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Cruise report SI_ARCTIC/Arctic Ecosystem survey R/V *Helmer Hanssen*, 17 August-7 September 2015

Survey: 2015843

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Content

Introduction

The survey was a joint SI_ARCTIC and Barents Sea Ecosystem survey. The main goal of the survey was thus twofold:

1. Conduct baseline studies/process studies of the Arctic Ocean ecosystem (oceanography, nutrients, phytoplankton, zooplankton, fish, benthos, marine mammals and birds). (SI_ARCTIC – exploratory focus).
2. Conduct the northern part of the joint IMR-PINRO Barents Sea Ecosystem survey. (The Barents Sea Ecosystem survey – annual monitoring focus).

The main scientific questions addressed in SI_ARCTIC 2015 survey were:

- What is the status and variability of temperature, sea ice cover and ocean acidification (OA) state in the shelf and deep basin in the ice-covered areas north of Svalbard?
- Which species/communities are present in the region?
- Who is eating whom?
- Are there changes regarding distribution and species composition compared to 2014?
- Mesopelagic layer
  - ➢ What are the dominating species in the different regions?
  - ➢ What is causing the mesopelagic layer (at these latitudes/light regimes)?
  - ➢ Does the layer, or parts of the layer, perform dial vertical migration?
- Do we find hotspots, and if so; what are the mechanisms driving the intensity/location?
- How far from the shelf break do we find cod in the pelagic?

To answer the above questions, we, in addition to standard trawl and plankton sampling, had special focus on obtaining vertically resolved data using acoustic measurements as well as trawl and plankton equipment in different depth layers.

The sea ice conditions were substantially better than in 2014 and the survey could cover both the shelf break and the deeper parts to the north of the shelf break as well as parts of the Yermak Plateau (Figure 1). Details of equipment and samples taken at each station are given in Table A1. During the survey, we conducted 2 case study stations, one section from shelf break and into Fram Strait (Fram Strait north), one section crossing the shelf break north of Svalbard and as far into the ice as possible (Hinlopen), a short section crossing the shelf break to the east of Hinlopen, and Ecosystem stations on a regular grid north of Svalbard and on the Yermak Plateau. In addition, lines for Greenland shark fishing were deployed two places on the slope north of Svalbard. Underway meteorological and sea surface temperature measurements and visual observations of marine mammals and sea birds were conducted. List of participants are given in Table A2.

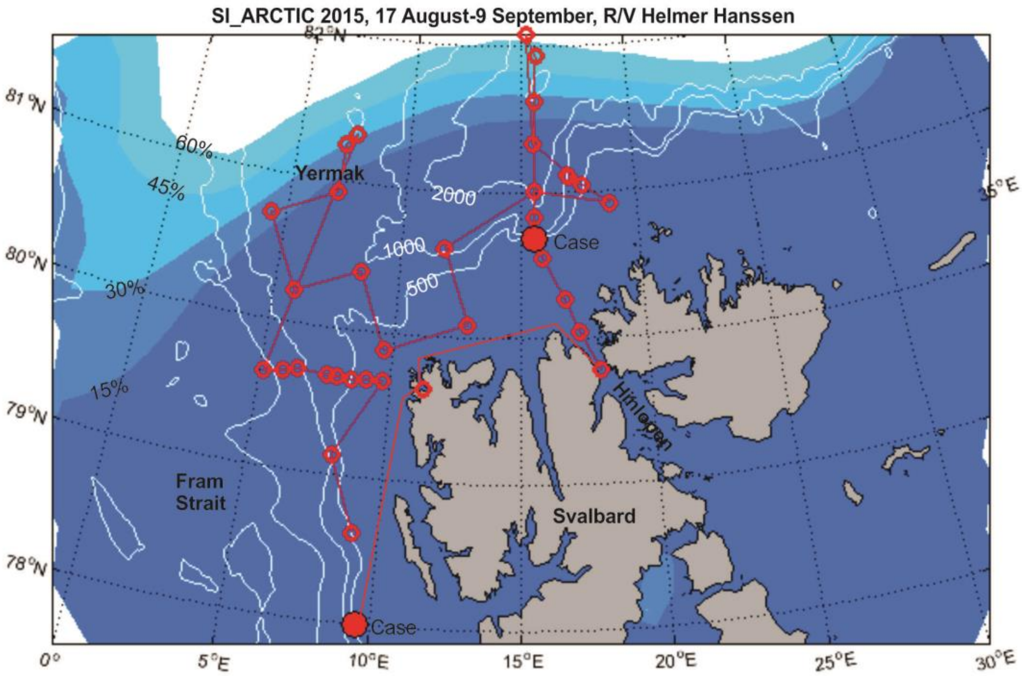


Figure 1. Cruise map showing stations (red circles), bathymetric lines (white lines) and average sea ice conditions during the survey.

Description of activity

The cruise started off on August 17, 2015 from Longyearbyen, Svalbard. We started with a case study station (Case 1) in Atlantic Water at the shelf break at approximately 480 m bottom depth to the west of Isfjorden (Figure 1). The station was extensively sampled (Table A1). Thereafter we headed northwards. Calibration of the EK60 was conducted in a fjord before starting on the Hinlopen section. Due to better ice conditions, the Hinlopen section was extended northwards compared to 2014. The northernmost part of this section was conducted in heavy ice. During sampling on this section, fishing lines for Greenland shark was deployed at two locations on the northern shelf break. This activity was part of the PhD work of Julius Nielsen.

After finishing the Hinlopen section, we worked our way westwards conducting Ecosystem stations on a regular grid (Figure 1). Several Ecosystem stations were conducted on the Yermak Plateau. Thereafter the Fram Strait north section was sampled in the same way as in 2014. A few Ecosystem stations were sampled heading southwards toward Isfjorden, and a 12 hour TS-probe station was conducted at the end before heading for Longyearbyen.

Case studies 1 and 2, the Fram Strait north section and the Hinlopen section were also sampled in 2014. Conducting identical stations/sections every year is important to evaluate inter-annual variations in the region.

Methods

Sea Ice distribution

On the first few days of the cruise, sea ice images were downloaded as netCDF files to the *Helmer Hanssen* from a University of Hamburg website (ftp://ftp-projects.zmaw.de/seaice/AMSR2/3.125km/), but lack of internet service for most of the cruise prevented getting more images until after the cruise. For information about the images see Kaleschke et al., 2001; Spreen et al, 2008; Beitsch et al., 2013). The NetCDf files were read into Matlab and the data plotted using the M_Map toolbox (Version 1.4f - http://www.eos.ubc.ca/~rich/).

Underway meteorological and oceanographic measurements

Along-track measurements were made continuously during the course of the cruise, to provide information on environmental conditions. Atmospheric measurements of air temperature, barometric pressure, wind speed and direction, other meteorological variables, plus sea surface temperature were collected along with time, latitude, and longitude at one minute intervals. These data were saved on the ship's data server on a daily basis in a several file formats including the "csv" file format. The daily csv files were moved into a single Excel "xlsx" file on separate sheets and then data of interest were imported directly into Matlab for further processing and plotting. The daily files were aggregated for display to correspond to the transect sections sampled on this cruise. There was a period on yearday 234 (22 August) when the MET system stopped logging data. Some of these data may be recovered later because a subset was telemetered from the ship to shore for use by meteorologists.

The along track data have been divided into six chronological sections to highlight the variation observed on the cruise using the CTD stations to mark beginning and ending of the sections:

1) Longyearbyen to Start of Hinlopen Transect (LB to CTD 61).
3) Hinlopen total transect South to North (CTD 61 to 76).
4) North Svalbard Shelf and Slope (CTD 76 to 78).
5) Magdelenefjorden to Northern Region on Nansenryggen (CTD 79 to 85)
6) Fram Strait transect (CTD 86 to 93)
7) West of Svalbard to Longyearbyen (CTD 93 to LB).

Light

Along-track measurements of visible light (in LUX) above sea level were conducted with a Licor Model LI-1400 data logger deployed on the vessel bridge roof. The sensor was set up a couple of days after we left port and the data were logged at 5 minute intervals.

Oceanographic measurements (physical and chemical)

Hydrography

Temperature and salinity was measured on all stations using a Seabird 911plus CTD with water carousel sampler (Figure 2 and Table A1). The CTD was lowered to ~5 m above seafloor, and samples for salinity calibration were taken at every station before up-cast started.

Current speed and direction

Velocities were measured using a RDI 75 kHz ADCP as well as with a RDI Sentinel 300kHz LADCP mounted on the CTD (looking downward) on stations 84-95 (northern Yermak Plateau and Fram Strait north section). The LADCP was configured with 15 bins with bin length 8 m and the data were processed using methods common in the oceanographic community (LDEO-IX-8, Visbeck 2002). The data was corrected for magnetic declination, and the tidal components were removed from the processed profiles using the Arctic Ocean Tidal Inverse Model (AOTIM-5, Padman and Erofeeva, 2004).

Nutrients

On all CTD stations waters samples was collected from specific depths, using 5 L Niskin water bottles on the CTD-carousel sampler (Figure 2 and Table A1). At all stations the ICES standard depths were used from surface to maximum depth. For a higher and better resolution of nutrients and chlorophyll, fixed depths were selected for the upper 200m (5, 10, 20, 30, 50, 100, 150 and 200m) at all stations. A total of 36 CTD stations were sampled for nutrients. The nutrient samples were preserved with chloroform and stored in refrigerator. The samples will be analyzed at the chemistry laboratory at IMR after the cruise. The water samples will be analyzed for nitrate, nitrite, silicate, and phosphate.

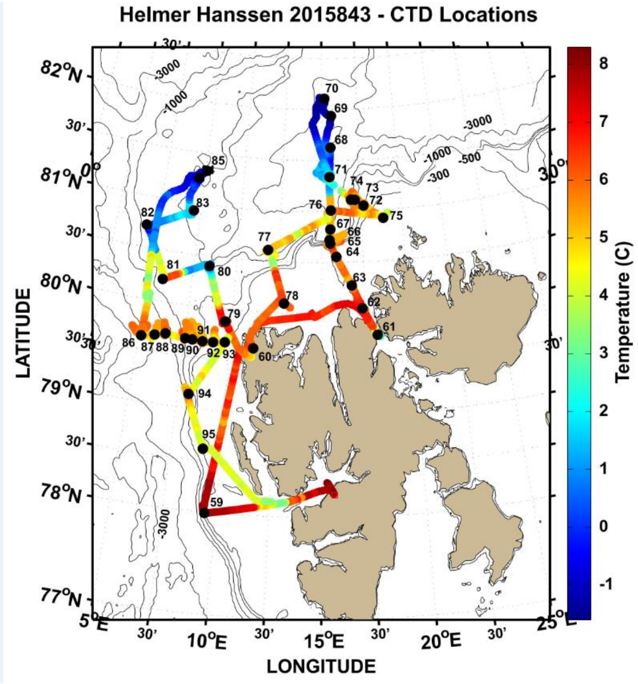


Figure 2. CTD stations with nutrient samples and phytoplankton.

The carbonate system (total alkalinity and pH)

Seawater sampling and determination of the carbonate system parameters pH and total alkalinity were performed directly onboard. Seawater samples were also collected for determination of oxygen isotope ($\delta^{18}O$) which will be used together with total alkalinity (A_T) and salinity to investigate water mass composition and freshwater content in the study area. Another part of the project was to sample for the aragonite-forming butterfly snail *Limacina* *helicina*, which has been found to be especially sensitive for low aragonite saturation states. Sampling for the *L.helicina* was undertaken opportunistically using plankton net tows. They were stored cold in ethanol for analysis of the shell density and thickness with collaborative partners at JAMSTEC (Japan). Unfortunately, we only found a few specimens (4) and all of them had broken shells.

Water sampling was performed in whole water column at standard depths (*example for 1000m station*: 5, 10, 20, 30, 50,100, 150, 200, 400, 600, 800, bottom-10 m) from a CTD-Rosette system with 12-Niskin bottles attached. The sample bottles were filled using tubing in the bottom of the bottle to provide minimal contamination with air in borosilicate glass bottles (250 ml) following standard protocols (Dickson et al., 2007). Determination of total alkalinity (A_T) and pH was performed directly onboard after a few hours thermostating to about 15 °C. A_T was determined by potentiometric titration with weak hydrochloric acid (0.05M) on a Metrohm® Titrando system with a pH sensitive glass electrode with temperature measurements (Aquatrode®) after Mattsdotter et al. (2014). pH was determined using a spectrophotometer (Agilent 8453 Diode-array) and pH sensitive dye (m-cresol purple, 2 mM) and a 1 cm Quartz cuvette. 3 ml of the sample was mixed with 35 µL of the indicator dye. The pH of the indicator was measured daily using a 0.2 mm quartz cuvette and correction for the perturbation of the indicator pH was performed according to Chierici et al. (1999). The precision was performed on replicate analysis of samples and was for A_T about ±1 µmol/kg, and for pH<±0.001. The accuracy of A_T was checked daily by analysis and correction based on analysed certified reference material (CRM#134) obtained from A. Dickson (SIO, USA).
The full carbonate system (*i.e.* pH at in situ temperature, total dissolved inorganic carbon, calcium carbonate saturation state (Ω), fugacity of CO_2 and other species) will be calculated using pH and A_T in the chemical equilibrium program CO2SYS (Pierrot et al., 2006). Samples for nutrients were taken in parallel to pH and A_T for post-cruise analysis. Phosphate and silicic acid will also be used in CO2SYS for proper calculation of derived parameters.
Preliminary calculations were performed onboard. Samples for $\delta^{18}O$ were collected in HDPE 25 ml vials, lids were wrapped with parafilm, and stored cold and dark in cooling room onboard until post-cruise analysis.

Water samples for pH and A_T was taken at all CTD-Rosette stations except five stations (#60, #72-74, 79, see Table A1 for summary). In total 350 seawater samples were taken from the whole water column at 31 stations for determination of pH and A_T. These samples were all analyzed directly onboard. $\delta^{18}O$ samples were collected at 7 stations (Table A1) from the full water column (12 depths) and at 12 stations from 200 m to surface (5 or 6 depths). A total of 146 samples were collected for post-cruise analysis of $\delta^{18}O$.

Phytoplankton

Quantitative samples

At all standard CTD stations (Figure 2 and Table A1) an approximately 100 ml water sample from 5 m depth were transferred to a glass bottle. The samples were preserved with a neutralized lugol solution. The samples will be analyzed at the algae laboratory at IMR and worked up using the Uthermöl method (IOC Manual and Guides, no 55.2010) after the cruise.

Qualitative samples

At all standard CTD stations (Figure 2 and Table A1) a vertical phytoplankton net hauls were made from 30 to 0 m. The phytoplankton net has a mesh size of 10 µm and was hauled at 0.1 m/s. The samples were preserved with neutralized formalin. The samples will be analyzed using light microscope after the cruise.

Biomass – chlorophyll a

Samples for chlorophyll *a* were collected at all stations (Figure 2 and Table A1). Chlorophyll samples have been collected from ICES standard depth from 0-200m. Samples have been taken from the same bottles and stations as nutrients. 265 ml water samples have been filtered onto GF/F filters (0.45 µm mesh), placed in vials and frozen at -20°C. All chlorophyll samples will be analyzed after the cruise at the IMR chemistry laboratory.

Fluorescence data

Fluorescence data (Seapoint sensor) from the CTD gives an estimate (relative distribution) of phytoplankton chlorophyll (Fluorescence) distribution. Fluorescence profiles were obtained from all CTD stations.

Oxygen data

Oxygen data were collected at all stations using oxygen sensor (SBE 43) mounted on the CTD. No samples were taken for calibration using Winkler's method.

Zooplankton collections

Zooplankton and micro-nekton were sampled with four different sampling systems, a WP2/Juday net pair, a 0.25 m2 Multinet system, a MIK net system, and a Macroplankton trawl. The principal zooplankton sampling system was a combined WP2 and Juday net pair mounted on a single frame with two rings on which the net mouths were tied. The tow pair was used at most stations where a CTD was deployed that collected water samples for nutrients and chlorophyll measurements (70 tows – Figure 3 and Table A1). The frame was attached to the end of the towing wire and the nets deployed vertically, usually to within 10 m of the seafloor. Both nets had 180 µm mesh. At most stations, two tows were taken back-to-back. The sample from the first tow was processed using a standard IMR procedure. The WP2 sample was split and 50% was fixed in borax-buffered 4% formaldehyde for identification and enumeration purposes. The other 50% was used for biomass estimation according to IMR standards. This part was divided into 3 size fractions using sieves with mesh-sizes 2000, 1000 and 180 µm. Most animals retained on the 2000 µm sieve were sorted, identified, counted, and individual lengths of amphipods, fish, krill, and shrimps were measured prior to rinsing in fresh water. The biomass retained on the 1000 and 180 µm as well as the identified animals belonging specific groups; Chaetognaths, Amphipods, fish, krill, shrimps, and the copepods *Pareuchaeta* sp. and *Calanus hyperboreus* retained on the 2000 µm sieve were put on pre-weighed aluminum dishes and dried in an oven at 60°C overnight, where after they were packed and stored in a freezer at -20°C awaiting new drying and weighing in the onshore laboratory at IMR. After drying the summed dry biomass per group is measured. The Juday net catch from the first haul was preserved in 95% alcohol for later genetics analyses. For the catches from the second tow pair, the WP2 sample was preserved in 95% alcohol for genetics work at the University of Connecticut. The second Juday net sample was used for picking individual species for genetic, stable isotope and fatty acid analyses. Some species were preserved individually by freezing in liquid nitrogen after which they were stored in a -80°C freezer, or directly stored in the -80°C freezer depending on the analyzes pending. Others were preserved in alcohol. There is more detail about the intended genetic analyses in the Genetics portion of this cruise report.

The MIK net was used seven times to collect larger macroplankton and micronekton (Figure 3 and Table A1). It had a circular mouth opening of 2 m diameter and a net with a mesh size of ~1.6 mm. Two Simrad acoustic sensors (depth and velocity) were intended to be deployed on the MIK mouth to determine its velocity through the water and depth during a tow. However, due to a malfunctioning velocity sensor, only the depth sensor was used. Contrary to how this system was operated in 2014, during the 2015 mission the MIK was generally towed in a W-like manner targeting acoustic layers to obtain a better quantitative understanding of which types of zooplankton were affiliated with these kinds of scattering structures. The samples were generally split into fractions suitable for analysis. One fraction was used to determine bulk biomass of the sample. Another was preserved in formalin for identification and enumeration purposes. A third fraction was preserved in alcohol for genetic studies, and the remainder of the sample was used for picking individual species for genetic and for stable isotope analyses as described above.

The Multinet system with five 180 μm mesh nets was used for stratified sampling on seven occasions to determine the depth distribution of the zooplankton (Figure 3 and Table A1). The Multinet was rigged and towed obliquely. On the final tow on 1 September (Station 86), the sampling system did not sample properly due to a failure in the underwater electronics package.

The Macroplankton trawl was deployed on one occasion north of Svalbard at 81.349°N; 15.299°E (Table A1). This trawl has a 36 square meter opening and a net with a mesh size of 3 mm all the way from trawl opening to the cod-end. The flow through the mouth opening of the trawl, symmetry and trawl performance should have been measured acoustically with a Scanmar trawl speed/ symmetry sensor, but due to malfunction only a depth sensor was used to keep track of depth of trawling. Upon completion of the haul the catch were weighed, and the entire catch or subsample were sorted, weighed, and measured at the desired taxonomic resolution, usually to species level where possible. Some species were picked from the sample alive and preserved for genetics analyses. This trawl should have seen more use, but it needed to be changed in place of the Harstad Trawl and this took too much time.

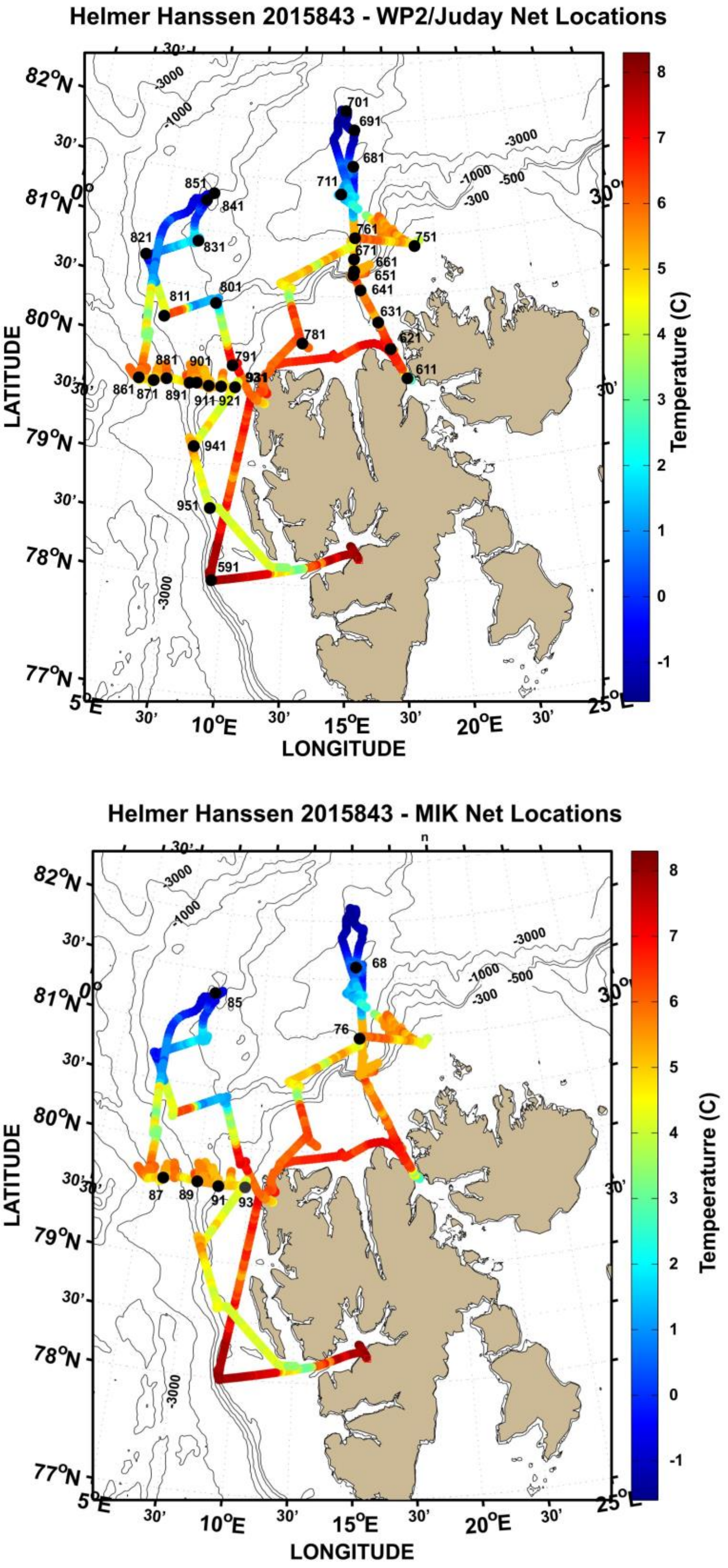


Figure 3. Location of zooplankton and micronekton sample collections. WP2/Juday paired net system (upper). MIK net system (lower).

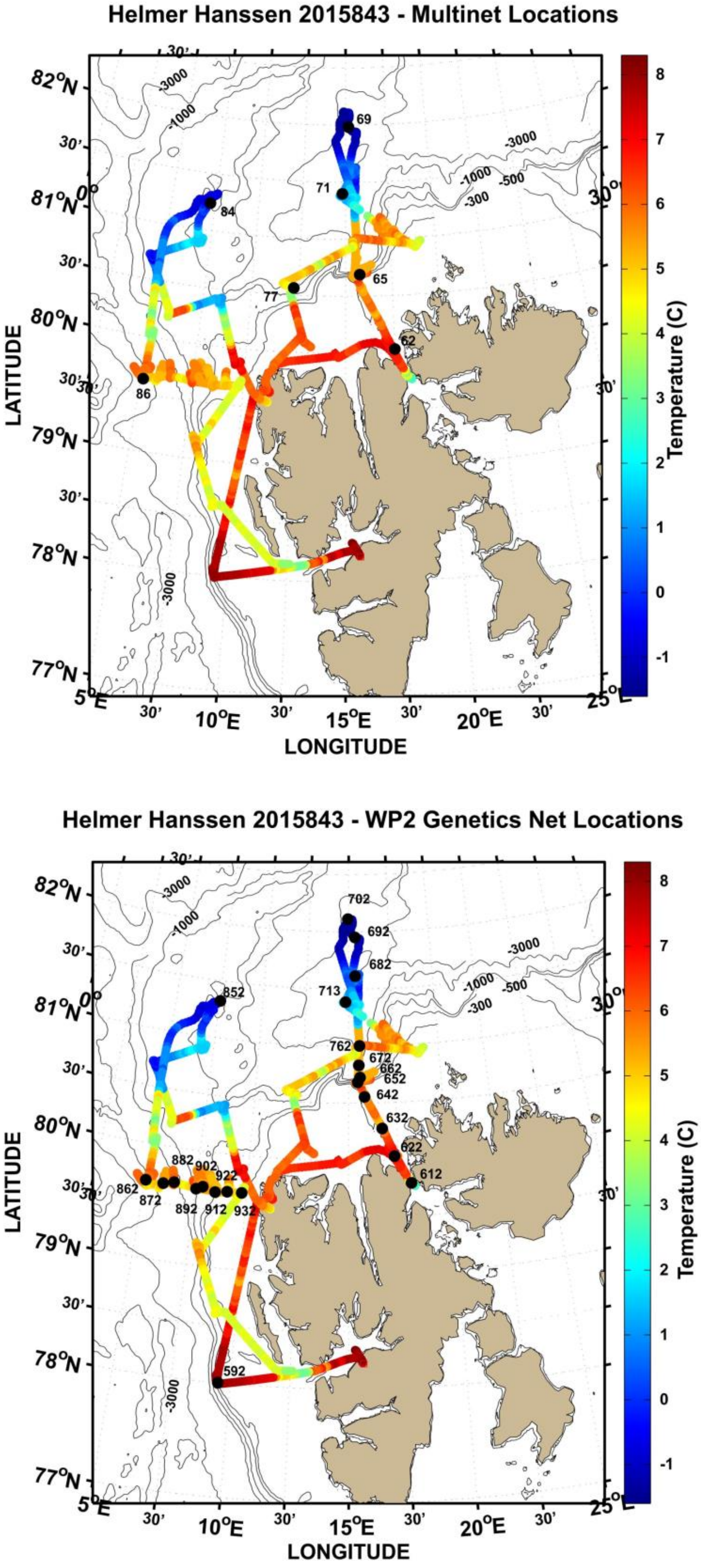


Figure 3 continues. Location of zooplankton and micronekton sample collections. Multinet system (upper). Genetics zooplankton sample collections (lower).

Zooplankton population genetics and environmental transcriptomics

The primary goals for Ann Bucklin's *(University of Connecticut, USA)* collaborative participation in SI_ARCTIC are the analysis of zooplankton species diversity, population genetics, and environmental transcriptomics (gene expression). The zooplankton samples collected during the cruise will be examined for species of interest, for which the mitochondrial cytochrome oxidase subunit I (COI) barcode region will be sequenced. The primary zooplankton groups for our particular interest are crustaceans, including copepods, euphausiids, and amphipods. Continued progress toward a taxonomically-comprehensive DNA barcode database for Arctic zooplankton species is intended as one goal of this SI_ARCTIC effort (see Bucklin et al., 2010, 2011). Plans for analysis of alcohol-preserved samples include high throughput sequencing of DNA extracted from unsorted samples or metagenetics (i.e., the large-scale analysis of taxon richness via the analysis of homologous genes).

Environmental transcriptomic analysis will focus on differential expression of genes hypothesized to be significant in adaptations of zooplankton to climate change, including warming and ocean acidification, will be analyzed. Analysis will include high throughput whole-transcriptome sequencing for gene expression (e.g., RNA-seq) and quantitative PCR (QPCR) analysis of genes of known physiological functions.

Particular focus is on species of the copepod genus *Calanus* (*C. finmarchicus*, *C. glacialis*, and *C. hyperboreus*) are important indicators of Arctic, Sub-Arctic, and Atlantic waters. We are using genetic approaches to develop an unbiased view of species distribution and population genetic structure of the several species, including detection of hybridization between *C. finmarchicus* and *C. glacialis* using a published molecular protocol by Smolina et al. (2014). We plan analysis using population genomic markers based on high throughput DNA sequencing to allow comparison with earlier studies of *C. finmarchicus* (e.g., Bucklin et al., 2000; Unal and Bucklin, 2010), which revealed small, but significant sub-regional scale structuring and large-scale population differentiation consistent with two, three, or four distinct populations.

Samples for genetic analysis were taken primarily from a second WP2 plankton net haul done at many stations during the 2015 SI_ARCTIC cruise (Figure 3). Samples were also obtained from some MIK and Juday net samples. Samples designated for UConn were preserved immediately in 95% undenatured ethyl alcohol (EtOH). In addition, living specimens of the target species were identified, photographed, and individually flash-frozen in liquid nitrogen for transcriptomic or gene expression analysis. See Table A3 and A4 for complete listing of LN2 flash-frozen specimens and collection information. At the end of the cruise, some specimens were transported to the University of Connecticut in a dry-shipper carried as extra baggage; other specimens remained in a -80^{o}C freezer for storage and transport to IMR (Bergen), from where onward transport to UConn will be arranged.

Fish and zooplankton acoustics

Acoustic surveying was conducted using the three scientific Simrad EK60 echo sounders of *Helmer Hanssen,* all mounted on the drop keel, and simultaneously operated from a common computer. These are the 18, 30 and 120 kHz split beam systems with a nominal half power beam widths of 11, 7 and 7 degrees, respectively. The echo sounders were calibrated at the start of the survey using a 64 mm WC sphere in Smeerenfjord, Spitsbergen (Figure 1). Only the split beam performance and on-axis gain, $G_{0,}$ was measured, as previous calibrations of the split beam system showed the same beam characteristics over several years. Only small deviations were measured at all three frequencies, 0.08, -0.15 and -0.15 dB for the three frequencies, and since this sphere was not optimal, the January 2015 calibration for all parameters was entered as valid. The noise level on the echo sounder frequencies were measured in deep water at several vessel speeds, as well as with the propeller disconnected as being used during stationary measurements. The recorded noise level at all frequencies was within noise acceptable limits when the vessel was at survey speed 10-11 knots, but also at the stationary vessel operation. Table A5 shows the echo sounder setting and calibration parameters for each of the echo sounder, including the noise level recorded at 10 knots with the sounders in passive mode. Simultaneous current measurements were made with a RDI 75 kHz ADCP, externally trigged by the echo sounder as a master. A fixed time delay in transmission were implemented to prevent interference from the ADCP transmit pulse to the echo sounder data. Multi-frequency scrutinizing and target strength analysis were conducted with the Large Scale Survey System (LSSS) post processing system (Korneliussen et al., 2016), which also was used for exporting files for subsequent analysis by MatLab or Systat.

Note: Deviations:

During the 2015 survey, a malfunction in the PC running the echo sounder software and recordings cased a loss of data for a period when crossing the shelf slope at the Hinlopen section when repairing the PC. After the new startup, one of the echo sounders used for interpretation and abundance estimation (the 38 kHz) was started with nominal Simrad factory settings, rather that with the entered calibration settings. 18 and 120 kHz systems were started up normally. The data scrutinized at 38 kHz should therefore be adjusted with a fixed factor for echo integration, corresponding to the 2 (G_0 +saCORR), converted to linear value. (Ona et al., 2009). This factor is 1.80 dB, and 1.513. All NASC values for the 38 kHz system: NASC (NEW) = NASC (OLD) * 1.513. For data after LOG 9601 on the Aug 21 1630UTC to the end of the survey. The data before this time should be unaltered. New database files should be generated, or, an official, corrected data file should be generated as valid for the survey.

Interpretation and scrutinizing

The multi-frequency recordings were interpreted daily, mainly at the 38 kHz system, but also some of the zooplankton registrations were scrutinized at the 120 kHz. However, the range of the 120 kHz system was limited to about 220m, and the latter part of the survey was only interpreted at 38 kHz. The fairly low noise level enabled measurements down to about 800m, while the main concentrations were found not deeper that 600m. The interpretation was made according to standard IMR procedures where the total backscatter was split into the target categories: cod, 0-group, plankton, mesfi, kriam, lodde, sild, uer, andre, øyepål, kolmule, sei og hyse.

Multi-frequency response was used for ID purposes, and sequential thresholding was used in order to separate weak and strong targets. For example, the layer containing krill and amphipods in mid water, 100 – 500m, could also contain mesopelagic fish with a TS between –60 and –50 dB. This means that the area scattering coefficient for the total layer could be separated by thresholding from the standard SV = –82 dB by 10 dB, only leaving the mesopelagic fish echoes in resolved situations. A similar technique was also used when large cod was mixed within the layer of mesopelagic fish and krill and amphipods. Turning on the TS location view in the echogram and setting the minimum TS to be detected to –40 dB, showed well the cod traces in the deep layer. Being aware that they were there, their contribution to the total backscattering was evaluated from a similar procedure, but thresholding to about SV = –65 dB. The integrator line now will make abrupt changes for each target, and a flat slope in between. You are then at the correct threshold level. Remaining area scattering coefficient is then given to COD, and the rest to the two other categories. A more difficult and not necessarily precise method was also used in the last part of the survey, where UER (Sebastes) was mixed with a few cod in the same layer. The catch data, which now normally should be used for separation was too scarce to do this, and evaluation of the number of detected targets on the screen for each 5 nautical mile, using two settings of the target detector was used to evaluate the mixture and relative contribution. It was the assumed that the COD targets was significantly higher that the TS from UER. The frequency response pattern for each target track was also used now.

Acoustic probing

The IMR TS probe was used in profiling mode (transducers in horizontal mode), and the multi-frequency echo sounder observing to 50m to the side of the probe was run at high PRF (3–4 Hz) while the probe was lowered from surface to the bottom at about 1 ms^{-1}. Full multi-frequency echograms was recorded during the profile, and still photo images from a stereo camera was captured during retrieval. A procedure for scrutinizing and storing the probe data to database was made during the survey. The echo sounders were calibrated according to standard procedures on the Aug. 19. 2015. Totally 33 probe stations profiles were made during the survey (Table A1).

Stationary acoustic investigations

Some of the major research stations during the survey left the vessel more or less stationary for more than 24 hours. In these cases, also inside the ice, the density of fish and the deep scattering layer was studied in the time domain by leaving log-based scrutinizing to ping or time based scrutinizing. Special procedures were developed for selecting valid, noise-free data over a 24 hour period. Within one particular hour, then, an arbitrary 10 minute interval with noise free data was selected as representative for this time interval. A new database was made for this purpose, storing data over 10 meter depth intervals.

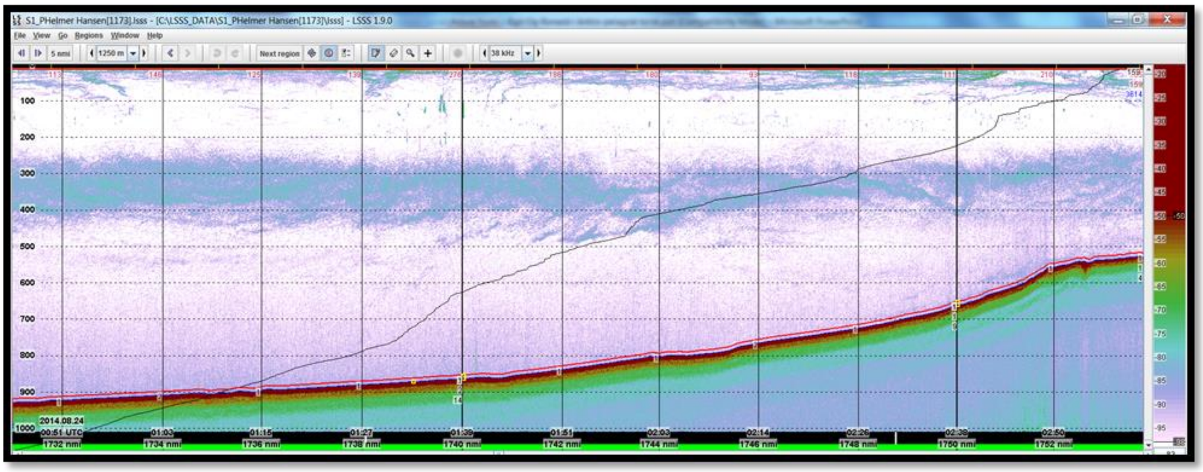


Figure 4. An example of the DSL layer in Fram Strait is shown at very low threshold setting SV= –98 dB.

Pelagic cod, interpretation and measurements

In the acoustic recordings, large targets with TS > –30 dB, can individually be measured at low density to 800m depth, and maybe as deep as 1100m by the 18 kHz system. High densities of cod were registered and trawled on the continental shelf north of Svalbard, and the cod layers extended out beyond the shelf and into mid water by following and feeding on the organisms within the layer. In Figure 4, an example of the DSL layer in Fram Strait is shown at very low threshold setting SV= –98 dB. When interpreting the echogram to isolate the fraction of the backscattering originating from cod, relatively hard thresholding and display settings was used. First, the TS detector was enabled and set to detect only very strong targets TS [–35, –10 dB], and show their location in the echogram. Further, the echogram was thresholded using the threshold response function in LSSS, the behavior of echo integrator line under gradual thresholding and the r(f). Note that the backscattering from the mixed “soup” of mesopelagic fish and zooplankton in the DSL is generally 20 dB’s weaker than the single targets we try to extract. The procedure is exemplified using a selected school box (Figure A1), first showing the normal threshold condition for 18 and 38 kHz systems for database storage, –82 dB.

The NASC for the mixture, cod and every other weak targets are now 48. To estimate how much of this backscattering originates from the strong cod tracks, the integrator line across the screen is increasing gradually with some steps across the visible cod tracks. The r(f) is increasing and the threshold response curve shows that there are two categories of targets in the volume selected; one category quite sensitive to thresholding, and one stronger group which may withstand thresholding. Only the 18 and 38 is selected because the 120 kHz system is not in reach of these layers at 300 – 400m depth. Thresholding to SV = –65, but gradually from –70 dB, towards –65, shows that the integrator line has almost zero rise between the single targets, and clear jumps for each single target (Figure A2). The threshold response shows that we have removed near more than 50% of the echo integral, but is moving towards the edge of the threshold response of the stronger targets. We are now at the approximate correct level to evaluate that the backscattering from the strong targets within this volume is 14 for cod, while the rest is arriving from the weaker target category. A similar result will also be seen if the inverted procedure is used, i.e. top thresholding, removing the strong targets. The basic knowledge we have for frequency response is also confirmed, that r(f) should be falling with frequency for large cod targets, and Figure A3 shows also the TS detections when using a TS window of [–35, –10]. Basically this procedure is followed for 5 nautical mile interpretations, and the accuracy in this mixed category interpretation is believed to be at 10% level for cod and even better for the mixed category. The density of cod can of course also be made using standards counting techniques. Pelagic trawling in these very low density layers has further confirmed the pretense of cod at similar densities, i.e 3 – 10 cod/trawl hour.

Fish sampling

Pelagic trawling

Åkra trawl is a medium large (538 m circumference) pelagic trawl having net with a mesh size of 8 mm in the cod-end (https://kvalitet.imr.no/EKWeb/docs/pub/dok01835.pdf). The trawl was equipped with a Multisampler; a device with three nets (8 mm) who could be opened and closed at predefined times (depths). The three nets were as a standard deployed at 1) lower base of the deep scattering layer (400-450m depth), 2) at high concentrations/particular scatters in deep scattering layer (300-350 m depth) and 3) at 50 m depth. Each depth layer was trawled for 20-45 min (Table A1). The trawl geometry was determined/visually inspected by the trawl sensor cable of the vessel.

Harstad trawl is a small pelagic trawl usually used for catching 0-group and small pelagic fishes like capelin and polar cod (https://kvalitet.imr.no/EKWeb/docs/pub/dok01811.pdf). This trawl was used on all Ecosystem stations in a step-vise manner covering the upper 60 m and on some other hauls (Table A1).

There were some problems using the Åkra trawl due to shifting between the pelagic trawls, quality of the trawl and to little weights. There were also some problems with the Multisampler due to damage during the survey. Thus we did not get as many trawl hauls in different depth layers as planned. Detailed sampling of the of the Fram Strait and Hinlopen sections is shown in Figure 5.

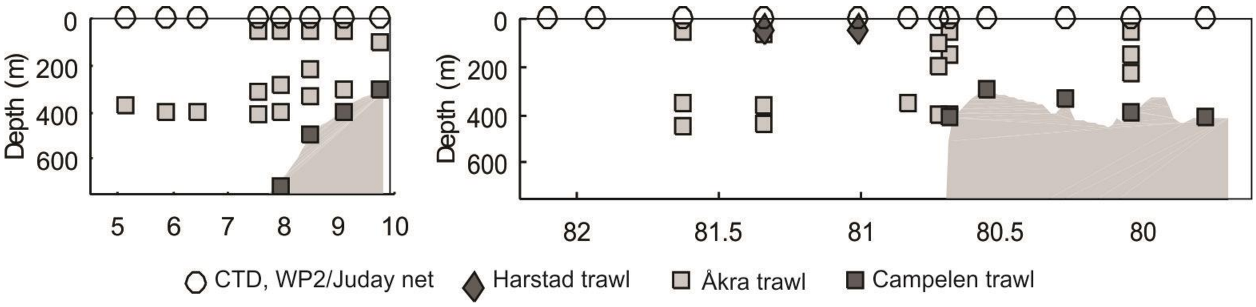


Figure 5. Equipment used and sampling depth in the Fram Strait (left) and Hinlopen (right) sections. CTD and WP2/Juday nets sampled all the way to the bottom except for on the westernmost station on the Fram Strait section where sampling was conducted to 1500 m depth.

Demersal fish and benthos

Campelen trawl is a small dermersal trawl originally designed for catching shrimps (https://kvalitet.imr.no/EKWeb/docs/pub/dok01838.pdf). Initially the Campelen was rigged with 100 titanium floats, which can withstand the pressure in deepwater hauls. Due to trawl damage during two of the early hauls, 40 deep water floats (8''; 2.4 kg buoyancy each) were added on the fish line, 20 deep water floats (10''; 5.1 kg buoyancy each) added on the head line and 2 deep water floats (10''; 5.1 kg buoyancy each) on each side. This means that the buoyancy changed from 240 kg to 448 kg. Trawling time was 15 min at seabed in the southern parts of the survey area and 30 min at seabed in the northern and eastern parts.

Benthos

Two cruises (in 2014 and in 2015, Figure 6) have been conducted where benthos has been collected, quantitative identified, together with collection of biological species for analyses of stable isotopes, and fish-stomachs have been identified for prey-species. On each station benthos was collected and quantitative identified on board from Campelen trawl as a minimum, but also in special cases with Beam trawl and grab (often as replicates). Benthos sampling by a Campelen trawl was conducted at 54 stations during 2014 (28) and 2015 (26) (Table A6).

Isotopes and stomack analyses

Pelagic species (vertebrates and invertebrates) was collected for stable isotope analyses from Harstad trawl, Åkra trawl, Macroplankton trawl and WP2. Filter samples for isotope analysis was taken from water-bottles while samples for isotope analysis from fish was obtained from Campelen trawl.

At each station isotope (Table A7) and stomack analyses (Table A8) was taken from as many species (benthos species, fish species, pelagic invertebrate species) as possible, together with isotope analyses of POM (seawater from chlorofyllmaximum sieved through filtres) and sediment (taken by spoon from the upper 3 cm sedimentcolum from grab). At each station both benthic and pelagic equipments was used, and an overview of this is given in Table A1.

Marine mammals

Visual observations of marine mammals were conducted by 2 experienced observers on the bridge covering approximately the front 90° sector (45° each). Species were recorded along the cruise transects when steaming between stations and when visibility were sufficient and the observers were on post. Species were also recorded when the ship was doing station work or working its way through the ice, coding the data accordingly. In describing the data, all observations have been included, also the sightings when the ship was stationary.

The spatial coverage of the sightings is obviously completely determined by the cruise track (Figures 1 and 2) as well as by visibility, suitable sighting conditions and observers on post. Thus “no sightings” does not mean that there were no marine mammals present.

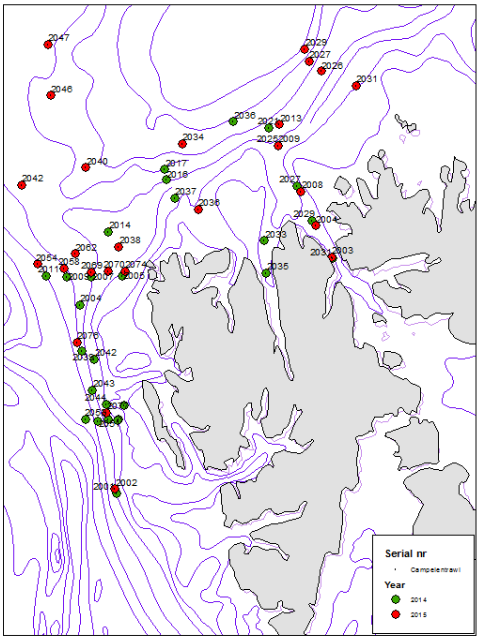


Figure 6. Spatial coverage of Campelen trawls during 2014 (red) and 2015 (green) labeled with serial nr. Station 2036 north of Svalbard was labeled same serial number both years and lays upon each other (only the red 2015 color visible).

Results

Sea ice distribution

At the beginning of the cruise (18 August), the sea ice margin north of Svalbard was at ~82^{o}N, almost a full degree further north than during the SI_ARCTIC cruise in August 2014 (Figure 7 A, B). In its most northerly position much of the sea ice was more than 50 % concentrated right to the ice edge and remained so during the northern section from Hinlopen Strait to the pack ice edge ~82^{o}N on 23 August. About 27 August, while working south towards Svalbard, the ice pack began to drift south and the movement increased after 29 August when northerly winds of 20 to 25 kts set in. By the end of the cruise on 6 September, the pack ice edge was half a degree further south than at the beginning of the cruise.

Underway meteorological and oceanographic measurements

For each section the mean, maximum, and minimum values were computed. Sea surface temperatures were highest (mean of 7.02^{o}C in section 1) in the warm Atlantic seawater flowing north along the Svalbard coast and persisting along the inner Svalbard shelf to Hinlopen Strait (Figure 8, Table 1). Along the entire Hinlopen transect from the Hinlopen strait to the pack ice at 82^{o}N, sea temperature averaged 3.38^{o}C. But the southern half of the transect (CTD 61 to 67 & 71 to 76) with an average water depth of 930 m was in relatively warm water (mean 4.65 ^{o}C). The northern portion (CTD 67 to 71 - mean water depth 2155 m), part of which was in the pack ice, was much colder (mean 0.74 ^{o}C). Moderate temperatures were encountered on the shelf north of Svalbard on the section from the Hinlopen transect through Smeerenburgfjorden and Magdelenefjorden 76 to CTD station 79 (mean 5.52^{o}C). From Station 79 to the most northern station (85) on Nansenryggen/Yermak Platau (in the pack ice) the mean temperature was 2.15°C, and the return section from Nansenryggen/Yermak Platau to the start of the Fram strait section was cooler (mean 1.21 °C). Along the Fram Strait transect, temperatures were like those observed on section 3 (North Svalbard Shelf and Slope) ranging from 4.3 to 6.7 °C. From the end of the Fram Strait transect to Longyearbyen sea surface temperatures were substantially lower (4.44 °C) than on the transit north over the same area. Lowest sea temperatures were encountered in the pack ice north of the Svalbard shelf on the Hinlopen transect with temperatures as low as -1.6 °C (Figure 8 – Yeardays 235 and 236 plot of along track surface temperature).

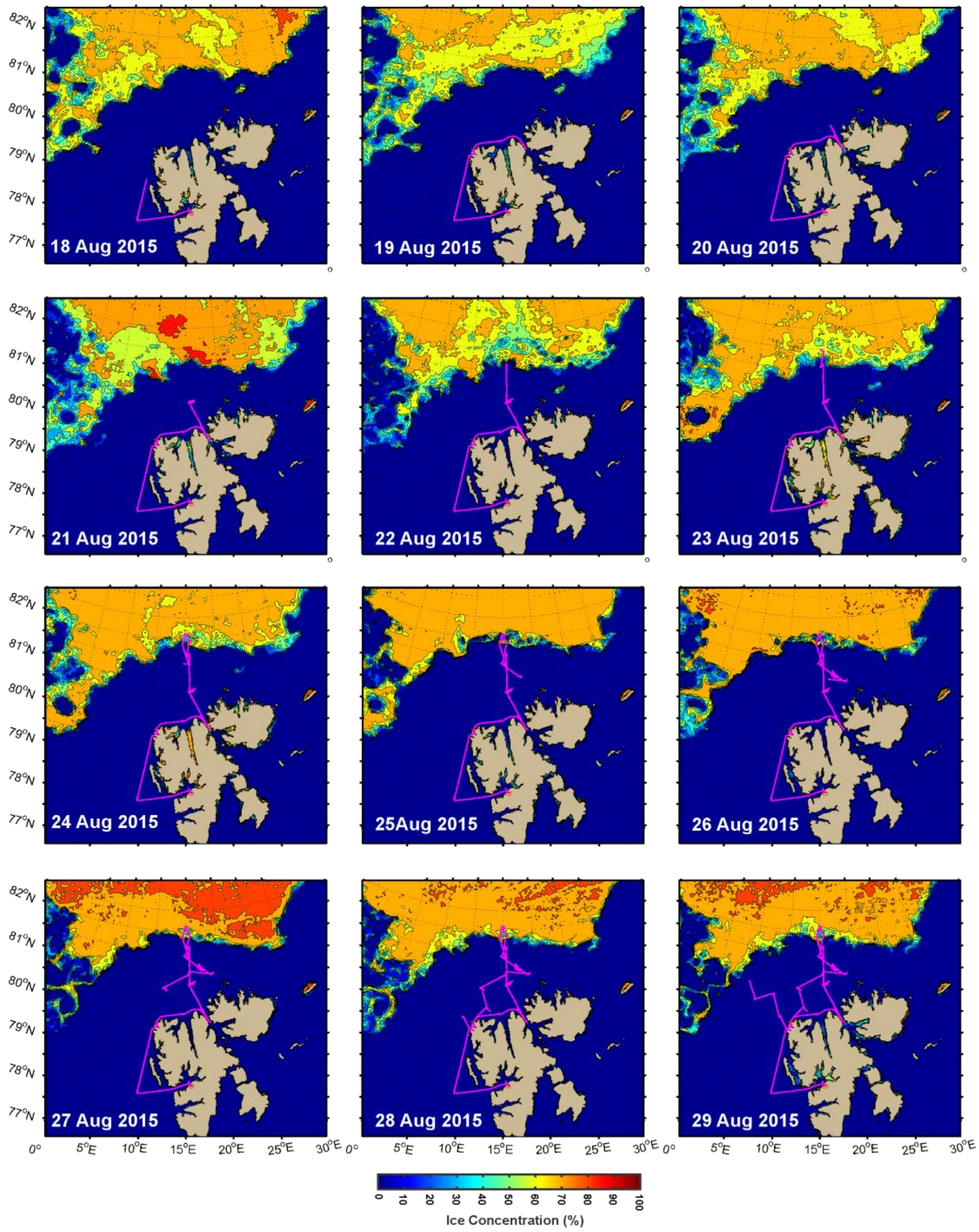


Figure 7A. Ice concentration maps for each day of the cruise (two panels).

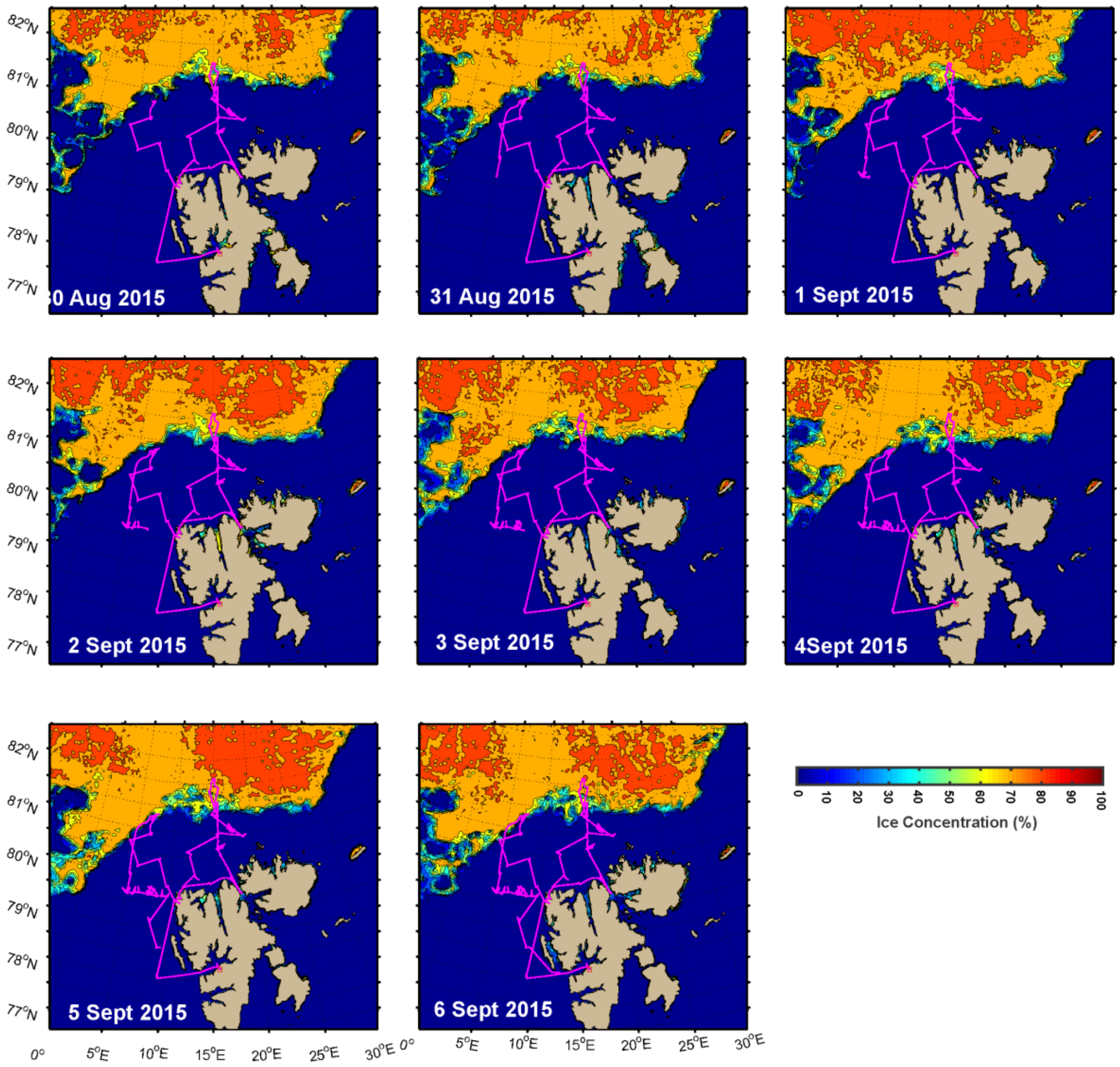


Figure 7B. Ice concentration maps for each day of the cruise (two panels).

Mean wind speeds varied throughout the cruise (Table 1). The highest winds (19.3 m/s – ~37 kts) occurred at the start of the cruise on the transit from CTD station 59 to CTD station 60 in Smeerenburgfjorden. On most of the sections, winds varied between 0/1 and 14. 8 m/s, and averaged between 5 and 9 m/s (10 to 17 kts – Figure 8). Air temperature was correlated with sea surface temperature (r ~=0.70), but it varied widely and ranged from above 8 °C to as low as –5.9°C. Barometric pressure remained above 1000 mb for the duration of the cruise and oscillated between 1006 and 1027.49 mb. There were a few periods of strong light, usually as flurries. Most days were cloudy, some with dense cloud cover and relatively low light levels and others had broken clouds with substantial sunlight (Figure 9). Brightest days occurred on yeardays 236 and 237 (24 & 25 August), and 240 to 242 (28 to 30 August). The sun remained above the horizon for most of the cruise. It began setting by the end of the cruise. There was a definite cycle of light being maximal at noon and minimal at midnight (Figure 9).

Table 1. Meteorological (MET) data Summary Statistics. See Figure 8 for a plot of the data.

	YearDay	Air Temp (‘C”)	Sea Temp (‘C”)	Wind Speed (m/s)	Wind Direction (Deg)	Barometric Pressure (mbar)	Bottom Depth (m)	Latitude	Longitude
Section 1 Longyearbyen to Start of Hinlopen Transect, CTD 59 to 61.									
mean	230.87	6.44	7.02	9.28	214.58	1010.71	276.08	78.85	11.49
max	231.97	8.30	8.30	19.33	349.00	1014.50	580.21	80.09	18.12
min	229.78	3.80	3.00	0.50	77.00	1006.10	26.38	77.98	9.38
Section 2 Henlopen Transect South to North, CTD 61 to 76									
mean	235.49	0.70	3.38	6.66	160.64	1020.62	1297.02	81.06	16.08
max	239.03	5.40	7.10	14.80	360.00	1027.40	2623.89	82.12	19.17
min	231.97	-2.90	-1.60	0.01	0.00	1011.90	142.37	79.76	14.36
Section 3 North Svalbard Shelf and Slope, CTD 76 to 79									
mean	239.94	0.19	5.52	5.11	233.82	1017.88	890.33	80.38	12.86
max	240.87	3.10	7.10	11.58	360.00	1019.30	2081.72	81.01	15.62
min	239.03	-1.60	3.10	0.03	0.00	1014.00	34.08	79.55	9.64
Section 4 Magdelenefjorden to Northern Region on Nansenryggen CTD 79 to 85									
mean	242.00	-1.40	2.16	6.67	64.03	1013.89	709.05	80.60	7.06
max	243.14	2.50	7.40	11.86	360.00	1015.50	923.98	81.33	9.76
min	240.87	-5.90	-0.90	0.01	0.00	1011.00	187.02	79.86	4.34
Section 5 Nansenryggen to Fram Strait transect, CTD 85 to 86									
mean	243.53	-4.08	1.21	8.83	30.79	1017.31	781.42	80.78	6.06
max	243.93	0.00	6.20	14.89	289.00	1018.60	2322.44	81.33	7.58
min	243.14	-6.20	-1.10	0.01	4.00	1015.50	414.90	79.64	4.91
Section 6 Fram Strait transect , CTD 86 to 93									
mean	245.84	0.50	5.57	8.87	109.31	1017.46	1173.99	79.70	6.93
max	247.73	2.40	6.70	14.89	360.00	1023.10	2732.81	79.84	9.72
min	243.94	-1.30	4.30	1.56	0.00	1008.50	306.22	79.63	4.56
Section 7 End of Fram Strait transect to LB , CTD93 to 95									
mean	248.54	2.25	4.44	5.72	157.44	1009.86	469.93	78.96	9.23
max	249.37	3.60	6.30	10.83	360.00	1011.30	956.43	79.73	12.70
min	247.73	-0.70	3.20	0.55	0.00	1008.20	75.80	78.15	7.84
Hinlopen warm shelf area (CTD 61 to 67 & 71 to 76)									
mean	235.47	1.40	4.65	6.78	178.22	1020.21	930.32	80.79	16.44
max	239.03	5.40	7.10	14.80	360.00	1027.40	2392.81	81.48	19.17
min	231.97	-1.70	0.60	0.07	0.00	1011.90	142.37	79.76	14.66
Hinlopen cold offshore region (CTD 67 to 71)									
mean	235.52	-0.99	0.74	6.37	118.07	1021.48	2155.59	81.61	15.32
max	236.67	1.60	5.30	14.04	360.00	1027.30	2623.89	82.12	15.68
min	234.37	-2.90	-1.60	0.01	1.00	1017.40	520.67	80.68	14.36

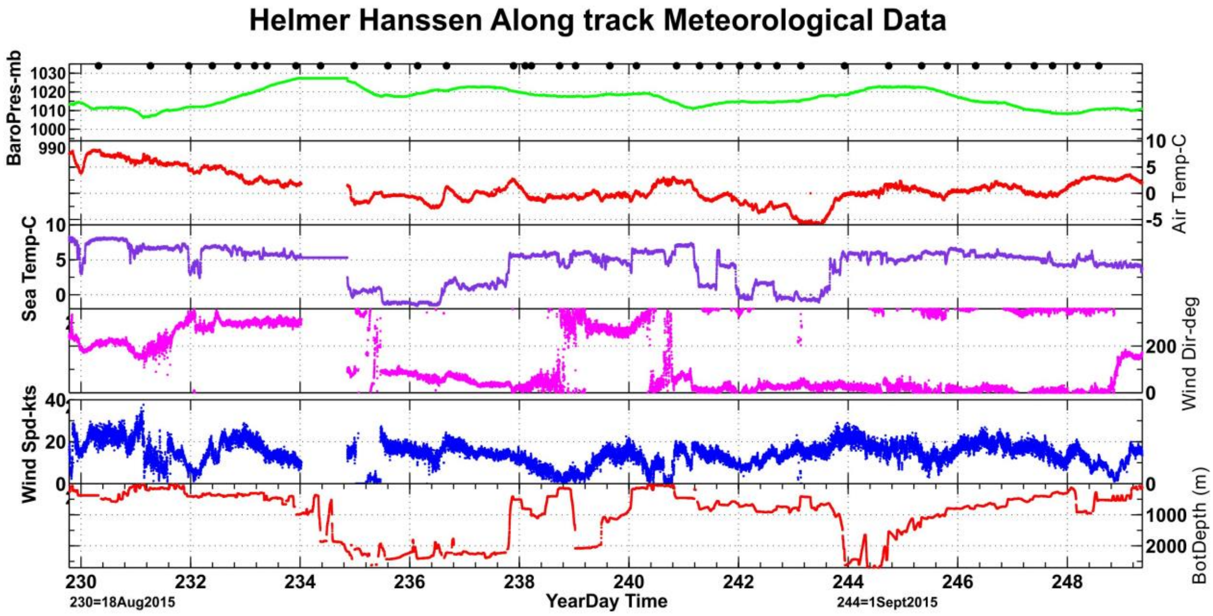


Figure 8. *Helmer Hanssen* 2015843 along-track meteorological, sea surface temperature, and bottom depth measurements made from 18 August to 6 September 2015. CTD station positions are indicated by the filled circle at the top of the plot.

Wind direction was also variable (Figure 8). Winds were predominately from the west-northwest for the first 6 days (yeardays 229 to 235, 17 to 23 August) and then shifted to southeasterly for the next 4 days (yeardays 235 to 238, 23 to 27 August). There was shift to northwest on yeardays 239 and 240 (27 & 28 August) and then another shift to northerly on yearday 241 (29 August), which persisted for 7 days (through yearday 248, 5 September). The cold air temperatures were associated with the northerly winds coming off the pack ice.

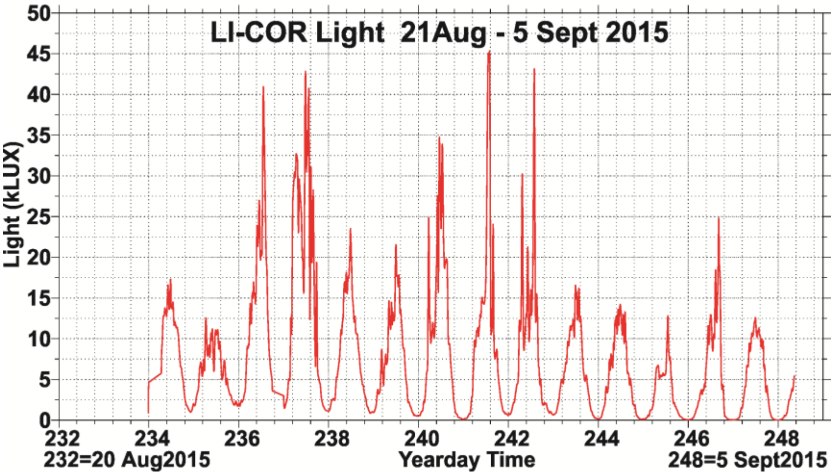


Figure 9. Visible light measured with a LI-COR Model LI-1400 data logger. The data were logged at 5 minute intervals and smoothed with a 11 point moving average filter.

Oceanographic measurements (physical and chemical)

Hydrography and currents

The general pattern in hydrography and currents in 2015 resemble the pattern from 2014 (Figure 10 and 11). The Fram Strait north section was, as in 2014, dominated by Atlantic Water (temperature>2°C and salinity>35) from about 600-700 m depth up to the surface layer (Figure 10). There was a fresher surface layer in most of the section, although with lateral gradients (Figure 12). However, as opposed to 2014 when sea ice and melt water dominated the upper 30−40 m in the western part of the section, the freshest surface water in 2015 was towards Svalbard (Figure 12). Another difference (probably also associated with lesser amount of melt water in the west), is a shift in the location of the main cores of Atlantic Water flow and re-circulating water (LADCP in Figure 10).

The Hinlopen section was sampled much further north in 2015 compared to 2014. In the southern parts (which were covered both years), the temperatures in 2015 were substantial higher in the upper layer (Figure 12). To the north of the shelf slope, Atlantic Water dominated in the 200-400 m depth layer all the way to 82°N, overlaid by fresh and cold melt water (Figure 11 and 12). Unfortunately, no LADCP or vessel mounted ADCP data exist from the slope region in 2015 due to malfunction of the instruments.

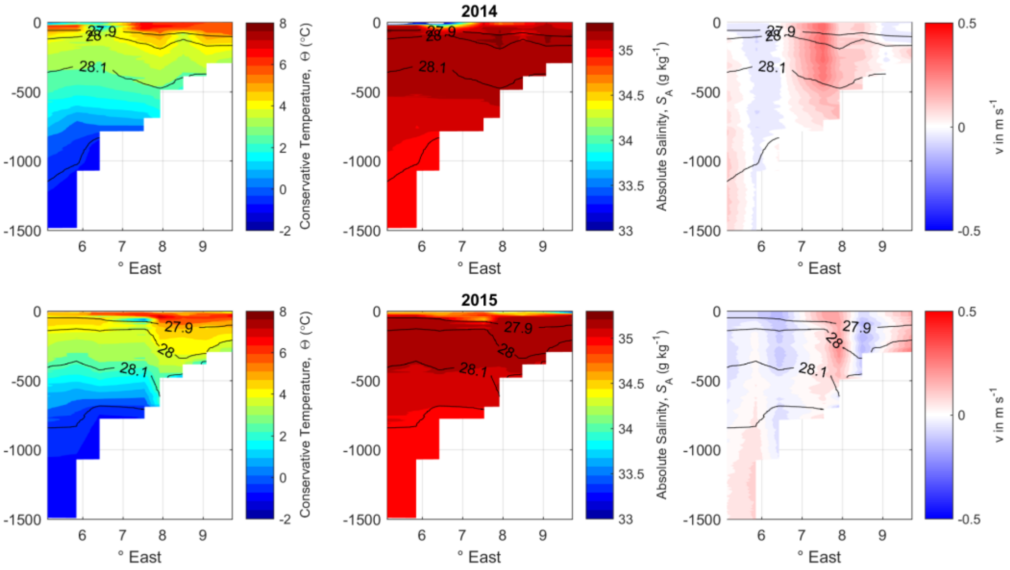


Figure 10. Temperature (left), salinity (middle), along-slope/northward velocity (V, positive northward) in the upper 1500 m in the northern Fram Strait section in 2014 (upper) and 2015 (lower). Data from CTD and LADCP.

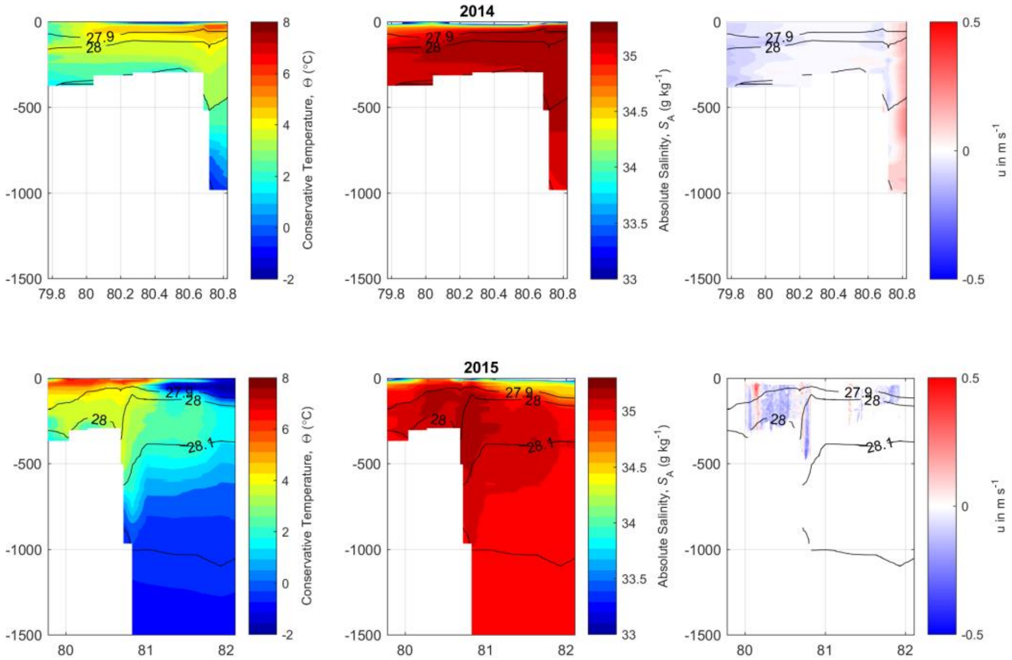


Figure 11. Temperature (left), salinity (middle), along-slope/eastward velocity (U, positive eastward) in the upper 1500 m in the Hinlopen section in 2014 (upper) and 2015 (lower). Note different horizontal scales between upper and lower plates. Velocity data are from LADCP in 2014 and vessel mounted ADCP in 2015 (no LADCP data from this section in 2015).

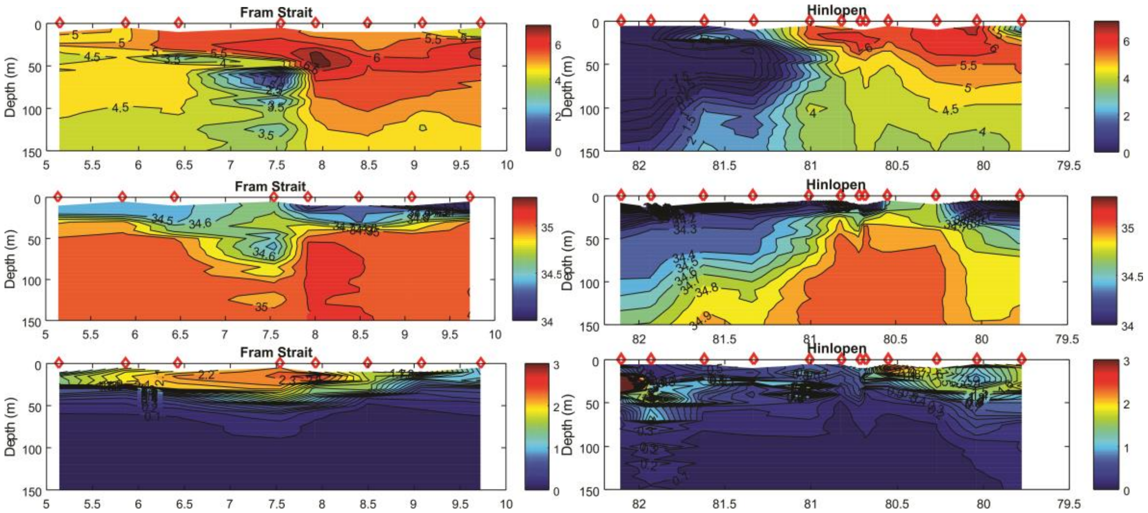


Figure 12. Temperature (upper), salinity (middle) and fluorecence (lower) in the upper 150 m in the northern Fram Strait north (left) and Hinlopen (right) sections in 2015.

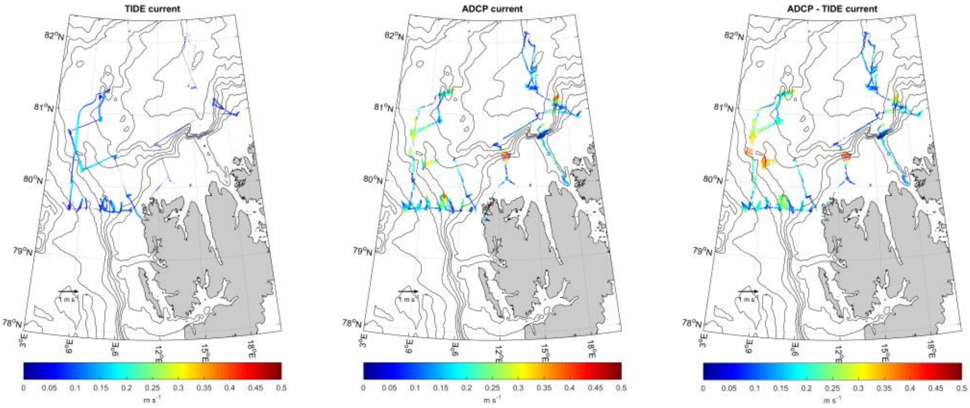


Figure 13. Average 0-400 m current from tidal model (left), vessel mounted ADCP (middle) and de-tided vessel mounted ADCP data.

The average 0-400 m current from the vessel mounted ADCP reveal rather strong currents in the main Atlantic Water inflow regions in the Fram Strait north section and at the steep slope in Hinlopen (Figure 13). The rest of the study region had low currents in comparison.

pH at Hinlopen section from south to North (~82 °N)

The pH varied between lowest pH of 8.05 in the deep waters to the maximum values of 8.45 in the surface waters. The high value sin the surface is due to a combination of primary production and temperature, and the lower values at depth are due to the influence of CO_2 from degradation of organic matter (Figure 14).

In the surface waters it is clear that the fresher water at the northernmost stations at the Yermak Plateau and nearby the coast in NW Svalbard have the lowest aragonite saturation states (ΩAr, Figure 15a and b). At the Yermak Plateau low values are likely due to the presence of sea ice melt water, which lowers ΩAr (Chierici et al., 2009), and in NW Svalbard it is likely an effect of fresher coastal waters.

Phytoplankton

Fluorescence

The fluorescence data from the Fram Strait north section show highest values in the middle of the section (Figure 12). In the fresher waters at the westernmost and easternmost parts of the section, the fluorescence values were lower. Highest fluorescence was observed near surface.

At the Hinlopen section the pattern was patchier (Figure 12). Relatively high values were observed near surface at the southernmost part of the section. North of the shelf break

(~81°N), highest fluorescence were evident below surface at 20−30 m depth. Maximum fluorescence occurred below surface at 82°N indicating relation to the sea ice cover.

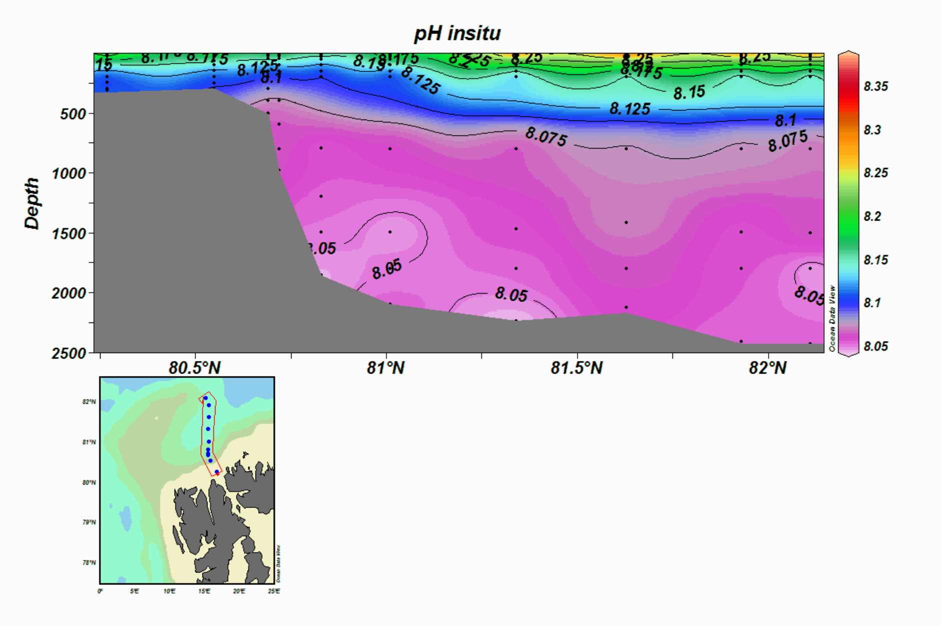


Figure 14. A section of pH from the coast to the deep basin in the north along the Hinlopen section (stations included are blue dots in the red marked box on the map below).

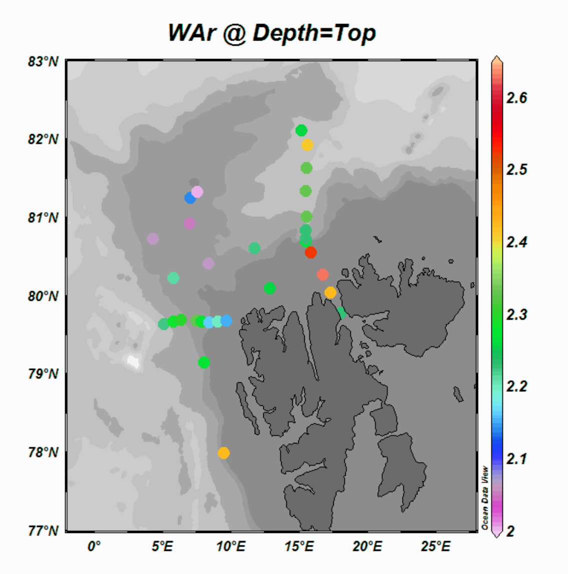


Figure 15a. Aragonite saturation in the surface waters (5 m) in the study area.

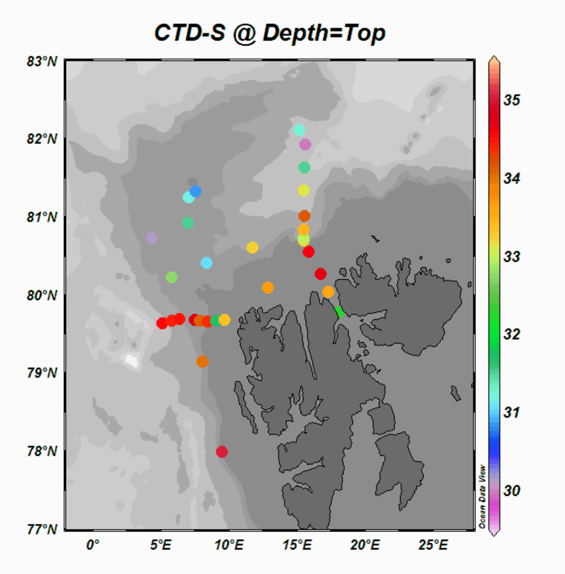


Figure 15b. Salinity in surface waters (5 m) in the study area

Zooplankton collections

The four different types of zooplankton gear used during the field work catch slightly different parts of the pelagic community. The double-net system, combining a standard 180 µm meshed WP2 and an identically meshed Juday 36 cm diameter net, target the mesozooplankton component as does also the 180 µm 0.25 m^2 Multinet system used. One of the key target organisms of interest was the highly important *Calanus* complex, the three species *Calanus finmarchicus*, *C. glacialis*, and *C. hyperboreus* that to a smaller or larger degree co-occur in the study region, given that the region is significantly influenced by water masses of both Atlantic and Arctic origin. *C. finmarchicus* is a key species in Atlantic boreal waters while the other two species can be considered true Arctic species having their center of distribution on the Arctic shelf (*C. glacialis*) and in the Arctic Ocean and Greenland Sea (*C. hyperboreus*).

The MIK net and the Macroplakton trawl were used to target the slightly larger and more motile macrozooplankton like krill, amphipods, and mesopelagic shrimps. Due to the larger mouth area of the Macroplankton trawl, mesopelagic fish also are possible to quantify if present, although the limited data obtained so far, suggests that the mesopelagic fish component diminishes moving from the northern part of the Norwegian Sea and Greenland Seas through the Fram strait and into the Arctic Ocean. However, the few number of hauls targeting macroplankton and mesopelagics in particular, still leaves this an open issue, also given that the water column is difficult to sample quantitatively due to sea ice.

In all regions sampled there was observed a mixed mesozooplankton community with all *Calanus* species present on many of the stations. Due to a seemingly highly variable phytoplankton abundance along the various transects, variable oceanographic conditions, and impact of water masses of both Arctic and Atlantic origin , the mesozooplankton community could also vary significantly from one station to another. On most of the shelf locations around Svalbard the dominating size fraction in terms of biomass was the 180 µm fraction, dominated by smaller copepods like *Oithona* sp and *Oncea* sp, and to some extent *Pseudocalanus* sp. and younger copepodite stages CII-CIV of *Calanus* sp. The size composition of the latter made it difficult to determine which of the two species *Calanus finmarchicus* and *Calanus glacialis* these copepodites could be assigned to since there is strong evidence that their sizes for a given copepodite stage overlap considerably (cf. Parent et al., 2011). However, stereomicroscope photography was used to document pigmentation differences between *Calanus* sp. individuals, a method that has been used successively by Nielsen et al. (2014) to separate live adults of *C. finmarchicus* and C. *glacialis*. Pigmentation has however, only been used as a rough proxy to get an impression which species could be a key player at various locations. Their taxonomic identification, separation, and quantitative assessment need to be resolved through a more detailed taxonomic analysis in the onshore laboratory and later by genetic analysis. The biomass retained on the 1000 µm fraction was normally low, suggesting that the older copepodites and adults of the above two species were low. In fact only very few females were spotted during the brief, but admittedly incomplete examination of the raw samples.

Macroplankton like the krill *Thysanoessa inermis, Thysanoessa longicaudata*, *Meganyctiphanes norvegica*, the amphipods *Themisto abyssorum* and *Themisto libellula* were caught on several occasions and were sometimes highly abundant, particularly when using the MIK net. On the shelf north of Spitsbergen different scattering layers were observed that could both be assigned to krill like *Thysanoessa inermis* and the two species of amphipods, the Atlantic *Themisto abyssorum* and the Arctic *Themisto libellula*, although a more detailed inspection of the acoustic data as well as the biological samples will be necessary to make any firmer conclusion whether these layers are monospecific or consist of a mixture of amphipods and krill. Some catches suggest that both scenarios are possible. The Northern krill *Meganctiphanes norvegica* having its center of distribution much further south was observed in several tows both on the northern Svalbard shelf and over deeper and ice-covered waters further north.

The transect conducted west of Spitsbergen showed particularly interesting although not unexpected features with respect to oceanographic conditions and zooplankton species composition when moving from the shallow eastern shelf to deep waters of the Greenland Sea in the west. Here *Calanus hyperboreus,* a species known to inhabit the deeper and colder waters of the Greenland basin were observed in high concentrations between 1000 and 2000 m depth. There seemed to be a predominance of females in these deeper waters, although a more detailed inspection and quantitative analyses must be undertaken to confirm this observation. Also in these waters west of Spitsbergen the surface mesozooplankton were dominated by a mixture of smaller copepods and younger stages of the complex *Calanus finmarchicus* and *C. glacialis*.

Brief comments on zooplankton biomass variability

West and north of Svalbard on the continental shelf and slope out to about 500 m depth, high zooplankton biomass was observed in 2015 (Figures 16−18). Average biomass in this area was 25.5 gm dry weight m^{-2} (N = 11) and therefore clearly higher than in 2014 (15.2 gm dry weight m^{-2}, N = 23 stations), although the area coverage was somewhat different between years. This is considerably higher than normally observed for the central Barents Sea during the same period. Maximum zooplankton biomasses were found in the outer part of Hinlopen strait and the slope facing the Arctic Ocean in the north. West of Spitsbergen across a transect in the Fram Strait, a gradual increasing biomass was observed moving westward, with an increasing amount of larger zooplankton shown by the > 2000 micron biomass size fraction, that simultaneously showed a greater proportion of *Calanus hyperboreus (*the larger Arctic relative of the boreal *Calanus finmarchicus*). The dominant species of zooplankton on the continental shelf observed with Multinet and WP2-nets was the medium sized copepod *Calanus finmarchicus*, probably with a pronounced element of *Calanus glacialis* north of Svalbard qualitatively evaluated based on pigmentation of antennas and genital segment. However, it was the much smaller copepod *Oithona* sp. that was most numerous. All stages of *Calanus* sp. from CI to CVI were present, but the stages CII-CIV dominated in the uppermost 50 meters.

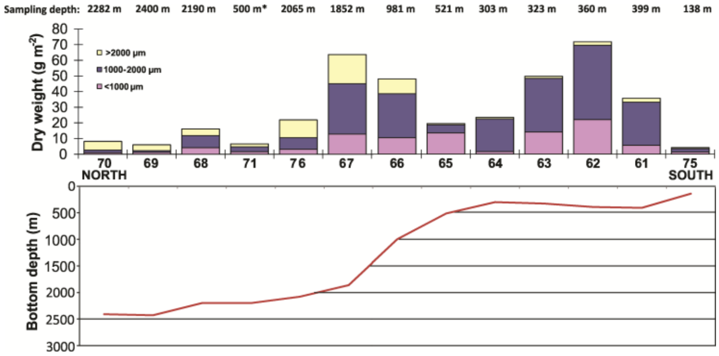


Figure 16. Upper panel: Size fractionated mesozooplankton biomass obtained with a 180 µm meshed vertically operated WP2 net on a transect from Hinlopen north of Svalbard to 82°6.4’N in the Sofia deep. Sampling depth from “bottom” to 0 m with maximum depth given above each column. Station 71 only sampled to 500 m depth. Station 75 represents a shallow shelf locality east of the actual transect. Lower panel: Bottom depth profile along transect.

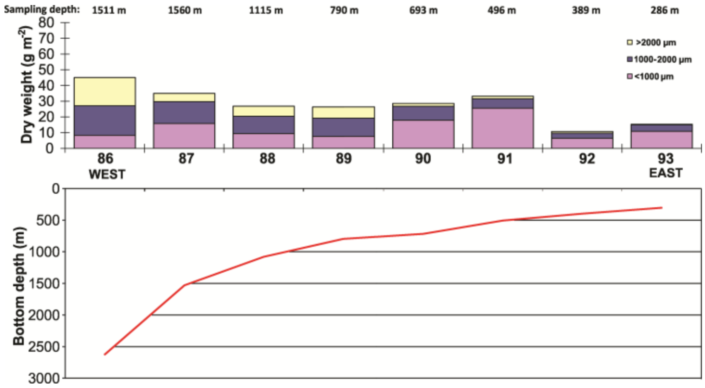


Figure 17. Upper panel: Size fractionated mesozooplankton biomass obtained with a 180 µm meshed vertically operated WP2 net from the Fram strait section west of Svalbard. Sampling depth from “bottom” to 0 m with maximum depth given above each column. Lower panel: Bottom depth profile along transect.

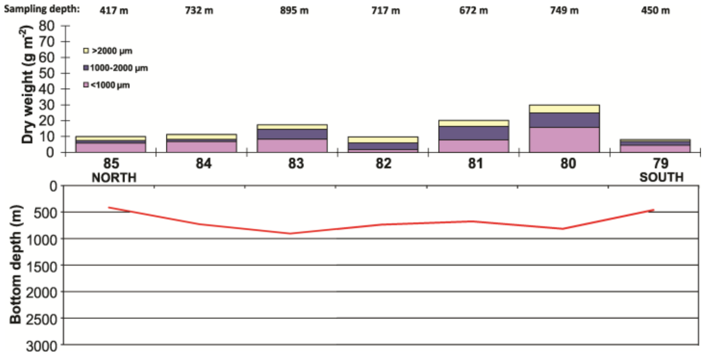


Figure 18. Upper panel: Size fractionated mesozooplankton biomass obtained with a 180 µm meshed vertically operated WP2 net towards the Yermak platau north of the Fram strait to 81°19.64’N. Sampling depth from “bottom” to 0 m with maximum depth given above each column. Lower panel: Bottom depths along cruise line.

In the Sofia deep, the northernmost area investigated, zooplankton biomass was far more moderate (on average ~ 10 gm dry weight m^{-2}), and usually dominated by somewhat larger forms like arrow worms and the Arctic copepod *Calanus hyperboreus*. Based on trawl catches in the area the deeper part of the water column was characterized by mesopelagic forms of Atlantic origin, the deep water shrimp *Hymenodora* sp. and lantern fish *Benthosema glaciale*, both normally abundant further south in the Norwegian Sea. Krill *Meganyctiphanes norvegica*, amphipods *Themisto abyssorum*, and *Themisto libellula* were also numerous locally, the first two species usually associated with Atlantic waters, while the latter is a typical Arctic representative.

The high biomass values and the observed stage composition of *Calanus* sp. show that the continental shelf area west and north of Svalbard is clearly different from the central part of the Barents Sea at this time of year. By comparison, the zooplankton biomass in the Barents Sea is very low over large areas, probably because blooms and peak production are over, and because it has also been utilized through extensive grazing by pelagic fish, especially by capelin.

Acoustic registrations and samples obtained with the MIK and Macroplankton trawl show that krill (*Thysanoessa inermis* and *Meganyctiphanes norvegica*), amphipods (*Themisto* sp.) as well as arrow worms (*Chaetognatha*) are abundant locally in the investigated area. Occasionally a mixed krill and amphipod community were registered, especially on the continental shelf north of Svalbard.

Gelatinous zooplankton

Samples from 25 stations were examined for gelatinous zooplankton by guest scientist Aino Hosia (University Museum of Bergen). Samples were quickly inspected over a light table immediately following sampling. Species composition of gelatinous zooplankton was noted and interesting specimens were picked out before the rest of the sample was processed following normal procedure. The picked jellyfish were identified and photographed live, prior to being fixed in ethanol for DNA barcoding in collaboration with the Norwegian Taxonomy Initiative project HYPNO (http://data.artsdatabanken.no/Pages/168312). Preliminary results show that DNA samples were collected from ca. 9 species of hydromedusae, 5 species of siphonophores, and 6 species of ctenophores.

Fish and zooplankton acoustics

The total acoustic backscatter in the Fram Strait north section in 2015 resembles the situation in 2014 (Figure 19). Strongest scatter was observed in the upper 50−100 m, but with a clear mesopelagic layer between 300 and 500 m depth. The scatter allocated to 0-group fish was a magnitude larger than the rest, especially in the eastern parts. The plankton contribution dominated the rest of the scatters in the eastern part, while krill, amphipods and mesopelagic fish dominated in the western part of the section. Cod was present in small quantities all across the section.

In Hinlopen failure of the eco sounder PC caused no data in a small part on the shelf and when crossing the shelf break (Figure 20). The strongest scatter was in the upper 50 m, but a weak mesopelagic layer was evident also into the deeper parts of the Arctic Ocean. 0-group and plankton dominated, but mesopelagic fish was also present. Capelin was present on the shelf and cod on the shelf break.

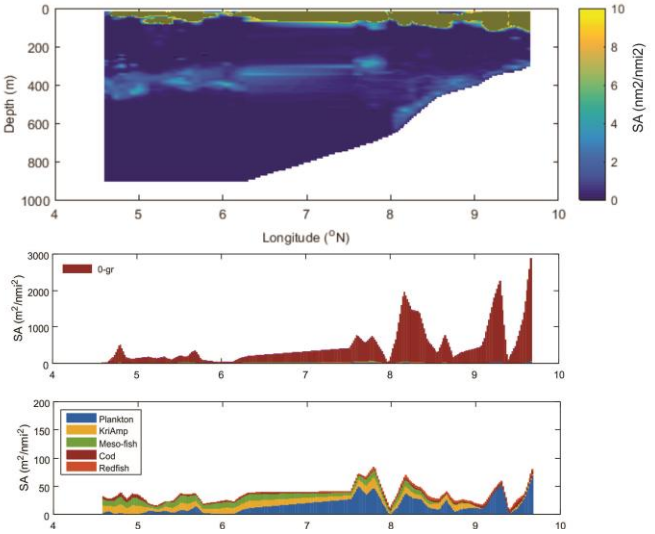


Figure 19. Total acoustic backscattering in the Fram Strait north section in 2015 (upper). Lower panels show contribution from different groups. Note different scale on the y-axis on the two lower figures.

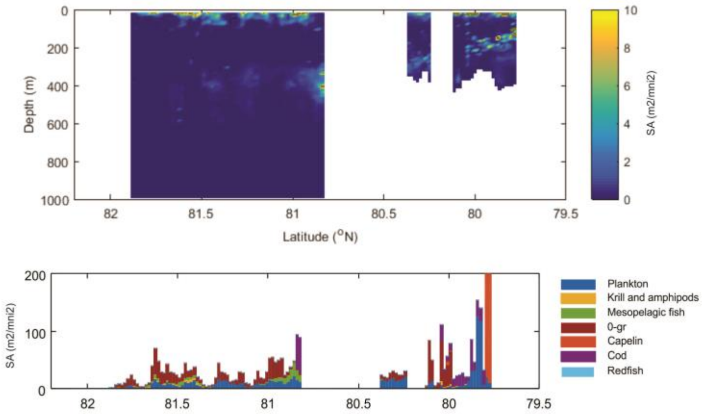


Figure 20. Total acoustic backscattering in the Hinlopen section in 2015 (upper). Lower panel shows contribution from different groups. White space shows failure of the eco sounder computer.

24-hour study of Diel Vertical Migration

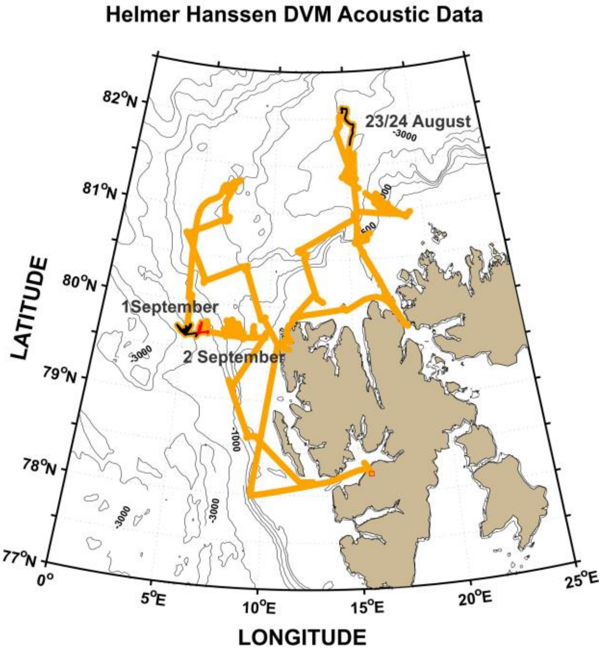
With the set-up of the LI-COR light sensor, it became possible to examine the relationship between the downwelling light and movements of the Deep Scattering Layer by the mesopelagic animals (Figure 21 and 22). Two 24 hour 38 kHz acoustic records were scrutinized at sea – 24/25 August and 1 September. The data in the form of s_A, Nautical Area Scattering Coefficient (NASC - units of m^2 nmi^{-2}) were summarized in 10 meter depth bins from the below the hull mounted 38 kHz transducers to below 700 m and stored in an Excel spreadsheet. A Matlab m-file was used to import the data and make plots of the light intensity and NASC data as a function of time. The weighted mean depth of the backscattering (WMD) for each time interval was computed using the following equation:

$$WMD = \sum_{j=1}^{N} z_j s_{A_j}(Meso) / \sum_{j=1}^{N} s_{A_j}(Meso)$$

where z is the depth of interval j, s_A (Meso) is the NASC value for that depth interval, and N is the number of depth intervals. A boxplot of the light data was used to determine the median light level and the 25th and 75th percentiles. The times where light levels were at or below the 25th percentile or at or above the 75th percentile were used to determine the times used to select the NASC data for comparison of the vertical distribution of between low-light levels and high-light levels. This objective procedure was used to avoid the transition periods in light levels.

The WMD of the mesopelagic backscattering in the three time periods was examined statistically (Table 2). During the first period on 24/25 August, which took place at the northern extent of the Hinlopen Transect, the data were divided into two sets. The first was from the beginning to the mid-point of the time series and the second was from the mid-point to the end of the time series. This was done because of the differences in the maximum amount of light on the 24th and 25th of August. In the first set, the high-light median depth

Figure 21. Locations in black or red along the SI_ARCTIC cruise track (in orange) where the acoustics data presented in Figure 22 were located.



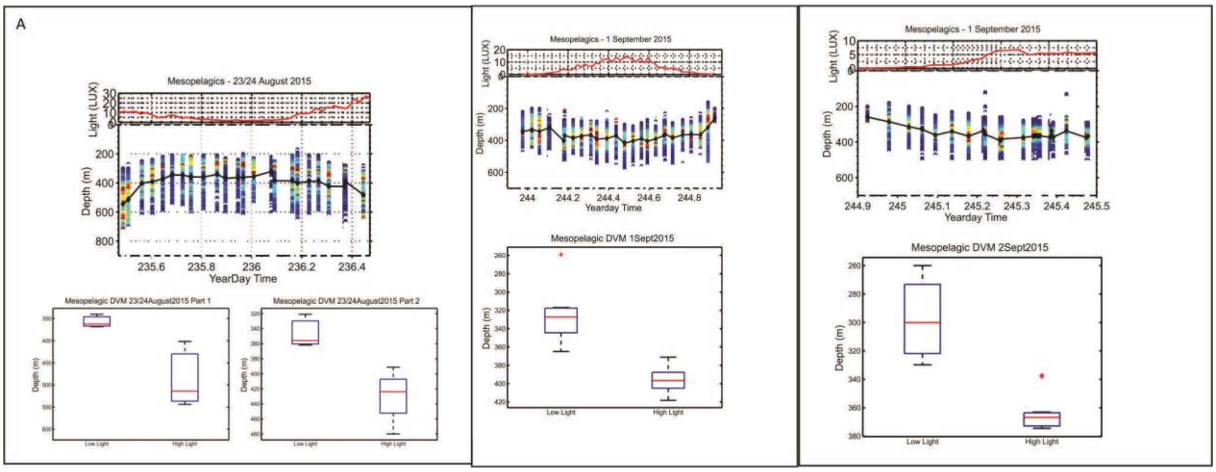


Figure 22. Vertical distribution of scrutinized acoustic data assessed as originating from backscattering from mesopelagic organisms. Light levels determined from a LI-COR light data logger are plotted on top. The black line in the lower panel marks the WMD of each vertical profile. Box plots show the depth distribution of the WMD versus depth for high and low light conditions.

was deeper than the low light depth by 151 meters (Table 2, Figure 22 left panel). In the second set, the difference was 68 m. For the 1 September time series, the median high-light WMD was 70 meters deeper than the low-light value (Figure 22 middle panel), and for the 2 September time series, the median high-light WMD was 66 m deeper (Figure 22 right panel). In all three data sets there is no overlap in the boxplot values. Although relatively small, there was significant Diel Vertical Migration taking place despite the sun remaining above the horizon.

Table 2. Depths of the highlight and lowlight weighted mean values of scrutinized mesopelagic backscattering at 38 kHz. See Figure 22 for data plots.

			Percentiles			
Percentiles	Minimum	**25th**	**Median**	**75th**	**Maximum**	Median Difference Meters
Set-1_24hr_Acoustics_23/24August2015						
Low-light	340.60	346.06	362.44	367.15	368.72	151.49
High-Light	401.84	536.41	513.93	536.41	543.90	
Se**t-2_24hr_Acoustics_23/24August2015**						
Low-light	321.01	329.73	355.91	360.39	361.89	67.91
High-Light	391.27	452.22	423.82	452.22	479.85	
24hr_Acoustics_1Sept2015						
Low-light	316.83	317.51	327.20	344.45	364.83	69.45
High-Light	371.13	404.94	396.65	404.94	418.25	
12hr_Acoustics_2Sept2015						
Low-light	259.9829	273.1548	300.0659	321.7828	329.7604	66.66
High-Light	362.982	372.7596	366.7287	372.7596	374.4844	

Fish and prawn caught in the trawl

78 trawl hauls were made during the survey. Altogether, 268 different species or higher taxons were caught in the various trawls. Of these, 49 taxons were fish, all determined to species level, and 37 were plankton. Benthos bycatches in the bottom trawl were this year recorded to species level by benthos experts. 171 taxons were found. The plankton caught in the fish trawls were lumped together into higher taxonomic groups. Bycatch of benthos and plankton is dealt with in other sections of the report.

Dominance and depth ranges

When excluding 0-group, the most dominating species in terms of number of stations they were caught was polar cod. This species was found in 40 of the 78 trawl hauls made (Table 3). Next ranged Greenland halibut, capelin, deepwater prawn, cod, beaked redfish, and long rough dab, which were found in 35, 21, 18, 17, 13, and 12 and 3 hauls respectively. All these are commercial species, apart from the polar cod and the long rough dab, which are not targeted species in this area. The cod had the highest average catch rate in biomass. Its catch rate of 18 kg per nautical mile was almost three times as high as the deepwater prawns, ranging next with 6.4 kg per nautical mile. The catch rates in weight of beaked redfish was 4.5, Long rough dab and Greenland halibut 2.5, polar cod 1, and capelin only 0.1 kg per nautical mile. Greenland halibut, capelin and polar cod showed the largest span in fishing depth in the bottom trawl; from less than 50 m to more than 1000 m depth. Cod and beaked redfish were caught down to 750 m depth while deepwater prawns were caught as deep as 980 m.

Table 3. SI_ARCTIC survey 2015. The most dominating species in terms of presence in trawl hauls, their standardized average catch in biomass, and their average size. Given are also the shallowest and deepest pelagic and bottom trawl haul where the species was observed.

Species	No of stations	Average catch (kg/nmi)	Average size (kg)	Depth range bottom trawl	Depth range pelagic trawl
Cod	17	17.73	1.079	153-655	200-755
Capelin	18	0.07	0.008	292-406	0-740
Haddock	1	0.12	0.011	-	0-80
Polar cod	39	0.82	0.018	156-1002	50 - 740
Deepwater prawns	18	7.40	-	139-538	-
Beaked redfish	12	4.43	0.195	292-525	342-740
Long rough dab	9	3.16	0.206	153-406	-
Greenland halibut	34	2.41	0.770	153-1002	370

Other, mostly non-commercial fish species like skates, sculpins, catfishes, eelpouts and rattails were present in most bottom trawl stations, and dominated, at least in terms of numbers, in the deepest hauls. In the pelagic trawls, mostly early life stages of commercial species (mainly redfish, cod and haddock) dominated in the upper layer together with plankton like krill and amphipods, while various mesopelagic fishes and shrimps were found together with cephalopods and cnidarians in a mesopelagic layer at 400-500 m depth beyond the shelf break (Figure 23 and 24).

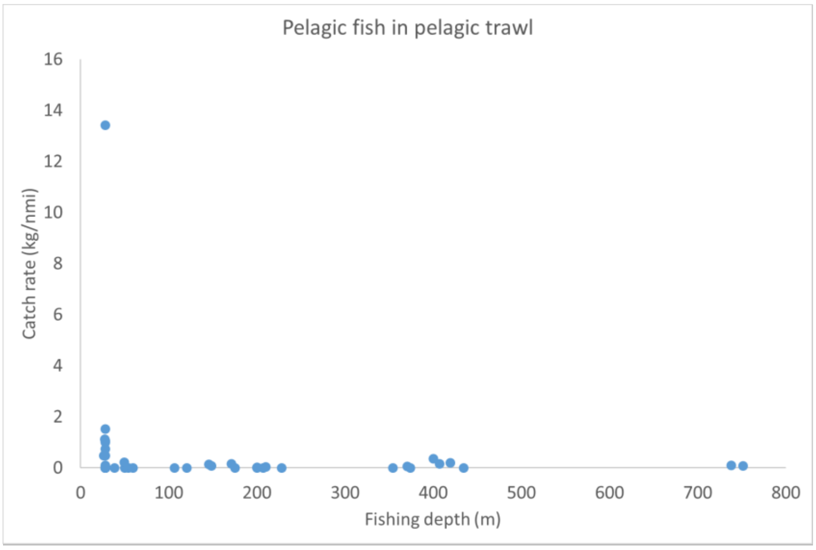


Figure 23. Catch rates of pelagic fish versus fishing depth in the Åkra trawl during SI_ARCTIC 2015 survey.

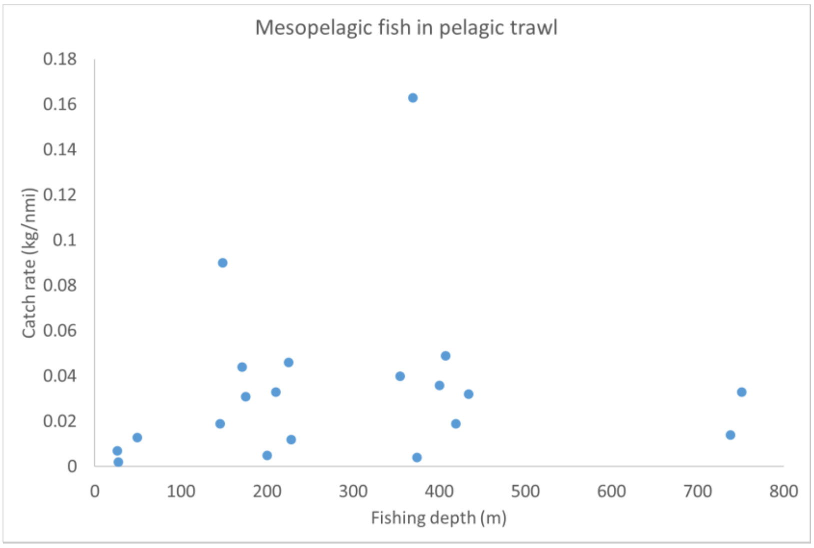


Figure 24. Catch rates of mesopelagic fish versus fishing depth in the Åkra trawl during SI_ARCTIC 2015 survey.

Trends in biomass caught in the Campelen trawl versus depth and temperature

A clear downward trend with bottom depth was seen (Figure 25). However, the relationship between catch and depth is not statistically significant at the 5% level (p=0.08) and only 12% of the variation in catch is accounted for by the regression.

A similar analysis was conducted for the benthos bycatch data. No trend can be seen for these data (Figure 26). There is a negative trend in catches with bottom depth, but when analyzed statistically it is not significant (p=0.09).

When the total catch/nmi of demersal species is plotted versus the temperature at the bottom, a positive trend is seen (Figure 27). A linear regression analysis was run on this dataset, and it was highly significant (N= 26, p = 0.01), suggesting that there is a positive relationship between bottom temperature and catch rates of fish in this area.

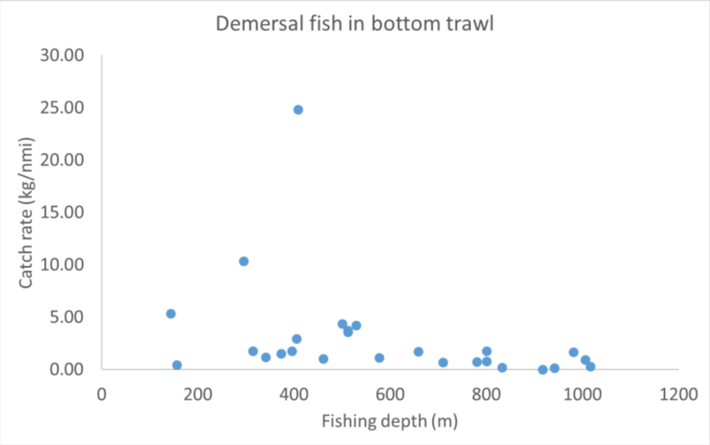


Figure 25. Catch rates of demersal fish versus fishing depth in the Campelen bottom trawl during SI_ARCTIC 2015 survey.

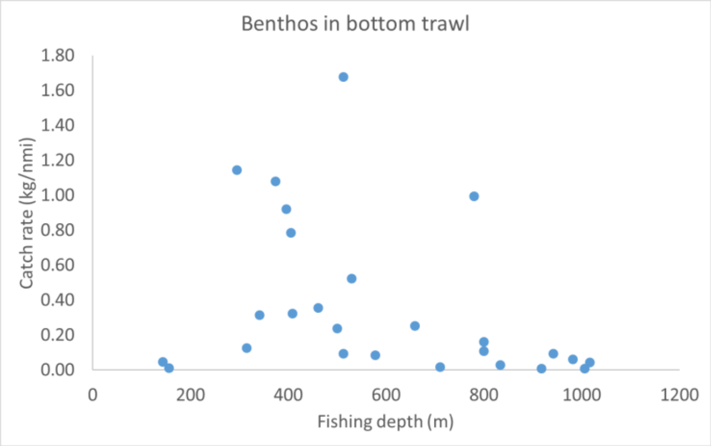


Figure 26. By-catch rates of benthos versus fishing depth in the Campelen bottom trawl during SI_ARCTIC 2015 survey.

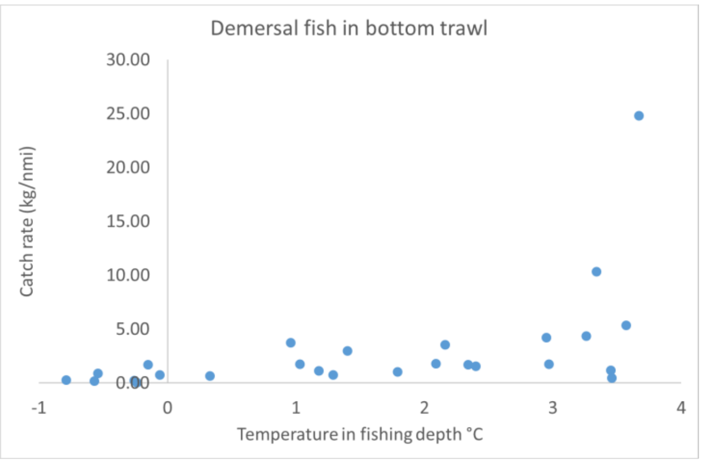


Figure 27. Catch rates of demersal fish versus temperature in the fishing depth in the Campelen bottom trawl during SI_ARCTIC 2015 survey.

Benthos

The number of specimens, the biomass and the species number at each station (excluding *Pandalus borealis*) varied in time and space but the highest biomasses (100-550 kg/10min trawling) were found offshore and deeper than 460 m (except st. 2036 which were offshore, but shallower). Stations with lower biomass were found both in- and offshore, and stations with very low biomasses were particularly frequent north of Svalbard (Figure 28 and Table A6). Species number was, as the abundance of individuals, scattered among stations and without any obvious pattern except having many low numbers north of Svalbard.

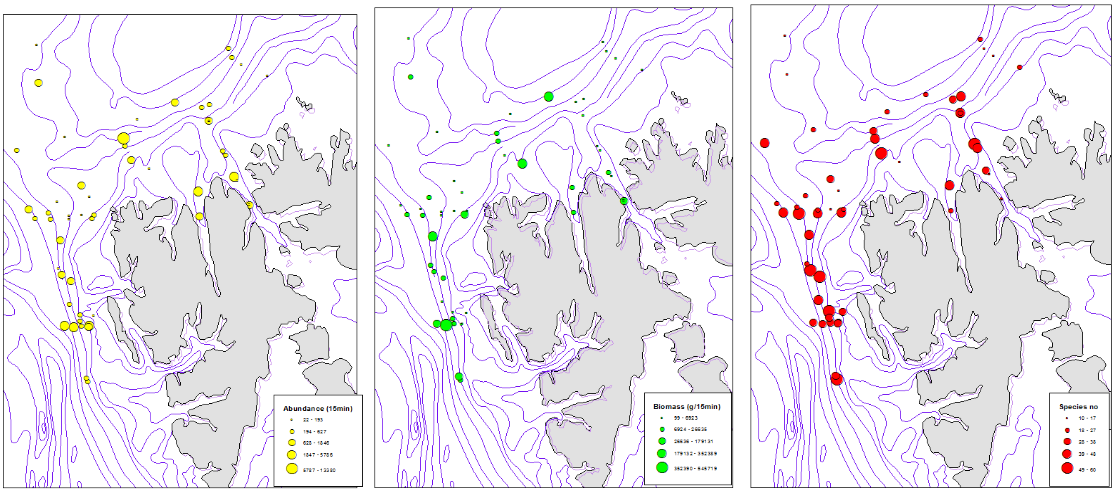


Figure 28. Abundance, biomass and species number from Campelen trawl catch for 2014 and 2015.

In order to investigate changes along depth gradients to the west and north of Svalbard, 5 transect is suggested (Figure 29). These include a south-western transect (SW: 126 - 1023 m depth), the Fram transect (Fram: 300 – 1025 m depth), the north-western transect (NW: 150 – 1011 m depth), the Hinlopen strait (HL Strait) including a transect from inshore to offshore (300 – 420 m depth), and the north-eastern transect (NE: 150 – 960 m depth).

The bottom temperatures recorded on the transects indicates positive temperatures above and negative temperatures below 700 m (Figure 30).

The largest biomasses and abundances are often recorded below 600−700 m, except on the NW and the Fram transect with one large catch shallower (Figure 31). At the SW,- Fram- and the NE transect the mean body weight per species increased with depth, while at the NW the body weight decreased. Species number did not show any pattern related to depth.

The inn-off shore Hinlopen transects (Figure 32) did not show any particular patterns in biomass, abundance, species number or body weight.

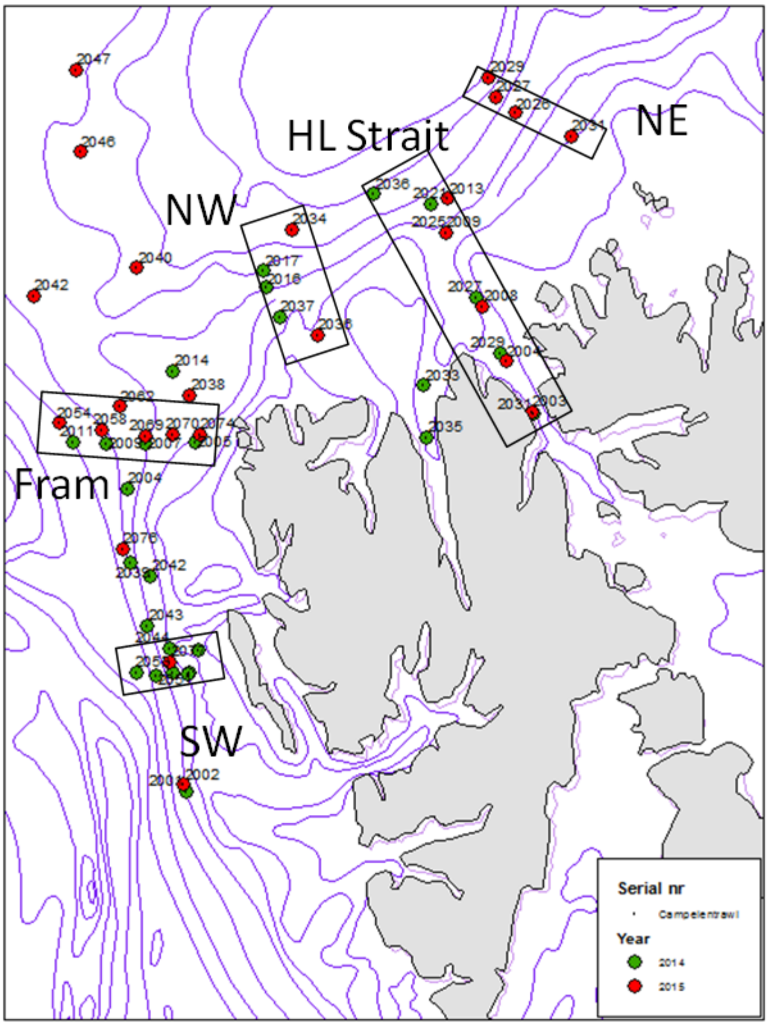


Figure 29. Campelen trawl stations taken in 2014 (green) and 2015 (red). Defined transects with transect name, serial number and year (-14 or -15): **SW** (2044-14, 2045-14, 2046-14, 2047-14, 2049-14, 2051-14, 2053-14), **Fram** (2005-14, 2007-14, 2009-14, 2011-14, 2054-15, 2058-15, 2062-15, 2069-15, 2070-15, 2074-15), **NW** (2016-14, 2017-14, 2037-14, 2034-15, 2036-15), **HL strait** (2021-14, 2025-14, 2027-14, 2029-14, 2031-14, 2036-14, 2003-15, 2004-15, 2008-15, 2009-15, 2013-15), **NE** (2026-15, 2027-15, 2029-15, 2031-15). See Table A9 for details.

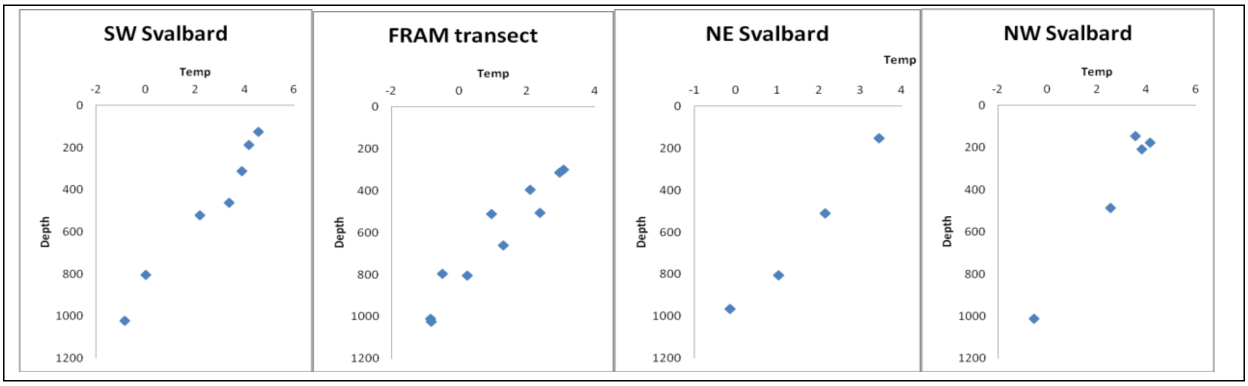


Figure 30. The depth – bottom-temperature profile of the four suggested depth gradients.

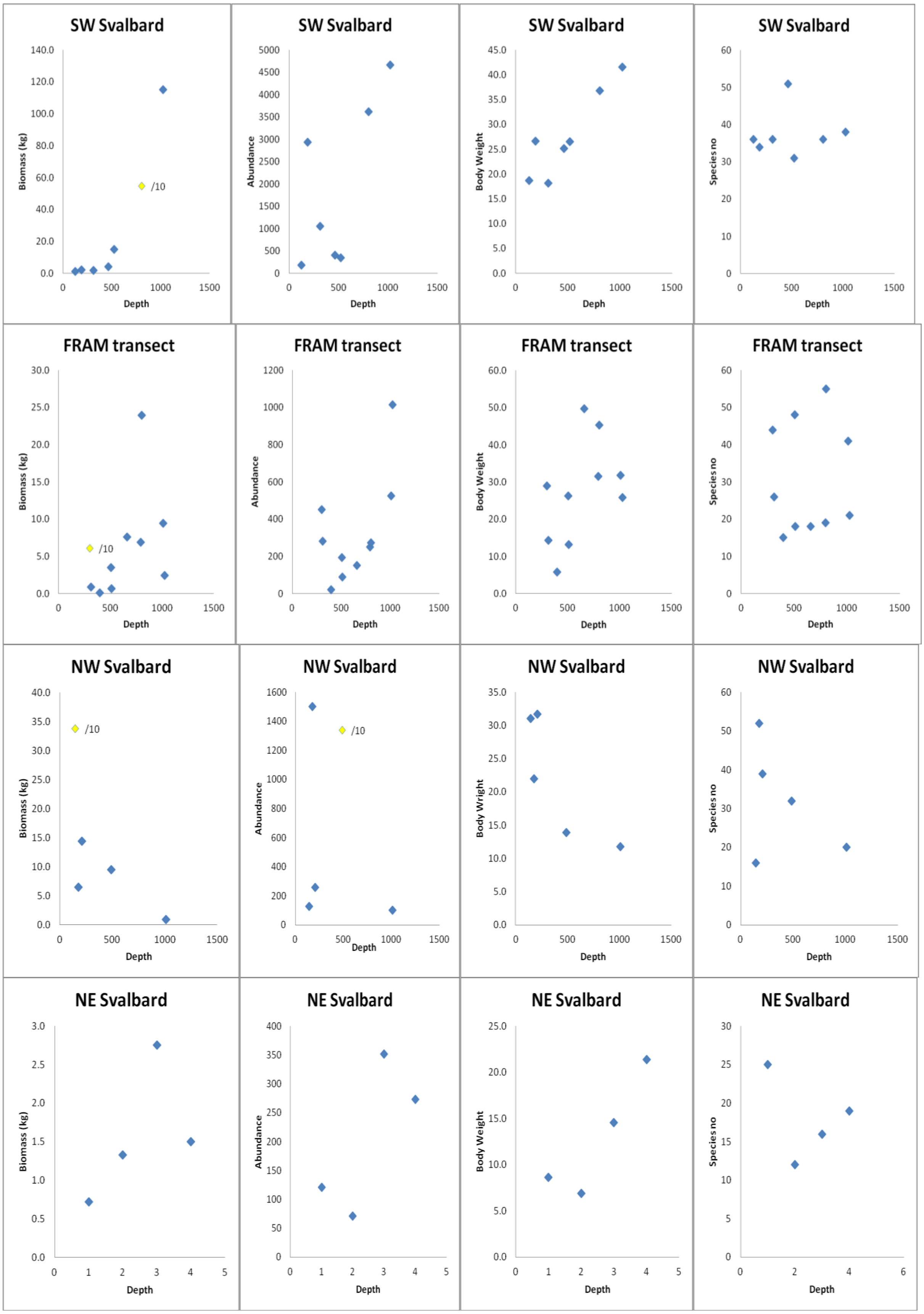


Figure 31. The biomass (kg), abundance, body weight (g) and species number per depth at the four depth transects. The yellow symbols show that the value was reduced by a factor 10.

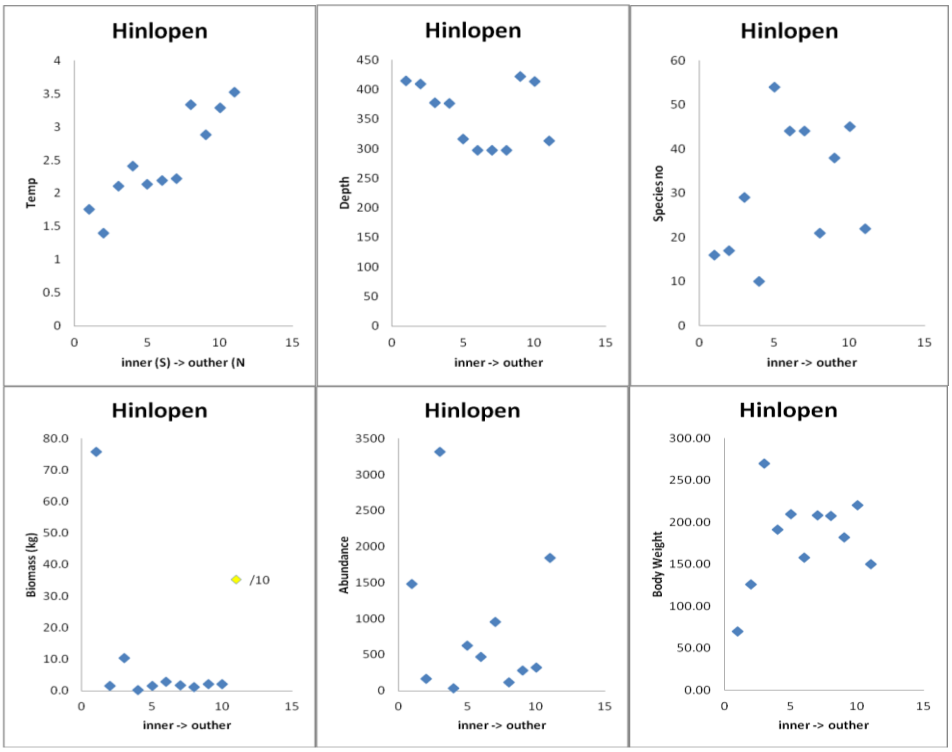


Figure 32. The Hinlopen strait with bottom temperature, depth, species number, biomass, abundance and mean body weight per species from inner to outher parts of the strait.

Marine mammals

During the survey, all together 16 blue whales, 39 fin whales, 6 humpback whales, 4 minke whales, 31 unidentified large whales, 2 killer whales, 10 white-beaked dolphins, 117 harp seals, 1 bearded seal, 4 unidentified seals and 11 walruses were observed (Table 4). The spatial distribution of these sightings is shown in Figure 33.

The general impression is that mammals were more frequently observed in the northern areas (north of 79^{o}30’N) than along the shelf edge further south. Whales were particularly abundant over the Yermak Plateau and along the south-north transect running from the mouth of the Hinlopen Strait (Figure 33). The seals, primarily harp seals, were found very concentrated on ice or along the ice edge over the Yermak Plateau. Walruses were observed in Svalbard coastal areas, in particular at Moffen.

The whales observed both over the Yermak Plateau and north of Hinlopen were dominated by fin and blue whales. Both these, and also the harp seals observed over the Yermak Plateau, are known to feed intensively on zooplankton, krill and amphipods in particular, during summer and autumn. The acoustic backscatter showed elevated levels in these regions between 300 and 500 m depth, but partly also in the upper layer <100 m depth (Figure 20) and the plankton net hauls confirmed the presence of copepods, krill and amphipods in the regions. The possibly high concentrations of zooplankton in key areas (and consequently) mammals are likely linked to topography and ocean currents.

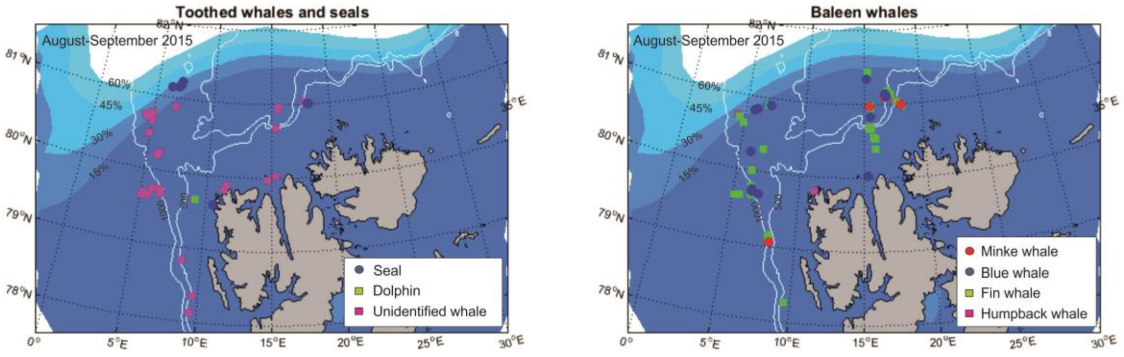


Figure 33. Locations where groups of toothed whale/seal (left) and baleen whale (right) species were observed. Each location denotes one sighting. For some of the sightings several animals were part of the observation. The unidentified whales in the left panel may have been both toothed and baleen whales.

During the SI_ARCTIC survey in 2014, two “hot spots” with particularly large numbers of baleen whales were observed north of Svalbard, along the transect proceeding from south to north from the Hinlopen Strait. The northernmost of these hot spots was located on the shelf break – this is an area where many baleen whales were observed also in 2015. The other hot spot was located further to the south, at the mouth and within the Hinlopen Strait – in these areas no whales were observed in 2015.

Killer whales and dolphins were only observed in areas west of Svalbard.

Table 4. Number of marine mammal individuals observed in 2015, sorted by four regions; Fram Strait south, Fram Strait north, Yermak and Hinlopen. All observations are given including also those recorded when the vessel was stationary.

Species	**Fram Strait south** (south of 79°N)	**Fram Strait north** (79°N-80°N)	**Yermak** (north of 80°N, west of 10°E)	**Hinlopen** (north of 80°N, east of 10°E)
	Animals (#)	Animals (#)	Animals (#)	Animals (#)
Blue whale		3	5	8
Minke whale		1		3
Fin whale	1	7	5	26*
Humpback whale		1	1	4
Killer whale			2	
Unidentified whale	3	10	10	8
White-beaked dolphin		10		
Harp seal			117	
Bearded seal				1
Unidentified seal		2	1	1
Walrus		7		4
Total	**4**	**41**	**141**	**55**

*14 of the 26 observations made when the vessel was stationary

Discussion

The second SI_ARCTIC survey was conducted with R/V *Helmer Hanssen* 17 August-7 September 2015. The survey covered open and partly ice covered waters west and north of Svalbard. During the survey, most parts of the marine ecosystem was sampled including physical, chemical and biological oceanography (temperature, salinity, currents, fluorescence, oxygen, nutrients and chlorophyll). Phytoplankton and zooplankton (species abundance and biomass), fish (species abundance, biomass, age and stomach content), and benthic organisms (species abundance and biomass) were sampled using a multitude of different gear. Detailed acoustic measurements in the water column were conducted using a TS-probe. Underway acoustic registration of fish and plankton (eco sounder) and ocean currents (ADCP), underway measurements of surface layer temperature, meteorology and sea state, and visual observations of marine mammals and birds were also conducted. Tissue samples for stable isotope analyses were collected from pelagic, dermersal and benthic species.

With regard to the main scientific questions of the survey the following results were obtained:

- New data were obtained on species and communities which will be used to describe who is eating whom in this region.
- Both the catches and acoustics suggested less biomass in 2015 compared to 2014. Thus there seem to be large inter-annual variations which might be related to distribution changes and/or changes in species composition. More analyses are needed before conclusions can be drawn.
- The mesopelagic layer:
  - The dominating species in the different regions were evaluated.
  - Parts of the layer perform dial vertical migration despite less varying sunlight compared to lower latitudes.
- Hotspots evident in 2014 were not present in 2015.
- Cod in the pelagic was evident all the way to the westernmost part of the Fram Strait north section.
- New data on the current status and variability of ocean acidification (OA) state in the shelf and deep basin in the ice-covered areas north of Svalbard were obtained.

Acknowledgements

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Appendix A. Tables and figures.

Table A1. Stations with equipment used during the SI_ARCTIC 2015 survey. Position and bottom depth are based on CTD. Station number for the different equipment is given.

Location	Date when starting	Latitude (average)	Longitude (average)	Bottom depth (m)	Ice	CTD	L-ADCP	Water samples (nutrient, phyto)	Water samp. CO2 (ph/ A_T)*	Phyto net (0-30m)	WP2/Juday	MIK	Multinet	Krill trawl	TS prob	Harstad trawl	Åkra trawl	Campelen trawl	Beam trawl	Grab	Comment *Samples for δ^{18}O
Case 1	**18.08**	**77°59.64**	**09°29.71**	**480**	0	59		59	59	59	59 (bottom-0, bottom-0)						132/2001 (failed)	133/2002			Case 1
Calibrate TS	18.08	79°38.40	11°17.12	123	0	60															
Hinlopen section	19.08	79°46.72	18°06.94	407	0	61		61	61*	61	61 (bottom-0, bottom-0)							134/2003			
	20.08	80°02.44	17°20.16	390	0	62		62	62*	62	62 (bottom-0, bottom-0)		62 (60-0m, 120-60m, 180-120m 240-180m, 300-240m)				136/2005 (54m) 137/2006 (152m) 138/2007 (222m)	135/2004			
	20.08	80°16.31	16°45.80	327	0	63		63	63*	63	63 (bottom-0, bottom-0)							139/2008			
	21.08	80°33.23	15°53.84	299	0	64		64	64*	64	64 (bottom-0, bottom-0)							140/2009			
	21.08	**80°41.12**	**15°31.89**	**512**	0	65		65	65*	65	65 (bottom-0, bottom-0)		65 (0-50m, 100-50m, 200-100m, 300-200m, 410-300m)				141/2010 (50m) 142/2011 (150m) 143/2012 (397m)	144/2013	2040	2010, 2011, 2012, 2014	Case 2, Greenland shark line
	22.08	80°43.15	15°30.67	998	0	66		66	66*	66	67 (bottom-0, bottom-0)						145/2014 (100m, 20 min) 146/2015 (200m, 20 min) 147/2016 (400m, 20 min)				
	22.08	80°49.61	15°33.89	1861	0	67		67	67*	67							148/2017 (354m, 75min)				Trawl on reg.
	27.08	81°00.60	15°35.92	2080	0	76		76	76	76	76 (bottom-0, 500-0)	76 (600-300m)			76	163/2032 (3 depths)					Ecosystem 461
	24.08	81°20.26	15°31.95	2200	0	71		71	71*	71	71 (bottom-0, 500-0)		71 (250-0m 500-250m, 1000-500m, 1700-1000m)	155/2024 (450-5m, 30 min)	71	156/2025 (3 depths)	152/2021 (59m, 30 min) 153/2022 (346m, 30 min) 154/2023 (434 m, 30 min)			5,6	Ecosystem 455
	23.08	81°37.58	15°36.77	2175	0	68		68	68*	68	68 (bottom-0, 500-0)	68 (500-350m)					149/2018 (50m-30min) 150/2019 (350m, 30min) 151/2020 (450-5m, 60 min)				Hinlopen outside ice
	23.08	81°55.90	15°40.78	2428	5	69		69	69*	69	69 (bottom-0, 500-0)		69 (0-50m, 250-50m, 500-250m, 1000-500m, 1700-1000m) (vertical)		69						Hinlopen in ice
	24.08	82°06.40	15°12.67	2409	5-6	70		70	70*	70	69 (bottom-0, 500-0)										
Slope crossing	25.08	81°02.90	17°38.93	504	0	72		72							72			157/2026			Greenland shark line
	26.08	81°06.51	17°07.39	815	0	73		73							73			158/2027			
	26.08	81°06.75	16°52.62	1031	0	74		74							74	159/2028 (3 depths)		160/2029			Trawl on reg.

Location	Date when starting	Latitude (average)	Longitude (average)	Bottom depth (m)	Ice	CTD	L-ADCP	Water samples (nutrient, phyto)	Water samp. CO2 (ph/ A$_T$)	Phyto net (0-30m)	WP2/Juday	MIK	Multinet	Krill trawl	TS prob	Harstad trawl	Åkra trawl	Campelen trawl	Beam trawl	Grab	Comment
Ecosystem stations	26.08	80°55.07	18°51.07	140	0	75		75	75	75	75 (bottom-0)				75	161/2030 (4 depths)		162/2031			Ecosystem 465
	27.08	80°36.61	11°48.68	1096	0	77		77	77	77			77 (200-0m, 300-200m, 400-300m, 500-400m, 600-500m)		77	164/2033 (3 depths)		165/2034			Ecosystem 464
	28.08	80°05.47	12°52.95	130	0	78		78	78	78	78 (bottom-0)				78	166/2035 (3 depths)		167/2036			Ecosystem 307
	28.08	79°52.73	09°37.93	460	0	79		79		79	79 (bottom-0)				79	168/2037 (3 depths)		169/2038			Ecosystem 227
	29.08	80°24.30	08°24.69	816	0	80		80	80*	80	80 (bottom-0)				80	170/2039 (3 depths)		171/2040			Ecosystem 463
	29.08	80°12.98	05°49.21	676	0	81		81	81*	81	81 (bottom-0)				81	172/2041 (3 depths)		173/2042			Ecosystem 462
	30.08	80°42.95	04°20.82	736	0	82		82	82*	82	82 (bottom-0)				82	175/2044		174/2043			Ecosystem 457
	30.08	80°55.45	07°03.47	898	0	83		83	83*	83	83 (bottom-0)				83	176/2045		177/2046			Ecosystem 458
Yermack ice edge	30.08	81°15.16	07 °06.94	729	0	84	84	84	84*	84	84 (bottom-0)		84 (100-0m, 200-100m, 300-200m, 500-300m 700-500m)		84	179/2048		178/2047		7	Yerm ice edge
Yermack in ice	31.08	81°19.64	07°34.47	414	4	85	85	85	85*	85	85 (bottom-0)	85 (0-65m)			85 (*2)					8	MIK on regist.
Fram Strait	31.08	79°38.34	05°08.34	2623 (1500)	0	86	86	86	86*	86	86 (1500-0, 500-0m)		86 (50-0m, 250-50m, 500-250m, 1000.500m, 1700-1000m)		86		180/2049 (375m-30 min) Due to uncertainties regarding trawl symmetry in the beginning of the haul, fishing depth varied and effective time is more than 30 min.				CTD and WPII to 1500 m. One net on Åkratrawl, open during entire haul.
	01.09	79°39.91	05°51.32	1532	0	87	87	87	87	87	87 (bottom-0, 500-0)	87 (200-300m)			87		181/2050 (255-400m)				
	02.09	79°41.53	06°25.81	1086	0	88	88	88	88	88	88 (bottom-0, 500-0)				88		182/2051 (failed) 183/2052 (failed) 184/2053 (0-400m)	185/2054			
	02.09	79°40.44	07°32.63	797	0	89	89	89	89	89	89 (bottom-0, 500-0)	89 (150-300m)			89		186/2055 (failed) 187/2056 (failed) 188/2057 (failed) 194/2063 (50m, 30 min) 195/2064 (315m, 30 min) 196/2065 (407m, 30 min)	189/2058		9	Åkratrawl 194-196 conducted on 3 Sept.
	03.09	79°40.32	07°55.39	716	0	90	90	90	90	90	90 (bottom-0, 500-0)				90		190/2059 (50m, 30 min) 191/2060 (280m, 30 min) 192/2061 (400m, 30 min)	193/2062			
	03.09	79°39.82	08°29.46	496	0	91	91	91	91	91	91 (bottom-0, bottom-0)	91 (200-300m)			91		197/2066 (50m, 30 min) 198/2067 (220, 30 min) 199/2068 (330m, 30 min)	200/2069		10	
	04.09	79°40.04	09°04.76	398	0	92	92	92	92	92	92 (bottom-0, bottom-0)				92		202/2071 (50m, 30 min) 203/2072 (300m, 30min)	201/2070			
	04.09	79°40.59	09°43.32	304	0	93	93	93	93*	93	93 (bottom-0, bottom-0)	93 (0-270m)			93		204/2073 (0-100m, 30 min)	205/2074			
Ecosystem Stations	05.09	79°08.12	08°04.86	924	0	94	94	94	94	94	94 (bottom-0)				94	206/2075 (3 depths)		207/2076			
	05.09	78°37.00	09°07.10	527	0	95	95	95		95	95 (bottom-0)				95	209/2078 (3 depths)		208/2077			TS probe station. 10-12 h probing.

Table A2. Participation list

Name	Expertise	Institution
Randi B. Ingvaldsen	Physical oceanography and cruise leader	Institute of Marine Research
Melissa Chierici	Chemical oceanography	Institute of Marine Research
Harald Gjøsæter	Fish, acoustics	Institute of Marine Research
Egil Ona	Acoustics	Institute of Marine Research
Silje Seim	Fish	Institute of Marine Research
Trine Haugen	Fish	Institute of Marine Research
Thomas Wenneck	Fish	Institute of Marine Research
Gunnar Langhelle	Fish	University of Bergen
Tor Knutsen	Plankton (zoo)	Institute of Marine Research
Lars-Johan Naustvoll	Plankton (phyto)	Institute of Marine Research
Peter Wiebe	Plankton (acoustics)	Woods Hole Oceanographic Institution, US
Ann Bucklin	Plankton (genetics)	University of Connecticut, US
Aino Hosia	Plankton (jellyfish)	University of Bergen
Lis L. Jørgensen	Benthos	Institute of Marine Research
Vitaly Syomin	Benthos	PINRO, Russia
Vera Helene Lund	Benthos - isotopes	Institute of Marine Research
Jenny Bortoluzzi	Benthos - isotopes	UK
Gunnar Rikardsen	Marine mammals observ.	Institute of Marine Research – external
Silje Vindenes	Marine mammals observ.	Institute of Marine Research – external
Stuart Murray	Seabirds	Norwegian Institute of Nature Research
Julius Nielsen	Grenland shark	Univeristy of Copenhangen/University of Tromsø
Samuel Iglesias	Chemical oceanography	Museum national d'Historie naturelle, France
Ronald Pedersen	Technician - instrumentation	Institute of Marine Research
Gunnar Lien	Technician - instrumentation	Institute of Marine Research

Table A3. Specimens of target zooplankton species that were identified, photographed, and individually flash-frozen in liquid nitrogen for transcriptomic or gene expression analysis. Columns show species names, life stages, collection information (station number, net or depth), and range of vial numbers and images numbers. "Sample" indicates images of unsorted samples prior to preservation in ethanol; "Mag" indicates magnification of images; "At UConn" indicates vials transported immediately following the cruise.

Species	Stage	Station	Net Sample	Net or Depth	Date	Vial # Start	Vial # End	Image # Start	Image # End	Mag	At UConn
C fin / C gla	F-CIII	87	Juday-1	1560m	1-Sep-15	442	451	0643	0652	3.2	X
C finmarchicus		86	Multinet	Net5	1-Sep-15	402	409	0607	0614	2.5	
C finmarchicus		86	Multinet	Net5	1-Sep-15	410	410	0617	0617	2.5	X
C finmarchicus		86	Multinet	Net5	1-Sep-15	411	411	0625	0625	2.5	
C finmarchicus		86	Multinet	Net5	1-Sep-15	412	412	0624	0624	2.5	
C finmarchicus		86	Multinet	Net5	1-Sep-15	413	413	0623	0623	2.5	
C finmarchicus		86	Multinet	Net5	1-Sep-15	414	418	0618	0622	2.5	
C glacialis	CIV-CV	89	WP-2 (2)	500m	2-Sep-15	510	519	0703	0712	3.2	X
C glacialis		61	Juday-2		19-Aug-15	1	1	0043	0043	2.5	
C glacialis		62	Juday-2		19-Aug-15	2	10	0044	0052	2.0	
C glacialis		62	Juday-2		19-Aug-15	11	18	0053	0060	2.5	
C glacialis		62	MN	N5 0-60	20-Aug-15	22	31	0061	0070	3.2	
C glacialis		63	Juday-2		20-Aug-15	35	40	0084	0090	1.25	
C glacialis		63	Juday-2		20-Aug-15	40	40	0091	0091	1.25	
C glacialis		63	Juday-2		20-Aug-15	42	50	0093	0101	2.5	
C glacialis		64	Juday-2		20-Aug-15	51	60	0105	0114	2.5X	
C glacialis		65	Multinet	N1	21-Aug-15	63	63	0124	0125	2.5	
C glacialis		66	Juday-2		22-Aug-15	91	100	0156	0165	2.5	
C glacialis		67	Juday-2		22-Aug-15	131	140	0181	0190	2.5	
C glacialis	CV	68	WP-2 (2)	0-500m	23-Aug-15	186	186	0206	0206	1.6	
C glacialis		75	Juday-1		25-Aug-15	247	256	0274	0284	3.2	
C glacialis		75	Juday-1		25-Aug-15	N/A	N/A	0277	0277	3.2	
C glacialis		75	Juday-1		25-Aug-15	257	266	0285	0295	3.2	
C glacialis		75	Juday-1		25-Aug-15	259	259	0288	0288	3.2	
C glacialis		76	WP-2(2)	0-500 m	26-Aug-15	267	276	0304	0313	3.2	
C glacialis		76	WP-2(2)	0-500 m	26-Aug-15	277	286	0314	0323	3.2	
C glacialis	CIII-CV	78	Juday-1		28-Aug-15	307	316	0375	0384	2.5	
C glacialis	CV?	81	Juday-1		30-Aug-15	317	323	0403	0409	2.5	
C glacialis	CV?	81	Juday-1		30-Aug-15	324	324	0410	0411	2.5	
C glacialis	CV?	81	Juday-1		30-Aug-15	325	325	0412	0412	2.5	
C glacialis	CIII-CV	84	Multinet	Net 5	30-Aug-15	331	340	0495	0504	2.5	
C glacialis	CIII-CV	84	Multinet	Net 5	30-Aug-15	341	350	0505	0514	2.5	X
C glacialis	CIII-CV	87	Juday-1	1560m	1-Sep-15	452	460	0653	0661	3.2	X
C glacialis	CIV-CV	89	WP-2 (2)	500m	2-Sep-15	520	529	0713	0722	3.2	X
C glacialis	CIV-CV	91	Juday-2	495m	3-Sep-15	558	567	0741	0750	2.5	X
C glacialis		93	Juday-2	270m	4-Sep-15	585	594	0755	0764	2.5	X
C glacialis		65	Multinet	N5	21-Aug-15	71	78	0131	0140	2.5	
C glacialis		93	Juday-2	270m	4-Sep-15	595	604	0765	0774	2.5	
C glacialis	CIV, CV	71	WP-2 (2)	0-500m	24-Aug-15	207	216	0257	0266	2.5	
C glacialis?	CIV, CV	71	WP-2 (2)	0-500m	24-Aug-15	197	206	0247	0256	2.5	
C glacialis?		86	Multinet	Net5	1-Sep-15	400	401	0605	0606	2.5	

Table A3. Continued

Species	Stage	Station	Net Sample	Net or Depth	Date	Vial # Start	Vial # End	Image # Start	Image # End	Mag	At UConn
C hyp/C gla		66	Juday-2		22-Aug-15	81	90	0146	0155	1.6	
C hyp?, C gla?		65	Multinet	N1	21-Aug-15	64	70	0124	0130	2.5	
C hyperboreus		65	Multinet	N1	21-Aug-15	61	61	0121	0121	2.5	
C hyperboreus	F, CV	67	Juday-2		22-Aug-15	121	126	0171	0176	1.6	
C hyperboreus		67	WP-2 (2)		22-Aug-15	127	130	0177	0180	1.6	
C hyperboreus	F	71	WP-2 (2)	0-500m	24-Aug-15	190	194	0240	0244	1.6	
C hyperboreus	CV	71	WP-2 (2)	0-500m	24-Aug-15	195	196	0245	0246	1.6	
C hyperboreus	F	84	Multinet	Net 5	30-Aug-15	327	330	0491	0494	1.6	
C hyperboreus	F	85	WP-2(2)	500m	31-Aug-15	351	357	0515	0521	1.6	X
C hyperboreus	CV	85	WP-2(2)	500m	31-Aug-15	358	359	0521	0522	1.6	X
C hyperboreus	F	85	WP-2(2)	500m	31-Aug-15	360	360	0523	0523	1.6	X
C hyperboreus	CV	85	WP-2(2)	500m	31-Aug-15	361	362	0524	0525	1.6	X
C hyperboreus	F	85	WP-2(2)	500m	31-Aug-15	363	366	0527	0530	1.6	X
C hyperboreus	CV	85	WP-2(2)	500m	31-Aug-15	367	368	0531	0532	1.6	X
C hyperboreus	F	85	WP-2(2)	500m	31-Aug-15	369	370	0533	0534	1.6	X
C hyperboreus	F	86	WP-2(1)	1511m	1-Sep-15	371	372	0580	0581	1.6	X
C hyperboreus	F	86	WP-2(1)	1511m	1-Sep-15	373	373	0582	0583	1.6	
C hyperboreus	F	86	WP-2(1)	1511m	1-Sep-15	374	380	584	590	1.6	
C hyperboreus	F	86	WP-2(1)	1511m	1-Sep-15	381	389	591	599	1.6	X
C hyperboreus		86	Multinet	Net5	1-Sep-15	419	421	0602	0604	1.6	X
C hyperboreus	F	87	Juday-1	1560m	1-Sep-15	432	438	0632	0638	1.6	X
C hyperboreus	F	87	Juday-1	1560m	1-Sep-15	439	439	0639	0640	1.6	X
C hyperboreus	F	87	Juday-1	1560m	1-Sep-15	440	441	0641	0642	1.6	X
C hyperboreus	F	87	Juday-1	1560m	1-Sep-15	461	464	0662	0665	1.6	
C hyperboreus	F	87	MIK	40m	2-Sep-15	480	489	0666	0675	1.6	X
C hyperboreus	F	87	MIK	40m	2-Sep-15	500	509	0681	0690	1.6	X
C hyperboreus	F	89	MIK	350-300m	2-Sep-15	540	551	0723	0734	1.6	X
C hyperboreus	F	68	WP-2 (2)	0-500m	23-Aug-15	171	185	0191	0205	1.6	
C hyperboreus	F	68	WP-2 (2)	0-500m	23-Aug-15	187	188	207	208	1.6	
C hyperboreus	CV	68	WP-2 (2)	0-500m	23-Aug-15	189	189	0209	0209	1.6	
C hyperboreus?	F	63	Juday-2		20-Aug-15	32	34	0082	0084	1.25	
C hyperboreus?	F	63	Juday-2		20-Aug-15	41	41	0092	0092	2.5	
Clio limacina		90	Juday-2	500m	3-Sep-15	557	557	N/A	N/A	N/A	X
Euchaeta		65	Multinet	N1	21-Aug-15	62	62	0122	0123	2.5	
M norvegica		68	MIK	0-500m	23-Aug-15	151	160	N/A	N/A	N/A	
M norvegica		75	Ptrawl	0-500m	25-Aug-15	217	226	N/A	N/A	N/A	
M norvegica		75	Ptrawl	0-500m	25-Aug-15	237	246	N/A	N/A	N/A	
M norvegica		76	MIK		27-Aug-15	287	296	N/A	N/A	N/A	
M norvegica		87	MIK	40m	2-Sep-15	465	474	N/A	N/A	N/A	X
M norvegica		89	MIK	350-300m	2-Sep-15	530	532	N/A	N/A	N/A	X
M norvegica		89	MIK	350-300m	2-Sep-15	552	554	N/A	N/A	N/A	X
M norvegica		91	MIK		4-Sep-15	568	573	N/A	N/A	N/A	X
Sample		62	MN	N5 0-60	20-Aug-15	N/A	N/A	0071	0078	0.71	
Sample		63	Juday-2		20-Aug-15	N/A	N/A	0079	0081	0.71	
Sample		64	Juday-2		20-Aug-15	N/A	N/A	0102	0104	0.71	
Sample		65	Multinet	N5	21-Aug-15	N/A	N/A	0115	0117	0.71	
Sample		65	Multinet	N1	21-Aug-15	N/A	N/A	0118	0120	0.71	
Sample		66	Juday-2		22-Aug-15	N/A	N/A	0141	0145	0.71	
Sample		67	Juday-2		22-Aug-15	N/A	N/A	0166	0170	0.71	
Sample		68	Juday-2	0-500m	23-Aug-15	N/A	N/A	0210	0215	0.71	

Table A3. Continued

Species	Stage	Station	Net Sample	Net or Depth	Date	Vial # Start	Vial # End	Image # Start	Image # End	Mag	At UConn
Sample		69	Multinet	Net 1	24-Aug-15	N/A	N/A	0216		0.71	
Sample		69	Multinet	Net 2	24-Aug-15	N/A	N/A	0224	0226	0.71	
Sample		69	Multinet	Net 3	24-Aug-15	N/A	N/A	0227	0228	0.71	
Sample		69	Multinet	Net 4	24-Aug-15	N/A	N/A	0229	0230	0.71	
Sample		69	Multinet	Net 5	24-Aug-15	N/A	N/A	0231	0233	0.71	
Sample		71	WP-2 (2)	0-500m	24-Aug-15	N/A	N/A	0234	0239	0.71	
Sample		75	Juday-1		25-Aug-15	N/A	N/A	0267	0273	0.71	
Sample		76	WP-2(2)	0-500 m	26-Aug-15	N/A	N/A	0296	0303	0.71	
Sample		77	Multinet	Net 1	28-Aug-15	N/A	N/A	0324	0331	0.71	
Sample		77	Multinet	Net 2	28-Aug-15	N/A	N/A	0332	0338	0.71	
Sample		77	Multinet	Net 3	28-Aug-15	N/A	N/A	0339	0348	0.71	
Sample		77	Multinet	Net 4	28-Aug-15	N/A	N/A	0349	0356	0.71	
Sample		77	Multinet	Net 5	28-Aug-15	N/A	N/A	0357	0365	0.71	
Sample		78	Juday-1		28-Aug-15	N/A	N/A	0366	0368	0.71	
Sample		78	Juday-1		28-Aug-15	N/A	N/A	0369	0374	1.25	
Sample		79	Juday-1		28-Aug-15	N/A	N/A	0385	0395	0.71	
Sample		81	Juday-1		30-Aug-15	N/A	N/A	0396	0402	0.71	
Sample		82	Juday-1		30-Aug-15	N/A	N/A	0413	0438	0.71	
Sample		84	Juday-1		30-Aug-15	N/A	N/A	0439	0448	0.71	
Sample		84	Multinet	Net 1	30-Aug-15	N/A	N/A	0449	0456	0.71	
Sample		84	Multinet	Net 2	30-Aug-15	N/A	N/A	0457	0471	0.71	
Sample		84	Multinet	Net 4	30-Aug-15	N/A	N/A	0472	0479	0.71	
Sample		84	Multinet	Net 3	30-Aug-15	N/A	N/A	0480	0485	0.71	
Sample		84	Multinet	Net 5	30-Aug-15	N/A	N/A	0486	0490	0.71	
Sample		86	WP-2(1)	1511m	1-Sep-15	N/A	N/A	0575	0578	0.71	
Sample		86	Juday-2	500m	1-Sep-15	N/A	N/A	600	601	0.71	
Sample		87	Juday-1	1560m	1-Sep-15	N/A	N/A	0627	0631	0.71	
Sample		88	Juday-2	500m	2-Sep-15	N/A	N/A	0691	0699	0.71	
Sample		89	WP-2 (2)	500m	2-Sep-15	N/A	N/A	0700	0702	0.71	
Sample		91	Juday-2	495m	3-Sep-15	N/A	N/A	0735	0740	0.71	
Sample		93	Juday-2	270m	4-Sep-15	N/A	N/A	0751	0754	0.71	
T inermis		62	Juday-2		20-Aug-15	21	21	N/A	N/A	N/A	
T inermis		68	MIK	0-500m	23-Aug-15	141	150	N/A	N/A	N/A	
T inermis		75	Ptrawl	0-500m	25-Aug-15	227	236	N/A	N/A	N/A	
T longicaudata		62	Juday-2		20-Aug-15	19	19	N/A	N/A	N/A	
T longicaudata		62	Juday-2		20-Aug-15	20	20	N/A	N/A	N/A	
T longicaudata		67	WP-2 (2)		22-Aug-15	101	120	N/A	N/A	N/A	
T longicaudata		68	MIK	0-500m	23-Aug-15	161	170	N/A	N/A	N/A	
T longicaudata		76	MIK		27-Aug-15	297	306	N/A	N/A	N/A	X
T longicaudata		86	Multinet	Net5	1-Sep-15	390	399	N/A	N/A	N/A	X
T longicaudata		87	Juday-1	1560m	1-Sep-15	422	431	N/A	N/A	N/A	X
T longicaudata		87	MIK	40m	2-Sep-15	475	479	N/A	N/A	N/A	
T longicaudata		89	MIK	350-300m	2-Sep-15	533	539	N/A	N/A	N/A	X
T longicaudata		90	Juday-2	500m	3-Sep-15	555	556	N/A	N/A	N/A	X
T longicaudata?		91	MIK		4-Sep-15	574	584	N/A	N/A	N/A	X
Themisto libellula		87	MIK	40m	2-Sep-15	490	499	0676	0680	0.71	X
XX Not preserved		86	Multinet	Net5	1-Sep-15	N/A	N/A	0626	0626	2.5	
XX Not preserved						79	80				
XX Not preserved			Null		Null	N/A	N/A	0579	0579	N/A	
XX Not preserved			Multinet	Net5	1-Sep-15	N/A	N/A	0615	0616	N/A	

Table A4. Samples preserved in 95% undenatured ethyl alcohol (EtOH) for genetic analysis during the 2015 SI_Arctic cruise. Samples were taken primarily from a second WP-2 plankton net haul done at many stations (see Figure 3). Samples were also obtained from some MIK and Juday net samples, as indicated here.

Station	Date	Species or Sample	Splits	Gear / Cast	Net or Depth	Time (UTC)	LAT	LONG
59	8-Aug-2015	Sample	1/2, 2/2	WP-2 (2)	479.89	9:22:46 AM	77.9936	9.4855
61	20-Aug-2015	Sample	1/2, 2/2	WP-2 (2)	407 m	12:02:03 AM	79.7800	18.0950
62	20-Aug-2015	Sample	1/2, 2/2	WP-2 (2)	370 m	9:42:31 AM	80.0387	17.3314
63	20-Aug-2015	Sample	1/4, 2/4	WP-2 (2)	342.82	9:08:25 PM	80.2730	16.7506
64	21-Aug-2015	Sample	1/2, 2/2	WP-2 (2)	318 m	4:40:00 AM	80.5531	15.8771
65	21-Aug-2015	Sample	1/2, 2/2	WP-2 (2)	470 m	10:13:42 AM	80.6848	15.5065
66	21-Aug-2015	Sample	1/2, 2/2	WP-2 (2)	968	11:12:41 PM	80.7210	15.5473
67	22-Aug-2015	Sample	1/2, 2/2	WP-2 (2)	1875	2:39:50 PM	80.8227	15.5475
68	23-Aug-2015	Sample	1/4, 2/4	WP-2 (2)	500 m	1:24:11 AM	81.6244	15.5519
69	23-Aug-2015	Sample	1/1	WP-2 (2)	500 m	3:15:28 PM	81.9394	15.6460
70	24-Aug-2015	Sample	1/2	WP-2 (2)	500 m	5:31:48 AM	82.1060	15.1459
71	25-Aug-2015	Sample	1/1	WP-2 (2)	500 m	3:50:18 AM	81.3849	14.8455
75	26-Aug-2015	Sample	1/1	Juday-1	149	6:59:53 PM	80.9183	18.8687
76	27-Aug-2015	Sample	1/1	WP-2 (2)	500 m	4:53:02 AM	81.0014	15.6036
77	28-Aug-2015	Sample	1/2	Multinet	Net 1	10:27:04 PM	80.5634	12.2388
77	28-Aug-2015	Sample	1/2	Multinet	Net 2	"	"	"
77	28-Aug-2015	Sample	1/2	Multinet	Net 3	"	"	"
77	28-Aug-2015	Sample	1/2	Multinet	Net 4	"	"	"
77	28-Aug-2015	Sample	1/4	Multinet	Net 5	"	"	"
78	28-Aug-2015	Sample		Juday-1	1096m	3:15:21 AM	80.0921	12.8732
80	29-Aug-2015	Sample	1/2	Juday-1	749 m	6:54:16 AM	80.4034	8.4124
81	29-Aug-2015	Sample	1/2	Juday-1	676m	3:39:36 PM	80.2168	5.8209
81	29-Aug-2015	T inermis	N/A	Harstad	60 m	19:46:18	80.2224	5.8577
82	30-Aug-2015	Sample	1/2	Juday-1	717 m	12:31:36 AM	80.7159	4.3466
83	30-Aug-2015	Sample	1/2	Juday-1	895 m	8:25:37 AM	80.9259	7.0621
84	30-Aug-2015	Sample	1/2	Juday-1	732m	4:49:18 PM	81.2514	7.1175
84	30-Aug-2015	Sample	1/2	Multinet	Net 5	9:27:13 PM	81.2381	7.2203
85	31-Aug-2015	Sample	1/1	WP-2 (2)	400m	4:55:28	81.3235	7.5359
86	31-Aug-2015	Sample	1/4	WP-2 (1)	1511m	23:53:20	79.6517	5.0856
86	1-Sep-2015	Sample	1/1	WP-2 (2)	500m	2:14:03 AM	79.6786	5.0366
86	1-Sep-2015	Sample	1/1	Juday-2	500m	"	"	"
86	1-Sep-2015	Sample	1/32	Multinet	Net 5	8:38:18	79.6300	5.1158
87	1-Sep-2015	Sample	1/2, 2/2	WP-2 (2)	500 m	9:34:13 PM	79.6742	5.9034
87	1-Sep-2015	Sample	1/1	Juday-1	1560	19:18:10	79.6500	5.8151
87	2-Sep-2015	Sample	1/8	MIK	40m	0:00:20	79.6599	5.8679
88	2-Sep-2015	Sample	1/1	WP-2 (2)	500m	10:53:13 AM	79.6976	6.4292
88	2-Sep-2015	Sample	1/1	Juday-2	500m	"	"	"
89	2-Sep-2015	Sample	1/2, 2/2	WP-2 (2)	500m	9:16:46 PM	79.6669	7.5280
89	2-Sep-2015	Sample	1/4	MIK	350-300m	0:24:29	79.6699	7.5164
90	3-Sep-2015	Sample	1/1	WP-2 (2)	500m	9:40:52 AM	79.6916	7.8423
91	3-Sep-2015	Sample	1/2, 2/2	WP-2 (2)	500m	11:46:17 PM	79.6578	8.4722
92	4-Sep-2015	Sample	1/2	WP-2(2)	500m	10:41:30 AM	79.6719	9.0555
93	4-Sep-2015	Sample	1/1	WP-2(2)	270m	6:31:00 PM	79.6738	9.7678
93	4-Sep-2015	Sample	1/1	Juday-2	270m	"	"	"
93	4-Sep-2015	Sample	1/16	MIK	273m	7:56:42 PM	79.6686	9.7955

Table A5. The EK60 echo sounder technical specifications and settings employed during the survey aboard the FRV "Helmer Hansen" August 2015. Calibrations of the systems were conducted in Smeerenburgfjord, Spitsbergen on 18 August 2015. All transducers were split beams; the raw EK60 data was sampled to a range 1000 m at a vertical resolution of 0.188 m for all frequencies.

EK60 system	18 kHz	38 kHz	120 kHz
Transducer			
Model	ES18-11	ES38B	ES120-7C
Equivalent beam angle 10log Ψ [dB]	-17.0	-20.6	-21.1
Calibration			
Sphere	CU64	CU60	WC-38.1
Range to sphere [m]	17	17	17
Sound speed [m/s]	1466	1466	1466
Absorption coefficient [dB km^{-1}]	3.1	10.4	31.3
Gain [dB]	23.15	26.25	25.28
Sa correction [dB]	-0.64	-0.65	-0.39
Beams			
Alongship half power opening angle[deg]	10.77	6.90	7.18
Offset Along. Angle [deg]	-0.11	-0.05	0.07
Athwartship half power opening angle [deg]	10.80	7.08	6.96
Offset Athwart. Angle [deg]	-0.16	-0.05	-0.01
Survey Settings			
Sound speed [m/s]	1466	1466	1466
Pulse duration [ms]	1.024	1.024	1.024
Electrical Power (W)	2000	2000	500
Noise Level (survey speed, 10 knots) (dB re. 1 uPa /√Hz), 38 kHz		39.5	

Table A6. Campelen bottom trawl stations 2014 and 2015 with species number, biomass and abundance of a 15 minutes trawl haul.

Year	Serial no	Lat	Lon	Species no	Biomass (kg/15min)	Abu/15min
2014	2001	78.00032	9.468997	56	7399.0	389
2014	2004	79.4605	8.017523	41	283402.4	1394
2014	2005	79.67239	9.726719	44	60718.3	451
2014	2007	79.66617	8.487932	48	3467.2	193
2014	2009	79.66366	7.523895	55	23981.5	274
2014	2011	79.67273	6.682681	41	9443.0	524
2014	2014	79.98366	9.152369	33	2293.3	899
2014	2016	80.33713	11.45504	39	14434.4	259
2014	2017	80.4044	11.39365	32	9455.6	13380
2014	2021	80.67838	15.5234	38	2150.3	282
2014	2025	80.56312	15.90677	44	1786.0	954
2014	2027	80.29426	16.63344	54	1578.5	627
2014	2029	80.06072	17.2636	29	10366.3	3319
2014	2031	79.79454	18.06665	16	75734.9	1482
2014	2033	79.91991	15.34559	41	9851.6	5786
2014	2035	79.69237	15.42584	27	10133.6	1648
2014	2036	80.71703	14.12978	22	352389.2	1846
2014	2037	80.21458	11.79296	52	6475.7	1500
2014	2039	79.1212	8.117242	60	8274.7	1177
2014	2042	79.06076	8.592092	51	26634.5	1118
2014	2043	78.82167	8.526508	47	2356.8	494
2014	2044	78.71399	9.069241	51	4267.5	401
2014	2045	78.70726	9.78075	36	1166.3	186
2014	2046	78.59833	9.578939	34	2256.4	2932
2014	2047	78.59185	9.507723	36	1791.2	1051
2014	2049	78.59486	9.144693	31	15016.4	348
2014	2051	78.58399	8.744547	36	545719.2	3622
2014	2053	78.59596	8.26811	38	115162.3	4665
2015	2002	78.03332	9.429965	36	179131.2	250
2015	2003	79.80432	18.02104	17	1447.6	167
2015	2004	80.02351	17.37955	10	187.4	30
2015	2008	80.25695	16.80233	44	2802.1	466
2015	2009	80.56138	15.892	21	1128.4	118
2015	2013	80.69868	15.95398	45	2144.8	322
2015	2026	81.03758	17.6112	12	1328.6	71
2015	2027	81.0975	17.12469	16	2751.0	351
2015	2029	81.16986	16.95454	19	1498.4	273
2015	2031	80.94505	18.98873	25	722.1	120
2015	2034	80.57214	12.08301	20	851.7	102
2015	2036	80.13665	12.72755	16	337705.5	128
2015	2038	79.87935	9.560385	14	335.1	69
2015	2040	80.41596	8.27385	18	180.8	33
2015	2042	80.30046	5.71132	40	3462.0	257
2015	2043	80.69013	4.4904	19	3866.7	54
2015	2046	80.88258	6.85837	11	7680.3	1212
2015	2047	81.19908	6.751055	12	535.7	48
2015	2054	79.75642	6.354885	21	2426.1	1014
2015	2058	79.72366	7.412075	19	6922.6	252
2015	2062	79.82749	7.83026	18	7624.4	150
2015	2069	79.7	8.483333	18	686.7	89
2015	2070	79.70717	9.146435	15	98.9	22
2015	2074	79.70492	9.81721	26	862.6	283
2015	2076	79.18489	7.915105	23	7348.8	163
2015	2077	78.64775	9.077015	35	14647.1	277

Table A7. Stations/equipmet/transects from where tissue samples for isotope analsis was retreived from benthos, fish and invertebrates (isotope-list is not completet)

Year	Equipment	Serial no	Transect	Invertebrate isotopes	Fish and Pelagic isotopes
2014	Bottles	2001	(C1)		POM
2014	Campelen	2001	(C1)		10
2014	Harstad	2001	(C1)		11
2014	Planktov net	2001	(C1)		5
2014	Beam Trawl 1	2001	(C1)	6	?
2014	Beam Trawl 2	2001	(C1)	5	?
2014	Beam Trawl 3	2001	(C1)	7	
2014	Grab	2003			sediment
2014	Campelen	2004	(Fram)		10
2014	Campelen	2005	Fram	18	6
2014	Harstad	2005	Fram		1
2014	Beam Trawl	2007	Fram	2	1
2014	Campelen	2009	Fram	9	4
2014	Campelen	2011	Fram	7	
2014	Åkra pelagisk trål	2013		11	
2014	Grab	2014			sediment
2014	Beam Trawl	2017	NW	1	
2014	Beam Trawl 2	2021	HL (C2)	1	
2014	Beam Trawl 3	2021	HL (C2)	4	
2014	Campelen	2021	HL (C2)	(?)	(?)
2014	Campelen	2037	NW (C3)	16	13
2014	Beamtrawl	2037	NW (C3)	(?)	(?)
2014	Grab	2037	NW (C3)		sediment
2014	Plankton net	2037			12
2014	Bottles	2037			POM
2014	Campelen	2045	SW		1
2014	Grab	2045	SW?		sediment
2014	Grab	2047	SW		sediment
2014	Campelen	2051	SW	39	
2014	Grab	2053	SW?		sediment
2015	Campelen	2003	HL	11	8
2015	Campelen	2004	HL	6	2
2015	Åkra 50 m	2005	HL		6
2015	Åkra 120 m	2006	HL		1
2015	Åkra 120 m	2007	HL		4
2015	Campelen	2008	HL	36	3
2015	Campelen	2009	HL	29	6
2015	Åkra 1	2010	HL		5
2015	Grab	2011	HL	3	1
2015	Åkra 1	2011	HL		
2015	Grab	2012	HL	4	1

2015	Åkra 1	2012	HL		
2015	Campelen	2013	HL (C2)	25	3
2015	Grab	2014	HL	5	
2015	Åkra trål	2020	HL		7
2015	Åkra trål	2021	HL		2
2015	Åkra trål	2023	HL		7
2015	Macroplankton	2024	HL		12
2015	Harstad trawl	2025	HL		5
2015	Campelen	2026	NE	6	
2015	Campelen	2027	NE	8	
2015	Harstad trawl	2028	NE		10
2015	Beamtrawl	2029	NE	14	
2015	Harstad trawl	2030	NE		8
2015	Campelen	2031	NE	21	2
2015	Harstad trawl	2032	HL		5
2015	Harstad trawl	2033	(NW)		5
2015	Campelen	2034	NW	21	
2015	Campelen	2036	NW	15	
2015	Campelen	2038	(NW)	9	
2015	Beam trawl	2040		18	
2015	Campelen	2040	Yermarck	14	
2015	Campelen	2042	Yermarck	38	
2015	Campelen	2043	?	14	
2015	Campelen	2046	Yermarck	12	
2015	Grab 7	2047	Yermarck	7	
2015	Grab	extra			10
2015	Longline	NA	NE		1

Table A8. Several fish species was, during the 2014 and 2015 cruises, analyzed for stomach content, and prey was identified, in situ, by benthos taxonomists to closest possible taxon. Isotope analyses were also taken from most of the fish (table not fully updated), together with length and weight of the fish.

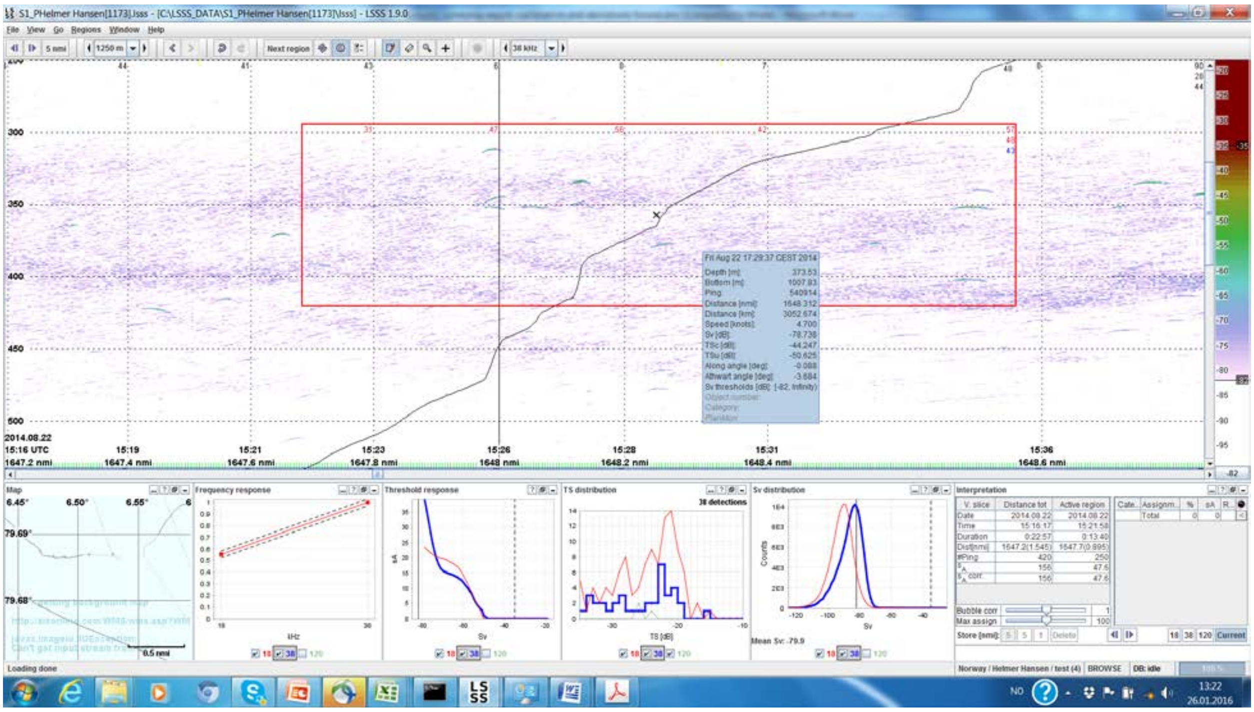
Year	Equip	Serial no	Fish and Pelagic species	Isotopes	Stomach
2014	Campelen	2001	Reinhardtius hippogloesoides	x	x
2014	Campelen	2001	Amblyraja radiata	x	x
2014	Campelen	2001	Ulvefisk (Hoplias malabaricus ?)	x	x
2014	Campelen	2007	Hippoglossoides platessoides		x
2014	Campelen	2007	Amblyraja radiata		x
2014	Campelen	2007	Ulvefisk (Hoplias malabaricus ?)		x
2014	Campelen	2007	Macrourus berglax		x
2014	Campelen	2009	Sølvtangbrosme (Gaidropsarus argentatus ?)	x	x
2014	Campelen	2037	Melanogrammus aeglefinus	x	x
2014	Campelen	2037	Anarhichas lupus	x	x
2014	Campelen	2037	Gadus morhua	x	x
2014	Campelen	2037	Melanogrammus aeglefinus		x
2014	Campelen	2037	Hippoglossoides platessoides		x
2014	Campelen	2044	Reinhardtius hippogloesoides		x
2014	Campelen	2044	Micromesistius poutassou		X
2014	Campelen	2044	Ulvefisk (Hoplias malabaricus ?)		X
2014	Campelen	2044	Gadus morhua		X
2014	Campelen	2045	Melanogrammus aeglefinus	x	x
2015	Campelen	2003	Reinhardtius hippogloesoides	x	x
2015	Campelen	2003	Lycotes eudipleurostictus	x	x
2015	Campelen	2003	Anarchichas minor	x	x
2015	Campelen	2003	Hippoglossoides platessoides	x	x
2015	Campelen	2004	Hippoglossoides platessoides	x	x
2015	Campelen	2004	Leptagonus decagonus	x	x
2015	Åkra 120 m	2007	Gadus morhua	x	x
2015	Campelen	2008	Hippoglossoides platessoides	x	x
2015	Campelen	2008	Anarchichas lupus	x	x
2015	Campelen	2008	Artediellus atlanticus europaeus	x	x
2015	Campelen	2009	Anarchichas minor	x	x
2015	Campelen	2009	Hippoglossoides platessoides	x	x
2015	Campelen	2009	Boreogadus saida	x	x
2015	Åkra 1	2012	Gadus morhua	x	x
2015	Campelen	2013	Anarchichas sp	x	x
2015	Campelen	2013	Gadus morhua	x	x
2015	Campelen	2013	Lycotes esmarki	x	x
2015	Longline	NE	Somnosus microcephalus	x	x

Table A9. Depth transects “Tr” (see also Figure 3), with all equipments used for collecting stable isotopes. Case study number (C), station number (s), latitude and longitude, serial number on equipment, period.

Tr	C	s	NN	EE	Serialnr	Equipment	Year	Date
NE	7	a	80.94955	19.01629	2031	**Campelen**	2015	26.8
NE	7	a	80.94045	18.9789	2030	Harstad	2015	26.8
NE	7	a			74	Phyto	2015	26.8
NE	7	b	81.04337	17.62536	2026	**Campelen**	2015	26.8
NE	7	c	81.09222	17.11197	2027	**Campelen**	2015	26.8
NE	7	c			73	Phyto	2015	26.8
NE	7	d	81.1551	16.95502	2029	**Campelen**	2015	26.8
NE	7	d			2029	Beamtrawl?	2015	26.8
NE	7	d	81.09987	16.85668	2028	Harstad	2015	26.8
NE	7	d			74	Phyto	2015	26.8
HL	8	a	79.795	18.067	2031	**Campelen**	2014	27.8
HL	8	a			557	WP2	2014	27.8
HL	8	a			2003	**Campelen**	2015	
HL	8	b	80.02143	17.37289	2004	**Campelen**	2015	20.8
HL	8	b	80.05027	17.39201	2005	Åkratrawl	2015	20.8
HL	8	b	80.07486	17.28651	2006	Åkratrawl	2015	20.8
HL	8	b	80.116	17.14851	2007	Åkratrawl	2015	20.8
HL	8	b	80.061	17.264	2029	**Campelen**	2014	27.8
HL	8	b			556	WP2	2014	27.8
HL	8	b			556	Mic	2014	27.8
HL	8	b			556	Multinet	2014	27.8
HL	8	c	80.25361	16.78349	2008	**Campelen**	2015	20.8
HL	8	c			2027	Campelen	2014	27.8
HL	8	c			555	WP2	2014	27.8
HL	8	d	80.57	15.90328	2009	**Campelen**	2015	21.8
HL	8	d			2025	**Campelen**	2014	27.8
HL	8	d			554	WP2	2014	27.8
HL	8	d			553	Multinet	2014	27.8
HL	8	d			2022	Macroplankton	2014	27.8
HL	8	e	80.69687	15.91767	2013	**Campelen**	2015	21.8
HL	8	e	80.69687	15.91767	2010	Åkratrawl	2015	21.8
HL	8	e	80.68659	15.74787	2011	Åkratrawl	2015	21.8
HL	8	e	80.70344	15.90443	2012	Åkratrawl	2015	21.8
HL	8	e	80.72577	15.6894	2014	Åkratrawl	2015	22.8
HL	8	e	80.74074	15.8976	2015	Åkratrawl	2015	22.8
HL	8	e	80.7584	16.18908	2016	Åkratrawl	2015	22.8
HL	8	e				Longline (shark)	2015	21.8
HL	8	e			2010-14	Grab	2015	21.8
HL	8	e			2040	Beamtrawl	2015	21.8
HL	8	e			65	Phytoplankton	2015	21.8
HL	8	e			65	WP2	2015	21.8

HL	8	e			65	CTD	2015	21.8
HL	8	e				Longline (shark)	2015	21.8
HL	8	e			2011, 12, 14	Grab	2015	21.8
HL	8	e			2021	**Campelen**	2014	
HL	8	e			2021 (rep 1-3)	Beamtrawl	2014	
HL	8	e			2021	Grab	2014	
HL	8	e			553	WP2	2014	
HL	8	e			551	Mic	2014	
HL	8	e			551	Multinet	2014	
HL	8	e			2020	Macroplankton	2014	
HL	8	f	80.9892056	15.55327902	2032	Harstad	2015	27.8
HL	8	f			76	Mic	2015	27.8
HL	8	f			76	WP2	2015	27.8
C2	9	a	80.1305	12.72352228	2036	**Campelen**	2015	
C2	9	a	80.2299	11.8034	2037	**Campelen**	2014	30.8
C2	9	a	80.2299	11.8034	2037 (rep 1-3)	Beamtrawl	2014	30.8
C2	9	a	80.2299	11.8034	2037 (rep 1-3)	Grab	2014	30.8
Fram	10	a	79.69205	8.48637	2069	**Campelen**	2015	3.9
Fram	10	a	79.69245	7.97034	2059	Åkratrawl	2015	3.9
Fram	10	a	79.73435	8.01013	2060	Åkratrawl	2015	3.9
Fram	10	a	79.77638	8.01697	2061	Åkratrawl	2015	3.9
Fram	10	a	79.9594	9.0401	2005	**Campelen**	2014	24.8
Fram	10	a	79.9594	9.0401	548	CTD	2014	24.8
Fram	10	a	79.9594	9.0401	548	WP2	2014	24.8
Fram	10	a	79.9594	9.0401	548	Mik	2014	24.8
Fram	10	b	79.71279	7.44934	2058	**Campelen**	2015	3.9
Fram	10	b	79.69711	7.56163	2055	Harstad	2015	3.9
Fram	10	b	79.73642	7.6118	2056	Harstad	2015	3.9
Fram	10	b	79.781	7.62228	2057	Harstad	2015	3.9
Fram	10	b			2007	**Campelen**	2014	
Fram	10	b			2007	Beamtrawl	2014	
Fram	10	b				WP2	2014	
Fram	10	b				Mik	2014	
Fram	10	c	79.74517	6.37207	2054	**Campelen**	2015	2.9
Fram	10	c	79.72138	6.40046	2051	Åkratrawl	2015	2.9
Fram	10	c	79.74376	6.36703	2052	Åkratrawl	2015	2.9
Fram	10	c	79.75903	6.34947	2953	Åkratrawl	2015	2.9
Fram	10	c			2009	**Campelen**	2014	
Fram	10	c			2009	Multinet	2014	
Fram	10	c			2009	WP2	2014	
Fram	10	c			2009	Mik	2014	
SW	11	a	78.5987	9.4929	2047	**Campelen**	2014	1.9
SW	11	a				Beamtrawl	2014	1.9
SW	11	a				Beamtrawl	2014	1.9
SW	11	a				Beamtrawl	2014	1.9

SW	11	a			5	Grab	2014	1.9
SW	11	a			6	Grab	2014	1.9
SW	11	a			7	Grab	2014	1.9
SW	11	a			589	CTD	2014	1.9
SW	11	a			589	WP2	2014	1.9
SW	11	a			589	Mik	2014	1.9
SW	11	b	78.5836	9.168	2048	Harstad	2014	1.9
SW	11	b	78.5836	9.168	2049	**Campelen**	2014	1.9
SW	11	b			14	Beamtrawl	2014	1.9
SW	11	b			15	Beamtrawl	2014	1.9
SW	11	b			16	Beamtrawl	2014	1.9
SW	11	b	78.5836	9.168	2050	Åkratrawl	2014	1.9
SW	11	b			2048	Harstad	2014	1.9
SW	11	b			591	CTD	2014	1.9
SW	11	b			591	Multinet	2014	1.9
SW	11	c	78.5832	8.7443	2051	**Campelen**	2014	2.9
SW	11	c	78.5832	8.7443	2052	Åkratrawl	2014	2.9
SW	11	c			593	CTD	2014	
SW	11	c			593	WP2	2014	
SW	11	c			593	Multinet	2014	
SW	11	d	78.5918	8.2645	2053	**Campelen**	2014	2.9
SW	11	d	78.5918	8.2645	2054	Åkratrawl	2014	2.9
SW	11	d			594	CTD	2014	
SW	11	d			594	WP2	2014	
SW	11	d			594	Multinet	2014	
SW	11	d			594	Mik	2014	
C1	12	a	78.02427	9.44105	2002	**Campelen**	2015	18.8
C1	12	a	78.02664	9.39507	2001	Åkratrawl	2015	18.8
C1	12	a				grab (extra?)	2015	
C1	12	a			2001	**Campelen**	2014	20.8
C1	12	a			2003	Harstad	2014	20.8
C1	12	a			2001 (3 rep)	Beamtrawl	2014	20.8
C1	12	a			539	Macroplankton	2014	20.8
C1	12	a			539	WP2	2014	20.8
C1	12	a			20 (3 rep)	Grab (rep 2, 3)	2014	20.8



Fri Aug 22 17:29:37 CEST 2014
Depth [m]: 373.53
Bottom [m]: 1007.83
Ping: 540914
Distance [nmi]: 1648.312
Distance [km]: 3052.674
Speed [knots]: 4.700
Sv [dB]: -78.738
TSc [dB]: -44.247
TSu [dB]: -50.625
Along angle [deg]: -0.088
Athwart angle [deg]: -3.684
Sv thresholds [dB]: [-82, Infinity)

Figure A1. Interpretation procedures for cod, exemplified. The normal threshold condition for 18 and 38 kHz systems for database storage, SV= -82 dB.

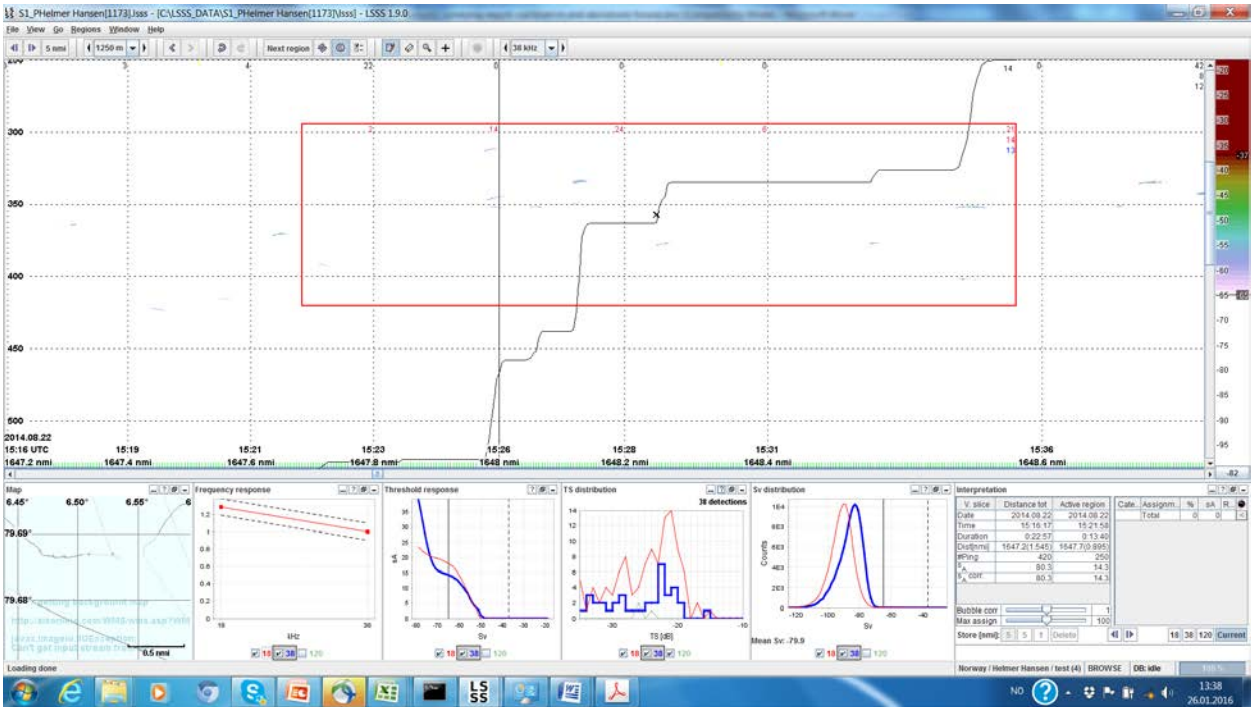
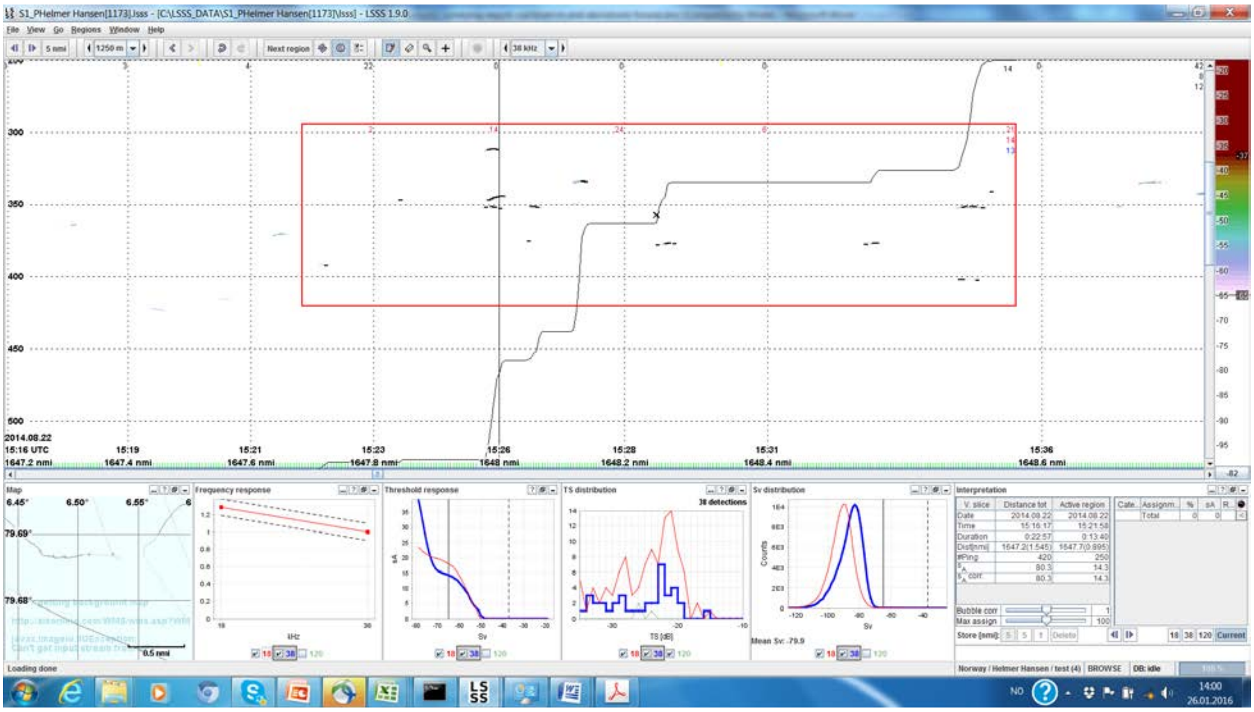


Figure A2. Interpretation procedures for cod, exemplified. Threshold SV= -65 dB



V. slice	Distance tot	Active region
Date	2014.08.22	2014.08.22
Time	15:16:17	15:21:58
Duration	0:22:57	0:13:40
Dist[nmi]	1647.2(1.545)	1647.7(0.895)
#Ping	420	250
s_A	80.3	14.3
s_A corr	80.3	14.3

Cate...	Assignm...	%	sA	R...
	Total	0	0	

Bubble corr 1

Max assign 100

Figure A3. Interpretation procedures for cod, exemplified. TS detection [-35,-10].