3.3 Biology

3.3.1 Sea ice ecology, pelagic food web and top predator studies

Hauke Flores[1,2], Jan Andries van Franeker[3], Anton Van de Putte[4], Giulia Castellani[1], Fokje Schaafsma[3], Julia Ehrlich[2], Martina Vortkamp[1], André Meijboom[3], Bram Feij[5], Michiel van Dorssen[6]

[1]AWI
[2]UHH
[3]IMARES
[4]RBINS
[5]NIOZ
[6]van Dorssen Metaalbewerking

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Objectives

Sea ice ecology, pelagic food web and top predator studies during PS89 were a main contribution to the Sea Ice Physics and Ecology Study (SIPES). SIPES was designed as an inter-disciplinary field study focussing on the inter-connection of sea ice physics, sea ice biology, biological oceanography and top predator ecology. Pelagic food webs in the Antarctic sea ice zone can depend significantly on carbon produced by ice-associated microalgae. Future changes in Antarctic sea ice habitats will affect sea ice primary production and habitat structure, with unknown consequences for Antarctic ecosystems. Antarctic krill *Euphausia superba* and other species feeding in the ice-water interface layer may play a key role in transferring carbon from sea ice into the pelagic food web, up to the trophic level of birds and mammals (Flores et al. 2011, 2012). To better understand potential impacts of changing sea ice habitats for Antarctic ecosystems, the HGF Young Investigators Group *Iceflux* in cooperation with IMARES (*Iceflux-NL*), aim to quantify the trophic carbon flux from sea ice into the under-ice community and investigate the importance of sea ice in the support of living resources. 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) applying sea ice-ocean models to project the flux of sea ice-derived carbon into the under-ice community in space and time, and 4) studying the diet of sea ice-associated organisms.

In the Southern Ocean, the exploitation of marine living resources and the conservation of ecosystem health are tightly linked to each other in the management framework of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Antarctic krill *Euphausia superba* is important in this context, both as a major fisheries resource, and as a key carbon source for Antarctic fishes, birds, and mammals. Similar to Antarctic krill, several abundant endothermic top predators have been shown to concentrate in pack-ice habitats in spite of low water column productivity (van Franeker et al. 1997). Investigations on the association of krill and other key species with under-ice habitats were complemented by systematic top predator censuses in order to develop robust statements on the impact of changing sea ice habitats on polar marine resources and conservation objectives.

The evolutionary processes supported by gene flow and genetic selection interact with ecological processes as they overlap temporally to some extent. While gene flow has the tendency to homogenise populations, selective pressure may lead to population differentiation over evolutionary time scales. Throughout the life history of marine organisms dispersal and connectivity play crucial roles in short and long term survival, fitness and evolution. Connectivity and dispersal are the result of interacting environmental limitations and dispersal capacity, which is influenced by physical and biological processes. The physical processes relate to hydrodynamics (barriers such as the Antarctic Polar Front (APF), transport routes (through deep-water formation) and geographical features (e.g., shallow land bridge of the Scotia Arc (Arntz et al. 2005; Ingels et al. 2006)). Biological processes include behavior, life-history traits, trophic niche, size and other basic biological characteristics. The Southern Ocean forms a unique environment to study evolutionary patterns over different time scales. During this expedition fish and amphipods samples for molecular analysis were collected. These samples were used for Barcoding (species identification) and phylogeographic and population genetic work at RBINS.

Work at sea

SUIT sampling

A Surface and Under-Ice Trawl (SUIT: van Franeker et al. 2009) was used to sample the pelagic fauna down to 2 m under the ice and in open surface waters. The SUIT had two nets, one 0.3 mm mesh plankton net and a 7 mm mesh shrimp net. During SUIT tows, data from the physical environment were recorded using a bio-environmental sensor array, e.g. water temperature, salinity, ice thickness, and multi-spectral light transmission. Seven SUIT deployments were completed along the 0° meridian from open waters into the closed pack-ice. Six hauls directed at the investigation of the vertical distribution of zooplankton in open waters were conducted near Atka Bay. On the return trajectory from Atka Bay to Cape Town, another 5 hauls were completed in the marginal ice zone and the open Ocean (see appendix Table 3.3.1A1). An overview of the sampling locations is given in Fig. 3.3.1.1. 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.

Pelagic sampling

A Multiple opening Rectangular Midwater Trawl (M-RMT) was used to sample the pelagic community. During sampling, 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 800-200 m, 200-50 m, and 50 m to surface. In the coastal waters near Atka Bay, sampling was conducted over the strata 200-100 m, 100-50 m, and 50 m to surface. We conducted 15 depth-stratified hauls with the M-RMT, each sampling 3 distinct depth layers. Five hauls were conducted between 57°S and 66°S on the 0° meridian (Station 18-30), 5 hauls were conducted near Atka Bay (Station 40-59), and 5 hauls were completed after leaving Atka Bay (Station 66-80; (Fig. 3.3.1.1)). The catch was sorted by depth stratum and taxon, and size measurements on euphausiids and fish larvae were performed in the analogous procedure described above for SUIT sampling.

Polarstern's EK60 echosounder recorded the distribution of acoustic targets continuously during sailing. Our sampling frequencies were 38 kHz, 70 kHz, 120 kHz, and 200 kHz. During station work, the EK60 was switched off to minimize potential risks for marine mammals approaching the ship. 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. Chlorophyll samples were filtered from CTD rosette water samples to calibrate fluorometers built in the ship's CTD, *Polarstern's* ferry box, and the SUIT's CTD (Table 3.3.1.1).

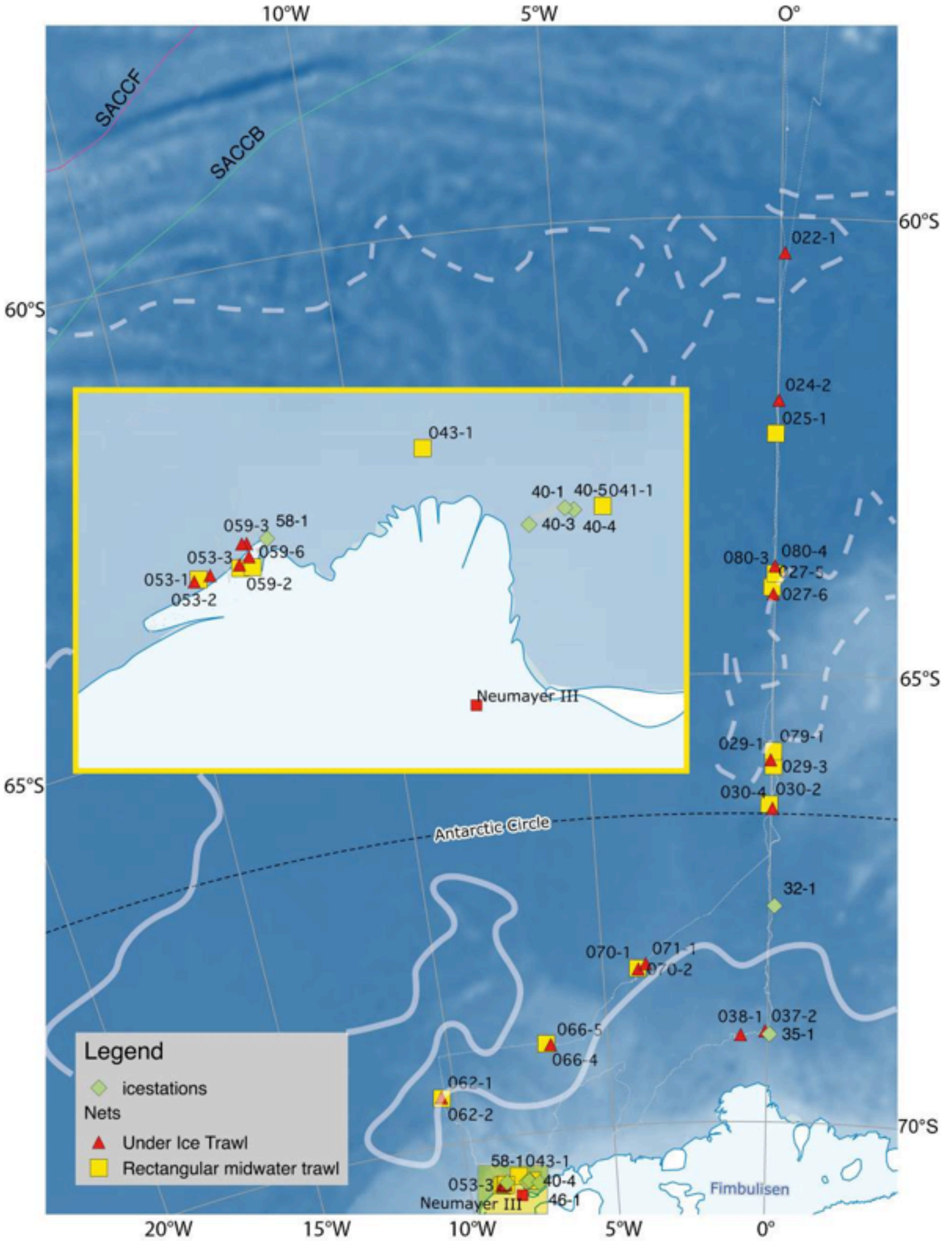


Fig. 3.3.1.1: Overview of stations sampled by the biological sampling of SIPES during PS89. The dashed white line indicates the position of the ice edge at the beginning of the sampling period; the position of the ice edge at the end of the sampling is indicated by a continuous white line. The cruise track is shown as a light-grey line.

Table 3.3.1.1: Summary of CTD casts performed and water samples collected. ferry: water sample from inflow of the ship's FerryBox system

Date	Time	Station	Gear	PositionLat	PositionLon	Depth [m]	Chl max depth [m]	Sampled depths [m]
07.12.2014	18:04:00	PS89/0006-1	CTD/rosette water sampler	46° 12.90' S	5° 40.50' E	4831.2	60	15,24,60,100
08.12.2014	07:43:00	PS89/0007-1	CTD/rosette water sampler	47° 40.28' S	4° 15.22' E	4540.5	50	15,25,50,100
09.12.2014	14:51:00	PS89/0009-1	CTD/rosette water sampler	50° 15.30' S	1° 25.53' E	3892.5	75	15,50,75,100,ferry
10.12.2014	11:48:00	PS89/0011-1	CTD/rosette water sampler	52° 28.72' S	0° 0.06' W	2597.6	80	35,50,80,100
11.12.2014	15:13:00	PS89/0014-1	CTD/rosette water sampler	54° 59.99' S	0° 0.02' W	1704.9	50	25,50,75,100,ferry
12.12.2014	23:17:00	PS89/0019-1	CTD/rosette water sampler	58° 0.08' S	0° 0.12' E	4528.3	25	15,25,50,100,ferry
14.12.2014	16:50:00	PS89/0023-1	CTD/rosette water sampler	60° 59.86' S	0° 0.38' W	5393.2	45	15,45,50,100,ferry
16.12.2014	00:14:00	PS89/0026-1	CTD/rosette water sampler	62° 59.37' S	0° 0.36' E	5310.9	40	9,40,60,100,ferry
19.12.2014	02:05:00	PS89/0030-1	CTD/rosette water sampler	66° 27.71' S	0° 1.49' W	4500.2	30	15,30,50,100,ferry
21.12.2014	02:49:00	PS89/0033-1	CTD/rosette water sampler	68° 0.03' S	0° 1.26' W	4512.9	40	5,40,75,120,ferry
22.12.2014	12:15:00	PS89/0035-1	CTD/ice	69° 0.14' S	0° 4.03' E			**50**
22.12.2014	23:23:00	PS89/0036-1	CTD/rosette water sampler	69° 0.61' S	0° 1.62' W	3369.4	25	15,25,50,100,ferry
27.12.2014	11:00:00	PS89/0040-1	CTD/ice	70° 5.27' S	7° 57.52' W			**50**
29.12.2014	11:00:00	PS89/0040-3	CTD/ice	70° 5.34' S	8° 4.54' W			**50**
30.12.2014	10:50:00	PS89/0040-4	CTD/ice	70° 5.27' S	7° 57.52' W			**50**
03.01.2015	00:24:00	PS89/0042-1	CTD/rosette water sampler	70° 34.46' S	9° 3.33' W	467	20	15,20,50,100,ferry
03.01.2015	05:17:00	PS89/0040-11	CTD/rosette water sampler	70° 31.40' S	7° 57.72' W	232	60	15,30,60,100,ferry
04.01.2015	10:00:00	PS89/0046-1	CTD/ice	70° 5.59' S	7° 38.56' W			**50**
07.01.2015	22:17:00	PS89/0049-1	CTD/rosette water sampler	70° 31.31' S	8° 45.46' W	156	20	20,ferry
08.01.2015	04:14:00	PS89/0049-7	CTD/rosette water sampler	70° 31.29' S	8° 45.44' W	153	10	10,ferry
08.01.2015	09:12:00	PS89/0049-12	CTD/rosette water sampler	70° 31.38' S	8° 45.58' W	179.2	25	25
09.01.2015	21:06:00	PS89/0052-1	CTD/rosette water sampler	70° 31.39' S	8° 45.58' W	168	30	30,ferry
10.01.2015	00:09:00	PS89/0052-4	CTD/rosette water sampler	70° 31.32' S	8° 45.42' W	155	15	15,ferry
10.01.2015	04:12:00	PS89/0052-8	CTD/rosette water sampler	70° 31.32' S	8° 45.48' W	157	15	15,ferry
10.01.2015	08:04:00	PS89/0052-12	CTD/rosette water sampler	70° 31.38' S	8° 45.49' W	163	50	50,ferry
11.01.2014	19:11:00	PS89/0058-1	CTD/ice	70° 30.80' S	8° 43.93' W			**50**
16.01.2015	10:55:00	PS89/0066-2	CTD/rosette water sampler	69° 0.31' S	6° 59.19' W	2948.8	50	15,25,50,100,ferry
20.01.2015	07:41:00	PS89/0080-1	CTD/rosette water sampler	63° 55.07' S	0° 0.44' E	5210.2	25	15,25,50,100,ferry
21.01.2015	10:48:00	PS89/0081-1	CTD/rosette water sampler	61° 0.02' S	0° 0.13' E	5384.6	15	15,25,50,100,ferry

Flores et al (2015) pp102-126 in Boebel 2015 Reports on Polar and Marine Research 689.

Tab. 3.3.1.2. Parameters of SUIT and M-RMT stations. SUIT under ice = stations where SUIT was trawled partly or entirely under ice; EcoRegion = broad biogeographical region: OW = open waters north of the ice edge; SIZ = Sea ice zone; Atka = shelf waters near Atka Bay

STATION	HAUL	GEAR	POSlat	POSlon	STRT_TRAWL	END_TRAWL	SUIT under ice	Eco Region	Comment
PS89/0022-1	1	SUIT	-60.384	0.093	14.12.2014 08:48	14.12.2014 09:18	NO	OW	1st SUIT station of survey; cable length only estimated visually
PS89/0024-2	2	SUIT	-61.985	0.030	15.12.2014 09:47	15.12.2014 10:17	YES	SIZ	Problem with oxenauge of weight, weight has been pulkled up between waypoint 011 and 012. Brown discolouration of ice visible.
PS89/0027-6	3	SUIT	-64.110	-0.046	17.12.2014 17:52	17.12.2014 18:22	NO	SIZ	
PS89/0029-1	4	SUIT	-65.948	-0.040	18.12.2014 09:28	18.12.2014 09:58	YES	SIZ	
PS89/0030-4	5	SUIT	-66.492	0.048	19.12.2014 14:09	19.12.2014 14:49	YES	SIZ	
PS89/0037-2	6	SUIT	-68.977	-0.091	23.12.2014 11:07	23.12.2014 11:17	YES	SIZ	Got stuck, hauled in after short time
PS89/0038-1	7	SUIT	-69.017	-0.818	23.12.2014 17:41	23.12.2014 17:54	YES	SIZ	SUIT lost due to broken cable at 17:54 , recovered, 1 cod end lost
PS89/0053-2	8	SUIT	-70.541	-8.941	10.01.2015 10:53	10.01.2015 11:33	NO	Atka	Large open water 'puddle' near ice shelf. Surrounding ice approx. 2-3 thick but not close to trawl.
PS89/0053-3	9	SUIT	-70.538	-8.901	10.01.2015 23:08	10.01.2015 23:39	NO	Atka	Large open water 'puddle' near ice shelf. Surrounding ice approx. 2-3 thick but not close to trawl.
PS89/0059-1	10	SUIT	-70.534	-8.819	12.01.2015 01:12	12.01.2015 01:42	NO	Atka	Trawl in our 'puddle' near ice shelf. Surrounding ice approx. 2-3 thick approx. 300 m away.
PS89/0059-3	11	SUIT	-70.518	-8.790	12.01.2015 08:16	12.01.2015 08:32	NO	Atka	Trawl in our 'puddle' near ice shelf. Surrounding sea ice approx. 2-3 thick.
PS89/0059-4	12	SUIT	-70.516	-8.806	12.01.2015 12:42	12.01.2015 13:11	NO	Atka	Trawl in our 'puddle' near ice shelf. Surrounding sea ice approx. 2-3 thick.
PS89/0059-5	13	SUIT	-70.531	-8.790	12.01.2015 20:06	12.01.2015 20:41	NO	Atka	Trawl in our 'puddle' near ice shelf. Surrounding sea ice approx. 2-3 thick.
PS89/0062-1	14	SUIT	-69.462	-1.461	15.01.2015 15:35	15.01.2015 16:11	YES	SIZ	10 - 20 cm snow. Note that ice conditions change from waypoint 115 onwards.
PS89/0066-5	15	SUIT	-69.027	-6.812	16.01.2015 17:27	16.01.2015 17:57	NO	OW	
PS89/0070-2	16	SUIT	-68.259	-3.925	17.01.2015 14:07	17.01.2015 14:41	YES	SIZ	Lot of brown discolouration on underside of ice. Peak weight on cable: 44 tons. 10-20 cm snow.

STATION	HAUL	GEAR	POSlat	POSlon	STRT_TRAWL	END_TRAWL	SUIT under ice	Eco Region	Comment
PS89/0071-1	17	SUIT	-68.203	-3.689	17.01.2015 16:36	17.01.2015 17:06	YES	SIZ	Lot of loose ice in between floes, occasionally small open water leads. Note change in cable length.
PS89/0080-4	18	SUIT	-63.814	-0.009	20.01.2015 14:48	20.01.2015 15:21	NO	OW	Last SUIT station!
PS89/0018-1		M-RMT	-57.44	0.11	12-12-2014 15:45	12-12-2014 16:44	NO	OW	
PS89/0025-1		M-RMT	-62.35	-0.04	15-12-2014 14:42	15-12-2014 15:12	NO	SIZ	
PS89/0027-5		M-RMT	-64.04	-0.07	17-12-2014 15:42	17-12-2014 16:19	NO	SIZ	
PS89/0029-3		M-RMT	-66.02	0.05	18-12-2014 14:43	18-12-2014 15:19	YES	SIZ	
PS89/0030-2		M-RMT	-66.45	-0.06	19-12-2014 04:36	19-12-2014 05:08	YES	SIZ	Voltage 316, current 0,02,
PS89/0040-2		M-RMT	-70.53	-7.89	27-12-2014 11:29	27-12-2014 11:35	NO	Atka	next to iceedge, Neumayer
PS89/0043-1		M-RMT	-70.46	-8.31	03-01-2015 13:46	03-01-2015 13:51	NO	Atka	
PS89/0053-1		M-RMT	-70.54	-8.91	10-01-2015 09:20	10-01-2015 09:26	NO	Atka	
PS89/0059-2		M-RMT	-70.53	-8.81	12-01-2015 03:02	12-01-2015 03:06	NO	Atka	
PS89/0059-6		M-RMT	-70.53	-8.78	12-01-2015 23:15	12-01-2015 23:19	NO	Atka	
PS89/0062-2		M-RMT	-69.47	-10.44	15-01-2015 17:49	15-01-2015 18:19	YES	SIZ	Bucket between the nets, all RMT 8 nets not complete open, RMT 1 ok
PS89/0066-4		M-RMT	-69.02	-6.94	16-01-2015 15:33	16-01-2015 16:08	NO	OW	
PS89/0070-1		M-RMT	-68.25	-3.95	17-01-2015 11:43	17-01-2015 12:13	YES	SIZ	Net 3 didn*t released (not in the water and not on deck)
PS89/0079-1		M-RMT	-65.83	0.05	19-01-2015 11:01	19-01-2015 11:37	NO	OW	net not released
PS89/0080-3		M-RMT	-63.89	0	20-01-2015 12:08	20-01-2015 13:36	NO	OW	net 1 open in to the water, it fished from 0 - 800 and from 800- 200m depth

Sea ice work

Our sea ice work was conducted in close collaboration with the AWI sea ice physics group (M. Nicolaus & S. Schwegmann). A total of 8 sea ice stations were sampled during PS89, of which 2 were completed during the southward passage on the 0° meridian (Table 3.3.1.1). The majority of stations (6) focused on the landfast ice of the Atka Bay (Fig. 3.3.1.1). 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 samplinge 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 transects of the sea ice physics group.

b) Various ice cores were taken for analysis of physical, biogeochemical and biological properties: Archive, texture, salinity and chlorophyll *a* content, particulate organic matter (POM) for biomarker analysis, sea ice infauna, and DNA (eukaryote microbial communities). At each coring site, snow depth, ice thickness and freeboard were noted.

c) We lowered a CTD probe equipped with a fluorometer through a coring 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 phytoplankton and microzooplankton composition and DNA sequencing with a handheld Kemmerer water sampler lowered to approximately 1 m under the ice.

e) At several ice stations in the Atka Bay, an *in-situ* pump was used to sample zooplankton from the platelet ice layer under the coastal fast-ice.

f) In collaboration with Melchior Gonzales-Davila and Magdalena Santana-Casiano we collected additional water samples for carbonate studies at depths of 20 m, 15 m, 10 m, 7 m, 5 m, 3 m, and 1 m under the ice.

Archive and texture cores were stored in the ship's -20°C storage room and transported back to AWI. Retained sections of all other cores were carefully melted at 4°C in the ship's temperature-controlled laboratory container. 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. Ice cores for salinity and chlorophyll *a* content were cut in 10 cm pieces to construct vertical profiles of these parameters. In cores for POM, sea ice infauna and DNA analysis, 10 cm sections from the bottom, the top and the inner part of the core were retained for sample collection. 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 2°C on 4 % formaldehyde/seawater solution.

Tab 3.3.1.3: List of the ice stations sampled, and number of ice cores taken at each sampling site. For each ice station it is specified if there have been conducted under ice radiation mesurements (L-arm), under-ice water sampling, under-ice zooplankton sampling by using a self-constructed pump (Pump), water column sampling for CO_2 and pH measurements (CO_2 samples) and under-ice CTD profiles. Ice stations 32-1 and 35-1 were sampled on drifting sea ice floes, whereas stations 40-1 to 58-1 were sampled on fast ice in Atka Bay

Station Nº	Position	Date	Nº of cores	L-arm	Water Samp.	Pump	CO_2 Samp.	CTD
32-1	67º 34.66' S 0º 8.86' E	20.12.2014	14	YES	NO	NO	NO	NO
35-1	69º 0.82' S 0º 4.03' E	22.12.2014	11	YES	YES	NO	YES	YES
40-1	70º 31.60' S 7º 57.52' W	27.12.2014	8	YES	NO	NO	NO	YES
40-3	70º 32.03' S 8º 4.54' W	29.12.2014	2	NO	YES	YES	YES	YES
40-4	70º 31.60' S 7º 57.52' W	30.12.2014	0	NO	YES	YES	YES	YES
40-5	70º 31.45' S 7º 58.83' W	31.12.2014	3	YES	NO	NO	NO	NO
46-1	70º 33.54' S 7º 38.56' W	04.01.2015	10	YES	YES	YES	YES	YES
58-1	70º 30.80' S 8º 43.93' W	11.01.2015	7	NO	NO	YES	NO	YES

Tab. 3.3.1.4: List of ice cores taken during PS89, with relative position on the ice floe (see Nicolauset al., this volume), and corresponding spectral, measurement site (Marker)

Station Nº	LABEL	POSITION	MARKER
32-1	PS89/32-1-OPT-1	(-32,-20)	L-arm
"	PS89/32-1-OPT-2	(-23,-16)	M37
"	PS89/32-1-OPT-3	(-14,-9)	M33
"	PS89/32-1-OPT-4	(-7,-4)	M32
"	PS89/32-1-OPT-5	(-41,-42)	M31
"	PS89/32-1-LSI-1	(-41,-42)	L-arm
"	PS89/32-1-LSI-2	(-41,-42)	L-arm
"	PS89/32-1-DNA	(-41,-42)	L-arm
"	PS89/32-1-MEI-1	(-41,-42)	L-arm
"	PS89/32-1-MEI-2	(-41,-42)	L-arm
"	PS89/32-1-DEN	(-41,-42)	L-arm
"	PS89/32-1-ARC	(-41,-42)	L-arm

Station Nº	LABEL	POSITION	MARKER
“	PS89/32-1-TEX	(-41,-42)	L-arm
“	PS89/32-1-SAL	(-22,11)	L-arm
35-1	PS89/35-1-OPT-1	(-17,23)	Coring
“	PS89/35-1-OPT-2	(-22,11)	M6
“	PS89/35-1-LSI-1	(-22,11)	Coring
“	PS89/35-1-LSI-2	(-22,11)	Coring
“	PS89/35-1-DNA	(-22,11)	Coring
“	PS89/35-1-MEI-1	(-22,11)	Coring
“	PS89/35-1-MEI-2	(-22,11)	Coring
“	PS89/35-1-DEN	(-22,11)	Coring
“	PS89/35-1-ARC	(-22,11)	Coring
“	PS89/35-1-TEX	(-22,11)	Coring
“	PS89/35-1-SAL	(-35,13)	Coring
40-1	PS89/40-1-BIO-1	(31,9)	Cores+L-arm
“	PS89/40-1-BIO-2	(-35,13)	M30m
“	PS89/40-1-LSI	(-35,13)	Cores+L-arm
“	PS89/40-1-MEI	(-35,13)	Cores+L-arm
“	PS89/40-1-DEN	(-35,13)	Cores+L-arm
“	PS89/40-1-ARC	(-35,13)	Cores+L-arm
“	PS89/40-1-TEX	(-35,13)	Cores+L-arm
“	PS89/40-1-SAL	-	Cores+L-arm
40-3	PS89/40-3-MEI-1	-	-
“	PS89/40-3-MEI-2	-	-
40-5	PS89/40-5-OPT	-	-
“	PS89/40-5-MEI	(-44,-61)	-
46-1	PS89/46-1-OPT-1	(-44,-61)	L-arm+Cores
¬“	PS89/46-1-LSI-1	(-44,-61)	L-arm+Cores
“	PS89/46-1-LSI-2	(-44,-61)	L-arm+Cores
“	PS89/46-1-DNA	(-44,-61)	L-arm+Cores
“	PS89/46-1-MEI-1	(-44,-61)	L-arm+Cores
“	PS89/46-1-MEI-2	(-44,-61)	L-arm+Cores
“	PS89/46-1-SED	(-44,-61)	L-arm+Cores
“	PS89/46-1-ARC	(-44,-61)	L-arm+Cores
“	PS89/46-1-TEX	(-44,-61)	L-arm+Cores
	PS89/46-1-SAL	(-41,-42)	L-arm+Cores

Top predator censuses

During steaming of the ship, surveys of top predators (all marine birds and mammals) were made from open observation posts installed on the monkey-deck. Standard band transect survey methods were applied, in time blocks of 10 minutes with snapshot methodology for birds in flight, and additional line-transect methods for marine mammals. In addition to the ship-based surveys, helicopters were used for further band-transect censuses in sea ice areas. Flights were conducted at the standard seal survey altitude of 300 ft and speeds of 60 to 80 knots. For unbiased sampling, surveys followed pre-determined straight transect lines to a maximum of 50 nautical miles away from the ship, with parallel outward and return tracks separated by at least 8 nautical miles. Helicopter counts were made in units of approximately 2 to 3 minutes flying time, identified by waypoints made on GPS. Bandwidth used in both ship based and aerial surveys was mostly 300 m (150 m to both sides of transect line), but was adapted according to conditions.

Densities of top predators were calculated from the number of densities of birds, seals and whales were then translated into food requirements using well established allometric formulas to calculate species-specific daily energy requirements. Energy requirements were translated to fresh food requirements using an energetic value of 4.5 KJ per gram fresh weight of food. For further methodological details see van Franeker et al. (1997). Data for the purpose of this cruise report could be analysed only for the southward leg to *Neumayer III*, 2 to 25 December. During this southward leg, 771 ship-based 10 minute counts were made, representing a survey surface of 688.6 km^2. Due to frequently poor weather conditions, only three helicopter surveys were made in the ice areas, with a total of 113 waypoint blocks representing a surveyed area of 179.1 km^2. Results from ship- and helicopter surveys were combined in the analyses, resulting in 884 count units representing a surface area of 867.7 km^2. On the return voyage to Cape Town at least a similar number of ship based observations has been made, but no additional helicopter surveys. Flying over denser sea ice was not possible due to a technical problem of *Polarstern*, preventing ship support in case of helicopter problems in dense sea ice sectors.

In addition to the at-sea density surveys of marine top predators, we conducted an aerial photographic survey of the emperor penguin colony in Atka Bay. The colony was not overflown. Instead, side angle photographs were taken from helicopter at 1,000 ft altitude, circling the colony at a radial distance of about 1,500 m from the concentration of birds. Photographs were analysed using the ITAG software produced by Sacha Viquerat.

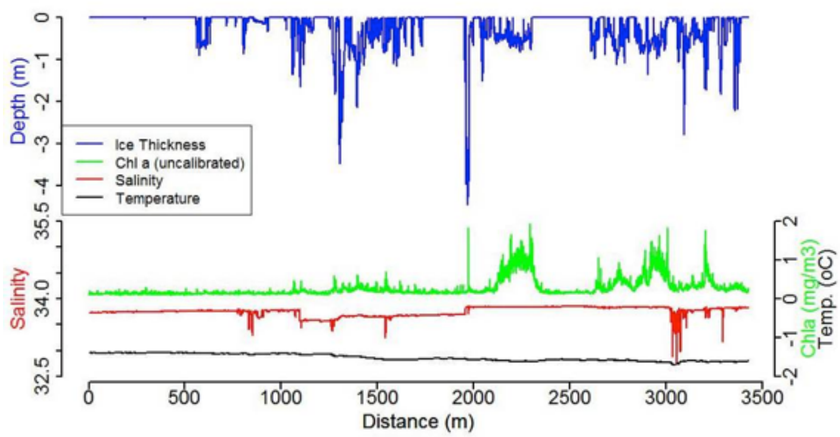


Fig.3.3.1.2: Example of environmental data profiles obtained from the SUIT's sensor array at station 30-4.

Preliminary results

SUIT sampling

SUIT sensors data. From the 18 SUIT hauls, 10 were conducted in open water, and 8 were conducted under various types of sea ice, including shattered ice floes in the marginal ice zone north of Atka Bay. Bio-environmental profiles were obtained from each SUIT haul (Fig. 3.3.1.2). The average ice coverage of the under-ice hauls was 90 %. Preliminary mean ice draft calculated based on pressure measurements of the SUIT's CTD ranged between 8 cm in the marginal ice zone, and 246 cm in heavy sea ice of the Coastal Current (Fig. 3.3.1.3 C).

The surface layer salinity increased towards the south. Near Atka Bay, the salinity was highly variable, which was possibly related to tidal currents. In a first analysis of surface chlorophyll-*a* content, a characteristic pattern of ice-free regions compared to ice-covered regions 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.

SUIT catch composition. The catch from the 7 mm mesh shrimp net was counted and sorted on board. Fig. 3.3.1.3 A & B show an overview of the species found in the open water and under-ice hauls on the incoming and returning trajectories to and from Atka bay. In the first open water station, biomass was low and dominated by appendicularians. In ice-covered waters the catch was dominated by the euphausiids *Euphausia superba* and *Thysanoessa macrura*, and amphipods of the genus *Eusirus*. The latter where mainly *E. laticarpus* and *E. microps*, except in station 80-4, where *E. tridentatus* was found. In general species diversity was low compared to 2007/2008, when the open water and under ice surface layer was also investigated in this area (Flores et al. 2011). *Euphausia superba* shows an increased abundance at stations with thicker ice (Fig. 3.3.1.3 C). Fig. 3.3.1.3 D shows the mean properties of the sea water during trawling.

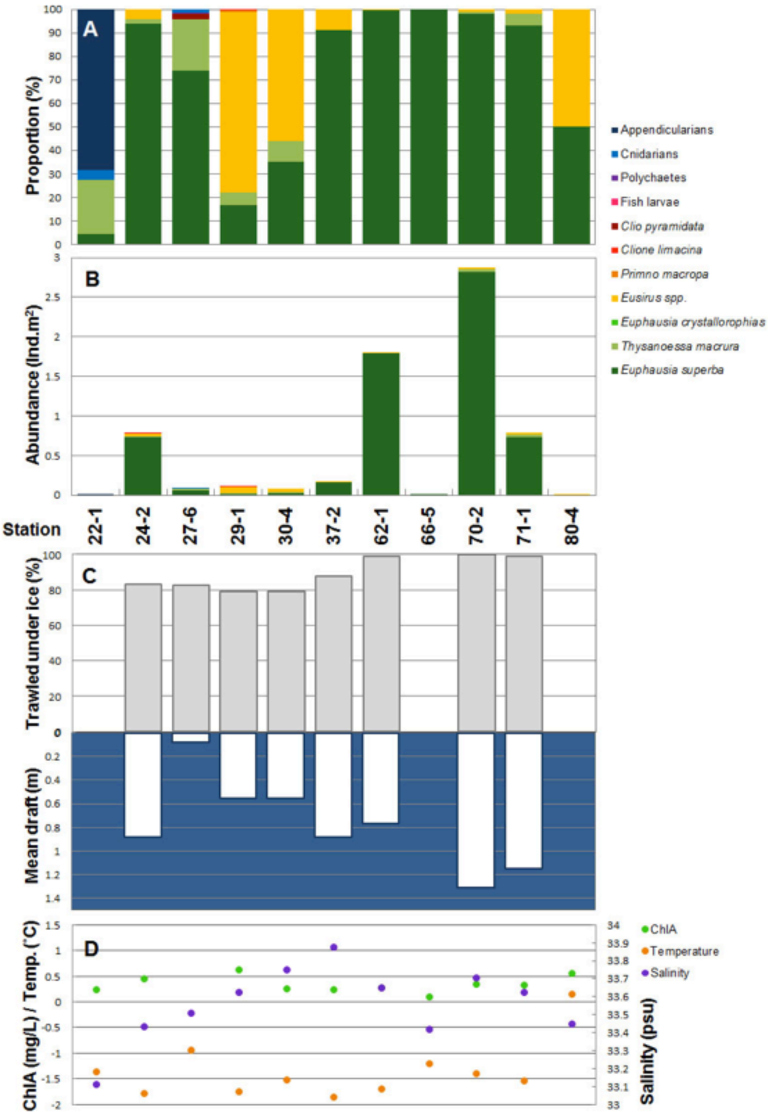


Fig. 3.3.1.3: SUIT catch, sea ice and under-ice water properties during trawling. A) Catch composition per station in percentage of total abundance. B) Abundance of major taxa at each SUIT station. C) Sea ice properties during SUIT hauls. The percentage of the haul that was conducted under ice is shown in grey bars. White bars represent the average ice draft during the haul. D) Mean surface water properties during each haul.

Near Atka Bay, the surface layer community was sampled over a 24 hour period to see if there were differences in the occurrence of macrofauna in the surface layer at different times of the day. In general the biomass in Atka Bay was very low (Fig. 3.3.1.4). Although also caught in the morning*, E. superba* seemed to be more abundant at night. All other species however were coming to the surface only at night time. These species included *Euphausia crystallorophias*, which is a known coastal species, *Eusirus* spp., fish larvae and polychaetes.

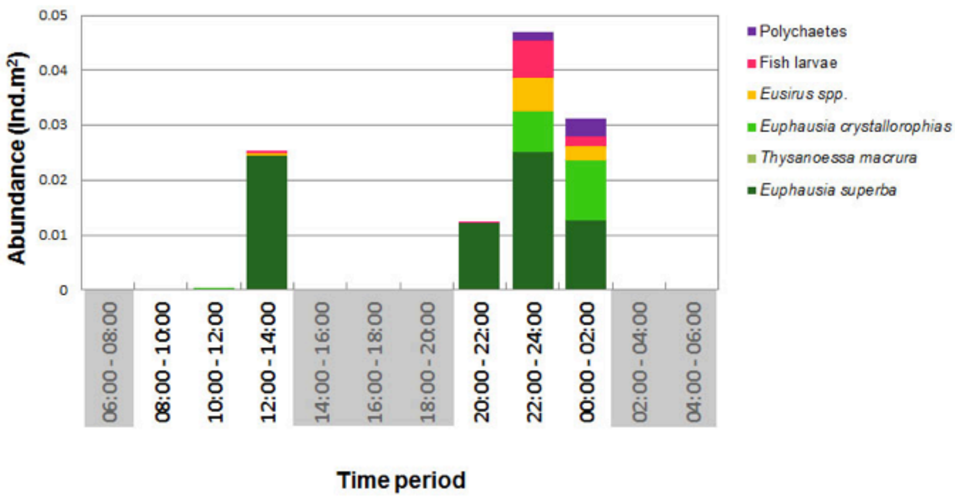


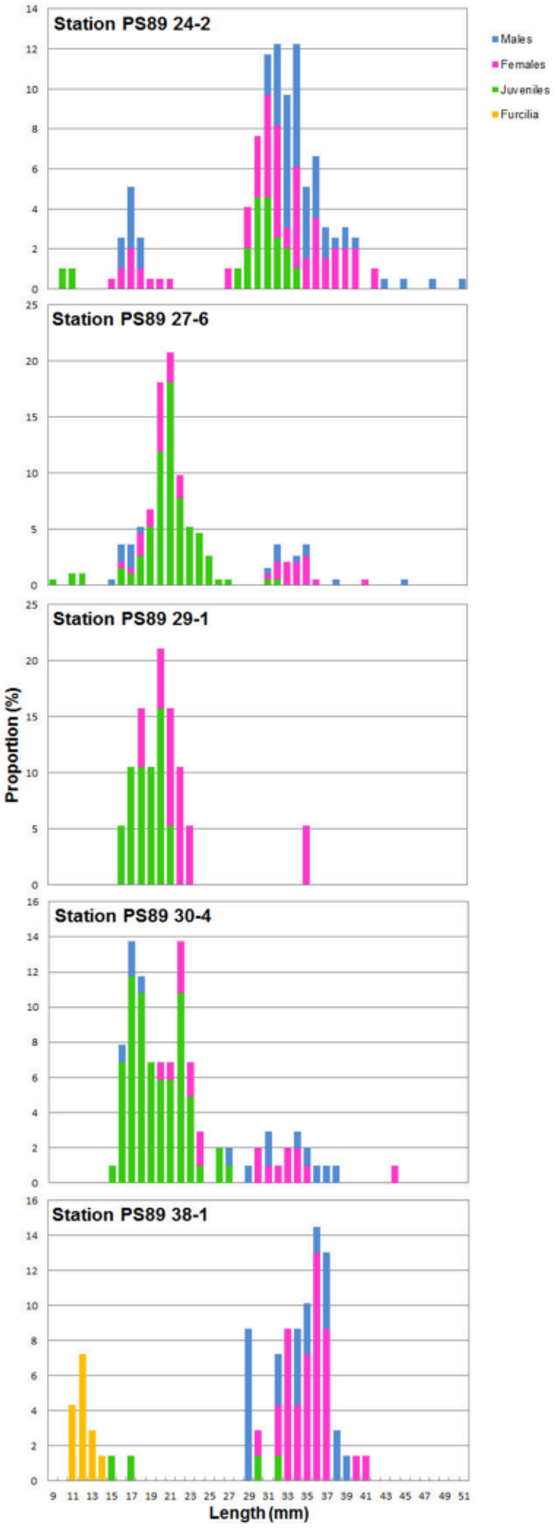
Fig. 3.3.1.4: Abundance of major taxa in the 0-2 m surface layer in Atka Bay per time period. The hauls at time periods 10:00 -12:00 hour and 22:00 – 24:00 hour were conducted on 10th January, while the others were conducted on the 12th. Time periods underlain in grey were not sampled.

The length frequency distribution of *E. superba* was analysed at the five stations completed along the southbound transect on the 0° meridian (Fig. 3.3.1.5). Three stations were dominated by juveniles with a modal length around 20 mm. Stations 24-2 and 38-1 where dominated by sub-adults with mean lengths of 31 and 34 mm. This is similar to the length distribution of 2007/2008 (Flores et al. 2012). The catch from station 38-1 also included larval krill (stage furcilia VI). This stage is often found in winter-early spring. There are, however, other studies that have found late stage furcilia in January and even until May (Marr 1962; Melnikov & Spiridonov 1996; Daly 2004).

RMT sampling

We completed in total 15 M-RMT hauls, mostly in close proximity to SUIT sampling locations (Fig. 3.3.1.1). One haul had to be excluded from analysis due to entanglement of the net. At station 79, depth-stratified sampling was irregular due to malfunctioning of the release mechanism. Technical failure further precluded the analysis of 4 of the 39 remaining net samples (Fig. 3.3.1.7, Fig. 3.3.1.8). In this report we present preliminary data on macrozooplankton and micronekton collected by the RMT-8 nets. Data on siphonophores and chaetognaths were not included in this preliminary analysis.

Macrozooplankton communities. On the 0° meridian, cumulative macrozooplankton abundances in any of the 3 depth layers sampled were below 25 ind. 1,000 m^{-3} at stations north of 65°S. The highest M-RMT catch abundances of this survey (more than 250 ind. 1000 m^{-3}) were obtained in the surface layer at Station 29, south-west of Maud Rise (Fig. 3.3.1.1, Fig. 3.3.1.6). South of 62°S, the macrozooplankton species composition was dominated by the euphausiid *Thysanoessa macrura*. Other abundant taxa were siphonophores and chaetognaths (both not quantified), pteropods, amphipods and fish larvae. Antarctic krill *Euphausia superba* was surprisingly rare, its abundances ranging clearly below 2 ind. 1,000 m^{-3} in any of the 3 depth layers sampled (Fig. 3.3.1.6). The size of *T. macrura* ranged from 7 to 30 mm, with modes at 9 mm in juveniles, 18 mm in males, and 21 mm in females (Fig. 3.3.1.9 A).



3.3.1.5: Length frequency and stage distribution of Euphausia superba per station in percentage of numbers of individuals measured

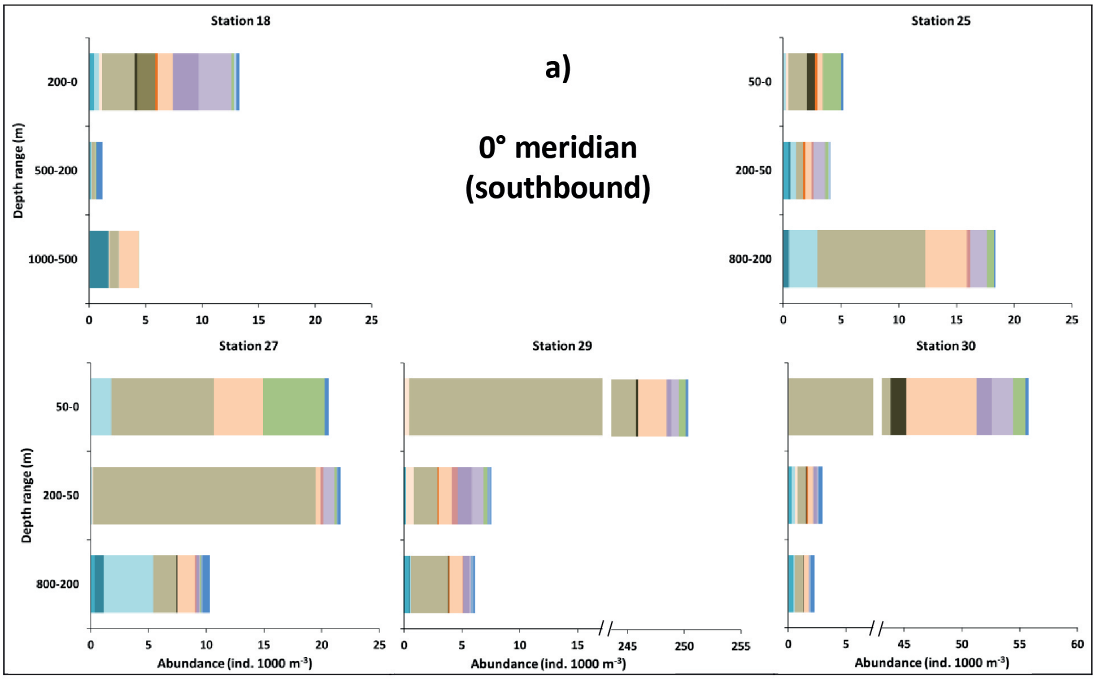


Fig. 3.3.1.6: Taxonomic composition and macrozooplankton abundance in M-RMT catches during the 0° meridian transect towards Neumayer III. The macrozooplankton community was sampled at 3 different depth layers. For figure legend refer to Fig. 3.3.1.8.

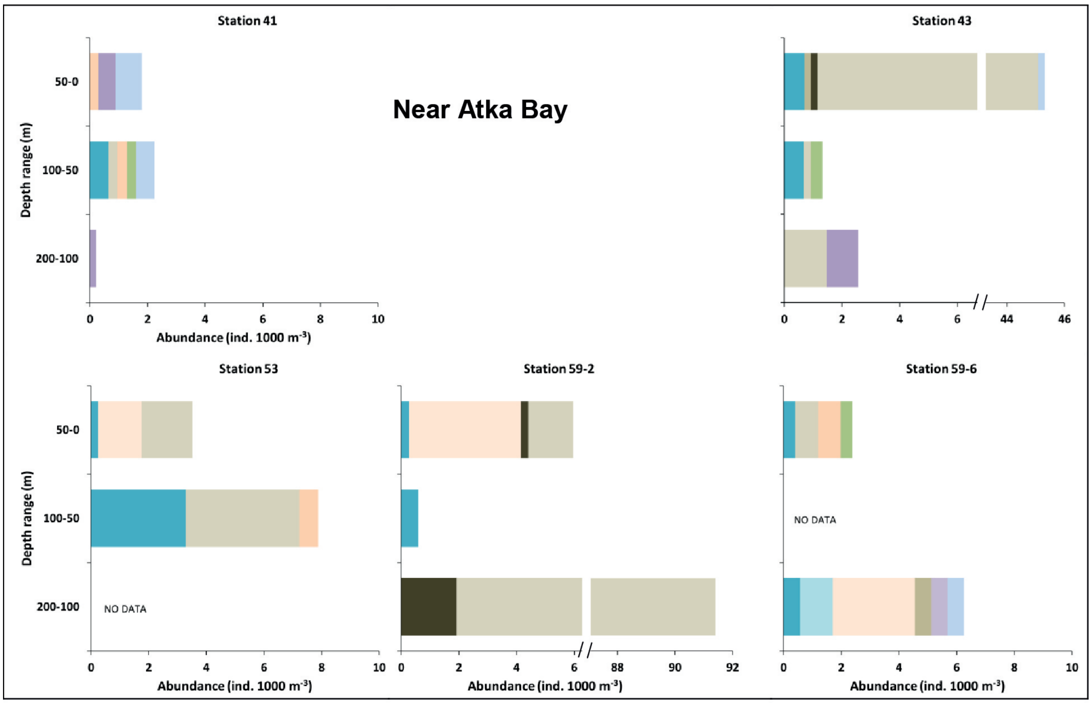


Fig. 3.3.1.7: Taxonomic composition and macrozooplankton abundance in M-RMT catches near Atka Bay. The macrozooplankton community was sampled at 3 different depth layers. For figure legend refer to 3.3.1.7.

Near Atka Bay, the macrozooplankton community was dominated by ice krill *Euphausia crystallorophias*. Peak abundances occurred both in the surface layer (Station 43: 45 ind. 1,000 m^{-3}), and in the 100-200 m depth layer (Station 59-2: 91 ind. 1000 m^{-3}) (Fig. 3.3.1.7). These 2 stations were also the only stations at which low numbers of Antarctic krill were caught. At the other 3 stations, cumulated macrozooplankton abundances were well below 10 ind. 1000 m^{-3} in any depth stratum (Fig. 3.3.1.7). There was a marked difference in the size distribution of *E. crystallorophias* caught in the 0-50 m surface layer at Station 43 versus the 100-200 m depth layer at Station 59. In the surface layer, the size composition was bimodal, with juveniles peaking at 19 mm and females at 30 mm. In the 100-200 m depth layer, the size composition was dominated by males, with a mode at 25 mm (Fig. 3.3.1.9 C, D). These vertical differences in the size distribution of ice krill were in line with similar observations made during PS82 in the Filchner region.

After leaving the Atka Bay area, 5 M-RMT stations were completed during the northbound transition to and on the 0° meridian. Unfortunately, only 3 of those stations were fully suitable for quantitative analysis due to technical problems during 2 hauls. Overall macrozooplankton abundances and species composition were similar to the catches during the southbound transect on the 0° meridian (Fig. 3.3.1.8). *Thysanoessa macrura* was again dominating in terms of abundance, and exhibited a similar size distribution (Fig. 3.3.1.8, Fig. 3.3.1.9 B). Station 79 and 80 were conducted at almost identical locations to Stations 29 and 27, respectively, during the southbound transect at the beginning of the expedition. Interestingly, the pattern of low abundances in the northern stations (27/80) versus high abundances in the southern stations (29/79) was confirmed during the return transect on the 0° meridian (Fig. 3.3.1.6, 3.3.1.8).

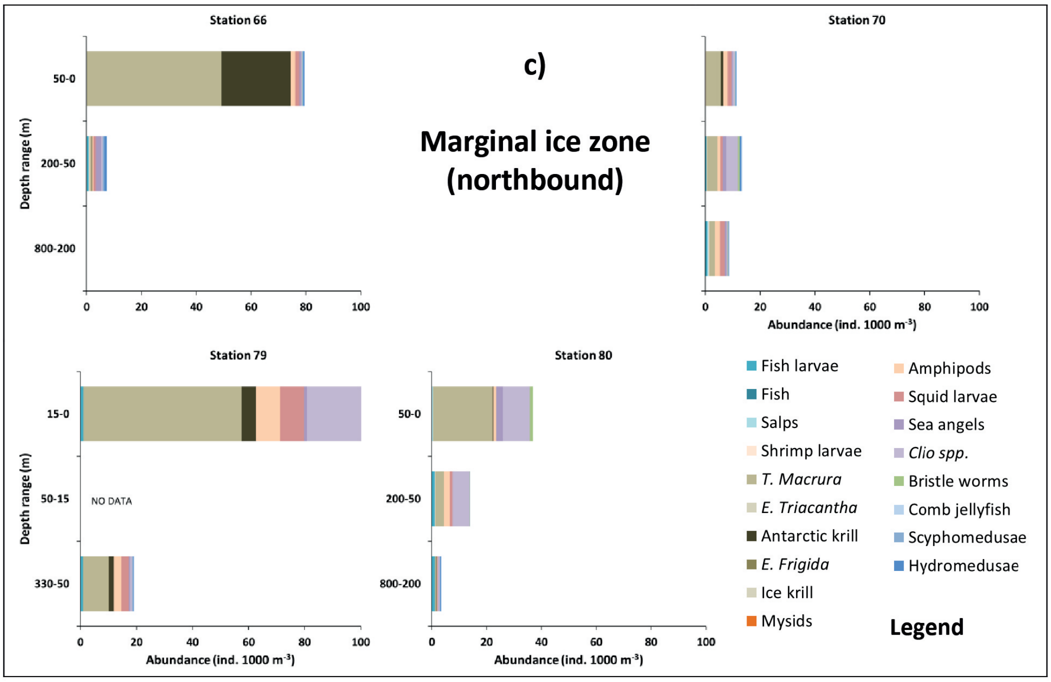


Fig. 3.3.1.8: Taxonomic composition and macrozooplankton abundance in M-RMT catches on the northbound leg after leaving the Atka Bay area. The macrozooplankton community was sampled at 3 different depth layers.

The vertical distribution of three euphausiid species in open and ice covered waters was investigated using SUIT and M-RMT data (Fig. 3.3.1.10). *E. superba* was most abundant in the surface layer under ice. In deeper layers, abundances were generally low. *T. macrura* was more abundant in deeper waters, especially in the upper 200 meters, with slightly higher abundances in ice-covered waters. These results are consistent with the results of 2007/2008 (Flores et al. 2012), demonstrating that abundances of Antarctic krill in the ice-water interface layer often far exceed integrated abundances of the 0-200 m layer. *E. crystallorophias* was mostly found in low numbers near Atka bay. The highest abundance of this species was caught between 100 and 200 meter depth.

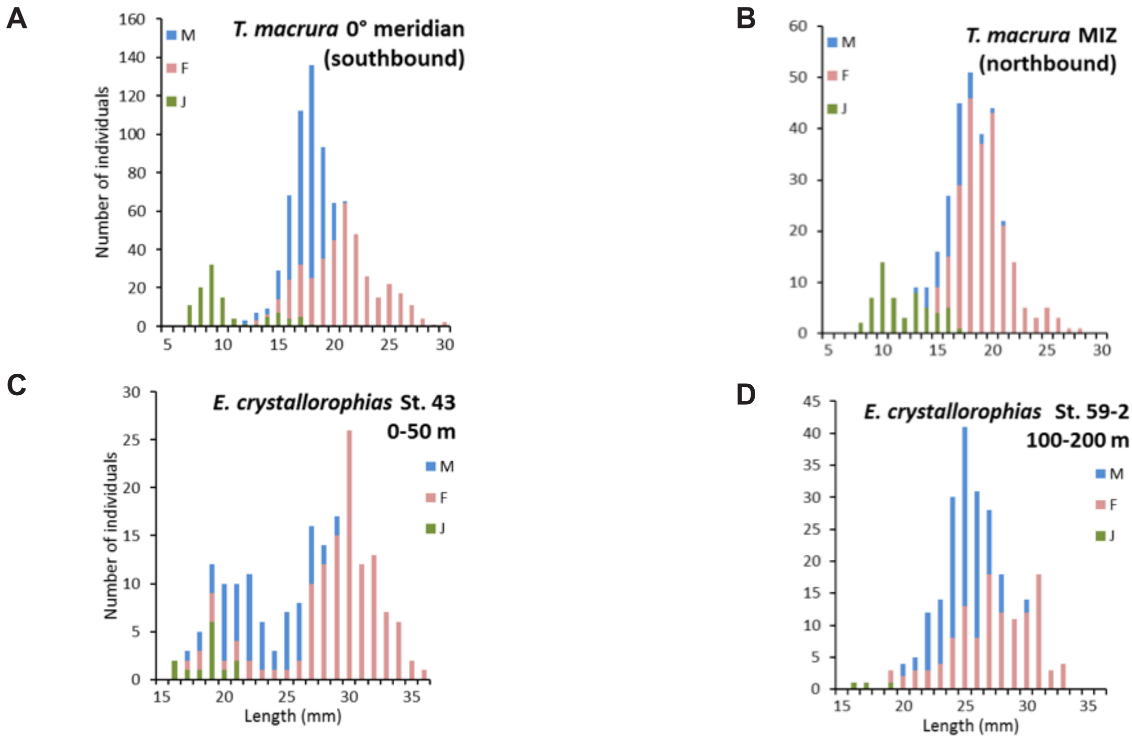


Fig. 3.3.1.9: Size composition of Thysanoessa macrura in the sea ice zone on the southbound 0° meridian and the northbound leg after leaving the Atka Bay area, and the size composition of Euphausia crystallorophias at different depth layers at 2 stations near Atka Bay.

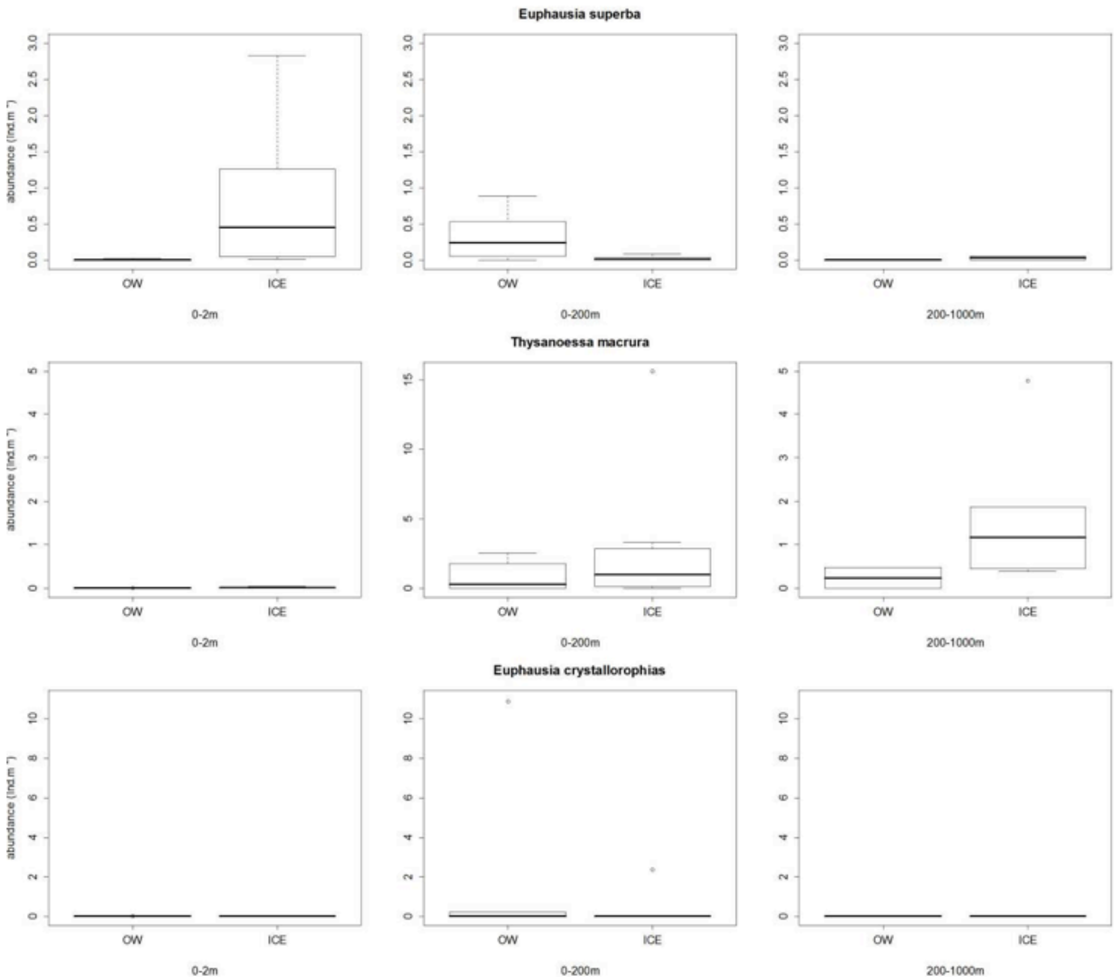


Fig. 3.3.1.10: Comparison of three euphausiid species sampled at different depth strata in open and ice-covered waters. Note the different scales in the Thysanoessa macrura plots. ICE = ice-covered SUIT stations and corresponding M-RMT stations; OW = open water SUIT stations and corresponding M-RMT stattions

Larval Fish. In oceanic waters, larval stages of *Electrona antarctica* and *Notelepis coatsi* were caught frequently, while *Bathylagus antarcticus* larvae were caught infrequently. In coastal waters, icefish (Channichthyidae) larvae and unidentified Nototheniids were caught occasioanally. Larval stages of *E. antarctica* showed peaks at 13 and 25 mm length (Fig. 3.3.1.11). Post-metamorphic and adults stages were also present but without displaying a clear pattern. This is likely due to the small number of these stages that were caught. *N. coatsi* covered a wide range from 12 up to 73 mm lengths, but most of them were between 28 and 43 mm in size. In coastal waters, the icefish and the unidentified Notothen showed similar size ranges peaking around 19 and 22 mm, respectively (Fig. 3.3.1.12).

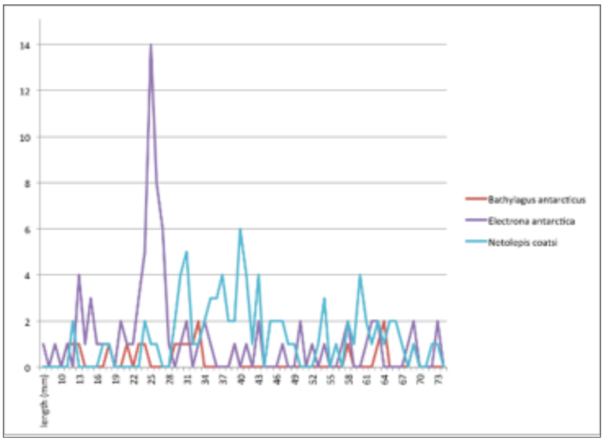


Fig.3.3.1.11: Length-frequency distribution of the most frequent oceanic fish, Electrona antarctica, Notolepis coatsi and Bathylagus antarcticus caught during PS89

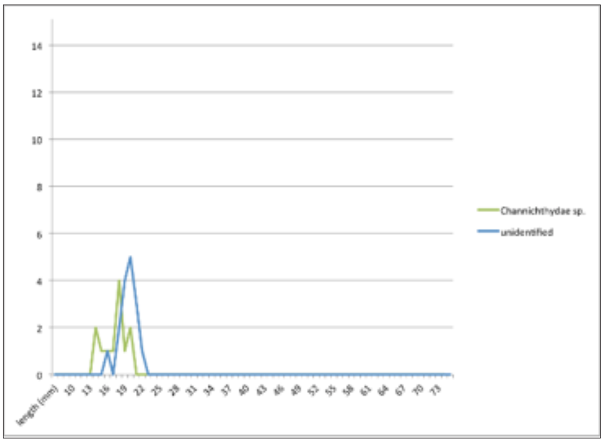


Fig. 3.3.1.12: Length-frequency distribution of the most frequent coastal fish, Channychtid and Nototheniid fish larvae caught during PS89

Samples for Genetic Analysis. Samples of amphipods, fish and other zooplankton were collected for further genetic analysis and will be integrated with other on-going efforts to collect samples of fish and amphipods around the Southern Ocean in order to perform phylogeographic and population genetic analyses (Table 3.3.1.3).

Tab. 3.3.1.3. Overview of samples collected for molecular Analysis

	100 % Ethanol	Frozen -20	Frozen -80°	Total
Amphipods	171			171
Amphipod sp.	1			1
Cyllopus lucasi	9			9
Eusirus laticarpus	54			54
Eusirus microps	10			10
Eusirus spp.	31			31
Hyperiella sp.	10			10
Hyperoche sp.	1			1
Primno macropa	53			53
Themisto gaudichaudii	1			1
Fish	92	84	46	222
Bathylagus antarcticus	9	3	5	17
Channichthydae spp.	6			6
Electrona antarctica	16	25	32	73
Gymnoscophelus nicholsi		1		1
Gymnoscophelus sp.		3		3
Myctophidae spp.		44		44
Notolepis coatsi	54	8	9	71
Notothenioid	1			1

Sea ice work

The sampled ice stations presented a very high variability in the majority of site parameters (Table 3.3.1.4). Ice thickness varied between ca 70 cm in sea ice on the 0° meridian, and more than 3 m in coastal fast ice at Atka Bay. The snow conditions were also highly variable, ranging from bare ice to more than 1 m snow cover. Thick snow cover was associated with negative freeboard (see stations 40-3, 40-5, and 48-1). Fig. 3.3.1.13 shows the typical coring grid taken at sites where also under-ice light measurements were performed.

Fig.3.3.1.13: Image of a typical coring grid taken at the L-arm site. The core hole on the right side was used to deploy the sensors attached to a L-arm underneath the ice. The ice cores were taken at the centre of the square in which the light measurements are performed. Picture by André Maijboom (IMARES).

Tab. 3.3.1.4: List of mean physical properties of the sampled ice for each sea ice station. The last 2 columns give information on the presence of a surface algae layer in the core holes and on the presence of (or signs of the presence of) platelet ice

Station	H (m)	H_{snow} (cm)	T (ºC)	Salinity (psu)	Freeboard (cm)	Algae Layer	Platelet Ice
32-1	1.21	18	-1.73	11.65	6	NO	NO
35-1	0.73	6	-1.66	9.28	7	NO	NO
40-1	2.05	17	-2.73	9.04	8	YES	YES
40-3	3.51	119	-	-	-11	NO	YES
40-4	-	-	-	-	-	-	-
40-5	1.93	56	-2.1	-	-14	NO	YES
46-1	1.12	30	-1.24	10.19	-2	NO	NO
58-1	2.34	0	-	-	26	NO	Signs

Tab. 3.3.1 lists the number of ice cores taken for the physical, biogeochemical and biological analysis. High variability was also seen in the vertical profiles of in-ice temperature (Fig. 3.3.1.14) and salinity (Fig. 3.3.1.15). The stations in Atka Bay were characterized by the presence of platelet ice or by visible indications at the bottom of the ice cores that there had been platelet ice which was flushed away by the tidal movement of the water, or by the ship's propellers nearby. The only exception is station 46-1, where the ice was melting at the bottom, as was also evident from the temperature profile in Fig. 3.3.1.14. In general, the stations in

Atka Bay appeared to host higher biomass in the ice, visible by a brownish layer at the bottom of the cores, compared to the stations taken on ice sea floes. Further detailed analysis on sea-ice biogeochemistry and biological properties in the laboratory at AWI will give a complete picture on the sea-ice biomass.

Tab. 3.3.1.5: List of ice cores taken at each ice station for the analysis of physical (texture-TEX, Salinity-SAL, Sediment-SED), biogeochemical and biological analysis (Meiofauna-MEIO, DNA)

Station Nº	BIO-OPT	LSI	DNA	MEIO	SED	ARC	TEX	SAL
32-1	5	2	1	2	1	1	1	1
35-1	2	2	1	2	1	1	1	1
40-1	2	1	1	1	1	0	1	1
40-3	0	0	0	2	0	0	0	0
40-4	-	-	-	-	-	-	-	-
40-5	1	0	0	1	0	0	1	0
46-1	1	2	1	2	1	1	1	1
58-1	2	2	1	2	0	0	0	0

The CTD profiles (Fig. 3.3.1.16) provided information on the water characteristics at the ice stations. The variability in the physical properties of the top 50 m of the water column resembled the high variability already found in the sea ice physical properties of sea ice. The sampling site of Station 40-1 was re-visited 4 days later (Station 40-4). At Station 40-1, the CTD profile showed a clear stratification in the upper about 18 m, where the uncalibrated chlorophyll *a* content reached levels of about 12 mg m^{-3} (Fig. 3.3.1.16 B). At the same spot four days later, no stratification was apparent, and chlorophyll *a* concentrations remained generally below 0.5 mg m^{-3} (Fig. 3.3.1.16 D). This pronounced difference in the vertical structure of the underlying water may have been related to the tidal movement of waters. This result highlights the high variability of the Atka Bay sea ice system, not only on a spatial scale, but also on a temporal scale.

At most stations we performed under-ice light field measurements. The high variability of the sampled places 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.

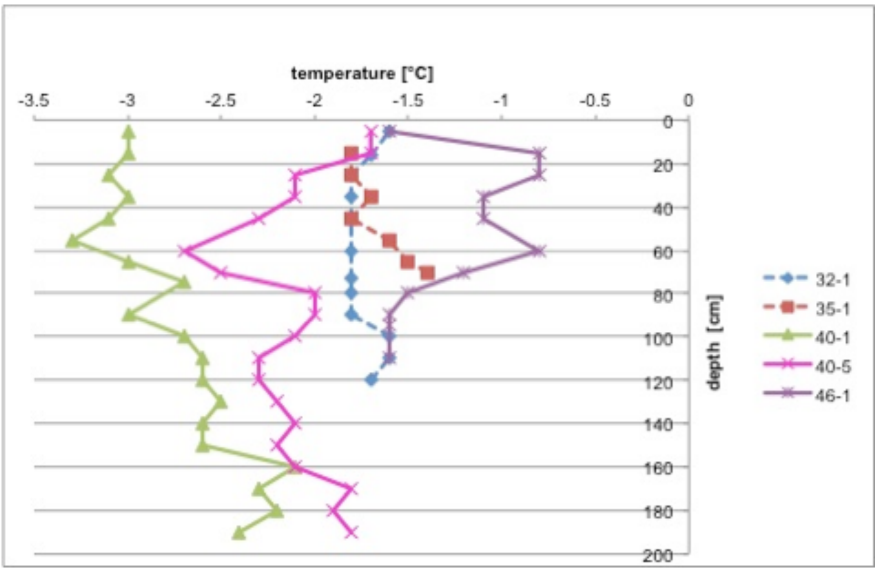


Fig.3.3.1.14: Temperature vertical profiles in the ice for stations 32-1, 35-1 (dashed line) on the ice floes and for stations 40-1, 40-5 and 46-1 (full line) on the fast ice.

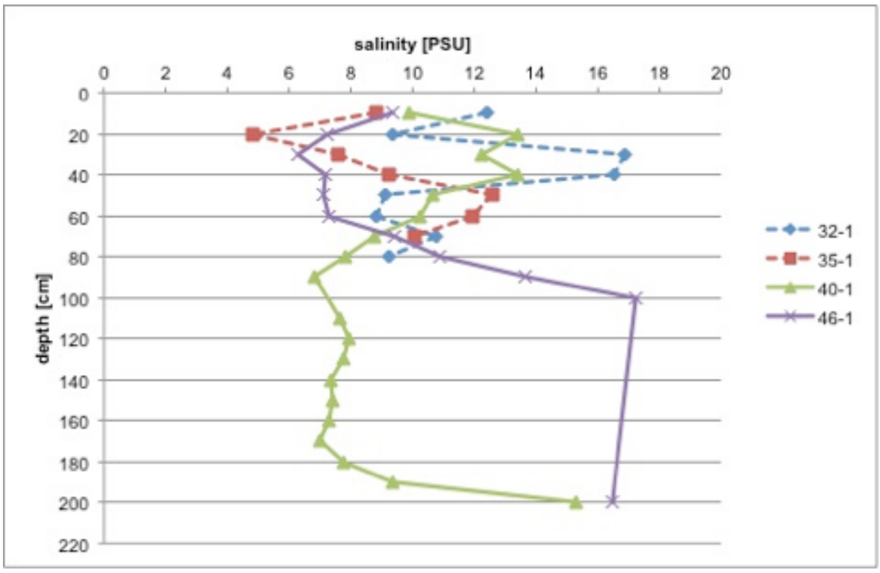


Fig. 3.3.1.15: Salinity vertical profiles in the ice for stations 1, 2 (dashed line) on the ice floes and for stations 40-1, 40-5 and 46-1 (full line) on the fast ice

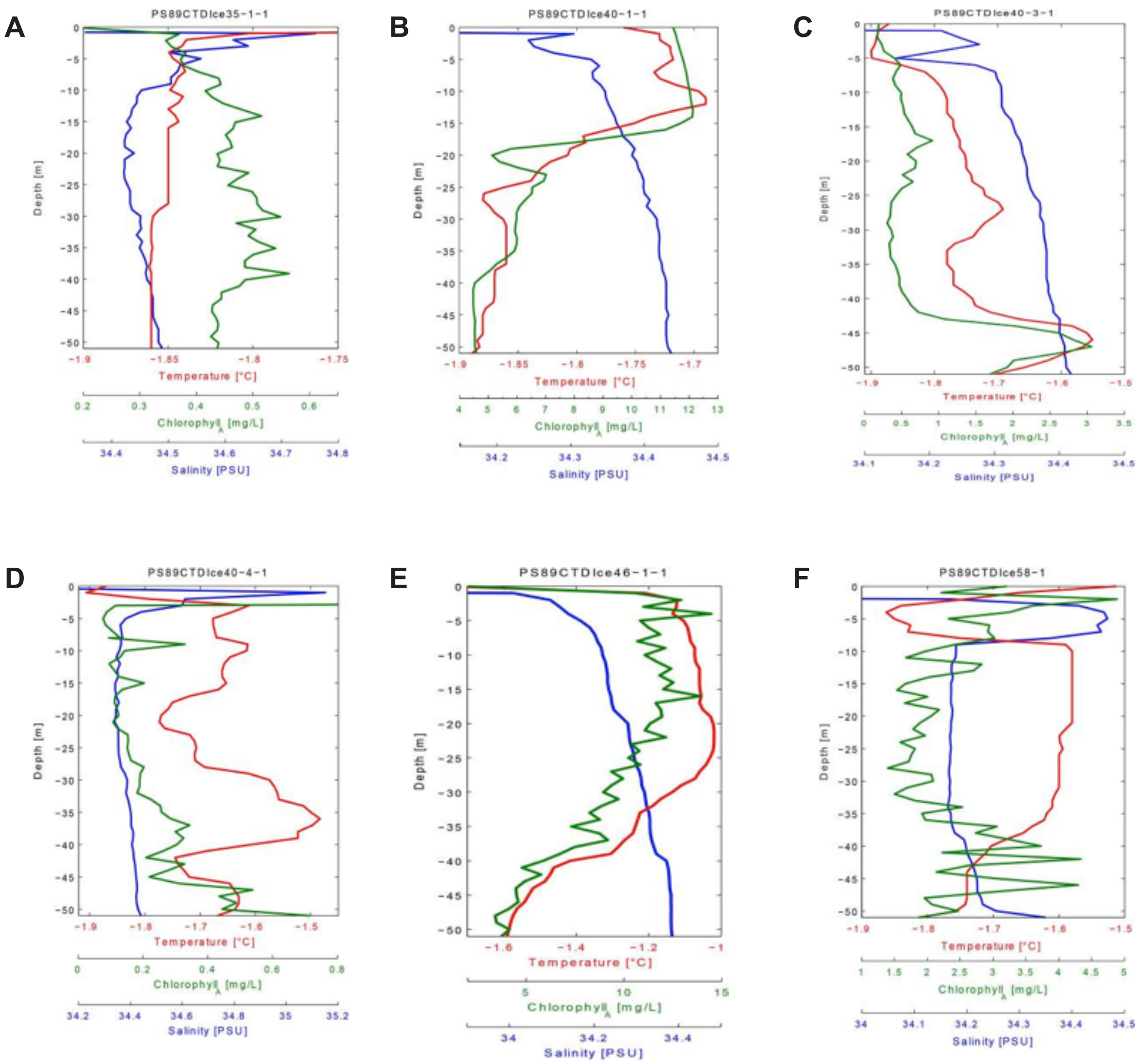


Fig. 3.3.1.16: CTD profiles in the 50 m water column under the ice at ice stations

Top predator censuses

Transect census. The southward leg of PS89 (ANT-XXX/2) was rather unusual in its pattern of food requirements of the top predators. In most earlier transects in this region, it was observed that birds, seals and whales had food requirements in ice covered waters that were much higher than in the open water further north. The background relates to a mix of increased numbers of individuals, larger sizes, and species restricted to life in sea ice. In the observations on this voyage, this pattern still holds for birds and seals. Fig. 3.3.1.17 A shows that flying seabirds, mainly tubenosed species, concentrated in the area of the Antarctic Polar Front around 49 to 50°S. Near and in the ice, penguins take over, with chinstrap penguins *Pygoscelis antarctica* in the outer zone, and Adélie penguins *Pygoscelis adeliae* and emperor penguins *Aptenodytes forsteri* further south. Apart from incidental fur seals *Arctocephalus gazella* in open waters, the crabeater seal *Lobodon carcinophagus* dominated in the sea ice. It concentrated in the far south but had remarkably low densities in the apparently suitable sea ice between 59°S and 64°S (Fig. 3.3.1.17 B). The overall picture of food requirements of top predators on this voyage (Fig. 3.3.1.17 C) was however dominated by larger whale species such as the fin whale

Balaenoptera physalus and the humpback whale *Megaptera novaeangliae*. Far north, these were rather incidental but influential observations, but just north of the ice edge observations became more regular. Deeper in the ice, the usually fairly abundant Antarctic minke whale *Balaenoptera bonaerensis* was not seen very frequently. The overall impression of top predator abundance in the sea ice was that it was relatively low compared to observations on earlier *Polarstern* cruises, but more detailed comparisons must await further analysis, including the data of the northward leg in mid-January, when the ice edge was positioned far south around 68°S. Data from that return trip have not been analysed yet, but the general impression is that abundances were still fairly low in denser sea ice. However, in the outer rim of the sea ice and north of it, whales were abundant, with both the Antarctic minke whale and several blue whales *Balaenoptera musculus* seen feeding around the ice edge, where also the SUIT net made its highest catches of Antarctic krill under the ice. Humpback whales were seen frequently over large parts of the zones that had been covered by sea ice in December.

Emperor Penguin colony census. On December 30, aerial photographs were made of the emperor penguin colony in Atka Bay near *Neumayer Station III* (Fig. 3.3.1.18). Preliminary counts of the *photos* sum up to approximately 3,200 chicks and 500 adults being present, with an additional presence of 22 Adélie penguins in adult plumage, apparently prospecting for breeding locations, which however are unavailable in the area. The number of emperor penguin chicks was much lower than made from a similar photo survey on 14 Dec 2007, when nearly 11,000 chicks and over 1,000 adults were counted. The lower number of chicks in the seasonally somewhat later 2014 survey cannot be explained by fledging of chicks. Only two fledged chicks were observed near the edge of the fast ice in 2014. In 2007, larger numbers of fledglings were seen only by mid-January. Reproductive success of Emperor penguin colonies is known to be extremely variable and dependent on winter weather, and position of the fast-ice edge during different critical phases of the breeding cycle. Undoubtedly, food availability will also vary and may have been low in this season or parts of it.

Concluding remarks

Based on the net catches, the area surveyed was characterized by low zooplankton abundances compared to earlier expeditions. The mere absence of Antarctic krill from pelagic M-RMT samples on the 0° meridian was remarkable. However, the well-known patchiness of zooplankton distribution in combination with the low number of net hauls accomplished during this expedition precludes any large-scale generalisation of this observation. Elevated abundances of juvenile Antarctic krill were only encountered in the ice-water interface layer, confirming earlier findings from the same region suggesting that Antarctic krill is often more abundant under sea ice than in the epipelagic layer. Patterns in top predator distribution resembled those of zooplankton, with elevated abundances of whales associated with relatively high under-ice krill abundances in the marginal ice zone on the northbound leg. Sea ice habitat properties evidently had a decisive impact on the distribution of animals in the investigation area. The high variability of sea ice properties found during our ice station work suggests that km-scale measurements of sea ice properties, such as those performed with SUIT, can be valuable in capturing this variability at more appropriate spatial scales.

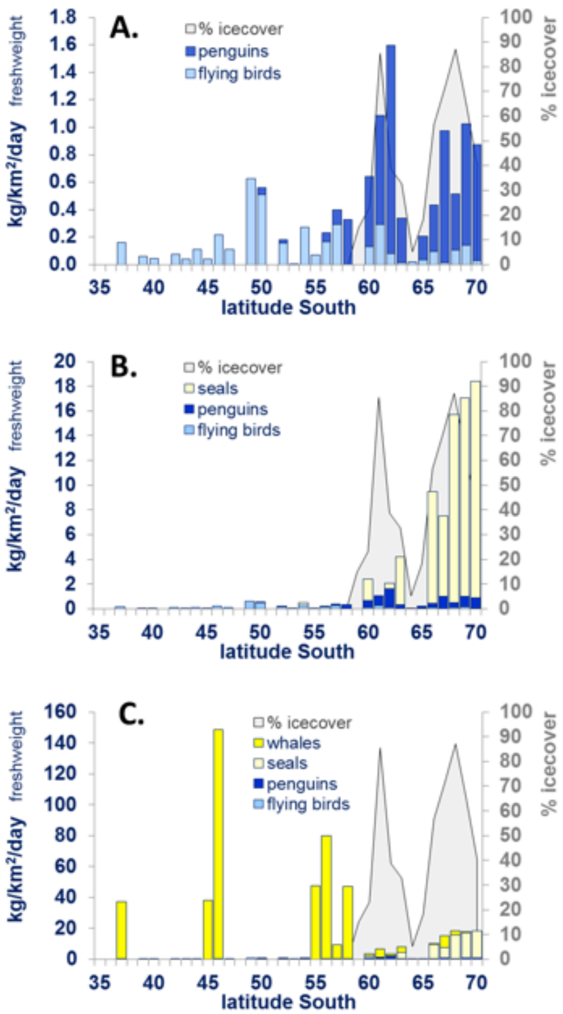


Fig. 3.3.1.17: Food requirement of top predators averaged by degree of latitude and in relation to average sea ice cover (884 ship based and aerial counts, 4-25 December 2014, Cape Town to Neumayer, largely following the 0° meridian). A. birds, B. birds and seals, C. birds, seals and whales.

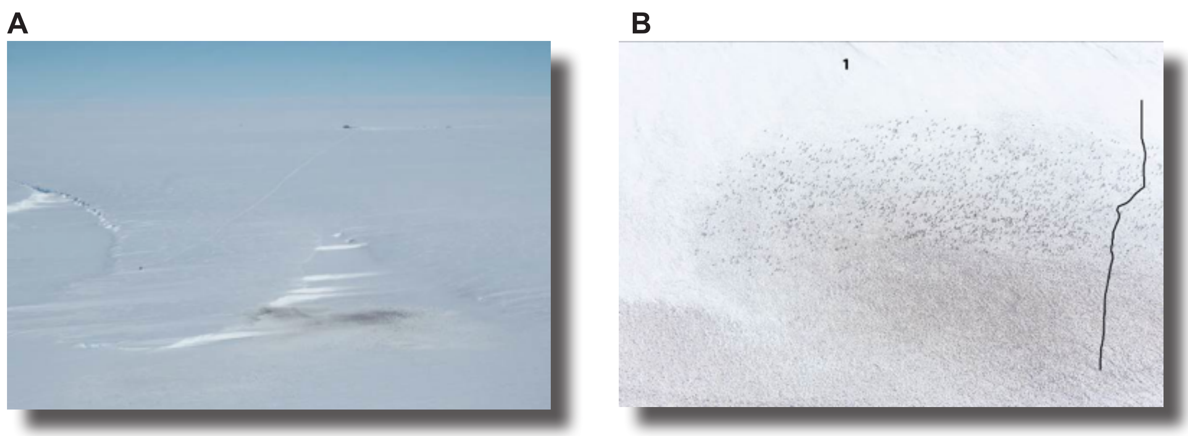


Fig. 3.3.1.18: Overview of the emperor penguin colony on the fast ice in Atka Bay, with Neumayer Station III visible in the back (A). On the right (B), the first of the five aerial photographs used to count the number of chicks and adults in the colony. Based on details on the pictures, the drawn line shows the separation between counts of different photographs.

Data management

Almost all sample processing will be carried out in the home laboratories at AWI, IMARES and RBINS. 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, the Antarctic Master Directory (including the Southern Ocean Observation System), the Antarctic Biodiversity Portal www.Biodiversity.aq, and will be open for external use.

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Chief scientist
Olaf Boebel

Coordinator
Rainer Knust

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