Master Thesis

Diversity and distribution of high-Arctic zooplankton
in the Eurasian Basin in late summer 2012

Submitted by

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1 Zusammenfassung/Summary

1.1 Zusammenfassung

Arktische Ökosysteme sind dem Klimawandel eher ausgesetzt als andere Ökosysteme, da die Erwärmung der Arktis bis zu drei Mal schneller abläuft als der globale Durchschnitt (Wassman et al. 2008). In Folge der globalen Erwärmung nahm das Mehrjahreseis der zentralen Arktis in den letzten Jahrzehnten deutlich ab und Einjahreseis dominierte die Eisbedeckung mit einer durchschnittlichen Dicke von weniger als einem Meter (Boetius et al. 2013). Das in der Schicht zwischen dem Eis und der Wassersäule lebende Zooplankton stellt einen wichtigen trophischen Link zwischen dem Meereis und dem pelagischen Nahrungsnetz dar. Somit führt das Schmelzen des Meereises zu einem Habitatverlust für Eis-assoziierte Arten, welcher auch einen Einfluss auf das pelagische Nahrungsnetz nehmen kann. Das Ziel dieser Arbeit war die Untersuchung der pelagischen Zooplanktongemeinschaft im Eurasischen Becken nach einem historischen Meereisminimum im Spätsommer 2012.

Alle Proben für diese Arbeit wurden während der *Polarstern* Expedition ARK XXVII/ 3 "IceArc" vom 2. August bis 7. Oktober 2012 genommen. Die Probennahme erfolgte mit einem multiple closing net (MultiNet, Midi type, HYDROBIOS Kiel). Zooplanktonproben von neun Stationen, davon vier im Nansen Becken und fünf im Amundsen Becken, sowie zwei Tiefenschichten (0 – 50 m und 50 – 200 m) wurden analysiert, um horizontale und vertikale Verteilungsmuster zu untersuchen. Zusätzlich wurde in der Nähe jeder MultiNet Station eine Vielzahl an Umweltparametern (Temperatur, Salinität, Eiseigenschaften) gemessen um herauszufinden, welche Parameter die Verteilung der Zooplankton-gemeinschaften am meisten beeinflussen.

Insgesamt wurden 30 Taxa in den Proben aus dem Eurasischen Becken identifiziert. Die Artenanzahl, Artenzusammensetzung und Abundanz der Zooplanktongemeinschaften veränderten sich hauptsächlich mit der Wassertiefe. So stieg die Artenanzahl signifikant von der 0 – 50 m Wasserschicht zur 50 – 200 m Wasserschicht an. Dagegen nahmen die Abundanzen mit der Tiefe signifikant ab und variierten zwischen 307 und 1606 Ind. m⁻³ in der 0 – 50 m Wasserschicht und zwischen 95 und 208 Ind. m⁻³ in der 50 – 200 m Wasserschicht. Weder hinsichtlich der Artenanzahl noch der Abundanz konnten signifikante Unterschiede zwischen dem Nansen Becken und dem Amundsen Becken festgestellt werden.

Die Zooplanktongemeinschaft wurde von Copepoden dominiert, während Nicht-Copepoden eine untergeordnete Rolle spielten. In beiden Tiefenschichten sowie in beiden Becken waren *Oithona* spp., *Corycaeus* spp. und Clausocalanidae die Arten mit der größten Abundanz. Die Nicht-Copepoden Foraminifera, Chaetognatha und Appendicularia machten den bedeutendsten Anteil in der 0- 50 m Tiefenschicht sowie im Nansen Becken aus. In der 50-200 m Tiefenschicht und im Amundsen Becken kamen Foraminifera, Ostracoda und Chatognatha am häufigsten vor.

Calanus spp. bildeten in beiden Tiefenschichten und in beiden Becken weniger als 8 % der Zooplanktongemeinschaft. Für *Calanus hyperboreus*, *Calanus glacialis* und *Calanus finmarchicus* konnte eine signifikante Abnahme der Abundanzen mit zunehmender Tiefe beobachtet werden. *C. finmarchicus* war in der 0 – 50 m Schicht die häufigste *Calanus* Art, während sie in der 50 – 200 m Schicht die geringste Abundanz zeigte. *C. glacialis* zeigte eine gegenteilige Verteilung und war in der oberen Schicht am geringsten und in der unteren Schicht am häufigsten von allen drei *Calanus* Arten vertreten. Beim Vergleich der beiden Becken war keine signifikante räumliche Verteilung der *Calanus* spp. Abundanzen zu erkennen. Adulte Weibchen und das Copepodidstadium V waren von allen drei *Calanus* Arten die am häufigsten vorkommenden Stadien. Da an den meisten Stationen junge Entwicklungsstadien der drei *Calanus* Arten gefunden wurden, kann von einer erfolgreichen Fortpflanzung im Eurasischen Becken ausgegangen werden.

Die Ergebnisse dieser Arbeit wurden mit den Ergebnissen von David et al. (2015) verglichen. David et al. (2015) nahm während der Expedition ARK XXVII/ 3 Proben mit dem Surface and Under-Ice Trawl (SUIT), um die unter dem Eis lebende Zooplankton-gemeinschaft des Eurasischen Beckens zu untersuchen. Die Analyse der MultiNet Daten dieser Arbeit lieferte im Vergleich zur Analyse der SUIT Daten von David et al. (2015) unterschiedliche Ergebnisse, insbesondere bei Betrachtung der Artenzusammensetzung. David et al (2015) erkannte ein von herbivoren Arten dominiertes Nansen Becken und ein von carnivoren Arten dominiertes Amundsen Becken. In der vorliegenden Arbeit konnten diese Beobachtungen für das pelagische Zooplankton nicht bestätigt werden, da herbivore Arten in beiden Becken dominierten. Das konstante Vorkommen von *C. finmarchicus* in allen MultiNet Proben auf der einen Seite und deren Abwesenheit in den SUIT Proben (abgesehen von einer Station) auf der anderen Seite, deutet auf eine Migration in die oberen Wasserschichten mit Meidung der 0-2 m Oberflächenschicht hin. Die These einer nördlichen Verschiebung des Vorkommens atlantischer Arten wie *C. finmarchicus* aufgrund einer

verstärkten atlantischen Einströmung in den Arktischen Ozean konnte in dieser Arbeit weder gestützt noch entkräftet werden.

Verglichen mit anderen MultiNet Studien im Bereich des Eurasischen Beckens waren keine bedeutenden Veränderungen in der Artenzusammensetzung, Biodiversität und Abundanz der Zooplanktongemeinschaft erkennbar. In der Zukunft sind Langzeituntersuchungen mit einem standardisierten und vergleichbaren Beprobungssystem die Grundvoraussetzung, um Veränderungen der arktischen Biodiversität und der arktischen Ökosysteme zu untersuchen und um herauszufinden, ob diese Veränderungen mit dem Klimawandel zusammenhängen.

1.2   Summary

Arctic ecosystems are exposed to climate-driven changes much sooner than other ecosystems, since Arctic warming is about three times faster than the global rates (Wassmann et al. 2008). In the central Arctic, multi-year ice has been largely decreased during the last decades as a result of melting by atmospheric heating. In 2012 a historical minimum in sea ice extent has been recorded. First-year ice was dominating with an average thickness of less than one meter (Boetius et al. 2013). Zooplankton that is dwelling in the ice-water interface layer and feeding on sea ice algae constitutes an important trophic link between the sea ice and the pelagic food web. Thus, the loss of sea ice causes a loss of habitat for ice related species which the pelagic food web depends on. This study aimed to investigate the pelagic zooplankton community in the Eurasian Basin in late summer 2012 after a historical sea ice minimum.

All samples for this study were taken during the *Polarstern* expedition ARK XXVII/ 3 "IceArc" from August 2nd to October 7th, 2012. Sampling was conducted with a multiple closing net (MultiNet, Midi type, HYDROBIOS Kiel). Zooplankton specimens of nine stations (four in Nansen Basin and five in Amundsen Basin) and two depth layers (0 – 50 m and 50 – 200 m) were classified to investigate horizontal and vertical patterns of zooplankton distributions. To identify environmental variables that structure the zooplankton communities a large set of physical data was recorded near all sampling stations.

In total 30 taxa were found in the Eurasian Basin during this study. Depth was the most important factor in structuring the zooplankton community. The number of taxa increased significantly with depth and ranged from 12 to 21 taxa in the 0 – 50 m water layer and from 16 to 24 taxa in the 50 – 200 m water layer. The zooplankton abundance decreased significantly with depth and ranged from 307 to 1606 ind. m⁻³ in the upper water layer and from 95 to 208 ind. m⁻³ in the deeper water layer. Spatial differences between Nansen Basin and Amundsen Basin were not significant for the number of taxa and the zooplankton abundance during this study.

Copepods clearly dominated the zooplankton community in terms of species number and abundances while non-copepods played only a minor role. *Oithona* spp., *Corycaeus* spp., and Clausocalanidae were the most abundant taxa of copepods in both depth layers and both basins. Foraminifera, Chaetognatha, and Appendicularia were the most abundant taxa of non-copepods in the 0 – 50 m depth layer and in the Nansen Basin whereas Foraminifera, Ostracoda, and Chaetognatha were the most abundant taxa in the 50 – 200 m depth layer and in the Amundsen Basin.

Calanus spp. represented <8 % of the zooplankton community in every depth layer and every basin. Abundances of *Calanus hyperboreus*, *Calanus glacialis*, and *Calanus finmarchicus* revealed significant vertical patterns as abundances of all three species decreased with depth. *C. finmarchicus* dominated the *Calanus* spp. community in the $0-50$ m water layer, but in the $50-200$ m water layer it was the least abundant. *C. glacialis* were highest in the deeper water layer, but lowest in the upper water layer. There was no significant spatial pattern for *Calanus* spp. concerning the distribution in Nansen Basin and Amundsen Basin. Adult females and the copepodid stage V were the most abundant developmental stages of all three *Calanus* species. The presence of young developmental stages of all *Calanus* species suggested successful reproduction at most of the stations for *C. hyperboreus*, *C. glacialis,* and *C. finmarchicus*.

The results of this study were compared with the study of David et al. (2015) who used the newly developed Surface and Under-Ice Trawl (SUIT) during the ARK XXVII/ 3 "IceArc" expedition to investigate the under-ice zooplankton community. The analysis of the MultiNet samples for this study and the SUIT samples for the study of David et al. (2015) delivered different results especially with regard to the composition of the zooplankton community. David et al. (2015) reported a herbivorous Nansen Basin regime and a carnivorous Amundsen Basin regime for the under-ice community in the Eurasian Basin. These findings could not be confirmed for the zooplankton community of the pelagial within this study, since herbivores prevailed in abundances in both basins. The constantly presence of *C. finmarchicus* in all MultiNet samples, but absence in the SUIT samples (except of one station) showed that *C. finmarchicus* migrated to the upper water layers, but avoided the 0-2 m surface layer. A northward migration of the North Atlantic species *C. finmarchicus* due to an increased Atlantic inflow into the Arctic Ocean could neither be confirmed nor rejected within this study.

In comparison to previous investigations in the Eurasian Basin, no drastic changes in species composition, biodiversity, and abundances of the zooplankton community were evident. In the future long-term monitoring programmes with a standardized sampling design are a key requirement to reveal changes in the Arctic biodiversity and ecosystem structure and to investigate if these changes are associated with the climate change.

2   Introduction

The Arctic Ocean is a closed ocean basin which is almost entirely surrounded by land. Its only deep gateway to the world oceans (Greenland Sea and Norwegian Sea) is the Fram Strait between Spitzbergen and Greenland. With depths up to 2.6 km and a width of 600 km the Fram Strait is by far deeper and wider than the other gateways Bering Strait, Barents Sea Opening, or channels in the Canadian Arctic Archipelago. The deep central region of the Arctic Ocean is separated by the Lomonosov Ridge into two major basins, the Eurasian Basin and the Canadian Basin. The Eurasian Basin, in turn, is divided by the Gakkel Ridge into two basins named Nansen Basin and Amundsen Basin.

The Arctic Ocean comprises three major water masses: Polar water, Atlantic water, and Arctic water. The Nansen Basin is most directly influenced by the inflow of Atlantic water (Mumm 1993), because along its southwestern side it borders the Fram Strait. Atlantic water (S> 34.5 PSU, T= 0.5 - 1°C, Auel and Hagen 2002) is carried northward through eastern Fram Strait with the West Spitsbergen Current. When entering the Nansen Basin, the Atlantic water flows beneath the Polar surface water (Carmack 1990) and follows the Eurasian continental slope as a counter clockwise boundary current. The Atlantic layer can be detected throughout the Arctic Ocean in 200 – 600 m depth below a pronounced halocline (Auel and Hagen 2002). In turn, the Polar surface water (S< 34.4 PSU, T< 0°C, Carmack 1990) moves southwestward across the Nansen Basin in the upper 50 m towards western Fram Strait where it flows into the East Greenland Current.

The history of zooplankton research in the central Arctic began with Nansen's Fram expedition (1879 - 1899). During the first 80 years of zooplankton research, the organisms were collected from drifting ice platforms or ships frozen in the ice. Within this period of sporadic data collection, basic knowledge on the major parameters and seasonal dynamics of the zooplankton communities of the Arctic Ocean were obtained. In the last three decades, biological observations in the Arctic Ocean have increased markedly (Kosobokova, Hopcroft, Hirche 2010). Due to ice-breakers that can reach even permanently ice-covered regions large-scale and efficient sampling can be accomplished nowadays, albeit with major logistical effort (Mumm et al. 1998). The interdisciplinary research brought a breakthrough in understanding of relationships between the structure of pelagic communities with hydrographic processes and environmental factors (Kosobokova and Hirche 2009).

Zooplankton developed sophisticated life history strategies to survive and reproduce in a pelagic realm characterized by frigid temperatures, a perennial or seasonal sea ice cover,

limiting nutrients in the surface layer, and an extremely pulsed cycle of primary production (Conover and Huntley 1991; Darnis et al. 2012). Being the major consumers of primary production (Kosobokova, Hopcroft, Hirche 2010), zooplankton species are an important component in the Arctic food web since they link primary production with higher trophic levels. The Arctic Ocean hosts two zooplankton communities: an autochthonous community and an allochthonous community of Atlantic origin (Kososbokova and Hirche 2000). Sub-Arctic and boreal North Atlantic zooplankton species are transported through the Norwegian and Greenland Seas towards the Fram Strait and from there into the Arctic Ocean (Kosobokova and Hirche 2009). The different zooplankton communities are dominated by different copepod species. There are three *Calanus* species in the Arctic Ocean: *Calanus finmarchicus, Calanus glacialis, and Calanus hyperboreus*. They resemble each other morphologically, but differ in body size, reproductive strategy, life cycle, and origin. While *C. hyperboreus* and *C. glacialis* are considered to be of true Arctic origin, *C. finmarchicus* is a boreal North Atlantic species (Conover 1988; Auel and Hagen 2002; Hirche and Kosobokova 2007). Large copepod species are key drivers of the transfer of energy through the Arctic marine ecosystem due to their high-energy lipid compounds and essential fatty acids (Darnis et al. 2012). The three main *Calanus* species migrate from the upper water masses to deeper layers for overwintering (Hirche 1991) which results in a shift of zooplankton composition in the surface layer from dominance of large copepods to dominance of small-sized zooplankton (Hansen, Nielsen, Levinsen 1999). Unlike the large *Calanus* spp., small copepods (e.g., *Oithona* spp.) mostly stay active during the long Arctic winter (Madsen, Nielsen, Hansen 2008) and do not perform extensive vertical migration in the Arctic (Fortier et al. 2001).

The extreme climate in the Arctic Ocean, e.g., strong seasonality in light regime and sea ice cover or the advection of waters from adjacent seas has shaped unique marine ecosystems (Kosobokova et al. 1998). During the sea ice maximum from February until March, the whole Arctic Ocean is covered by sea ice whereas the Arctic sea ice minimum is reached in September. The ice is forming a substrate on which primary production can be concentrated. This condition contrasts to the generally diluted nutritions prevailing in the pelagial and makes the under-ice zone a suitable place for ice-associated and pelagic species (Conover and Huntley 1991). Ice-associated species are organisms that complete their entire life cycle within the sea ice or spend only part of their life cycle associated with the ice (Melnikov and Kulikov 1980). The ice-associated fauna plays a key role in transmitting carbon from sea ice algae into the pelagic and benthic food webs (David et al. 2015).

How pelagic zooplankton communities use the under-ice habitat is sparsely explored until today. The determination of the trophic link between the sea ice and the water column in the Arctic Ocean will be helpful for a better evaluation of the effects of continuous ice melting on the Arctic ecosystem. Zooplankton species are expected to be the first showing a response to climate change because of their short life histories and their sensitivity to environmental changes (Hunt et al. 2013). If climate change is ongoing, model-based studies indicate a northward migration of Atlantic species like *C. finmarchicus* with an increased inflow of Atlantic water into the Arctic Ocean (Richardson 2008). *C. hyperboreus* and *C. glacialis* have higher nutritional values than *C. finmarchicus* (Kosobokova and Hirche 2000). Thus, a replacement of *C. hyperboreus* and *C. glacialis* by *C. finmarchicus* would cause changes in the zooplankton community of the Arctic Ocean and effect the pelagic food web structure.

An indication for drastic changes of the Arctic Ocean in response to climate forcing was the decline of the sea-ice extent to a historical minimum in September 2012. The aim of this study was to provide a basin-wide inventory of zooplankton fauna in the Eurasian Ocean out of multiple closing net (MultiNet) samples collected from August to September 2012 during the ARK XXVII/ 3 "Ice Arc" expedition of *Polarstern*.

Specific objectives were as follows:

1) Describing the faunal composition and abundance of zooplankton in the two Eurasian basins (Nansen Basin and Amundsen Basin)

2) Analysing the patterns of vertical and horizontal distribution of zooplankton in these two basins

3) Investigating the association of the zooplankton communities with environmental variables (e.g., temperature, salinity, sea ice properties, chlorophyll *a*)

Another focus of this thesis was to compare the results from the MultiNet with a dataset from the Surface and Under-Ice Trawl (SUIT) provided by David et al. (2015), especially in order to analyze the spatial distribution patterns of the three *Calanus* species: *C. finmarchicus, C. glacialis*, and *C. hyperboreus* in ice-covered waters.

3 Methods

3.1 Sample collection

All samples for this study were taken during the *Polarstern* expedition ARK XXVII/ 3 "IceArc" from August 2nd to October 7th, 2012. The material was collected at nine stations between 82°N – 89°N and 17°E – 131°E (Fig. 1). Four stations were located in the Nansen Basin (stations 226, 243, 261, and 386) and five in the Amundsen Basin (stations 279, 328, 337, 351, and 367).
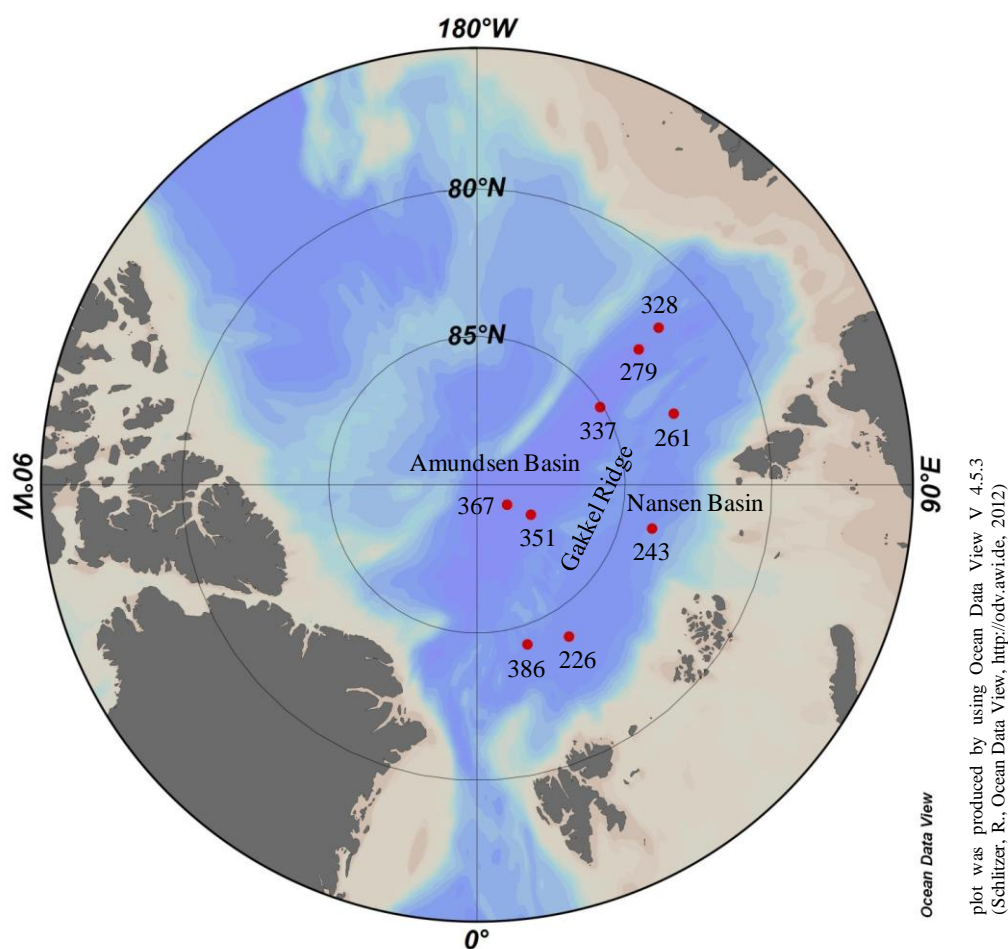
Fig. 1: Multiple closing net sampling stations during the expedition ARK XXVII/ 3 of *Polarstern*; number codes refer to station identifiers

In order to investigate the pelagic zooplankton communities in the Eurasian Basin, a multiple closing net (MultiNet, Midi type, HYDROBIOS Kiel) was used. This sampling system is equipped with a series of nets which can be opened and closed sequentially on command, e.g., in different water depths. The MultiNet used for this study had a net opening of 0.25 m² and was equipped with five nets, each of it with 150 µm mesh size.

A flowmeter installed in the opening of the net measured the filtered water volume for each net and depth range, respectively.

Zooplankton was collected from vertical hauls in five depth ranges (0 – 50 m, 50 – 200 m, 200 – 500 m, 500 – 1000 m, 1000 – 1500 m). Immediately after catch, the samples were preserved in a 4 % formaldehyde/seawater solution and buffered with hexamethylene-tetramine. The samples were stored at room temperature for later analysis of species composition, abundances, and distribution patterns in the laboratories of the Alfred-Wegener-Institute. For this study, samples of the two depth layers 0-50 m and 50-200 m from all nine stations were analyzed.

A large set of physical data was recorded with a Conductivity Temperature Depth rosette (CTD) near every MultiNet station (Tab. 1, Tab. 2). The CTD (Seabird SBE9+) was equipped with a seafloor altimeter (Benthos), a fluorometer (Wetlabs FLRTD), a dissolved oxygen sensor (SBE 43), and a transmissometer (Wetlabs C-Star). Boetius et al. (2013) provided details of the CTD sampling procedures. Data are available online in the PANGAEA database (Rabe et al. 2012). Modal CTD ice thickness (Tab. 4) was estimated from environmental sensors attached to the SUIT, including a CTD and an altimeter. Pressure data from the CTD and the distance to the sea ice estimated by the altimeter were used to derive ice thickness (for details see David et al. 2015). Ice concentrations (Tab. 4) were derived from grid cell ice coverage data of the SIC (AMSR2) satellite and were downloaded from the sea ice portal of the University of Bremen (http://www.meereisportal.de/de/datenportal.html).

Tab. 1: Sampling dates, stations and positions for the MultiNet in the Eurasian Basin during the ARK XXVII/ 3 expedition of *Polarstern*

Date	Time	Station No.	Gear	Position Latitude	Position Longitude	Depth [m]
09.08.2012	17:08	PS80/226-1	**MN**	84° 1.600'N	31° 13.810'E	4010.6
16.08.2012	09:30	PS80/243-1	**MN**	83° 54.930'N	75° 57.860'E	3420.0
21.08.2012	15:32	PS80/261-1	**MN**	82° 56.650'N	109° 53.160'E	3597.9
25.08.2012	21:55	PS80/279-1	**MN**	82° 53.060'N	129° 57.880'E	4166.0
05.09.2012	06:59	PS80/328-1	**MN**	81° 53.310'N	130° 49.140'E	4035.4
07.09.2012	12:25	PS80/337-1	**MN**	85° 5.560'N	122° 16.650'E	4356.2
18.09.2012	20:59	PS80/351-1	**MN**	87° 55.940'N	61° 0.110'E	4381.6
23.09.2012	01:30	PS80/367-1	**MN**	88° 47.390'N	56° 33.310'E	4376.1
28.09.2012	15:48	PS80/386-1	**MN**	84° 22.170'N	17° 30.670'E	3785.8

Tab. 2: Sampling dates, stations and positions for the Conductivity Temperature Depth probe (CTD) in the Eurasian Basin during the ARK XXVII/ 3 expedition of *Polarstern*

Date	Time	Station No.	Gear	Position Latitude	Position Longitude	Depth [m]
09.08.2012	19:25	PS80/227-1	**CTD/RO**	84°1.460'N	31°13.660'E	4011.2
16.08.2012	11:25	PS80/245-1	**CTD/RO**	83°55.140'N	75°58.890'E	3420.1
22.08.2012	05:14	PS80/263-1	**CTD/RO**	83°4.730'N	110°8.990'E	3606.4
26.08.2012	04:19	PS80/280-1	**CTD/RO**	82°53.380'N	129°48.680'E	4173.1
05.09.2012	10:44	PS80/329-1	**CTD/RO**	81°52.550'N	130°52.650'E	4032.2
07.09.2012	09:44	PS80/336-1	**CTD/RO**	85°5.660'N	122°15.970'E	4355.4
19.09.2012	01:52	PS80/353-1	**CTD/RO**	87°55.520'N	60°58.070'E	4383.6
22.09.2012	20:25	PS80/365-1	**CTD/RO**	88°48.180'N	57°2.950'E	4374.5
28.09.2012	18:07	PS80/387-1	**CTD/RO**	84°22.070'N	17°31.510'E	3897.2

3.2 Species identification

For analyzing the species composition and distribution patterns, all MultiNet samples were split into an aliquot of at least ¼ using a plankton splitter (Motoda 1959). In case of very abundant species, the sample was split into an aliquot of up to 1/265 of the total catch.

Representative subsamples were analyzed to a minimum of 30 individuals of each taxon. Zooplankton was sorted in a Bogorov plate and identified under a binocular (LEICA MZ125) with 8x to 100x magnification. Individuals were identified according to most recent taxonomy (Razouls et al. 2005-2012; http://copepodes.obs-banyuls.fr/en/). All copepods were determined to genus or species level, except of the copepods belonging to the family Clausocalanidae.

For bigger copepods (e.g., *Calanus* spp., *Paraeuchaeta* spp., *Metridia* spp.), the copepodid stages were determined. Copepod nauplii were separated by *Oithona* nauplii and *Calanus* nauplii, respectively, but no species level was identified. The individuals of *Calanus* spp. were selected for more detailed investigations. Prosome length measurements were used to distinguish between *Calanus finmarchicus, Calanus glacialis*, and *Calanus hyperboreus* according to Madsen, Nielsen, Hansen (2001) (Tab. 9). All non-copepod organisms (Ostracoda, Polychaeta, Chaetognatha etc.) were determined to phylum or class level due to time restrictions. Abundances [ind. m^{-3}] were calculated for all taxa based on data from the flowmeter.

3.3 Length measurements of *Calanus* spp.

The three species: *Calanus finmarchicus, Calanus glacialis,* and *Calanus hyperboreus* are morphologically similar (Hirche 1997) and are usually separated by differences in prosome length (PL) (Hirche et al. 1994; Madsen, Nielsen, Hansen 2001). During this study, stages, prosome, and urosome lengths of 1002 individuals from the $0 – 50$ m depth range and 706 individuals from the $50 – 200$ m depth range were analyzed. As these individuals came from different sample aliquots (at least ¼ of the total catch), the length measurements were extrapolated to the actual amount. That is why altogether 5736 length measurements represented the size-frequency distribution of the $0 – 50$ m water layer and 1868 length measurements represented the size-frequency distribution of the $50 – 200$ m water layer.
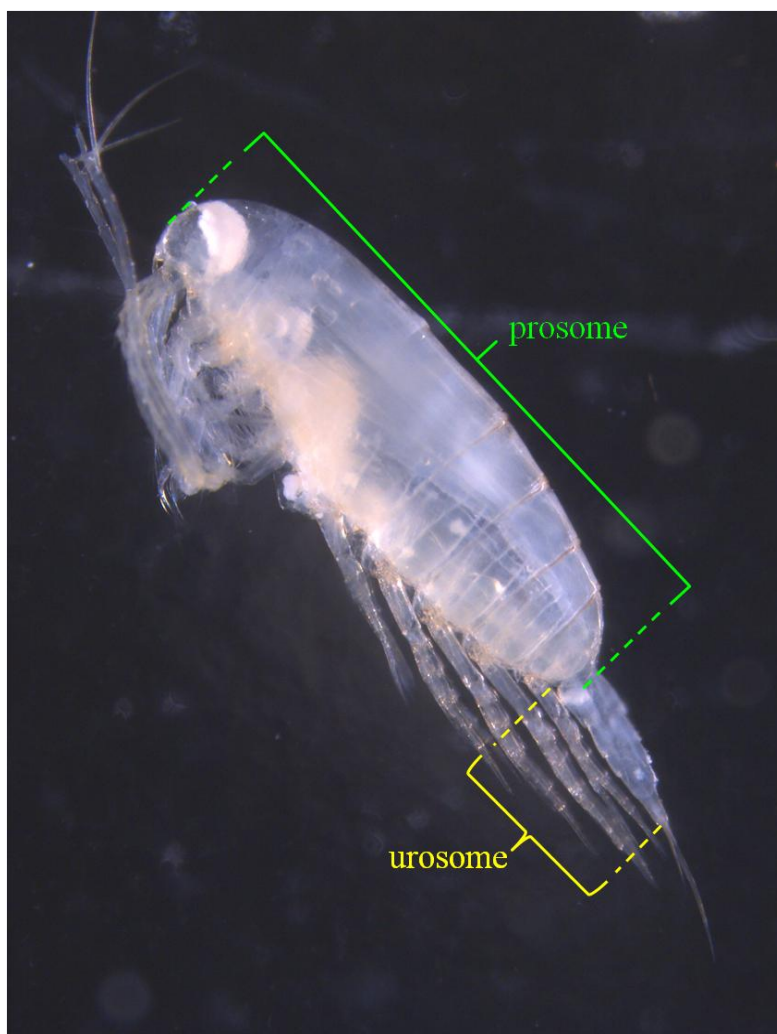
Fig. 2: Prosome and urosome of a calanoid copepod (*Calanus* spp.)

For prosome length measurements specimens of all developmental stages were measured from the tip of the cephalosome to the distal lateral end of the last thoracic segment (Fig. 2).

Measurements were conducted with a stereo microscope (LEICA M205C) and the lens PLANAPO 0.63x. For prosome and urosome measurements, the LEICA Application SUITE Version 4.4.0 software was used. Length frequency diagrams were constructed in R version 3.1.1 for all five copepodid stages (CI – CV) and adult females (AF). The individuals were separated into species by the PL distributions within each developmental stage using the software R version 3.1.1. Therefore, data were compared with the prosome length distributions published by Madsen, Nielsen, Hansen (2001) (Tab. 9).

3.4 Data analysis

3.4.1 Diversity indices

Several diversity indices were calculated to obtain a quantitative estimate of biological variability for each station and depth range. In general, three types of indices can be distinguished:

Species richness indices as a measure for the total number of species in a community. However, a complete inventory of all species present at a certain location is an almost unachievable goal in practical applications (Magurran and McGill 2011).

Species richness (S), the total number of species identified in a sample, is among the simplest descriptors of community structure (Magurran and McGill 2011). This measure strongly depends on sampling size and effort.

Species richness: $\quad\quad\quad S =$ **total number of species**

Margalef's index is a species richness index which tries to account for this problem. This index represents the number of species present in a sample or community in relation to the total abundance. Despite the attempt to correct for sample size, this index is strongly influenced by sampling effort (Magurran 2006) which may cause problems when studies with different sampling designs are compared.

Margalef's index: $\quad\quad\quad \boldsymbol{d = \frac{(S-1)}{\ln(N)}}$ $\quad\quad\quad\quad\quad\quad$ (Eq 1)

$N \quad\quad = \quad\quad$ total abundance of the sample

Diversity indices are a function of both richness and evenness, with less even communities being less diverse (Magurran and McGill 2011).

In order to take abundances and relative proportions of different species into account, Simpson and Shannon indices are commonly used as a measure of species diversity (Magurran 2006; Magurran and McGill 2011).

The Simpson index (Simpson 1949) gives the probability that two individuals, which are taken randomly from a sample, are not representing the same species.

Simpson diversity index: $\quad 1 - l = 1 - \sum_{i=1}^{S}(\frac{n_i \cdot (n_i - 1)}{N \cdot (N-1)})$ $\hspace{2cm}$ (Eq 2)

$l \qquad = \qquad \sum_{i=1}^{S}(\frac{n_i \cdot (n_i - 1)}{N \cdot (N-1)})$

$n_i \qquad = \qquad$ abundance of a single species i

Since N increases with a decreasing number of species, 1-l obtains small values in datasets of high diversity and large values in datasets of low diversity. The Simpson index is a dominance index because it gives more weight to common or dominant species.

Like the Simpson diversity index, the Shannon diversity index (Shannon 1948) accounts for both abundance and evenness of the species present in a sample.

Shannon diversity index: $\quad H' = -\sum_{i=1}^{S}(p_i \cdot \ln(p_i))$ $\hspace{2cm}$ (Eq 3)

$p_i \qquad = \qquad \frac{n_i}{N}$

$\sum p_i \qquad = \qquad 1$

The Shannon index represents the share of a species i compared to the total abundance of a sample (N). Here, a high value of H' would be a representative of a diverse and equally distributed community and lower values represent a less diverse community.

Evenness indices are a measurement of how different the abundances of the species in a community are from each other. Perfect evenness is reached in a community where all species have the same abundance. Since all natural communities are uneven, evenness is a relative statement (Magurran and McGill 2011).

The Shannon evenness index (Pielou 1969) measures the evenness of a community and can be easily calculated by dividing the value of H' with H'_{max} which is equal to $\ln(S)$ (S = total number of species).

Shannon evenness index: $\quad J' = \frac{H'}{\ln(S)}$ $\hspace{2cm}$ (Eq 4)

Shannon evenness ranges from 0 - 1, with $J' = 1$ indicating a complete evenness in a community or sample. This index is useful especially when communities with different species numbers shall be compared.

All indices were compared with the species richness-, diversity-, and evenness indices published by Kosobokova, Hopcroft, Hirche (2010) (Tab. 10).

3.4.2   Cluster analysis and Non-Metric Multidimensional Scaling (NMDS)

Cluster analysis and Non-Metric Multidimensional Scaling (NMDS) (Kruskal 1964) were used to estimate and visualize the similarities of the zooplankton community among the nine stations across the two depth layers $0 - 50$ m and $50 - 200$ m. Cluster analysis and NMDS were explored using the PRIMER-E 6® software package (Clarke and Gorley 2006). Similarity clusters were produced by using abundance averages for each station and depth range. Extreme outliers were removed from the dataset in order to not falsify the result. The abundance data were power transformed (4th root), Bray-Curtis similarity (Bray and Curtis 1957) was calculated between all samples and then projected onto two-dimensional (2D) plots. The performance of the Cluster and NMDS plot was appraised with Shepard plots and stress values (Legendre and Legendre 2012). The two-dimensional plots show the samples in such a way that their faunistic similarities are reflected in a hierarchical array. In contrast to PCA, this form of analysis deals better with raw data matrices which contain predominantly "0", such as abundance matrices (Lozán and Kausch 2007).

3.4.3   Statistical analysis

The software R version 3.1.1 was used for statistical analysis. For data which were not normally distributed a non-parametric test was performed. The Mann-Whitney U test was used to assess the statistical difference of diversity indices and species abundances (Mann and Whitney 1947). For all procedures the significance level α was set to 0.05. The obtained values of the Mann-Whitney U test express the significance of the differences among the results. If $p < 0.05$, the differences among the results were significant. To visualize significant patterns boxplots were generated in R version 3.1.1.

4 Results

4.1 Environmental conditions

During the ARKXXVII/ 3 expedition, station 226 was the first MultiNet station where zooplankton was sampled (August 9th, 2012) and station 386 was the last station (September 28th, 2012). In the following, all tables of MultiNet stations are not arranged according to their date of sampling, but according to their associated basin (Nansen Basin: 226, 243, 261, and 386; Amundsen Basin: 279, 328, 337, 351, and 367).

Polar surface water (S< 34.4 PSU, T< 0°C, Carmack 1990) was present at all nine stations in the upper 50 m of the water column (Tab. 3, Fig. 3). Whereas water temperature was relatively similar (-1.59 to -1.79°C) in the upper 50 meters of all nine stations, salinity was the more varying parameter (31.87 to 33.86 PSU). The opposite was true for the deeper water layer (50 – 200 m) where temperature was the most varying parameter (+1.25 to -1.64°C) and salinity was more similar between the stations (33.99 to 34.73 PSU). The deeper water layer of six stations was characterized by Polar surface water and of three stations (station 226, 243, and 386) by Atlantic water (S> 34.5 PSU, T= 0.5 – 1°C, Auel and Hagen 2002). In the Nansen Basin averaged salinities and temperatures were slightly higher than in the Amundsen Basin (Tab. 3). Especially station 328, which was located in the Amundsen Basin and thus far away from the Atlantic inflow through Fram Strait was characterized by low salinities (31.87 PSU and 33.99 PSU) and relatively low temperatures (-1.6 and -1.52°C) in both depth layers (Tab. 3). In terms of oxygen and chlorophyll *a* concentrations, the upper water layer (0 – 50 m) showed slightly higher concentrations than the deeper water layer (50-200m) (Tab. 3, Fig. 3). The stations 351 and 367 had highest oxygen concentrations in the 0 – 50 m depth layer (Tab. 3, Fig. 3). Highest chlorophyll *a* concentrations were reached in the 0-50 m depth layer of the stations 243 and 337 (Tab. 3, Fig. 3). There were no differences between Nansen Basin and Amundsen Basin concerning oxygen and chlorophyll *a* concentration, respectively (Tab. 3). The mixed layer depth (15 - 33 m) differed not as much in temperatures between Amundsen Basin and Nansen Basin, but in salinities which were higher for Nansen Basin than for Amundsen Basin (Tab. 3). The mixed layer depth was on average 8 m deeper for stations in the Amundsen Basin (26 m) than for stations in the Nansen Basin (18 m). Deepest mixed layer depths could be found at the stations 351 and 367, both located in the Amundsen Basin (Tab. 3). The shallowest mixed layer depths could be detected at the stations 226 and 261 which were both located in the Nansen Basin (Tab. 3).

Tab. 3: Environmental parameters of all MultiNet stations

	station	latitude	longitude	depth range [m]	salinity [PSU]	temperature [°C]	O_2 [µmol l^{-1}]	chlorophyll *a* [mg m^{-3}]	mixed layer depth (mld) [m]	mld temperature [°C]	mld salinity [PSU]	mld chlorophyll *a* [mg m^{-3}]
Nansen Basin	PS80 / 226	84° 2'N	31° 1'E	0 - 50	33.86	-1.59	390.77	0.14	15	-1.53	33.36	0.10
				50 - 200	34.64	0.64	328.39	0.14				
	PS80 / 243	83° 5'N	75° 6'E	0 - 50	33.79	-1.59	372.01	0.16	18	-1.53	33.22	0.19
				50 - 200	34.73	1.25	331.42	0.14				
	PS80 / 261	82° 6'N	109° 5E	0 - 50	33.45	-1.72	394.73	0.14	15	-1.67	33	0.14
				50 - 200	34.11	-1.64	365.00	0.14				
	PS80 /386	84° 2'N	17° 3'E	0 - 50	33.58	-1.72	393.48	0.14	22	-1.76	32.87	0.15
				50 - 200	34.53	0.08	338.72	0.14				
Amundsen Basin	PS80 / 279	82° 5'N	129° 6'E	0 - 50	32.04	-1.64	384.66	0.14	22	-1.58	31.27	0.16
				50 - 200	34.36	-0.39	330.85	0.14				
	PS80 / 328	81° 5'N	130° 5'E	0 - 50	31.87	-1.6	386.75	0.14	20	-1.53	30.77	0.3
				50 - 200	33.99	-1.52	347.61	0.14				
	PS80 / 337	85° 6'N	122° 2'E	0 - 50	31.91	-1.6	391.66	0.15	25	-1.52	31.11	0.29
				50 - 200	34.26	-0.6	338.89	0.14				
	PS80 / 351	87° 6'N	61° 0'E	0 - 50	33.43	-1.78	399.58	0.14	30	-1.78	33.17	0.21
				50 - 200	34.41	-0.35	332.18	0.14				
	PS80 / 367	88° 5'N	56° 3'E	0 - 50	33.2	-1.79	408.02	0.14	34	-1.79	33.03	0.06
				50 - 200	34.25	-0.7	338.76	0.14				
	mean 0-50 m				33.01	-1.67	391.3	0.15				
	mean 50-200 m				34.36	-0.36	339.09	0.14				
	mean Nansen Basin				34.09	-0.79	364.32	0.14	17.5	-1.62	33.15	0.15
	mean Amundsen Basin				33.37	-1.2	365.9	0.14	26.2	-1.64	31.87	0.2

During the ARK XXVII/ 3 expedition of *Polarstern* the sea ice coverage of the Arctic Ocean showed a marked decline from August to September 2012 (Fig. 4). Whereas the average ice coverage was slightly higher in the Nansen Basin than in the Amundsen Basin, the modal ice thickness was slightly lower in the Nansen Basin than in the Amundsen Basin (Tab. 4). The ice coverage was more than 95 % at most stations. Only at station 337 (91 %) and at station 328 (73 %) the ice coverage was lower (Tab. 4). Modal ice thickness ranged between 0.70 m and 1.40 m. Lowest values were reached at station 386 (0.7 m) and station 261 (0.75 m) which were both located in the Nansen Basin. The highest ice thickness was reached at the stations 367 (1.4 m) and 351 (1.38 m), both located in the Amundsen Basin (Tab. 4).

Tab. 4: SIC (AMSR2) coincident grid cell ice coverage [%] and modal CTD ice thickness [m] for all MultiNet stations

	station	ice coverage [%]	ice thickness [m]
Nansen Basin	PS 80 / 226	98	1.15
	PS 80 / 243	98.5	1.14
	PS 80 / 261	97.5	0.75
	PS 80 / 386	100	0.70
Amundsen Basin	PS 80 / 279	96.5	0.85
	PS 80 / 328	73	n.v.
	PS 80 / 337	91	1.05
	PS 80 / 351	100	1.38
	PS 80 / 367	100	1.40
	mean Nansen Basin	98.5	0.94
	mean Amundsen Basin	90.13	1.09
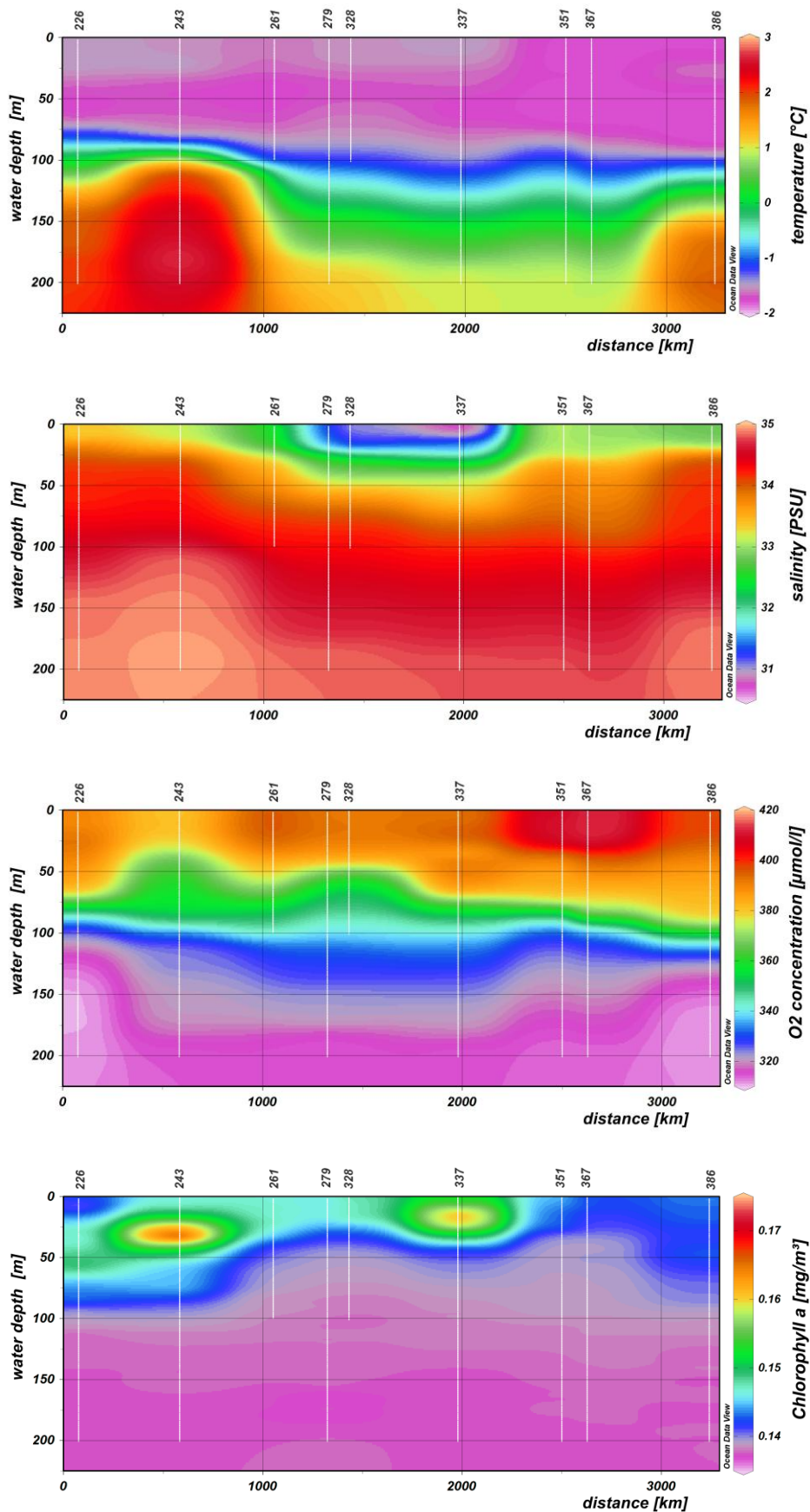
Fig. 3: Profiles of temperature, salinity, O₂, and chlorophyll *a* along the transect of the MutliNet stations; plot was produced by using Ocean Data View V 4.5.3; data were taken from closest CTD stations to the MutliNet stations
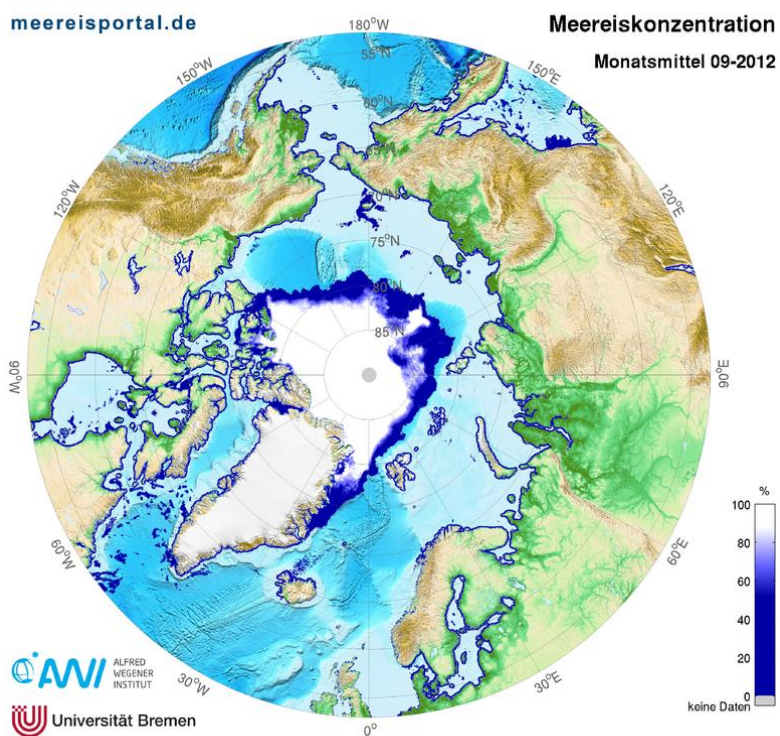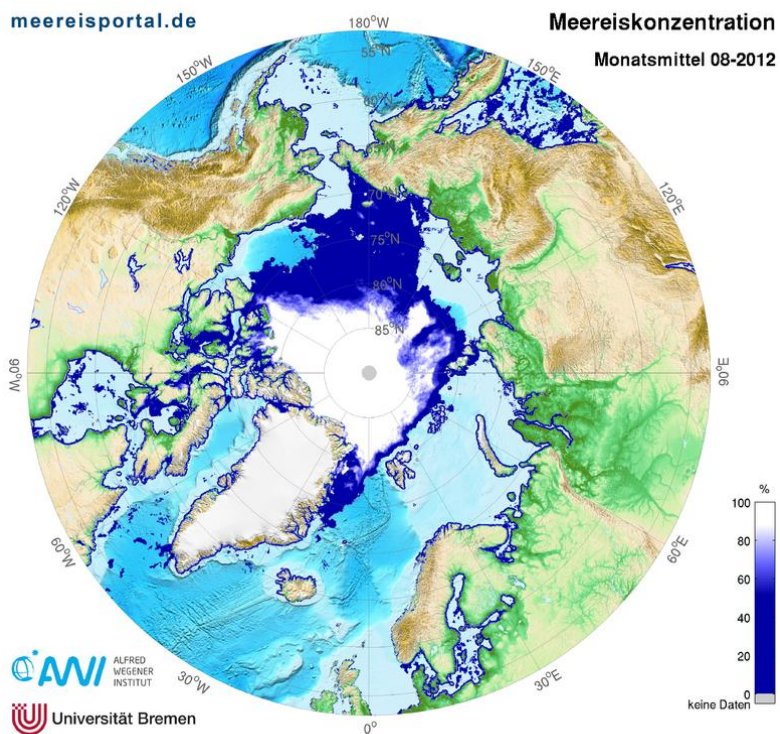
Fig. 4: Sea ice concentration for August and September 2012 (monthly mean) during the ARK XXVII/ 3 expedition of *Polarstern*; data available at http://www.meereisportal.de/de/datenportal.html

4.2 Zooplankton composition

In total, 30 taxa were identified during this study (Tab. 6, App. Tab. 1). Among these taxa, 18 copepod taxa were found while non-copepod species were represented by 12 taxa. Thirty percent of all identified taxa (7 copepod taxa and 2 non-copepod taxa) appeared at every station and both depth ranges (Tab. 6).

Species richness was significant higher in the $50 - 200$ m than in the $0 - 50$ m water layer (W = 11, p-value < 0.05) (App. Fig. 3). At all nine sampling stations the total taxa number increased with depth (Tab. 5). With 25 taxa, the Nansen Basin was less diverse than the Amundsen Basin where 29 taxa could be found, but those differences were not significant. Species richness reached its maximum at station 337 (n = 28) which geographically belonged to Amundsen Basin and its minimum at station 243 (n = 19) which belonged to Nansen Basin. The total number of taxa at the remaining stations ranged between 20 and 24 (Tab. 5).

The number of copepod taxa increased significantly with depth and ranged from 9 to 14 in the upper water layer ($0 - 50$ m) and from 11 to 16 in the deeper water layer ($50 - 200$ m). Station 328 which was located in the Amundsen Basin showed a minimum in the mean share of copepod taxa to the total community with 60 %. Station 243 showed a peak in copepod mean share with 71 % and was located in the Nansen Basin (Tab. 5). All in all, there was a little but not significant difference in the mean share of copepod taxa between the Nansen Basin (68 %) and the Amundsen Basin (64 %).

Tab. 5: Total number of taxa, and number and share of copepod taxa at all MultiNet stations

	station	total taxa number	depth range [m]	number of taxa	number of copepod taxa	share of copepod taxa [%]	integrated share of copepod taxa [%]
Nansen Basin	PS80 / 226	21	0-50	12	9	75	67
			50-200	21	13	62	
	PS80 / 243	19	0-50	15	11	73	71
			50-200	16	11	69	
	PS80 / 261	23	0-50	18	11	61	66
			50-200	17	12	71	
	PS80 / 386	20	0-50	12	9	75	69
			50-200	20	13	65	
Amundsen Basin	PS80 / 279	22	0-50	17	10	59	62
			50-200	20	13	65	
	PS80 / 328	23	0-50	18	10	56	60
			50-200	22	14	64	
	PS80 / 337	28	0-50	21	14	67	67
			50-200	24	16	67	
	PS80 / 351	24	0-50	14	9	64	66
			50-200	21	14	67	
	PS80 / 367	22	0-50	15	9	60	64
			50-200	21	14	67	

In terms of presence or absence, most species had a wide horizontal and vertical range and only a few species were limited to one basin or one depth range. To study the possible effect

of varying water depths and varying basins on the presence of species, the relative frequency of occurrence was calculated for every taxon (Tab. 6). The most frequent taxa were *Calanus* spp., *Calanus* nauplii, Clausocalanoida, *Metridia* spp., *Oithona* spp., *Corycaeus* spp., Foraminifera, and Chaetognatha, which were present in each depth layer at all nine stations (Tab. 6).

All in all, the number of present taxa increased with depth, thus more species inhabited the 50 – 200 m depth layer than the 0 – 50 m depth layer. Of the 30 taxa found, 3 taxa were exclusively present in depths of more than 50 m (*Scaphocalanus* spp., *Chiridius* spp., and Radiolaria) and only one taxon (*Centropages* spp.) was exclusively found in the 0 – 50 m depth layer. *Heterorhabdus* spp. and *Paraeuchaeta* spp. showed clear preferences for the deeper water layer (50 – 200 m) where they were twice as present as in the upper water layer (0 – 50 m) (Tab. 6). Similar preferences showed Siphonophora. By contrast, Cirripedia and Appendicularia occurred most notably in the 0 – 50 m depth layer. With regard to basin preferences, some taxa had a higher presence in the Amundsen Basin than in the Nansen Basin, such as *Temora* spp., *Mormonilla* spp., *Heterorhabdus* spp., *Centropages* spp., Appendicularia, Bryozoa, and Gastropoda (Tab. 6). The only taxon which occurred solely in the Nansen Basin was Cirripedia (Tab. 6).

Tab. 6: Frequency of occurrence for every taxon in the 0-50 m and 50-200 m depth layer at all stations and at stations in the Nansen Basin and the Amundsen Basin

| | | frequency of occurence | | | | | |
	taxon	all stations 0 - 50 m	all stations 50 -200 m	Ammundsen stations 0 - 50 m	Nansen stations 0 - 50 m	Ammundsen stations 50 - 200 m	Nansen stations 50 - 200 m
copepods	*Calanus* spp.	100%	100%	100%	100%	100%	100%
	Calanus hyperboreus	100%	100%	100%	100%	100%	100%
	Calanus nauplii	100%	100%	100%	100%	100%	100%
	Centropages spp.	11%	0%	20%	0%	0%	0%
	Clausocalanidae	100%	100%	100%	100%	100%	100%
	Chiridius spp.	0%	89%	0%	0%	100%	75%
	Paraeuchaeta spp.	44%	100%	40%	50%	100%	100%
	Scaphocalanus spp.	0%	89%	0%	0%	100%	75%
	Metridia spp.	100%	100%	100%	100%	100%	100%
	Heterorhabdus spp.	22%	78%	40%	0%	100%	50%
	Temora spp.	11%	11%	20%	0%	20%	0%
	Mormonilla spp.	33%	11%	40%	25%	0%	25%
	Oithona spp.	100%	100%	100%	100%	100%	100%
	Oithona nauplii	100%	89%	100%	100%	100%	75%
	Oncaea	44%	78%	40%	50%	100%	50%
	Corycaeus spp.	100%	100%	100%	100%	100%	100%
	Microsetella spp.	33%	67%	20%	50%	80%	50%
	Tisbe spp.	22%	22%	20%	25%	20%	25%
non-copepods	Foraminifera	100%	100%	100%	100%	100%	100%
	Radiolaria	0%	44%	0%	0%	40%	50%
	Bryozoa	0%	11%	0%	0%	20%	0%
	Cnidaria	33%	33%	60%	0%	60%	0%
	Siphonophorae	11%	67%	20%	0%	80%	50%
	Gastropoda	0%	22%	0%	0%	40%	0%
	Polychaeta	67%	100%	100%	25%	100%	100%
	Ostracoda	67%	100%	80%	50%	100%	100%
	Cirripedia	11%	0%	0%	25%	0%	0%
	Amphipoda	89%	67%	100%	75%	60%	75%
	Appendicularia	78%	44%	100%	50%	40%	50%
	Chaetognatha	100%	100%	100%	100%	100%	100%

4.3 Vertical and horizontal distribution of the zooplankton community

For the abundances of zooplankton in the Eurasian Basin depth dependent patterns were apparent. The upper $0-50$ m water layer was more abundant than the $50-200$ m water layer (W = 81, p-value <0.05) (App. Fig. 2). At all stations zooplankton abundances decreased from the $0-50$ m water layer to the $50-200$ m layer (Tab. 7, Fig. 5). Zooplankton abundance of the upper water layer ranged from 307 to 1606 ind. m^{-3} and was on average 800 ind. m^{-3}. Zooplankton abundance of the $50-200$ m depth layer ranged from 96 to 208 ind. m^{-3} and was on average 148 ind. m^{-3} (Tab. 7).

Highest depth-integrated $(0-200$ m) abundance of zooplankton was found at station 328 (857 ind. m^{-3}) and lowest abundance at station 351 (201 ind. m^{-3}), both stations were located in the Amundsen Basin (Tab. 7, Fig. 5).

When comparing the two Eurasian Basins with regard to zooplankton abundances, only small, but no significant differences between Nansen Basin and Amundsen Basin were apparent. With an average of 485 ind. m^{-3}, Nansen Basin was little more abundant than Amundsen Basin with 465 ind. m^{-3} (Tab. 7).

Tab. 7: Abundances [ind m^{-3}] and percentual shares of the zooplankton-, the copepod-, and the non-copepod community in both depth layers (0-50 m & 50-200 m) at all MultiNet stations

	station	depth range [m]	zooplankton abundance [ind. m^{-3}]	non-copepod abundance [ind. m^{-3}]	copepod abundance [ind. m^{-3}]	share of copepod abundance [%]	depth-integrated zooplankton abundance [ind. m^{-3}]	depth-integrated non-copepod abundance [ind. m^{-3}]	depth-integrated copepod abundance [ind. m^{-3}]	depth-integrated share of copepod abundance [%]
Nansen Basin	PS80 / 226	0-50	697	119	578	83	422	71	350	83
		50-200	146	24	122	84				
	PS80 / 243	0-50	736	116	619	84	461	69	392	85
		50-200	186	21	166	89				
	PS80 / 261	0-50	458	168	289	63	282	100	182	65
		50-200	106	31	75	71				
	PS80 / 386	0-50	1355	13	1342	99	776	12	764	98
		50-200	198	12	186	94				
Amundsen Basin	PS80 / 279	0-50	718	71	647	90	450	45	406	90
		50-200	183	19	164	90				
	PS80 / 328	0-50	1606	128	1478	92	857	72	785	92
		50-200	107	17	91	85				
	PS80 / 337	0-50	436	105	331	76	322	84	238	74
		50-200	208	64	144	69				
	PS80 / 351	0-50	307	81	226	74	201	49	152	76
		50-200	96	17	78	82				
	PS80 / 367	0-50	887	58	829	93	494	35	459	93
		50-200	101	12	89	88				
	mean 0-50 m		800	95	704	88				
	mean 50-200 m		148	24	124	84				
	mean Nansen Basin		485	63	422	87				
	mean Amundsen Basin		465	57	408	88				

Fig. 5: Abundances [ind m^{-3}] and percentual shares of the zooplankton (copepod & non-copepod) community in two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

4.3.1 Vertical and horizontal distribution of the copepod community

Over the entire study area, zooplankton abundance was clearly dominated by copepods. Mean shares of copepods to the zooplankton community ranged between 65 % and 98 % for all nine sampling stations (Tab. 7). Averaged copepod abundance decreased considerably from 704 ind. m^{-3} in the upper water layer (0 – 50 m) to only 124 ind. m^{-3} in the deeper

water layer (50 – 200 m) (Tab. 7). This depth dependent pattern in copepod abundance was verified by a Mann-Whitney U test (W = 81, p-value < 0.05) (App. Fig. 2). The copepod community in the Eurasian Basin consisted of eighteen taxa. The rank order of averaged abundances over the 0 – 50 m depth layer for taxonomical categories of copepods revealed that *Oithona* spp., *Corycaeus* spp., Clausocalanidae, *Calanus* nauplii, and *Oithona* nauplii were the five most common groups, constituting 92 % of the copepod community in this depth layer (Fig. 6, App. Tab. 3). The deeper water layer (50 - 200 m) was dominated by specimens of Clausocalanoida, *Oithona* spp., *Corycaeus* spp., *Metridia* spp., and *Calanus* spp. which represented 93 % of the copepod community in this depth layer (Fig. 6, App. Tab. 3). The average depth distributions of the two water layers revealed that individuals of *Oithona* spp. dominated the upper 50 m with an average share of 57 % and specimens of the Clausocalanidae family dominated the 50 – 200 m water layer with an average share of 46 % (Fig. 6, App. Tab. 3). All of these numerically most important taxa decreased to the deeper water layer in abundances, especially *Calanus* spp., *Calanus* nauplii, *Oithona* spp., and *Oithona* nauplii (App. Tab. 3). In contrast, *Heterorhabdus* spp*., Temora* spp., and *Paraeuchaeta* spp. increased to the deeper water layer whereas *Chiridius* spp. and *Scaphocalanus* spp. were only found in the 50 – 200 m depth layer, but all of the latter five taxa showed very low abundances and represented only 0.1 % of the 0 – 50 m copepod community and only 2 % of the 50 – 200 m copepod community (App. Tab. 3).

Amundsen Basin and Nansen Basin had the same most abundant taxa: *Oithona* spp., Clausocalanidae, *Corycaeus* spp., *Calanus* nauplii, and *Oithona* nauplii, which constituted 88 % in Nansen Basin and 94 % in Amundsen Basin (Fig. 6, App. Tab. 3). Two copepod taxa were exclusively present in Amundsen Basin (*Centropages* spp. and *Temora* spp.), but both with low abundances. Some taxa increased in abundances from Nansen Basin to Amundsen Basin and some taxa decreased, but mean abundances of copepods differed not significantly between the two basins (422.15 and 407.77 ind. m^{-3}) (Fig. 6, App. Tab. 3).

By taking a look at particular variations of single stations and copepod taxa, it becomes obvious that the stations 328_0 and 386_0 stand out as they had highest total copepod abundances of all stations with 1478.22 ind. m^{-3} and 1341.50 ind. m^{-3}, respectively (Fig. 6, App. Tab. 3). Both stations plus station 367_0 had also the highest abundances of *Oithona* spp. specimens of all stations (Fig. 6, App. Tab. 3).

Fig. 6: Abundances [ind m⁻³] and percentual shares of the copepod community in two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "station_depth range" ("_0"= 0-50 m depth range & "_50" = 50-200 m depth range)

Oithona spp., *Oithona* nauplii, *Calanus hyperboreus*, and *Calanus* nauplii had highest abundances in the 0 – 50 m water layer and also high contributions to the copepod community, whereas in the 50 – 200 m water layer abundances were much lower and so was the contribution to the copepod community (Fig. 6, App. Tab. 3).

Species of the family Clausocalanidae showed distinct patterns as their abundances were always relatively high and on average the same in both depth layers, but their share of the copepod community increased immensely to the deeper water layer, since total abundance of the copepod community decreased in this layer (Fig. 6, App. Tab. 3).

Some taxa showed marked outliers at single stations like *C. hyperboreus* at station 226_0, *Calanus* spp. at station 243_0, *Paraeuchaeta* spp. at station 243_50, *Metridia* spp. and *Chiridius* spp. at station 328_50 (Fig. 6, App. Tab. 3).

4.3.2 Vertical and horizontal distribution of the non-copepod community

Non-copepod taxa had a mean share of 2 to 25 % to the whole zooplankton community, since their total abundances were always very low with 12 to 168 ind. m^{-3} (Tab. 7). Similar to the copepod taxa, also mean abundances of non-copepod taxa decreased significantly with depth from 95 ind. m^{-3} in the $0-50$ m depth layer to 24 ind. m^{-3} in the $50-200$ m depth layer (W = 73, p-value < 0.05) (Tab. 7, Fig. 7).

Twelve identified taxa constituted the non-copepod part of the zooplankton community. Foraminifera, Appendicularia, Chaetognatha, Ostracoda, and Amphipoda represented the five most abundant taxa in the upper 50 m where they contributed to 99 % of the non-copepod community (Fig. 7, App. Tab. 4). The rank order of averaged abundances in the deeper water layer ($50-200$ m) for non-copepods revealed that Foraminifera, Chaetognatha, Ostracoda, Polychaeta, and Amphipoda were the five most common groups representing 97 % of the non-copepod community in this depth layer (App. Tab. 4). The vertical distribution of abundances showed that Foraminifera dominated both depth layers with an average share of 86 % to the upper 50 m and 59 % to the $50-200$ m depth layer (Fig. 7, App. Tab. 4). Chaetognatha were the second most important taxon which showed similar mean abundances for both depth layers, but increased in its share to the non-copepod community with depth from 4 % in the upper to 16 % in the deeper water layer (Fig. 7, App. Tab. 4). Polychaeta and Ostracoda increased only slightly in mean abundances with depth, but had a markedly higher share to the non-copepod community in the deeper water layer, since mean abundance of the non-copepod community decreased with depth (Fig. 7, App. Tab. 4). Appendicularia was a dominant taxon in the upper 50 m with a mean share of 7 % to the non-copepod community, but decreased to 0.05 % in the deeper water layer (Fig. 7, App. Tab. 4).

Except of one group, Nansen Basin and Amundsen Basin had the same most abundant taxa. Foraminifera, Appendicularia, Chaetognatha, Ostracoda, and Amphipoda represented the five most abundant taxa of the Nansen Basin with a share of 99 % to the non-copepod community, whereas Foraminifera, Chaetognatha, Ostracoda, Appendicularia, and Polychaeta were the five most important taxa of the Amundsen Basin and contributed 97 % to the whole non-copepod community (Fig. 7, App. Tab. 4).

All in all, the Nansen Basin had a slightly higher mean abundance for non-copepods with 63.02 ind. m^{-3} than the Amundsen Basin with 57.07 ind. m^{-3}, but the differences were not significantly (Tab. 7).
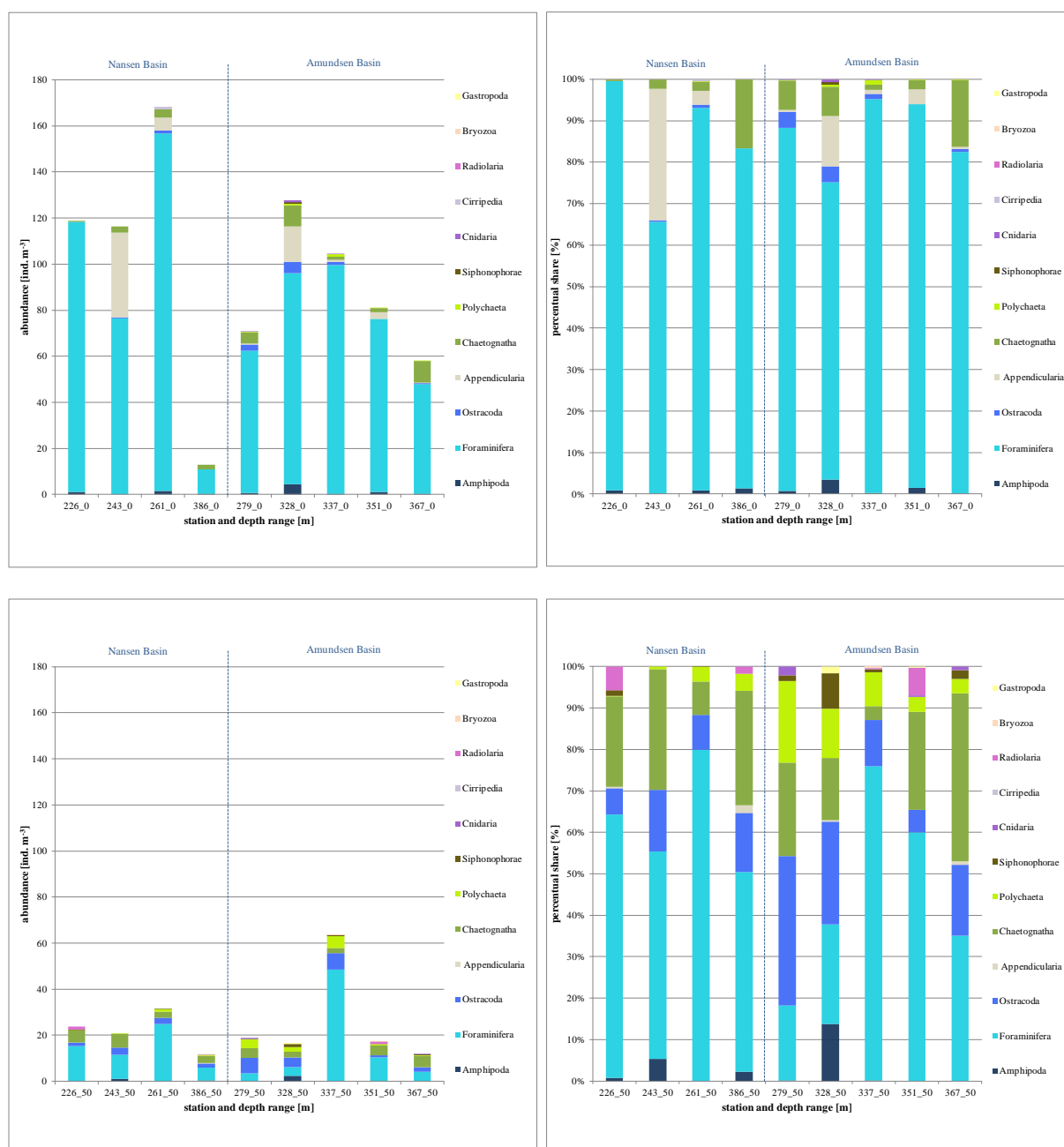
Fig. 7: Abundances [ind m^{-3}] and percentual shares of the non-copepod community in two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

Particular variations of non-copepod taxa at single stations revealed that the stations 261_0 and 386_0 stand out as they had highest (168.31 ind. m^{-3}) and lowest (13.00 ind. m^{-3}) non-copepod abundances in the upper 0 – 50 m water layer, respectively (Tab. 7, Fig. 7).

Furthermore there was a constant decrease of the non-copepod abundance along the transect beginning with the southernmost station 328_0 and ending with the last station 386_0 in the Amundsen Basin (Tab. 7, Fig. 7).

In the deeper water layer (50 – 200 m), station 337_50 had the highest abundance with 63.95 ind. m^{-3} (Tab. 7, Fig. 7). Some taxa showed marked outliers at single stations like Radiolaria at the stations 226_50 and 351_50, Polychaeta, Ostracoda, and Cnidaria at station 279_50, Amphipoda, Ostracoda, Polychaeta, and Siphonophora at station 328_50 (Fig. 7).

4.4 Diversity metrics

Several diversity indices were calculated to investigate biodiversity patterns of the high Arctic zooplankton community.

At every station species richness was higher in the 50 – 200 m water layer than in the 0-50 m water layer, except of station 261 in Nansen Basin. With an average of 20.22 species, the deeper water layer (50 – 200 m) was richer than the upper water layer (0 – 50 m) with an average of 15.78 species (W = 11, p-value < 0.05) (Tab. 8, App. Fig. 3). The Amundsen Basin had an average of 19.30 species and the Nansen Basin an average of 16.38 species (Tab. 8), but the difference was not significant.

The same pattern was true for Margalef's indices, which indicated also a difference between the upper water layer (1.53 to 3.29) and the deeper water layer (2.87 to 4.49) as it was for each station higher for the deeper water layer (W = 1, p-value <0.05) (Tab. 8, App. Fig. 3). No significant differences of Margalef's indices could be found between the Amundsen Basin and the Nansen Basin.

When looking at the average values of the Simpson diversity, no clear pattern was obvious, as it was on average similar for the 0 – 50 m depth layer (0.67) and the 50 – 200 m depth layer (0.69) and only somewhat higher for the Amundsen Basin (0.71) than for the Nansen Basin (0.64), but not significantly higher. Nevertheless, the stations 261 and 386 showed immense differences in Simpson diversity indices between the upper water layer and the deeper water layer (Tab. 8).

Shannon diversity values were on average higher for the 50 – 200 m water layer than for the 0 – 50 m water layer and also higher for Amundsen Basin than for Nansen Basin, but the Mann-Whitney *U* test showed no significance for those differences (Tab. 8). Nevertheless, the stations 386 and 367 showed high differences in Shannon diversity indices for different depth layers (Tab. 8).

The evenness ranged from 0.12 to 0.35 (Tab. 8). There was no difference in averaged evenness between the Amundsen Basin and the Nansen Basin (both 0.29). Concerning the difference between the depth layers, Shannon evenness showed the same pattern like Shannon diversity. The deeper water layer was more even (0.3) than the upper water layer (0.28) but also here the difference was not significant. Highest differences in evenness indices between the two depth ranges could be noticed at the stations 386 and 367 which were the last MutliNet stations of the ARKXXVII/ 3 cruise of *Polarstern* (Tab. 8).

In summary, diversity metrics indicated that the community of the deeper water layer was richer, but not more divers neither more even than the upper water layer (Tab. 8, App. Fig. 3). No significant differences could be found for richness, diversity, and evenness between the Nansen Basin and the Amundsen Basin.

Tab. 8: Species richness, diversity, and evenness (± standard deviation) for two depth layers (0-50 m & 50-200 m) of all MultiNet stations

	station	depth range [m]	S = species richness	N = abundance [ind. m^{-3}]		d = Margalef's index	1-ℓ = Simpson diversity index			H' = Shannon diversity index			J' = Shannon evenness
Nansen Basin	PS80 / 226	0-50	12	697.21 ±	47.76	1.68	0.83	±	0.01	0.87	±	0.06	0.35
		50-200	21	146.15 ±	12.65	4.01	0.75	±	0.04	0.92	±	0.05	0.30
	PS80 / 243	0-50	15	735.56 ±	52.71	2.12	0.82	±	0.02	0.89	±	0.05	0.33
		50-200	16	186.39 ±	16.91	2.87	0.73	±	0.04	0.82	±	0.05	0.30
	PS80 / 261	0-50	18	457.54 ±	33.62	2.78	0.77	±	0.02	1.00	±	0.05	0.35
		50-200	17	106.32 ±	8.48	3.43	0.18	±	0.12	0.88	±	0.05	0.31
	PS80 / 386	0-50	12	1354.50 ±	209.56	1.53	0.27	±	0.14	0.30	±	0.02	0.12
		50-200	20	197.63 ±	17.30	3.59	0.75	±	0.03	0.77	±	0.05	0.26
Amundsen Basin	PS80 / 279	0-50	17	717.69 ±	73.54	2.43	0.63	±	0.06	0.82	±	0.05	0.29
		50-200	20	183.23 ±	19.00	3.65	0.64	±	0.06	0.85	±	0.04	0.28
	PS80 / 328	0-50	18	1606.00 ±	133.79	2.30	0.71	±	0.03	0.93	±	0.06	0.32
		50-200	22	107.45 ±	7.59	4.49	0.79	±	0.02	1.09	±	0.05	0.35
	PS80 / 337	0-50	21	435.84 ±	36.04	3.29	0.77	±	0.03	0.85	±	0.05	0.28
		50-200	24	207.83 ±	15.44	4.31	0.81	±	0.02	0.89	±	0.05	0.28
	PS80 / 351	0-50	14	307.00 ±	24.78	2.27	0.78	±	0.02	0.77	±	0.06	0.29
		50-200	21	95.58 ±	7.45	4.39	0.78	±	0.02	0.97	±	0.05	0.32
	PS80 / 367	0-50	15	887.00 ±	118.79	2.06	0.45	±	0.10	0.49	±	0.03	0.18
		50-200	21	100.70 ±	8.20	4.34	0.78	±	0.02	0.80	±	0.05	0.26
	mean 0-50 m		15.78 ± 2.99	799.82 ±	99.12	2.27 ± 0.53	0.67	±	0.06	0.77	±	0.05	0.28 ± 0.08
	mean 50-200 m		20.22 ± 2.44	147.92 ±	13.20	3.90 ± 0.55	0.69	±	0.05	0.89	±	0.05	0.30 ± 0.03
	mean Nansen Basin		16.38 ± 3.34	485.16 ±	79.75	2.75 ± 0.91	0.64	±	0.07	0.81	±	0.05	0.29 ± 0.07
	mean Amundsen Basin		19.30 ± 3.20	464.83 ±	64.24	3.35 ± 0.98	0.71	±	0.05	0.85	±	0.05	0.29 ± 0.04

4.5 Community analysis

Community analysis was performed in order to detect similarities in taxa composition and abundances among the stations of the Eurasian Basin. The comparison of all 18 samples by cluster analysis showed two clearly separated clusters (Fig. 8), one for the upper water layer (0 – 50 m) and one for the deeper water layer (50 – 200 m). Thus, the cluster analysis revealed strongest similarities in species composition and abundances between samples of the same depth interval (Fig. 8).

Cluster 1 has a similarity level of about 77 % and consists of samples from the 50 – 200 m water layer. On a similarity level of about 75 %, cluster 2 consists of all samples from the 0-50 m water layer and is divided into two sub clusters (Fig. 8). One of the sub clusters is composed of the three stations 351_0, 226_0, and 386_0 and the other sub cluster includes all remaining stations of the upper water layer (Fig. 8).
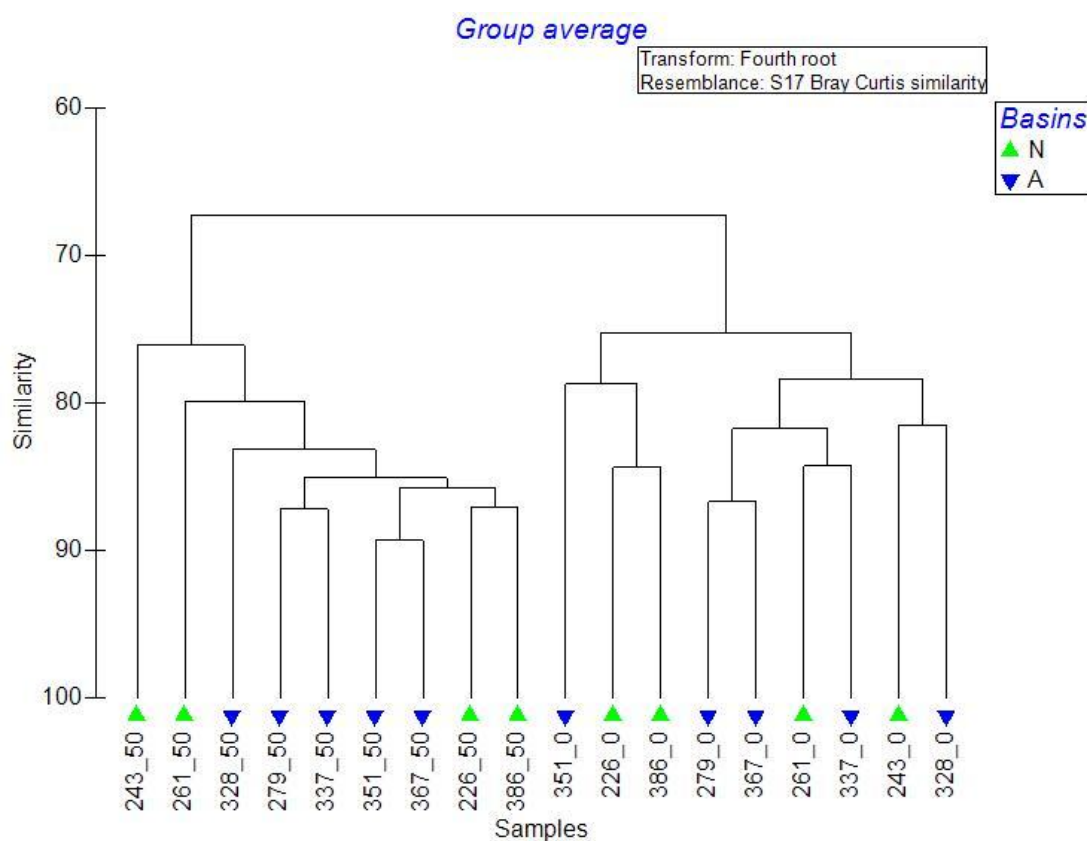
Fig. 8: Cluster analysis of two depth layers (0-50 m & 50-200 m) of all MutliNet stations; analysis based on Bray Curtis similarity of fourth root transformed data; nomenclature of samples: "station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

The Non-Metric Multidimensional Scaling (NMDS) confirmed the results of the cluster analysis, since a clear depth dependent pattern was evident (Fig. 9).

Samples of the same depth range are grouped on the left and on the right side of the plot, respectively (Fig. 9). Since samples of the Nansen Basin and the Amundsen Basin of the 0-50 m water layer are randomly distributed over the left side of the plot, no spatial pattern was evident. In the 50 – 200 m water layer, a gradual separation is apparent, since samples of the Nansen Basin and samples of the Amundsen Basin are grouped together (Fig. 9).

Nevertheless, vertical changes in species composition and abundances were more pronounced than regional differences between the two Eurasian basins. The 2D stress value is 0.09 which indicates that the MDS results are in good ordination (Fig. 9).

Both procedures, cluster analysis and NMDS, grouped the samples according to their depth range and revealed that samples from the same depth range were more similar to each other than samples from the same stations (Fig. 8, Fig. 9).
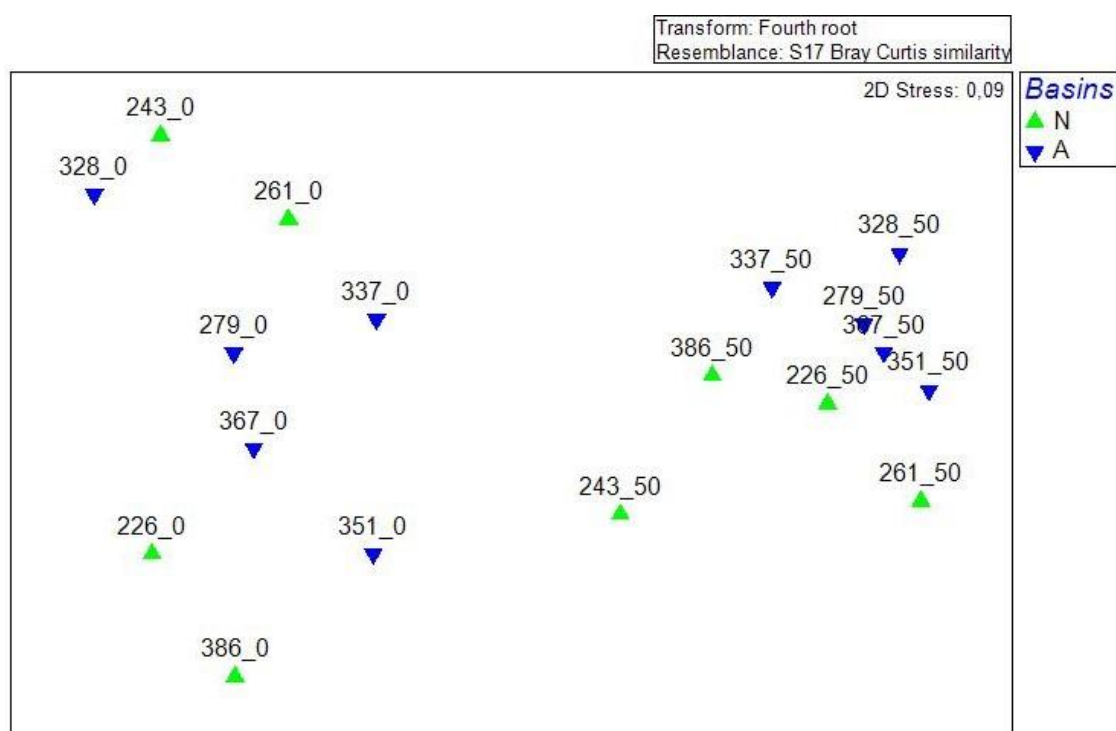
Fig. 9: Non-Metric Multidimensional Scaling for two depth layers (0-50 m & 50-200 m) of all MutliNet stations; analysis based on Bray Curtis similarity of fourth root transformed data; nomenclature of samples: "station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

4.6   Selected copepod taxa: *Calanus* species

During the ARK XXVII/ 3 expedition of *Polarstern*, *Calanus* species played only a moderate role in the copepod community with regard to abundances which ranged from 2.81 to 123.56 ind. m^{-3}, and with regard to their contribution to the copepod community which ranged from 2 to 20 % (App. Tab. 3). Highest abundances of the *Calanus* species were almost always found in the 0 – 50 m depth layer, especially at station 243 and lowest abundances in the 50-200 m depth layer, especially at station 351 (Fig. 6, App. Tab. 3).

4.6.1   Species identification of selected *Calanus* species

Based on prosome length measurements, size-frequency distributions for all five copepodid stages (CI-CV) as well as for adult females (AF) were obtained to distinguish the three morphologically similar species: *Calanus hyperboreus*, *Calanus glacialis*, and *Calanus finmarchicus*. During this study, five adult male (AM) individuals of *Calanus* spp. were found (three of them at station 279), but were not implied in further analyses due to the low number of individuals obtained. In total, 5736 measurements from the 0 – 50 m water layer and 1868 measurements from the 50 – 200 m water layer were analyzed.

As all three species differ in their size, a trimodal distribution of the size-frequencies was expected. However, the histograms of the size-frequency distributions are overlapping and show no clear trimodal distribution, which would allow to identify the *Calanus* spp. individuals to species level (Fig. 10). Hence, the results of a previous study were used (Madsen, Nielsen, Hansen 2001) to distinguish *C. hyperboreus*, *C. glacialis*, and *C. finmarchicus* by comparing the prosome lengths of this study with published prosome lengths from Madsen, Nielsen, Hansen (2001) (Tab. 9).
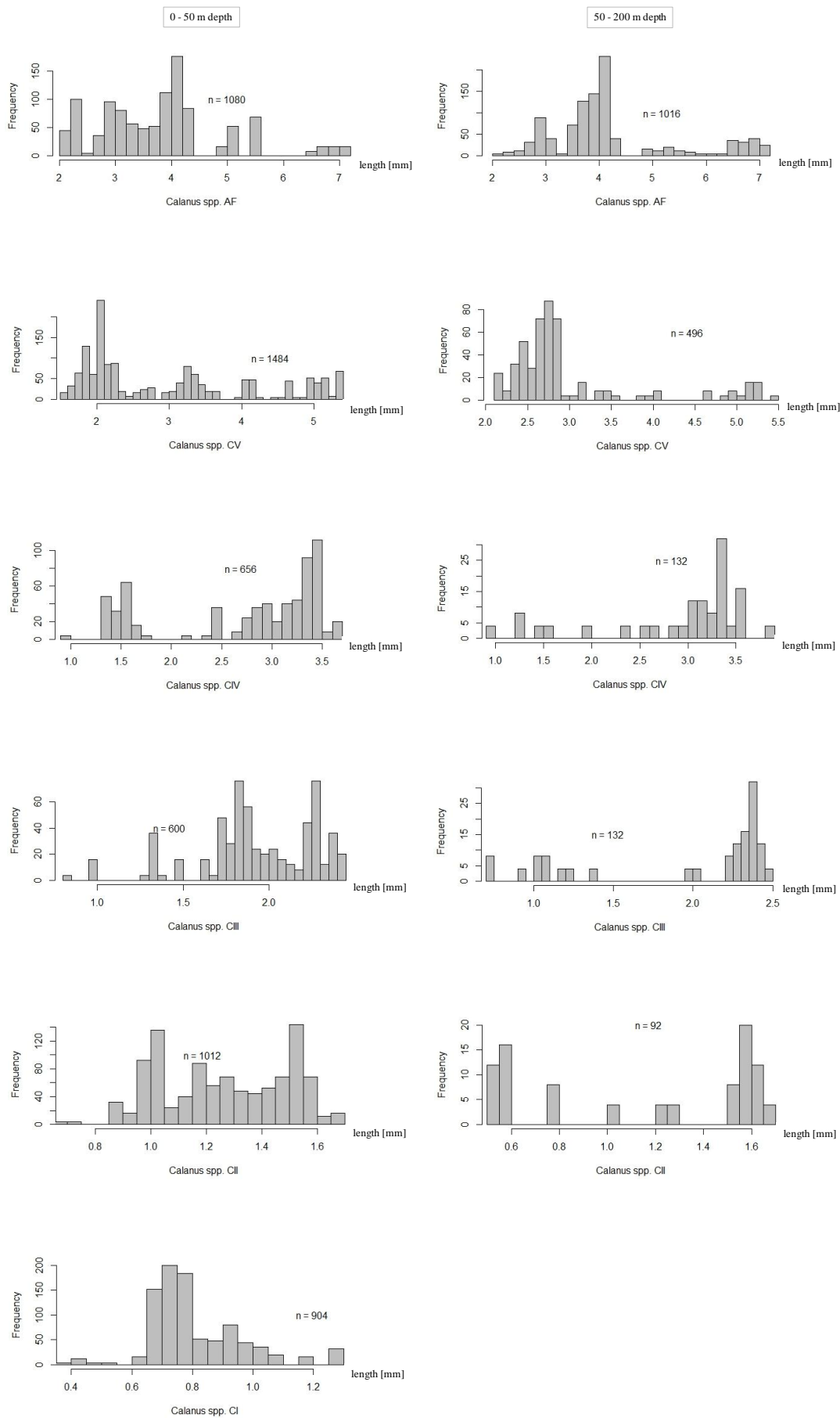
Fig. 10: Size-frequency distributions for the prosome lengths of developmental stages of *Calanus* spp. for the 0-50 m and the 50-200 m depth layer

4.6.2 Abundances and stage compositions of selected *Calanus* species

Prosome length reference data from Madsen, Nielsen, Hansen (2001) were used to distinguish between the three main *Calanus* species: *Calanus hyperboreus*, *Calanus glacialis*, and *Calanus finmarchicus* (Tab. 9). In total, 5736 measurements from the $0-50$ m depth layer were analyzed including 904 CI, 1012 CII, 600 CIII, 656 CIV, 1484 CV, and 1080 AF stages. From the $50-200$ m depth layer, 1868 measurements were analyzed including 92 CII, 132 CIII, 132 CIV, 496 CV, and 1016 AF stages. Based on the analysis of the prosome length measurements, abundances [ind. m^{-3}] for all developmental stages (CI-CV & AF) of every species were calculated (App. Tab. 6).

Tab. 9: Reference data for the prosome length distribution of *Calanus* spp. provided by Madsen, Nielsen, Hansen (2001)

stage	*Calanus hyperboreus*	*Calanus glacialis*	*Calanus finmarchicus*
AF	≥4.5	≥3.0 <4.5	<3.0
CV	≥3.9	≥2.7 <3.9	<2.7
CIV	≥2.925	≥2.0 <2.925	<2.0
CIII	≥1.975	≥1.475 <1.975	<1.475
CII	≥1.4	≥1.2 <1.4	<1.2
CI	≥0.975	≥0.75 <0.975	<0.775

Mean abundances of the three *Calanus* species were significantly higher in the 0-50 m water layer than in the 50-200 m water layer (W = 79; p < 0.05) (Fig. 11, App. Tab. 6, App. Fig. 4). Abundances of the *C. hyperboreus*, *C. glacialis*, and *C. finmarchicus* populations revealed the dominance of *C. finmarchicus* in the $0-50$ m water layer with a mean abundance of 20.86 ind. m^{-3}, but in the $50-200$ m water layer it was the least abundant with 1.34 ind. m^{-3} (App. Tab. 6). As opposed to this, mean abundance of *C. glacialis* were lowest in the upper water layer (14.93 ind. m^{-3}), but highest in the deeper water layer (2.50 ind. m^{-3}) (App. Tab. 6). The average abundances of *C. hyperboreus* were for each depth layer in-between the abundances of the other two species (App. Tab. 6).

The copepod *C. hyperboreus* dominated the *Calanus* spp. population at the stations 226, 386, and 351 in both depth layers, while *C. glacialis* contributed considerably to the *Calanus* spp. community at station 279 and *C. finmarchicus* at station 243 (Fig. 11). Whereas the 0-50 m depth layer of the stations 261, 328, and 367 were dominated by *C. finmarchicus*, the 50-200 m depth layer at these stations was dominated by *C. glacialis* (Fig. 11).

Mean abundances of *C. hyperboreus* and *C. finmarchicus* decreased from the Nansen Basin to the Amundsen Basin, but the opposite was true for *C. glacialis* which increased slightly in mean abundance from the Nansen Basin to the Amundsen Basin. However, for all three *Calanus* species no significant regional pattern was evident concerning the distribution in the two Eurasian basins (App. Tab. 6).
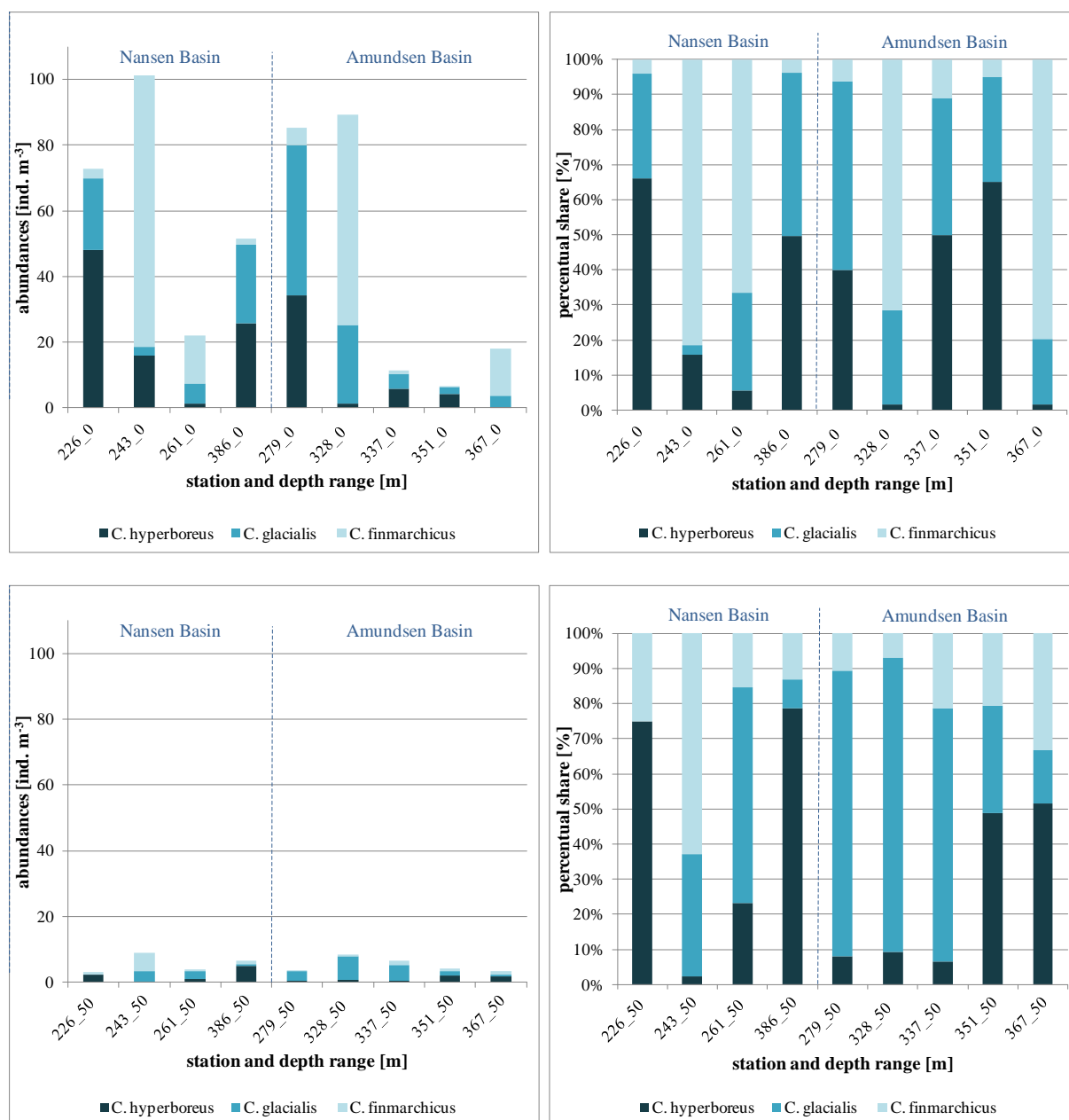
Fig. 11: Abundances [ind m^{-3}] and percentual shares of the three *Calanus* species in two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

For all three *Calanus* species, mean abundances of each developmental stage (CI - CV and AF) decreased from the $0 - 50$ m depth layer to the $50 - 200$ m depth layer (App. Tab. 6). Late developmental stages (CIV - AF) dominated the *Calanus* spp. communities in

mean abundances over all nine stations and depth ranges (Fig. 12, App. Tab. 6). Thus, CV was the most abundant stage of *C. finmarchicus* in both depth layers and had a share of 35 % (0-50 m) and 46 % (50 – 200 m) to the total *C. finmarchicus* community (Fig. 12, App. Tab. 6). Adult females (AF) were instead the most abundant stage of *C. glacialis* in both depth layers with contributions of 32 % (0 – 50 m) and 74 % (50 – 200 m) to the *C. glacialis* community (Fig. 12, App. Tab. 6). For *C. hyperboreus* the most abundant stage changed with depth from CV, which represented 23 % of the *C. hyperboreus* community in the 0-50 m water layer, to AF, which represented 40 % of the *C. hyperboreus* community in the 50-200 m water layer (Fig. 12, App. Tab. 6).

With abundances up to 60 ind. m^{-3}, young developmental stages (CI - CII) were almost restricted to the 0 – 50 m depth layer, as CI was not present at all and abundances of CII and CIII did not exceed 2 in. m^{-3} in the 50 – 200 m depth layer (Fig. 12, App. Tab. 6). *C. finmarchicus* showed highest mean abundances of CI – CIII of all *Calanus* species in the upper water layer, but presence was limited to five stations. Young developmental stages of *C. glacialis* were present at nearly every station (8 stations) of the 0 – 50 m water layer, but showed lowest mean abundances. The values for presence and mean abundances of CI-CIII stages of *C. hyperboreus* were in-between the values for the other two species (Fig. 12, App. Tab. 6).

C. finmarchicus was present with all developmental stages at station 367, *C. glacialis* at station 386, and *C. hyperboreus* occured at stations 279 and 386 with all stages (Fig. 12, App. Tab. 6). Station 243 was the station with the least presence of developmental stages as only the late stages CIV; CV, and AF were found for the three *Calanus* species (Fig. 12).

In terms of spatial patterns, mean abundances of late developmental stages (CIV - AF) of *C. finmarchicus* decreased whereas young developmental stages (CI – CIII) increased from the Nansen Basin to the Amundsen Basin (App. Tab. 6). The stages CV and AF of *C. glacialis* increased from the Nansen Basin to the Amundsen Basin whereas all other stages (CI - CIV) decreased in mean abundances. All stages of *C. hyperboreus* decreased from the Nansen Basin to the Amundsen Basin, except of stage CI which increased (App. Tab. 6). Nevertheless, the difference in abundances between the two basins were for none of the developmental stages significant.
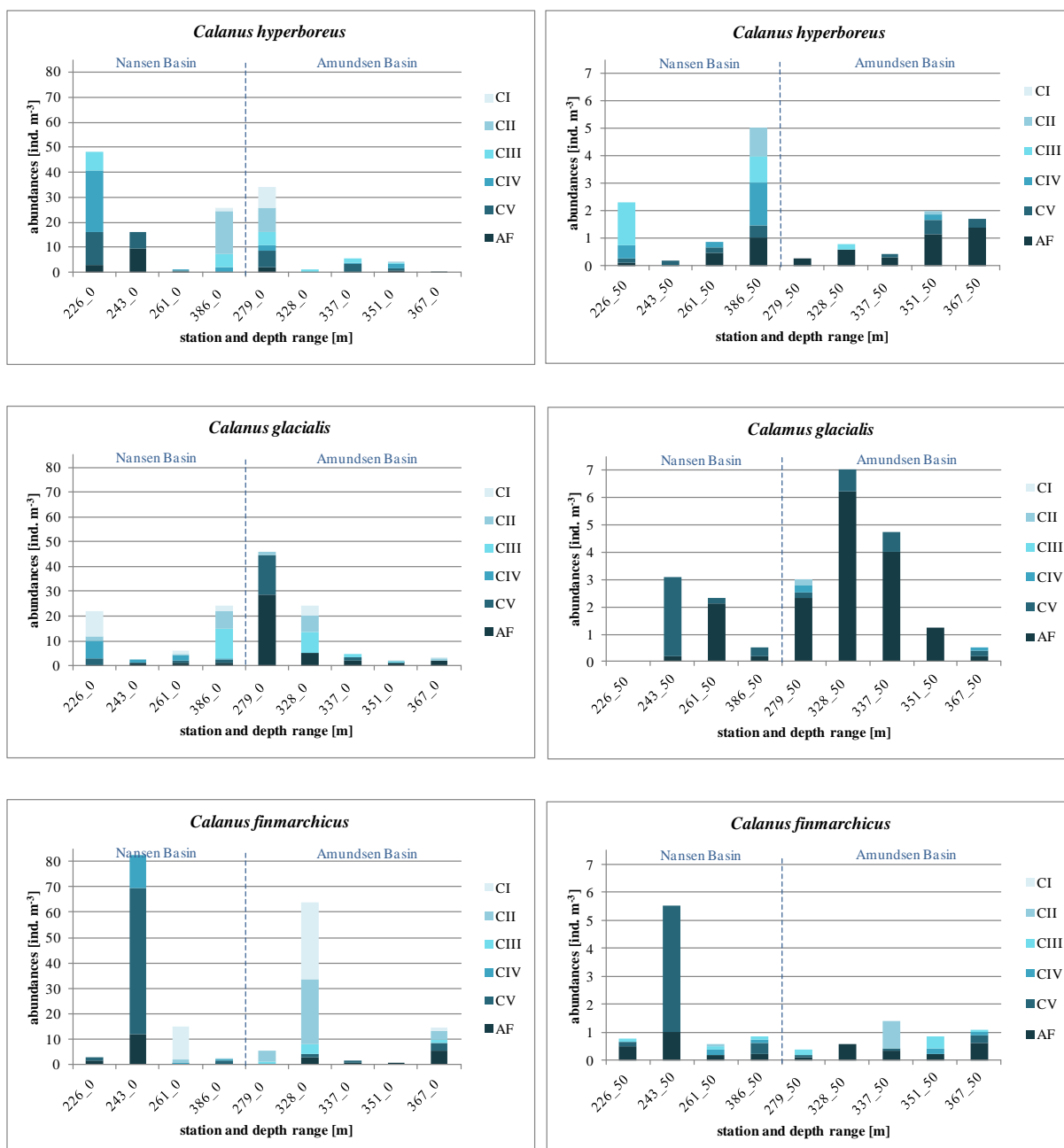
Fig. 12: Abundances [ind. m^{-3}] of the developmental stages (CI-CV & AF) of *Calanus hyperboreus*, *Calanus glacialis,* and *Calanus finmarchicus* in two depth layers (0-50 m & 50-200 m) of all MutliNet stations; note that y-axes are not uniformly scaled; nomenclature of samples: "station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

5   Discussion

5.1   Vertical and horizontal distribution of the zooplankton community across the Eurasian Basin

All 30 taxa which were identified in the MultiNet samples from the ARK XXVII/ 3 expedition have been reported from earlier investigations of the central Arctic Ocean (Kosobokova and Hirche 2000; Kosobokva, Hopcroft and Hirche 2010). According to Mumm (1993), a total of 158 mesozooplankton species is recorded from the central Arctic Ocean. Of those 158 species, 97 are known to occur in the Eurasian Basin from which copepods make up the largest fraction (Mumm 1993). This study agrees with the observations from Mumm (1993) as copepods also clearly dominated the zooplankton community at all stations. The reason for the relatively low taxa number (30) of this study is that identification of the taxa was mostly done to genus level for copepods and not further than to order level for non-copepods due to time restrictions. Determination to species level was only realized for the three *Calanus* species (*Calanus hyperboreus*, *Calanus glacialis*, and *Calanus finmarchicus*). Thus, the actual species number of this study ought to be much closer to the indications of Mumm (1991) for the Nansen Basin or of Mumm (1993) for the Eurasian Basin. A second important aspect for the relatively low taxa number in this study may be the analyzed depth range of 0 to 200 m. Typical vertical distribution ranges of zooplankton and an overall increase of diversity with depth are facts which structure the zooplankton community in all Arctic Ocean basins (Mumm et al. 1998, Kosobokova and Hirche 2000). Mumm (1991) sampled the upper 500 m of the water column and had lower values of species richness than Richter (1994) where samples of more than 500 m depth were taken. In the study of Richter (1994) waters of 500-1000 m depth were found to be especially rich in species numbers. Even for this study, the species richness was increasing from the 0-50 m water layer to the 50 – 200 m water layer and can be assumed to further increase if samples from deeper waters were analyzed.

The composition of the zooplankton community did not change fundamentally across the stations of the ARK XXVII/ 3 expedition of *Polarstern*. Eight of the 30 identified taxa (27%) were present at every station in both depth layers. This is in good relation to Mumm (1991) where one third of all taxa were present at all MultiNet stations of the Nansen Basin.

Copepods clearly dominated the zooplankton community not only with regard to taxa numbers, but also with regard to abundances. The numerical importance of copepods in the Arctic Ocean has already been pointed out in the earliest publications (Sars 1900; Grainger 1961; Mumm 1993; Thibault, Head and Wheeler 1999). Especially small copepods like *Oithona* spp., Clausocalanoida, and *Corycaeus* spp. showed high abundances across all stations of the ARK XXVII/ 3 expedition and represented together 68 % of the entire zooplankton community. This result is similar to the findings of Auel and Hagen (2002) and Kosobokova, Hopcroft, Hirche (2010) where small copepods also dominated the epipelagic zone (0 to 200 m) of the Arctic Ocean basins. Due to their high abundance, global distribution and year-round presence in the upper water masses, small copepods such as *Oithona* spp. play a key role for the structure and functioning of the Arctic pelagic food web (Svensen et al. 2011). However, their biomass is negligible compared to the large-bodied copepods (Hopcroft et al. 2005) like *Calanus* spp., *Paraeuchaeta* spp., and *Metridia* spp. which represented together 7 % of the total zooplankton community within this study. Thus, during the short time-frame when *Calanus* species are active in the surface waters, the contribution of *Calanus* species to the biomass is superior to that of the small coepepod taxa (Svensen et al. 2011).

Depth was the major structuring element for zooplankton distribution in this study which coincides with the finding of Kosobokova, Hopcroft, Hirche (2010) for the Arctic Ocean. During the study of Kosobokova, Hopcroft, Hirche (2010) zooplankton diversity through the depths of the Arctic's central basins was examined (Tab. 10). Species richness, diversity and evenness were increasing from the $0 - 50$ m water layer to the $50 - 200$ m water layer in Kosobokova's publication and also during this study (Tab. 10). However, significant differences between the two depth layers could only be verified for the species richness ($W = 11$, p-value < 0.05) and for the Margalef's index ($W = 1$, p-value < 0.05) during this study. In contrast to species richness, the abundance of zooplankton was higher in the 0-50 m depth layer than in the $50 - 200$ m depth layer ($W = 81$, p-vaule < 0.05). Already Brodsky (1957) determined that the highest abundance of zooplankton occurred in the uppermost 50 m and decreased with depth.

Tab. 10: Species richness, diversity, and evenness for the two depth layers (0-50 m & 50-200 m) in the Eurasian Basin during this study and during the study of Kosobokova, Hopcroft, Hirche (2010)

depth range [m]	S= species richness	N= Abundance [ind. m⁻³]	d= Margalef 's index	H'= Shannon index	J'= Shannon evenness	Kosobokova et al., 2010 S= species richness	Kosobokova et al., 2010 N= Abundance [ind. m⁻³]	Kosobokova et al., 2010 d= Margalef's index	Kosobokova et al., 2010 H'= Shannon index	Kosobokova et al., 2010 J'= Shannon evenness
mean 0-50	15.78	799.82	2.27	0.77	0.28	25	1000	2.55	1.25	0.45
mean 50-200	20.22	147.92	3.9	0.89	0.3	32.5	350	3.25	1.75	0.55

Most of the taxa which were determined during this study live in the epipelagic layer (0 to 200 m) and/or the mesopelagic layer (200 to 1000 m), but some species can also exist in depths of up to 3000 m (bathypelagic (B): 1000 to 3000 m). Depth preferences for many zooplankton species of the Eurasian Basin (and other Arctic basins) are provided in Kosobokova, Hopcroft, Hirche (2010). The most abundant taxon of this study was *Oithona* spp. which has a wide vertical range from the epipelagic (E) to the mesopelagic (M) zone. In this study *Oithona* spp. showed a strong preference for the 0 to 50 m depth layer which agrees with Longhurst (1985) and Kosobokova and Hirche (2000). The same is true for *C. hyperboreus* (E‐B), *C. glacialis* (E‐M), and *C. finmarchicus* (E‐M). Furthermore, *Calanus* nauplii and *Oithona* nauplii were concentrated in the upper 50 m, which is in agreement with Fortier et al. (2001). *Scaphocalanus* spp. and *Heterorhabdus* spp. are normally deep-living taxa (M – B), but have their preferences in the transition layer between Arctic and Atlantic water (Kosobokova and Hirche 2000). In this study, both of them had a high frequency of occurrence and did mainly occur in the 50 – 200 m water layer, but with low abundances. Similar to the copepod species, most of the non-copepod species decreased in abundances from the 0 – 50 m depth layer to the 50 – 200 m depth layer. The most abundant taxon were Foraminifera which decreased rapidly in abundance to the deeper water layer (50 – 200 m), but still represented 10 % of the zooplankton community in both depths. Planktonic Foraminifera are considered to be major producers of carbonate as their shells are commonly made of calcium carbonate ($CaCO_3$). Besides Foraminifera, Chaetognatha were the most frequent occurring non-copepod taxon during this study and had similar average abundances in both depth layers. According to other studies, Chaetognatha are widely distributed over water depths from the epipelagic to the bathypelagic, but single species have specific depth preferences (Longhurst 1985; Kosobokova, Hopcroft, Hirche 2010).

The influence of depth in structuring the zooplankton community is also reflected in the results of the Cluster Analysis and Non-Metric Multidimensional Scaling (NMDS). In both procedures samples of the same depth range were grouped together. However, the NMDS showed also a gradual change in the zooplankton community between the Nansen Basin and the Amundsen Basin in the 50 – 200 m depth layer. Whereas taxa like *Temora* spp., Gastropoda, and Bryozoa occurred only in the Amundsen Basin, *Mormonilla* spp. was only present in the Nansen Basin, but these species represented less than 1 % of the zooplankton community of this depth layer. *Oithona* spp. and Clausocalanidae represented 65 % of the zooplankton community of the 50 – 200 m depth layer in the Nansen Basin, but only 58 % in the Amundsen Basin. Furthermore, *Corycaeus* spp. contributed 9 % to the zooplankton

community of the 50 – 200 m depth layer in the Nansen Basin, but increased to a contribution of 13 % in the Amundsen Basin. Nevertheless, the Cluster Analysis revealed that the communities of the 50 – 200 m depth layer still had a similarity level of 77 %. All in all, vertical changes in species composition and abundances were more pronounced than regional differences between the two Eurasian basins.

Hydrography plays a prominent role in shaping the zooplankton distribution, especially the spreading of Atlantic water into the Arctic Ocean (Hirche and Mumm 1992; Kosobokova and Hirche 2000). Atlantic water which is transported through the Fram Strait into the Eurasian Basin flows beneath the Polar surface water in the 200 to 600 m depth layer (Auel and Hagen 2002) and transports boreal Atlantic species (e.g., *C. finmarchicus*) into the Eurasian Basin (Kosobokova and Hirche 2009). However, it may be that the analyzed depth range of 50 to 200 m of this study was not deep enough to reach the Atlantic water layer, but salinity and temperatures gave indications for Atlantic water (>34.5 PSU, 0 - 1°C, Auel and Hagen 2002) in the 50 – 200 m depth layer of the stations 386, 226, and 243. All of these stations were located near the Atlantic inflow of the Fram Strait, but particularly station 243 was located near a convergent front induced by the Atlantic Water boundary current (Lalande et al. 2014). In addition to that, an episode of freezing conditions occurred prior to the time of sampling at station 243 and may have caused mixing due to haline convection during freezing (Lalande et al. 2014; David et al. 2015). The mixing of water masses could have added nutrients from the Atlantic inflow to the upper water layer, explaining the higher chlorophyll *a* concentrations at station 243. Furthermore, station 243 had the highest abundance of the Atlantic species *C. finmarchicus* whereas the stations 226 and 386 were dominated by *C. hyperboreus*. Nevertheless, *C. finmarchicus* occurred at every station in both depth layers. Already Mumm et al. (1998) reported that species like *C. finmarchicus* follow the boundary current of the Atlantic water eastward and spread throughout the Arctic Ocean. Thus, *C. finmarchicus* can occur in low densities in all Arctic basins (Mumm et al. 1998). An increased portion of Atlantic fauna was also observed at recirculating branches of the Atlantic inflow along the Gakkel Ridge (Hirche and Mumm 1992). All these findings support the widespread occurrence of *C. finmarchicus* during this study and the fact that individuals were also present at the northernmost station (station 367) and at the southernmost station (station 328), both located in the Amundsen Basin. Auel and Hagen (2002) reported *Oithona* spp. and Clausocalanidae being the most abundant copepods in the Atlantic layer. This coincides with the findings of this study, where *Oithona* spp. and Clausocalanidae were also the most abundant species in the 50 – 200 m water layer of the three stations with

Atlantic influence. However, variations in the intensity of the Atlantic inflow, changes in ice concentration or ice thickness, and surface water movement due to strong winds are physical factors that may influence the drifting routes of zooplankton organisms in the Arctic Ocean.

Zooplankton is not distributed evenly throughout the Eurasian Basin. Studies in the Nansen Basin revealed a sharp decline in zooplankton abundance and increase in species richness at a frontal zone at 83°N (Mumm 1991; Carsten and Wefer 1992; Hirche and Mumm 1992; Kosobokova and Hirche 2009). At this deep-reaching hydrographic front, physical characteristics of water masses change abruptly from those representative of the Fram Strait to those more typical for the central Arctic Ocean (Kosokova and Hirche 2009). During this study, four stations were located in the Nansen Basin and one of them, station 261, was almost located at the 83°N front. Indeed, taxa number was highest and abundance was lowest directly at station 261. According to Carstens and Wefer (1992), the latitudinal boundary at 83°N divides the Foraminifera community into two distinct provinces: north and south. In the southern area, the concentrations of planktonic Foraminifera are highest and individuals prefer depths around 100 m. In the north of 83°N they have their maximum abundance in the upper 50 m, where the water is colder and fresher. In this study, Foraminifera showed highest abundances at station 261 which was located nearly to the assumed position of front at 83°N. There was no station which was located more southerly in the Nansen Basin than station 261, but all of the farther north located stations showed lower abundance for Foraminifera. Moreover, at all stations abundances of Foraminifera were highest in the 0 - 50 m water layer. Thus, the findings of Carstens and Wefer (1992) from the Nansen Basin match with the findings of this study.

The highest abundances of zooplankton and copepods only were found at station 328 in the Amundsen Basin. This may be, because station 328 was not only the southernmost station (81.5°N), but also the station with the lowest ice concentration (73 %). In contrast to that, lowest abundances of zooplankton and copepods only were found at station 351 which was one of the northernmost stations with an ice concentration of 100 %. However, not only physical conditions of the habitat, but also food, predators, and time are dimensions that influence the horizontal and vertical distribution of zooplankton and limit the comparability of results from different stations. Seasonal vertical migration, which is typical for many polar zooplankton organisms, may influence the drifting routes of zooplankton organisms in the Arctic Ocean. Seasonal migrations of small copepods (e.g., *Oithona* spp.) were described already by Kosobokova (1980) and Mumm (1993). Factors that determine the vertical ascent and descent could be the avoidance of predators or the reduction of metabolic costs by

migration into deeper waters of low temperature. Surviving, when there is not enough food as well as finding the food when it becomes available, requires adaptation to the seasonally limited nutritional environment. Thus, to shorten the relatively long tale of starving, most of the northern herbivores feed intensively during the Arctic summer and then sink into deeper waters where their development becomes arrested and their metabolism reduced (Conover and Huntley 1991). Also ontogenetic vertical migration is possible to synchronize reproduction and population growth with favorable environmental conditions. However, seasonal vertical migrations in the Arctic Ocean are usually limited to the upper 500 m (Kosobokova 1982) and are not as extensive as in subpolar and boreal seas such as the Greenland Sea (Mumm et al 1998).

5.2 Distribution patterns of selected *Calanus* species

The three *Calanus* species: *Calanus hyperboreus*, *Calanus glacialis*, and *Calanus finmarchicus* occurred at every station of the ARK XXVII/ 3 expedition. *Calanus* species were not the most abundant copepod species during this study, but they are known to be important components in the Arctic marine food web because of their high biomass and energy content (Diel 1991; Hirche 1991; Falk-Petersen et al. 2009).

C. hyperboreus had highest abundances at the southern stations 226, 279, and 386 and lowest abundances at the northernmost stations 337, 351, and 367 of this study. This is untypical as *C. hyperboreus* is deemed to be of true Arctic origin (Grainger 1961) and is prevailing northern stations (85° - 90°N) in the Amundsen Basin in other studies (Mumm et al. 1998; Auel and Hagen 2002). Abundance of *C. hyperboreus* was lowest at station 261 which was located near the 83°N front. Moreover, there was no spatial pattern in abundances from east to west which coincides with the findings of Kosobokova and Hirche (2009).

C. glacialis is also regarded as a species of true Arctic origin which presence is strongly associated with Arctic water (Hirche et al. 1994). In contrast to *C. hyperboreus*, *C. glacialis* is considered to be most abundant over the Eurasian shelves and along the continental slope and less abundant along the western transects of the Nansen Basin and in Atlantic waters (Kosobokova and Hirche 2009). This matches with the findings of this study as *C. glacialis* showed highest abundances at the stations 279 and 328 which were characterized by Arctic water. Lowest abundances were reached at the northernmost stations 351 and 367 and at station 243 which was the station most influenced by Atlantic water. Diel (1991) reported that *C. glacialis* dominates the polar domain of Fram Strait. In the present study *C. glacialis*

was relatively abundant in the upper water layer of the stations 226 and 386 which were located near Fram Strait and characterized by Polar surface water in the upper 50 m.

C. finmarchicus is regarded as a boreal Atlantic species dominating the southern to central Nansen Basin where the Atlantic inflow is strongest and its population enters the Arctic Ocean (Auel and Hagen 2002). In this study, *C. finmarchicus* had the highest abundance at station 243 which was most influenced by Atlantic water from the Fram Strait. However, *C. finmarchicus* was also abundant at station 261 at the 83°N front and at the northernmost station 367, both characterized by Polar surface water. These findings are not consistent with the observations of other studies which indicate a drastic decrease of *C. finmarchicus* in direction to the central deep basins (Kosobokova and Hirche 2009; Kosobokova, Hopcroft, Hirche 2010). Nevertheless, there were also studies which support the finding that *C. finmarchicus* can occur in low densities in all Arctic basins (Mumm et al. 1998).

5.3   Stage composition of selected *Calanus* species

Seasonal ontogenetic migration is part of the life cycle of all three *Calanus* species and can influence not only the plankton community structure, but also the pelagic carbon flux (Madsen, Nielsen, Hansen 2001).

Individuals of *Calanus hyperboreus* have a large plasticity in their life strategy (Falk - Petersen et al. 2008) as they can have 2- to 4-year life cycles in the Arctic Ocean and can survive longest without feeding (Arnkvaern, Daase, Eiane 2005; Kosobokova and Hirche 2009). Females store reserves for overwintering and reproduction by extensive feeding during summer so that their spawning during winter/early spring is fueled by internal lipid reserves independent of the first algal bloom in spring (Conover 1988; Falk-Petersen et al. 2008; Kosobokova and Hirche 2009). The eggs of *C. hyperboreus* develop rapidly to stage CIII or CIV during the spring bloom in the following summer (Falk-Petersen et al. 2008). Stages CIII-AF can be overwintering stages of *C. hyperboreus* (Hirche et al. 1994; Hirche 1997). The descent of these stages in late August into deeper water layers is the most occurring migration pattern (Hirche 1997; Madsen, Nielsen, Hansen 2001). During this study, most CIII-CV stages were found at station 226 which was the first station of the cruise in the beginning of August. At all other stations, the overwintering stages CIII-CV of *C. hyperboreus* were only present with much lower abundances. Furthermore, the integrated abundances of CIII-CV stages decreased clearly from August stations to September stations indicating the descent of the overwintering stages. Females of *C. hyperboreus*

occurred at every station, but were highest at the stations 226, 243, and 279 which were sampled in the beginning and the mid of August. In September, integrated abundances of females decreased and did not exceed 1 ind. m^{-3}. Also here, descent of the overwintering stage AF to the deeper water layers (> 200m) could explain the decline of female abundances at September stations during the ARK XXVII/ 3 expedition of *Polarstern*. Young copepodid stages CI and CII were found at two stations in the Amundsen Basin. The first station was 279 which was one of the southernmost stations and was sampled relatively late in the end of August. The second was station 386 which was the westernmost station and was sampled as the last station in the end of September. At both stations development from eggs to CI and CII stages may have already occurred until the end of August and September, respectively.

Calanus glacialis has a shorter life cycle than *C. hyperboreus*. In very productive years only one year is needed and in less productive years two years are needed to complete the whole life cycle (Arnkvaern, Daase, Eiane 2005). Individuals in the Arctic Ocean have mostly a 2-year life cycle (Arnkvaern, Daase, Eiane 2005). Females of *C. glacialis* use a combination of internal fat reserves and feeding on ice algae to maturate and reproduce before the bloom (Madsen, Nielsen, Hansen 2001). Thus, this species is more suitable for life in the high Arctic than *C. finmarchicus*, since the capability to reproduce successfully early in spring is independent of food supply from the Arctic phytoplankton spring bloom (Arnkvaern, Daase, Eiane 2005). Stages CIV-AF can be the overwintering stages of *C. glacialis* (Hirche et al. 1994; Madsen, Nielsen, Hansen 2001). During this study, stages of CIV-AF were most abundant at station 279 which is one of the easternmost stations of this study and was sampled at the end of August. The decrease in abundance of these stages from stations sampled in August to stations sampled in September is in good accordance to Madsen, Nielsen, Hansen (2001) who reported descent of overwintering stages from September onwards. Stages of AF and CV dominated the whole population of *C. glacialis* during this study. Station 386, which was the very last station of the expedition at the end of September, was the only station where all developmental stages of *C. glacialis* were found and had the highest abundance of young developmental stages (CI-CIII). There was a clear increase of young CI-CIII stages from August stations to September stations, indicating that at these stations eggs had already developed to young copepodites.

Calanus finmarchicus was the most abundant *Calanus* species in this study. A 1-year life cycle is reported from Madsen, Nielsen, Hansen (2001). In contrast to *C. hyperboreus* and *C. glacialis*, individuals of this species depend on pelagic food supply to maintain maturation and egg production in order to spawn after the onset of the spring bloom

(Arnkvaern, Daase, Eiane 2005). *C. finmarchicus* is an expatriate in the Arctic Ocean as it is a boreal North Atlantic species. Expatriates are either unable to reproduce or unable to reproduce at sufficient rates to offset their mortality (Kosobokova, Hopcroft, Hirche 2010). Their distribution in the Arctic Ocean depends on the intensity of water advection and abundance of their population in the source area. Other factors structuring their distribution are life span and survival under Arctic conditions (Kosobokova, Hopcroft, Hirche 2010). The overwintering stages of *C. finmarchicus* can be stages of CIV-AF (Madsen, Nielsen, Hansen 2001; Arnkvaern, Daase, Eiane 2005). During this study, stages of CIV-AF were most abundant at station 243 which was the station mostly influenced by Atlantic water. Madsen, Nielsen, Hansen (2001) reported a descent of overwintering stages of *C. finmarchicus* to deeper waters and a new generation which is active in the surface waters. These findings coincide with this study as there was a decrease in abundance of CIV-AF stages and an increase of CI – CIII from the stations which were sampled in August to the stations which were sampled in September. Highest abundance of young developmental stages CI-CIII was reached at the southern- and easternmost station 328. Stage CV dominated the *C. finmarchicus* community over all stations which is in good accordance with the findings of Hirche et al. (1994) and Madsen, Nielsen, Hansen (2001). However, all developmental stages were only present at station 367 which was the northernmost station of the cruise at the end of September.

The presence of the full range of developmental stages in this study coincides with other studies from other areas all over the Arctic Ocean (Kosobokova et al. 1998; Kosobokova and Hirche 2000). The presence of young developmental stages of all *Calanus* species suggests successful reproduction at most of the stations for *C. hyperboreus, C. glacialis*, and *C. finmarchicus*.

In contrast to Kosobokova and Hirche (2000) there was no strong bias between (high) abundance of late developmental stages and (low) abundance of young copepodid stages in this study. Peak abundance of juvenile copepodites, representing the new generation, was in September for *C. finmarchicus* and *C. glacialis* and in the end of August and end of September for *C. hyperboreus*.

Nevertheless, there is the possibility of an insufficient identification of the three *Calanus* species by using prosome length measurements. Although size limits used for *C. glacialis* and *C. finmarchicus* were in accordance with previous studies (Madsen, Nielsen, Hansen 2001; Arnkvaern, Daase, Eiane 2005; David et al. 2015),

these distinctions may not have been appropriate for the species of this study and could have caused an overestimation of *C. finmarchicus* and an underestimation of *C. glacialis.* For verifying the length-based identification of the *Calanus* species, subsamples could be taken for molecular analysis as this species differ in their mitochondrial rRNA (Bucklin, Frost, Kocher 1995).

5.4 Comparison of the results from the MultiNet samples with the results from the SUIT samples of the ARK XXVII/ 3 "IceArc" expedition of *Polarstern*

Similar to this study, the study of David et al. (2015) based on data which were taken during the ARK XXVII/ 3 expedition of *Polarstern*. Instead of the MultiNet David et al. (2015) used the Surface and Under-Ice Trawl (SUIT) to sample the under-ice fauna of the Eurasian Basin. The SUIT enables large-scale horizontal sampling of the 0 – 2 m surface water layer and can be used for sampling of zooplankton under the sea ice or in the open water. The aim of David et al. (2015) was to sample the under-ice fauna which includes ice-associated species that complete their entire life cycle within the sea ice or spend only part of their life cycle associated with the ice (Melnikov and Kulikov 1980). Ice-associated fauna is necessary for the functioning of the ecosystem as it transfers energy to higher trophic levels (Budge et al. 2008). The ice forms a suitable nursery for pelagic and benthic organisms since the mixed layer under the ice is usually more stable and primary production is more concentrated under the ice than in the open water (Conover and Huntley 1991).

 David et al. (2015) reported two environmental regimes, broadly coherent with the Nansen Basin and Amundsen Basin for physical parameters and for the under-ice community. According to David et al. (2015), the Nansen Basin regime had higher salinity in the 0-2 m surface layer, higher ice concentration, higher ice thickness and higher nutrient concentrations than the Amundsen Basin regime. In contrast to that, the Amundsen Basin regime showed higher chlorophyll *a* concentrations in the 0-2 m surface layer than the Nansen Basin regime. Overall diversity indices of the under-ice fauna were slightly higher in the Amundsen Basin regime than in the Nansen Basin regime, but abundances were higher in the Nansen Basin regime (David et al. 2015). Similar patterns were found during this study, although there were no differences in chlorophyll *a* concentrations between the two basins and also differences in zooplankton abundance between the Nansen Basin and the Amundsen Basin were not significant. According to the under-ice community, David et al. (2015) found a more herbivorous fauna in the Nansen Basin regime and a more carnivorous fauna in the Amundsen Basin regime. These findings could not be confirmed within this study since

herbivores prevailed in abundances in both basins. Indeed, mean contributions of the carnivorous *Corycaeus* spp. increased from 7 % in Nansen Basin to 13 % in Amundsen Basin during the present study, but other carnivores like Chaetognatha did not change much in their abundance from the Nansen Basin to the Amundsen Basin and only represented <1 % of the zooplankton community in each basin. However, the Cluster Analysis and Non-Metric Multidimensional Scaling (NMDS) showed a gradual change in the zooplankton community between the Nansen Basin and the Amundsen Basin in the 50 – 200 m depth layer during this study, but differences could not be attributed to a herbivorous fauna in Nansen Basin and a carnivorous fauna in Amundsen Basin, respectively. In the samples of the SUIT, the contribution of copepods differed markedly between the two Eurasian basins. Copepods represented over 82 % of the mean abundance in the Nansen Basin regime, whereas Amphipoda played a dominant role in the Amundsen Basin regime and codominated the community with 43 %. In the present study, copepods represented 87 % of the zooplankton community in both basins and Amphipoda represented only 0.1 % in the Nansen Basin and 0.2 % in the Amundsen Basin. The higher proportion of Amphipods in the SUIT samples is reasonable due to the better sampling efficiency of the SUIT for large species and the presence of ice Amphipods in the under-ice community. Within the copepod community, *Calanus hyperboreus* and *Calanus glacialis* were the most abundant species in the SUIT samples whereas small species like *Oithona* spp. and Clausocalanidae dominated the MultiNet samples. David et al. (2015) found a drastic decrease of adult (AF) *Calanus* spp. from the Nansen Basin regime to the Amundsen Basin regime and an increase of young *Calanus* spp. stages CI und CII. In contrast to that, abundances of AF, CII, and CI stages were slightly higher in the Amundsen Basin than in the Nansen Basin during this study. These findings support the assumption that descent of the overwintering stages to the deeper water layers was in the beginning at the September stations of the ARK XXVII/ 3 expedition.

Calanus finmarchicus was only present at one station (station 248) in the SUIT samples. This station was located near station 243 of the MultiNet which was also dominated by *C. finmarchicus*. Mixing events which occurred prior to the sampling of station 243 could have added more nutrients to the upper water layer and favored increasing productivity and immigration of grazers (e.g., *C. finmarchicus*). The constantly presence of *C. finmarchicus* in all MultiNet samples, but absence in the SUIT samples (except of station 248) shows that *C. finmarchicus* migrated to the upper water layers, but avoided the 0 – 2 m surface layer.
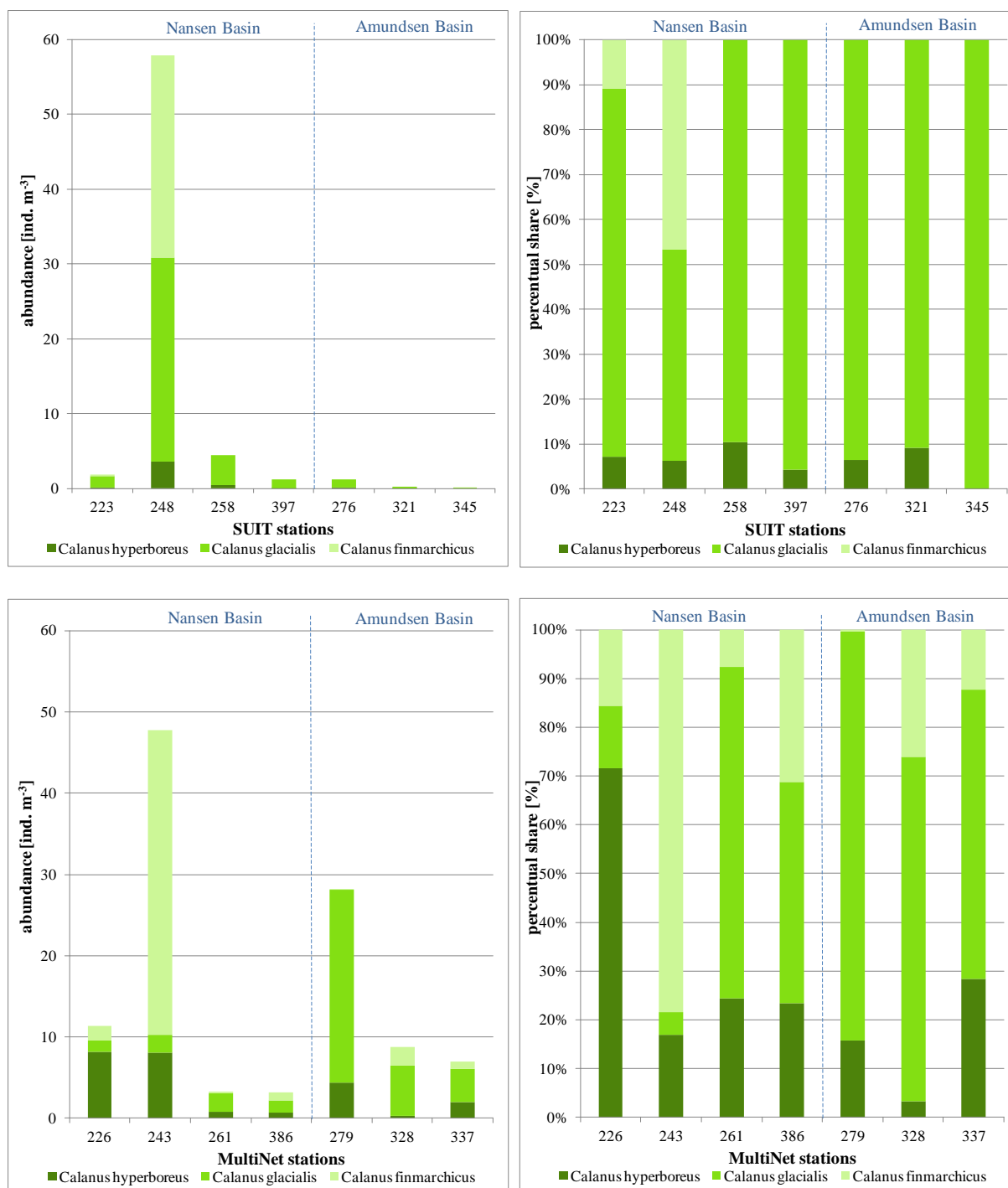
Fig. 13: Abundances [ind. m⁻³] and percentual shares of the three *Calanus* species in the 0-2 m depth layer of seven SUIT stations and in the 0-200 m depth layer of seven MultiNet stations during the ARK XXVII/ 3 expedition of *Polarstern;* note: for better comparison only SUIT and MultiNet stations from similar locations were chosen

The analysis of the MultiNet samples for this study and the SUIT samples for the study of David et al. (2015) delivered different results especially with regard to the composition of the zooplankton community. This may be for a variety of reasons. The first and one of the most important aspects is that both sampling gears differ in the method of sampling. The MultiNet is towed through the water in a vertical direction and is made to sample different depths,

the SUIT is made to remain on the water surface and is towed horizontally through the water to sample the upper two meters of the water column. As a guideline for catch efficiency it is indicated that the SUIT samples 4 % of the upper 50 m and only 1 % of the upper 100 m. Moreover the SUIT was equipped with a net of 300 μm mesh size, the MultiNet with a less coarse net of 150 μm mesh size. Thus, net avoidance of larger organisms may be lower, but underrepresentation of smaller individuals (e.g., *Oithona* spp., young copepodid stages) may be higher when sampling with the SUIT compared to the MultiNet.

5.5   Methodological constraints

There are several methodological constraints which may have occurred during the quantitative MultiNet sampling of zooplankton. In general, those net samplings can only give estimates of the numbers of taxa and individuals. Patchiness, escapement, and net avoidance of the zooplankton specimens can cause underestimation of the actual values (Mumm 1991; Richter 1994). Especially the common plankton nets with 150 to 200 μm mesh size underestimate significantly the small species of zooplankton (Mumm 1991; Galienne and Robins 2001).

Zooplankton organisms are patchily distributed on a vertical and a horizontal scale which is due to physical processes (Mumm 1991). This patchiness causes up to 10-fold variations in individual numbers when sampling the same station in a row (Mumm 1991). During the ARK XXVII/ 3 expedition of *Polarstern* only one haul per station was carried out which was not enough for analyzing the small scale variability of the zooplankton community at one station. Nevertheless, this study could reveal clear tendencies concerning the variability of species composition and zooplankton abundances between the two depth layers and among stations that were influenced by different water masses.

Net avoidance of zooplankton specimens is an important source of error and increases with decreasing mesh size, since fine gauzes clog more than coarse gauzes (Unesco 1968). Especially bigger individuals like adults of Chaetognatha and *Paraeuchaeta* spp., which are highly sensitive for movement stimuli, may not be caught quantitatively (Mumm 1991).Wires that are installed in front of the net opening for mounting and electricity can additionally intensify net avoidance (Mumm 1991). The MultiNet used for this study had a net opening of 0.25 m² and several wires crossed in front of it. However, numbers of individuals and species of this study are comparable with many other studies that used the same net and mesh size (e.g., Kosobokova and Hirche 2009; Kosobokova, Hopcroft, Hirche 2010).

Another methodological constraint is the escapement of organisms through the mesh due to excessive filtration pressure (Skjoldal et al. 2013). About 50 % of the zooplankton organisms which have an equal width to the mesh size escape through the mesh (Skjoldal et al. 2013). The effect of towing speed is an additional loss due to escapement as it causes extrusion of small individuals (Skjoldal et al. 2013). According to Svensen et al. (2011), small copepods such as *Oithona* spp. are underestimated even with mesh sizes of 90 μm. Thus, although a mesh size of 150 μm was used for this study, an underrepresentation of small individuals (e.g., *Oithona* spp.*, Oithona* nauplii, *Calanus* nauplii, Clausocalanidae, and *Oncaea* spp.) may still have occurred. Optimal sampling of a zooplankton community is always a compromise between mesh size and speed. Reducing the mesh size could improve the catch efficiency of smaller individuals, but would increase the avoidance of larger organisms. Increasing the towing speed could improve the catch efficiency of larger individuals, but would result in an increasing escapement of organisms through the mesh and extrusion of small individuals (Skjoldal et al. 2013).

Because MultiNet samples can technically only be taken in the open water, zooplankton which is directly living under the ice was not or not quantitatively sampled.

The time difference between the first and the last sampling sites could have biased the results as the last stations in the Amundsen Basin were characterized by autumn conditions compared to summer conditions of the first sampling stations in the Nansen Basin. Since only the upper 200 meters of the water column were analyzed during this study, seasonal ontogenetic migration to the deeper water layers may have influenced the results.

For advanced investigations of the zooplankton community, especially in terms of most important species of the food web, calculations of biomass would be necessary. Small zooplankton taxa like *Oithona* spp. and Clausocalanidae can be the most important taxa in terms of individual numbers like in this study, but big species like *Calanus* spp. are the most important ones when it comes to biomass. There are a lot of studies with biomass data for zooplankton species of the Arctic Ocean (e.g., Kosobokova and Hirche 2000; Kosobokova and Hirche 2009) that provide a good basis for data comparison.

6   Conclusions

Copepods were by far the most important zooplankton group in this study since they contributed 88 % to the total zooplankton community in the $0-50$ m depth layer and 84 % in the 50-200 m depth layer. Even when assuming underestimation of the small zooplankton species due to the sampling gear (MultiNet) zooplankton abundance was dominated by small copepods like *Oithona* spp., *Corycaeus* spp. and Clausocalanidae in both depth layers.

Vertical changes in abundance and species composition were much more pronounced than regional differences between the basins. These finding is contrary to the finding of David et al. (2015) from the Surface and Under-Ice Trawl (SUIT) samples of the same expedition. It is likely that a seasonal trend defined the two regimes of Nansen Basin and Amundsen Basin in both studies. However, the two distinct regimes of the under-ice fauna for the Nansen Basin and the Amundsen Basin could not be confirmed for the fauna of the pelagial. Therefore it might reasonably be assumed that the findings of David et al. (2015) were mostly determined by the sea ice and are not reflected at the pelagial.

Polar surface water and Atlantic water with their distinct physical characteristics (e.g., temperature, salinity) influenced the community structure and distribution in the central Arctic Ocean. The distribution of the Atlantic copepod *Calanus finmarchicus* reflected the hydrographic regime as it was most abundant at the station with the highest Atlantic influence (station 243). However, during this study *C. finmarchicus* was present at all stations in both depth layers, even at the stations which were not influenced by Atlantic water masses. The constantly presence of *C. finmarchicus* in all MultiNet samples, but absence in the SUIT samples (except of one station) showed that *C. finmarchicus* migrated to the upper water layers, but avoided the 0-2 m surface layer.

In the future the central Arctic will be exposed to continuing environmental changes. Johannessen et al. (2002) predicted a reduction of the Arctic pack ice of 20 % during winter and 80 % during summer by the end of this century. Studies like the present one are important to improve the understanding of how the response of Arctic marine ecosystems to climate warming will alter Arctic biodiversity and food web structure. The determination of the trophic link between the sea ice and the water column in the Arctic Ocean will be helpful for a better assessment of the effects of continuing ice melting on the Arctic ecosystem.

7 Literature

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Declaration of academic honesty

I hereby declare that this master thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institute. I confirm that if any passage(s), figure(s) or diagram(s) have been copied from academic books, papers, the internet or other sources, these are clearly identified by the use of quotation marks and the references are fully cited.

Hamburg, April 2th, 2015   ………………………………………

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Hamburg, den 2. April 2015 ………………………………………

Appendix

App. Tab. 1: List of species for the MultiNet samples of the ARK XXVII/ 3 expedition of *Polarstern*

copepods	*Calanus finmarchicus*	Gunnerus, 1765
	Calanus glacialis	Jaschnov, 1955
	Calanus hyperboreus	Kroyer, 1838
	Calanus nauplii	
	Centropages spp.	Krøyer, 1849
	Clausocalanidae	Giesbrecht, 1893
	Chiridius spp.	Giesbrecht, 1893
	Paraeuchaeta spp.	Scott A., 1909
	Scaphocalanus spp.	Sars G.O., 1900
	Metridia spp.	Boeck, 1865
	Heterorhabdus spp.	Giesbrecht, 1898
	Temora spp.	Baird, 1850
	Mormonilla spp.	Giesbrecht, 1891
	Oithona spp.	Baird, 1843
	Oithona nauplii	
	Oncaea	Philippi, 1843
	Corycaeus spp.	Dana, 1845
	Microsetella spp.	Brady & Robertson D., 1873
	Tisbe spp.	Lilljeborg, 1853
non-copepods	Foraminifera	
	Radiolaria	Muller, 1858
	Bryozoa	
	Cnidaria	Verrill, 1865
	Siphonophorae	Eschscholtz, 1829
	Gastropoda	Cuvier, 1795
	Polychaeta	Grube, 1850
	Ostracoda	Latreille, 1802
	Cirripedia	Burmeister, 1834
	Amphipoda	Latreille, 1816
	Appendicularia	Fol, 1874
	Chaetognatha	

App. Tab. 2: Presence and absence for every taxon in two depth layers (0-50 m & 50-200 m) of all MultiNet stations during the ARK XXVII/ 3 expedition of *Polarstern*

taxa		Nansen Basin								Amundsen Basin									
		226_0	226_50	243_0	243_50	261_0	261_50	386_0	386_50	279_0	279_50	328_0	328_50	337_0	337_50	351_0	351_50	367_0	367_50
Calanus spp.	copepods	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Calanus hyperboreus		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Calanus nauplii		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Centropages spp.														X					
Clausocalanidae		X	X	X		X	X	X	X		X	X	X		X	X	X	X	X
Chiridius spp.			X				X		X		X	X	X	X	X		X		X
Paraeuchaeta spp.		X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X
Scaphocalanus spp.			X			X	X		X		X	X	X		X	X	X		X
Metridia spp.		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Heterorhabdus spp.		X	X		X		X		X	X	X		X	X	X		X		X
Temora spp.														X	X	X			
Mormonilla spp.		X		X	X	X		X	X	X	X	X	X	X	X	X	X		X
Oithona spp.		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Oithona nauplii			X	X	X	X		X	X		X	X	X	X	X	X	X		X
Oncaea		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Corycaeus spp.		X	X	X	X	X	X	X	X			X	X	X	X		X	X	X
Microsetella spp.			X	X		X	X							X	X			X	X
Tisbe spp.				X		X								X	X				
Foraminifera	non-copepods	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Radiolaria		X	X						X			X		X	X		X	X	
Bryozoa														X	X				X
Cnidaria										X							X		X
Siphonophorae		X	X			X					X		X	X					X
Gastropoda													X			X	X		
Polychaeta		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Ostracoda		X	X		X	X	X		X	X	X	X	X	X	X		X	X	X
Cirripedia		X				X										X			
Amphipoda		X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X
Appendicularia		X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X
Chaetognatha		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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App. Tab. 3: Abundances [ind m⁻³] and percentual shares for all copepod taxa in the two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "cruise/station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

abundance [ind. m⁻³]

Basin	station	Calanus hyperboreus	Calanus spp.	Calanus nauplii	Clausocalanidae	Paraeuchaeta spp.	Metridia spp.	Temora spp.	Oithona spp.	Oithona nauplii	Corycaeus spp.	Oncaea	Mormonilla spp.	Microsetella spp.	Tisbe spp.	Chiridius spp.	Heterorhabdus spp.	Scaphocalanus spp.	Centropages spp.	sum
Nansen	PS 80/ 226_0	66.91	3.88	80.48	128.00	1.45	3.39	0.00	178.42	21.33	94.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	578.42
Nansen	PS 80/ 243_0	28.89	94.67	20.44	52.00	0.00	9.33	0.00	252.44	114.67	38.67	5.33	0.00	0.00	0.89	1.78	0.00	0.00	0.00	619.11
Nansen	PS 80/ 261_0	1.23	23.69	51.69	23.59	0.00	7.90	0.00	90.26	32.00	50.46	4.92	1.64	1.85	0.00	0.00	0.00	0.00	0.00	289.23
Nansen	PS 80/ 386_0	48.67	1.67	25.33	56.00	1.67	17.50	0.00	1152.00	8.00	30.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1341.50
Amundsen	PS 80/ 279_0	2.67	41.24	34.84	29.51	0.00	3.56	0.00	396.44	65.78	69.69	8.89	1.87	0.58	1.33	0.00	0.00	1.42	0.00	647.02
Amundsen	PS 80/ 328_0	50.89	8.22	232.00	87.78	0.00	5.78	0.00	660.44	154.67	268.22	8.89	0.32	1.33	0.00	0.00	0.00	0.00	0.00	1478.22
Amundsen	PS 80/ 337_0	6.83	2.56	21.55	17.92	0.96	6.93	0.50	166.40	58.45	45.87	2.13	0.33	0.00	0.96	0.00	0.11	0.11	0.21	331.20
Amundsen	PS 80/ 351_0	5.83	0.83	5.33	88.00	0.00	6.83	0.33	76.00	2.00	40.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	225.83
Amundsen	PS 80/ 367_0	0.90	20.85	26.56	39.18	0.31	0.15	0.00	651.90	17.33	71.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	828.97
Nansen	PS 80/ 226_50	2.06	1.89	0.69	62.97	0.82	6.32	0.00	28.90	0.69	15.48	0.00	0.27	0.82	0.00	0.69	0.69	0.52	0.52	122.32
Nansen	PS 80/ 243_50	0.07	10.60	6.02	82.60	4.38	1.91	0.00	47.04	1.37	8.68	2.74	0.27	0.00	0.08	0.00	0.00	0.05	0.00	165.68
Nansen	PS 80/ 261_50	0.85	3.46	1.95	34.15	0.49	3.78	0.00	24.39	0.00	5.73	0.00	0.00	0.07	0.08	0.00	0.05	0.05	0.05	75.06
Nansen	PS 80/ 386_50	5.74	2.84	2.32	77.05	1.47	8.58	0.00	54.11	0.63	30.74	0.84	0.00	0.00	0.00	0.16	0.16	0.58	0.79	185.84
Amundsen	PS 80/ 279_50	1.57	1.24	2.20	101.32	0.41	4.93	0.00	28.88	0.15	18.85	2.49	0.00	0.00	0.00	0.54	0.54	1.34	0.46	164.37
Amundsen	PS 80/ 328_50	0.26	7.28	2.08	38.57	0.52	12.46	0.43	14.57	0.33	7.87	0.72	0.00	0.10	0.00	5.59	0.39	0.20	0.39	90.93
Amundsen	PS 80/ 337_50	4.32	1.84	1.73	54.05	0.16	2.38	0.43	48.00	1.08	25.73	2.16	0.00	0.49	0.05	0.76	0.76	0.54	0.53	143.89
Amundsen	PS 80/ 351_50	2.37	2.63	0.11	32.95	0.21	1.58	0.00	21.16	0.11	15.37	0.74	0.00	0.21	0.00	0.53	0.21	0.05	0.00	78.21
Amundsen	PS 80/ 367_50	2.10	1.95	0.80	29.50	0.25	1.80	0.00	31.50	0.10	19.20	0.80	0.00	0.10	0.00	0.35	0.35	0.20	0.35	89.00
	mean 0-50	23.65	21.96	55.36	58.00	0.49	6.82	0.04	402.70	52.69	78.95	2.36	0.43	0.45	0.30	0.30	0.30	0.17	0.02	704.39
	mean 50-200	2.15	3.75	1.99	57.02	0.97	4.86	0.05	33.17	0.49	16.41	1.16	0.03	0.20	0.01	0.93	0.39	0.13	0.35	123.92
	mean Nansen Basin	19.30	17.84	23.62	64.54	1.28	7.34	0.00	228.45	22.34	34.37	1.73	0.24	0.45	0.23	0.11	0.11	0.13	0.17	422.15
	mean Amundsen Basin	7.77	8.87	32.72	51.88	0.28	4.64	0.08	209.53	30.00	58.33	1.79	0.22	0.22	0.10	0.74	0.35	0.40	0.18	407.77

percentual share [%]

| Basin	station	Calanus hyperboreus	Calanus spp.	Calanus nauplii	Clausocalanidae	Paraeuchaeta spp.	Metridia spp.	Temora spp.	Oithona spp.	Oithona nauplii	Corycaeus spp.	Oncaea	Mormonilla spp.	Microsetella spp.	Tisbe spp.	Chiridius spp.	Heterorhabdus spp.	Scaphocalanus spp.	Centropages spp.	sum
Nansen	PS 80/ 226_0	11.57	0.67	13.91	22.13	0.25	0.59	0.00	30.85	3.69	16.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Nansen	PS 80/ 243_0	4.67	15.29	3.30	8.40	0.00	1.51	0.00	40.78	18.52	6.25	0.86	0.00	0.00	0.14	0.29	0.00	0.00	0.00	100.00
Nansen	PS 80/ 261_0	0.43	8.19	17.87	8.16	0.00	2.73	0.00	31.21	11.06	17.45	1.70	0.57	0.64	0.00	0.00	0.00	0.00	0.00	100.00
Nansen	PS 80/ 386_0	3.63	0.12	1.89	4.17	0.12	1.30	0.00	85.87	0.60	2.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Amundsen	PS 80/ 279_0	0.41	6.37	5.39	4.56	0.00	0.55	0.00	61.27	10.17	10.77	1.51	0.29	0.09	0.29	0.00	0.00	0.22	0.00	100.00
Amundsen	PS 80/ 328_0	3.44	0.56	15.69	5.94	0.00	0.39	0.00	44.68	10.46	18.14	0.60	0.09	0.09	0.29	0.00	0.00	0.00	0.06	100.00
Amundsen	PS 80/ 337_0	2.06	0.77	6.51	5.41	0.29	2.09	0.15	50.24	17.65	13.85	0.64	0.10	0.00	0.29	0.00	0.53	0.03	0.21	100.00
Amundsen	PS 80/ 351_0	2.58	0.37	2.36	38.97	0.00	3.03	0.15	33.65	0.89	18.01	0.00	0.00	0.00	0.00	0.00	0.27	0.03	0.07	100.00
Amundsen	PS 80/ 367_0	0.11	2.51	3.20	4.73	0.04	0.02	0.00	78.64	2.09	8.66	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Nansen	PS 80/ 226_50	1.69	1.55	0.56	51.48	0.67	5.17	0.00	23.63	0.56	12.66	0.00	0.17	0.67	0.00	0.56	0.56	0.39	0.42	100.00
Nansen	PS 80/ 243_50	0.04	6.40	3.63	49.86	2.64	1.16	0.00	28.39	0.83	5.24	1.65	0.17	0.00	0.04	0.00	0.00	0.06	0.00	100.00
Nansen	PS 80/ 261_50	1.14	4.61	2.60	45.49	0.65	5.04	0.00	32.50	0.00	7.64	0.00	0.00	0.10	0.11	0.00	0.06	0.06	0.06	100.00
Nansen	PS 80/ 386_50	3.09	1.53	1.25	41.46	0.79	4.62	0.00	29.11	0.34	16.54	0.45	0.00	0.00	0.00	0.08	0.08	0.31	0.31	100.00
Amundsen	PS 80/ 279_50	0.95	0.76	1.34	61.64	0.25	3.00	0.00	17.57	0.09	11.47	1.51	0.00	0.00	0.00	0.33	0.33	0.82	0.28	100.00
Amundsen	PS 80/ 328_50	0.29	8.01	2.29	42.42	0.57	13.70	0.30	16.02	0.36	8.66	0.79	0.00	0.11	0.04	6.15	0.43	0.21	0.38	100.00
Amundsen	PS 80/ 337_50	3.01	1.28	1.20	37.57	0.11	1.65	0.30	33.36	0.75	17.88	1.50	0.00	0.34	0.04	0.53	0.53	0.11	0.27	100.00
Amundsen	PS 80/ 351_50	3.03	3.36	0.13	42.13	0.27	2.02	0.00	27.05	0.13	19.65	0.94	0.00	0.27	0.00	0.67	0.27	0.07	0.00	100.00
Amundsen	PS 80/ 367_50	2.36	2.19	0.90	33.15	0.28	2.02	0.02	35.39	0.11	21.57	0.90	0.06	0.11	0.00	0.39	0.39	0.22	0.39	100.00
	mean 0-50	3.36	3.12	7.86	8.23	0.07	0.97	0.01	57.17	7.48	11.21	0.34	0.06	0.06	0.04	0.00	0.00	0.02	0.00	100.00
	mean 50-200	1.73	3.03	1.60	46.01	0.78	3.92	0.04	26.77	0.40	13.24	0.94	0.02	0.16	0.01	0.75	0.31	0.28	0.28	100.00
	mean Nansen Basin	4.57	4.23	5.59	15.29	0.30	1.74	0.00	54.12	5.29	8.14	0.41	0.06	0.11	0.06	0.03	0.03	0.04	0.04	100.00
	mean Amundsen Basin	1.91	2.17	8.02	12.72	0.07	1.14	0.02	51.38	7.36	14.30	0.44	0.05	0.05	0.02	0.18	0.10	0.10	0.01	100.00

App. Tab. 4: Abundances [ind m⁻³] and percentual shares for all non-copepod taxa in the two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "cruise/station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)

abundance [ind. m⁻³]

	station	Amphipoda	Foraminifera	Ostracoda	Appendicularia	Chaetognatha	Polychaeta	Siphonophorae	Cnidaria	Cirripedia	Radiolaria	Bryozoa	Gastropoda	sum
Nansen Basin	PS 80 / 226_0	0,97	117,33	0,00	0,00	0,48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	118,79
	PS 80 / 243_0	0,00	76,44	0,44	36,89	2,67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	116,44
	PS 80 / 261_0	1,44	155,28	1,23	5,74	3,59	0,21	0,00	0,00	0,82	0,00	0,00	0,00	168,31
	PS 80 / 386_0	0,17	10,67	0,00	0,00	2,17	0,00	0,00	0,00	0,00	0,00	0,00	0,00	13,00
Amundsen Basin	PS 80 / 279_0	0,53	61,87	2,67	0,36	5,07	0,09	0,00	0,09	0,00	0,00	0,00	0,00	70,67
	PS 80 / 328_0	4,44	91,56	4,89	15,56	9,11	0,67	0,67	0,89	0,00	0,00	0,00	0,00	127,78
	PS 80 / 337_0	0,21	99,41	1,39	0,96	1,28	1,17	0,00	0,21	0,00	0,00	0,00	0,00	104,64
	PS 80 / 351_0	1,17	75,17	0,00	2,83	1,83	0,17	0,00	0,00	0,00	0,00	0,00	0,00	81,17
	PS 80 / 367_0	0,08	47,79	0,38	0,31	9,38	0,08	0,00	0,00	0,00	0,00	0,00	0,00	58,03
Nansen Basin	PS 80 / 226_50	0,17	15,14	1,51	0,09	5,20	0,04	0,30	0,00	0,00	1,38	0,00	0,00	23,83
	PS 80 / 243_50	1,09	10,39	3,08	0,00	6,02	0,14	0,00	0,00	0,00	0,00	0,00	0,00	20,72
	PS 80 / 261_50	0,00	24,98	2,66	0,00	2,51	1,10	0,02	0,00	0,00	0,00	0,00	0,00	31,27
	PS 80 / 386_50	0,26	5,68	1,68	0,21	3,26	0,47	0,00	0,00	0,00	0,21	0,00	0,00	11,79
Amundsen Basin	PS 80 / 279_50	0,02	3,41	6,80	0,00	4,24	3,71	0,27	0,39	0,00	0,00	0,00	0,00	18,85
	PS 80 / 328_50	2,28	3,97	4,10	0,07	2,47	1,95	1,43	0,00	0,00	0,00	0,00	0,26	16,52
	PS 80 / 337_50	0,11	48,43	7,19	0,00	2,11	5,19	0,49	0,00	0,00	0,22	0,22	0,00	63,95
	PS 80 / 351_50	0,00	10,42	0,95	0,00	4,11	0,63	0,00	0,05	0,00	1,16	0,00	0,05	17,37
	PS 80 / 367_50	0,00	4,10	2,00	0,10	4,75	0,40	0,25	0,10	0,00	0,00	0,00	0,00	11,70
	mean 0-50	1,00	81,72	1,22	6,96	3,95	0,26	0,07	0,13	0,09	0,00	0,00	0,00	95,42
	mean 50-200	0,44	14,06	3,33	0,05	3,85	1,51	0,31	0,06	0,00	0,33	0,02	0,03	24,00
	mean Nansen Basin	0,51	51,99	1,33	5,37	3,24	0,24	0,04	0,00	0,10	0,20	0,00	0,00	63,02
	mean Amundsen Basin	0,88	44,61	3,04	2,02	4,44	1,41	0,31	0,17	0,00	0,14	0,02	0,03	57,07

percentual share [%]

	station	Amphipoda	Foraminifera	Ostracoda	Appendicularia	Chaetognatha	Polychaeta	Siphonophorae	Cnidaria	Cirripedia	Radiolaria	Bryozoa	Gastropoda	sum
Nansen Basin	PS 80 / 226_0	0,82	98,78	0,00	0,00	0,41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00
	PS 80 / 243_0	0,00	65,65	0,38	31,68	2,29	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00
	PS 80 / 261_0	0,85	92,26	0,73	3,41	2,13	0,12	0,00	0,00	0,49	0,00	0,00	0,00	100,00
	PS 80 / 386_0	1,28	82,05	0,00	0,00	16,67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00
Amundsen Basin	PS 80 / 279_0	0,75	87,55	3,77	0,50	7,17	0,13	0,00	0,13	0,00	0,00	0,00	0,00	100,00
	PS 80 / 328_0	3,48	71,65	3,83	12,17	7,13	0,52	0,52	0,70	0,00	0,00	0,00	0,00	100,00
	PS 80 / 337_0	0,20	95,01	1,33	0,92	1,22	1,12	0,00	0,20	0,00	0,00	0,00	0,00	100,00
	PS 80 / 351_0	1,44	92,61	0,00	3,49	2,26	0,21	0,00	0,00	0,00	0,00	0,00	0,00	100,00
	PS 80 / 367_0	0,13	82,37	0,66	0,53	16,17	0,13	0,00	0,00	0,00	0,00	0,00	0,00	100,00
Nansen Basin	PS 80 / 226_50	0,72	63,54	6,32	0,36	21,84	0,18	1,26	0,00	0,00	5,78	0,00	0,00	100,00
	PS 80 / 243_50	5,28	50,17	14,85	0,00	29,04	0,66	0,00	0,00	0,00	0,00	0,00	0,00	100,00
	PS 80 / 261_50	0,00	79,88	8,50	0,00	8,03	3,51	0,08	0,00	0,00	0,00	0,00	0,00	100,00
	PS 80 / 386_50	2,23	48,21	14,29	1,79	27,68	4,02	0,00	0,00	0,00	1,79	0,00	0,00	100,00
Amundsen Basin	PS 80 / 279_50	0,13	18,11	36,09	0,00	22,51	19,66	1,42	2,07	0,00	0,00	0,00	0,00	100,00
	PS 80 / 328_50	13,78	24,02	24,80	0,39	14,96	11,81	8,66	0,00	0,00	0,00	0,00	1,57	100,00
	PS 80 / 337_50	0,17	75,74	11,24	0,00	3,30	8,11	0,76	0,00	0,00	0,34	0,34	0,00	100,00
	PS 80 / 351_50	0,00	60,00	5,45	0,00	23,64	3,64	0,00	0,30	0,00	6,67	0,00	0,30	100,00
	PS 80 / 367_50	0,00	35,04	17,09	0,85	40,60	3,42	2,14	0,85	0,00	0,00	0,00	0,00	100,00
	mean 0-50	1,05	85,64	1,28	7,29	4,14	0,28	0,08	0,14	0,10	0,00	0,00	0,00	100,00
	mean 50-200	1,82	58,58	13,87	0,21	16,05	6,31	1,28	0,25	0,00	1,37	0,10	0,14	100,00
	mean Nansen Basin	0,81	82,50	2,10	8,52	5,14	0,39	0,06	0,00	0,16	0,31	0,00	0,00	100,00
	mean Amundsen Basin	1,55	78,18	5,32	3,54	7,77	2,46	0,54	0,30	0,00	0,24	0,04	0,05	100,00
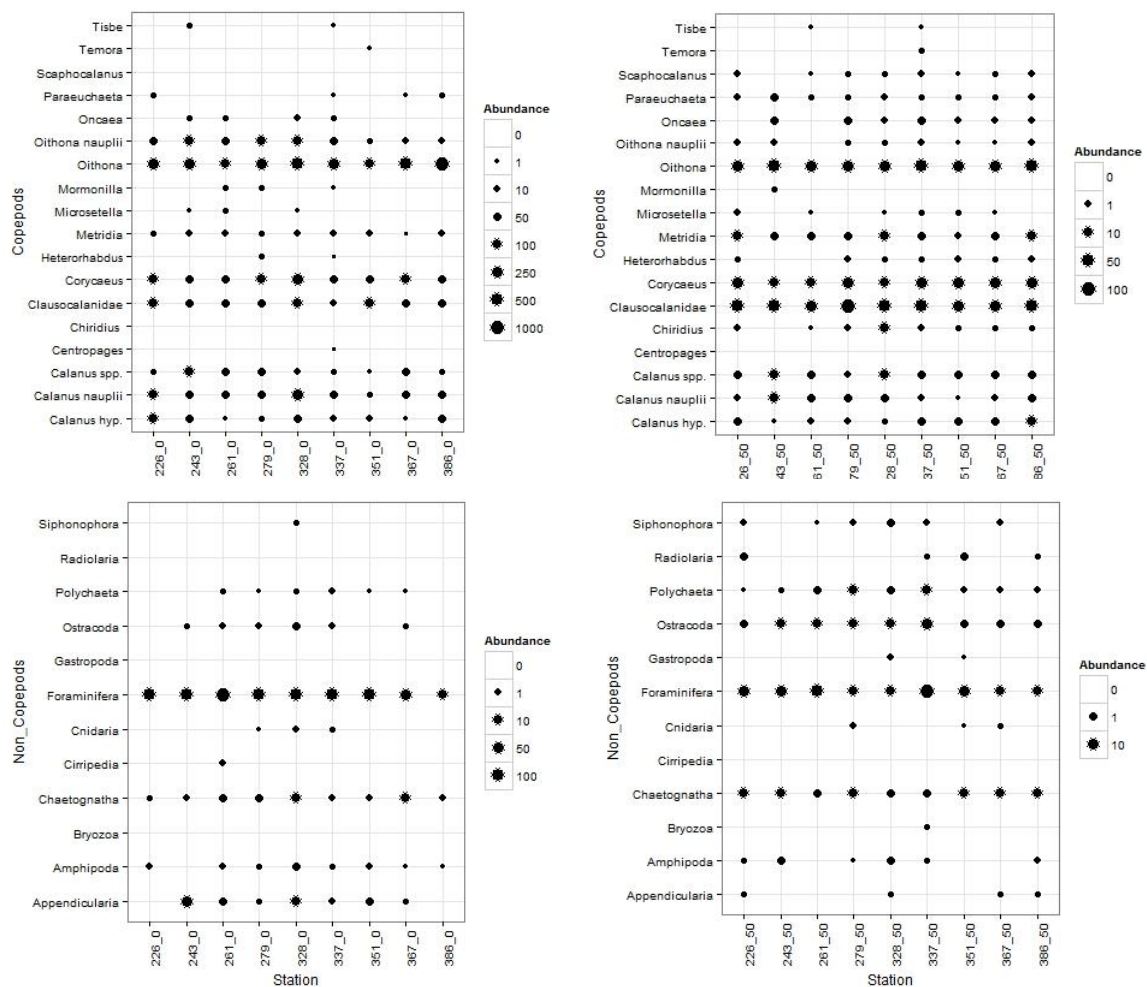
App. Fig. 1: Pooled abundances for all copepod and non-copepod taxa in the two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range)
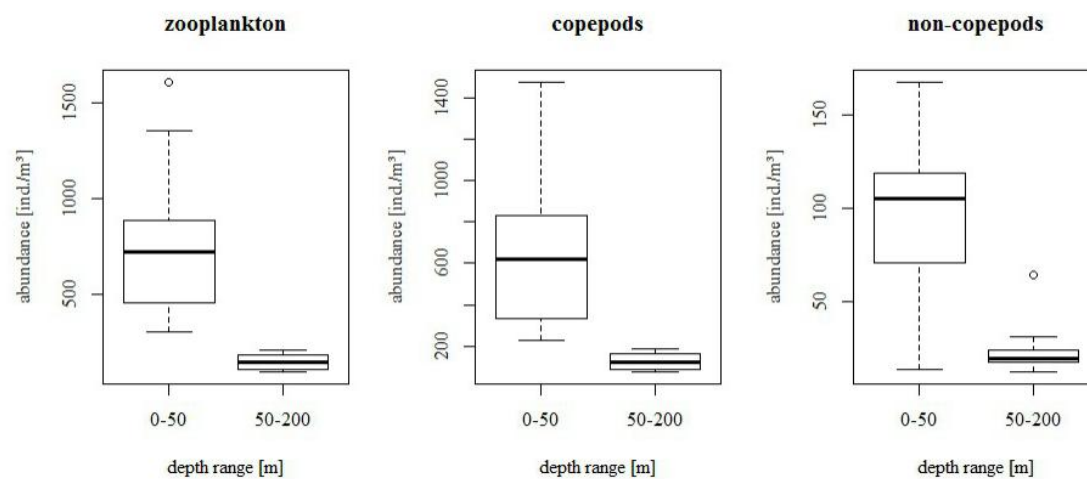
App. Fig. 2: Boxplots for significant differences in abundances between the two depth layers (0-50 m & 50-200 m) for zooplankton, copepods, and non-copepods
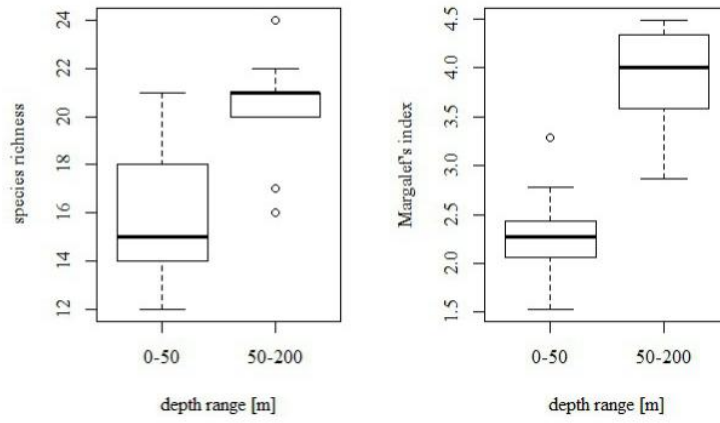
App. Fig. 3: Boxplots for significant differences between the two depth layers for species richness and Margalef's indices

App. Tab. 5: Presence and absence for developmental stages of *Calanus hyperboreus*, *Calanus glacialis*, and *Calanus finmarchicus* in the 0-200 m depth layer of all MultiNet stations during the ARK XXVII/ 3 expedition of *Polarstern*

	Calanus hyperboreus	AF	CV	CIV	CIII	CII	CI
Nansen Basin	PS 80 / 226	x	x	x	x		
	PS 80 / 243	x	x				
	PS 80 / 261	x	x	x			
	PS 80 / 386	x	x	x	x	x	x
Amundsen Basin	PS 80 / 279	x	x	x	x	x	x
	PS 80 / 328	x			x		
	PS 80 / 337	x	x	x	x		
	PS 80 / 351	x	x	x	x	x	
	PS 80 / 367	x	x				

	Calanus glacialis	AF	CV	CIV	CIII	CII	CI
Nansen Basin	PS 80 / 226		x	x		x	x
	PS 80 / 243	x	x	x			
	PS 80 / 261	x	x	x		x	x
	PS 80 / 386	x	x	x	x	x	x
Amundsen Basin	PS 80 / 279	x	x	x		x	
	PS 80 / 328	x	x		x	x	x
	PS 80 / 337	x	x		x		
	PS 80 / 351	x	x		x	x	
	PS 80 / 367	x	x	x		x	x

	Calanus finmarchicus	AF	CV	CIV	CIII	CII	CI
Nansen Basin	PS 80 / 226	x	x		x		
	PS 80 / 243	x	x	x			
	PS 80 / 261	x		x	x	x	x
	PS 80 / 386	x	x	x	x	x	
Amundsen Basin	PS 80 / 279	x	x		x	x	
	PS 80 / 328	x	x		x	x	x
	PS 80 / 337	x	x			x	
	PS 80 / 351	x		x	x		
	PS 80 / 367	x	x	x	x	x	x

App. Tab. 6: Abundances [ind m⁻³] and percentual shares of all developmental stages of *Calanus hyperboreus*, *Calanus glacialis,* and *Calanus finmarchicus* in the two depth layers (0-50 m & 50-200 m) of all MutliNet stations; nomenclature of samples: "cruise/station_depth range" ("_0" = 0-50 m depth range & "_50" = 50-200 m depth range); calculations based on published data of Madsen, Nielsen, Hansen (2001)

50 – 200 m — abundance [ind. m⁻³]

Calanus hyperboreus

Station	AF	CV	CIV	CIII	CII	CI	sum
PS 80 / 226_50	0,13	0,13	0,52	1,55	0,00	0,00	2,32
PS 80 / 243_50	0,00	0,21	0,00	0,00	0,00	0,00	0,21
PS 80 / 261_50	0,49	0,20	0,20	0,00	0,00	0,00	0,88
PS 80 / 386_50	1,05	0,42	1,58	0,95	1,05	0,00	5,05
PS 80 / 279_50	0,29	0,00	0,00	0,00	0,00	0,00	0,29
PS 80 / 328_50	0,59	0,00	0,00	0,20	0,00	0,00	0,78
PS 80 / 337_50	0,32	0,11	0,00	0,00	0,00	0,00	0,43
PS 80 / 351_50	1,16	0,53	0,21	0,00	0,11	0,00	2,00
PS 80 / 367_50	1,40	0,30	0,00	0,00	0,00	0,00	1,70
mean Nansen Basin	0,42	0,24	0,57	0,62	0,26	0,00	2,11
mean Amundsen Basin	0,75	0,19	0,04	0,04	0,02	0,00	1,04
mean over all stations	0,60	0,21	0,28	0,30	0,13	0,00	1,52
relative abundances [%]	39,74	13,79	18,30	19,69	8,47	0,00	100,00

Calanus glacialis

Station	AF	CV	CIV	CIII	CII	CI	sum
PS 80 / 226_50	0,00	0,00	0,00	0,00	0,00	0,00	0,00
PS 80 / 243_50	0,21	2,87	0,00	0,00	0,00	0,00	3,08
PS 80 / 261_50	2,15	0,20	0,00	0,00	0,00	0,00	2,34
PS 80 / 386_50	0,21	0,32	0,00	0,00	0,00	0,00	0,53
PS 80 / 279_50	2,34	0,20	0,29	0,00	0,20	0,00	3,02
PS 80 / 328_50	6,24	0,78	0,00	0,00	0,00	0,00	7,02
PS 80 / 337_50	4,00	0,76	0,00	0,00	0,00	0,00	4,76
PS 80 / 351_50	1,26	0,00	0,00	0,00	0,00	0,00	1,26
PS 80 / 367_50	0,20	0,20	0,10	0,00	0,00	0,00	0,50
mean Nansen Basin	0,64	0,85	0,00	0,00	0,00	0,00	1,49
mean Amundsen Basin	2,81	0,39	0,08	0,00	0,04	0,00	3,31
mean over all stations	1,85	0,59	0,04	0,00	0,02	0,00	2,50
relative abundances [%]	73,78	23,61	1,74	0,00	0,87	0,00	100,00

Calanus finmarchicus

Station	AF	CV	CIV	CIII	CII	CI	sum
PS 80 / 226_50	0,52	0,13	0,00	0,13	0,00	0,00	0,77
PS 80 / 243_50	1,03	4,51	0,00	0,00	0,00	0,00	5,54
PS 80 / 261_50	0,20	0,00	0,20	0,10	0,10	0,00	0,59
PS 80 / 386_50	0,21	0,42	0,11	0,11	0,00	0,00	0,84
PS 80 / 279_50	0,10	0,10	0,00	0,20	0,00	0,00	0,39
PS 80 / 328_50	0,59	0,00	0,00	0,00	0,00	0,00	0,59
PS 80 / 337_50	0,32	0,11	0,00	0,00	0,97	0,00	1,41
PS 80 / 351_50	0,21	0,00	0,21	0,42	0,00	0,00	0,84
PS 80 / 367_50	0,60	0,30	0,10	0,10	0,00	0,00	1,10
mean Nansen Basin	0,49	1,27	0,08	0,08	0,02	0,00	1,94
mean Amundsen Basin	0,36	0,10	0,06	0,14	0,19	0,00	0,86
mean over all stations	0,42	0,62	0,07	0,12	0,12	0,00	1,34
relative abundances [%]	31,21	46,16	5,06	8,69	8,87	0,00	100,00

0 – 50 m — abundance [ind. m⁻³]

Calanus hyperboreus

Station	AF	CV	CIV	CIII	CII	CI	sum
PS 80 / 226_0	2,91	13,09	24,73	7,27	0,00	0,00	48,00
PS 80 / 243_0	9,33	6,67	0,00	0,00	0,00	0,00	16,00
PS 80 / 261_0	0,31	0,62	0,31	0,00	0,00	0,00	1,23
PS 80 / 386_0	0,00	0,00	2,00	5,33	17,33	1,00	25,67
PS 80 / 279_0	2,13	6,40	2,13	5,33	9,60	8,53	34,13
PS 80 / 328_0	0,00	0,00	0,00	1,33	0,00	0,00	1,33
PS 80 / 337_0	0,00	3,52	0,32	1,92	0,67	0,00	5,76
PS 80 / 351_0	0,67	1,00	1,67	0,33	0,67	0,00	4,33
PS 80 / 367_0	0,31	0,00	0,00	0,00	0,00	0,00	0,31
mean Nansen Basin	3,14	5,09	6,76	3,15	4,33	0,25	22,72
mean Amundsen Basin	0,62	2,18	0,82	1,78	2,05	1,71	9,17
mean over all stations	1,74	3,48	3,46	2,39	3,07	1,06	15,20
relative abundances [%]	11,45	22,88	22,78	15,74	20,18	6,97	100,00

Calanus glacialis

Station	AF	CV	CIV	CIII	CII	CI	sum
PS 80 / 226_0	0,00	2,91	7,27	0,00	1,45	10,18	21,82
PS 80 / 243_0	1,33	0,00	1,33	0,00	0,00	0,00	2,67
PS 80 / 261_0	1,23	0,92	2,15	0,00	0,31	1,54	6,15
PS 80 / 386_0	1,00	1,33	0,67	11,67	7,33	2,00	24,00
PS 80 / 279_0	28,80	16,00	0,00	0,00	1,07	0,00	45,87
PS 80 / 328_0	5,33	0,00	0,00	8,00	6,67	4,00	24,00
PS 80 / 337_0	2,24	1,28	0,00	0,96	0,00	0,00	4,48
PS 80 / 351_0	1,00	0,33	0,00	0,33	0,33	0,00	2,00
PS 80 / 367_0	2,15	0,00	0,00	0,00	0,62	0,62	3,38
mean Nansen Basin	0,89	1,29	2,86	2,92	2,27	3,43	13,66
mean Amundsen Basin	7,91	3,52	0,00	1,86	1,74	0,92	15,95
mean over all stations	4,79	2,53	1,27	2,33	1,98	2,04	14,93
relative abundances [%]	32,07	16,95	8,50	15,60	13,23	13,65	100,00

Calanus finmarchicus

Station	AF	CV	CIV	CIII	CII	CI	sum
PS 80 / 226_0	1,45	1,45	0,00	0,00	0,00	0,00	2,91
PS 80 / 243_0	12,00	57,33	13,33	0,00	0,00	0,00	82,67
PS 80 / 261_0	0,31	0,00	0,31	0,00	1,23	12,92	14,77
PS 80 / 386_0	0,33	1,00	0,33	0,00	0,33	0,00	2,00
PS 80 / 279_0	0,00	0,00	0,00	1,07	4,27	0,00	5,33
PS 80 / 328_0	2,67	1,33	0,00	4,00	25,33	30,67	64,00
PS 80 / 337_0	0,64	0,64	0,00	0,00	0,00	0,00	1,28
PS 80 / 351_0	0,33	0,00	0,00	0,00	0,00	0,00	0,33
PS 80 / 367_0	5,23	3,08	0,00	1,23	3,69	1,23	14,46
mean Nansen Basin	3,52	14,95	3,49	0,00	0,39	3,23	25,59
mean Amundsen Basin	1,77	1,01	0,00	1,26	6,66	6,38	17,08
mean over all stations	2,55	7,20	1,55	0,70	3,87	4,98	20,86
relative abundances [%]	12,23	34,53	7,44	3,35	18,57	23,87	100,00

App. Fig. 4: Boxplots for significant differences in abundances [ind m^{-3}] between the two depth layers for *Calanus hyperboreus*, *Calanus glacialis*, **and** *Calanus finmarchicus*

App. Tab. 7: Abundances [ind. m^{-3}] for developmental stages of the three *Calanus hyperboreus*, *Calanus glacialis*, and *Calanus finmarchicus* of all SUIT 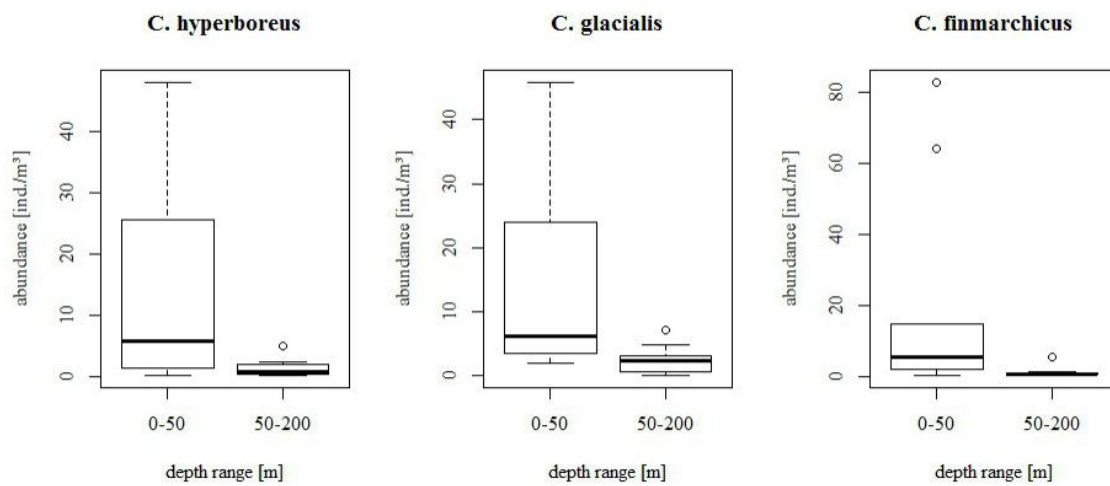stations during the ARK XXVII/ 3 expedition of *Polarstern;* data were provided by Carmen David (Alfred-Wegener-Insitute)

Calanus hyperboreus	AF	CV	CIV	CIII	CII	CI	AF-CI
204	0,00	0,00	0,00	0,00	0,00	0,00	0,00
216	0,04	0,00	0,00	0,00	0,00	0,00	0,04
223	0,05	0,09	3,89	1,23	0,00	2,21	7,46
233	0,07	0,88	2,10	0,07	0,00	0,04	3,15
248	0,32	3,28	1,34	0,12	0,24	0,08	5,39
258	0,08	0,38	0,10	0,02	2,18	7,00	9,76
276	0,00	0,08	0,39	0,00	0,27	0,57	1,32
285	0,02	0,10	0,19	0,33	0,64	0,00	1,29
321	0,00	0,01	0,01	0,30	0,68	0,44	1,45
331	0,00	0,00	0,01	0,71	1,48	0,37	2,56
333	0,01	0,01	0,06	0,41	0,85	0,28	1,61
345	0,00	0,00	0,00	0,30	0,03	0,00	0,34
397	0,00	0,05	0,05	1,12	0,55	0,00	1,78
mean over all stations	0,05	0,37	0,63	0,36	0,53	0,84	2,78

Calanus glacialis	AF	CV	CIV	CIII	CII	CI	AF-CI
204	0,49	24,62	3,38				28,48
216	0,01	0,02	0,00				0,04
223	0,23	1,32	0,41				1,96
233	3,15	8,41	1,02				12,57
248	4,01	23,27	3,24				30,53
258	1,81	2,14	0,20				4,15
276	0,88	0,26	0,04				1,18
285	0,41	1,79	0,02				2,22
321	0,01	0,17	0,00				0,18
331	0,03	0,12	0,01				0,15
333	0,20	0,28	0,02				0,50
345	0,04	0,05	0,09				0,18
397	0,20	0,91	0,02				1,12
mean over all stations	0,88	4,87	0,65				6,40

Calanus finmarchicus	AF	CV	CIV	CIII	CII	CI	AF-CI
204	0,00	0,00					0,00
216	0,00	0,00					0,00
223	0,09	0,11					0,20
233	0,00	0,00					0,00
248	2,07	24,97					27,04
258	0,00	0,00					0,00
276	0,00	0,00					0,00
285	0,00	0,00					0,00
321	0,00	0,00					0,00
331	0,00	0,00					0,00
333	0,00	0,00					0,00
345	0,00	0,00					0,00
397	0,00	0,00					0,00
mean over all stations	0,17	1,93					2,10

App. Tab. 8: Integrated Abundances [ind. m^{-3}] for two developmental stages (adult females and copepodid stage V) of *Calanus hyperboreus, Calanus glacialis, and Calanus finmarchicus* of seven SUIT stations and seven MultiNet stations during the ARK XXVII/ 3 expedition of *Polarstern; n*ote: for better comparison only SUIT and MultiNet stations from similar locations were chosen

abundance [ind. m^{-3}]

SUIT	AF-CV	AF-CV	AF-CV
station	*Calanus hyperboreus*	*Calanus glacialis*	*Calanus finmarchicus*
223	0,14	1,55	0,20
248	3,61	27,28	27,04
258	0,46	3,95	0,00
397	0,05	1,11	0,00
276	0,08	1,14	0,00
321	0,02	0,18	0,00
345	0,00	0,09	0,00

abundance [ind. m^{-3}]

MutliNet	AF-CV	AF-CV	AF-CV
station	*Calanus hyperboreus*	*Calanus glacialis*	*Calanus finmarchicus*
226	8,13	1,45	1,78
243	8,10	2,21	37,44
261	0,80	2,25	0,25
386	0,74	1,43	0,98
279	4,41	23,67	0,10
328	0,29	6,18	2,29
337	1,98	4,14	0,86