8. SEA ICE ECOLOGY, PELAGIC FOOD WEB AND COPEPOD PHYSIOLOGY - ICEFLUX / PEBCAO

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Objectives

Pelagic food webs in the Arctic sea ice zone can depend significantly on carbon produced by ice-associated microalgae. Future changes in Arctic sea ice habitats will affect sea ice primary production and habitat structure, with unknown consequences for Arctic ecosystems. Under-ice amphipods, polar cod *Boreogadus saida* and other species feeding in the ice-water interface layer can play a key role in transferring carbon from sea ice into the pelagic food web, up to the trophic level of birds and mammals (David et al 2015, David et a in review). To better understand potential impacts of changing sea ice habitats for Arctic ecosystems, the HGF Young Investigators Group *Iceflux* in cooperation with IMARES (*Iceflux-NL*) and AWI's PEBCAO group aim to quantify the trophic carbon flux from sea ice into the under-ice community and to investigate physiological capacities of abundant Arctic copepods to adapt to environmental conditions. This should be achieved by 1) quantitative sampling of the in-ice, under-ice and pelagic community in relation to environmental parameters; 2) using molecular and isotopic biomarkers to trace sea ice-derived carbon in pelagic food webs; 3) studying the diet of sea ice-associated organisms, and 4) an experimental study on the resilience of *Calanus* spp to a changing food regime.

Work at sea

SUIT sampling

A Surface and Under-Ice Trawl (SUIT: van Franeker et al 2009) was used to sample the meso- and macrofauna down to 2 m under the ice. The SUIT had two nets, a 0.3 mm mesh plankton net, and a 7 mm mesh shrimp net. During SUIT trawls, data from the physical environment were recorded, e.g. water temperature, salinity, fluorescence, ice thickness, and multi-spectral light transmission. Fifteen SUIT deployments were completed in the closed pack-ice between the Svalbard shelf and the Yermak Plateau (Table 8.1). An overview of the sampling locations is given in Fig. 8.1. Macrofauna samples from the SUIT shrimp net were sorted to the lowest possible taxonomic level. The catch was entirely preserved frozen (-20°C / -80°C), on ethanol (70 % / 100 %), or on 4 % formaldehyde/seawater solution, depending on analytical objectives In euphausiids, the composition of size and sexual maturity stages was determined 48 hrs after initial preservation in formaldehyde solution.

Tab. 8.1: Summary statistics of SUIT hauls conducted during PS92

Station	Date	Start Time (UTC)	Latitude (North)	Longitude (East)	Bottom depth (m)
19-1	27-05-15	15:22	19.907	81.007	188.5
27-1	31-05-15	4:16	17.767	81.368	827.9
28-4	2-06-15	13:13	19.417	81.513	928.2
31-1	3-06-15	4:41	19.575	81.552	1050.5
32-12	7-06-15	17:00	19.702	81.180	335.6
38-1	9-06-15	15:46	16.311	81.317	2249.1
39-17	12-06-15	18:53	11.817	81.652	1954.7
43-23	16-06-15	15:23	7.0983	82.152	793.6
43-24	16-06-15	17:21	7.068	82.148	799.4
44-1	17-06-15	7:23	9.258	81.942	814.4
45-1	17-06-15	12:26	9.802	81.912	921.5
47-1	19-06-15	7:00	13.650	81.380	2139.1
48-1	21-06-15	6:59	12.963	81.013	2046.9
49-1	21-06-15	13:23	12.848	81.030	2083.1
56-2	23-06-15	12:02	8.190	81.015	848.8

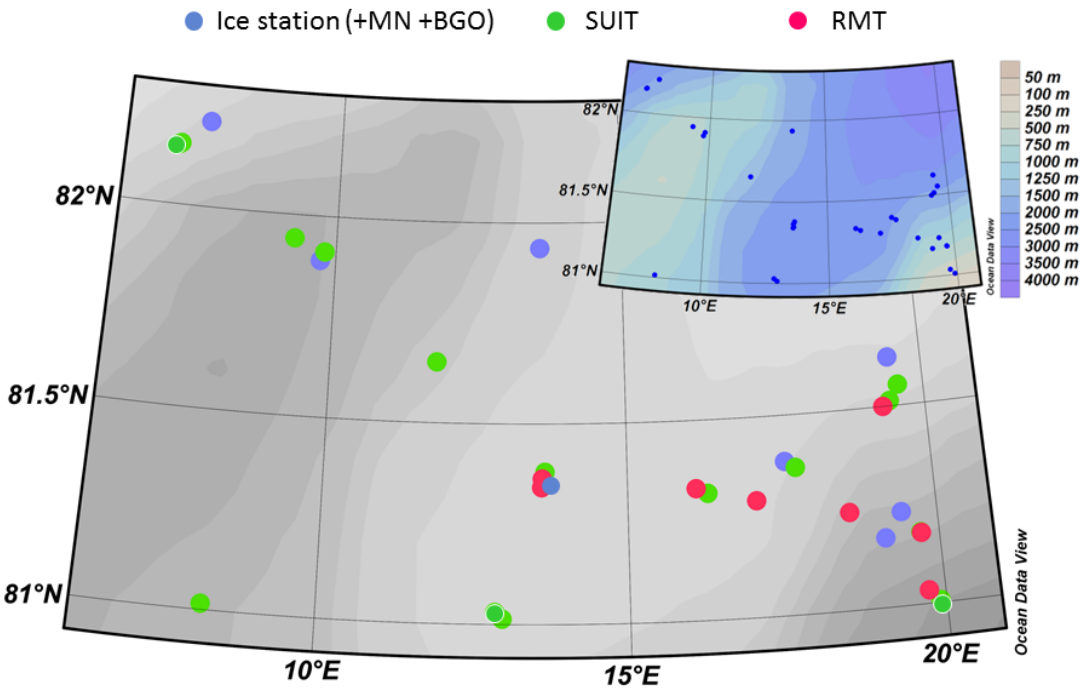

Fig. 8.1: Overview of stations sampled by the Iceflux/PEBCAO team during PS92 BGO: Bongo net; MN: Multinet

Pelagic sampling

A Multiple opening Rectangular Midwater Trawl (M-RMT) was used to sample the pelagic community. During trawling, sampling depth, water temperature and salinity were recorded with a CTD probe attached to the bridle of the net. The standard sampling strata in offshore waters were 1000-200 m, 200-50 m, and 50 m to the surface. In shallow waters or when heavy ice limited the length of the trawl, the lowest depth stratum varied between 100 and 800 m. We conducted 8 depth-stratified hauls with the M-RMT. The catch was sorted by depth stratum and taxon. Sample collection and size measurements on euphausiids were performed in the analogue procedure described above for SUIT sampling.

Tab. 8.2: Summary statistics of RMT hauls conducted during PS92

Station	Date	Start Time (UTC)	Latitude (North)	longitude (East)	Bottom depth (m)	Lower limits of depth strata sampled
19-2	27.05.15	18:16	81.033	19.737	173	25 m, 50 m, 100 m
24-2	30.05.15	14:37	81.245	18.592	477.6	50 m, 200 m, 400 m
27-17	1.06.15	14:47	81.292	17.100	866.2	50 m, 200 m, 300 m
28-5	2.06.15	16:04	81.500	19.295	908.1	50 m, 100 m, 200 m
32-11	7.06.15	14:48	81.178	19.710	320	50 m, 200 m, 290 m
38-2	9.06.15	17:58	81.330	16.123	2273.8	50 m, 200 m, 500 m
47-2	19.06.15	9:35	81.363	13.607	2145.4	50 m, 200 m, 300 m
47-23	20.06.15	22:37	81.342	13.593	2175.4	50 m, 200 m, 1000 m

The pelagic mesozooplankton community was sampled with a Multinet at each ice station. The Multinet had an opening of 0 25 m^2 and a mesh size of 150 µm. Sampling was performed over 5 discrete depth layers: 1500-1000 m, 1000-500 m, 500-200 m; 200-50 m, and 50 m to the surface. At stations shallower than 1500 m, the lowest depth stratum extended to 30 m above bottom depth. In total, 9 Multinet stations were completed, including one day/night comparison (Tab. 8.3).

Tab. 8.3: Summary statistics of Multinet hauls conducted during PS92

Station	Date	Time	Latitude (North)	Longitude (East)	Bottom Depth [m]
19-11	2015-05-28	16:48	81.192	19.013	412.3
27-9	2015-05-31	17:17	81.358	17.475	821.3
31-8	2015-06-03	20:17	81.593	19.075	1421
32-9	2015-06-07	9:19	81.212	19.605	447
39-13	2015-06-12	5:58	81.787	12.570	1741.1
43-18	2015-06-15	22:48	82.207	7.142	871.4
46-8	2015-06-18	6:06	81.888	9.852	929.3
46-11	2015-06-18	8:49	81.878	9.863	942.1
47-10	2015-06-19	21:15	81.338	13.600	2184.1
47-18	2015-06-20	11:51	81.348	13.688	2175.5

At each ice station, Bongo nets with a mesh size of 500 µm were used to sample the mesozooplankton community from 200 m depth to the surface. Samples were taken for respiration measurements in collaboration with N Morata and for fecal pellet production experiments in collaboration with C Dybwad. At the last two stations, in total 3 additional Bongo net hauls were conducted for the sampling of living copepods for experiments at the AWI (Table 8.4).

Tab. 8.4: Summary statistics of Bongo net hauls conducted during PS92

Station	Date	Time	Latitude (East)	Longi-tude (North)	Bottom Depth [m]	Purpose
19-16	2015-05-29	8:29	81.210	18.655	438.6	on-board experiments
20-2	2015-05-29	23:30	81.033	19.342	178.1	on-board experiments
27-11	2015-05-31	19:41	81.353	17.433	814.7	on-board experiments
31-5	2015-06-03	16:13	81.605	19.257	1451.9	on-board experiments
32-17	2015-06-08	8:05	81.098	19.642	209	on-board experiments
32-18	2015-06-08	8:52	81.102	19.690	196.1	on-board experiments
39-12	2015-06-12	4:27	81.800	12.648	1731	on-board experiments
43-10	2015-06-15	11:43	82.208	7.410	812.7	on-board experiments
43-11	2015-06-15	12:13	82.208	7.393	806.3	on-board experiments
46-6	2015-06-18	4:30	81.892	9.820	924.5	on-board experiments
46-7	2015-06-18	5:02	81.892	9.832	924.7	on-board experiments
46-12	2015-06-18	9:47	81.873	9.853	943	on-board experiments
46-13	2015-06-18	10:19	81.870	9.847	948.2	on-board experiments
47-8	2015-06-19	19:14	81.338	13.610	2176	on-board experiments
47-9	2015-06-19	19:43	81.338	13.608	2177.3	on-board experiments
47-13	2015-06-20	6:15	81.345	13.673	2175.8	AWI experiments
47-14	2015-06-20	6:45	81.345	13.683	2176.8	AWI experiments
56-6	2015-06-23	16:31	81.015	8.292	853.9	AWI experiments

Polarstern's EK60 echosounder recorded the distribution of acoustic targets continuously during sailing, only paused during geological surveys of bottom sediments. Our sampling frequencies were 38 kHz, 70 kHz, 120 kHz, and 200 kHz All EK60 data were backed up on the ship's mass storage server.
For biomarker analysis, Particulate Organic Matter (POM) was collected from filtered seawater obtained from the CTD rosette at each ice station.

Sea ice work

Our sea ice work was conducted in close collaboration with the AWI sea ice physics group (T Krumpen et al.). A total of 8 sea ice stations were sampled during PS92 (Table 8.5) Depending on time availability and weather conditions, the following sampling procedure was completed during sea ice stations:

a) We conducted measurements of the under-ice light field using a RAMSES spectroradiometer attached to an L-arm, sampling light spectra under the sea ice well away from the drilling hole. At each L-arm site, a bio-optical core was taken straight above one RAMSES measurement point. Additional bio-optical cores were sampled above RAMSES measurement points along ROV transect of the sea ice physics group.
b) Ice cores were taken for biomarker analysis and sea ice infauna, respectively.
c) We lowered a CTD probe equipped with a fluorometer through a hole down to 50 m depth, thus obtaining vertical profiles of temperature, salinity and chlorophyll *a* content in the upper 50 m under the sea ice.
d) We collected under-ice water for the analysis of the microzooplankton composition with a handheld Kemmerer water sampler lowered to approximately 1 m under the ice.

In bio-optical cores, the bottom 10 cm were separated from the rest of the core, and both retained sections were processed for chlorophyll *a* content in order to determine the relationship of ice algal biomass with the under-ice spectral light properties. Additionally, subsamples from the melted bio-optical core sections were taken for pigment analysis (HPLC), POM, and microscopic analysis In cores for sea ice infauna, 10 cm sections from the bottom, the top and the inner part of the core were retained for sample collection. Retained sections of sea ice infauna cores were carefully melted at 4°C in the ship's temperature-controlled laboratory container 200 ml filtered sea water per cm core section were added to melting sections of sea ice infauna cores. Filters for POM and pigment analysis obtained from melted ice core sections and water samples were frozen at -80°C. Microscopy samples from bio-optical cores, under-ice microzooplankton and sea ice infauna were stored at 4°C on 4 % formaldehyde/seawater solution.

Tab. 8.5: List of the ice stations sampled, and number of ice cores, L-arm measurements and CTDs taken at each sampling site. For each ice station it is specified if there have been conducted under ice radiation mesurements (L-arm), and the number of under-ice CTD profiles conducted

Ice st. no	Station	Cores	L-arm	CTD
01	19-6	7	1	2
02	22-1	7	1	2
03	31-2	7	1	2
04	32-4	5	1	1
05	39-9	5	1	1
06	43-6	5	1	2
07	46-3	3	-	1
08	47-5	4	-	1

Preliminary (expected) results

SUIT sampling

SUIT sensors data: All 15 SUIT hauls were conducted under sea ice. Bio-environmental profiles were obtained from each SUIT haul (Fig. 8.2) The average ice coverage of the under-ice hauls was 51 %. Preliminary mean ice draft calculated based on pressure measurements of the SUIT's CTD ranged between 175 cm and 394 cm in heavy sea ice (Fig. 8 3). In a first analysis of surface water chlorophyll-*a* content, a characteristic pattern could not be identified.

More insight on the biological productivity of the system, however, can be expected as soon as spectral data from the SUIT's RAMSES sensor can be related to the chlorophyll *a* content of sea ice derived from our L-arm measurements and associated ice core sampling.

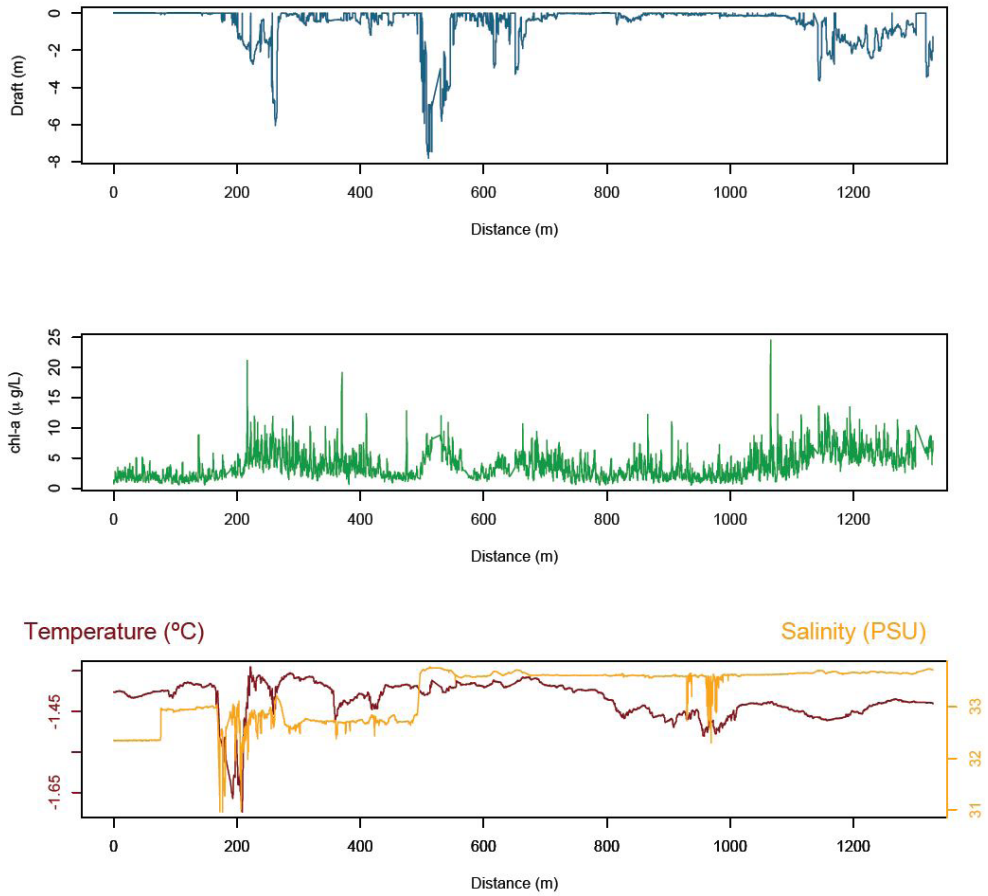

Fig. 8.2: Example of environmental data profiles obtained from the SUIT's sensor array at station 27-1.

SUIT catch composition: A large part of the catch from the 7 mm mesh shrimp net was counted and sorted on board. Several abundant taxa, however, were excluded from this preliminary analysis due to time limitations. These include the often dominant chaetognaths (mainly *Sagitta* spp), *Calanus* spp , and appendicularians. Fig. 8.3 shows an overview of the taxa quantified In terms of abundance, the catch was heavily dominated by amphipods. The under-ice amphipod *Apherusa glacialis* was the most abundant species over all SUIT hauls. Other ice amphipods, such as *Onisimus* spp , *Eusirus holmii* and *Gammarus wilkitzkii*, were practically omnipresent, albeit at lower abundances. The catch composition in the eastern part of the survey area was clearly dominated by *A glacialis* and other ice amphipods. In this region, low numbers of polar cod *Boreogadus saida* were caught at stations deeper than 1,000 m. In the western part of the investigation area, the pelagic amphipod *Themisto libellula* co-dominated. In this region, several stations also had high abundances of the krill *Thysanoessa* spp , and the sea angel *Clione limacina* (Fig. 8.3). Increased numbers of *Thysanoessa* spp and *appendicularians* (data not shown) may indicate a higher Atlantic influence in the western part of the survey area.

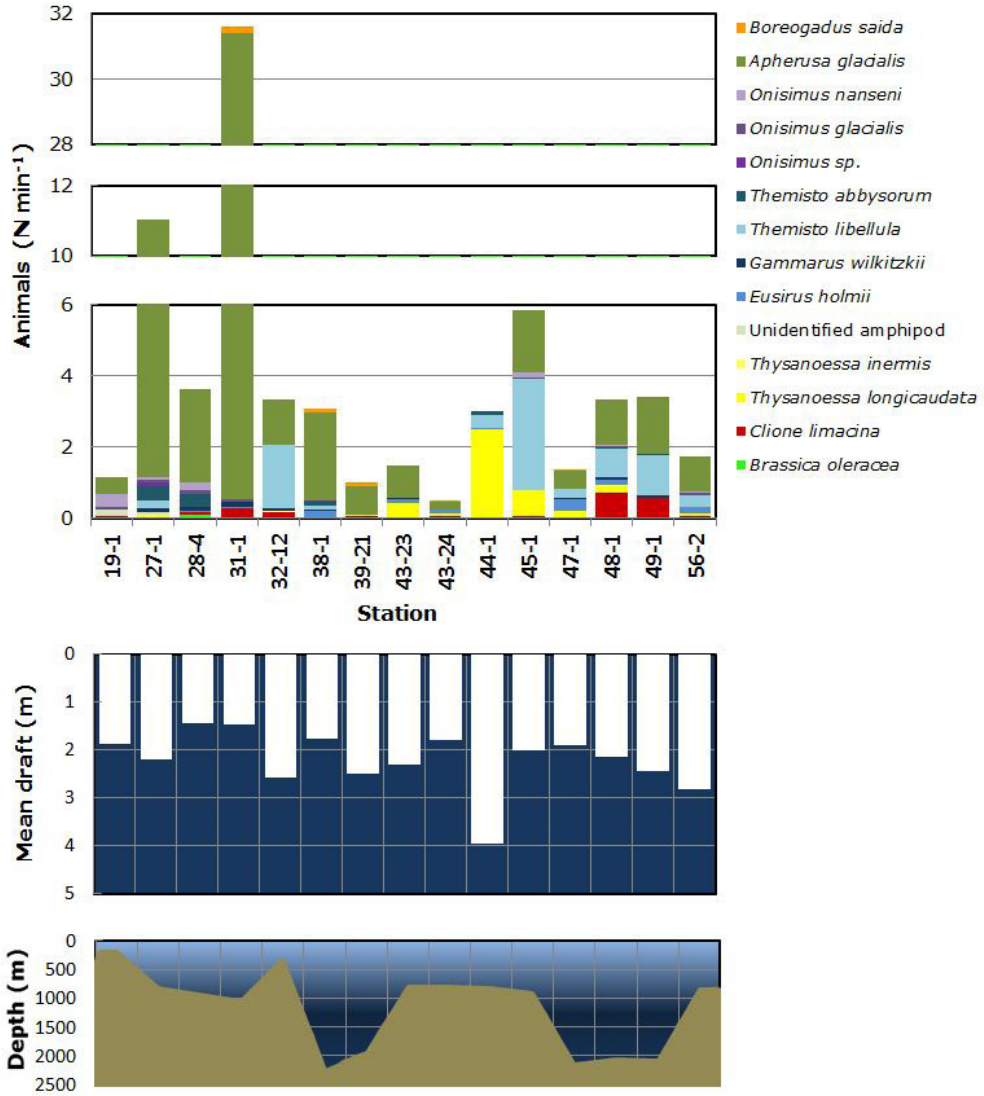

Fig. 8.3: SUIT catch composition, sea ice draft and bottom depth during trawling. The top panel shows the abundance of major taxa at each SUIT station in numbers per minute trawled In the center panel, the white bars represent the modal ice draft during each haul. The lower panel shows the bottom depth at each SUIT station Depths between SUIT sampling stations were interpolated and do not represent the actual depth profile of the cruise track

RMT sampling

We completed in total 8 M-RMT hauls, mostly in close proximity to SUIT sampling locations. However, no RMT hauls were conducted in the western part of the survey area due to heavy ice and time limitations (Fig. 8.1). In this report we present preliminary data on macrozooplankton and micronekton collected by the RMT-8 nets of the upper 200 m of the water column. Data on cnidarians, ctenophores, copepods, chaetognaths and appendicularians were not included in this preliminary analysis.

Macrozooplankton communities: The catch composition was heavily dominated by euphausiids ('krill') at each station (Fig. 8.4). *Thysanoessa longicaudata* and *T inermis* co-dominated in terms of abundance, whereas the considerably larger *Meganyctiphanes norvegica* probably dominated in terms of biomass (Fig. 8.5). At several stations, the more temperate *Nematocelis megalops* was present. After the euphausiids, pelagic amphipods *Themisto* spp represented the second most abundant taxon (Fig. 7.4). High abundances were also obtained by the copepod *Calanus hyperboreus*, and the chaetognath *Sagitta* spp (both not quantified) Ctenophores (not quantified) and sea angels *Clione limacina* were regularly present, but in lower numbers. We caught several squid larvae and one lanternfish (Myctophidae). Due to the lack of sampling locations in the western part of the survey area, no spatial pattern similar to the SUIT catch composition was apparent from the RMT data.

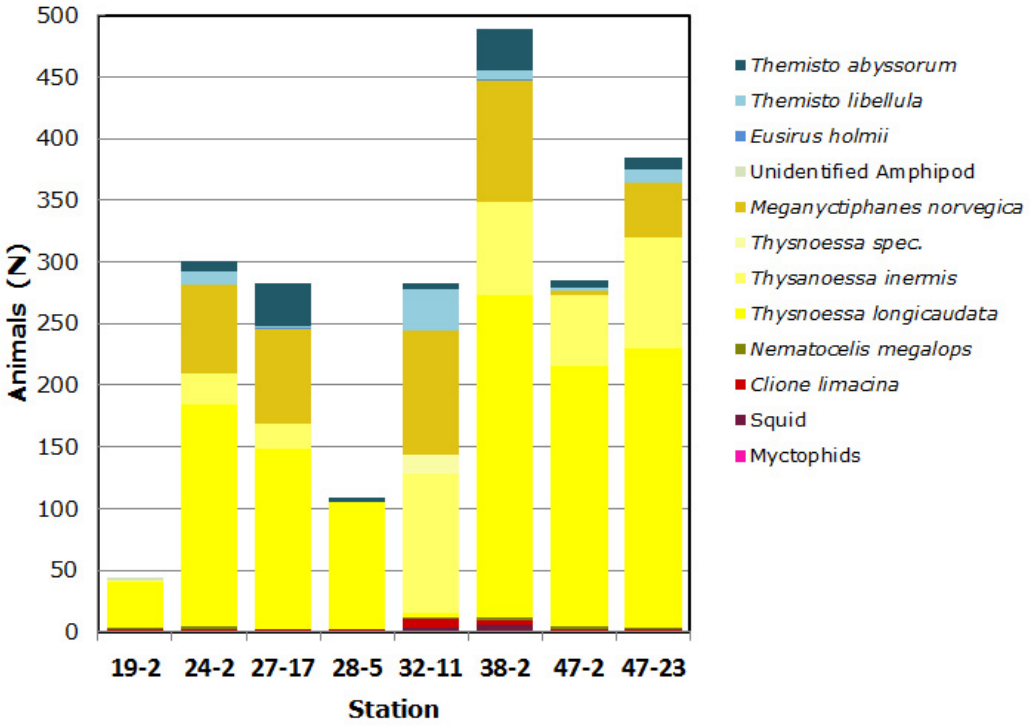

Fig. 8.4: RMT catch composition of the upper 200 m

Euphausiid size distribution: The size of *Meganyctiphanes norvegica* ranged between 12 and 40 mm, with a mode at 25 mm. Most animals were adults, with an approximately equal proportion of females and males. The majority of females were in maturity stage 2; whereas about 60 % of the males were in maturity stage 3A, and each about 20 % in stage 2 and 3B, respectively. The length distribution of *Thysanoessa inermis* reached from 10 to 32 mm. It had two modes at 16 and 25 mm, respectively. The 16 mm-mode was dominated by juveniles Krill over 20 mm length were predominantly adults. About 80 % of the females were in maturity stage 2 and 3A. Only 20 % of the females were in maturity stage 3B. In males, about 40 % were in stage 3A and 3B, respectively. The size of *Thysanoessa longicaudata* ranged from 7 to 17 mm. The size distribution was bimodal, with modes at 10 and 13 mm. Less than 5 % of the sampled krill were juveniles. About 25 % of the females and 35 % of the males were in maturity stage 3A. In both sexes, about 15 % of the animals were in maturity stage 3B, and less than 10 % were in maturity stage 2.

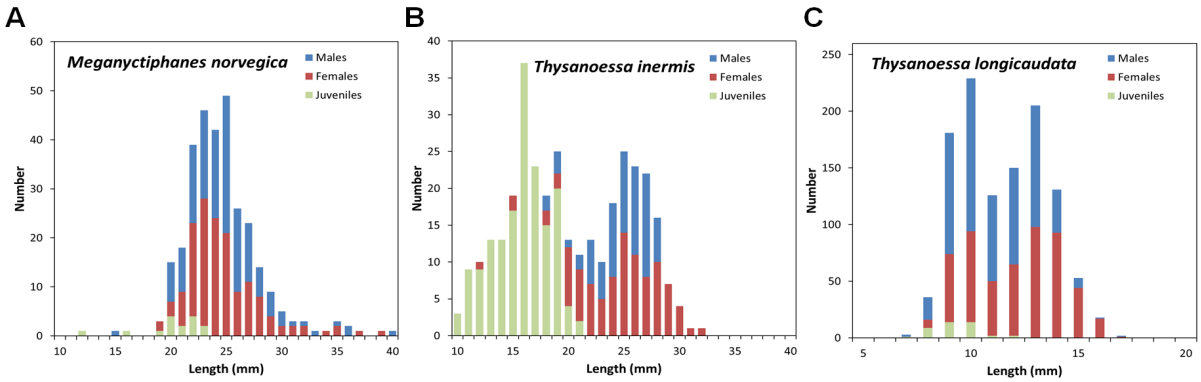

Fig. 8.5: Length-frequency distributions of the three most abundant krill species Meganyctiphanes norvegica (A), Thysanoessa inermis (B), and T longicaudata (C) in the upper 200 m of the water column

Sea ice work

The basic parameters of each sea ice station and their sampling sites were summarised in the sea ice biology section of this report. Table 8.6 lists the number of ice cores taken for the bio-optical work, sea ice infauna, and biomarker analysis.

Tab. 8.6: Numbers of ice cores taken at each ice station for bio-optical, biomarker (LSI) and sea ice meiofauna analysis

Ice	*Station*	*Meiofauna*	*LSI*	*BioOptical*
01	*19-6*	*2*	*2*	*3*
02	*22-1*	*2*	*2*	*3*
03	*31-2*	*2*	*2*	*3*
04	*32-4*	*2*	*2*	*1*
05	*39-9*	*2*	*2*	*1*
06	*43-6*	*2*	*2*	*1*
07	*46-3*	*2*	*0*	*1*
08	*47-5*	*2*	*0*	*2*

The CTD profiles provided information on the water characteristics at the ice stations. The temporal variability of CTD profiles at one station could significantly exceed between-station variability, both in physical parameters and chlorophyll *a* concentrations (Fig. 8.6).

At most ice stations we performed under-ice light field measurements. The high variability of the sampled ice floes offers the possibility to study light transmission through ice of different types and thicknesses as well as through different snow covers. This will help to parameterize the under-ice radiation in relation to different sea-ice physical conditions and, once the further analysis on the chlorophyll *a* will be completed, with different biomass content.

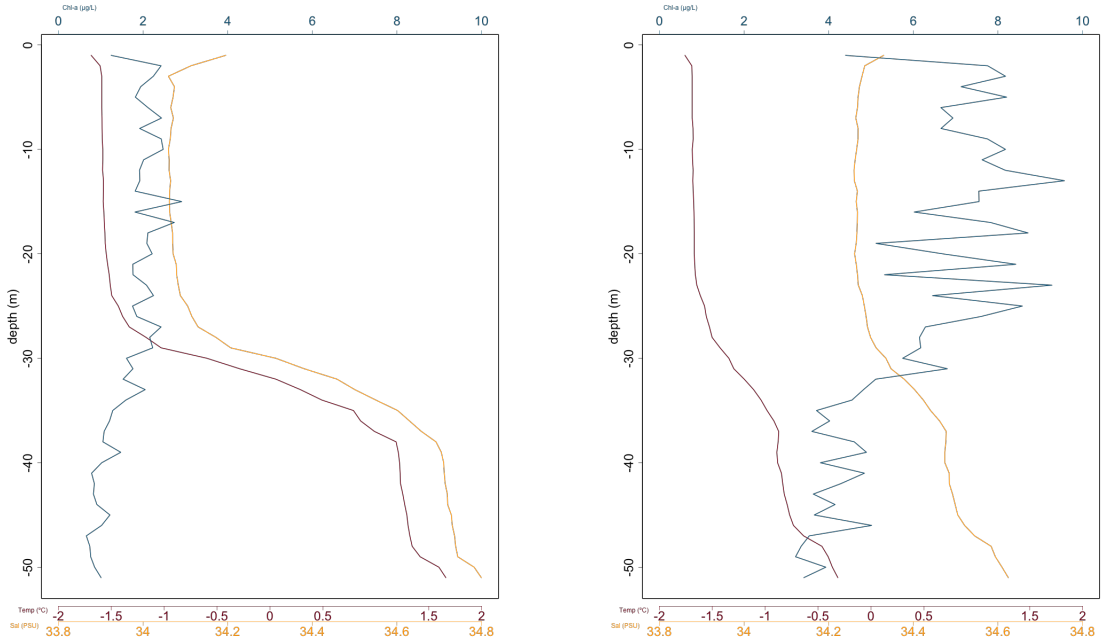

Fig. 8.6: Repeated CTD profiles in the top 50 m of the water column at ice station 31-2 The period between the two measurements was approximately 24 hours

Data management

Almost all sample processing will be carried out in the home laboratories at AWI and IMARES. This may take up to three years depending on the parameters as well as analytical methods (chemical measurements and species identifications and quantifications). As soon as the data are available they will be accessible to other cruise participants and research partners on request. Metadata will be shared at the earliest convenience; data will be published depending on the finalization of PhD theses and publications. Metadata will be submitted to PANGAEA, and will be open for external use.

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Chief scientist
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Coordinator
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Contents

1.	Zusammenfassung und Fahrtverlauf		3
	Summary and Itinerary		11
2.	Weather Conditions		15
3.	Activities of the Sea Ice Physics Group during PS92		18
	3.1	AEM bird ice thickness measurements	18
	3.2	Ground-based ice thickness and snow measurements	21
	3.3	Airborne digital video camera survey of surface properties	23
	3.4	Snow temperature and grain size evolution	25
	3.5	ROV work and optical properties of sea ice	26
	3.6	Ice observations	28
4.	Physical Oceanography		29
5.	Trace Gases and Carbonate Chemistry		44
	5.1.	Trace gases	44
	5.2	Water column carbonate chemistry	47
6.	Geochemistry		49
	6.1	Organic biomarkers in suspended particles	49
	6.2.	Water mass signatures ($\delta^{18}O$, $\delta^{13}C_{DIC}$)	51
	6.3.	Suspended particulate matter (SPM)	53
	6.4.	Dissolved neodymium isotopes and rare earth elements	54
	6.5	Source and transformations of chromophoric dissolved organic matter and its role in surface ocean heating	57
7.	Sea Ice Biota		65
	7.1	Ecological consequences of climate change in the Transpolar Drift region	65
	7.2	Heterotrophic microbial activity and the fate of ice associated production	77
8.	Sea Ice Ecology, Pelagic Food Web and Copepod Physiology - Iceflux / PEBCAO		81
9.	Ecosystems		91
	9.1	Nutrients, primary production and nitrogen cycling (GREENEDGE)	91
	9.2	Distribution patterns of protists with special emphasis on toxic dinoflagellates in the North Atlantic and Arctic Waters	96

	9.3	Nitrogen cycling and microbial ecology in the Arctic: measurements of dinitrogen fixation rates, characterization of diazotroph assemblages, and nifH gene expression	102
	9.4	Vertical export	106
	9.5	Watercolumn biogeochemistry	109
	9.6	Benthos ecology	110
10.		Geology and Paleoceanography	113
	10.1	Parasound and Hydrosweep	116
	10.2	Sediment coring	118
	10.3	Multi-sensor core logging	123
	10.4	Inorganic geochemistry	125
	10.5	Water column and sea ice studies	128
Appendix			135
A.1		Teilnehmende Institute / Participating Institutions	136
A.2		Fahrtteilnehmer / Cruise Participants	140
A.3		Schiffsbesatzung / Ship's Crew	142
A.4		Stationsliste PS92 / Station List	144