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Cruise report SI_ARCTIC/Arctic Ecosystem Survey R/V *Helmer Hanssen*, 2-16 September 2016

Survey: 2016838

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Content

Introduction

This survey was the third SI_ARCTIC survey. While the surveys in 2014 and 2015 were three weeks combination surveys of SI_ARCTIC and the Barents Sea Ecosystem survey, the 2016 survey was a two week SI_ARCTIC survey. The main goal of the survey was:

- To conduct baseline investigations of the marine ecosystem north of Svalbard
- Diet investigations of harp seals
- Extend the investigations/sampling in the marginal ice zone on the Yermak Plateau and above the deeper basins (compared to 2014 and 2015)
- Obtain data for evaluating inter-annual variations 2014-2017

The specific scientific questions addressed in SI_ARCTIC 2016 survey were:

- Which species/communities are present in the region?
- Who is eating whom?
- Are there changes in harp seals diets compared to earlier periods?
- Do we find hotspots, and if so; what are the mechanisms driving the intensity/location?
- What is the status and variability of temperature, sea ice cover and ocean acidification state in the shelf and deep basin in the ice-covered areas north of Svalbard?
- Are there changes in distribution, species composition and biomass compared to 2014 and 2015?

There was substantially more ice than in 2015 and about the same as in 2014. Thus, an extension into the deeper parts of the Arctic Ocean was not possible. The survey covered the ice edge zone north of Svalbard as well as the Hinlopen section and parts of the Fram Strait north section (Figure 1). In addition, we conducted two case study stations, hunted seals for biological sampling along the ice edge and partly in the drift ice. The case studies and the sections are conducted to, among other things, have direct comparable stations during all years (to evaluate inter-annual variations). Details of equipment and samples taken at each station are given in Table A1. 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.

Description of activity

The cruise commenced on September 2, 2016 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 for the ice edge zone on the western flank of the Yermak Plateau. Due to sea ice, we did not manage to get as far north and west as planned before heading eastwards across Yermak. Following the ice edge zone eastwards, we looked for seals and undertook stations along the way. As station work took long (maybe 8-9 hours on each station), and it was important to use the daytime to look for seals, we left some stations for the return. Thereafter we continued eastwards slightly past the Hinlopen section to Sjuøyene.

The Hinlopen section was sampled with the same coverage as in 2014, starting in the north. After sampling the deepest station (1850m), we conducted an acoustic and marine mammal observation transect (triangle) in the Magdalena deep outside the shelf-break (Figure 1). Thereafter we resumed section work heading southwards into Hinlopen. When finished we headed north for the ice edge zone again going westwards along the ice edge zone sampling stations not sampled on the eastward tour, and looking for seals. Seal hunting took place at about 11°E, and multiple samples for isotopes and other analyses were obtained from 26 animals.

The ice edge zone was followed as far as possible westwards. The survey ended with sampling a limited Fram Strait north section (three stations). The Åkra trawl was torn at the first (westernmost) station, so larger pelagic fish was only sampled on this station of the section in 2016.

Due to the overall ice conditions, the survey coverage in 2016 resembles the coverage in 2014. Both the Hinlopen section and a limited version of the Fram Strait north section was sampled in the same way. However, the sampling strategy for the rest of the survey was different as we in 2016 had focus on stations along the ice edge zone while we in 2014 had stronger focus on sections across the shelf break.

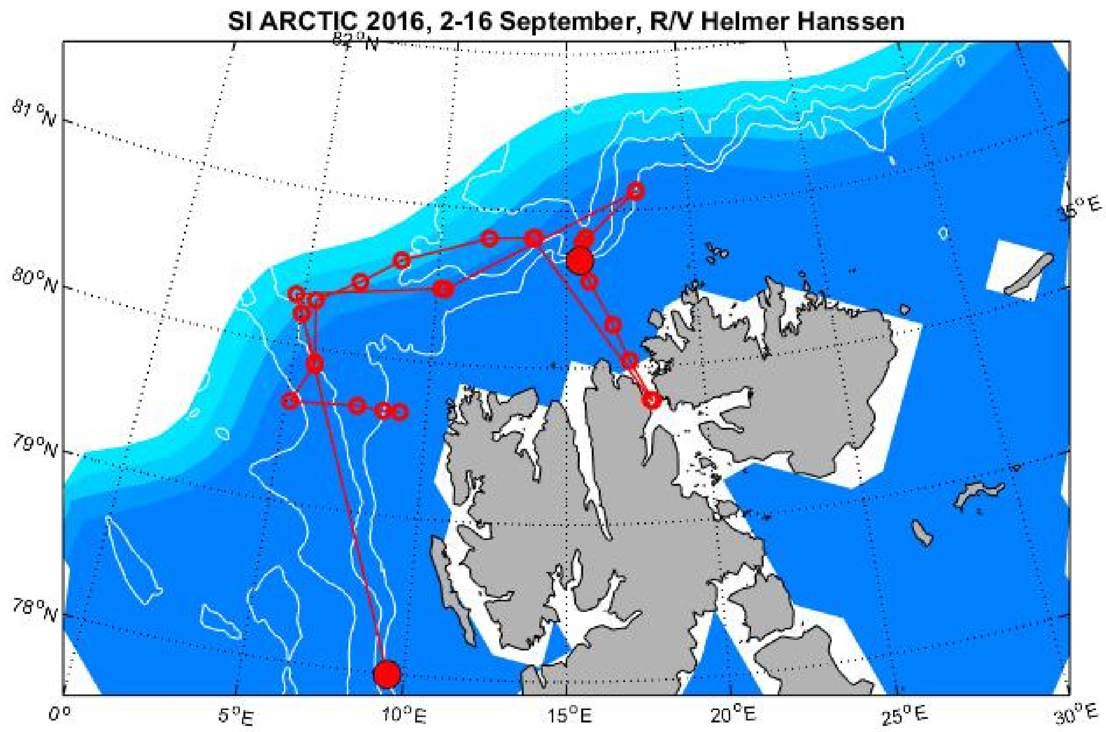


Figure 1. Cruise map showing stations (red circles, solid ones show Case 1 and 2), bathymetric lines (white lines) and average sea ice conditions during the survey.

Methods

Underway meteorological and oceanographic measurements

Along-track measurements of sea surface temperature (SST) from water intake at 4 m were recorded. Air temperature, air pressure (PTP220 sensor), wind speed and direction (Gill wind sensor) from the meteorological station on bridge roof were collected along with time, latitude, and longitude at one minute intervals. The logging of the data stopped a few times over shorter periods.

Light

Along-track measurements of surface irradiance, PAR (400-700 nm), were acquired using a spherical QSR-2100 sensor (Biospherical Inst.), and along-track measurements of visible light were measured using a LI-210SA Photometric Sensor connected to a LI-COR Model LI-1400 data logger. Both sensors were deployed on the vessel bridge roof, and both sensors were set to measure mean light intensity every minute. Data from the sensors were logged using "LoggerLight" (Biospherical Inst) and LI1000 data logger (Li-Cor). Light units were $\mu E/m^2/s$ for the QSR-2100 and Klux for the Li-Cor sensor.

In addition, light measurements where performed at every CTD stations using a QSR-240 sensor for surface PAR and a SAT-QR-99019 underwater sensor on the CTD for *in situ* light measurements. Both sensors logged data using Sea-Bird software and observations were stored in the CTD *.CSV-files. The units of both these sensors were $\mu E/m^2/s$.

Oceanographic measurements (physical and chemical)

<u>Hydrography</u>

Temperature and salinity was measured on all stations using a Seabird 911plus CTD (27 stations) with water carousel sampler (Figure 1 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. Some few CTD casts were taken to sample only eDNA from the water bottles.

<u>Current speed and direction</u>

Velocities were measured using a RDI 75 kHz ADCP as well as with a RDI Sentinel 300kHz LADCP mounted on the CTD (looking downward). The LADCP was configured with 15 bins with bin length 8 m. The LADCP 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).

<u>Nutrients</u>

On all CTD stations waters samples was collected from specific depth, using 5 L Niskin water bottles on the CTD-carousel sampler. 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 24 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 shows the CTD stations (see Table A1 for details).

Oxygen

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.

The carbonate system (total alkalinity, A_T, and total dissolved inorganic carbon, C_T)

Water sampling was performed in whole water column at standard depths from a CTD-Rosette system with 12-Niskin flasks attached. Water samples for C_T and A_T was taken at 15 stations (Table A1). In total 196 seawater samples were taken from the whole water column at 31 stations. The sample flasks were filled using tubing in the bottom of the flask to provide minimal contamination with air in borosilicate glass bottles (250 ml) following standard protocols (Dickson et al., 2007). Determination of A_T and C_T will be performed after the survey. The full carbonate system (*i.e.* pH at *in situ* temperature, calcium carbonate saturation state (Ω), fugacity of CO_2 and other species) will be calculated using C_T and A_T in the chemical equilibrium program CO2SYS (Pierrot et al., 2006). Samples for nutrients were taken in parallel to C_T and A_T for post-cruise analysis. Phosphate and silicic acid will also be used in CO2SYS for proper calculation of derived parameters. Samples for $\delta^{18}O$ were collected at the same stations at C_T and A_T in HDPE 25 ml vials, lids were wrapped with parafilm, and stored cold and dark in cooling room onboard until post-cruise analysis.

Phytoplankton

Quantitative samples

An approximately 100 ml water sample from 5 m depth were transferred to a glass bottle at all standard CTD stations (Figure 2). 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

Vertical phytoplankton net hauls were made at all standard CTD stations (Figure 2) from 30 to 0 m. The phytoplankton net has a mesh size of 10 µm and was hauled in with a vertical velocity of 0.1 m/s. The samples were preserved with 20% 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) at ICES standard depth from 0-200 m. Samples were taken from the same bottles and stations as nutrients (Table A1). 265 ml water samples were 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

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

Zooplankton collections (meso and macro)

Zooplankton and micro-nekton were sampled mainly with two different sampling systems, a WP2/Juday net pair and a Macroplankton trawl. A third system, a MIK ring-net (opening 2-m diameter, 1600 µm mesh size), was used once when in heavy ice to get sampling of prey for harp seals. The different types of zooplankton gear used during the field work catch slightly different parts of the pelagic community.

A single WP2-net was used on a restricted number of stations (N=10) to obtain fresh and live samples of the pelagic snails *Limacina* sp. (Thecosomata) for assessment of shell susceptibility to ocean acidification.

Mesozooplankton

A WP2/Juday net pair was used to target the mesozooplankton component. The principal mesozooplankton 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 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. A total of 23 paired WP2/Juday net hauls were conducted, most of them covering the whole water column from about 10 m above the bottom to surface (Figure 2). However, two hauls were not successful (St59). For one of the hauls, the catches from WP2 and Juday nets were pooled and fixated in 95% ethanol for genetic analyses. The second unsuccessful haul gave no catch, hence the haul was not registered, but replaced with a single WP2-haul (St 59). Here 25% of the sample was fixated on 95% alcohol and another 25% was fixated on formalin. The remaining 50% of the sample was used for size fractionated biomass determination. The samples were 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. 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 to specific groups; Chaetognaths, Amphipods, fish, krill, shrimps, and the copepods *Paraeuchaeta* 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 was preserved in 95% alcohol for later genetics analyses.

Macrozooplankton

A Macroplakton trawl and a MIK net were used to target the slightly larger and more motile macrozooplankton like krill, amphipods, and mesopelagic shrimps. The Macroplankton trawl also makes it possible to quantify the mesopelagic fish component. The trawl was used on 18 stations (Figure 2, Table A1). It has a 36 m^2 opening and a net with a stretched mesh size of 3 mm all the way from trawl opening to the cod-end. The velocity of the trawl through water and depth of the trawl were monitored acoustically using Scanmar trawl speed/symmetry and depth sensors. The trawl was most of the time towed in a V-haul fashion with a ship speed of 2.5-3 knots. Most hauls were conducted down to 800 m depth when bottom depth allowed. Some few stations were sampled to shallower depths in a similar manner, but with the trawl towed horizontally at a specific depth for 15−20 minutes to aid the identification of acoustic scattering structures observed underway. Upon completion of hauls the catches were weighed, and either the entire catch or a representative subsample was sorted, weighed, and length measurements undertaken of the largest components like fish, squid and crustacean macrozooplankton. Species identification were undertaken to the nearest possible taxonomic unit, usually to genus or species level.

The MIK net was used only once (Figure 2) and the sampling was a V-haul from 0-200 m. The MIK has a circular mouth opening of 2 m diameter and a net with a mesh size of ~1.6 mm. The last 1.5 m of the net prior to the cod-end consists of a 500 µm plankton net. Ship speed was around 2 knots during the operation.

DNA barcoding of gelatinous zooplankton

Material for DNA barcoding of gelatinous zooplankton was collected opportunistically from mesozooplankton and macrozooplankton samples. In the case of mesozooplankton samples, the net samples were quickly inspected on a light table immediately upon retrieval and interesting gelatinous specimens were individually picked using a pipette, with the species and number of specimens removed from the sample recorded. Voucher photographs documenting the morphological characters of selected live specimens were then taken using a camera attached to a stereomicroscope and/or a macro photography set-up, prior to fixing the specimens individually in 95% ethanol for later genetic analysis. In the case of macrozooplankton samples, interesting gelatinous specimens were fixed for further analysis after the routine processing. Selected specimens were also fixed in 4% borax buffered formalin for later morphological studies. The collected material will be used in assembling a comprehensive database of DNA barcode markers for pelagic hydrozoans (project HYPNO, http://data.artsdatabanken.no/Pages/168312) and ctenophores (project GooseAlien, http://www.artsdatabanken.no/Article/Article/134378) occurring in Norwegian waters. The resulting sequences will be deposited and made public available in the BOLD database.

DNA samples were collected from 40 specimens of pelagic hydrozoans representing 12 species and 15 specimens of ctenophores representing 6 species, including one currently undescribed cyddipid ctenophore. In addition, 10 samples representing 4 species of Hydrozoans meriting closer morphological examination were fixed in formalin for further work.

Fish and zooplankton acoustics

The Simrad EK60 echosounder was equipped with transducers of three frequencies: 18 kHz, 38 kHz and 120 kHz at 1 ms pulse duration. The echo sounders were connected to transducers mounted on a protruding instrument keel with transducer faces ~3 m below the hull, usually ~8.5 m below the sea surface. Only area backscattering values (s_A) from the 38 kHz was allotted to various species or groups of scatterers and stored in the acoustic database, but the frequency response of scatterers and inspection of echograms at other frequencies were used in addition to the catch from near-by trawl hauls as auxiliary information when scrutinizing and interpreting the echograms. The s_A-values were distributed to the following groups: cod, capelin, polar cod, blue whiting, redfish, O-group, krill and amphipods, mesopelagic fish, and plankton. The LSSS post-processing software was applied for scrutinizing acoustic data, while the data were stored in the LSSS database as well as in the S2D Echosounder database with 10 m (vertical) by 1 nautical mile (nmi) horizontal resolution. The scrutinized processing involved spike-filtering (to remove unwanted acoustic temporal noise from e.g.

trawl sensors during trawl operations), compensation for the placement of transducers, and noise removal. The main tool for identifying plankton and fish was the frequency response and trawl data were used to corroborate the interpretation of the acoustic data. More information about the scrutinizing can be found in the SI_ARCTIC 2015 cruise report (Ingvaldsen et al., 2016). The acoustic backscattering data were in the form of s_A, Nautical area scattering coefficient (NASC) in units of (m^2 nmi^{-2} – MacLennan et al. 2002).

Note:

- The instrumentation synchronizing the ADCP signal with the EK60 transducers was not working. Thus, noise from the ADCP reduced the quality of the EK60 data, in particular in deep water. The data after log 1295 on 13 September (22.02 UTC) were scrutinized using the SpikeFilterModule in Korona which remove the noise from the ADCP. The data prior to this time and date are to be corrected accordingly using the same filter after the survey.
- The transmit power of the 18 and 38 kHz systems had been changed from the default 2000W to 200W. This was discovered on 12. September, and then reset to 2000W. Thus, all data from before log 3562.2 on 12 September (04.37.03 UTC) are obtained with transmit power 200W. The quality of the data should still be as good as usual as a lower transmit power are to be adequately self-adjusted by the eco sounder.

Fish sampling

Pelagic fish

Sampling of pelagic fish was conducted with an Åkra trawl which is a medium large (538 m circumference) pelagic trawl with a net with a mesh size of 8 mm in the net in the cod-end. 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 (400-450 m depth), 2) high concentrations/particular scatters in deep scattering layer (300-350 m depth) and 3) at 50 m depth. Each depth layer was trawled for 30 min. The trawl geometry was determined/visually inspected by the trawl sensor cable of the vessel. The trawl geometry was good even though the trawl was used with lighter weights than specified. 15 hauls with 3 nets on each was conducted with the Åkra trawl (Figure 2). One of the trawl sweeplines was damaged on station 128 at the westernmost location on the Fram Strait north section (Table A1). As it happened when the trawl was coming onboard, the catch from the station was not damaged. However, no further hauls with this trawl was possible (during the survey).

Demersal fish and benthos

Sampling of demersal fish and benthos was conducted with a Campelen trawl which is a small demersal trawl originally designed for catching shrimps. The trawl was rigged with deep water floats according to standard specification on delivery, but to prevent damage due to rocky bottom, 40 deep water floats deployed at fish line. 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. 17 hauls were conducted with this trawl (Figure 2, Table A1).

Sorting and sampling

Trawl catches (full catches or subsamples) were sorted to species level. Individual sampling (length, weight, age, stomach content) according to IMR standard procedures were conducted for cod, capelin, polar cod, Greenland halibut, haddock and redfish caught in Campelen trawl. Individual sampling (length, weight, age, stomach content) were conducted on all specimens from larger fish caught in the pelagic trawl.

Environmental DNA

At 4 stations samples for environmental DNA (e-DNA) of fish was collected at 3 different depths (Table A1) using 5L Niskin water bottles mounted on the CTD-carousel. The CTD was rinsed with 10% bleach between stations to prevent contamination between stations. 3 sample depths were identical with sampling depths for pelagic fish conducted with Åkra trawl. Water from 3 Niskin bottles (15 liters in total) was transferred to a new 25L plastic container. Water was filtered in triplicates on a 0.22 µm Sterivex filter (Millipore) using a peristaltic pump (closed system) and new silicon tubes. To test the sensitivity of the methods different volumes were filtered (100-3000 ml). To test the sampling repetitively simple CTD cast to the same depth was performed. Filters were pumped dry before sealed with parafilm and stored in 50 ml centrifuge tubes in a -80^{o}C freezer until analyses in Tromsø.

The pelagic shelled snails *Limacina retroversa* and *L. helicina* (Thecosomata) were collected using a single vertically deployed WP2-net (mesh size 180 µm) at 10 stations in the upper 20-50 m of the water column (Table A1). Living individuals were preserved in buffered ethanol for later analysis of shell thickness.

Benthos

Benthos was collected and quantitative identified on board on all Campelen trawl stations and on the beam trawl station (Figure 2).

Marine mammals

Visual observations of marine mammals were conducted by 3 experienced observers on the bridge covering approximately the front 90° sector (45° each). Species were recorded along the cruise transects when steaming between stations, if visibility and weather conditions were acceptable. Species were also recorded when the ship was cruising along the ice edge zone and even when it was working its way through the ice. Observations were made during some of the station work – primarily when weather and visibility permitted.

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

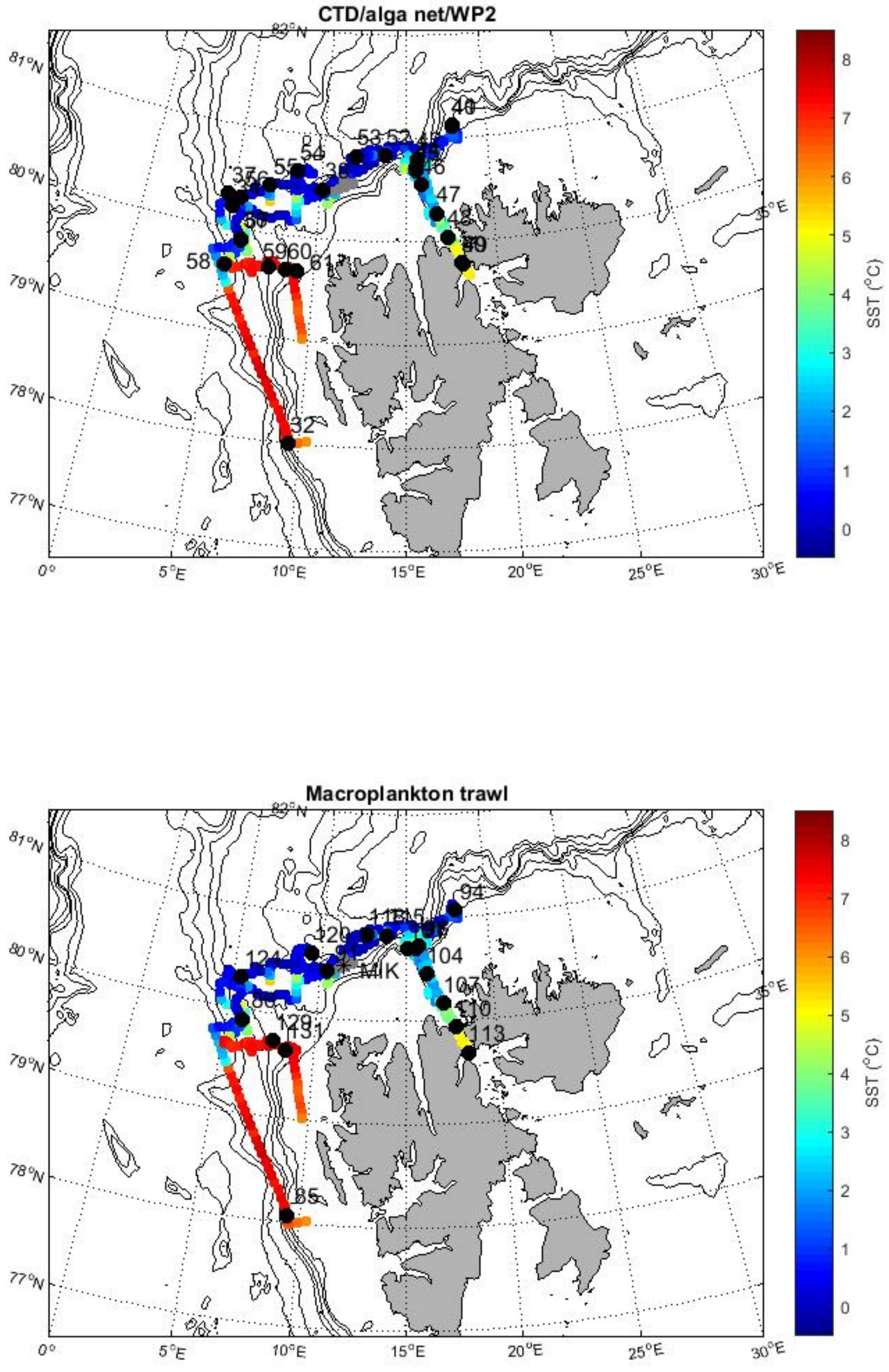
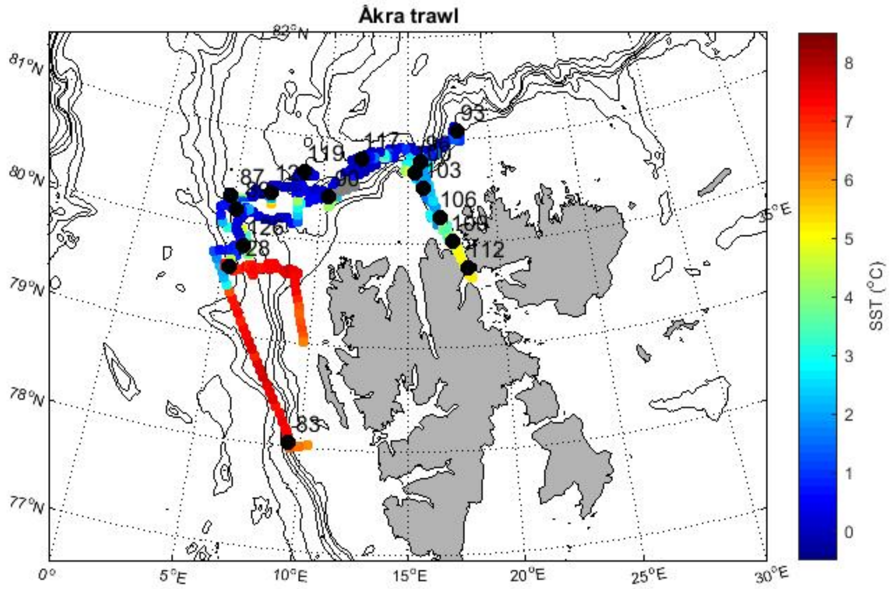


Figure 2. Location of stations with CTD with water samples for nutrients and phytoplankton, LADCP, algae net and WP2 (upper). Location of Macroplankton trawl (lower). The single MIK station is marked with a *.



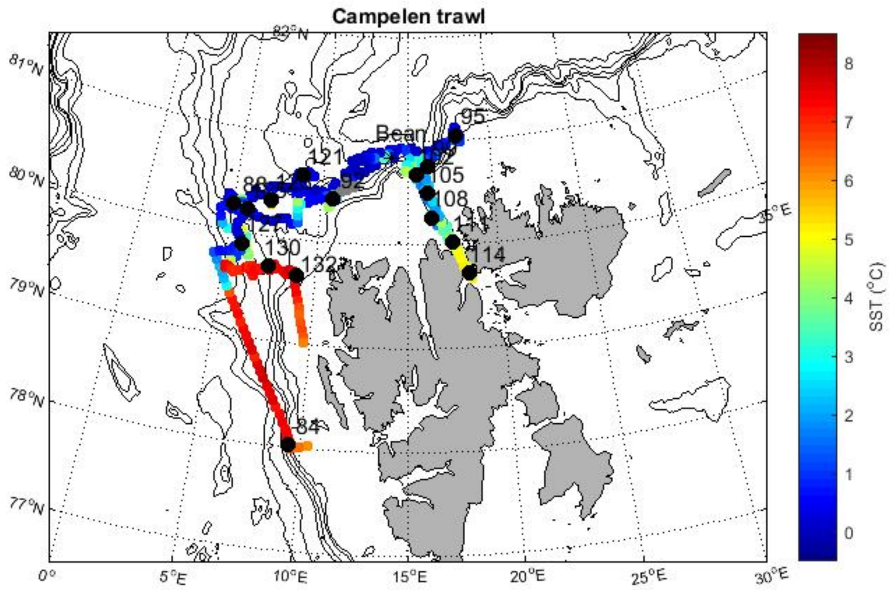


Figure 2 continues. Location of Åkra trawl with Multisampler. Only the uppermost net is shown (upper). Location of Campelen trawl (lower). The single beam trawl station is marked with a *.

Results

Underway meteorological and oceanographic measurements

Along-track sea surface temperature (SST), air temperature, air pressure, wind speed and direction are shown in Figure 3. SST were 6-7ºC in Isfjorden and somewhat along the western Spitsbergen coast, but decreased rapidly to sub-zero temperatures when reaching the sea ice at the western Yermak Plateau. Relatively high temperatures (~4ºC) were observed inside Hinlopen and at the end of the cruise (>7ºC). The air temperatures showed some similarities to the SST. The air temperatures were mostly above 0ºC, except on the most northern part of the Hinlopen section (7 September) and when hunting seals (11-12 September). During these periods the vessel was close to, or within, the sea ice, and the winds were northerly. The air pressure was relatively high (>1000 mbar) most of the period except when conducting the northern Fram Strait section at the end of the survey. During this period, the wind speed reached almost 20 m/s.

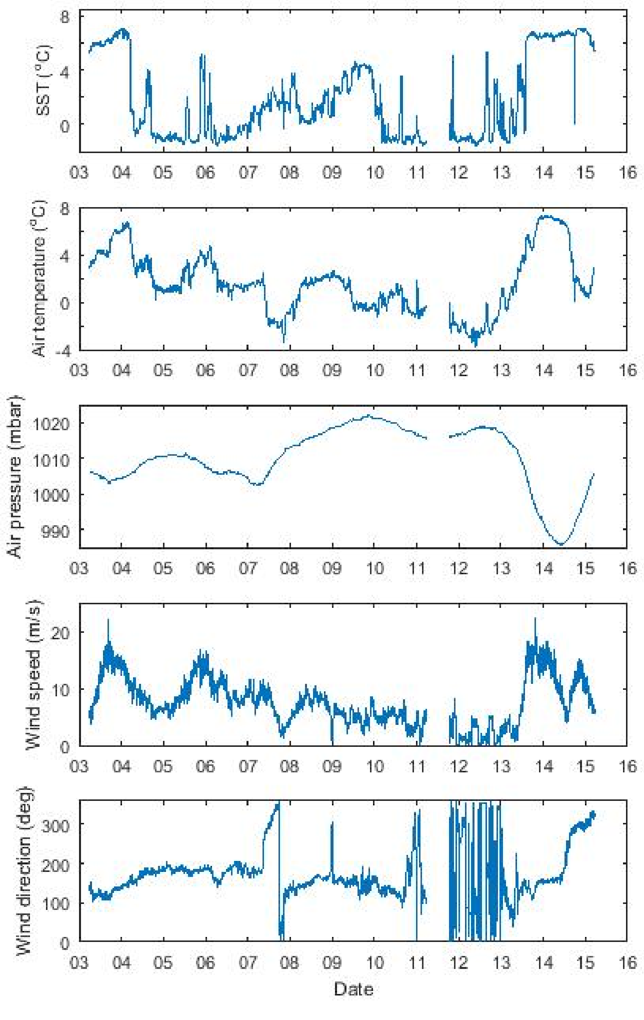


Figure 3. Along-track sea surface temperature, air temperature, air pressure, wind speed and direction during the survey 3-16 September 2016.

Light

Measurements of surface PAR are shown in Figure 4. A substantial daily variation in surface PAR was observed most of the survey, in particular when being in the northern part of the study area (along the ice edge zone and in Hinlopen during 7-12 September). A weaker daily cycle was observed at the start and end of the survey during poorer (more cloudy) weather conditions (Figure 3).

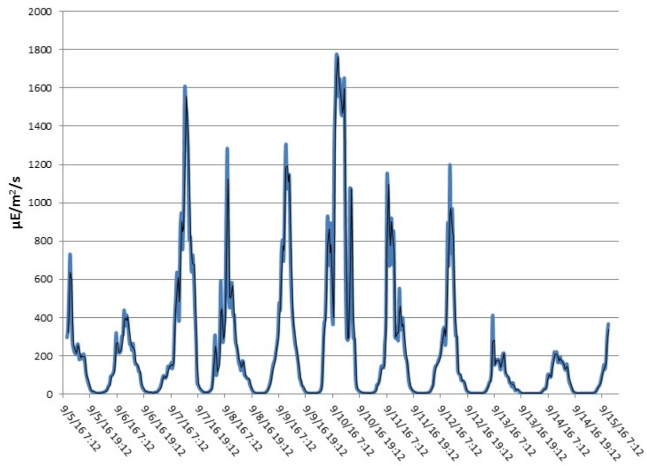


Figure 4. Light intensity. Measurements of surface PAR from 5 to 15 September 2016. Average light intensity for every 30 minutes as µE/m^2/s based on the Biospherical sensor QSR2100.

Physical oceanographic measurements

Temperature, salinity and along-slope currents in the Fram Strait north section in 2014, 2015 and 2016 are shown in Figure 5. Note that only 4 (out of 8) stations were sampled in 2016, and they were only sampled to 500 m depth. The stations sampled in 2016 was the westernmost station in the deeper Fram Strait (no 1, at 2280 m depth), and the three stations crossing the shelf-break (no 4 close to the 800 m isobath, no 6 close to the 500 m isobath, and no 7 close to the 400 m isobath, all counted from west). The homogenous pattern in 2016 compared to the two former years are due to the long distance between the shelf-break and the deeper stations. With this station grid no recirculation and surface fronts were captured. Both along the shelf-break and at the westernmost station the temperatures were as high or higher than the two years before in the intermediate depth layers (100-500 m depth).

Temperature, salinity and along-slope currents in the Hinlopen section in 2014, 2015 and 2016 are shown in Figure 6. Due to sea ice, the station coverage in 2016 were as in 2014 (and much narrower than in 2015). Compared to the two former years, 2016 had more Atlantic Water on the shelf. However, in 2016, the fresh and cold surface layer were present in the entire section and the Atlantic Water did not reach surface anywhere in the section. The currents were rather like the situation in 2014 showing the highest velocities in the Atlantic slope current.

The SI_ARCTIC 2016 survey started about two weeks later than the surveys the previous two years, and the temperature measurements from the case study stations (taken every year) show that lower temperatures were recorded on the ocean surface in 2016 than in 2014 and 2015, while the opposite was the case in the deeper layers of water. West of Svalbard, the temperatures in the North Atlantic Current were almost 0.5˚C higher than in 2014 and 2015, and the differences north of Svalbard were even greater. In this area, all the water at a depth of around 50 m or more was between 1 and 1.5˚C warmer than the previous years.

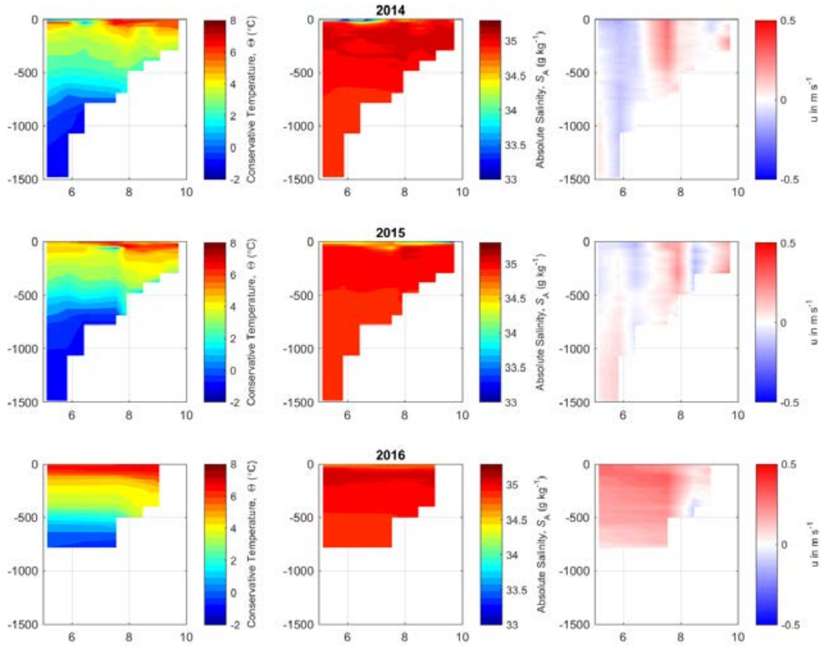


Figure 5. Temperature (left), salinity (middle), and along-slope/northward velocity (V, positive northward) in the upper 1500 m in the Fram Strait north section in 2014 (upper), 2015 (middle) and 2016 (lower). Note that only 4 stations were sampled in 2016. Data from CTD and LADCP.

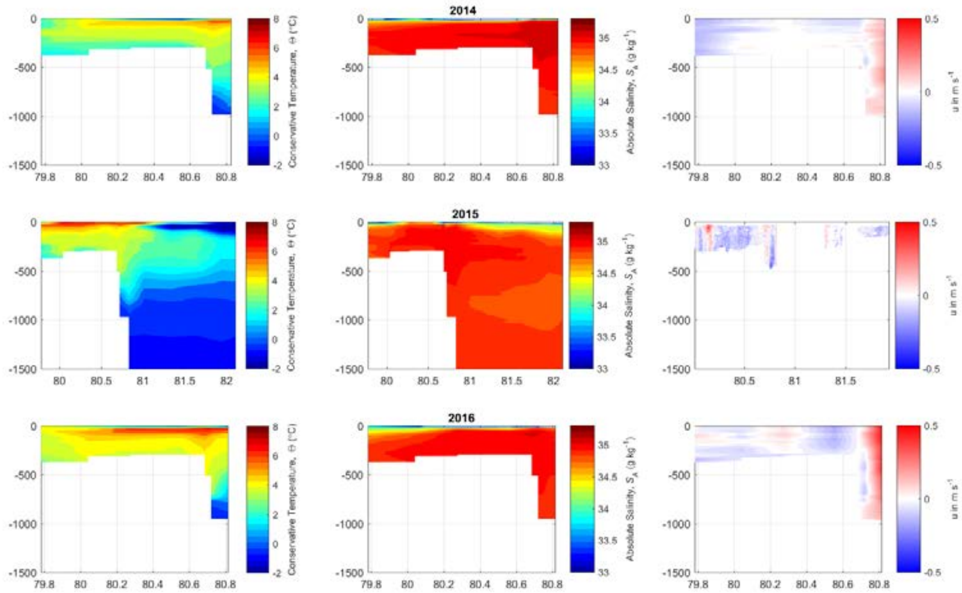


Figure 6. Temperature (left), salinity (middle), along-slope/eastward velocity (U, positive eastward) in the upper 1500 m in the Hinlopen section in 2014 (upper), 2015 (middle) and 2016 (lower). Note different horizontal scales between upper and middle plates. Velocity data are from LADCP in 2014 and 2016 and vessel mounted ADCP in 2015 (no LADCP data from this section in 2015).

Average current over the upper 400 m from the vessel mounted ADCP with tidal motions removed show that the strongest currents occurred in the Atlantic slope current (along the slope, Figure 7 left). Also, the current pattern seems to be dominated by small-scale topographic features as well as mesoscale eddies. The detailed features of the upper 400 m flow in the acoustic triangle conducted in the Magdalena deep show eastward flow in most of the region except on the shelf-break where the flow is southwards towards the shelf (Figure 7 right).

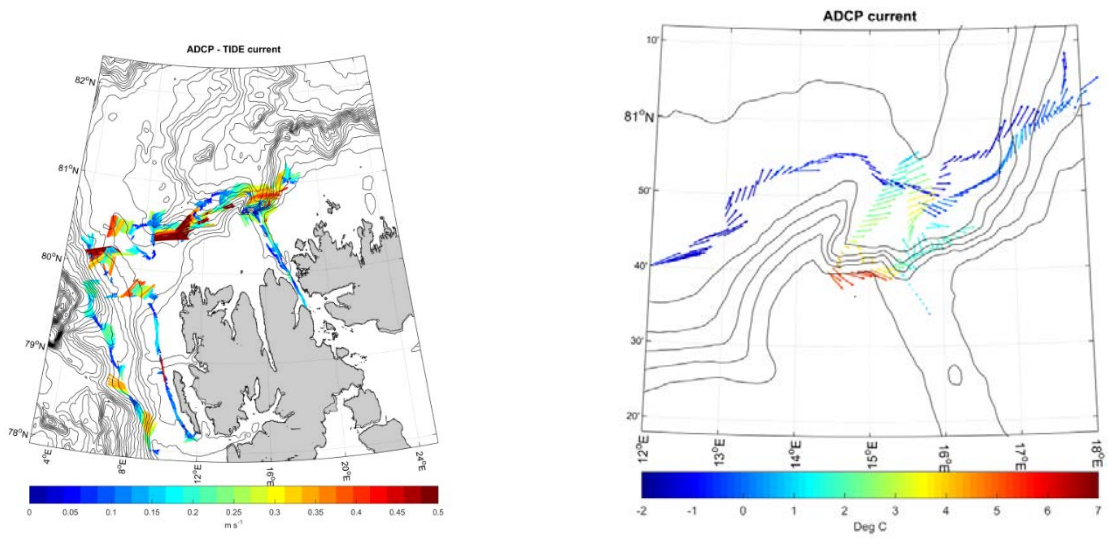


Figure 7 Average 0-400 m currents from vessel mounted ADCP with tides removed in the study area (left) and in the acoustic triangle in the Magdalena deep (right).

Zooplankton collections (meso and macro)

One of the target groups during this field campaign, as the previous two seasons was the highly important *Calanus* complex, consisting of the three species *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus* that to a smaller or larger degree co-occur in the study region, since 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 are also possible to quantify if present, although the limited data obtained so far, suggests that this component diminishes rapidly moving from the northern part of the Norwegian Sea through the Fram strait and into the Arctic Ocean. However, the few number of hauls conducted so far still leaves this an open issue. Sampling with a pelagic trawl in partly ice-covered areas is an additional challenge for obtaining quantitative information on the distribution and biomass of fish and macroplankton in the mesopelagic domain.

In all regions sampled, there were observed mixed mesozooplankton communities with all *Calanus* species present on many of the stations. Due to seemingly high variation in phytoplankton abundance, variable oceanographic conditions, and impact of water masses of both Arctic and Atlantic origin, the mesozooplankton community varied considerably from one station to another. In 2016, depth stratified sampling was planned, but because of time constraints, not undertaken. By qualitatively assessing the mesozooplankton samples, high biomass could be traced on some stations while other stations had quite low biomass. During size fractionation of samples, it was noted quite high biomass both for the 180 μm and 1000 μm size fractions on a couple of occasions. Since most of the younger copepodite stages (CI-CIII) of *C. finmarchcius and C. glacialis* will be found on the 180 μm sieve, and not be retained on the coarser 1000 μm sieve, high biomass on the former suggests high activity and abundance in the surface layers since the younger stages are mostly located here. Other copepods found on the 180 μm fraction, were *Oithona* and *Oncea*, and to some extent *Pseudocalanus*. However, the size composition of *Calanus* sp. makes 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). Species separation needs to be resolved by more detailed taxonomic analyses in the onshore laboratory and later by genetic analysis. The biomass retained on the 1000 μm fraction normally contains the majority the *Calanus* sp. CIV, CV and CVI's, but due to the sampling procedures, integrated sampling from bottom-0m, it cannot be currently resolved if these were abundant in the surface region or had departed to deeper waters for overwintering. Only a 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 libellua* were caught on numerous occasions and were sometimes highly abundant. On the shelf north of Spitsbergen different scattering layers were observed that could be assigned to krill, like *Thysanoessa inermis* or 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 many of the tows both on the northern Svalbard shelf and over deeper waters north of the shelf break. Also in 2016 specimens of the krill *Nematoscelis megalops***,** a temperate Atlantic species**,** was found in this region. The occurrence of the latter two species indicates sustained advection of warm Atlantic water and transport of organisms from more southern regions. In some Macroplankton tows a substantial amount of chaetognaths and the sea angel *Clione limacina* (Gymnosomata) were observed, occasionally including numerous young of the year, due to their small size. Also in several deep water tows north of the shelf a substantial amount of the mesopelagic shrimp *Hymenodra* sp. was recorded along with moderate amounts of *Benthosema glaciale*, a mesopelagic myctophid, being more common and abundant further south in the Norwegian Sea, and possibly the only representative of this group in these northern waters. Another mesopelagic fish that was recorded on several occasions was *Arctozenus risso* (=liten laksetobis) (Paralepididae). It was however not caught in any of the Macroplankton trawl hauls in 2016, but was observed in the larger Åkratrawl and even in the Campelen bottom trawl catches on a couple of occasions.

Fish and zooplankton acoustics

Total s_A during the survey is shown in Figure 8; second panel show vertically integrated s_A while third panel show the vertical distribution of the scatter. The black line on 1295 nmile (13 September) show the split in the filtering procedures used during the survey; the data before the line where scrutinized without any filtering removing the ADCP noise, while the data after the line were scrutinized using the SpikeFilterModule in Korona to remove the noise. The scatterers in the deeper layers before 13 September seems to be more or less completely dominated by the noise. The data after 13 September do however show a mesopelagic layer in 300-500m depth consistent with earlier years. Further analyses on this will be conducted after the entire data set is processed in the same manner.

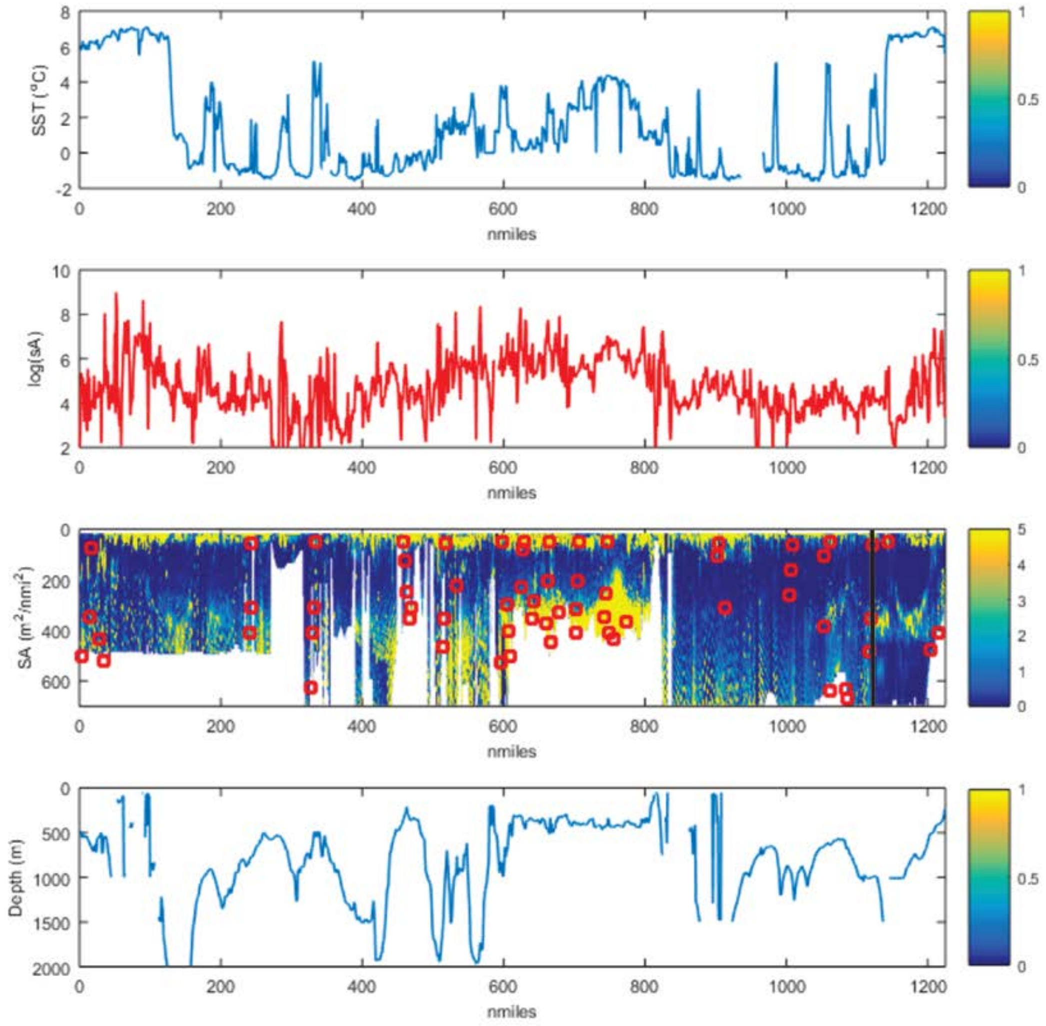


Figure 8. Along-track sea surface temperature, total vertical integrated backscatter from 38kHz (s_A), vertically resolved total backscatter from 38kHz (s_A), and bottom depth from 38kHz from during the survey 3-16 September 2016. In the third panel the red squares denote trawl hauls and the black line denote from where the scrutinizing was conducted using spike filter removal from Korona to remove the noise from the ADCP.

The distribution of acoustic registrations of polar cod in 2014 and 2016 are shown in Figure 9. The distributions show that this species was most abundant in and around Hinlopen while further west and south there were no polar cod. The acoustic registrations of 0-group in 2014, 2015 and 2016 show substantial registrations due to 0-group all three years (Figure 10). The highest scatterers were west of Spitsbergen and on the Yermak Plateau in 2014 and 2015. In 2016, high values of 0-group were present west of Forlandet and in the Hinlopen section. Acoustic registrations of cod show that this species was captured by the acoustics in most of the area except over the deeper regions north of Svalbard in 2015 (Figure 11). Additionally, substantial higher registrations of cod were present in Hinlopen in 2016 compared to the former years.

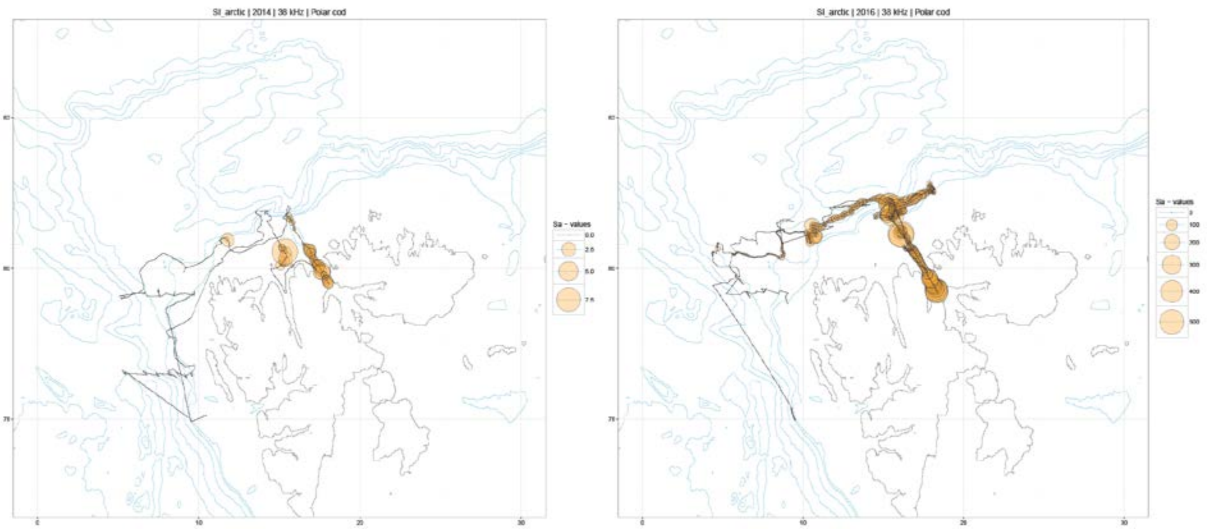


Figure 9. Distribution of acoustic registrations (s_A) of polar cod SI_ARCTIC 2014 (left) and 2016 (right). The category was not used when scrutinizing data in 2015. Note difference scale between years.

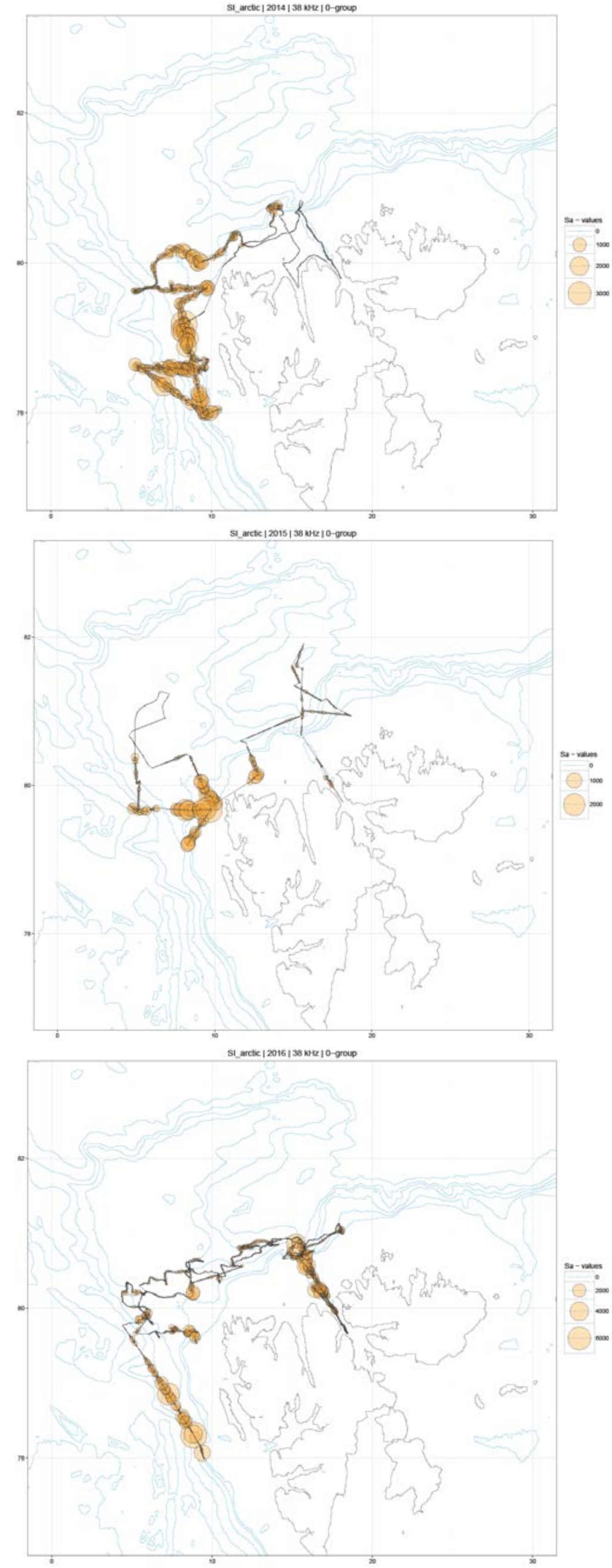


Figure 10. Distribution of acoustic registrations (s_A) of 0-group SI_ARCTIC (upper), 2015 (middle) and 2016 (lower). Note difference scale between years.

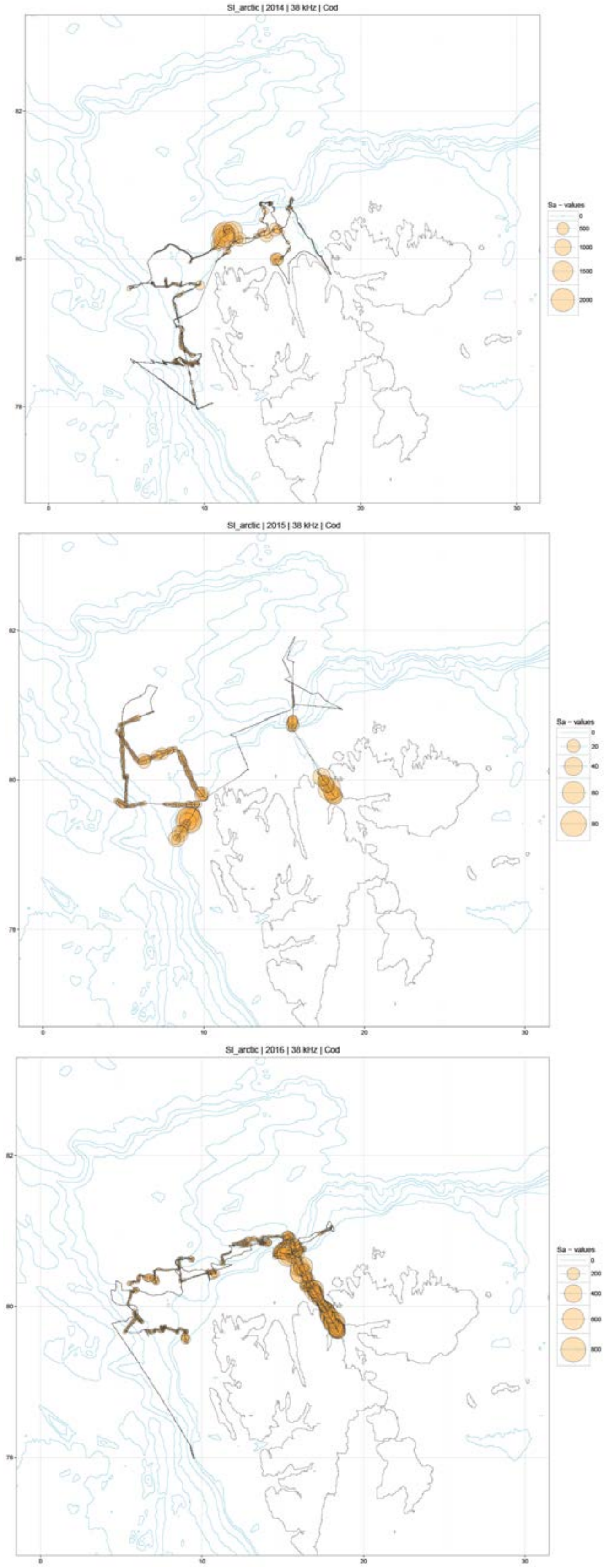


Figure 11. Distribution of acoustic registrations (s_A) of cod SI_ARCTIC 2014 (upper), 2015 (middle) and 2016 (lower). Note difference scale between years.

Fish distribution based on trawl catches in 2014, 2015, and 2016

General

When studying fish distribution from trawl hauls it should be taken into account that the trawl hauls are placed differently each year. Since there are large differences in depth from a relatively shallow shelf region along the coast to depths greater than 2000 m just a few miles further offshore, and there is a clear trend towards larger catches on the shelf compare to further offshore, the placement of the trawl hauls, in particular the demersal trawl hauls, will have large consequences for the catch rates of the various species.

When considering the total catches, a few “hotspots” with increased catch rates were found, and the position of these did not change much among the years 2014, 2015, and 2016. Catch rates of all species in all demersal trawls all three years are shown in Figure 12. The hotspots are found at depths around 500 m northwest and north of the Vest Spitsbergen island, and north of the Hinlopen strait. The most influential catches are the large catches of cod obtained in these areas, and if these had been removed the “hotspot pattern” would be less conspicuous.

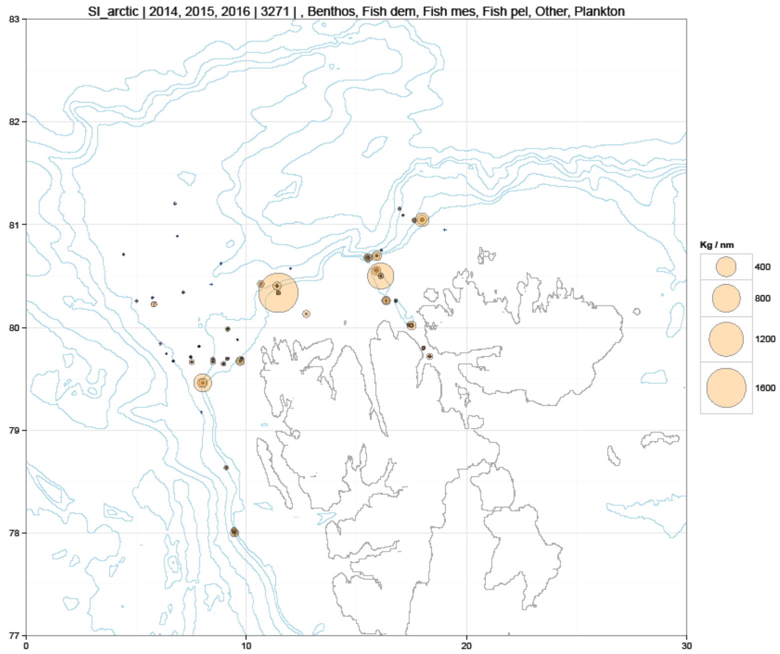


Figure 12. Distribution of all species catch (in kg) in demersal trawls SI_ARCTIC 2014, 2015 and 2016.

“Commercial species”

We analysed the catches of cod, blue whiting, deep sea prawns, deepwater redfish, Greenland halibut and haddock (termed commercial species) in the Campelen trawl and the distribution maps of these catches (catch rate in kg/nmi) are shown in Figure 13 a, b, c for 2014, 2015, and 2016 respectively. There are clear resemblances among the geographical distributions these three years. First; there is a clear depth gradient all three years, with larger catches on the shelf compared to the slope and deep water. Further, the largest catches all three years were taken on the shelf north of Svalbard; in the vicinity of the Hinlopen strait. However, there are also big differences among the years; while the maximum catch rates in 2014 was about 1600 kg/nmi, the maximum in 2015 was 75 kg/nmi and in

2016 600 kg/nmi (note different scale of bubble sizes on the map). These differences are mainly due to one big catch of cod in 2014 and one in 2016, while no such big catches were taken in 2015. The average catch rates were 7.7 kg/nmi in 2014, 0.5 kg/nmi in 2015, and 3.8 kg/nmi in 2016. The big catches partly mask other differences that may exist these years. Excluding the biggest catch of cod in 2014 and 2016 changed the average catch rates these years to 3.3 and 1.9 kg/nmi respectively. This shows that even without the extreme values the average catch rate in 2014 and 2016 were 6.5 and 4 times as large as those in 2015. These metrics are not directly comparable, since the number of stations at the shelf (where the catch rates are generally higher) and beyond the shelf (where the catch rates are generally low) are not identical these years.

Atlantic cod (*Gadus morhua*)

The geographical distribution of cod in the demersal trawl during the three years 2014, 2015, and 2016 (not shown) very much resemble the maps for commercial species. Some individuals of cod were also caught in the pelagic trawls (Figure 14). In 2014 cod were caught in pelagic trawl only at one of the stations over the slope on the Fram Strait north section (Figure 14a). In 2015, cod were caught in pelagic trawls both at the Fram Strait north section, where cod was also caught in 2014, and at some stations along the Hinlopen section (Figure 14b). In 2016, cod was only caught pelagically at the Hinlopen section. However, only one (the outer) station with pelagic trawl on the Fram Strait north section could be made in 2015, because the trawl was damaged at that station. The catch at that station was deemed representative, but no cod was caught.

Greenland halibut (*Reinhardtius hippoglossoides*)

An increasing amount of Greenland halibut were found in demersal trawl from 2014 to 2016 (Figure 15 a, b, c), with maximum catch rate increasing from 7.5 kg/nmi in 2014, and 12.5 kg/nmi in 2015, to 40 kg/nmi in 2016. In 2014, the largest catches were taken in the western part of the surveyed area; on the shelf-break to the west of Isfjorden and the southern part of the Yermak Plateau. In 2015, a wider distribution was observed; on the slope towards the Fram Strait; on the southern part of the Yermak Plateau, and outside the Hinlopen strait. In 2016, the highest catch rates were found on the northern slope towards the Magdalena deep, on the southern rim of the Yermak Plateau and in the northern part of the Hinlopen strait. Greenland halibut were mostly found in trawl hauls between 500 m and 1000m depth, but some few catches were also taken shallower than 300 m and deeper than 1000 m.

Polar cod (*Boreogadus saida*)

Judged from the trawl catches (and consistent with the acoustics) only small amount of polar cod has been found in the survey area during the three SI_ARCTIC project surveys (Figure 16). Low catch rates were the rule in most of the trawl hauls. However, the polar cod show and increase in catch rates during the period 2014-2016. In 2014, the maximum catch rate was about 1 kg/nmi, in 2015 it was about 10 kg/nmi, while in 2016 it was nearly 30 kg/nmi. The number of trawl hauls are too low to conclude that this increase reflects a real increase in abundance of polar cod in the area. The geographical distribution of the catches was rather equal in these three years; with maximum catch rates in or just north of the Hinlopen strait. Catches further west were small. In 2015 and 2016 some few catches of polar cod were also taken in pelagic trawls, north of the Hinlopen strait.

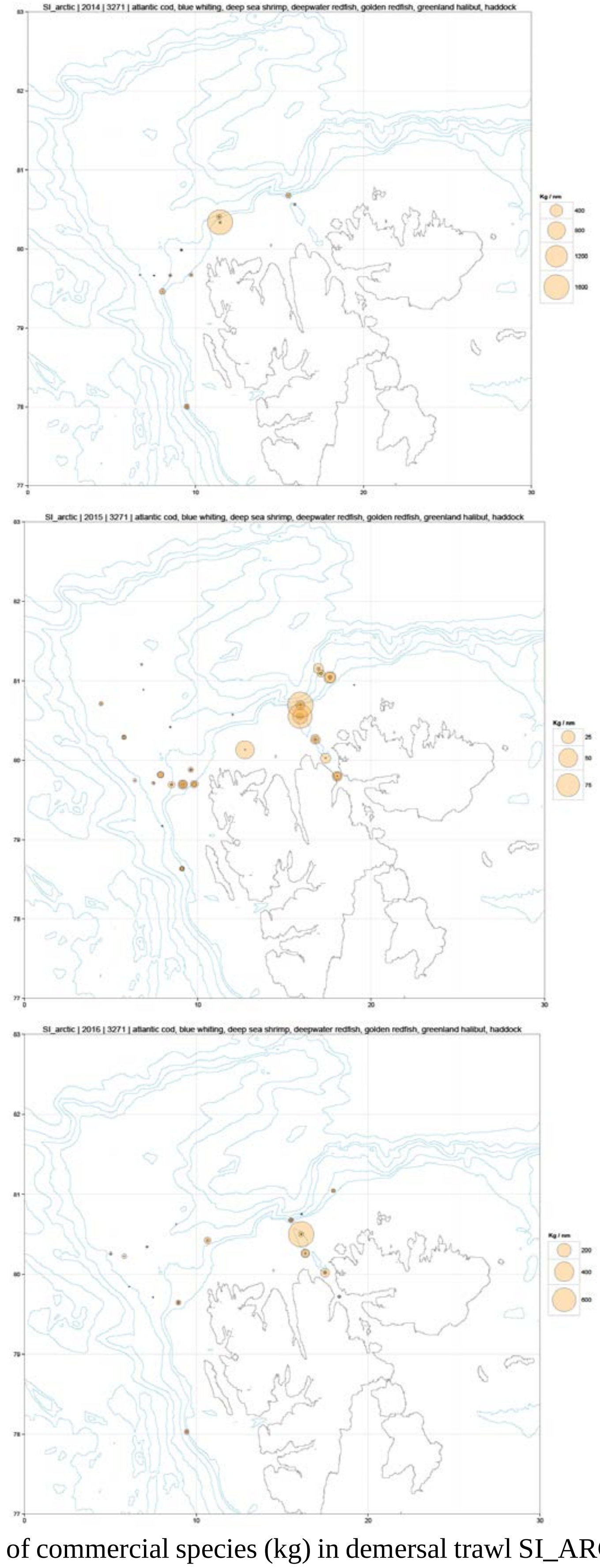


Figure 13. Distribution of commercial species (kg) in demersal trawl SI_ARCTIC 2014 (upper), 2015 (middle) and 2016 (lower). Note difference scale between years.

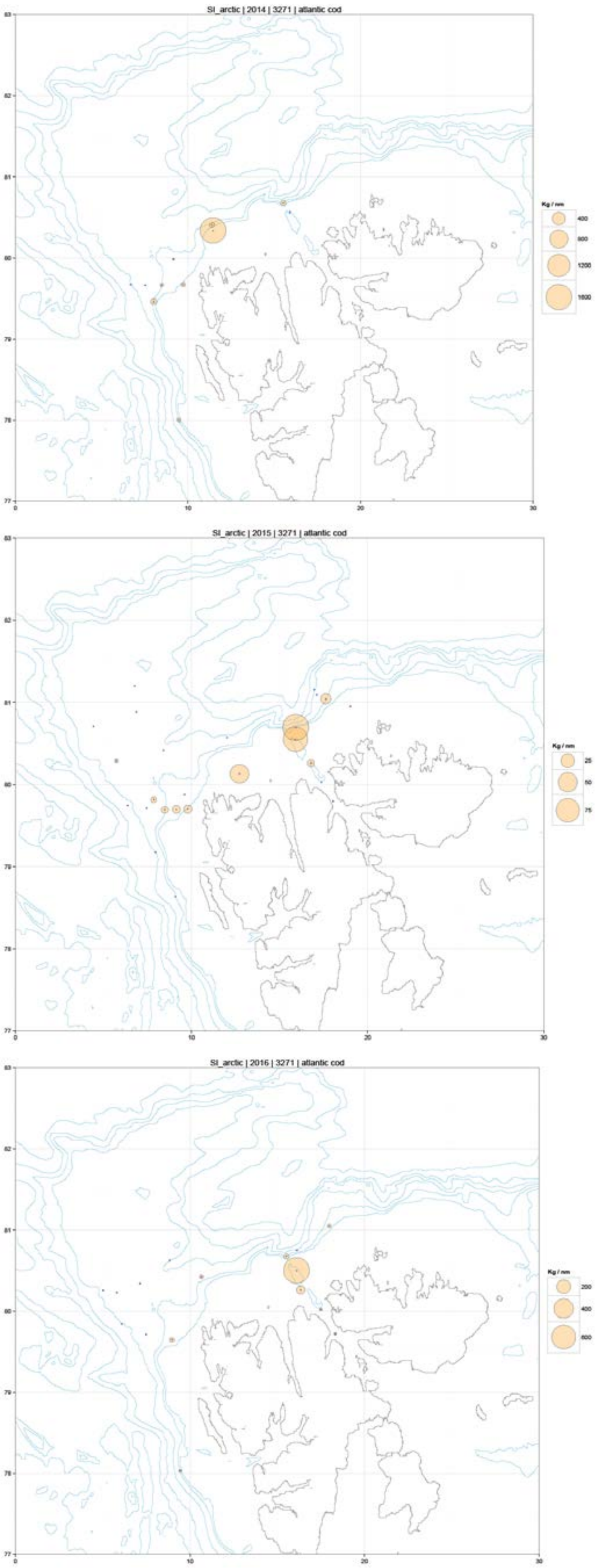


Figure 14. Distribution of cod in pelagic trawls SI_ARCTIC 2014 (upper), 2015 (middle) and 2016 (lower). Note difference scale between years.

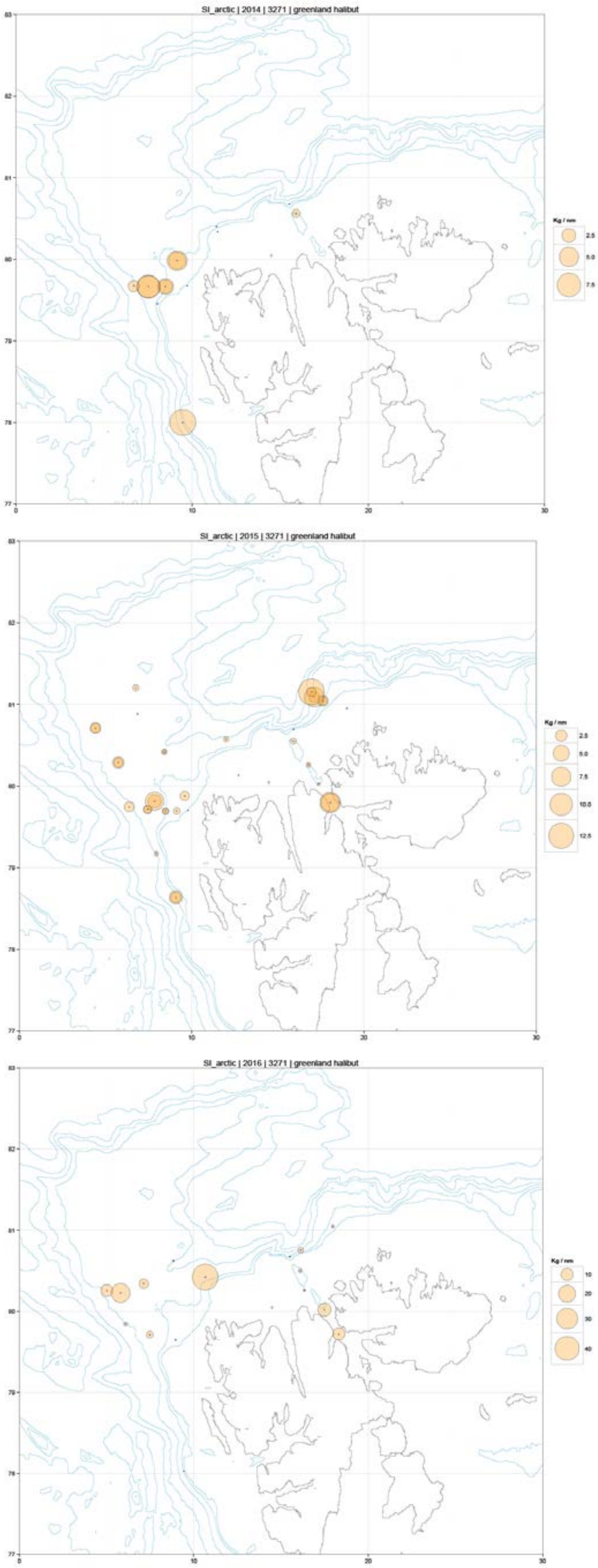


Figure 15. Distribution of Greenland halibut in demersal trawls SI_ARCTIC 2014 (upper), 2015 (middle) and 2016 (lower). Note difference scale between years.

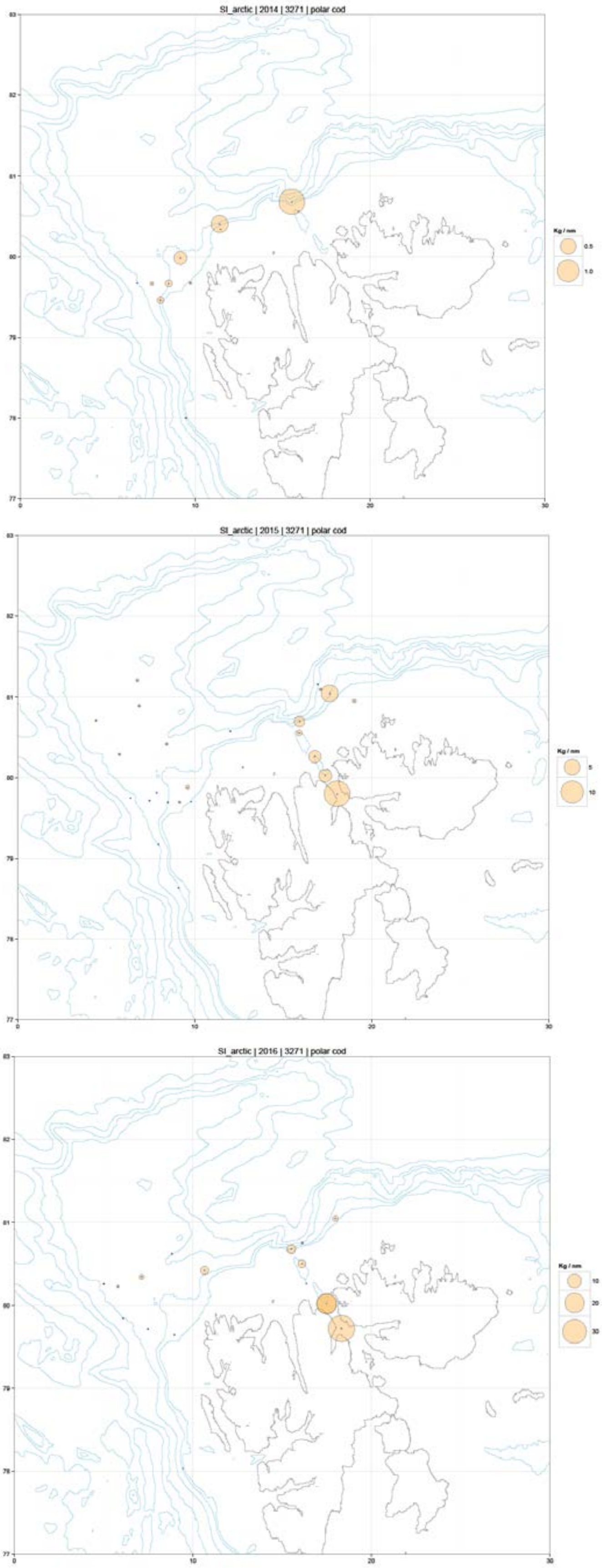


Figure 16. Distribution of polar cod in demersal trawls SI_ARCTIC 2014 (upper), 2015 (middle) and 2016 (lower). Note difference scale between years.

Benthos

Quantitative mapping of mega-benthos

Identification and measures of mega-benthos from bottom trawling (17 Campelen trawls serial no 2004-2052; 2063-2080) and 1 Beam trawl (serial no 2054) was made during the cruise in 2016 (Figure 2, Table A3). More than 191 species were recorded. Stations with the largest mega-benthic biomass (*Pandalus borealis* excluded), number of individuals (abu) and species number (SpNo) were recorded at the Yermak Plateau and north east of Svalbard (Figure 17). High abundance, but relative low biomass and species number was recorded in the Hinlopen strait, while high species number, but relative low biomass and abundance was recorded on the shelf west of Svalbard.

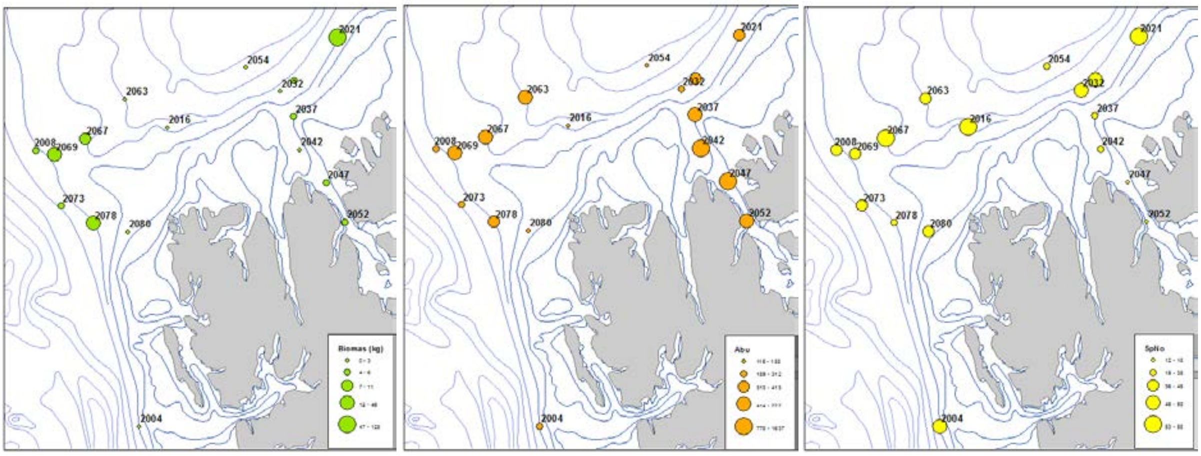


Figure 17. Biomass, abundance and species number of mega-benthos (*Pandalus borealis* excluded) on the SI_ARCTIC 2016 survey.

Comparison 2014-2016

Catch rate of mega-benthos (including the commercial shrimp *Pandalus borealis*) in the Campelen trawl for the three years 2014, 2015, and 2016 are shown in Figure 18a, b, and c. While the last two years show highest amount of mega-benthos in the Hinlopen strait and the areas to the north, in 2014 the highest rates of mega-benthos were from the area just south of the Yermak plateau. This is mostly due to one station with a catch rate of 300 kg/nmi, which partly masks the variation in catch rates in the rest of the area this year (Figure 18a).

Isotopes and stomack analyses

At 17 stations, isotope and stomack analyses (Table A4) was taken from individuals of several fish species.

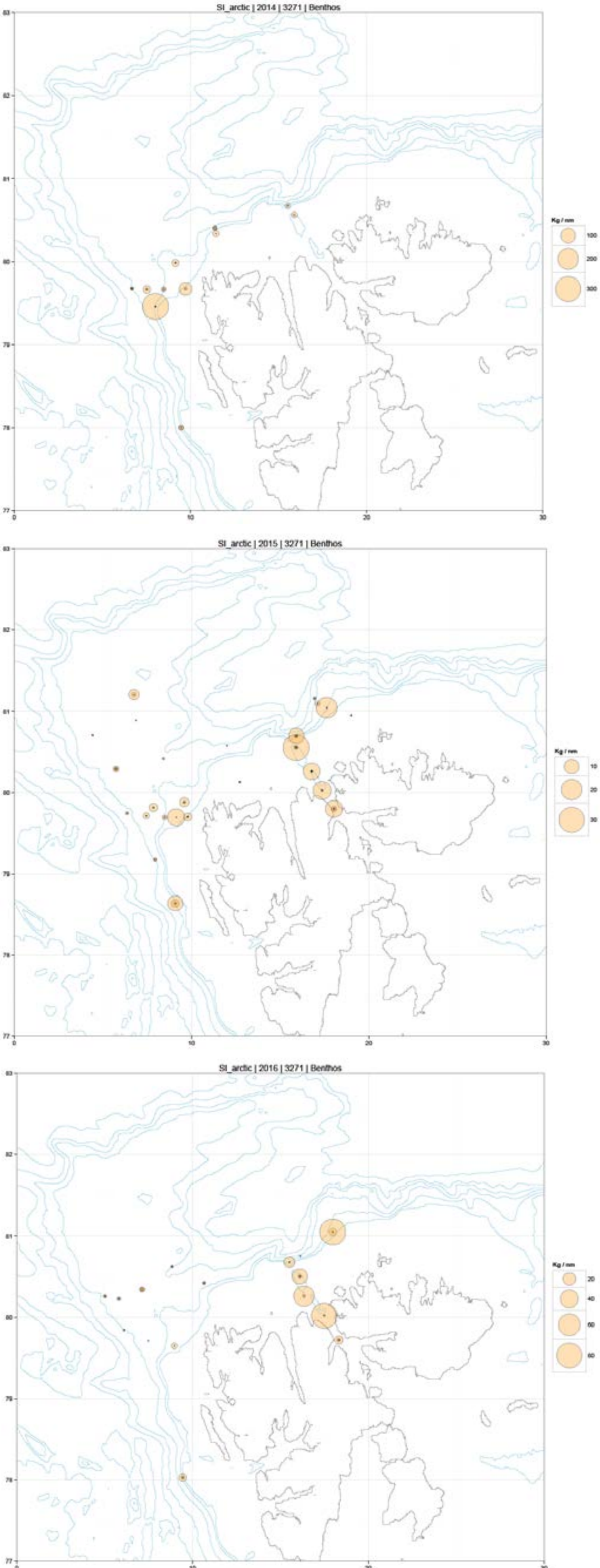


Figure 18. Distribution of mega-benthos catch (kg/nmiles) including the commercial *Pandalus borealis* shrimp in demersal trawls SI_ARCTIC 2014 (upper), 2015 (middle) and 2016 (lower). Note difference scale between years.

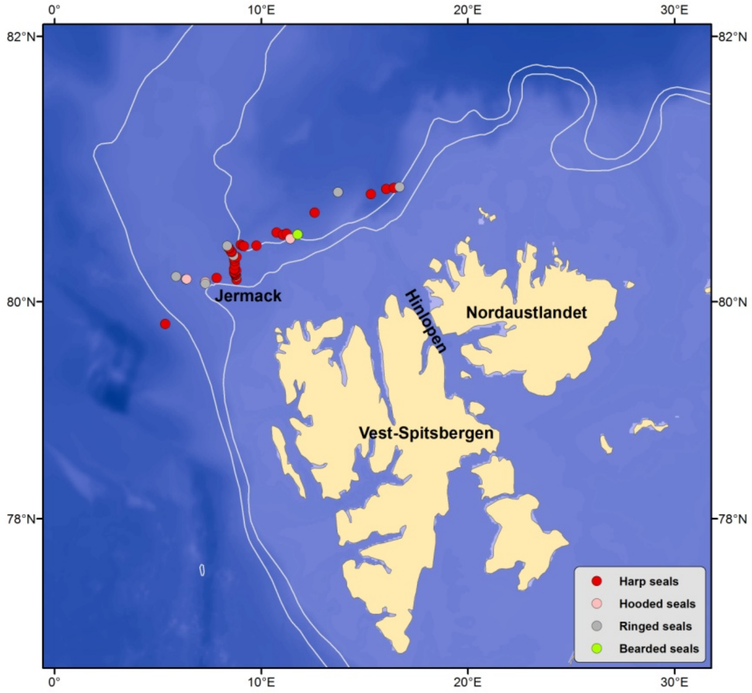
Marine mammals

During the SI_ARCTIC 2016 survey, all together 6 blue whales, 7 fin whales, 4 minke whales, 1 unidentified large whale, 8 killer whales, 14 white-beaked dolphins, 409 harp seals, 10 ringed seals and 1 bearded seal were observed (Table A5). The spatial distribution of these sightings is shown in Figure 19.

The baleen whales were most frequently observed in the eastern areas while odontocetes were only seen in the west. Harp seals were distributed in larger and smaller numbers along the entire ice edge surveyed. Since priority were given to the ice edge, there were fewer cruise lines in open waters in 2016 as compared with previous years of SI_ARCTIC surveys. This may have contributed to the lower numbers of baleen whales observed in 2016 than in 2014 and 2015. It is also worth to note that humpback whales, frequently seen in both 2014 and 2015, were not observed at all in 2016. The high number of harp seals is of course a result of the priority to survey the ice edge which is their preferred habitat.

During the SI_ARCTIC survey in 2014 and 2015, “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 in 2014 – this is an area where many baleen whales were observed also in 2015. The other hot spot in 2014 was located further to the south, at the mouth and within the Hinlopen strait – in these areas no whales were observed in 2015. In 2016, the large baleen whales were most frequently found in the southern hot spot area. The Hinlopen whales were primarily fin and blue whales. Both these, and also the harp seals observed scattered along the ice edge surveyed, are known to feed intensively on zooplankton, krill and amphipods in particular, during summer and autumn.

Killer whales and dolphins were only observed in the western area, whereas the harp seals and other seal species were observed in both areas, although very scattered in the easternmost parts, and always close to the ice edge (Figure 19). In one harp seal hot spot (between 11°E and 12°E), where the seals had hauled out on the ice, 26 animals were shot and taken onboard for scientific sampling. Sampling included parameters such as weight and length, blubber thickness, teeth taken for ageing, stomach/intestines for diet studies and muscle, blubber, liver and whiskers for studies of contaminants and stable isotopes. For comparison, also samples of relevant prey (krill, amphipods, squid and some fish species, all taken from trawl samples) were secured for the stable isotope analyses.



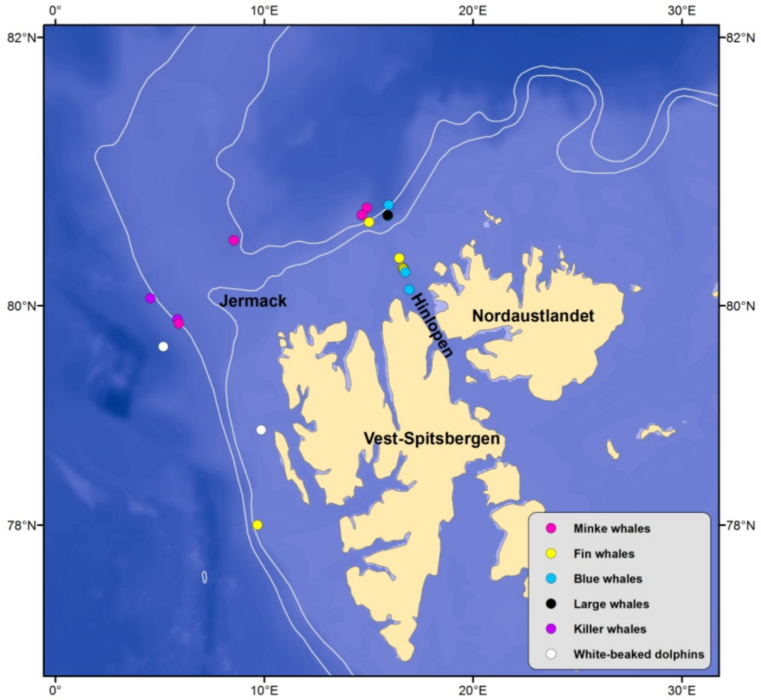


Figure 19. Locations where groups of seals (above) and whales (below) species were observed. Each location denotes one sighting. For some of the sightings several animals were part of the observation. The 500 m and 1000 m depth contrours are shown.

Discussion

The third SI_ARCTIC survey was conducted with R/V *Helmer Hanssen* 2−16 September 2016. 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. Underway acoustic registration of fish and plankton (echosounder) and ocean currents (ADCP), underway measurements of light (irradiance), surface layer temperature, meteorology and sea state, and visual observations of marine mammals and birds were also conducted. Environmental DNA (e-DNA) was conducted, and in addition, we conducted biological sampling of harp seals to investigate diet.

Regarding the main scientific questions of the survey the following results were obtained:

- West of Svalbard, the temperatures in the North Atlantic Current were almost 0.5˚C higher than in 2014 and 2015, and the differences north of Svalbard were even greater. In this area, all the water at a depth of around 50 m or more was between 1 and 1.5˚C warmer than the previous years.
- Both the catches and acoustics suggested biomass levels were as obtained 2014 and higher than in 2015. Thus, there seem to be large inter-annual variations which might be related to environmental impacts on distribution changes and/or changes in species composition. More analyses are needed before conclusions can be drawn.
- Hinlopen was identified as a hotspot region as in 2014. The inner part of this section has substantial higher biomass than the areas around. Higher biomass is also evident in the deeper regions just to the north of the shelf break (the Magdalena deep). Why this region seems to be more productive than elsewhere remains to be investigated.
- There were lesser whales than observed the last years. This might be due to that more of the survey took place near the ice edge zone.
- Comparing fish catches 2014-2016 show clear resemblances among the geographical distributions of the commercial species these three years. The largest catches were taken on the shelf north of Svalbard, but the maximum catch varies substantially between years. Both Greenland halibut and polar cod were found in increasing amounts in the demersal trawl from 2014 to 2016.
- The catch rate of mega-benthos show that in 2015 and 2016 the highest amount of mega-benthos was found in the Hinlopen strait and the areas to the north. This differs from in 2014 when the highest rates of mega-benthos were from the area just south of the Yermak
- New data were obtained on species and communities which will be used to describe who is eating whom in this region.
- New data were obtained on the status and variability of ocean acidification state in the shelf and deep basin in the ice-covered areas north of Svalbard.

Acknowledgements
We gratefully acknowledge the assistance provided by the Captain and Crew of the R/V *Helmer Hanssen*. We are also grateful to Marit Reigstad, UiT, for borrowing the LADCP. The Research Council of Norway is thanked for the financial support through the project "The Arctic Ocean Ecosystem" – (SI_ARCTIC, RCN 228896). The work is a contribution to the Barents Sea Programme at IMR.

References
Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds), Guide to Best Practices for Ocean CO2 Measurements, PICES Special Publication, 3, 191 pp, 2007.

Ingvaldsen RB, Bucklin A, Chierici M, Gjøsæter H, Haug T, Hosia A, Jørgensen LL, Knutsen T, Naustvoll LJ, Ona E, Wiebe P (2016) Cruise report SI_ARCTIC/Arctic Ecosystem survey R/V *Helmer Hanssen*, 17 August-7 September 2015. Toktrapport/Havforskningsinstituttet/ISSN 1503 6294/Nr. 14–2016 (http://www.imr.no/filarkiv/2016/12/cruise_report_si_arctic_2015_final.pdf/nb-no).

Intergovernmental Oceanographic Commission og UNESCO. 2010. Karlson B, Cusack C, Bresnan E (editors). Microscopic and molecular methods for quantitative phytoplankton analysis. Paris, UNESCO. (IOC Manuals and Guides 55. (IOC/2010/MG/55)

MacLennan, D. N., Fernandes, P. G., and Dalen, J. 2002. A consistent approach to definitions and symbols in fisheries acoustics. – ICES Journal of Marine Science, 59: 365–369.

Padman L, Erofeeva S (2004) A barotropic inverse tidal model for the Arctic Ocean, *Geophys. Res. Lett.*, 31(2), L02303, doi:10.1029/2003GL019003.

Parent, G. J., S. Plourde, and J. Turgeon, 2011. Overlapping size ranges of Calanus spp. off the Canadian Arctic and Atlantic coasts: Impact on species' abundances. J. Plankton Res. 33: 1654–1665, doi:10.1093/plankt/fbr072

Pierrot, D., Lewis, E., and Wallace, D. W. R.: MS Excel Program developed for CO2 system calculations, ORNL/CDIAC-105, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, 2006.

Appendix A - Tables
The tables are given on the following pages:

Table A1. Stations with equipment used during the SI_ARCTIC 2016 survey. Position and bottom depth are based on CTD. Station number for the different equipment is given.

Location	Date when starting	Latitude (CTD)	Longitude (CTD)	Bottom depth (CTD, m)	Ice	CTD	LADCP	Water samples (nutrient, phyto)	Water samp. (C_T/A_T)	Water samp. eDNA	Algae net (0-30m)	WP2/Juday (bottom-0)	Krill trawl	Åkra trawl	Campelen trawl	Comment
Case 1	03.09 03.09	77 59.94 78 01.33	09 29.54 09 27.20	480 480	0 0	32 33*	33	32	32	33	32	32**	85/2005 (0-520m)	83/2001 (437m) 83/2002 (350m) 83/2003 (77m)	84/2004 (504m)	* Extra CTD for eDNA **Extra WP2 for Limicina
Ice station	04.09	79 52.16 79 54.66	05 50.39 05 47.55	1038 1050	2 2	34 35	34	34 35	34 35	-	34	34	86/2006 (0-806m)	No trawl due to ice	No trawl due to ice	CTD 35 to 10 m due to bottle failure.
Yermak crossing	04.09 05.09	80 19.38 80 12.35	04 41.89 05 01.88	884 860	2 0	36 37	36 37	36	36	-	36	36	87/2007 (0-782m)	89/2009 (411m) 89/2010 (311m) 89/2011 (55m)	88/2008 (827m)	Consider both of this as one station. CTD 37 test for VBAT. Åkra when we got out of the ice (where Campelen finished)
Along ice edge (east)	05.09	80 28.51 80 28.39	10 09.08 10 19.01	733 785	0	38 39*	38	38	38	39	38	38	91/2015 (0-626m)	90/2012 (407m) 90/2013 (312m) 90/2014 (51 m)	92/2016 (643m)	Rock (250 kg) in Campelen. A small rift, trawl fixed. *Extra CTD for eDNA
	06.09	81 06.86 81 07.31	17 51.77 17 52.82	431 432	0	40 41	40	40 41	40	-	40	40**	94/2020 (0-310m)	93/2017 (50m) 93/2018 (125m) 93/2019 (250m)	95/2021 (352m)	Extra CTD due to bottle failure. Light sensor operative from this station. Greenland shark caught in trawl. **Extra WP2 for Limicina
Hinlopen	07.09	80 48.09 80 49.89	15 38.24 15 45.79	1799 1782	0	42 43*	42	42	42	43	42	42	97/2025 (941m)	96/2022 (467m) 96/2023 (355m) 96/2024 (56m)		* Extra CTD for eDNA
	07.09	80 43.01	15 33.13	933	0	44	44	44	44	-	44	44	98/2026 (0-223m)		99/2027 (927-835m)	No Åkra as we already had trawled over this station when conducting Åkra on the station before.
Case 2	08.09	80 41.14	15 33.20	519	0	45	45	45	45	-	45	45	101/2031 (526m)	100/2028 (405m) 100/2029 (300m) 100/2030 (50m)	102/2032 (501-432m)	2 Greenland halibut in trawl
	08.09	80 33.23	15 53.48	304	0	46	46	46	46	-	46	46**	104/2036 *(283)	103/2033 (230m) 103/2034 (80m) 103/2035 (50m)	105/2037 (356m)	**Extra WP2 for Limicina *U-haul (20 min at fishing depth)
	08.09	80 16.48	16 45.06	323	0	47	47	47	47	-	47	47*	107/2041* *(444m)	106/2038 (373m) 106/2039 (204m) 106/2040 (52m)	108/2042 (329m)	**Extra WP2 for Limicina *U-haul (20 min at fishing depth)
	09.09	80 02.46	17 19.89	384	0	48	48	48	48	-	48	48*	110/2046 *(368m)	109/2043 (314m) 109/2044 (207m) 109/2045 (53m)	111/2047 (408m)	**Extra WP2 for Limicina *U-haul (20 min at fishing depth)
	09.09	79 46.87 79 47.16	18 06.72 18 02.25	415 402	0	49 50[a]	49	49	49	50	49	49**	113/2051 *(410m)	112/2048 (350m) 112/2049 (254m) 112/2050 (52m)	114/2052 (434m)	[a]Ekstra CTD for eDNA **Extra WP2 for Limicina *U-haul (20 min at fishing depth)
Along ice edge (west)	10.09	80 49.54 80 49.89	13 39.38 13 44.15	1289 1273	2	51* 52	52	52	52	-	52	52	115/2053 (815m)	Cut due to low registrations on EK	Beam trawl 116/2054 (1300m)	*CTD 51 at seabed, new CTD.
	10.09	80 48.94	11 55.34	1641	2	53	53	53	53	-	53	53	118/2058 (824m)	117/2055 (312m) 117/2056 (104m) 117/2057 (54m)	-	
Seal station	11.09	80 31.74	11 20.39	863	4	-	-	-	-	-	-	-	MIK obliq. 2059 (200-0m)	-	-	Seal catch, 26 animals. MIK conducted for prey sampling. MIK v-haul.
	11.09	80 37.82	08 31.98	861	3	54	54	54	54	-	54	54	120/2062 (908m)	119/2059 (260m) 119/2060 (161m) 119/2061 (62m)	121/2063 (930m)	One Åkra-net twisted and around the others. All nets given code 5.
	12.09	80 27.65	07 02.89	667	3	55	55	55	-	-	55	55	-	122/2064 (387m) 122/2065 (109m) 122/2066 (51m)	123/2067 (641m)	No Macroplankton trawl due to very limited catch in Åkra

Location	Date when starting	Latitude (CTD)	Longitude (CTD)	Bottom depth (CTD, m)	Ice	CTD	LADCP	Water samples (nutrient, phyto)	Water samp. (C_T/A_T)	Water samp. eDNA	Algae net (0-30m)	WP2/Juday (bottom-0)	Krill trawl	Åkra trawl	Campelen trawl	Comment
Yermak western flank	12.09	80 18.17	05 27.82	646	3	56	56	56	-	-	56	56**	124/2068 (632m)	-	125/2069 (669m)	No Åkra due to sea ice ** Extra WP2 for Limicina
Same station as ice station (no 2)	13.09	79 53.76	05 48.83	1004	3	57	57	57	-	-	57	57**		126/2070 (485m) 126/2071 (352m) 126/2072 (65m)	127/2073 (988m)	*Macroplankton trawl taken last time. Åkra and Campelen not taken last time due to ice. ** Extra WP2 for Limicina
Fram Strait north -reduced section	13.09	79 38.58	05 08.47	2280 (1500)	0	58	58	58	-	-	58	58**	Too bad weather	128/2074 (420m) 128/2075 (297m) 128/2076 (50m)	-	Åkra trawl distroyed when getting into vessel. Catch alright, but the trawl could not be used any more. ** Extra WP2 for Limicina
	14.09	79 40.57	07 32.06	792	0	59	59	59	-	-	59	59	129/2077 (712m)	-	130/2078 (784m)	Lots of mud in Campelen catch
	14.09	79 39.77	08 28.34	503	0	60	60	60	-	-	60	60**	131/2079 (478m)	-	-	** Extra WP2 for Limicina
	15.09	79 40.08	09 03.29	400	0	61	61	61	-	-	61	61	-	-	132/2080 (407m)	

Table A2. Participant list for the SI_ARCTIC 2016 survey.

Participant	Main field	Institution
Harald Gjøsæter	Acoustics/fish	IMR
Lis Lindal Jørgensen	Benthos	IMR
Hildegunn Mjanger	Fish	IMR
Silje Elisabeth Seim	Fish	IMR
Gunnar Langhelle	Fish/taxonomi	UiB
Elvar H. Hallfredsson	Acoustics/fish	IMR
Kjell Tormod Nilssen	Mammals	IMR
Tore Haug	Mammals	IMR
Nils-Erik Skavberg	Mammals	IMR
Ronald Berntsen	Instrument	UiT
Ronald Pedersen	Instrument/VBAT/	IMR
Helene Hodal Lødemel	Chem ocean/eDNA	IMR
Sebastian Menze	Phys ocean/VBAT	IMR
Lars-Johan Naustvoll	Plankton	IMR
Tor Knutsen	Plankton	IMR
Aino Hosia	Plankton	UiB
Eirik Grønningsæter	Sea birds	NINA
Ann Mikaela Tillmann	Benthos	UiT
Randi Ingvaldsen	Cruise leader	IMR

Table A3. Campelen bottom trawl stations with species number, biomass and abundance of a 15-minute trawl haul. These measures do not include the commercial shrimp *Pandalus borealis* as in Figure 17.

Year	Serial no	Locality	Lat	Lon	Depth	Temp (ºC)	Records of taxa	Biomass (kg/15min)	Abu/15min
2016	2004	South-West	78.0278	9.43942	503	3.1692	52	1.6	264
2016	2008	North-West	80.25715	5.02107	809	-0.6878	45	5.4	300
2016	2016	North Shelf	80.4222	10.65815	609	-0.2226	57	2.3	179
2016	2021	North-East	81.0478	17.97917	345	3.4218	54	127.8	376
2016	2027	North-East	80.7519	16.13053	831	-0.3425	52	3.7	353
2016	2032	Hinlopen	80.67852	15.51338	432	4.2048	48	1.2	298
2016	2037	Hinlopen	80.50048	16.1023	320	3.6714	35	4.3	709
2016	2042	Hinlopen	80.2606	16.3441	322	3.2975	26	2.7	1373
2016	2047	Hinlopen	80.01989	17.49395	398	3.7166	12	5.9	1632
2016	2052	Hinlopen	79.7195	18.32288	402	2.7769	18	4.4	777
2016	2054*	Hinlopen	80.84396	14.02265	1250	-0.6746	35	0.5	116
2016	2063	Yermak	80.6233	8.83641	907	-0.4576	41	1.9	754
2016	2067	Yermak	80.34139	7.13425	619	-0.4147	58	11.4	707
2016	2069	Yermak	80.22622	5.80956	653	-0.2001	46	45.2	624
2016	2073	Fram	79.84295	6.09743	984	-0.7889	39	3.6	307
2016	2078	Fram	79.71146	7.48336	784	-0.5058	35	43.84	346
2016	2080	Fram	79.6458	8.96543	396	3.302834	41	0.42	188

*Beam trawl

Table A4. Equipmet and serial no for fish species with analysed stomack content and for fish species simultainaously sampled for isotopes in 2016

Trawl	Serial no	NO of Sp for stomacks	Isotopes
Åkratrawl 1	2001-03	7	
Campelen	2004	3	
Campelen	2008	3	
Åkratrawl 1	2009	5	
Campelen	2016	1	
Campelen	2021	2	
Åkra trawl 1	2017	2	
Åkra trawl 2	2018	1	
Åkra trawl 1	2023	4	
Krill trawl	2015	3	
Åkra trawl 1	2028	1	
Åkra trawl 2	2029	3	3
Åkra trawl 3	2030	1	
Campelen	2032	3	2
Åkratrawl 1	2033	2	1
Åkratrawl 2	2034	3	3
Åkratrawl 3	2035	5	2
Campelen	2037	1	
Åkratrawl 1	2038	1	
Åkratrawl 2	2040	1	
Campelen	2042	1	
Campelen	2047	1	
Åkratrawl	2048	3	

Table A5. Number of marine mammal individuals observed in 2016, sorted by two regions; Yermak and Hinlopen. All observations are given, including also those recorded when the vessel was stationary.

Species	**Jermack** (West of 10°E)	**Hinlopen** (East of 10°E)	**Total**
	Animals (#)	Animals (#)	Animals (#)
Blue whale		6[1]	6
Minke whale	2	2	4
Fin whale	1	6	7
Killer whale	8[2]		8
White-beaked dolphin	14[3]		4
Harp seal	90	319	409
Bearded seal		1[4]	1
Ringed seal	7	3[4]	10
Total	**112**	**337**	**449**

Number of animals observed when the vessel was working on a station: [1]: 2; [2]: 6; [3]: 4; [4]:1