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MARINE AND FRESHWATER RESEARCH IN ICELAND

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Ástþór Gíslason, Klara Jakobsdóttir, Kristinn Guðmundsson,
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Ágrip

Gagnasöfnun fyrir alþjóðlegt rannsóknaverkefni um lífríki miðsjávarlaga (MEESO), sem styrkt er af Evrópusambandinu, fór fram í rannsóknaleiðangri Hafrannsóknastofnunar á uppsjávarvistkerfi norðurhafa að sumarlagi sumarið 2020. Tilgangurinn var að rannsaka magn, dreifingu og samsetningu miðsjávarfánu í tengslum við umhverfisþætti og vöxt og viðgang plöntsvifs. Meginsvæði rannsóknarinnar fylgdi sniði sem liggur nokkurn veginn eftir 61°50’N-breiddarbaug, frá 38°49’V og að 16°05’V, þ.e. frá Grænlandshafi yfir Reykjaneshrygg og inn í Suðurdjúp, sem og á stöð í Grindavíkurdýpi.

Eftir endilöngu sniðinu var u.þ.b. 50 m þykkt blöndunarlag sem svifgróður virtist dafna í. Samkvæmt bergmálsmælingum voru tvö meginlög miðsjávarlífvera. Hlutfallslega sterkt endurvarp á tíðninni 18 kHz stafaði einkum frá miðsjávarfiskum sem héldu sig tiltölulega grunnt á nóttunni (ofan við 100 m dýpi) en djúpt á daginn (~300-400 m). Annað lag af sterku endurvarpi, sem ekki virtist ferðast upp á nóttunni en halda sig á 500-700 m dýpi allan sólarhringinn, kom fram á 38 kHz tíðni. Þetta voru aðallega miðsjávarfiskar og sviflæg krabbadýr.

Lífmassi dýrasvifs í efstu 200 m sjávar var yfirleitt meiri í Grænlandshafi (~7,5-10 g þurrvigt m-2) en í Suðurdjúpi (<5 g þurrvigt m-2). Þéttleiki dýrasvifsins var jafnan meiri í efstu lögunum (0-50 m) heldur en þar fyrir neðan (50-200 m).

Marglyttur (aðallega *Periphylla* sp. og *Atolla* sp.) voru yfirleitt meira en helmingur lífmassans sem kom í stórátuvörpu. Um það bil 130 tegundir voru greindar úr sjö dýraflokkum. Þar af voru um 50 fisktegundir og 40 tegundir krabbadýra. Algengustu fisktegundirnar reyndust vera ísalaxsíld (*Benthosema glaciale*), fiskar af stirnaætt (*Gonostomatidae*) og íshafslaxsíld (*Protomyctophum arcticum*) Í skýrslunni eru sýnd lengdar-þyngdarsambönd nokkurra helstu tegunda sem komu í vörpuna.

Abstract

A sampling dedicated for the project "Ecologically and economically sustainable mesopelagic fisheries" (MEESO), funded by the European Union, took place during a cruise designed to study pelagic ecosystems of the Nordic Seas during summer (IESSNS) in July 2020. The main aim of the MEESO work was to study the abundance, distribution and composition of mesopelagic organisms in relation to hydrography and phytoplankton productivity. The focus was on a longitudinal transect along ~61°50'N, from ~38°49'W to ~16°05'W, from the Irminger Sea and into the Iceland Basin and including a station in Grindavík basin.

Water density distribution along the transect confirmed a shallow mixed surface layer in the uppermost 50 m with moderate phytoplankton growth.

Acoustic registrations identified two main deep scattering mesopelagic layers. A relatively strong backscatter at 18 kHz, composed mainly of mesopelagic fish maintaining a depth of ~300-400 m during the day and migrating to above 100 m depth during the night. Another layer with minimal diel vertical movement with relatively strong backscatter at 38 kHz was evident at 500-700 m, mainly composed of mesopelagic fish and crustaceans.

Zooplankton biomass in the uppermost 200 m was generally higher in the Irminger Sea (c. 7.5-10 g dw m^{-2}*) than in the Iceland Basin (<5 g dw* m^{-2}*). Furthermore, zooplankton densities were generally higher in the 0-50 m layer than in the 50-200 m layer.*

Jellyfish (mainly Periphylla sp. *and* Atolla sp.*) generally made up more than half of the catch of the macroplankton trawl in terms of weight. Approximately 130 species were identified, belonging to seven animal classes. It included approximately 50 fish species and about 40 species of crustaceans.The most abundant fish species were* Benthosema glaciale, bristle mouths *such as* Cyclothone and Protomyctophum arcticum.. *Over the Reykjanes Ridge and off the Iceland shelf,*Benthosema glaciale *was generally predominant. Length-weight relationships of a few of the most abundant fish species caught are reported.*

Lykilorð: *MEESO, mesopelagic fauna, ecosystem, Irminger Sea, Iceland Basin*

Undirskrift verkefnisstjóra:	**Undirskrift forstöðumanns sviðs:**

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1. Introduction

The A7-2020 cruise of the RV Arni Fridriksson was the 11th in a series of annual cruises carried out by the Marine and Freshwater Research Institute (MFRI) as a part of the International Ecosystem Summer Survey in Nordic Seas (IESSNS; Olafsdottir and Kennedy 2020). The cruise covered the Icelandic exclusive economic zone north, northeast, and south of Iceland, and also two offshore basins, the Iceland basin and the southern part of the Irminger Sea basin. The survey lasted for 30 days (1-30 July); of which 2 days of wire-time were dedicated to sampling for the "Ecologically and economically sustainable mesopelagic fisheries" project (MEESO) funded by the European Union (grant no 817669). This MEESO sampling is presented in this report.

The overall aim of the MEESO project is to quantify the spatio-temporal distributions of biomass, production, and ecosystem role of mesopelagic resources in the North Atlantic and to assess options to sustainably manage and govern exploitation. The main aim of the MEESO work conducted during the A7-2020 cruise was to study the abundance, distribution, and composition of mesopelagic organisms in relation to hydrography and phytoplankton productivity in the deep basins south and southwest of Iceland, the Iceland basin, and the Irminger basin, respectively, using CTD, plankton nets, fine meshed pelagic trawls, video plankton recorder and acoustics.

The two basins are separated by the Reykjanes Ridge, which is a part of the Mid-Atlantic Ridge (MAR), stretching out to the southwest from the Icelandic continental shelf. As described below, the MAR has profound influence on the oceanic circulation, and hence biological productivity in the area (Magnusson and Magnusson 1995; Sigurdsson et al. 2002: Gudfinnsson et al. 2008). The present study thus seeks to compare biological productivity on both sides of the MAR.

2. Methods

2.1. Cruise participants

The cruise was divided into two parts with sampling for MEESO during the latter part. Crew shift took place in Vestmannaeyjar on 13 July. Table A1 lists the scientific personnel that took part in the second half of the cruise and their roles.

2.2. Study area and main ocean currents

The Reykjanes Ridge has profound influence on the flow of currents in the oceanic area southwest of Iceland, and in the deeper layers it restricts flow between the two ocean basins, the Iceland Basin and the Irminger Basin (Valdimarsson and Malmberg 1999). The prominent features of the current pattern in both the basins are large cyclonic gyres, that are strongly controlled by the topographic margins and the Reykjanes Ridge (Schmitz and McCartney 1993; van Aken and de Boer 1995; Mortensen 1997; Valdimarsson and Malmberg 1999; Hansen and Østerhus 2000) (Figure 1).

On the shelf southwest of Iceland and out to ~1,000 m depth beyond the shelf, the Atlantic Water (AW) dominates the whole water column (Malmberg 1978; Hansen et al. 1998). The deep-water masses in the Iceland and Irminger Basins include the Labrador Sea Water (LSW), which originates by deep convection in the Labrador Sea, and the Iceland Scotland Overflow Water (ISOW), which comes from the Norwegian Sea overflowing the Iceland–Scotland Ridge on its way. In the deepest layers in the Irminger Basin there is in addition Denmark Strait Overflow water (DSOW), which overflows the Denmark Strait from the Iceland Sea (Figure 1) (Hansen 1985; van Aken and de Boer 1995; Blindheim et al. 1996; Mortensen 1997; Casanova-Masjoan 2020).

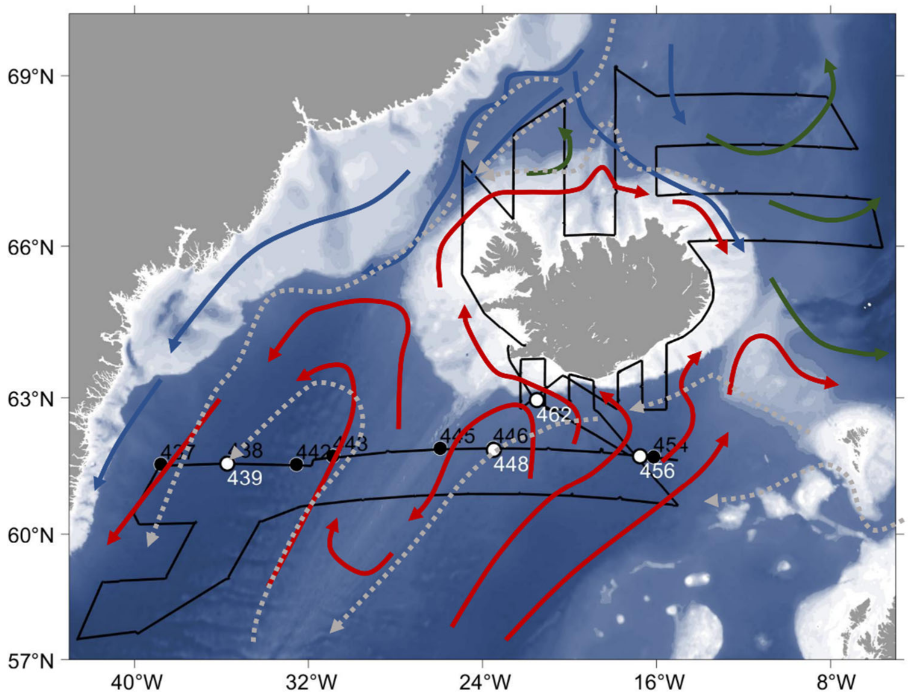

Figure 1. Map of the IESSNS survey area showing the position of the four trawl sampling stations taken for the MEESO project (white circles) (Ólafsdóttir and Kennedy 2020). Also shown are seven stations from where results on zooplankton sampling with WP2 are presented (black circles). Station numbers are indicated. The black line denotes the cruise track. Inserted on the figure are the main ocean currents in the upper layers, adapted from Valdimarsson and Malmberg (1999) and Casanova-Masjoan et al. (2020), and bottom currents adapted from Hansen and Österhus (2000) and Casanova-Masjoan et al. (2020). Red arrows Atlantic water, blue arrows Polar water, green arrows mixed water, grey broken arrows bottom currents.

2.3. Physical oceanography, profiling and water sampling

The physical and chemical properties of the water were profiled at each of the stations, using a sonde with Sea-Bird 911plus Conductivity Temperature and Depth sensors (CTD) and additional sensor for chlorophyll-*a* fluoroscence (Seapoint Chlorophyll Fluorometer; relative FSU). A rosette with 5L Nisken water bottles was used to collect samples at selected depths, *i.e.* 0, 10, 20, 50 m for measurement of chlorophyll-*a* and 0, 20, 50, 100, 200, 500 m for analysing the concentrations of dissolved nutrients (nitrate, silicate and phosphate, respectively). Furthermore, water samples were collected for measurement of the salinity at the maximum depth profiled (1000 m) for calibration of the salinity obtained from the CTD records.

2.4. Nutrients and chlorophyll-*a* measurements

The dissolved nutrients were analysed, using a Seal Autoanalyzer AA3 and the methods described by Grasshoff (Grasshoff 1970), except for the phosphate were a modified version of the Murphy and Riley method was automated (Murphy and Riley 1962). Filtered phytoplankton, on Whatman GF/F for pigment analysis, were stored in capped glass tubes in freezer, submerged in 5 ml extraction solvent (90% acetone). The chlorophyll-*a* and phaeopigments were measured according to the method described by Holm-Hansen *et al*. (1965).

The results of chlorophyll-*a* measurements will be used for calibration of the recorded rFSU profiles and for scaling the rFSU recorded by the VPR's (Wetlabs ECO puck) to approximated chlorophyll-*a* values.

2.5. Acoustic registrations

2.5.1. Hull borne acoustics

Hull-mounted acoustics data were collected with a calibrated Simrad EK80 echosounder split beam at five frequencies (18, 38, 70, 120, and 200 kHz) at 1 ms pulse duration. On each MEESO station, acoustic backscatter was sampled down to 1000 m depth collecting broadband data centred at the frequencies 38, 70, and 120 kHz. Between stations the data were sampled down to 750 m using narrowband. Multi-frequency post-processing analysis was performed on the acoustic data with the LSSS (Large Scale Survey System) software (version 2.9.0).

The interpretation and scrutinization to groups/species level were made on all frequencies (within their sampling range) for every 5 nmi, based on catch information, on the multiple frequency response of specific regions or schools and the acoustic records' characteristics (Ingvaldsen et al. 2016; Korneliussen et al. 2016). All acoustic backscatter was identified to the following categories: Jellies, Redfish, Herring, Krill, Plankton, Squid, Mesopelagic fish & crustaceans, Mesopelagic fish, and Other. During the survey, it was evident that one mesopelagic layer with stronger backscatter at 18 kHz was composed of mesopelagic fish. This layer was classified as a "clear" mesopelagic layer and was characterized with the relative frequency response *r(f)* (Korneliussen and Ona 2003) stronger at 18kHz (*r(f)* >2.5) than at 38 kHz (*r(f)* = 1). The -72 dB threshold was used under the 18kHz frequency to define the layer's start and end. Another layer with minimal diel vertical movement had a much stronger backscatter at 38 kHz and it was composed of mesopelagic fish and crustaceans (*r(18 kHz)* = 0.5 and *r(38 kHz)* >2.5). The scrutinization was done at the 38 kHz with a visual interpretation of -72 dB and -82 dB to define the DSML start and end. Thresholding was used to distinguish plankton within the upper layers (0-300) from other pelagic/mesopelagic organisms backscatter utilizing the difference between -82 dB to -60 dB (as detailed in e.g. Ingvaldsen et al. (2016)). Further work is planned to use the automatic categorization with the KORONA post-processing tool available in LSSS. The defined categories and total backscatter at all frequencies was stored as Nautical Area Scattering Coefficient Values (NASC, S_A, m^2 nmi^{-2}) with -82 dB lower threshold in 0.1 nmi resolution and 10 m vertical resolution.

2.5.2. Submersible echosounder

The submersible echosounder is equipped with a Wide-Band Transceiver TUBE (WBT-TUBE, Simrad EK80, Figure 2), ES38 18-DK-split and ES120-7CD kHz transducers and depth, salinity, and temperature sensors. It was first deployed in proximity of deep scatter mesopelagic layers (DSML, 300 – 500 m). The equipment was lowered down to ~50 m distance from each dense DSML (Table 1) situated south of Iceland, in the Irminger basin and the Iceland basin. Broadband acoustic data (35 to 45 and 90 to 170 kHz, respectively) were recorded for at least 15 minutes. Backscatter from all targets was stored as volume backscattering coefficient (S_v, dB) and Nautical Area Scattering Coefficient Values (NASC, S_A, m^2 nmi^{-2}) with -82 dB lower threshold in 1s analysis windows at ranges of 15-80 m from the transducers.

Table 1. Stations, dates, depths, and locations where the submersible echosounder was deployed (see Figure 1).

	Station	Date and time	Depth (m)	Location
MEESO1	438	24-07-2020,19:26- 20:00	350 450	Irminger Basin
MEESO2	447	27-07-2020, 04:24-05:29	60, testing 220 Layer400	Iceland Basin
MEESO3	457	29-07-2020, 03:41-05:23	100, testing 220 400	Iceland Basin
MEESO4	463	30-07-2020, 03:31-04:43	50, testing 100 400	Off shelf south of Iceland

The submersible echosounder was calibrated both for narrowband and broadband pulses (April 2020) using a tungsten sphere with a diameter of 34.9 mm suspended about 20 m bellow the submersible transducers. A calibration of the submersible echosounder at different depths is planned for the summer of 2021. The acoustic data will be further corrected to account for any potential target strength bias with depth (Haris et al. 2018).

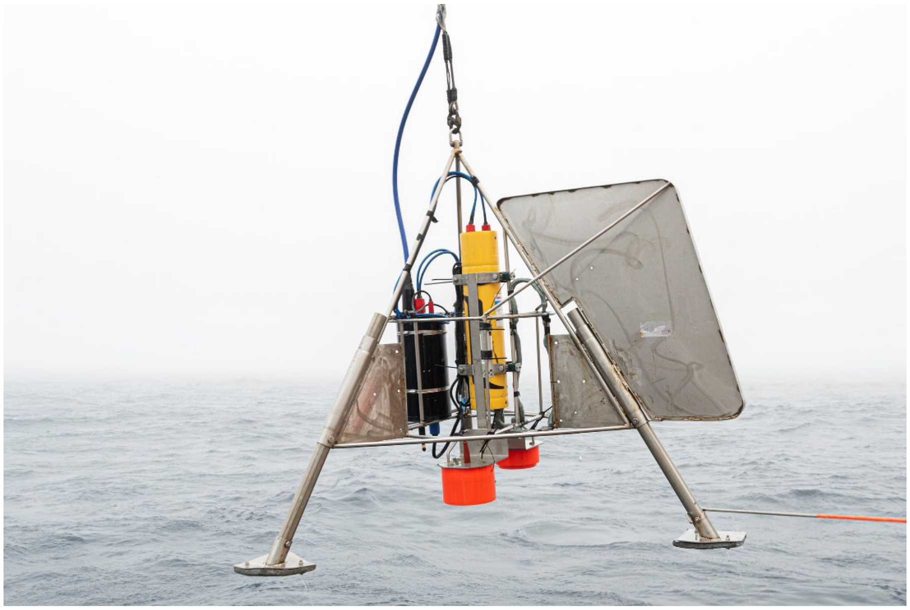

Figure 2. The WBT-TUBE being deployed. Image Svanhildur Egilsdóttir MFRI.

2.6. Mesozooplankton

2.6.1. WP2 net

The zooplankton samples were collected using a WP2 net (0.25 m^2 mouth area and 200 µm mesh size). The nets were shot two times from 200 m and 50 m, respectively, to the surface with a speed of ~45 m min^{-1}. The depth of the net was monitored by a Scanmar acoustic depth sensor and the volume of water filtered by the net was measured with HydroBios flowmeters fitted in the mouth of the net. The zooplankton samples were preserved in 4% neutralized formalin until analysis in the laboratory. As a rule, the entire sample was counted for the larger plankton (euphausiids, amphipods, mysids, decapods, chaetognaths and copepods >1 mm prosome length). Except when the sample was very small, the remainder was subsampled with a Motoda splitter (Motoda 1959) and an aliquot containing at least 500 individuals analyzed for species composition. Further, the copepods *Calanus finmarchicus, C. hyperboreus*, and *C. glacialis* were classed to developmental stages. Abundance (numbers m^{-2}) was calculated based on data from the flowmeter. In order to estimate abundance of zooplankton in the 50-200 m depth layer the catch in the 0-50 m depth layer was subtracted from the catch in the 0-200 m depth layer.

2.6.2. Video Plankton Recorder (VPR)

A video plankton recorder (VPR, Figure 3) which takes colour images at a rate of up to 15 images per second, was used to estimate the abundance and distribution of plankton and particles (Davis et al. 2004). The VPR was fitted with a SBE-49 Seabird CTD and Wetlabs ECO Puck fluorometer/turbidity sensor, by which temperature, salinity, density (depth), fluorescence and turbidity were measured from essentially the same parcel of water where the images were taken. Towing speed was 2.5-3 knots, and the vertical speed of the VPR during lowering and hauling was ~0.5-1 m sec^{-1}. During the tow, the depth of the VPR was monitored with a Scanmar depth sensor fitted on the wire just above the VPR. The VPR is a self- contained system powered by a 24 V NiMH battery.

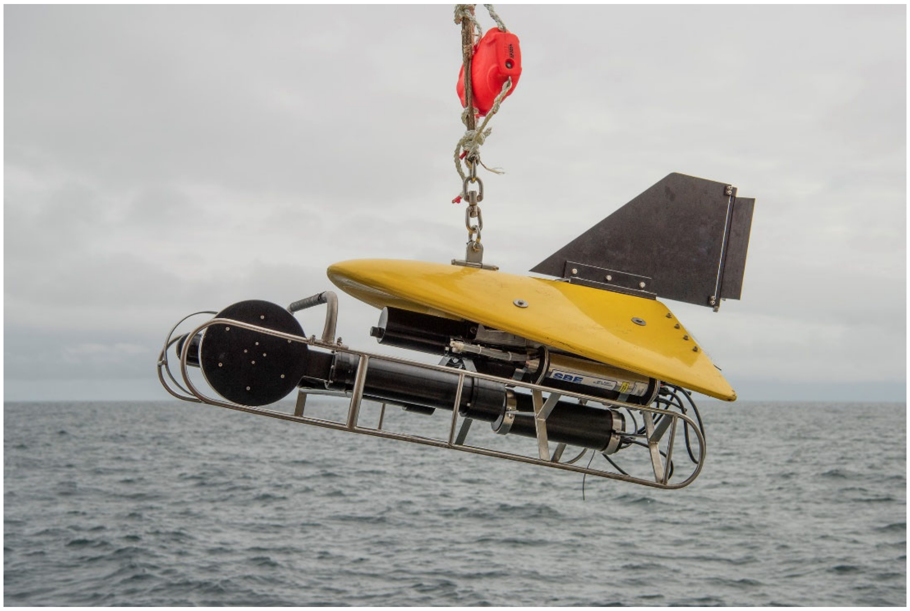

Figure 3. The VPR being deployed. Image Svanhildur Egilsdóttir MFRI.

The VPR was deployed vertically at each station from surface and to 800 m depth. At each station, the VPR was lowered and hived two times. After each tow, the VPR was taken aboard the ship and the data were downloaded from the instrument and the battery was replaced by a freshly charged one.

The VPR tows produce compressed data files of images as well as ancillary CTD and fluorescence data (Hu and Davis 2006). In-focus images of plankton/particles (Regions of Interest, ROIs) and environmental data were extracted from these files using the software AutoDeck (Seascan Inc.).

The images were then analysed automatically on board for abundance by the software Visual Plankton following the methods of Hu and Davis (2006). For this study, all the automatic identifications were checked manually for correctness of the classifications. The environmental data collected by the VPR (temperature, salinity, density, fluorescence, turbidity) were binned by 1 s intervals. The count data were binned in the same manner and the information on total imaged volume (calibrated as in Gislason et al. 2016) and counts of plankton/particles within the bins used to calculate abundances (individuals l^{-1}). The environmental data and the abundance data where then merged into one data table based on the time bins.

2.7. Macroplankton and nekton

Pelagic midwater trawl, 'macrozooplankton trawl', (opening ~27m^2, knotless nylon net with 4 mm meshes, 6 mm stretched), with the same mesh size in the whole body of the trawl, from the mouth opening to the cod-end, was employed for verification of backscatter signal and to collect macroplankton and nekton from the mesopelagic layer (Figure 4). The trawl is equipped with relatively short lastridge lines that causes the trawl net to undulate when towed through the water, preventing animals from being enmeshed in it. The trawl has short 800 mm mesh size wings with floats at the upper wing linings and chains as weight at the lower linings. Floats are also fastened to the headline and chains to the bosom (i.e. the centre portion). The trawl is spread by trawl doors that are fastened to the wing ends by 30 m long dynice towing ropes (Silva et al. 2017).

Figure 4. Hauling in the Pelagic midwater trawl, macrozooplankton trawl. Image Svanhildur Egilsdóttir MFRI.

The decision on towing depth of the targeted tows (see below) was made in accordance to kHz 38/18 acoustics but also the 120kHz if possible.

Four sets of stations were obtained (Figure 1). Each set consisted of one integrated tow from 1000 m and up to the surface, followed by a targeted tow in the upper acoustic scattering layer and finally a targeted tow in the lower acoustic scattering layer. Effort was made to tow during night-time when the scattering layers tended to be most separated. However, at one station the integrated tow had to be made around noon.

Integrated tows: The trawl was lowered slowly to 1000 m depth and then hived slowly up again while the ship cruises at slow speed (ca. 1.5-2 knots). Thus, an integrated sample of the water columns down to 1000 m depth was obtained.

Target tows: The trawl was towed horizontally through two layers of dense acoustic backscattering registrations. The trawl was lowered to the regions of interest and then towed horizontally at low speed (ca. 1.5-2 knots) for 0.5 nmi through the layer. First tow was targeted for upper acoustic layer (250-325 m), the second for the lower acoustic layer (400-570 m).

Tow depths are shown in Table 2. Thus, information on catch composition of the acoustic backscattering layers was obtained.

The total catch (see Figure 5 for an example) was weighted. Large jellyfish and fish were initially sorted out, weighted, and removed from the sample. Other catch (fish and other invertebrates) was sorted and identified to the lowest taxonomic category possible (Figure 6). If catch was large, a subsample was taken and sorted to lowest taxa possible. All categories were weighted. A subsample of fish was length measured and weighted. All catch (without jelly fish) was frozen for more extensive analysis in lab.

Figure 5. Typical catch from the pelagic midwater trawl, the macrozooplankton trawl. Image Svanhildur Egilsdóttir MFRI.

Figure 6. Sorting out species from the catch. Image Svanhildur Egilsdóttir MFRI.

3. Results and discussion

3.1. Physical oceanography

Plotted depth profiles for the trawling stations (Figure 7 a, c, e, g) illustrate the recorded temperature and salinity, and reveal lower temperature and salinity west of the Reykjanes Ridge (Stn 438) compared to the three stations over and east of the ridge (Stns 446, 455 and 461). Furthermore, at all the stations, water density distribution confirms a shallow mixed surface layer in the uppermost 50 m, separated from the water below by a well-established pycnocline. Apparently, phytoplankton is growing above the pycnocline, as expected. The water column below the pycnocline is somewhat stratified in the Atlantic water at the ridge and east of it, while all the profiled parameters are relatively constant down to the maximum depth observed (1000 m) at Stn 438 in the Irminger Sea.

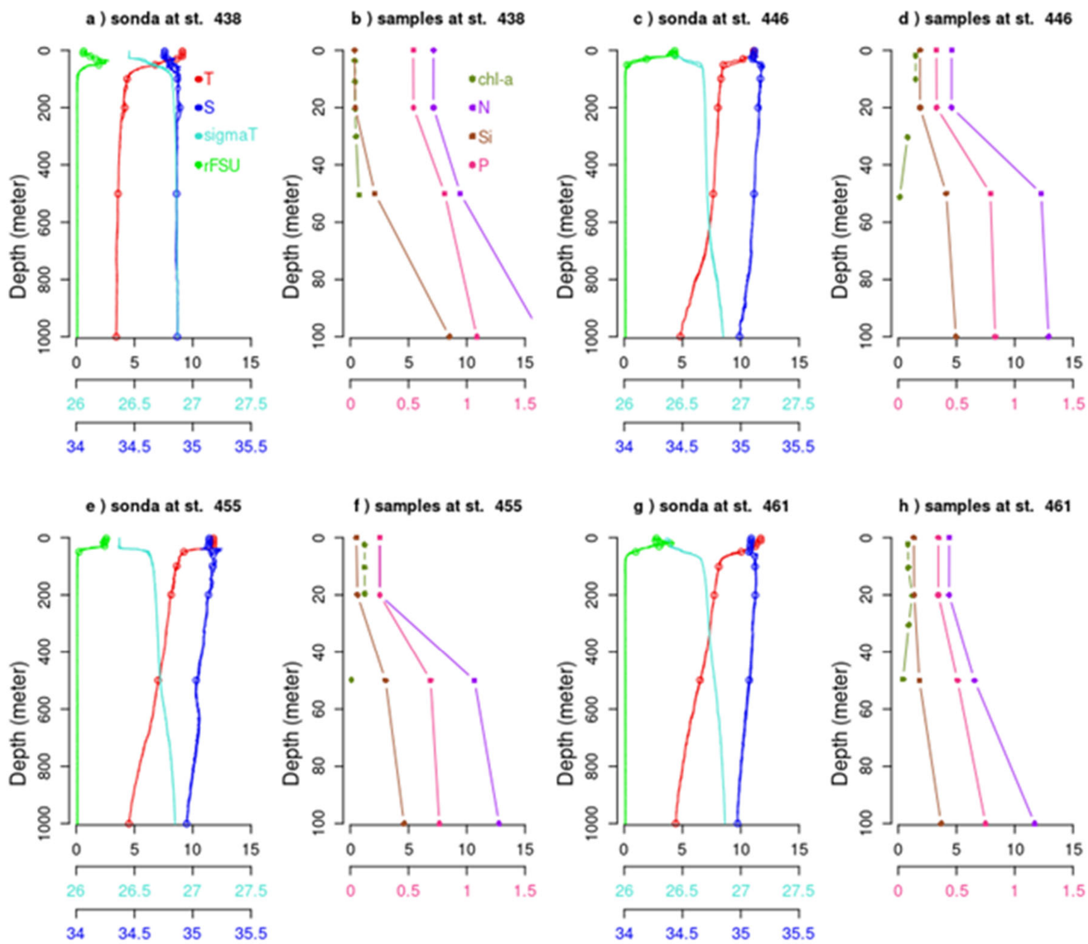

Figure 7. Plots illustrating the depth distribution of temperature (T), salinity (S), sigma-theta (sigmaT) and relative fluorescence for chlorophyll-a (rFSU) recorded with sonde (a, c, e, g), and chlorophyll-a (chl-a), nitrate (N), silicate (Si) and phosphate (P) concentrations measured from water samples (e, f, g, h), at the four trawling stations (438, 446, 455, 461). The units for the plotted variables are °C, PSU, kg $m^{-3,}$ rFSU, mg m^{-3} and for the nutrients (N, Si, P) mmol $m^{-3,}$ respectively. The variables are scaled according to the black axis ranging from 0 – 15, except for the sigma T (scaled between 26 and 27.5; turquoise), the salinity (scaled between 34 and 34.5; blue) and the phosphate (scaled between 0 and 1.5; violet). For location of stations refer to Figure 1.

3.2. Nutrients and chlorophyll-*a*

The measured concentrations of dissolved nutrients (N, P and Si) showed strong linear correlations with each other (Figure 7 b, d, f, h and Figure 8), especially below 50 meter depth (Figure 8). Nevertheless, a consequent deviation from the linear relationship of Si *vs.* N was noticed in a surface layer (> 50 m) of the Atlantic water at stations east of the Reykjanes Ridge. Deviation from linear relationship of P *vs.* N was also apparent west of the ridge (Figure 8; red and blue circles, respectively).

The measured chlorophyll-*a* concentrations, as expected for observations in July, confirmed a moderate phytoplankton biomass at all the four stations. Phytoplankton growth is dependent on available nutrients. Li et al. (2010) demonstrated that on short scales (intra-day, intra-annual) one may expect 1.1 mg increase in chlorophyll-*a* for each mmol-N of dissolved nitrate used for growth in the surface layer in high latitude waters (*i.e.,* with annual mixing of the water column). Thus, the difference of expected *initial nitrate concentrations* at the beginning of an annual growth season, after mixing of the water column during the winter months (INC) and the *measured nitrogen concentrations* from water sampled during a cruise (MNC) may be considered as an estimate of *minimum phytoplankton new production in terms of nitrate* since previous winter (MiN). Assuming the INC were equal to the average concentration of nitrate at 100 and 200 m depth at the station in question, the estimated reduction in nitrate concentrations (using simple integration from the surface down to 50 m depth) equals 439, 315, 417 and 398 mmol-N m^{-2} for the respective stations in numerical order. In accordance with the above-mentioned assumptions and commonly used ratio of phytoplankton carbon and chlorophyll-*a* (50:1), the above MiN estimates indicate a minimum new production of phytoplankton of approximately 24, 17, 23 and 22 gCm^{-2} yr^{-1} at Stns 438, 446, 455, 461, respectively. Of course that does not tell anything about the fate of this carbon production, its turnover in the surface layer or transport to deeper water. No direct observations are available of these processes during the productive season.

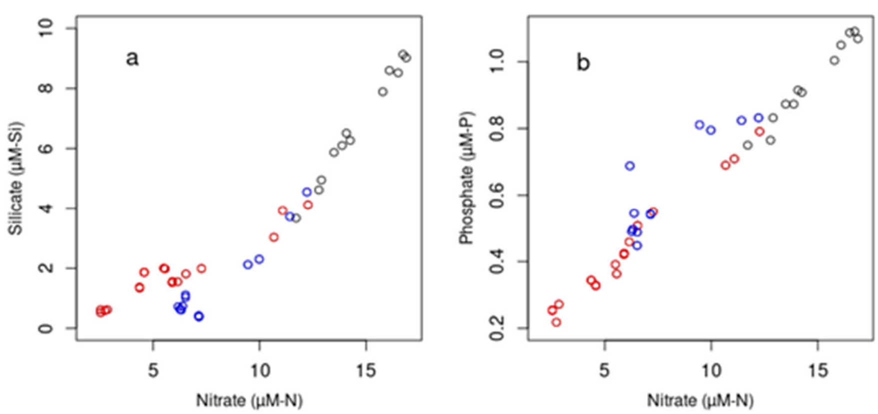

Figure 8. Plots illustrating linear correlations of nutrients for (a) silicate (Si) vs. nitrate (N) and (b) phosphate (P) vs. nitrate. The colours highlight on the one hand measurements of water samples collected from a surface layer (0 – 50 m) at station west of the Reykjanes Ridge (Irminger sea, blue) and that of stations east of the ridge (Atlantic water, red), and on the other hand that from depth greater than 50 meters at all stations (black).

3.3. Acoustic registrations

Macrozooplankton and nekton were collected at two main DSMLs evident in the 18 kHz and 38 kHz echograms (Figure 9). It was clear during the survey that one mesopelagic layer with stronger backscatter at 18 kHz was composed mainly of mesopelagic fish that would maintain a dept of ~300-400 m during the day and migrate to above ~100 m depth during the night. Another layer with minimal diel vertical movement was with stronger backscatter at 38 kHz between 500-700 m was mainly composed of mesopelagic fish and crustaceans (Figure 9).

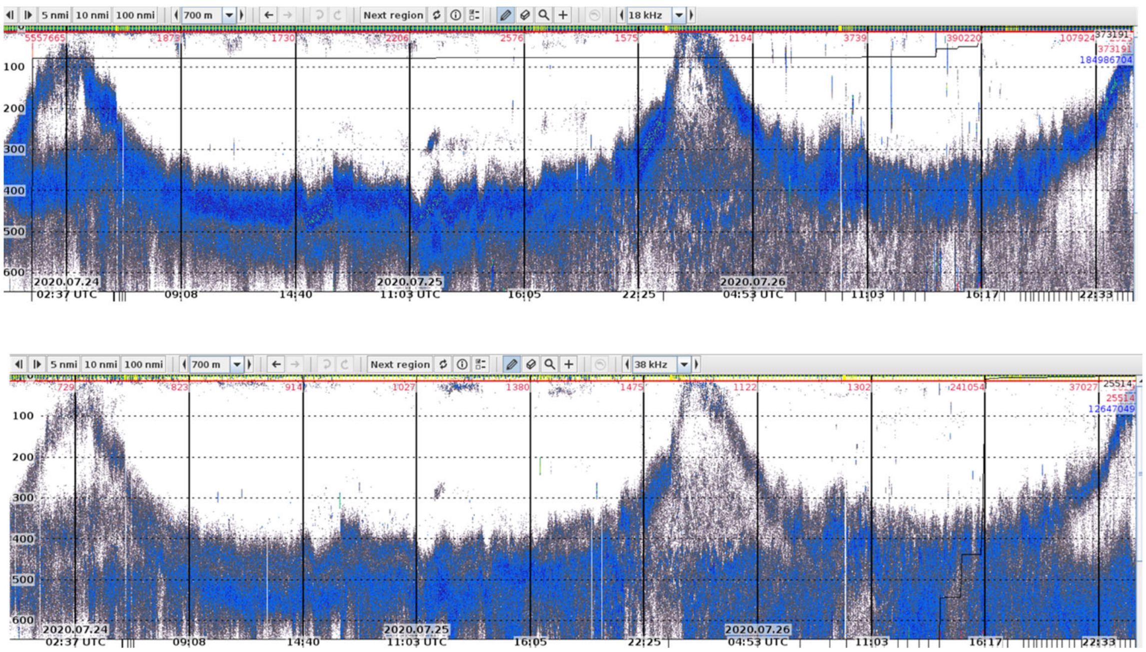

Figure 9. Example of two days of acoustic backscatter (18, upper panel, and 38kHz, lower panel) collected at a longitudinal transect along ~61°50'N running from the Irminger Sea and into the Iceland Basin (from Stn 437 to Stn 445, see Figure 1). The vertical axis indicates the depth range of the echogram (100 to 600 m), the horizontal axis indicates the sampling date from 24 to 26 of July 2020 and time (UTC) which corresponds to around 500 nmi performed by the RV (including the stations).

The abundance of mesopelagic fishes and crustaceans in the water column (0-750 m) is clear by their high proportion in total backscatter along the longitudinal transect along ~61°50'N (Figure 10).

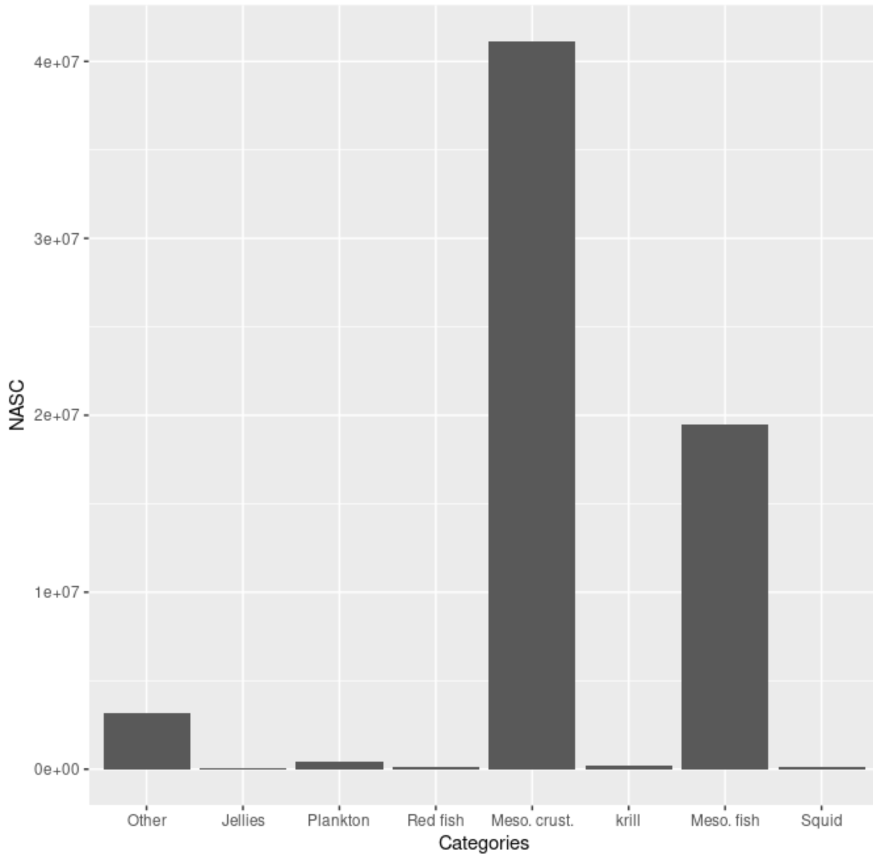

Figure 10. Total acoustic backscatter (S_A values m^2nmi^{-2}) at 38kHz for the categories scrutinized at a longitudinal transect along ~61°50'N from 38°49'W to 16°05'W running from the Irminger Sea and into the Iceland Basin (see location in Figure 1). Categories are Jellies, Red fish, Krill, Plankton, Squid, Mesopelagic fish and crustaceans (Meso.crust.), Mesopelagic fish (Meso.fish) and other organisms (Other).

Preliminary results from the submersible echosounder, from one of four MEESO stations, indicate that backscatter at 120 kHz was stronger in the uppermost mesopelagic layer (350 m) than in the lower mesopelagic layer (450 m) (Figure 11). Macrozooplankton and nekton tend to migrate to upper layers during the night to feed (e.g. Kaartvedt 2010), therefore this difference observed on the first station (taken at ~20 h, Table 1) could be an indication of the upward movement and concentration of organisms in the upper layers.

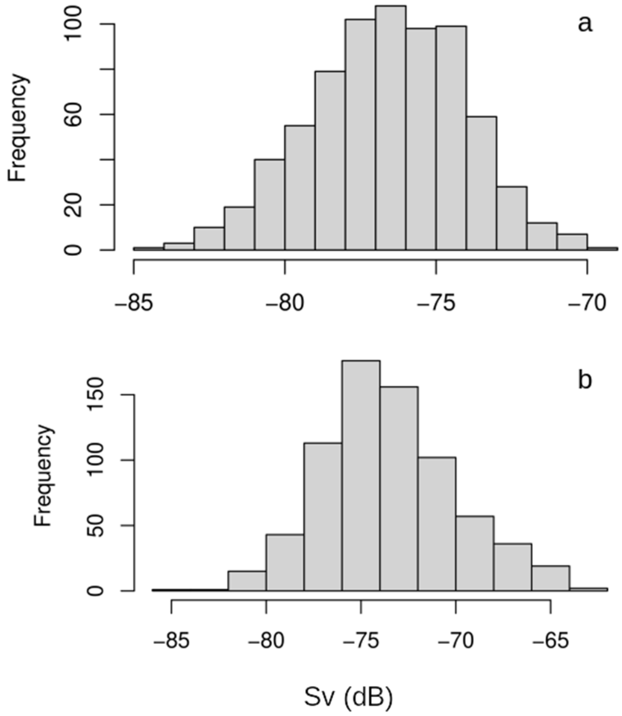

Figure 11. Distribution of acoustic backscatter (Sv(120kHz), dB) at Stn 438 detected by the submersible echosounder of the two mesopelagic layers observed, one at 350 m (a) and another at 450 m (b). Please note that the axes are not at the same scale. For location of station see Figure 1.

Data from the submersible echosounder will be used to provide high-resolution acoustics data of macrozooplankton and nekton target strength properties from specific deep acoustic layers observed by the hull-mounted acoustics (e.g. Figure 12).

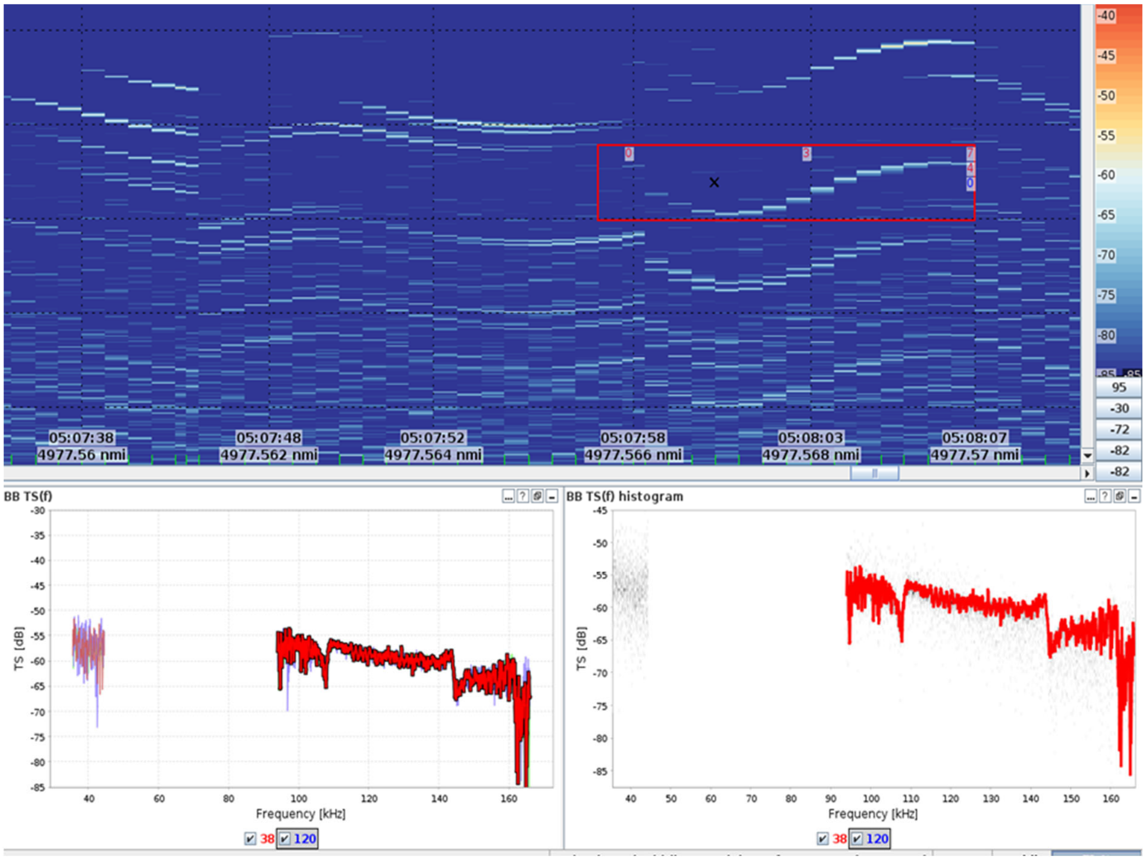

Figure 12. Target strength (TS) frequency spectra (lower left) and histogram (lower right) of a single mesopelagic target selected in the echogram (120 kHz, upper red rectangle).

3.4. Mesozooplankton

At a longitudinal transect along ~61°50’ N from 38°49’ W to 16°05’ W, zooplankton biomass in the uppermost 200 m was generally higher in the Irminger Sea (c. 7.5-10 g dw m^{-2}) than in the Iceland Basin (<5 g dw m^{-2}, Figure 13A). This is also indicated by WP2 samples that were taken in the surface layers (0-200 m) in a much larger area during the cruise (Olafsdottir and Kennedy 2020). It is evident that the zooplankton density (concentration) was generally higher in the 0-50 m layer than in the 50-200 m layer (Figure 13B).

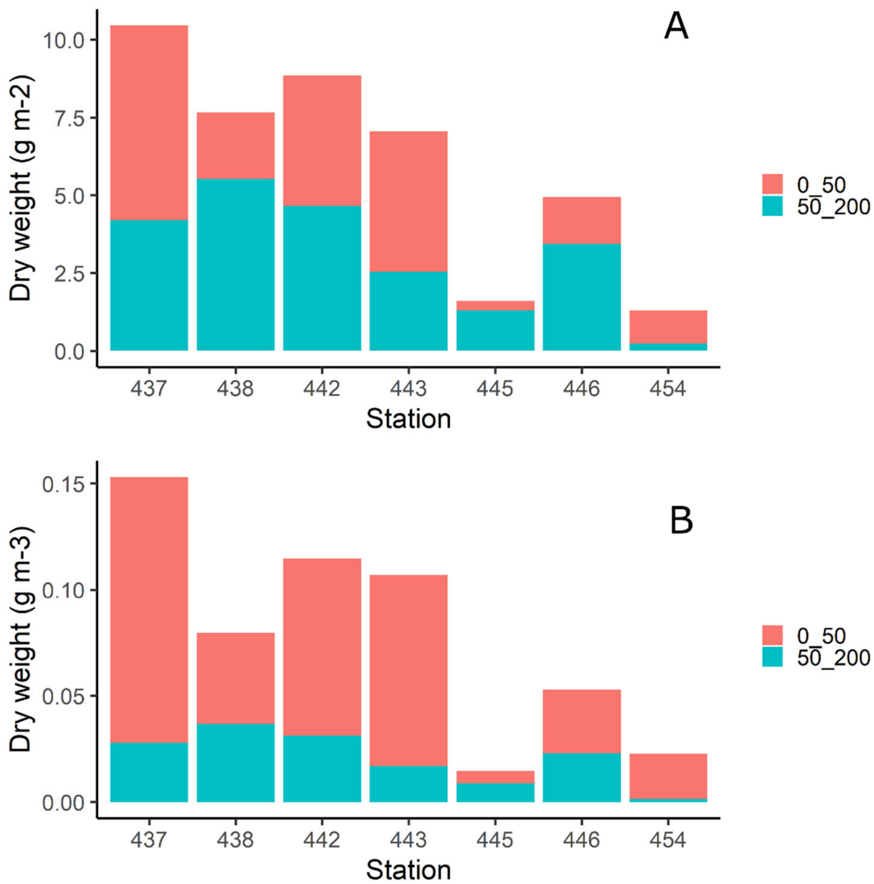

Figure 13. Mesozooplankton biomass (dry weight) standardised per m^{-2} (A) and m^{-3} (B) in two depth layers (0-50 m, 50-200 m) at a longitudinal transect along ~61°50' N from 38°49' W to 16°05' W. For location of stations refer to Figure 1. Note different scales of y-axes.

Preliminary analysis of the VPR data shows that copepods, mainly *Calanus finmarchicus*, were by far the most abundant animal group. At Stn 439 in the Irminger Sea, they were most abundant above a depth of 30 m, with very low numbers being observed below 50 m depth (Figure 14A). At Stn 456 in the Iceland basin, numbers were also highest above 30 m depth, while generally lower than in the Irminger Sea (Figure 14B). In the Iceland Basin, relatively high densities of *C. finmarchicus* were also observed relatively deep in the water column (below 200 m depth). This contrasts with what was observed in the Irminger Sea, where very few copepods were found so deep in the water column.

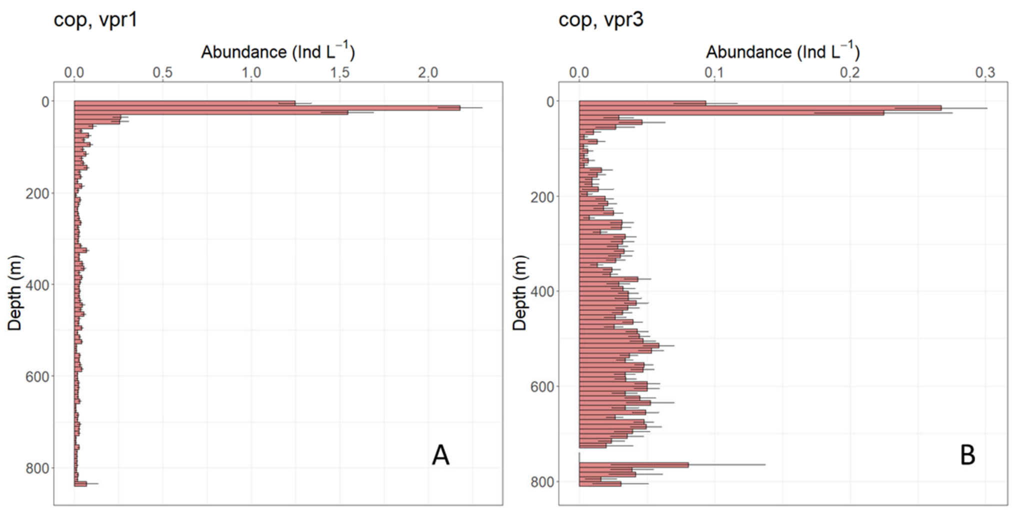

Figure 14. Mean abundance (number l^{-1}) of copepods (mainly *C. finmarchicus*) at Stn 439 in Irminger Sea (A) and Stn 456 in Iceland Basin (B) on 23 and 25 June 2020, respectively. The figure shows average values of two VPR two-yos binned by 10 m depth intervals. Error bars show standard error. For location of stations refer to Figure 1.

Example images of some zooplankters and particles are shown in Figure 15.

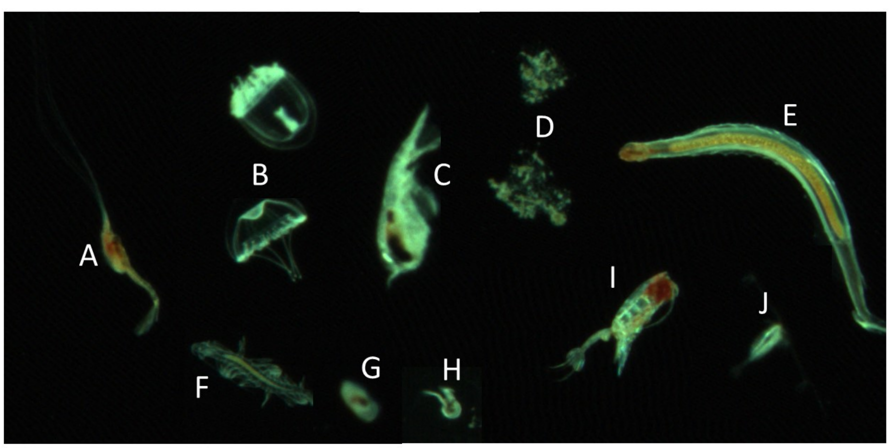

Figure 15. Example images taken by the VPR in the present study: Deep water shrimp (A), hydromedusae (B), amphipod (C), marine snow (D), chaetognath (E), *Tomopteris* (F), ostracod (G), pteropod (H), *Pareuchaeta norvegia* (I), *Calanus finmarchicus* (J). Note that the images are not in the same scale.

3.5. Macroplankton and nekton

3.5.1. General composition

Catch by the macrozooplankton trawl varied from approximately 5 to 49 kg nm^{-1} with an average of 20 kg nmi^{-1} (Table 2). On average, catches in the integrated tows were highest (30 kg nmi^{-1}). The catch in upper layer tow and lower layer tow were on average 12 and 20 kg nmi^{-1}, respectively. In general, jellyfish (mainly *Periphylla* sp. and *Atolla* sp.) made up more than a half of the catch in terms of weight, or on average 62% of integrated tows, and 57% and 51% of upper layer tow and lower layer tow, respectively (Table 2). Of other catch, approximately

130 species of animals were identified onboard, belonging to seven animal classes. Fish (approximately 50 species) and crustaceans (approximately 40 species of decapods, euphausiids and copepods) were the most numerous groups of animals in catch. Other animals, besides jellyfish, were cephalopods, wing snails, chaetognaths and salpa. A preliminary list of fish species identified onboard is found in Table A3 in the appendix. Several species still need a taxonomic identification.

Table 2. Tows with macroplankton trawl (refer to Table A2 for position). Date, Time of day (TOD), tow type, tow depth, total catch, proportion of jelly fish in catch (weight), preliminary number of fish species, mean size and range and preliminary number of crustacean species.

Station	Date	TOD	Tow type	Depth (m)	Total catch (kg/nmi)	Jelly fish (%)	Species fish (n)*	Mean size fish (cm)	Range size fish (cm)	Species crustaceans (n)*
A7-2020-439	24. July 2020	23:16	Intergrated	1000-0	49.3	63.45	16	13.6	2.3-74.0	7
A7-2020-440	24. july 2020	6:00	Target_upperlayer	325	9.1	69.51	10	5.0	2.1-26.0	4
A7-2020-441	24. july 2020	7:30	Target_lowerlayer	440	20.2	37.22	7	6.1	2.5-25.0	3
A7-2020-451	27. July 2020	11:30	Intergrated	1000-0	13.3	70.00	21	8.0	1.0-58.0	15
A7-2020-448	27. July 2020	6:49	Target_upperlayer	280	14.0	68.57	10	4.0	1.0-19.0	3
A7-2020-449	27. July 2020	8:02	Target_lowerlayer	570	20.0	53.00	23	6.8	2.4-38.0	16
A7-2020-456	28. July 2020	2:00	Intergrated	1000-0	24.3	48.11	21	15.1	2.8-102.0	19
A7-2020-458	28. July 2020	7:00	Target_upperlayer	260	5.2	38.46	13	6.5	2.5-45.0	4
A7-2020-459	28. July 2020	8:00	Target_lowerlayer	400	13.0	64.62	9	5.7	2.5-21.0	8
A7-2020-462	30. july 2020	2:00	Intergrated	1000-0	31.7	64.47	19	10.6	1.0-56.0	16
A7-2020-464	30. july 2020	6:00	Target_upperlayer	250	20.0	50.00	11	9.1	2.4-47.0	5
A7-2020-465	30. july 2020	7:00	Target_lowerlayer	470	25.0	48.00	13	9.6	2.5-82.0	9

**Preliminary results*

3.5.2. Fish

Preliminary results showed that number of fish species ranged from 7 to 23 species per tow. In general, highest catch of fish was obtained in the integrated tows. The most frequent species by number in all tows and areas was the lanternfish *Benthosema glaciale*. Main species (in weight) besides BGH were *Bathylagus euryops*, bristlemouths such as *Cyclothone, Serrivomer beani, Lampanyctus macdonaldi* and *Protomyctophum arcticum*. Relative proportion of species varied among tows and areas (Figure 16). *Benthosema glaciale* dominated the catch of tows taken near Reykjanes ridge. *Lampanyctus* and *Protomyctophum* were mainly caught in the Irminger Sea. *Lampanyctus* was caught only in an intergrated tow but *Protomyctophum* was frequent in all tows in that area. *Bathylagus* and *Serrivomer* were mainly caught in intergrated tows.

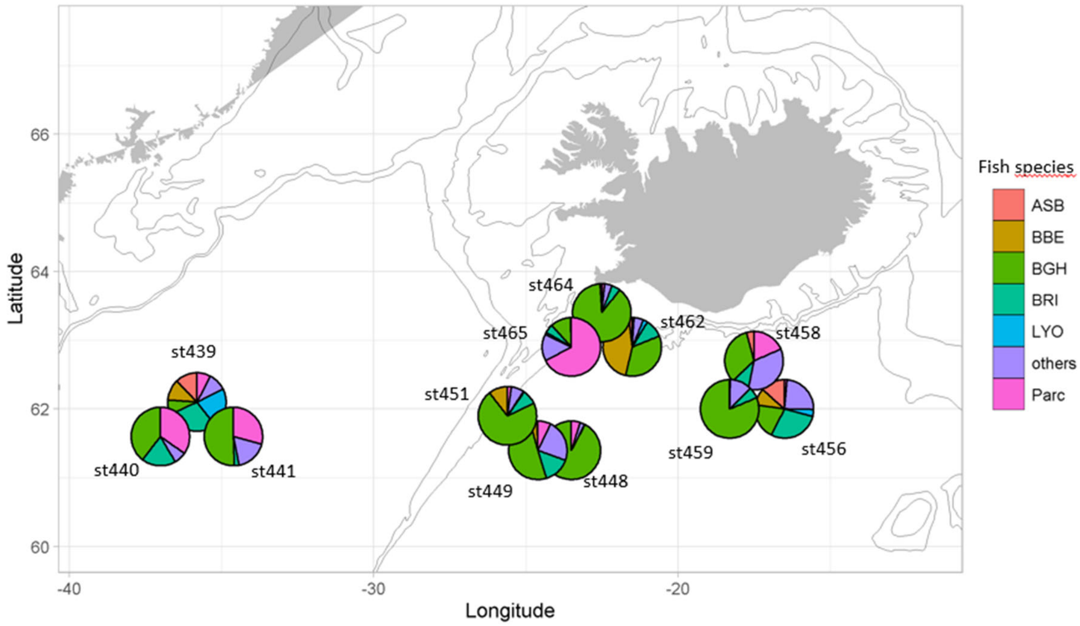

Figure 16. Map showing approximate location of trawl sampling stations for the MEESO project (see Figure 1 for exact position of tows). Note that adjacent pies were collected at the same position but at different depths. Pie chart shows proportion of most frequent fish species by number in each tow of the macrozooplankton trawl. Station numbers are shown (See Table 2 for information on tow type). BGH=*Benthosem*a, BBE=*Bathylagus*, BRI=Bristlemouths, ASB=*Serrivomer*, Parc=*Protomyctophum*, LYO=*Lampanyctus*.

Preliminary findings indicate that number of species and the size distribution of mesopelagic catches seem to depend on the type of trawl deployment. The average size of fish was higher in the integrated tows than the other two, mainly due to high proportion of large species such as *Serrivomer, Bathylagus* and *Lampanyctus* in these types of tows (Table A3 and Figure 17). Length-weight relations of five main species of fish are shown in Figure 18.

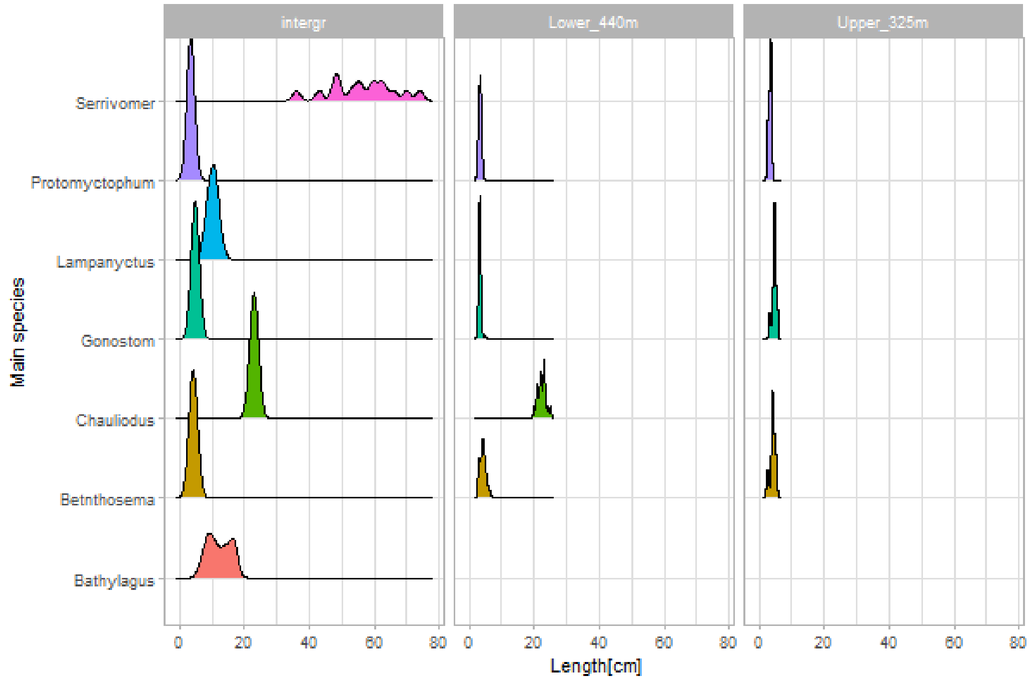

Figure 17. Length frequency distribution of main fish species caught by the macrozooplankton trawl at the first set of MEESO stations (Stns 439, 440 and 441). Three deployments were conducted, an integrated tow from 0-1000 m (Stn 439), one target layer at 440 m (Stn 441) and a second target layer at 325 m (Stn 440). The target tows were chosen based on the DSML found in the 18 and 38 kHz hull-mounted acoustics.

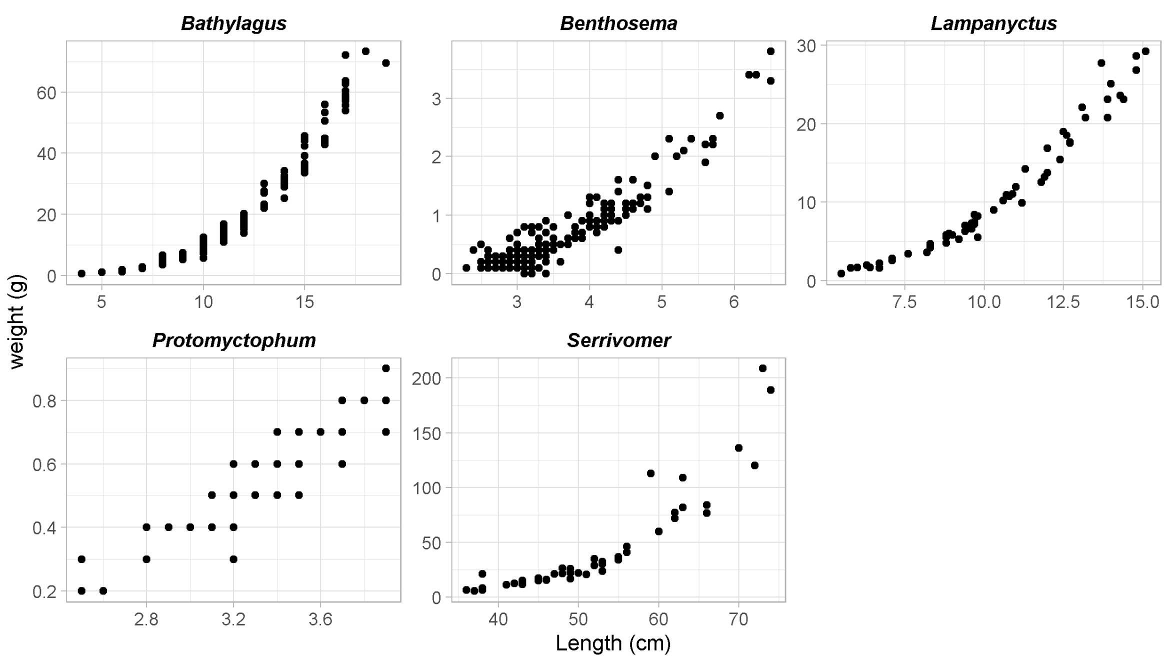

Figure 18. Total length-whole body weight relationships of the five most abundant fish species caught by the macrozooplankton trawl. All data combined.

4. Outreach

During the expedition, photos were taken of most of the organisms that were caught in the fishing gear (e.g. Figures 19-24). Pictures of individual species were taken in a studio that was set up on board. Photographs were also taken of people at work and of work processes. During the survey, photos were posted on the MFRI's Instagram account https://www.instagram.com/hafrannsoknastofnun/

In addition, video footages were taken of work processes with the aim of showing exactly how the work was done.

The photos have been made publicly available at the MEESO share point site (https://havforskningsinstituttet.sharepoint.com/sites/hi/Meeso). The video footage from the expedition will be posted on the MEESO project's website and on the MFRI's website.

Figure 19. Example of the catch from the Pelagic midwater trawl, macrozooplankton trawl. Image Svanhildur Egilsdóttir MFRI.

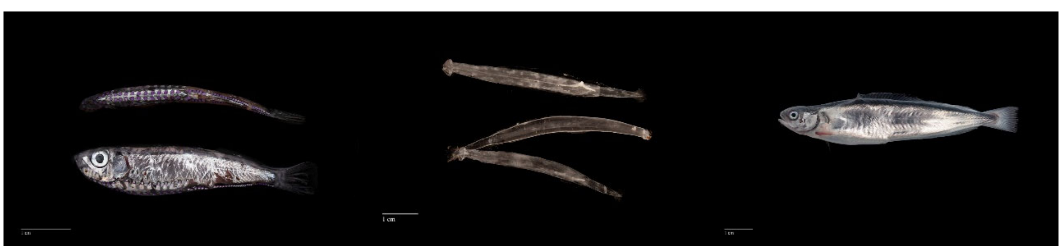

Figure 20. Pearlside (*Maurolicus muelleri*), arrow worms (*Eukrohnia hamata*) and Arctic rockling (*Gaidropsarus argentatus*). Image Svanhildur Egilsdóttir MFRI.

Figure 21. Two species of squids (*Teuthowenia megalops*) and (*Histioteuthis bonnellii*). Image Svanhildur Egilsdóttir MFRI.

Figure 22. Lightless loosejaw (*Malacosteus niger*) and Kroeyer´s lanternfish (*Notoscopelus kroyeri*). Image Svanhildur Egilsdóttir MFRI.

Figure 23. Fangtooth, ogrefish (*Anoplogaster cornuta*). Image Svanhildur Egilsdóttir MFRI.

Figure 24. Glacier lanternfish (*Benthosema glaciale*). Image Svanhildur Egilsdóttir MFRI.

5. Acknowledgements

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7. Appendices

Table A1. Scientific personnel and their roles during the latter part of the IESSNS survey (13-30 July 2020) when sampling was carried out for the MEESO project.

Name	Institute	Role
Anna Heiða Ólafsdóttir	MFRI	Cruise leader, acoustics
Arnþór B. Kristjánsson,	MFRI	Acoustics, technology
Ástþór Gíslason,	MFRI	VPR, biological samples
Birkir Bárðarson,	MFRI	Acoustics, Biol. samples
Enrique G.A. Garcia,	DTU Aqua	SUMMER project
Guðrún Finnbogadóttir	MFRI	Biol. samples
Halldór Tyrfingsson,	MFRI	VPR, Biologoical samples
Klara Jakobsdóttir,	MFRI	Biol. Samples
Martina Blumel,	GEOMAR	SUMMER project
Ragnhildur Ólafsdóttir,	MFRI	Biol. samples
Svanhildur Egilsdóttir	MFRI	Biological photographer
Teresa S.G. da Silva,	MFRI	Acoustics

Table A2. Stations and equipment used on the MEESO stations during cruise A7-2020. Station number for different equipment is given.

MEESO Stn	**Stn**	**Lat**	**Long**	**Date 2020**	**Bottom depth (m)**	**CTD**	**Water samp.**	**WBT-TUBE**	**WP2**	**Macropl. trawl**	**VPR**
MEESO-1	438	6135	3543	24.07	~2300	X	X	X	X		X
	439	6135	3543	24.07	~2300		X			X (0-1000m)	
	440	6140	3539	25.07	~2300					X (~300m)	
	441	6135	3536	25.07	~2300					X (~450m)	
MEESO-2	446	6155	2328	27.07	~1550	X	X		X		
	447	6155	2328	27.07	~1550			X			
	448	6153	2328	27.07	~1550					X (270-300m)	
	449	6153	2334	27.07	~1550					X (570-625m)	
	450	6153	2342	27.07	~1550						X
	451	6153	2354	27.07	~1550					X (0-1000m)	
MEESO-3	455	6145	1644	28.07	~2300	X	X		X		
	456	6144	1645	29.07	~2300					X (0-1000m)	
	457	6146	1652	29.07	~2300			X			
	458	6146	1553	29.07	~2300					X (~260m)	
	459	6146	1659	29.07	~2300					X (~400m)	
	460	6146	1714	29.07	~2300						X
MEESO-4	461	6257	2129	30.07	~1040	X	X		X		
	462	6257	2129	30.07	~1040					X (0-1000m)	
	463	6253	2131	30.07	~1040			X			
	464	6253	2129	30.07	~1040					X (250-280m)	
	465	6255	2129	30.07	~1040					X (470-520m)	
	466	6255	2129	30.07	~1040						X

Table A3. Preliminary list of fish species caught by the macroplankton trawl. The list is ordered alphabetically according to scientific name.

Scientific name	Icelandic name	English name
Ammodytidae	Síli	NA
Anoplogaster cornuta	Bjúgtanni	Fangtooth, ogrefish
Argyropelecus hemigymnus	Suðræni silfurfiskur	Short silver hatchetfish
Bathylagus euryops	Skjár / Blálax	Goitre blacksmelt
Bathylagus sp.	Dökkskjár	NA
Benthosema glaciale	Ísalaxsíld	Glacier lanternfish
Borostomias antarcticus	Broddatanni	Antarctic snaggletooth
Cetostoma regani	Glókollur	Pink flabby whalefish
Chauliodus sloani	Slóans-gelgja	Viperfish
Chiasmodon harteli	Svelgur	NA
Cyclothone microdon	Ægisstirnir	Veiled anglemouth
Eurypharynx pelecanoides	Gapaldur	Pelican eel, pelican gulper
Flagellostomias boureei	Faxaskeggur	Threadbearded dragonfish
Gaidropsarus argentatus	Rauða sævesla	Arctic rockling
Gonostomatidae	Stirnaætt	NA
Lampadena speculigera	Gljálaxasíld	Mirror lanternfish
Lampanyctus crocodilus	Fenrislaxsíld	Jewel lanternfish
Lampanyctus intricarius	Atlantslaxsíld	NA
Lampanyctus macdonaldi	Brúnalaxsíld	NA
Malacosteus niger	Kolbíldur	Lightless loosejaw
Mallotus villosus	Loðna	Capelin
Maurolicus muelleri	Gulldepla / Norræna gulldepla	Pearlside
Myctophum punctatum	Punktalaxsíld	Spotted lanternfish
Nemichthys scolopaceus	Álsnípa	Slender snipe eel
Neonesthes capensis	Svartmeiti	Shortnosed snaggletooth
Normichthys operosus	Sæangi	Multipore searsid
Notoscopelus kroeyeri	Langalaxsíld	Kroeyer´s lanternfish
Oneirodidae	Hyrna ógr.	NA
Polyipnus polli	Orðufiskur	Poll´s hatchetfish
Poromitra megalops	Blaðhaus	Largeeyed rhinofish
Protomyctophum arcticum	Íshafslaxsíld	NA
Rhadinesthes decimus	Skeggmeiti	NA
Rouleina attrita	Mjúkhaus	Softskin smoothhead
Sagamichthys schnakenbecki	Ránarangi	Schnakenbeck´s searsid
Scopelogadus beanii	Kistufiskur	Squarenose helmetfish
Scopelosaurus lepidus	Uggi	NA
Sebastes mentella	Djúpkarfi	Deepwater redfish
Sebastes sp.	Karfi ógreindur	NA
Serrivomer beanii	Trjónuáll	Beans´s sawtoothed eel
Stomias boa ferox	Marsnákur	Boa dragonfish
Xenodermichthys copei	Bersnati	Bluntsnout smoothhead

HAFRANNSÓKNASTOFNUN

Rannsókna- og ráðgjafarstofnun hafs og vatna