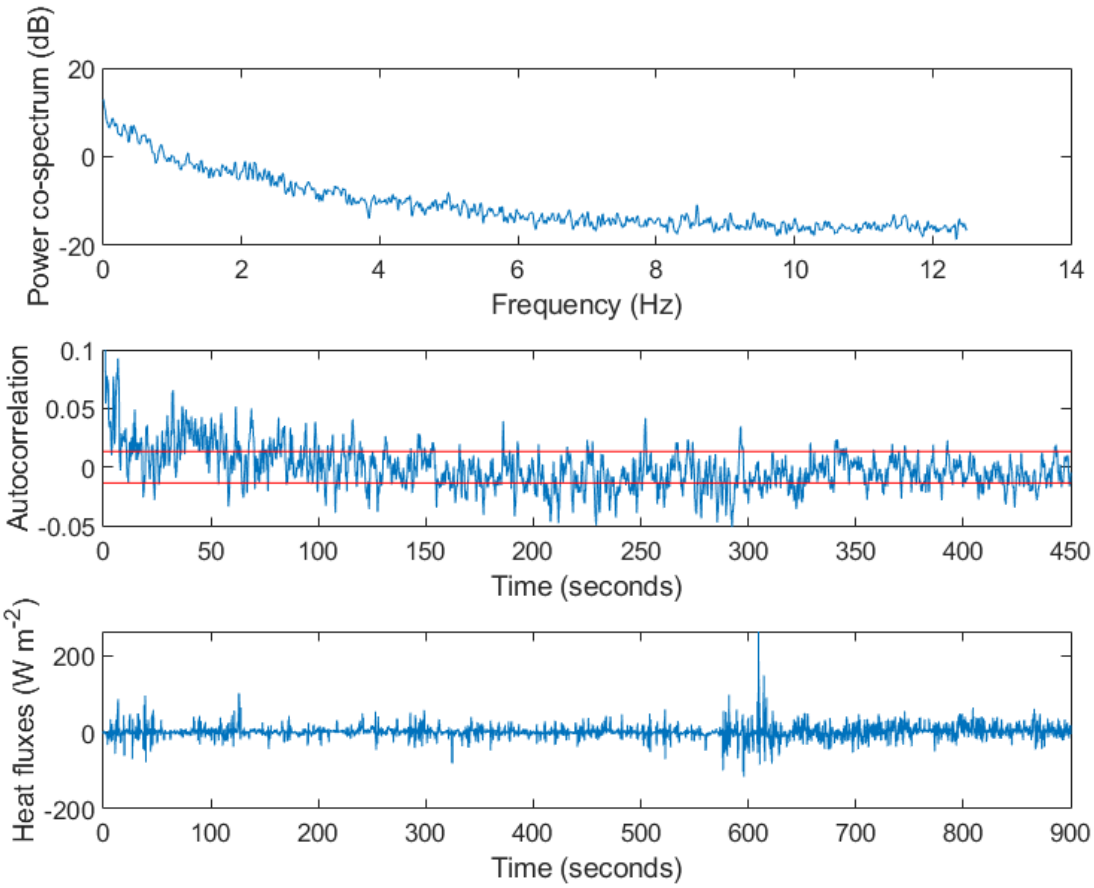

Figure 21: Results from burst #44 of the deployment in Kvitøyarenna. Upper graph shows the power co-spectrum of vertical velocity (w) and temperature deviations from the corresponding averages. Middle graph shows the autocorrelation of heat fluxes as a function of time lag. The bottom graph shows the heat fluxes over time (15 minutes).

ADV Hardware configuration

Probe Orientation ---------> UP
CompassInstalled ----------> YES
RecorderInstalled ---------> YES
TempInstalled -------------> YES
PressInstalled ------------> YES
Pressure Offset -----------> -2.330600000 dbar
Pressure Scale ------------> 0.000467000 dbar/count
Pressure Scale_2 ----------> -0.000000000020 dbar/count2
ExtSensorInstalled --------> NO
ExtPressSensorInstalled ---> NONE
CtdSensorInstalled --------> NO
LisstSensorInstalled ------> NO
Transformation Matrix -----> 2.634 -1.351 -1.285
-----> 0.075 2.215 -2.288

-----> 0.345 0.345 0.345

ADV Deployment Setup

DefaultTemp ----- (deg C) -> -1.90
DefaultSal ------ (ppt) ---> 34.50
DefaultSoundSpeed (m/s) ---> 1439.50
TempMode ----------> MEASURED
VelRange Index ----------> 2
CoordSystem ----------> XYZ
OutFormat ----------> BINARY

	Sampling 1	Sampling 2	Sampling 3
Number of Bursts ->	58	0	0
SampRate - (Hz) -->	25.00	0.00	0.00
BurstInterval (s)->	1800	0	0
SamplesPerBurst -->	22500	0	0
RecordAmpCorr ---->	YES	YES	YES
RecordCompass ---->	YES	YES	YES
RecordSensor ----->	YES	YES	YES
RecordStat ------->	YES	YES	YES
RecordExtSensor -->	NO	NO	NO
RecordExtPress --->	NO	NO	NO
RecordCtd -------->	NO	NO	NO
Bytes per Burst -->	495098	0	0

3.3.3 Chemical Oceanography (Tasks 2-1.1)

Elizabeth Jones (IMR), Marit Kollstuen (NPI)

Three sea ice stations were sampled (P5, P7, SICE-Kvitøyrenna) for ice cores, snow, brine and under-ice water. At all stations snow depth, ice thickness and freeboard were measured alongside temperature and salinity for each ice core. Under-ice water was sampled by Niskin from 0.5 and 5 m below the ice surface. Brine was sampled from sack holes drilled 10-20 cm into the ice with an ice corer. Ice cores were sampled and processed as described in *Nansen Legacy Sampling Protocol version 10*. Ice cores were sliced into 10-cm sections from the top (snow-air interface) to the base (ice-seawater interface) and were melted in airtight bags at laboratory temperature and subsampled for carbonate chemistry, nutrients and $\delta^{18}O$. Samples were preserved and stored for post-cruise analysis as described above. Total samples for carbonate chemistry, inorganic nutrients and stable oxygen isotopes in seawater and sea ice were 531. During each ice station (P5, P7, SICE-Kvitøyrenna) a SeapHOx instrument was deployed for between 20-48 hours at 1.5 m below the ice surface. The instrument contains a MicroCAT combined with a SeaFET sensor package for the time series measurements of conductivity, temperature, pressure, pH and dissolved oxygen.

3.3.4 Microbes (/Lower trophic level) (T3-1.1, T3-1.3)

Miriam Marquardt (UiT), Evan Patrohay (UiT), Lucie Goraguer (NPI), Rosalie McKay (UiT), Megan Lenss (NPI/UiT)

Sea ice samples were collected at three stations; P5, P7 and Sice-K (Sice-Kvitøyrenna). Sea ice thickness at P5 varied between 50-60cm (positive freeboard) and at P7 ice thickness was around 40cm (with negative freeboard) and at Sice-K around 50cm, freeboard positive to null. Sampling included ice-cores and water from under the ice (0.5m and 5m depth, sampled through a hole in the ice). In addition, a handheld phytoplankton net (20µm) was used to collect samples from under ice (5-0m and 15-0m depth). Table 14 shows an overview of which samples were collected (number of ice cores). Bio bulk samples were cut into sections which were pooled, and divided into sub-samples for metabarcoding, chlorophyll *a* and POC/PON. All ice core samples were cut on the ice and processed on board, except "backup core" and "physics (stratigraphy)" which were stored whole and frozen for later analyses. A CTD profile was obtained from under the ice using a handheld RBR CTD equipped with fluorescence sensor and PAR sensor. Light was measured using a LiCOR light-profiler with a metal arm through an ice core hole. At P5 we sampled a few cores at a second coring site.

At the ice-covered stations (P5, P7 and S-ice Kvitøyrenna), the aforementioned water sampling and experimental work was carried out as described (see Section 3.2.3 and Table 4). Additionally, cores were taken for net community production (NCP), P vs I incubations and an in situ PP incubation. For NCP incubations, 3 cores were sectioned at 0-3 cm, 3-10 cm, 20-30 cm (10-20cm at P7) and the top 10cm, pooled, and incubated in a light bottle and a dark bottle for each depth at -1.5°C under constant stirring with PAR of 14-37 µmol m^{-1} s^{-1}. The change in oxygen concentration was recorded every 2 s by Firesting oxygen optode sensors. A P vs I curve was also generated using the oxygen optode system from the bottom 10 cm of 3 pooled cores. At P7 and S-ice, P vs I curves were also generated using ^{14}C incubations from the pooled bottom 0-3cm and 3-10 cm of cores. At P5 and S-ice Kvitøyrenna, the bottom 3cm of 1 ice core was sampled and spiked for an in *situ* incubation in a light and a dark bottle to measure under-ice primary production.

Ice meiofauna (T3-1.1 and T3-1.3) was sampled at all three ice station (P5, P7 and Sice-K) and beside P7, all samples were assessed onboard. Similar as on the Q1 cruise in 2021, there was no or only little ice meiofauna found within the sea ice. Only at Sice-K a couple of Cyclopoida Nauplii, few ciliates and an unidentified larvae was found. All samples were preserved on either Ethanol or 2% Formaldehyde for further processing at UiT.

T3-1.1 Characterize biological communities in sympagic, pelagic and benthic realms in the northern Barents Sea and adjacent slope in terms of biodiversity, abundance, biomass and distribution patterns

Table 14: Overview over parameters sampled from the ice at the main coring sites.

	P5_ice	P7_ice	Sice-K
Ice-cores			
Chemistry	1	1	1
Physics	8	5	5
Bio bulk	5	5	1
Meiofauna/algae	6	3	6
Nutrients/salinity (Bio)	1	1	
In situ PP	1		1
P versus I	3	3	3
Net community production	3	3	3
^{14}C P versus I		2	
Nutrients (BREATHE)	1	1	1
Under ice water (0.5 and 5m depth)			
ChlA, POC/PON	x	x	x
Metabarcoding (only 0,5m)	x		
phytoplankton taxonomy	x	x	x
phytoplankton net 20µm (15-0m)	x	x	x
phytoplankton net 20 µm (5-0m)	x	x	x

3.3.5 Technology (TC-1.1, TC-1.2)

Karoline Barstein & Kristian Lampe Gjemdal (NTNU)

3.3.5.1 Blueye mini-ROV

Blueye is a small (mini) Remotely Operated Vehicle (ROV). For the JC3 cruise, three Blueyes were brought: two Blueye Pioneer and one Blueye X3.

Blueye Pioneer – Double Blueye setup

Blueye Pioneer is the first version of Blueye. It has several sensors, including wide-angle front HD camera, LED lights, and depth sensor. The Blueye Pioneer supports automatic depth and heading control. The double Blueye setup (Løvås et al., 2020) is a multi-vehicle ROV system assembled by two Blueye Pioneers and a plastic frame, made to carry larger payload instruments. The double Blueye was supposed to be used as a platform for carrying SilCam to collect particle images in the size range of zooplankton under the ice. Due to the unfortunate events described in Section 3.3.5.2, this was not carried out during the cruise.

Blueye X3
Blueye X3 is the latest version of Blueye. It has a tiltable front camera, and one can add several kinds of external equipment like gripper, camera, and lights. For this cruise the external camera and lights were mounted, facing upwards to film the underside of the sea ice.

3.3.5.2 SilCam – particle camera

SilCam system and setup
Two Silhouette Cameras (SilCam) including software, made by SINTEF, were brought to the cruise with the purpose of collecting image data of small particles (mainly zooplankton). The sensor-carrying platform was a custom-made ROV, consisting of two Blueye Pioneer mini-ROVs, one frame for mounting the two vehicles together and one frame for mounting the SilCam. The SilCam was also supposed to be mounted on CTD rosette or nets for profiles. The depth rating of the camera is 300 meters, with a safety factor of 1.4.

SilCam profile on Multinet, 22-02-2022
The first deployment of the SilCam was planned on the first deployment of Multinet. The SilCam comes with an aluminum frame for profiling. While testing the mounting of the frame to the Multinet, the frame broke in one of the corners, probably because of the force from hose clamps on the camera affecting the aluminum joints. The frame was fixed by removing both joints and mounting the camera on the frame with three hose clamps and a security string/rope. The frame was mounted on the Multinet top box with heavy-duty straps. The Multinet was deployed to 280 meters depth. When the net was surfacing, it was discovered that the glass of the camera housing was broken. The cause is still unknown, but probably a mix of low temperature, high pressure (making the sapphire glass brittle), and perhaps some external object hitting the glass. The entire interior of the SilCam (including computer, hard drive, and battery) was filled with seawater and was not possible to recover.

Other SilCam deployments
A second, identical, SilCam was brought as a backup. This device worked properly when
A second, identical, SilCam was brought as a backup. This device worked properly when tested before shipping to Tromsø. Onboard the ship, it was discovered that the camera was only collecting images sporadically. The camera and the computer were debugged for several days together with SINTEF and instrument personnel onboard. This was due to a network configuration problem which disallowed the computer to connect to the camera lens. This was outside the cruise participants scope of knowledge and was not possible to fix during the cruise. Due to the problems with the two cameras, the planned work with SilCam was not possible to conduct.

3.3.5.3 Under-ice navigation – µPAP system

Kongsberg µPap system

The under-ice navigation system consists of a Kongsberg uPap USBL, a cNode transponder, a SeaNav DGPS and a computer with the APOS software. The uPap is mounted under the ice and is connected to APOS. By connecting the SeaNav to APOS as well, the position of the cNODE can be given in a global coordinate frame.

System setup

The uPap was mounted under the ice using a 2m aluminum pole that extended under the ice. On the top side the pole was attached to two wooden pallets. The cNODE was mounted to the Blueye X3 using a 3D-printed custom mount. The mount broke partially on the second ice station and broke completely on the third. The SeaNav was placed by the uPap with the same orientation.

Operations

Sea-ice station 1 – P5

Day 1: uPAP mounted on ice. Three extra holes were drilled at 50, 80 and 100m away from the uPap and the cNODE was lowered down to measure the accuracy of the system.
Day 2: uPAP mounted and the Blueye with the cNODE was deployed. A 100m straightline transect was performed at 8-10m depth before lunch. Ice floe broke and the ice station was abandoned after lunch before the Blueye could be deployed.

Sea-ice station 2 – P7

Day 1: Video footage of the ice recorded on the Blueye while gathering navigation data with the uPap at the same time.
Day 2: uPAP performance tested by performing two straight line transects right under the ice and at 10m depth. Transects performed driving the Blueye in a straight line directly underneath the uPap to test mathematical singularity when using single transponder navigation. Lawnmower pattern transects performed to have a data set similar to a typical AUV mission.

Sea-ice station 3 – SIce Kvitøyrenna

Day 1: Deployment of KPH's HiPAP system. Collected log data from the HiPAP and recorded video data from the Blueye. Filmed the ridges near the deployment sites. Did an attempt to dive to the seafloor (approximately 280 meters) but had to abort due to battery capacity and ice drift.

3.4 Glider recoveries

Zoe Koenig (NPI), Angelika Renner (IMR)

One NL Seaglider (SG564) and one Seaglider and one Slocum glider for partner projects were recovered during the cruise.

3.4.1 Seagliders

Sg564 was recovered on 22 February 2022 17:15 UTC at P1 (75 59.95N, 31 13.15 E). The glider was recovered using a lasso system from the deck of RV Kronprins Haakon. Recovery was smooth. A CTD cast from the moonpool (sta0001) was conducted just after the recovery.

Figure 22: Recovery of Sg560 with the lasso system.

SG560 was recovered on 10 March 2022 12:32 UTC at 77.7278N, 7.6622E. The glider had been drifting with the currents since 20 Feb 2022. Regular position updates were sent with increasing frequency towards the recovery, at 5 minute intervals right before spotting the glider. Recovery was again using a lasso system from the deck of RV Kronprins Haakon. No calibration CTD was done as the glider had stopped measuring well before recovery.

3.4.2 Slocum glider

One Teledyne Webb Research 1000m electric glider (Slocum G3) was recovered on 10 March 2022 at 2:30 UTC offshore Kongsfjorden. The glider was picked up by releasing

the nose. Then the recovery rope was hooked and craned up. The recovery was smooth. A CTD cast from the moonpool (sta028) was conducted just after the recovery.

3.5 Mooring search

Zoe Koenig (NPI)

We tried to recover the mooring F1 that was deployed in October 2020 across the polar front in the Barents (77°N 21.629'; 31°E 01.590'). This mooring was pinged already in November 2021 through the moonpool during the AeN/A-TWAIN MSC2 cruise but it was unsuccessful. We pinged the mooring along a more or less north-south axis upstream and downstream of the supposed location of the mooring. We pinged the mooring approximately every 2 miles, twice upstream and twice downstream of the supposed mooring location and at the location. We did not get any coherent results, could not localize the mooring and did not get it back.

3.6 Satellite data usage and ordering

Marit Kollstuen (NPI), Angelika Renner (IMR)

SAR imagery was used for planning and navigation before and throughout the cruise. While with internet coverage, images were acquired through PolarView (www.polarview.aq) and on the bridge via the IcySeas app. Outside of internet coverage, NPI's Vixed service enabled acquisition of daily updated SAR images (see below). The SAR imagery was invaluable to assess sea ice conditions and evaluate potential locations for sea ice stations as well as planning the route through dense sea ice.

Radarsat-2: high resolution SAR imagery from the Radarsat-2 (RS-2) satellite was ordered for the P4 station to be acquired on the 26th of February, but was not used in the end, as swell broke up the sea ice around P4 and the station was not visited. Other attempts to acquire RS-2 imagery was abandoned as plans for sea ice work changed swiftly and the ordering of such imagery requires the order to be delivered 72 hours in advance.

Sentinel 1: SAR imagery from Sentinel 1A (S1A) was acquired for planning purposes using Vixed. Vixed is a processor intended to obtain primarily earth observation data asynchronously across thin internet connections and is driven and maintained by NPI.

4 Health & safety

4.1 General procedures for sea ice work

Safety procedures for sea ice work during NL cruises have evolved over the project's fieldwork period. With a larger number of scientists working on the ice than on many earlier projects and cruises, and the group of scientists including many early career scientists with less experience of the Arctic environment, the need for better advance planning, coordination between ship and science crew, and efficient communication during an ice station became obvious early on and measures were put in place and refined accordingly. We based our safety plan on the experiences from earlier cruises and in particular on the summary for safety implementations during the JC2-2 cruise (see Fransson et al., 2022). It was invaluable to have two highly experienced safety officers on the team, a cruise leader and co-lead to cover duty on bridge at all times, and team leads with extensive experience from previous NL cruises who thus were familiar with the different activities and needs by different teams on the ice. A good rapport and relationship with the captain and the officers on the bridge ensured successful execution of the planned sea ice work and achievement of the cruise goals.

4.1.1 Pre-cruise planning

After having established planned work on sea ice stations and teams and people involved, safety measures were planned out. This included:

- risk assessments for all planned activity both onboard and on the ice;
- personal equipment for work in cold environment/on sea ice (i.e., immersion suit, Regatta suit) and on deck (helmet);
- rescue equipment on ice – KPH snowmobiles & sleds, throw lines and ice spikes;
- first aid kits;
- communication equipment for regular and emergency use – VHF radios, satellite phones, InReach beacons, AIS, PLB;
- protective equipment against polar bears – binoculars, flare guns, rifles.

In particular, the handling of rifles must be planned in good time before the cruise for acquisition of the permits for polar bear guards to be able to use NPI rifles/rent rifles (processing time at the police of several weeks to months!). Rifle training was given in Tromsø before the cruise; here, too, prior planning is vital as access to suitable shooting ranges in winter is problematic.

4.1.2 During the cruise

The safety officers held a briefing with the entire science party prior to the first sea ice station about risks and dangers of sea ice work and procedures to follow to minimize risks. This included a demonstration of the VHF radios, a run through the setup of rifle and ammunition storage onboard (in the CTD winch control room and out on deck), and practice with the throw lines.

A meeting with the science party was held before each sea ice station (ideally the day before) to discuss and plan the order and approximate time schedule of activities and people on the ice, and update meetings were held as needed in the evenings of ongoing ice stations. During the meetings, bear guards on the ice were assigned to the different teams as required, with one of the safety officers usually staying with the team at the turbulence site, the other safety officer joining any long transect work, and the ice core team staying close to the ship and using a bear guard from the science team.

Ice floes for station work were chosen by cruise leader/co-leader and safety officers in consultation with the sea ice physicists and team leads based on location, information from satellite images, and suitability for the planned work.
Prior to the first people going onto the ice, a toolbox meeting was held on the bridge with the captain/chief mate, the cruise leader/co-leader, the safety officers, and teams leads if appropriate to assess the general situation regarding sea ice quality, weather (temperatures, wind, visibility) and potential bear visits, and to establish the plan for the station, locations of work, teams involved and schedule. Short toolbox meetings were repeated each morning of an ongoing ice station for updates.

The safety officers together with the sea ice physics team then inspected the ice conditions with thickness drilling and visual assessment from the ice. Two flag transects were set up by snowmobile – to starboard and from the bow – to aid the bear watches on the bridge with assessment of distance from the boat. Then the science teams could start their work.
During the entire period of people on the ice, either cruise leader or co-leader were on duty on the bridge and handled communication with the safety officers and the teams on the ice, the bear watches on the bridge, and with the person on duty on the bridge (captain/chief mate/first officer). They also kept track of science personnel movements between ship and ice using a list of names and magnets as described in Fransson et al. (2022).

Bear watches on the bridge were established as soon as the first people entered the ice and ended with the last people returning onboard. Each bear watch was equipped with binoculars and VHF radios, and at least three persons were on duty at any time to cover the full 360° view from the bridge. Bear watches did 1-hour shifts; the shift plan was on display on the info screen. As this was a late winter cruise, daylight was very limited and for large parts of the ice stations, the ship's beams were used for scanning the ice in fading light or darkness.

Work on the ice paused during mealtimes to allow everybody on the ice a break and get them warmed up, and to relief the bear watches on the bridge. Sea ice work after dinner was limited to focused measurements that were needed to resolve daily cycles and were restricted in duration to minimize risks in the dark and ensure sufficient rest for everybody involved.

In case of incidents (e.g., floe break up, polar bear incidents), a debrief was done afterwards within the science party with cruise leader/co-leader and safety officer, and as appropriate or required with the captain, or other people involved.

For further details please refer to Fransson et al. (2022).

4.1.3 Recommendations for future cruises

A few points could be improved on from our experiences. Because of lack of communication and unclear distribution of roles/responsibilities, vital safety equipment such as the snowmobiles was not in working order when we arrive onboard although we were assured otherwise. Thanks to the capabilities of our safety officers and the time we had in port in Tromsø, this could be fixed, but had that not been the case, the lack of snowmobiles would have seriously impacted the sea ice work.

We had several bear encounters during the cruise (see next section). All bears that came close while people were on the ice were spotted by one of the bear watches on the bridge. Bear watches proved again to be the greatest safety measure to prevent dangerous situation with surprise bear visits! However, they are also very people-intensive. Due to experimental and night-time work, the number of people remaining onboard during ice stations that could serve as bear guards was at times very limited and demanded some people to take on considerably more shifts than others. Also, the cruise leader/co-leader at times took on bear watch in addition to their regular duty on the bridge, limiting their flexibility to move around and/or address other situations. Ideally, cruise leaders/co-leaders should not be part of the bear watch rota.

The ship's beams were invaluable for bear watch in low light/darkness. However, some of the beams did not function well or at all, limiting their range and the quality of beams available. Night vision binoculars could alleviate the dependency on the rather vulnerable beams.

4.2 Polar bear encounters during JC3

Prior to the cruise, guidelines were provided in Norwegian language by the section leader for the Norwegian Polar Institute's head of the Operations and Logistics Department Arctic, Geir Ove Aspnes (Appendix 3: Instructions for polar bear encounters issued by NPI). These were approved by the Governor of Svalbard and formed the base of our strategy for handling polar bear encounters during sea ice work. In addition, guidelines by IMR and UiT were consulted. The guidelines were translated into English by members of the science team for communication across the science team.

All science team members were briefed about the strategy outlined in the document, which we followed during the cruise during several bear encounters.

The first polar bear was observed on 03/03/2022 at sea ice station P7. At time of spotting (08:50 ship time), the ice science party was just preparing to go on the ice, but nobody

was on the ice yet. The bear came from in front of the ship (12 o'clock off the ship axis), walking towards the bow of KPH. It moved around the bow for a little bit before heading to "Zoe site", 230 m from the ship at 2 o'clock from the ship axis. There, instruments had been moored in the ice and a tent had been set up one day before. The bear inspected the tent and started to bite into it.
The decision was made to scare it away to prevent it from ingesting tent fabric or potentially other harmful material (cables, batteries). Six rounds of bangers (knall und blitz) were fired with the flare gun by the safety officer at 09:05 ship time from the helicopter deck towards the bear.
The bear noticed the shots and did not seem particularly scared, but rather just enough disturbed to lose interest in the tent and the other installations. It moved away from the tent in a fairly straight line towards 1-2 o'clock from the ship axis. The bear was observed for another 30 minutes before making the decision to continue the sea ice work. After that period, the bear was >1000 m away, exploring ridges and moving slowly further away. People entered the ice at 10:00 ship time. Three scientists as bear watch on the bridge continuously checked the bear´s location.

During the afternoon of the same day, 03/03/2022, another bear was spotted while people were working on the ice. The bear was about 2-3 km away at 5 o'clock from the ship axis. All teams on the ice were informed over VHF radio and updated regularly on the bear's movements.
The bear came closer to about 1.5 km, crossed a lead onto the station floe, but then kept that distance and moved towards 6 o'clock and eventually 7 o'clock from the ship axis while increasing the distance to the boat. Sight of the bear was lost at about 3 km away. The work on the ice was not interrupted.

During the night 03/03 to 04/03/2022, a female bear with a cub came up to the ship at around 01:00am ship time, and another single bear visited at 04:00am ship time. No personnel were on the ice, the bears did no show interest in equipment, no action was taken.

The last bear at P7 was spotted on 04/03/2022 at 11:00am ship time roughly 1.5 km away in direction 7-8 o'clock from the ship axis. All teams on the ice were about to finish their work on the ice including all instrument recovery. All personnel returned to the ship as planned. The bear eventually approached the ship and the ice station, inspecting the various water holes left behind by the scientists before moving away. No action was taken.

On 07/03/2022 at sea ice station Kvitøyrenna, a bear was spotted at 16:30 ship time. First at a distance of ca. 1.5 km at about 7-8 o'clock from the ship axis, it swiftly moved towards the vessel on a straight line. At that time, one team of three people was on the ice at "Zoe site", approximately 200 m away from the ship. The team was called back to the vessel and used a snow scooter for faster transport.

Figure 23: Polar bear at P7 biting on a rope to an instrument deployed below the ice. A banger was fired immediately after this photo was taken. (Photo: Rolf Gradinger)

The bear was clearly interested in the ship. To deter it from seeking closer contact, a banger was fired from deck when it came close to 100 m. It then moved along the vessel on portside towards the bow and eventually towards "Zoe site" where instruments were deployed and a tent was set up. The bear was interested but also hesitant in its approach, but eventually started pulling and biting a rope which was connected to a sensor (Figure 23). Another banger was fired which startled the bear enough to let go of the rope, but not to move away properly. Another two bangers were fired almost simultaneously. This scared the bear enough to run away a short distance and then keep moving away from the ship in direction 2 o'clock from the ship axis. As it moved away almost as determined as it first approach the ship, the decision was made after 15 minutes of observing to resuming the sea ice work and people return onto the ice at 17:12 ship time. Sight of the bear was lost at 17:40.

All bears spotted during sea ice station work were first observed by the polar bear watch on the bridge.
A total of 10 bangers were fired during two bear encounters.
In total, seven bears were observed.

4.3 COVID-19 related measures prior to and during JC3:

JC3 took place during a period in the pandemic when infection rates in the general population were high and nearing infection top. COVID rules in Norway were greatly

relaxed compared to earlier in the pandemic. At the same time, vaccines have been available for everybody for long enough that all adults had the possibility to get two, if not three vaccine shots.
In accordance with the rules for COVID-19 measures for fieldwork and scientific cruises in remote regions by UiT, IMR and NPI, and the risk assessment conducted for the cruise and agreed on by all parties, all cruise participants were asked prior to the cruise to:

- provide prove of vaccination status (fully vaccinated required, booster recommended);
- reduce social contact to an absolute minimum and follow general FHI advice to avoid infection;
- travel to Tromsø at least three day prior to boarding the vessel;
- wear a face mask during travel and whenever outside the own home/hotel room;
- take a PCR test three days prior to boarding (unless having had COVID-19 within the last three months prior to the cruise);
- take a rapid test every day after the PCR test and until boarding, and continue testing daily throughout the first week onboard (unless having had COVID-19 within the last three months prior to the cruise).

All scientific participants tested negative on both PCR and rapid tests prior to boarding or had COVID-19 recently and were thus cleared to participate in the cruise.

Figure 24: COVID-safe group photo (photo: Olaf Schneider)

After boarding while alongside on the 19. February, one member of crew and instrument team that joined the day before tested positive. They immediately went into isolation in their cabin, and after consultation with captain and cruise leader went ashore and did not participate in the expedition. A replacement joined the ship on 20. February before

leaving Olavsvern. All personnel that were in close contact with the infected person were tested and tested negative. Personnel that had brief contact with the infected person kept distance from the rest of crew and science team for the next days.

All science party members were asked to use rapid tests as soon as they experienced COVID like symptoms. On 26. February, the first positive case was detected in the science party, followed by a positive case in the crew on the 27., and further positive cases amongst the scientists on the 28. Feb., 01., 02., and 04. March. All concerned people were isolated in their cabin for at least 4 days (5 days in one case with stronger symptoms). If they shared cabin, the non-infected person moved out immediately. Where necessary, potentially infectious surfaces in labs, cabins or the auditorium were disinfected by fumigation. It proofed to be important to have empty cabins available to mitigate such situations.

On 28. February, after the second confirmed case in the science party, further measures were put in place to prevent or at least slow down new infections. This included enhanced use of hand sanitizer, use of face masks, general social distancing (1m rule) and dividing up the science party in two groups for meal times to allow for greater distancing.

People in isolation had to stay the entire 4-5 day period in their cabin and were provided with meals at their cabin door and followed up regularly through phone calls. Thankfully, nobody turned seriously ill; main symptoms were fever, sore throat, and headaches. On 08. March, all were out of isolation and able to join the activities onboard again. No new infections occurred.

Two major general recommendations for future cruises include:
- Sufficient number of test kits to test the entire science team also regularly during the cruise
- Empty cabins available to isolate cases.

The provided test kits turned out to be frequently incomplete and for example the buffer solution was missing. This reduced further the number of available kits during our cruise and limited our ability to respond to conduct tests for the entire science party.

5 Outreach

Pernille Armdahl (MET)

This late winter expedition included a communications advisor from MET with the communication responsibility for our big and small events along the expedition.
Main task was the story map with a daily publication of stories or articles in Norwegian, plotted on the expedition track on the day of publication. The stories described different perspectives of the scientific tasks and daily life onboard the ship.
What can we learn by measuring the windspeed from a moving vessel, and what kind of information on toxic pollution and climate change can we gather by studying copepod? These were some of the questions to be found in the stories that sometimes also included short interviews or profiles on scientific researchers and the crew.

Stories were also published on Facebook and Instagram and included images from the expedition.

All stories were transmitted by the communications advisor onboard to a shore-based colleague that prepared it for publication on the different media platforms. The communications advisor also filed additional images in an image bank for future reference and use. Several skillful members of the expedition team contributed with high quality photos and agreed to share images and videos (with credits) to be included in later publications from the project.

Each scientific research team was encouraged to contribute a blog post.
An overview of outreach from the cruise can be found in

Appendix 4: Overview over blogs and other **outreach**.

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Appendix

Appendix 1: Cruise participants, working hours, lab use

Captain: Johnny Peder Hansen
Chief mate: Øyvind Nilsen

Table 15: Cruise participants. Team (co-)leads in bold.

#	Name	Institute	Email	RF/ RA	Group/ Team	Task
1	Angelika Renner	IMR	angelika.renner@hi.no		Lead	Chief Scientist
2	Rolf Gradinger	UiT	rolf.gradinger@uit.no		Lead	Co-Chief Scientist
3	Jørn Dybdahl	NPI	jorn.dybdahl@npolar.no		Safety	Safety officer
4	Kunuk Lennert	UiT	kunnuk.lennert@uit.no		Safety	Safety officer
5	**Zoe Koenig**	**NPI**	zoe.koenig@npolar.no	RF1	Ocean & ice	
6	**Adam Steer**	**NPI**	adam.steer@npolar.no	RF1	Ocean & ice	
7	Julie Sortland	UiT/IMR	julie_sortland@outlook.com	RF1	Ocean & ice	
8	Bonnie Raffel	NPI	bonnie.raffel@npolar.no	RF1	Ocean & ice	
9	**Elizabeth Jones**	IMR	elizabeth.jones@hi.no	RF2	Chem	Chemical responsible
10	Marit Kollstuen	NPI	marit.kollstuen@npolar.no	RF2	Chem	
11	**Miriam Marquardt**	**UiT**	miriam.marquardt@uit.no	RF3	LTL microbes	Verneombud CTD/water budget
12	Evan Patrohay	UiT	epa042@uit.no	RF3	LTL microbes	
13	Lucie Goraguer	NPI	lucie.goraguer@npolar.no	RF3	LTL microbes	
14	Rosalie McKay	UiT	rosalie.d.mckay@uit.no	RF3	LTL microbes	
15	Megan Lenss	UiT	mle085@uit.no	RF3	LTL microbes	
16	Pedro Duarte	NPI	pedro.duarte@npolar.no	RF3	LTL microbes	
17	**Janne Søreide**	**UNIS**	jannes@unis.no	RF3	Zooplankton & fish	
18	Anette Wold	NPI	anette.wold@npolar.no	RF3	Zooplankton & fish	
19	Elisabeth Halvorsen	UiT	elisabeth.halvorsen@uit.no	RF3	Zooplankton & fish	
20	Amalie Gravelle	UiO	amgravel@student.ibv.uio.no	RF2	Zooplankton & fish	
21	Marius F. Maurstad	UiO	marimaur@student.ibv.uio.no	RF2	Zooplankton & fish	
22	Andreas Altenburger	UiT	andreas.altenburger@uit.no	RF3	Benthos	
23	Birte Schuppe	UiT	birte.katarina.schuppe@hi.no	RF3	Benthos	
24	Karoline Barstein	NTNU	karoline.barstein@ntnu.no	RA-C	ROV/ technology	
25	Kristian Lampe Gjemdal	NTNU	kristilg@stud.ntnu.no	RA-C	ROV/ technology	

26	Hugo Rubio Hurtado	Fraun-hofer IWES	hugo.rubio@iwes.fraunhofer.de	RF1	Atmosphere	
27	Shokoufeh Malekmohammadi	UiB	shokoufeh.malekmohammadi@uib.no	RF1	Atmosphere	
28	Olaf Schneider	NPI	olaf.schneider@npolar.no	RA-B	Data management	
29	Pernille Amdahl	MET	pernillea@met.no	RA-D	Outreach	
	Asgeir Steinsland	IMR	asgeir.steinsland@hi.no		Instrument chief	
	Jan Vidar Nordstrand	IMR	jan.vidar.nordstrand@hi.no		Instrument engineer	

Table 16: Working hours (ship time).

Working hours 0400-1200, 1600-2000	**Working hours 2000-0400, 1200-1600**
Angelika Renner (0800-1200, 1600-2400)	Rolf Gradinger (0000-0800, 1200-1600)
Jørn Dybdahl	Marit Kollstuen
Kunuk Lennert	Pedro Duarte
Zoe Koenig	Janne Søreide
Adam Steer	Anette Wold
Julie Sortland	Elisabeth Halvorsen
Bonnie Raffel	Amalie Gravelle
Elizabeth Jones	Marius F. Maurstad
Miriam Marquardt	Andreas Altenburger
Evan Patrohay	Birte Schuppe
Lucie Goraguer	Hugo Rubio Hurtado
Rosalie McKay	Schokoufeh Malemohammadi
Megan Lenss	Olaf Schneider
Karoline Barstein	Pernille Amdahl
Kristian Lampe Gjemdal	
Asgeir Steinsland	Jan Vidar Nordstrand

Table 17: Use of laboratories, cold rooms and freezer rooms onboard Kronprins Haakon during JC3. For last names of users see participant table.

Lab no.	**Name of laboratory**	**Use during JC3**	**Lab users**
102	Clean seawater sample room	Seawater intake room & TSG, pCO_2 underway instrumentation	Libby
301	Chilled lab	Mesozooplankton experiments, trace metal experiment	Elisabeth
302	Dry lab common (Chem. lab)	Sample handling for analyses of AT, DIC, pH, nutrients, stable oxygen isotopes; dissolved oxygen analyses, ice core processing; under-ice sensors (SeapHOx) testing and maintenance	Libby/Marit
303	Wet lab common, (Zoopl. lab) Thermax 1+2	Meso- and macrozooplankton, filtration (viruses, bacteria, XRF)	Janne, Anette, Elisabeth, Amalie
307	Radioisotope lab	Primary (PP) and bacterial production (PB)	Rosalie/Megan/Pedro

308/309	Wet lab biology (fish lab)	Ocean physics	Zoe/Julie/Pedro, Marius
310	Catch sample room	Trawl processing, rinsing & storage of sea ice equipment (ice stations)	Marius (trawl) All ice teams
311	Toxicology lab	Trace metal clean lab	Rosalie/Megan
312	Cooler room (inside fish lab)	OA & pollutants exp.	Marius
313	Freezer room converted to cold room (accessible from fish lab)	Experiments, cultures	Amalie
314	Cold room (by benthos lab)	Fish (Temp +2°C)	Marius
315	Cold room (by benthos lab)	Benthos exp. (Temp. in situ), storage samples (<4°C)	Andreas/Birte
316	Filtration lab	Filtration (metabarcoding), ice core pooling	Miriam/Lucie/Evan
317	Education lab	Label printer, microscope, sample labeling & logging, common use	Lucie (microscope) Label printer, Miriam CTD logs, others
319	Wet Lab Geology/Benthos	Benthos	Andreas/Birte, Adam/Bonnie
320	Microbiology lab	Filtrations (Chl a, POC/PON, FA/SI/HBI, and more); fluorometer	Miriam/Evan/Lucie
322	Ice Lab	Storage of phys/chem ice cores	Adam/Bonnie
323	Cold room (Greenland)	Ice core melting (°C), zooplankton sample temporary storage, storage filtered seawater	Microbes & zoop. teams
325	Freezer ice samples	For biological frozen samples	Primarily biologists
503	Dive room	Ice physics	Karoline/Kristian
AUD	Auditorium	Meetings; drying ice containers	All; ice bio group
701 (deck 9)	Observation Central	Common, ice observation support	Everyone
Incubators			
Thermax1	303 Wet lab	Zooplankton respiration exp.	Janne/Amalie
Thermax2	303 Wet lab	Zooplankton respiration exp.	Janne/Amalie
Thermax3	Hangar	Zooplankton egg production exp.	Elisabeth
Thermax4	Hangar	Zooplankton egg production exp.	Elisabeth
Lab cont.	Deck main	Sea ice physics	Adam/Bonnie
Lab cont.	Deck main	Benthos	Andreas/Birte
Safety/logistic storage	Deck2/little CTD hangar (radios charging area, weapons)	Logistics	Jørn/Kunuk
Atmosphere equipment	Heli deck/heli hangar	Atmosphere equipment	Hugo/Shokoufeh

Appendix 2: Cruise diary, full station table

Cruise diary (all times in UTC)

19/02/2022

08:00 Cruise participants arrive and board KPH. Passport control on the kai at 10:00.

Loading delayed because of repairs on the big crane, finished in the afternoon. Spend day with preparing the labs, safety brief, setting up instruments.

20/02/2022
05:00 leave Breivika for bunkering at Olavsvern; alongside in Olavsvern at 09:00
17:00 leave for Barents Sea; sail inshore first part because of strong winds.

21/02/2022
Continuing towards P1.
Sea ice safety brief by safety officers for all cruise participants.

22/02/2022
Continuing towards P1.
Fair weather in the morning, increasing wind and sea state after breakfast. Some snow showers.
17:00 arrive at Seaglider (SG564) recovery position near P1; glider spotted at 17:10, on deck at 17:30. Move on to P1.
17:45 start with P1 station work: CTD, phytoplankton and zooplankton nets

23/02/2022
Continue P1 station work: Epibenthos sled, box corer, pelagic trawl.
Wind increasing throughout night.
05:30 finish P1, start steaming towards F1 mooring position
Meet the ice edge at around lunch time; bottom trawl before entering the ice.
Wind calming down in the afternoon; pass a sharp drop in sea surface temperature at around 14:00 – Polar front. Air temperature dropping to -29 at night.
22:35 start pinging for missing mooring F1, ca. 5nm upstream amidst dense pack ice. Try on further positions along a line towards and past F1.

24/02/2022
Continue pinging for F1, not possible to determine location or confirm that mooring still there. Steam towards P4.
Change clock forward by one hour for more daylight during sea ice stations (local time = UTC+2).
Cold (air temperature -30 in the morning, -25 at lunch), some fog. Dense ice cover consisting mostly of small floes and brash frozen together, difficult to move through. Slow progress.
Bad weather with strong winds and cold temperatures forecast for Friday afternoon to Saturday morning.

25/02/2022
Whiteout and zero visibility in the morning. Winds up to 25 m/s straight against us. No progress towards potential CTD section and no weather for ice station. Head to Kvitøya to hide from the weather in the east of the island.

26/02/2022
Less wind but still enough to stop work, snowing. Decision to move ice station to P5 due to extensive polynya reaching down to P4 and uncertain ice conditions.
Use the open water for a pelagic trawl at 08:30.
Head north to P5 afterwards. At position at 13:00. Thin ice, southerly drift. Start P5 slightly north of nominal position. Ice thickness and safety check before dinner. Leave the floe for plankton nets, start sampling at 16:50. All zooplankton nets during the night.

27/02/2022
Cloudy, starting to clear up, still a bit of wind, air temperature -17.
"In" the floe, parked at 05:00, safety check of the floe and marking of safety corridors before breakfast.
Sea ice station work starts at 07:00. Break for lunch, all back for dinner. Two trips for turbulence profiling after dinner.
CTD before dinner. Box corer sampling in the evening.

28/02/2022
Sea surface temperature slightly up from freezing point to -1.5 to -1.3. Air temperature up to -12. Snowing, increasing wind and change in wind direction. Varied drift pattern throughout the ice station.
Ice station work continues after breakfast, break for lunch.
Ice floe starts breaking up at 11:20 while people on the ice. Evacuate the floe, rescue equipment. All people back on board 12:00. Rescue of turbulence equipment in afternoon, all equipment off the ice at 15:05.
Continue pelagic work at P5: CTD, phytoplankton net, additional zooplankton nets.
Steam to benthos station at NLEG19.

01/03/2022
Grey and overcast, air temperature -15, sea surface temperature -1.0, wind at ~7 m/s. About 50% ice concentration, thin, grey or grey/white ice.
Box coring start at 04:15, finish by 06:15, three successful cores straightaway.
Pelagic trawl at 08:15, comes up basically empty.
Transit to P7. At position in the afternoon; suitable floe spotted at around 14:45. Stay in open water over night and do all the phytoplankton and zooplankton nets.
Sea surface temperature back down to -1.9 and plenty of nilas and young grey ice in leads.

02/03/2022
Nets continued throughout the night.
Move ship into position at dawn (~04:00). Ice safety check before breakfast. Start of ice station work after breakfast.
Air temperature -10, OK visibility though at times poor contrast.
Box corer at 07:45. Multinets and MIK net after lunch and throughout evening.

Sea ice work throughout the day, two trips for turbulence profiling after dinner.
Bowhead whale surfaces behind aft deck just before 22:00.

03/03/2022
CTD in the morning, on deck at breakfast.
Polar bear spotted just as everybody prepares to go on the ice after breakfast. Delayed ice station start until bear in safe distance. People on the ice at 08:00.
Mostly clear sky all day; air temperatures from -20 to -26 after dinner. Little wind. Sea surface temperature -1.9, leads are refreezing.
Another polar bear spotted in the afternoon. Stays in safe distance, no evacuation required.
Continue box corer sampling during the day and multinets during afternoon and evening.
One trip for turbulence profiling after dinner.

04/03/2022
Slightly cloudier then previous day. Air temperature -18, sea surface temperature -2.0. Slightly more wind with 8 m/s. Ice unchanged, leads and holes refreezing.
CTD in the morning.
Continuation and wrapping up of sea ice work after breakfast and until lunch.
Polar bear spotted at 09:00. All teams ready to return, all back onboard including all equipment at 09:25. Bear checking out the ship and all the water holes before moving away.
Start CTD transect towards NLEG23.

05/03/2022
Continue CTD transect during night.
Box coring at NLEG23 from 03:20. Another bear spotted at start of last box corer.
Clear skies, beautiful sunrise. Air temperature -12 to -13, some easterly wind. Thin ice everywhere with lot of nilas and young ice, plenty of rafting.
Move on along transect to NLEG21/P6. Pelagic sampling with CTD, turbulence profiler, phytoplankton and zooplankton nets at P6. Strong northward drift requiring repositioning between nets.
Continue CTD transect.

06/03/2022
Finish CTD transect before breakfast with increasing wind and drift.
Grey and overcast, 14 m/s southerly wind. Air temperature -7, sea temperature varying.
Transit to Kvitøya for CTD transect between Kvitøya and Nordaustlandet; start 17:50. Walrus sighting during transect. Lots of open water and thin ice during transit. Closely packed ice close to Kvitøya.

07/03/2022
Finish CTD transect during the night, reposition ship for ice station over Kvitøyrenna. Bit challenging to find suitable ice.

Snow showers and windy (13.5 m/s), air temperature ~-2. Clearing up during afternoon, temperature drops to -6 in the evening.
Ice safety check after breakfast, Viking suit-conditions. Sea ice station work starts 07:30. Multinets and MIK net during the morning.
First bird spotted since leaving the Norwegian coast!
Polar bear spotted at 14:30 while team on the ice. Evacuate people. Bear approaches ship and equipment on ice, had to be scared away. Moves away swiftly. Work on ice resumed 15:15. Two trips after dinner for turbulence profiling.

08/03/2022
Air temperature -6 to -7, sea surface temperature -1.8, wind speed 9 m/s. Clear and beautiful day, ice conditions unchanged, drifting northwards, at time with >1 knot.
CTD in the morning.
Sea ice work continues after breakfast, all finish and return with all equipment by 09:10. Move to open water nearby for zooplankton and phytoplankton nets and epibenthos sled. All station work finished by 12:45, start steaming west.

09/03/2022
Clock moved back to Norwegian time (ship time = UTC+1).
Sailing through bits of ice, sea is getting warmer.
Bottom trawl after dinner.
Sailing on to Slocum glider recovery

10/03/2022
Slocum recovery at 01:00, followed by CTD. Calm conditions.
Wind and sea state increasing during the day, wind streaks on the water by afternoon.
Seaglider (SG560) recovery at 11:30.
Sailing to Longyearbyen. Wind up at 15 m/s.

11/03/2022
Alongside in Longyearbyen at 00:00. Unloading starts 07:00.

Station table

Station Name	Local Station ID	Activity	Date	Time (UTC)	Latitude (N)	Longitude (E)	Bottom Depth (m)	Sample Depth (m)	Comments
P1 (NLEG01)	5	Glider recovery	22/02/2022	17:30	75.9905	31.2596	324	0	
P1 (NLEG01)	1	CTD w/bottles	22/02/2022	17:45	75.9993	31.2193	328	317-0	
P1 (NLEG01)	1	Phytoplankton net 10 um	22/02/2022	19:31	75.9993	31.2192	329	50-0	with RBR CTD attached to the net
P1 (NLEG01)	2	Bongonet 180 um	22/02/2022	19:50	75.9993	31.2192	329	310-0	
P1 (NLEG01)	3	Bongonet 64 um	22/02/2022	20:24	75.9993	31.2192	329	310-0	
P1 (NLEG01)	4	Multinet 180 um	22/02/2022	21:30	75.9993	31.2192	329	310-0	
P1 (NLEG01)	5	Bongonet 180 um	22/02/2022	22:00	75.9993	31.2192	329	310-0	
P1 (NLEG01)	6	Multinet 64 um	22/02/2022	22:40	75.9994	31.2192	329	310-0	
P1 (NLEG01)	7	MIK-net 1500 um	22/02/2022	23:54	75.9994	31.2193	329	300-0	
P1 (NLEG01)	1	Epibenthos sled	23/02/2022	00:50	75.9994	31.2195	329	328	
P1 (NLEG01)	2	Box core	23/02/2022	02:14	75.9997	31.2179	329	329	
P1 (NLEG01)	3	Box core	23/02/2022	02:57	75.9997	31.2179	329	329	
P1 (NLEG01)	1	Harstad trawl	23/02/2022	04:58	75.9548	31.1560	324	130-100	
2 (on transit north)	2	Campelen trawl	23/02/2022	12:22	76.4994	31.1935	316	310-300	
3 (on transit north)	3	Harstad trawl	26/02/2022	08:59	80.1774	33.7740	221	123-50	
P5 (NLEG13)	8	WP3 1000 um	26/02/2022	16:49	80.6240	33.9680	177	167-0	
P5 (NLEG13)	9	WP3 1000 um	26/02/2022	17:15	80.6254	33.9732	176	170-0	
P5 (NLEG13)	10	WP3 1000 um	26/02/2022	17:34	80.6284	33.9857	179	170-0	
P5 (NLEG13)	11	WP3 1000 um	26/02/2022	17:51	80.6310	33.9887	186	170-0	
P5 (NLEG13)	12	WP3 1000 um	26/02/2022	18:12	80.6338	34.0031	194	170-0	
P5 (NLEG13)	13	WP3 1000 um	26/02/2022	18:35	80.6367	34.0224	190	170-0	
P5 (NLEG13)	14	Multinet 180 um	26/02/2022	19:03	80.6400	34.0403	189	175-0	
P5 (NLEG13)	15	Bongonet 180 um	26/02/2022	19:26	80.6436	34.0593	199	180-0	
P5 (NLEG13)	16	Multinet 64 um	26/02/2022	19:50	80.6436	34.0774	194	-	aborted d/t no contact with electronics
P5 (NLEG13)	17	Multinet 64 um	26/02/2022	20:10	80.6447	34.0931	193	180-0	

P5 (NLEG13)	18	MIK-net 1500 um	26/02/2022	20:44	80.6443	34.1073	193	170-0	
P5 (NLEG13)	19	Bongonet 180 um	26/02/2022	21:15	80.6435	34.1219	191	180-0	
P5 (NLEG13)	20	Bongonet 64 um	26/02/2022	21:33	80.6427	34.1257	189	180-0	
P5 (NLEG13)	21	Bongonet 64 um	26/02/2022	21:58	80.6413	34.1171	191	180-0	
P5 (NLEG13)	6	Sea ice station	27/02/2022	07:15	80.6865	33.9812	165	0	end of sea ice work: 28/02, 16:57
P5 (NLEG13)	2	CTD w/bottles	27/02/2022	14:15	80.6784	33.8064	182	50-0	
P5 (NLEG13)	4	Box core	27/02/2022	17:33	80.6845	33.6606	186	186	
P5 (NLEG13)	5	Box core	27/02/2022	18:15	80.6869	33.6423	185	184	
P5 (NLEG13)	6	Box core	27/02/2022	18:54	80.6891	33.6327	187	187	
P5 (NLEG13)	7	Box core	27/02/2022	19:18	80.6902	33.6307	194	194	
P5 (NLEG13)	3	CTD w/bottles	28/02/2022	08:08	80.5971	33.5644	115	100-0	
P5 (NLEG13)	4	CTD w/bottles	28/02/2022	15:26	80.5228	33.7354	180	167-0	
P5 (NLEG13)	22	Phytoplankton net 10 um	28/02/2022	16:04	80.5190	33.7294	165	50-0	
P5 (NLEG13)	23	WP3 1000 um	28/02/2022	16:19	80.5173	33.7291	158	170-0	
NLEG19	8	Box core	01/03/2022	04:34	81.4601	31.0695	518	518	
NLEG19	9	Box core	01/03/2022	05:10	81.4601	31.0696	518	518	
NLEG19	10	Box core	01/03/2022	05:40	81.4601	31.0696	518	518	
NLEG19	5	CTD w/bottles	01/03/2022	06:28	81.4605	31.0681	520	505-0	
4 (on transit north)	4	Harstad trawl	01/03/2022	08:37	81.4593	31.4519	382	315-66	
P7 (NLEG25/NPAL16)	7	Sea ice station	01/03/2022	14:45	82.0386	29.8910	3390	0	end of sea ice work: 04/03, 10:02
P7 (NLEG25/NPAL16)	24	Phytoplankton net 10 um	01/03/2022	14:46	82.0387	29.8906	3390	50-0	
P7 (NLEG25/NPAL16)	25	Multinet 180 um	01/03/2022	15:32	82.0385	29.8787	3390	3328-0	
P7 (NLEG25/NPAL16)	26	WP3 1000 um	01/03/2022	20:01	82.0382	29.7970	3396	200-0	
P7 (NLEG25/NPAL16)	6	CTD w/bottles	01/03/2022	20:42	82.0377	29.7794	3398	200-0	
P7 (NLEG25/NPAL16)	27	Bongonet 64 um	01/03/2022	21:12	82.0373	29.7672	3399	180-0	

P7 (NLEG25/NPAL16)	28	Bongonet 64 um	01/03/2022	21:30	82.0370	29.7595	3400	180-0
P7 (NLEG25/NPAL16)	29	Bongonet 180 um	01/03/2022	23:00	82.0353	29.7186	3404	180-0
P7 (NLEG25/NPAL16)	30	Bongonet 180 um	02/03/2022	00:07	82.0337	29.6834	3404	50-0
P7 (NLEG25/NPAL16)	31	MIK-net 1500 um	02/03/2022	00:30	82.0333	29.6718	3404	1000-0
P7 (NLEG25/NPAL16)	32	MIK-net 1500 um	02/03/2022	01:47	82.0337	29.6431	3407	1000-0
P7 (NLEG25/NPAL16)	33	MIK-net 1500 um	02/03/2022	03:02	82.0380	29.6420	3412	1000-0
P7 (NLEG25/NPAL16)	11	Box core	02/03/2022	07:46	82.0458	29.4858	3435	3435
P7 (NLEG25/NPAL16)	34	Multinet mammoth	02/03/2022	11:35	82.0448	29.3882	3381	3380-0
P7 (NLEG25/NPAL16)	35	Multinet 64 um	02/03/2022	16:58	82.0459	29.2529	3428	3351-0
P7 (NLEG25/NPAL16)	36	MIK-net 1500 um	02/03/2022	22:12	82.0469	29.0895	3416	3400-0
P7 (NLEG25/NPAL16)	7	CTD w/bottles	03/03/2022	02:24	82.0442	28.9543	3437	3535-0
P7 (NLEG25/NPAL16)	12	Box core	03/03/2022	08:47	82.0355	28.7897	3484	3484
P7 (NLEG25/NPAL16)	13	Box core	03/03/2022	12:24	82.0281	28.6882	3517	3517
P7 (NLEG25/NPAL16)	37	Multinet mammoth	03/03/2022	15:22	82.0236	28.6319	3518	3500-0
P7 (NLEG25/NPAL16)	38	Multinet mammoth	03/03/2022	22:39	82.0171	28.5704	3502	3500-0
P7 (NLEG25/NPAL16)	8	CTD w/bottles	04/03/2022	04:59	82.0144	28.5184	3504	3561-0
NLEG24_1	9	CTD w/bottles	04/03/2022	12:16	81.8526	29.6223	3192	3241-0
NLEG24_1	8	MSS	04/03/2022	15:10	81.8562	29.6185	3198	360-2
NLEG24	10	CTD w/bottles	04/03/2022	18:58	81.6837	30.5295	2838	2878-0
NLEG24	9	MSS	04/03/2022	22:17	81.6829	30.4892	2825	220-2
NLEG23	11	CTD w/bottles	05/03/2022	00:11	81.6227	30.6660	2023	2104-0

NLEG23	14	Box core	05/03/2022	03:20	81.5845	30.7813	1478	1477	failed
NLEG23	15	Box core	05/03/2022	05:04	81.5821	30.7973	1469	1469	
NLEG23	16	Box core	05/03/2022	06:49	81.5848	30.8015	1499	1499	
NLEG23	17	Box core	05/03/2022	08:41	81.5849	30.7919	1487	1487	
NLEG22	12	CTD w/bottles	05/03/2022	10:47	81.5867	30.7576	1507	1584-0	
P6 (NLEG21/NPAL15)	13	CTD w/bottles	05/03/2022	13:25	81.5496	30.8521	899	947-0	
P6 (NLEG21/NPAL15)	10	MSS	05/03/2022	14:50	81.5682	30.9409	1132	300-2	
P6 (NLEG21/NPAL15)	39	Phytoplankton net 10 um	05/03/2022	15:21	81.5721	30.9467	1217	50-0	
P6 (NLEG21/NPAL15)	40	Multinet 180 um	05/03/2022	15:50	81.5777	30.9571	1391	1398-0	
P6 (NLEG21/NPAL15)	41	Bongonet 180 um	05/03/2022	18:26	81.5432	30.7811	875	200-0	
P6 (NLEG21/NPAL15)	42	Multinet 64 um	05/03/2022	18:32	81.5451	30.7773	88	867-0	
NLEG20	14	CTD w/bottles	05/03/2022	21:31	81.5031	30.9646	706	699-0	
NLEG20	11	MSS	05/03/2022	22:23	81.5108	30.9361	736	140-2	
NLEG19	15	CTD w/bottles	05/03/2022	23:34	81.4592	31.0758	504	515-0	
NLEG18	16	CTD w/bottles	06/03/2022	01:13	81.4306	31.1558	250	268-0	
NLEG17	17	CTD w/bottles	06/03/2022	02:05	81.4136	31.2551	212	199-0	
NLEG16	18	CTD w/bottles	06/03/2022	03:04	81.3818	31.2906	188	180-0	
NLEG15	19	CTD w/bottles	06/03/2022	04:21	81.3096	31.3530	197	183-0	
Kvit1	20	CTD w/bottles	06/03/2022	17:51	80.0525	30.8069	73	59-0	
Kvit2	21	CTD w/bottles	06/03/2022	18:41	80.0616	30.5735	170	160-0	
Kvit3	22	CTD w/bottles	06/03/2022	20:21	80.0816	30.0125	295	284-0	
Kvit4	23	CTD w/bottles	06/03/2022	21:32	80.0950	29.6200	347	342-0	
Kvit5	24	CTD w/bottles	06/03/2022	23:01	80.1077	29.2474	276	292-0	
Kvit6	25	CTD w/bottles	07/03/2022	00:07	80.1172	28.9599	247	246-0	
Kvit7	26	CTD w/bottles	07/03/2022	01:25	80.1199	28.6668	89	84-0	drifted to 40m depth during cast
SIce Kvitøyrenna	12	Sea ice station	07/03/2022	07:28	80.1205	29.2725	306	0	end of sea ice work: 08/03. 12:35
SIce Kvitøyrenna	43	Multinet 64 um	07/03/2022	07:36	80.1204	29.2732	305	280-0	
SIce Kvitøyrenna	44	Multinet 180 um	07/03/2022	08:41	80.1224	29.2729	308	280-0	

SIce Kvitøyrenna	45	MIK-net 1500 um	07/03/2022	10:50	80.1420	29.2689	314	280-0
SIce Kvitøyrenna	27	CTD w/bottles	08/03/2022	07:48	80.3865	29.7668	187	178-0
SIce Kvitøyrenna	46	Bongonet 180 um	08/03/2022	10:08	80.4295	29.9115	297	270-0
SIce Kvitøyrenna	47	Bongonet 64 um	08/03/2022	10:40	80.4388	29.9020	275	260-0
SIce Kvitøyrenna	48	Phytoplankton net 10 um	08/03/2022	11:07	80.4434	29.9009	236	50-0
SIce Kvitøyrenna	18	Epibenthos sled	08/03/2022	11:50	80.4751	29.7860	468	467
5 (on transit to LYR)	5	Campelen trawl	09/03/2022	18:03	80.2524	11.0463	219	230-200
13 (on transit to LYR)	13	Glider recovery	10/03/2022	02:27	79.1405	8.8928	183	0
28 (on transit to LYR)	28	CTD w/bottles	10/03/2022	02:53	79.1413	8.9153	171	163-0
14 (on transit to LYR)	14	Glider recovery	10/03/2022	12:32	77.7278	7.6622	751	0

Appendix 3: Instructions for polar bear encounters issued by NPI

Original document

NORSK POLARINSTITUTT • NORWEGIAN POLAR INSTITUTE

Dato: 2022-01-31

Til: Sysselmesteren på Svalbard

Fra: Seksjonsleder OLA Arktis

Kopi:

Rutinebeskrivelse for håndtering av isbjørn ifm feltarbeid.

I forbindelse med feltarbeid på land, sjøis og sjø er det en risiko for å møte isbjørn og dette dokumentet beskriver ønsket rutinebeskrivelse.

Hovedprinsippet er at vi skal unngå konfrontasjon med isbjørn, dette inkluderer skremming og i ytterste konsekvens avlivning. Samtidig skal sikkerheten til personell ivaretas.
Det er behov for å beskrive noen grunnleggende senarioer.

1. Aktivitet er IKKE iverksatt.
    a. Det er IKKE tillatt å skremme isbjørn i føre var prinsippet.
    b. Planlagt aktivitet avventer eller flyttes til nytt sted.
    c. Det skal ikke iverksettes aktivitet før isbjørnvakt med samband er etablert Spesielt sikt for isbjørnvakt/sikkerhetsansvarlig skal vurderes før aktivitet iverksettes..
2. Aktivitet er iverksatt.
    a. Det er tillatt å skremme bjørn hvis fare for konfrontasjon.
    b. Den som oppdager isbjørn må sørge for at samtlige blir varslet umiddelbart.
    c. Det er sikkerhetsansvarlig i dialog sammen med brovakt/kaptein som definerer hvilke tiltak som iverksettes. På land er det sikkerhetsansvarlig sammen med prosjektleder som trekker tilsvarende beslutning.
3. Det kan oppstå situasjoner hvor isbjørn kan komme i kontakt med etterlatt materiell, dette være seg både etterlatt med hensikt i forbindelse med datainnhenting, forskning og/ eller etterlatt på grunn av rask evakuering.
    a. Hensynet til miljøet veier tyngst og det må derfor vurderes om materiellet kan skade miljø og/eller isbjørn. Hvis ja, skal skremming iverksettes.
    b. I enkelte tilfeller kan det være behov for å sette igjen materiell i felt over lengre tid for å innhente data. Primært skal materiellet isbjørnsikres for å unngå skade på isbjørn og eller materiell. Hvis det ikke lar seg sikre på en hensiktsmessig måte skal materiellet overvåkes. Ansvaret for å organisere vakt ligger hos prosjekteier og vaktmannskap organiseres blant forskergruppen.
4. Et viktig prinsipp ved skremming av isbjørn, uavhengig om det er nødverge eller planlagt, er at det skal gi isbjørnen en negativ opplevelse av konfrontasjonen med mennesket. Den skal etter en konfrontasjon IKKE ønske å etablere seg i nærheten av menneskelig aktivitet.

   a. I enkelte tilfeller kan det være nødvendig å skremme isbjørn, selv om verken materiell eller personell er i direkte fare. Spesielt ved arbeid i tilknytning fartøy er det lett å «glemme» at isbjørnen IKKE skal vennes til menneskelig aktivitet (lyder, lukt og inntrykk).
   b. Isbjørn skal IKKE tillates å klatre på eller oppholde seg lags skuteside/hytte/feltcamp.
   c. Ved skremming skal tid og sted registreres, samt antall isbjørn og med hvilken type skremming.
5. De som er tildelt ansvaret som sikkerhetsansvarlig og som isbjørnvakt skal ha dette som sin eneste oppgave og dermed ikke settes til andre oppgaver ved siden av sitt virke.
   a. Isbjørn vil lett kunne skade og mest sannsynlig drepe et menneske, det er derfor kritisk at den oppdages tidligst mulig. Dette for å tilrettelegge for en sikker og ryddig evakuering uten fare for liv og helse.
   b. Innehar isbjørnvakten spesiell kompetanse som må nyttes i en spesiell operasjon, skal ny isbjørnvakt overta ansvar og ansvarsområde før vedkommende forlater sin post.
   c. Det påligger den enkelte et ansvar å forholde seg til faren isbjørn utgjør, men spesielt sikkerhetsansvarlig og isbjørnvakt skal påse at sikkerheten ivaretas og unngå foto-sessions.

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English translation (by members of the science team)

Standard routines related to polar bear encounters during field work 20.2.22

There is the risk of encountering polar bears when conducting Arctic fieldwork on land, on sea ice or at sea. This document outlines standard principles of operations.

The main principle is to avoid any kind of confrontation with polar bears (including scaring them away or killing). At the same time, safety of people is priority.

In the following some basic scenarios are described.

1. Science activity has **not** started:
    a. It is **not** allowed to scare the bear away as a precautionary measure.
    b. Planned science activities must wait or they have to be moved to a different location.
    c. No new science activities can be started without establishing a polar bear watch. Responsible safety officers/safety personnel must evaluate the situation before any science activity can start.
2. Science activity has started:
    a. It is allowed to scare the bear away if there is the risk of a confrontation.
    b. The person discovering the bear must immediately ensure that the entire science team is informed and warned.
    c. At sea, the safety officers/personnel will decide with the bridge watch/captain, which safety measures will be taken. On land, the project/team leader makes the relevant decisions.

3. The polar bear comes into contact with scientific material left on the ice (e.g. instrumentation for long term data recording, research, and/or left due to evacuation of site):
    a. Damage to the environment and/or harm to the bear must be minimized. If the scientific material/equipment can harm the bear or the environment, the bear should be scared away.
    b. At times, scientific equipment is placed on sea ice or in the field for scientific data collections over an extended period. Such installations should be made polar bear-proof to minimize risks for bear and equipment. If this is not possible, the equipment should be monitored. Responsibilities for such monitoring/watch lies with the project owner and is organised by the science party.
4. An important principle for scaring a bear away, whether in emergency or planned, is to give the polar bear a negative experience related to confrontations with humans. The bear should <u>not wish</u> to approach humans after this experience.
    a. In special cases it can be necessary to scare a bear away even if there is no direct risk for humans or equipment. Specifically, while working on ships,

it is easy to forget that polar bears should not get used to or be attracted to human activities (smell, sounds, impressions).

   b. Polar bears should not be allowed to crawl on or explore cabins, field camps, or ships.
   c. For each such encounter, when bears are scared, time and location must be recorded including number of bears and approach used for scaring the bear away.

5. Those who have responsible duties as safety personnel or polar bear watch should have this as their only duty and not carry out other tasks.
   a. Polar bears can harm and kill humans. Therefore, it is critical to detect an approaching bear as soon as possible. This is essential for a safe and orderly evacuation without risk for life and health.
   b. If a current polar bear watch is needed for specific operations, a new polar bear watch needs to fill the open position immediately and takes over responsibility for area and task.
   c. Each person in the science team has the responsibility to understand and behave according to the risks associated with polar bears, but specifically the safety officers/personnel and the polar bear watches have the responsibilities to ensure safety and avoid e.g. photo sessions.

Appendix 4: Overview over blogs and other outreach

Storymap of the cruise:
En reise til den arktiske vinteren – jakten på mer kunnskap om Barentshavet
https://storymaps.arcgis.com/stories/38a6650b509448f48c6e5faf958550bc

Blog posts:
The Nansen Legacy Winter Gaps Cruise – Rolf Gradinger (UiT) and Angelika Renner
https://sciencenorway.no/blog-nansen-legacy-project-blog-researchers-zone/the-nansen-legacy-winter-gaps-cruise/1985589
https://arvenetternansen.com/2022/02/22/the-nansen-legacy-winter-gaps-cruise/
(in Norwegian: https://blogg.forskning.no/arven-etter-nansen/arven-etter-nansens-kunnskapstokt-vinter/1985603)

Fulbright students join Nansen Legacy cruise – Megan Lenss and Evan Patrohay
https://arvenetternansen.com/2022/03/09/the-nansen-legacy-and-fulbright/

Hvorfor skal vi bry oss om små organismer på havbunnen? – Andreas Altenburger
https://blogg.forskning.no/arven-etter-nansen/hvorfor-skal-vi-bry-oss-om-sma-organismer-pa-havbunnen/2031758
https://uit.no/nyheter/forskerhjornet/772220/hvorfor_vi_skal_bry_oss_om_sma_organismer_pa_havb

Social media:
Posts on Nansen Legacy, UiT, NPI and IMR's Instagram, Facebook and Twitter channels

Appendix 5: Datasets

Who		Sample info		Analyses					Relevance to Nansen Legacy implementation plan		Data						Sampling gear
Cruise participant JC 3	**NL PI**	**Sample type**	**Intended method**	**Parameter**	**Section in NL protocol V10**	**Dataset**	**Where will analyses be done**	**Planned analysed**	**RF**	**Task/Subtask**	**Sharing within project**	**Publishing data**	**Ask for embargo of data?**	**If yes, why?**	**Comments**		
Asgeir Steinsland	Rudolf Krakauer (DWD, Germany)	only data	Radiosondes	Air temp., pressure, moisture, wind		Altitude profile of air temp., pressure, moisture, wind during the cruise period	DWD	2021	RF1	T1-2.3, T1-2.2, T1-1.2	2021	2022-2023					
Adam Steer, Bonnie Raffel	Sebastian Gerland, Arild Sundfjord	geolocated imagery of sea ice captured by remotely piloted aircraft (drone)	Parrot ANAFI USA	Ice and snow topoography, surface types		small scale orthophotos and elevation models of sea ice	NPI	Q2-Q4 2022	RF1	T1.1-1.2, T1-2.2	2022	2022	No				
Adam Steer, Bonnie Raffel	Sebastian Gerland, Arild Sundfjord	Electromagnetic induction soundings of snow + ice thickness	GEM2 electromagnetic induction sounder	Ice and snow thickness		geolocated ice and snow combined thickness	NPI	Q2-Q4 2022	RF1	T1.1-1.2, T1-2.2	2022	2022	No				
Adam Steer, Bonnie Raffel	Sebastian Gerland, Arild Sundfjord	Snow probe surveys of snow depth	Magnaprobe GPS snow probe	Snow depth		Geolocated snow depths	NPI	Q2-Q4 2022	RF1	T1.1-1.2, T1-2.2	2022	2022	No				
Adam Steer, Bonnie Raffel	Sebastian Gerland, Arild Sundfjord	Detailed snow stratigraphy	Direct observation using standardised snow stratigraphy tools	Snow structure, density		Snow structure, density used with	NPI	Q2-Q4 2022	RF1	T1.1-1.2, T1-2.2	2022	2022	No				
Adam Steer, Bonnie Raffel	Sebastian Gerland, Arild Sundfjord	Sea ice cores	Ice sampling using Kovacs corer	Physical characteristics of sea ice - stratigraphy, density, salinity and temperature profile	Section 14	Physical charactersistics of sea ice in the northern Barents Sea from in situ observations	NPI	Q2-Q4 2022	RF1	T1.1-1.2, T1-2.2	2022	2022	No				
Adam Steer, Bonnie Raffel	Sebastian Gerland, Arild Sundfjord	Under ice video from GoPro or ROV	Use a gopro on a long pole, or Blueeye ROV to	Under ice landscape		Added information for interpretation of	NPI	Q2-Q4 2022	RF1	T1.1-1.2, T1-2.2	2022	2022	No				

			collect under ice imagery			ice characteristics										
Adam Steer, Bonnie Raffel	Dmitry Divine, Sebastian Gerland	Sea ice observations	Sea ice observations/pictures from the bridge follow ASSIST protocol	Sea ice coverage, Sea ice age and type, Snow cover	Section 4.1	Sea ice observations	NPI	Q2-Q4 2022	RF1	T1.1-1.2, T1-2.2	2022	2022	No			
Birte Schuppe, Andreas Altenburger	Bodil Bluhm, Lis Lindal Jørgensen	d13C / d15N organisms (mostly benthic)	IRMS coupled to C/N analyser	d13C, d15N	10.3.13	Carbon and nitrogen stable isotope composition	UiO	2021-2023	RF3	T3-3.4	2022-2023	2023	possibly	Post doc project		
Birte Schuppe, Andreas Altenburger	Bodil Bluhm, Lis Lindal Jørgensen	Water POM, sea ice POM	IRMS coupled to C/N analyser	d13C-d15N pPOM, iPOM	14.7.1, 9.1.5	IRMS	UiO		RF3	T3-3.4						
Anette Wold, Janne Søreide; Elisabeth Halvorden	Anette Wold, Janne Søreide; Camilla Svensen	Mesozooplankton & small mesozooplankton t taxonomy & abundance	Morphological identification	ind/m3 & mg dry mass/m3 using species-specific dry mass values from published sources	chapter 9.2.1	Mesozooplankton & small mesozooplankton abundance (ind/m3), biomass (mg dry mass/m3) and species composition (species list)	IOPAN	2022	RF3	T3-1.1 & 2.1	2023	2023/24	No			Multinet 180 um & 64 um
Anette Wold, Janne Søreide; Elisabeth Halvorden	Janne Søreide; Kim Præbel	Mesozooplankton community	Morphological identification; Metabarcoding; Weighing; Fatty acid	ind/m3; COI sequences; mg dry weight of community; fatty acid composition of community	chapter 9.2.1	Mesozooplankton & smalll mesozooplankton taxonomy, metabarcoding, biomass and fatty acid composition	UiT, Kim Præbel(barcoding); IOPAN (taxonomy)	2022	RF4	T3-1.1 & 2.1 T3-2.1 & 2.3	2023	2023/24	No			Bongonet 64 um & 180 um
Anette Wold, Janne Søreide; Elisabeth Halvorden	Espen Bagøien, Post Doc	Macrozooplankton	Morphological identification, metabarcoding	taxonomic composition, biomass	9.2.2	Key organims, e.g. Euphausiids and amphipods, Map spatial distribution, taxonomic compostion and biomass indices, temporal and spatial variation in abundance, biomass, diveristy	IMR	2022	RF3	T3-1.1; T3-2.1	2023	2023/24	No			MIK-net

Anette Wold, Janne Søreide; Elisabeth Halvorden	Anette Wold; Janne Søreide; Camilla Svensen (in collabaoration with Sanna Majaneva, NTNU)	Gelatinous zooplankton	Genetic analyses, counts, size measurmnts	species list; ind/m3; ml/m3	9.2.1.5	Gelatinous zooplankton abundance (ind/m3), volume & species composition (species list)	Counts, weight and length measurements done onboard; species identification NTNU (Sanna Majaneva)	2022	RF3	T3-1.1 & 2.1 T3-2.1 & 2.2	2023	2023/24	No			MIK-net; Multinet Mammoth 64 & 180 um; Bongonets 64 & 180 um
Janne Søreide, Amalie Gravelle	Janne Søreide; Khuong Van Dinh	Respiration data	Mesozooplankton respiration (Calanus spp)	rates (oxygen consumption)	chapter 9.3.4	Oxygen consumption and individual body weight and body sizes	UNIS	2022	RF2/RF3	T3-2.2	2023	2023/24	No			MIK, Mammot/Multinet 180 and WP3
Janne Søreide	Janne Søreide	Dry mass, carbon and nitrogen content of individual zooplankton	Freeze dry and later on combust for C and N content (CHN analyser)	Dry mass, carbon and nitrogen content of individual zooplankton	chapter 9.3.4	Dry mass, C and N content	UNIS	2022	RF2/RF3	T3-2.2	2023	2023/24	No			MIK, Mammot/Multinet 180 and WP3
Miriam Marquardt, Lucie Goraguer, Evan Patrohay	Anna Vader	Chlorophyll a in water and ice	Fluorometric analysis	Chl a total and > 10um biomass	7.13	Chl a total and > 10um biomass	Onboard KPH	During cruise	RF3	T3-1.1	2023	2023	No			
Miriam Marquardt, Lucie Goraguer	Anna Vader; Bente Edvardsen	Protist diversity (DNA and RNA) in water and ice	metabarcoding using rDNA	Protist diversity		Protist diversity, proportional abundance, dynamics and distribution along the JC2-2 transect	UNIS; UiO	2021-2023	RF3	T3.1.1, T3.1.2, T3.2.1	2023	2023	No	PhD-project		
Miriam Marquardt, Lucie Goraguer	Anna Vader/Lise Øvreås	Bacterial diversity (DNA and RNA) in water and ice	metabarcoding using rDNA and rDNA	Bacterial diversity		Bacterial diversity, proportional abundance, dynamics and distribution along the JC2-2 transect	UNIS; UiB	2021-2023	RF3	T3.1.1, T3.1.2, T3.2.1	2023	2023	No			
Birte Schuppe, Andreas Altenburger	Paul Renaud	Sediment pigments	HPLC	mg pigment type / m2		sediment pigments HPLC	Plymouth Marine Laboratory	2019-2020	RF3, CAO	T3-1.2	2021-2022	2021-2022	no	no embargo		
Birte Schuppe, Andreas Altenburger	Elisabeth Alve	Sediment samples	Laser Diffraction Particle Size Analyzer	sediment grain size fractions	10.3.3	sediment grain size fractions	UiO	2019-2022	RF1; RF3	RF1, RF3 T3-1.2	2020	2021-2022	Yes, possibly	PhD project		

Birte Schuppe, Andreas Altenburger	Elisabeth Alve (Forams), Bodil Bluhm/ Andreas Altenburger (metazoans)	Meiofauna abundance in sediment	Sorting and morphological identification	number of individuals/ cm2	10.3.5	Foraminifera abundance, diversity and composition; metazoan meiofauna abundance, diversity and composition	UiO (Foraminifera), UiT (metazoan meiofauna)	2019-2022	RF1; RF3	T3-1.1	2020	2021-2022	Yes, possibly	PhD project		
Birte Schuppe, Andreas Altenburger	Lise Øvreås	Bacterial diversity in sediment	Metabarcoding	taxonomic composition, abundance and distribution	10.3.4	Microbial eukaryote diversity in sediment across season based on metabarcoding	UiB	2019-2021	RF3	T3-1.1, T3-1.2, T3-1.3, T3-4.1	2021	?	Unsure			
Birte Schuppe, Andreas Altenburger	Paul Renaud	Sediment pigment	Fluorometric analysis	mg Chl a / m2, mg phaeopigment / m2	10.3.2	Sediment pigments	APN	2019-2021	RF3	T3-1.2	2020	2020-2022	No			
Birte Schuppe, Andreas Altenburger	Bodil Bluhm, Paul Renaud	Macrofauna diversity and abundance	Sorting and morphological identification	number of (taxon) / cm2, diversity indexes, community analysis	10.3.9	Macrofauna abundance, diversity and composition; metazoan macrofauna abundance, diversisty and composition, community analysis	Nord/IOPAN	2019-2020	RF3	T3-1.1, T3-1.3	2021-2023	2021-2023	Yes, possibly	PhD project		
Birte Schuppe, Andreas Altenburger	Elisabeth Alve	Sediment samples	combustion in muffle furnace	sediment total organic carbon (TOC, %)	10.3.3	sediment total organic carbon (TOC, %)	UK lab	2019-2022	RF1; RF3	RF1, RF3 T3-1.2	2020	2021-2022	Yes, possibly	PhD project		
Birte Schuppe, Andreas Altenburger	Elisabeth Alve	Sediment samples	combustion in muffle furnace	sediment total nitrogen (TN, %)	10.3.3	sediment total nitrogen (TN, %)	UK lab	2019-2022	RF1; RF3	RF1, RF3 T3-1.2	2020	2021-2022	Yes, possibly	PhD project		
Birte Schuppe, Andreas Altenburger	Elisabeth Alve	Sediment organic matter	IRMS	d13C (per mil), d15N (per mil)	10.3.3	d13C (per mil), d15N (per mil)	UK lab	2019-2022	RF1; RF3	RF1, RF3 T3-1.2	2020	2021-2022	Yes, possibly	PhD project		
Asgeir Steinsland/Jan Vidar Nordstrand	Randi Ingvaldsen, Elena Eriksen	Acoustic signal	Acoustic data analysis	Target strength and identity		Target strength and identity	IMR		RF3							

Elisabeth Halvorsen	Camilla Svensen	Productivity of Oithona similis	Egg hatching experiment	egg production rate, weight specific egg production rate	9.3.3.	spatial and temporal variability of copepod secondary production, specific egg production rate as an estimate for copepod production	UiT	2019 - 2022	RF3	T3-2.2	2022	2023-24	yes	PhD project		
Elisabeth Halvorsen	Camilla Svensen	Productivity of Calanus hyperboreus	Egg hatching experiments	egg production rate, weight specific egg production rate	9.3.3.	spatial and temporal variability of copepod secondary production, specific egg production rate as an estimate for copepod production	UiT	2019 - 2022	RF3	T3-2.2	2022	2023-2024	yes	PhD project		
Zoe Koenig, Julie Sortland	Arild Sundfjord	Data only	CTD data	Temperature and salinity		Temperature and salinity data	NPI	2022	RF1	T1.1.2	2022	2022-2023	No			
Zoe Koenig, Julie Sortland	Arild Sundfjord	Water	Salinometer	Salinity		Salinity data	IMR	2022	RF1	T1.1.2	2022	2022-2023	No			
Elizabeth Jones, Marit Kollstuen	Melissa Chierici, Agneta Fransson	Water samples from the CTD-Rosette niskin bottles	Winkler titration	dissolved oxygen (DO)		Dissolved oxygen	IMR/NPI	2021	RF2	T2-1.1	2021	2021	No			
Elizabeth Jones, Marit Kollstuen	Melissa Chierici, Agneta Fransson	Water samples from the CTD, and sea ice cores, snow, brine, under-ice water	Gasextraction of acidified seawater followed by photometric detection and coulometric titration (VINDTA system); Potentiometric titration in open cell with hydrochloric acid	dissolved inorganic carbon (DIC), total alkalinity (AT)	7.2.1	dissolved inorganic carbon, µmol/kg	onboard	2021	RF2	T2-1.1	2021	2022	No			
Elizabeth Jones, Marit Kollstuen	Melissa Chierici, Agneta Fransson	Water samples from the CTD, and sea ice cores, snow, brine, under-ice water	Autoanalyzer	Inorganic nutrients (NO2, NO3, PO4, Si)	7.12	nutrients, µM	IMR Bergen	2021	RF2	T2-1.1	2021	2022	No			
Elizabeth Jones, Marit Kollstuen	Melissa Chierici, Agneta Fransson	Water samples from the CTD, and sea ice cores,	Stable oxygen isotope (d18O), mass spectrometer	d18O	7.3	d18O, promille	NPI	2021	RF2	T2-1.1	2022	2022	No			

		snow, brine, under-ice water														
Miriam Marquardt	Marit Reigstad, Gunnar Bratbak	POC/PON water and ice	CN analyses	µg/L	14.7.1, 7.4	POC/PON	UiT/UiB	2020-2023	RF3		2020-2023	2022-2023	yes	PhD project		
Miriam Marquardt	Miriam Marquardt, Rolf Gradinger, Bodil Bluhm	Nutrients from sea ice cores	Nutrient analyses	µg/L	7.12	Nutrients	UiT	2020-2023	RF3		2020-2023	2022-2023	no			
Miriam Marquardt, Lucie Goraguer, Evan Patrohay	Miriam Marquardt, Rolf Gradinger, Bodil Bluhm	Ice meiofauna abundance/taxonomy	Microscopy	Ind/m3; ml/m3	14.7.5	Ice meiofauna abundance/taxonomy	UiT	2020-2023	RF3		2020-2023	2022	Yes, possibly			
Birte Schuppe, Andreas Altenburger	Murat V. Ardelan	Sediment samples	Hg determination, DMA-80 and REE elements, mass spectometry	THg in ng/g, Trace element concentrations	7.7	Distribution of trace elements in sediments	NTNU	2019-2022	RF2	T2-2.2	2020-2022	2022	maybe, check with PI			
Khuong Van Dinh	Katrine Borgå, Ketil Hylland	Alive copepods	Exposure experiments to oil compounds	Life history traits	9.3.5	Survival, body size, development, egg reproduction	UiO	2022-2023	RF2	T2-2.2	2021	2021-2023	yes	Postdoc		
Lucie Gorageur	Philipp Assmy, Bente Edvardsen	Fixed water samples from Niskin bottles 6 depths, phytoplankton nets, and ice stations	Utermöhl cell counts under the microscope	Cell abundances of protists > 10 µm	7.15	Phytoplankton/protist abundance	NPI	2023	RF3	T3.1.1	2023	2023	No			
Zoe Koenig, Julie Sortland	Arild Sundfjord	Data only	Post processing	Turbulence		Turulence	NPI	2023	RF1	T1.2.1	2023	2023	No			
Zoe Koenig, Julie Sortland	Arild Sundfjord	Data only	Post processing	Current velocity		Current velocity	NPI	2023	RF1	T1.1.2	2023	2023	No			
Rosalie McKay	Karley Campbell	melted sea ice incubations with 3H leucine	Bacterial Production	Bacterial production rate uptake 3H leucine	7.20	Bacterial production rate	UiT	2022					Yes	PhD-project		
Rosalie McKay	Karley Campbell	Microbial abundance in ice	Flow cytometry	cell counts	7.19	Bacteria, virus and small protists abundance	UiT	2022					yes	PhD-project		
Rosalie McKay	Karley Campbell	Chlorophyll a	fractionated algal pigments, filtered through GF/F filters from ice samples	Chl a total	7.13	Chlorophyll a	Onboard KPH	During cruise					yes	PhD-project		

Rosalie McKay	Karley Campbell	PAR measurement with li-cor	Under ice transmission, upwelling, downwelling	PAR			on ice	During cruise					yes	PhD-project		
Rosalie McKay	Karley Campbell	POC/PON ice	Quantification of POC in ice	POC	7.4	POC/PON	UiT	2022					yes	PhD-project		
Rosalie McKay	Karley Campbell	Nutrients from sea ice cores	Nutrient analyses	nutrients (NO2, NO3, PO4, Si)		Nutrients	UiT	2022					yes	PhD-project		
Rosalie McKay	Karley Campbell	DOC	Quantification of DOC in ice	DOC		DOC	UiT	2022					yes	PhD-project		
Rosalie McKay	Karley Campbell	Melted sea ice incubations with oxygen optodes	Change in oxygen concentration	Net community production			UiT	2022					yes	PhD-project		
Megan Lenss	Karley Campbell	Radioactively labelled algae on GF/F filters	Primary production in situ incubations	Primary production rate (14C uptake)	7.25	Vertical profiles of primary production across latitude and seasons	UiT	2022	RF3	T3-1.1/T3-1.2/T3-1.3/T3.2.1/	2022	2022	? Need to ask Marti	PhD-project		
Zoe Koenig, Julie Sortland	Arild Sundfjord	Data only		Nutrient fluorescence data		Vertical profiles and moored instrument under the sea ice	NPI	2022	RF1				No			
Kristian Lampe Gjemdal, Karoline Barstein	Martin Ludvigsen	Data only		Navigation data		Navigation data of ROV under ice using USBL	NTNU/UNIS	2022	RAC	TC-1-1/TC-1-2	2022	2022	No			
Kristian Lampe Gjemdal, Karoline Barstein	Martin Ludvigsen	Data only		Video footage		Video recordings from ROV under ice	NTNU	2022	RAC	TC-1-1/TC-1-2	2022	2022	No			
Andreas Altenburger	Andreas Altenburger, Bodil Bluhm	Sediment	extraction of eDNA	taxonomic composition	10_3_16	eDNA	UiT	2022	RF3	T3.1.1	2022	2023	No			
Andreas Altenburger	Andreas Altenburger	Invertebrate tissue	genome sequencing and microRNA sequencing	genome and microRNA	10_3_17	genome and microRNA	UiT	2022-2023	RF3	T3.1.1	2022	2023	No			
Marius Filomeno Maurstad	Sissel Jentoft	Fish metadata	Genome sequencing	Genome sequencing	V9 chapters 11.1 and 11.3.	Metadata	UiO	2023-2024	RF2	T2-3.1	2023-2024	2024	Yes	PhD/ MSc project		
Hugo Rubio, Shokoufeh Malekmohammadi	Joachim Reuder (UiB)	Data only	Remote sensing lidars, weather station and Inertial Motion Unit	Wind speed and direction, air temp., pressure, precipitatio		Vertical profile of wind speed and direction, air temp., pressure, rel. humidity, precipitation and	UiB and Fraunhofer IWES	2022	RF1	T1-2.3	2023	2023	No			

				n, rel. humidity, ship speed and tilting, ship position		ship motion information										

The Nansen Legacy in numbers

6 years

The Nansen Legacy is a six-year project, running from 2018 to 2023.

1 400 000 km² of sea

The Nansen Legacy investigates the physical and biological environment of the northern Barents Sea and adjacent Arctic Ocean.

>10 fields

The Nansen Legacy includes scientists from the fields of biology, chemistry, climate research, ecosystem modelling, ecotoxicology, geology, ice physics, meteorology, observational technology, and physical oceanography.

>350 days at sea

The Nansen Legacy will conduct 15 scientific cruises and spend more than 350 days in the northern Barents Sea and adjacent Arctic Ocean between 2018 and 2022. Most of these cruises are conducted on the new Norwegian research icebreaker RV *Kronprins Haakon*.

280 people

There are about 230 researchers working with the Nansen Legacy, of which 73 are early career scientists. In addition, 50 persons are involved as technicians, project coordinators, communication advisers and board members.

10 institutions

The Nansen Legacy unites the complimentary scientific expertise of ten Norwegian institutions dedicated to Arctic research.

50/50 financing

The Nansen Legacy has a total budget of 740 million NOK. Half the budget comes from the consortiums' own funding, while the other half is provided by the Research Council of Norway and the Ministry of Education and Research.

Norwegian Ministry of Education and Research

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