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Results of the Icelandic part of the International Ecosystem Summer Survey in Nordic Seas (IESSNS) in 2020 on R/V Árni Friðriksson

Anna Heiða Ólafsdóttir og James Kennedy

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Ágrip

Hafrannsóknastofnun hefur frá árinu 2010 tekið þátt í alþjóðlegum uppsjávarleiðangri í norðaustur Atlantshafi. Markmið leiðangursins er vistkerfisvöktun að sumarlagi, frá yfirborði sjávar niður á 500 m dýpi. Fellst m.a. í því mælingar á styrk næringarefna, hitastigi, seltu, magni og útbreiðsla átu, markríls, kolmunna, síldar og hrognkelsa. Sumarið 2020 fór íslenski hluti leiðangursins fram dagana 1.-30. júlí á rannsóknaskipinu Árna Friðrikssyni. Rannsóknasvæðið var íslenska landgrunnið norðan, norðaustan og sunnan við landið auk Íslandsdjúps og suðurhluta Irmingerhafs. Alls voru sigldar 5596 sjómílur og athuganir gerðar á 181 hefðbundnum mælistöðvum sem og 112 stöðvum fyrir önnur rannsóknaverkefni. Makríll veiddist í 24% af stöðluðum yfirborðstogum á landgrunninu fyrir sunnan landið og fyrir austan í Noregshafi. Mun minna mældist af makríl sunnan við landið en undanfarin áratug. Hitastig í yfirborðslagi sjávar var á bilinu 2,1 – 12,1 °C. Yfirborðshitastig var yfir 9°C á öllu leiðangurssvæðinu fyrir sunnan Ísland og í Irmingerhafi en það hitastig er nægjanlega hátt fyrir makríl en einungis mældist makríll á litlum hluta af þessu svæði. Magn átu (þurrvigt) var á bilinu 1,3 – 19,4 g*m^{-2}. Takmarkað magn markríls við Ísland er ekki hægt að útskýra sem bein áhrif af of lágum sjávarhita eða vöntun á æti. Síld mældist fyrir sunnan, norðan og norðaustan landið líkt og verið hefur undanfarin ár. Kolmunni mældist einungis á litlu svæði fyrir austan landið sem er mun minna en undanfarin ár og var áberandi að enginn kolmunni mældist við landgrunnsbrúnina fyrir sunnan land.

Abstract

The Marine and Freshwater Research Institute has participated in the International Ecosystem Summer Survey in Nordic Seas (IESSNS) every summer since 2010. The aim is to monitor the pelagic ecosystem including measurements of nutrients, temperature, salinity, mesozooplankton, abundance and geographical distribution of mackerel (Scomber

*scombrus), blue whiting (Micromesistius poutassou), herring (Clupea harengus) and lumpfish (Cyclopterus lumpus). In 2020, the Icelandic part of IESSNS was conducted from July 1st to 30th on R/V Árni Friðriksson in Icelandic and Greenlandic exclusive economic zones, and in international waters. Survey track was 5596 nautical miles and a total of 181 stations were sampled for the survey and 112 stations for various other research projects. Mackerel was caught at 24 % of predetermined surface trawl stations and the highest density was in inshore waters southeast of Iceland. No mackerel was caught north and northeast of Iceland. Temperature of the surface mixed layer, ranged from 2.1 °C to 12.1 °C. Areas with temperatures suitable for mackerel (> 9 °C) were found south of Iceland, both inshore and offshore, and in the southern Irminger Sea, however mackerel was only present in a small part of the area. Mesozooplankton dry weight ranged from 1.3 g*m^{-2} to 19.4 g*m^{-2}. Direct effects of temperature and mesozooplankton availability cannot explain low abundance of mackerel. Herring was present in shelf areas south of Iceland, and both in shelf areas and offshore in areas north and northeast of Iceland. This is similar distribution pattern compared to previous years. Blue whiting was only present in a small area east of Iceland which is a decline in distribution compared to previous years when blue whiting has been distributed along the shelf edge south of Iceland.*

Lykilorð: *Mackerel, blue whiting, herring, lump fish, stock index, geographical distribution, zooplankton, temperature, ecosystem summer survey, SUMMER*

Undirskrift verkefnisstjóra:	**Undirskrift forstöðumanns sviðs:**
	

pTable of content

List of Tables

List of Figures

List of Annex

1. Introduction

This report documents the results of the Icelandic part of the International Ecosystem Summer Survey in Nordic Seas (IESSNS), which is governed by the ICES Working Group of International Pelagic Surveys (WGIPS). In total, six vessels from five nations participated in IESSNS 2020. Survey results from all vessels are presented in a joint cruise report, see ICES (2020). The main objectives of IESSNS are to explore: (1) through standardized surface trawling and acoustical measurements, the distribution and quantity of the Northeast Atlantic mackerel (*Scomber scombrus*), Norwegian spring-spawning herring (NSSH; *Clupea harengus*), blue whiting (*Micromesistius poutassou*) and other pelagic fish stocks; and (2) hydrographical- and mesozooplankton communities' conditions.

IESSNS is an ecosystem survey which samples data for various long-term data series ranging from annual monitoring of oceanographic conditions in the pelagic zone to providing stock index used for assessment purposes. The survey standard sampling protocol includes surface trawling at predetermined positions which provides age-segregated abundance index for mackerel that is used as a tuning series in annual stock assessment within ICES Working Group on Widely Distributed Stocks (WGWIDE). Acoustical data provide information about distribution and quantity of herring and blue whiting during their summer feeding season. The aim is to include the age-segregated indices in stock assessment as the time-series matures. Hydrographical and zooplankton measurements are an integrated part of long-term monitoring of the pelagic ecosystem during summer in the Northeast Atlantic. Finally, opportunistic registrations of whale observations by crew and scientific staff are collected.

This survey is conducted annually and commenced in 2007 by two vessels from Institute of Marine Research (IMR) (Norway). In 2010, the Marine and Freshwater Research Institute (MFRI) (Iceland), and the Faroe Marine Research Institute joined (Faroe Islands). Greenland Institute of Natural Resources (Greenland) joined in 2013 and Technical University of Denmark (Denmark) in 2018. The survey was originally limited to the Norwegian Sea but as the summer distribution of mackerel expanded and more nations joined, geographical coverage increased. As the summer distribution of mackerel expanded westward and northward from their traditional feeding grounds in the Norwegian Sea (Astthorsson et al., 2012, Olafsdottir et al., 2018, Utne et al., 2012) the survey expanded to the west coast of Iceland in 2010, to the east coast of Greenland and south to Cape Farewell in 2014. In order to increase the coverage of the juvenile portion of the stock, the survey expanded into the North Sea in 2018. In recent years, the survey coverage has been approximately 3 million km^2 of the Northeast Atlantic. The spatial coverage of the survey, up until 2015, was mainly determined by the mackerel distribution, but also to some degree by the distribution of NSSH. Thus, the survey is considered to have mostly covered the range in distribution of mackerel and NSSH during their summer feeding migration in Nordic Seas from 2010 onward. Since 2016 the objective of the surveys has included covering the range in distribution of blue whiting, which involved a slight expansion of the survey to the south of Iceland to latitude 60 °N. It also included dedicated trawling on acoustic registrations at depths greater than the predetermined surface trawl stations.

2. Materials and methods

2.1 Survey description

Atlantic mackerel (*Scomber scombrus*). Image Svanhildur Egilsdóttir MFRI.

The survey area covered by R/V Árni Friðriksson in July 2020 included five of thirteen IESSNS strata (Figure 1; Table 1). Survey planning includes determining location of swept area surface trawl stations and location of survey transects for acoustic measurements. The survey employs a stratified systematic transect design, with random starting point within each stratum, and a distance that is the same between all predetermined surface trawl stations and between all transects within each stratum. The distance is based upon mackerel distribution and abundance in previous years, and available survey time. During survey planning, location of the first transect is selected randomly and then other transects are placed at predefined intervals. Similarly, the first station is selected randomly, and the other stations located at the predetermined distance from adjacent station along the transect. On the adjoining transect, the stations were set in the middle between the stations on the first transect. Survey transects were east-to-west in all strata but two, north of Iceland and inshore south of Iceland where transects were from north-to-south (Figure 1). This difference in transect direction is to ensure proper acoustic data sampling of pelagic species across the shelf edge. For detailed survey description see ICES (2015).

At predetermined surface trawl stations, a standardized Multpelt832 trawl with a fish lock, specifically designed for the IESSNS, is employed according to a standardized IESSNS protocol (ICES, 2015). It is towed for 30 minutes at a speed of 5 knots while turning the vessel 5°, creating a “banana” shaped tow track. Further details can be found in ICES (2015). During surface trawling, scientific personnel and the captain or first mate monitored live effective trawl width (door spread), horizontal opening of trawl, and presence of the trawl headline on the surface using Scanmar trawl sensors located on both trawl doors, and the trawl ground rope and headrope (Table 2). In addition, Starmon DT depth and temperature loggers from Star Oddi (https://www.star-oddi.com) were attached to the trawl at the same locations as the trawl sensors which provided high resolution depth information (recorded every 10 seconds) with a precision of ~1 m (https://www.star-oddi.com/products/data-loggers/time-depth-recorder-tdr-starmon).

In 2018, the strata boundaries south and west of Iceland were changed to better reflect areas with similar mackerel densities as observed in previous years. The same boundaries were used in the 2019 and 2020 surveys. Survey coverage was similar in 2020 compared to 2019, however the survey area was partly changed as in 2020 the Icelandic vessel surveyed the southern part of the Irminger Sea (stratum 11) while the Greenland vessel surveyed the waters west of Iceland (stratum 5). MFRI kindly asked the Greenland Institute of Natural Resources to trade survey areas as MFRI had a special research project (MEESO) which needed sampling in the Irminger Sea.

R/V Árni Friðriksson hauling in the Multpelt832 pelagic trawl. Image Svanhildur Egilsdóttir MFRI.

R/V Árni Friðriksson departed from Reykjavik at 9 am on July 1st and headed to the area north of Iceland (stratum 4) where the first station was taken. The survey then continued clockwise around the island. On July 13, there was a crew change in Vestmannaeyjar. Crew list is in Appendix 1. From Vestmannaeyjar, the vessel headed southwards to stratum south offshore and continued from there westward. The vessel arrived in Reykjavik at 6 pm on July 30th. The total distance covered during these 30 days was 5596 nautical miles with 181 stations sampled (Table 3). The survey successfully sampled 58 of 60 predetermined trawl stations, located in five strata, and most of the predetermined acoustic survey track. Seven deep trawls were sampled to ground-truth acoustic backscatter and for the MEESO projects 23 stations were sampled. No drift ice was encountered in the survey areas which has been a problem north of Iceland in previous years. The weather was exceptionally rough, stormy conditions hampered plankton sampling and demanded reduced sailing speed for acoustic recordings for a total of 6 days.

Additionally, to the standard IESSNS survey protocol, samples were collected for sixteen research projects, internal MFRI projects, for two international projects in which MFRI participates, SUMMER (funded by the European Commission (Project number 817806) and MEESO (funded by the European Commission (Project number 817669), and for one international project, COLDFISH (https://www.changing-arctic-ocean.ac.uk/project/coldfish/) of which MFRI is not an active participant. The research projects comprised of the following, whether this was an internal, or externally funded project is indicated in brackets:

- tagging of live lumpfish (MFRI),
- opportunistic registrations of whale observations (MFRI),
- whole frozen mackerel and blue whiting for analysis of the presence of microplastic within the stomach (MFRI),
- measure somatic condition of mackerel, blue whiting and herring at selected stations (MFRI),
- sample hearts from Icelandic summer spawning herring to monitor parasite infection rate (MFRI),
- more detailed measurements, and collection, of squid and octopuses (MFRI),
- collection of water samples for environmental DNA (eDNA) research (SUMMER),
- collection of mesopelagic fish and invertebrates at IESSNS stations (SUMMER),
- collection of microbes from guts of mesopelagic fish and invertebrates (SUMMER – visiting scientist),
- collection of mesozooplankton and mesopelagic fish and invertebrates for storage in liquid nitrogen (SUMMER – visiting scientist),
- collection of acoustic data using a Simrad EK80 wide band transceiver tube, frequency 38 kHz and 120 kHz (MEESO),

- collection of microzooplankton samples using a microzooplankton trawl (MEESO),
- stratified sampling of mesozooplankton at five depths using a multisampler (MEESO),
- video recording of plankton from surface to 1000m depth using a vertical plankton recorder (MEESO),
- professional photographs and video recordings of fish, invertebrates, and scientific work on board (MEESO),
- collection of polar cod for The Alfred Wagner Institute in Germany (COLDFISH),
- the survey posted about science and life onboard on MFRI Instagram account (#hafrannsoknastofnun)

Results from all sampling conducted for the MEESO project will be published in a separate report from the current one. Sampling by SUMMER visiting scientists is not presented in the current report. In total 112 samples were collected for the various research projects additional to the survey standard operation.

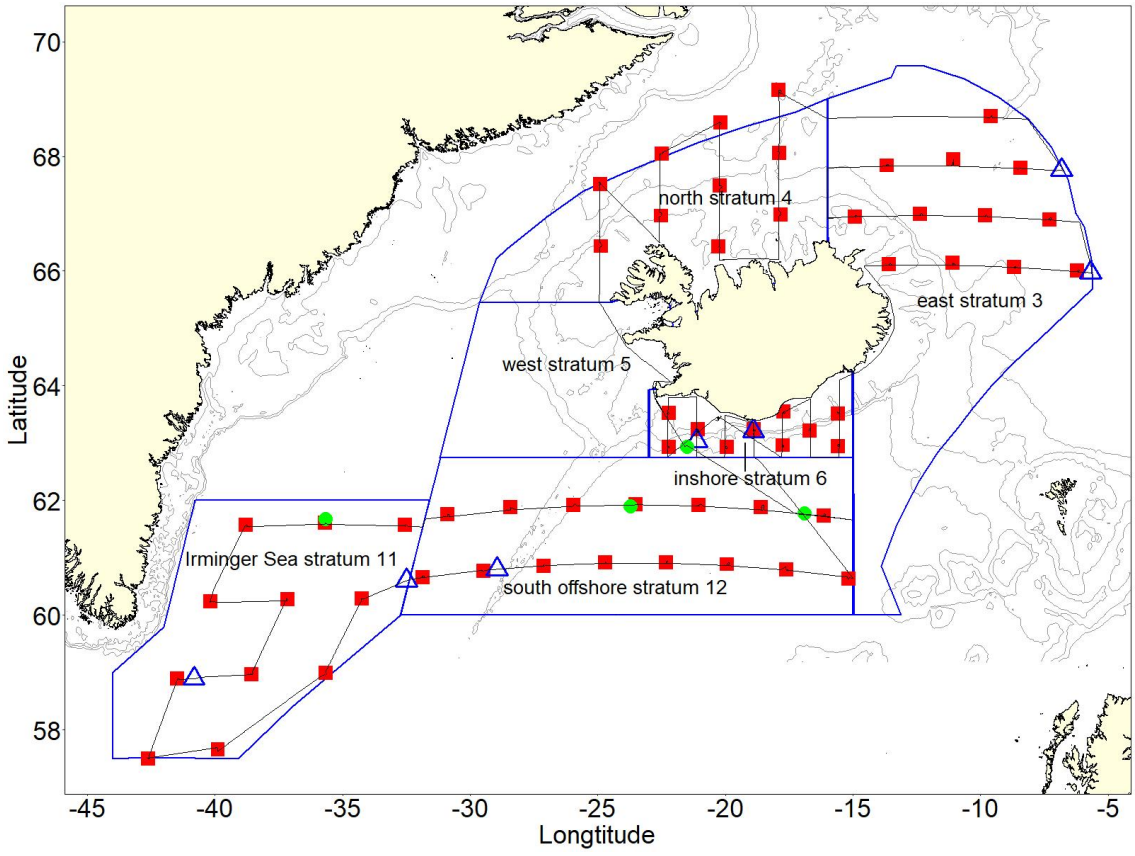

Figure 1. The Icelandic participation in IESSNS 2020. Predetermined surface trawl stations, including CTD and WP2-net (filled red rectangle), deep trawling on acoustic registrations (open blue triangle), and sampling sites for the MEESO project (green filled circles) as sampled by R/V Árni Friðriksson in July 2020. Also displayed is the survey track (black line), strata boundaries (blue line), and depth contours at 200m, 500m and 1000m (grey lines).

2.2 Acoustic and trawl sampling

Klara Björg Jakobsdóttir (right) and Anna H. Ólafsdóttir (left) in the acoustic room of R/V Árni Friðriksson. Image Svanhildur Egilsdóttir MFRI.

Acoustic scatters were recorded continuously using a Simrad EK80 echosounder on four frequencies (18-38-70-200kHz). Sampling depth was limited to 500 m in strata north and east of Iceland and was 750 m in the south and Irminger Sea strata. Data collected at 38 kHz were post-processed using the LSSS software (version 2.3) with a plankton sieve threshold of -72dB. Backscatter was identified to categories: herring or blue whiting and was then stored in respective categories as 1 nautical mile and 10 m vertical depth s_A averages. Acoustic instruments and settings on R/V Árni Friðriksson are described in detail in the IESSNS post cruise report (ICES, 2020). Dedicated trawl sampling on potential blue whiting acoustic registrations was executed at 7 stations. Trawl catch composition was used for species identification of acoustic registrations and for providing length distributions of fish targets. The echosounder was calibrated in May 2020.

The main trawl sampling was in the surface (0 – 35 m depth) using a standardized Multpelt832 pelagic trawl at predefined locations. The vertical opening of the trawl was around 35 m, which denotes the depth of the footrope. The specifications of the Multpelt832 trawl settings and performance are given in in the IESSNS post cruise report (ICES, 2020). A total of 58 standardized surface hauls were conducted. At two stations surface trawling was not executed, in cold waters northeast of Iceland, due to high winds. All tows were considered of appropriate quality, and thereby applicable for abundance estimation, both with respect to the trawl settings and to trawl operation.

2.3 Sampling of hydrographic and plankton data

Hydrographic probe put in the water by Bárður Birkisson (left) and Þorsteinn Búi Harðarson (right). Image Svanhildur Egilsdóttir MFRI.

Hydrographic and plankton data was collected at the predetermined surface trawl stations, except for 11 stations where plankton was not sampled due to high winds. Sea temperature, salinity and fluorescence were measured from the surface to 500 m depth or bottom, which ever came first, using a SeaBird CTD. Water samples were collected at four depths: at 0 m, 20 m, and 50 m for calibrating chlorophyll measurements and to measure nutrient concentrations of phosphate, silicate, nitrate and nitrite, and at 500m, for calibrating salinity measurements. A total of 66 CTD stations were taken, including four stations specifically to sample eDNA for the SUMMER project and two stations specifically for the MESSO project.

A WP-2 net (60-cm diameter; mesh size 200 µm; with a flowmeter) was used to measure mesozooplankton density. Three vertical hauls were made at each station, *i.e.* two from 50 m and one

from 200 m, to the surface. Samples from 200 m and one from 50 m were size fractionated with a 1000 µm sieve and frozen on board in small aluminium containers for measuring dry-weight in the laboratory on-shore. The second 50 m sample was preserved in formaldehyde for quantitative species identification after the survey (not presented here). A total of 55 WP-2 stations were sampled, including four stations specifically to sample eDNA for the SUMMER project and two stations specifically for the MESSO project.

As in previous years, continuous recording of sea surface temperature and salinity, and light intensity were conducted throughout the survey. Furthermore, a water sample was collected from the continuous recording system at noon every day and filtered to measure chlorophyll content.

2.4 Sampling for various research projects

2.4.1 Collection of stomach samples

Stomach samples from mackerel and herring were collected from the first 10 individuals, of both species, at every third station. Stomach samples from the first 10 individuals of blue whiting were collected at every station in which they were caught. During the survey, a total of 43 mackerel, 98 herring, and 20 blue whiting stomachs were sampled at 16 trawl stations (Table 3). The stomach samples were frozen on board and will be analysed later at the MFRI laboratory, thus no results from these analyses are presented in the current report. Sampling of stomachs is a part MFRI monitoring of the pelagic ecosystem during the summer feeding season.

2.4.2 Determination on somatic condition of target pelagic fish species

Guðrún Finnbogadóttir (front) and Klara Björg Jakobsdóttir (back) measure somatic condition of herring. Image Svanhildur Egilsdóttir MFRI.

Somatic condition of mackerel, herring and blue whiting were determined for the second time during the survey. The determinations were made on the same specimen that stomach samples were collected from. The goal of this research is to monitor condition of major pelagic species during peak of their annual feeding migration. For mackerel and herring, somatic condition was estimated by measuring lipid content using fish fatmeter (model FFM-992) from Distell (Old Levenseat, Fauldhouse, West Lothian EH47 9AD, Scotland, UK, distell.com). Each specimen was measured four times while still intact as per fatmeter instructions which was to measure above and below the lateral line on both sides. For blue whiting, their liver was weighted to the nearest 0.1 g, and represented the somatic condition.

2.4.3 Environmental DNA (eDNA)

Environmental DNA (eDNA) samples were collected at 4 opportunistic deep trawl stations. At each eDNA station, 5 litres of seawater were filtered from four different depths: 0m, 50m, 200m, and 500m,

using a Sterivex filter. The sampling was for the international research project SUMMER (funded by the European Commission (Project number 817806) which Christophe Pampoulie and Anna Ólafsdóttir at MFRI are participants. The samples will be analysed later in a laboratory on land and the results are not presented in the current report. This was the third year that eDNA was sampled during the survey.

2.4.4 Tagging of live lumpfish

To gain information on growth, migration and population origin of the lumpfish caught during the survey, all lumpfish caught alive and longer than approximately 15 cm were tagged, with a plastic tag in the dorsal hump and released. Maximum number to be tagged per station was set at 30 individuals. Tagging was done as part of the Lumpfish research project coordinated by James Kennedy at MFRI. The tagging was first done in 2018 and the goal is to continue the project in the future.

2.4.5 Sampling of the mesopelagic layer

At all trawling stations, mesopelagic fish and invertebrates were sorted to the lowest taxonomic rank possible, length measured, weighted and frozen. This was the third year of sampling for the international research project SUMMER. The samples will be analysed in a laboratory ashore later and the results are not published in the current report. Two collaborators from the SUMMER project from DTU Aqua, Denmark, and GEOMAR, Germany, joined the 2nd leg of the survey for specialized sampling of mesopelagic organism.

Teresa Sofia Giesta da Silva sorting mesopelagic catch to species (left), mesopelagic catch sorted to species (middle), and Guðrún Finnbogadóttir prepares mesopelagic fish for freezing (right). Image Svanhildur Egilsdóttir MFRI.

2.4.6 Mackerel and blue whiting samples for microplastic analysis of stomachs

In recent years, microplastic pollution in the world's oceans has become of increasing concern. During the 2019 IESSNS, we initiated research on microplastic in prey of pelagic fish by sampling ten specimen of mackerel and blue whiting in two different water masses, the cold east Iceland current (see Figure 1, stratum 3 east) and the warm North Atlantic current (see Figure 1, stratum 6 south inshore), for microplastic research of stomach content. Sampling was repeated in 2020 in similar areas with sample size increased to 20 specimens per sample. In 2020, we did not catch any blue whiting in the warm North Atlantic current. The samples are being analysed by Anni Malinen, a master student in Resource Management, Coastal and Marine Management, at the University Centre of the Westfjords, for her thesis. Results of the microplastic research will be published in Anni´s thesis due in spring 2021.

2.4.7 Opportunistic marine mammal observations

A dedicated whale observer was aboard during the first leg of the survey with a total of 20 hours of dedicated whale observing activity during the period July 1st-13th, 2020. Furthermore, for the third time during IESSNS on R/V Árni Friðriksson, opportunistic observations of marine mammals were conducted by bridge staff for duration of the survey. Information on species, number of individuals, activity, location and date were recorded. Data were collected with the intention of merging the observation effort to that of the Norwegians vessels participating in the IESSNS.

2.4.8 Parasite infection in Icelandic summer spawning herring

It is standard procedure on pelagic surveys conducted by MFRI to collect hearts of Icelandic summer-spawning herring in order to monitor parasite infection rates of the stock. Icelandic summer-spawning herring were caught at ten trawl stations and 50 hearts frozen at each station where specimens where caught. The samples will be analysed in MFRI laboratory later and the results are not published in the current report. Project coordinator is Lísa Anne Libungan at MFRI.

2.4.9 Sampling of polar cod

All available polar cod specimen were frozen whole, after measurements, for an English-German research project called COLDFISH (www.changing-arctic-ocean.ac.uk/project/coldfish/). In total, 129 specimens were frozen, sampled at nine stations, number of specimens frozen per station ranged from 1 to 50. Samples were shipped to Dr. Hauke Flores at the Alfred Wegener institute in Germany. No results are published in the current report.

3. Results and Discussion

The survey total trawl catch amounted to 45.6 tonnes and included 42 taxon groups of which 36 were identified to species level (Table 4). This includes catches from trawling with Multpelt832 but excludes macrozooplankton trawl catch. Herring made up the highest proportion (90%) of the total catch by weight while 8% was mackerel, 1% was lumpfish, 0.1% was blue whiting, 0.5% was invertebrates, and 0.4% were other fish species. 99% of catch was caught during surface trawling (n = 58) and 1% during deep trawling (n = 7). A comparison between 2019 and 2020 is not possible due to changes in survey area between these years.

3.1 Mackerel

Mackerel was caught at 14 of 58 (24%) predetermined surface trawl stations (Figure 2). Total weight of mackerel catch was 3466 kg, catch per station ranged from < 1 kg to 2412 kg, with a median of 10 kg and average of 248 kg. There was a large decline in mackerel abundance in Icelandic waters in 2020 compared to 2019. The shelf west of Iceland was covered by the Greenland vessel and they only caught a few kg of mackerel in the area (ICES, 2020). The limited mackerel caught was on the shelf and the shelf edge south and southeast of Iceland which is the same area mackerel was first recorded during their distribution expansion into Icelandic waters in mid-2000s (Astthorsson *et al.*, 2012). No mackerel abundance estimate from predetermined surface trawl catches are presented here and readers are referred to the 2020 IESSNS post cruise report (ICES, 2020).

Historical data have shown that sea surface temperatures of >7°C are needed to support low densities of mackerel, while temperatures >9°C are needed to support high densities (Olafsdottir et al., 2018). Temperature in the surface mixed layer north of Iceland was >9°C on the shelf and offshore areas south and west of Iceland and in the Irminger Sea, yet mackerel was absent from these areas. Hence the lack of mackerel in these areas cannot be explained by directs effects of sea temperature. In addition, the density of major prey (Óskarsson et al., 2012) does not explain the observed mackerel distribution as mesozooplankton was present in low to high densities in geographical areas with no mackerel present.

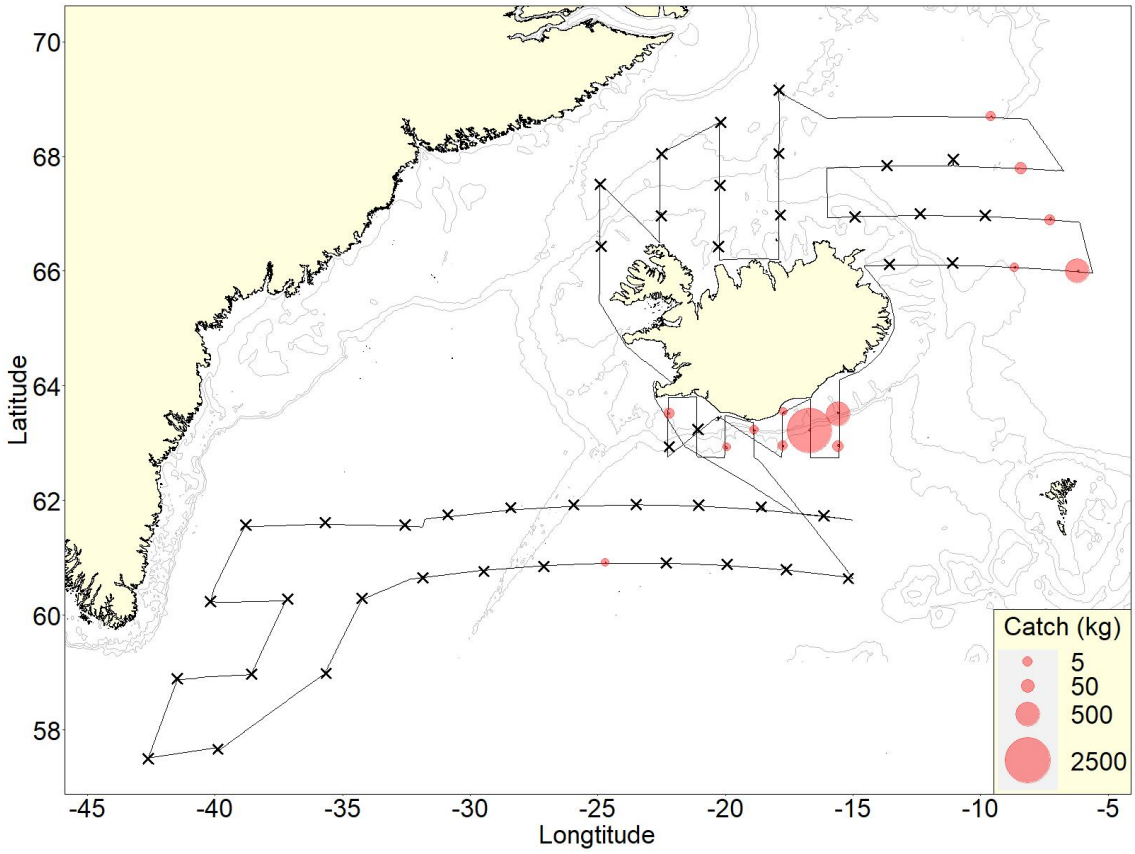

Figure 2. Mackerel (*Scomber scombrus*) catch at predetermined surface stations sampled by R/V Árni Friðriksson in July 2020. Black crosses represent zero catch. The survey track (black line) and depth contours at 200, 500 and 1000 m are also shown (grey lines).

Mackerel length distribution ranged from 34 – 43 cm with an average of 38.9 cm and median of 38 cm (Figure 3 top left). There was a size difference between strata with greater proportion of smaller mackerel inshore south of Iceland (stratum 6) compared to waters east of Iceland (stratum 3). Weight-at-length was also similar between strata (Figure 3 bottom left). Mackerel ranged in age from three to fourteen years. Length-at-age and weight-at-age was similar between strata (Figure 3 top right and bottom right).

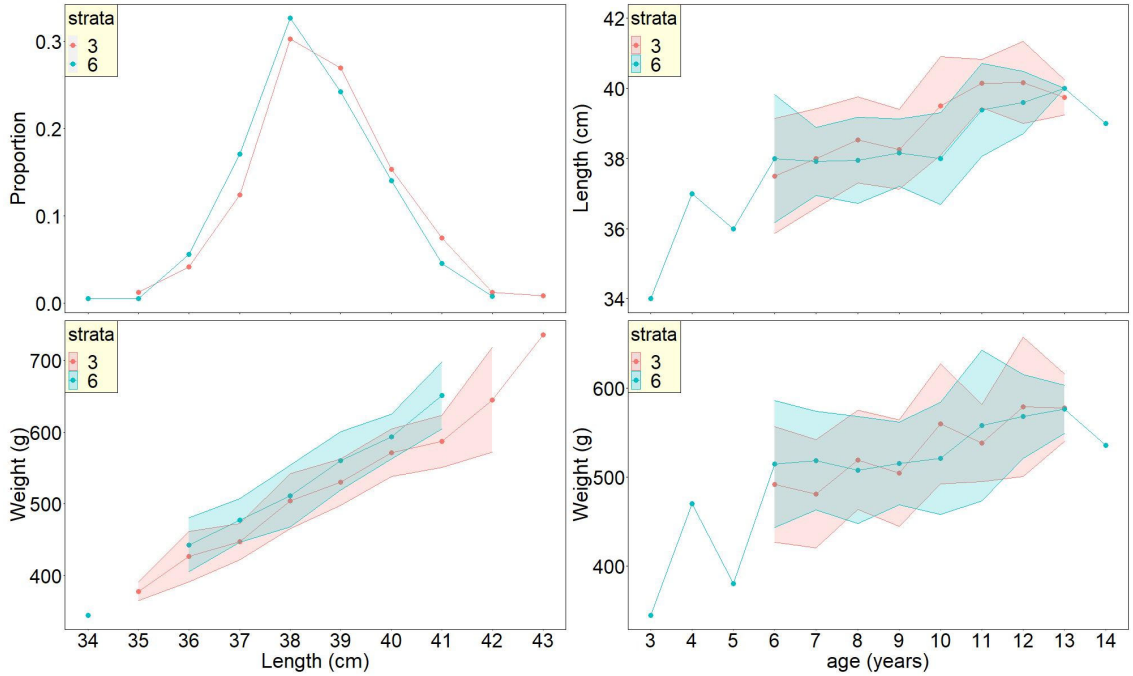

Figure 3. Proportion of mackerel at each 1 cm length bin (top left), mean weight at length (bottom left), mean length-at-age (top right) and mean weight-at-age (bottom right) in strata 3 (n = 241) and 6 (n = 393) measured from predetermined surface trawl stations sampled by R/V Árni Friðriksson in July 2020. Boundary of the different strata are displayed in Figure 1. Shaded areas display one standard deviation around mean value.

3.2 Herring

In the current report, acoustic backscatter and trawl samples for Norwegian spring-spawning herring (NSSH) and Icelandic summer-spawning herring (ISSH) are not presented separately. The two stocks can be more or less separated by location in July with NSSH located north and east of Iceland, and ISSH south and west. Southeast of Iceland, the boundaries between stocks were set at longitude 14°W. According to acoustic recordings, ISSH was distributed on the shelf along the south coast of Iceland (Figure 4). NSSH was distributed over the shelf edge and in deeper waters north, northeast, and east of Iceland. Comparing herring density measured using acoustic registration and surface trawling (Figure 5) reveals a good overlap for presence but a poorer one for density when present. High and low herring trawl catches in the north and northeast coincided with similar level of acoustic registrations. The high acoustic registration on the southeast shelf coincided with average trawl catches. We expect better overlap between acoustic registration and trawl catches for NSSH compared to ISSH. The spawning of ISSH coincides with the timing of the IESSNS, and therefore they have a patchy distribution and are often distributed closer to the bottom rather than in the surface mixed layer where the trawling occurs (0-35m). The NSSH, which is feeding during the survey period, is more evenly distributed horizontally and mostly located in the surface mixed layer.

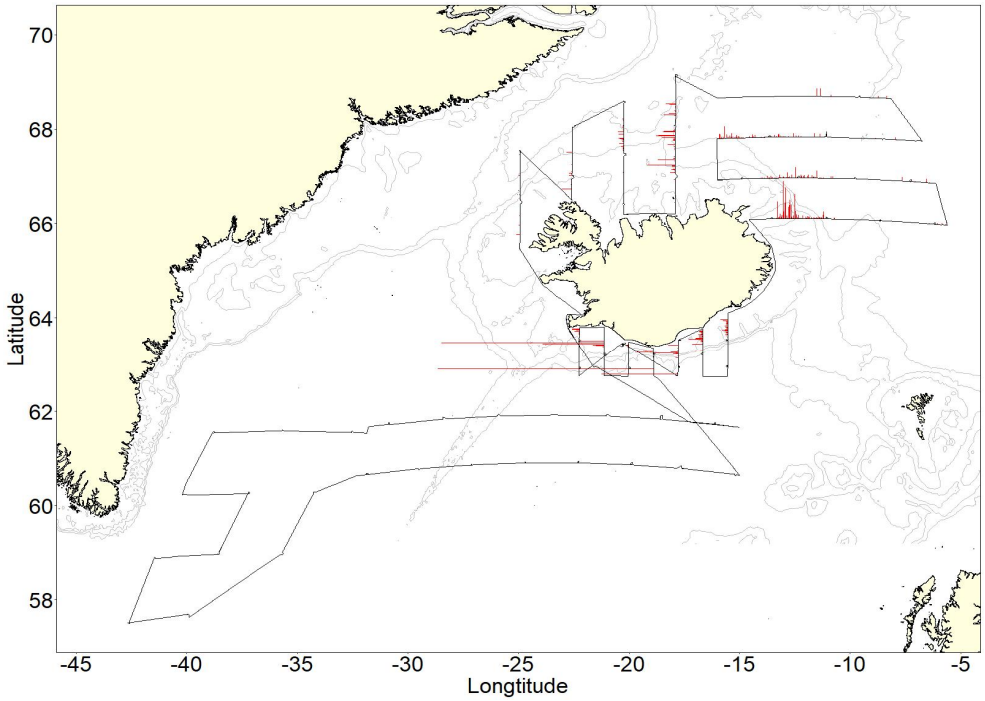

Figure 4. Herring (*Clupea harengus*) acoustic backscatter values (log10 of sa: red bars) as measured on R/V Árni Friðriksson in July 2020. The survey track (black line) and depth contours at 200, 500 and 1000 m are also shown (grey lines).

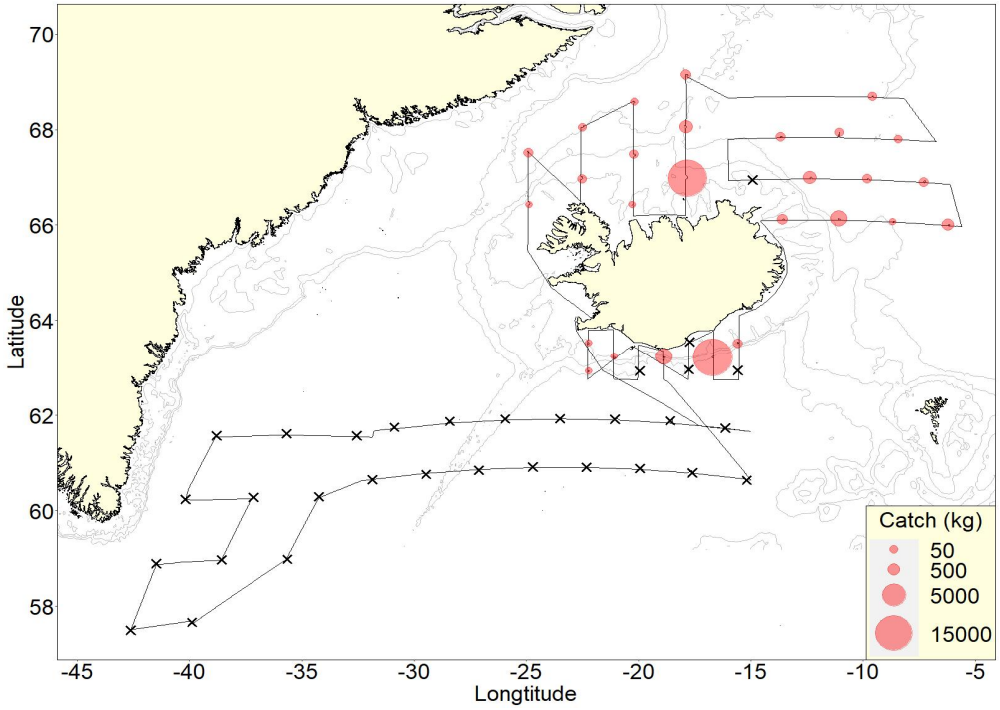

Figure 5. Herring (*Clupea harengus*) catch at predetermined surface stations sampled by R/V Árni Friðriksson in July 2020. Black crosses represent zero catch. The survey track (black line) and depth contours at 200, 500 and 1000 m are also shown (grey lines).

Herring was recorded for 488 nmi along the survey track on the shelf south of Iceland, and in shelf areas and offshore north and northeast of Iceland. This is similar distrubution compared to previous years. Herring was distributed in similar areas in 2020 compared to 2019, with the exception that herring were recorded in very low amounts north and west of the Westfjords in 2020. No herring abundance estimate from acoustical measurements is made in the current report and readers are referred to the 2020 IESSNS post cruise report (ICES, 2020).

NSSH (strata 3 and 4) was present from 10 – 470 m depth (Figure 6). Highest density of herring was in the surface 50 m and was present for all hours of the day as is expected during summer feeding at Northern latitudes. In late afternoon and evening, 1600 – 2200, low densities of herring were observed at all depths in the water column to 470 m depth. ISSH herring (stratum 6) was present from 10 – 180 m depth or from the surface to the bottom as they were mostly located in shelf areas (Figure 7). There was no distinctive diurnal pattern in their vertical distribution. It must be noted that the depth is relative to the transducer, which is mounted on a drop keel at ~8 m depth.

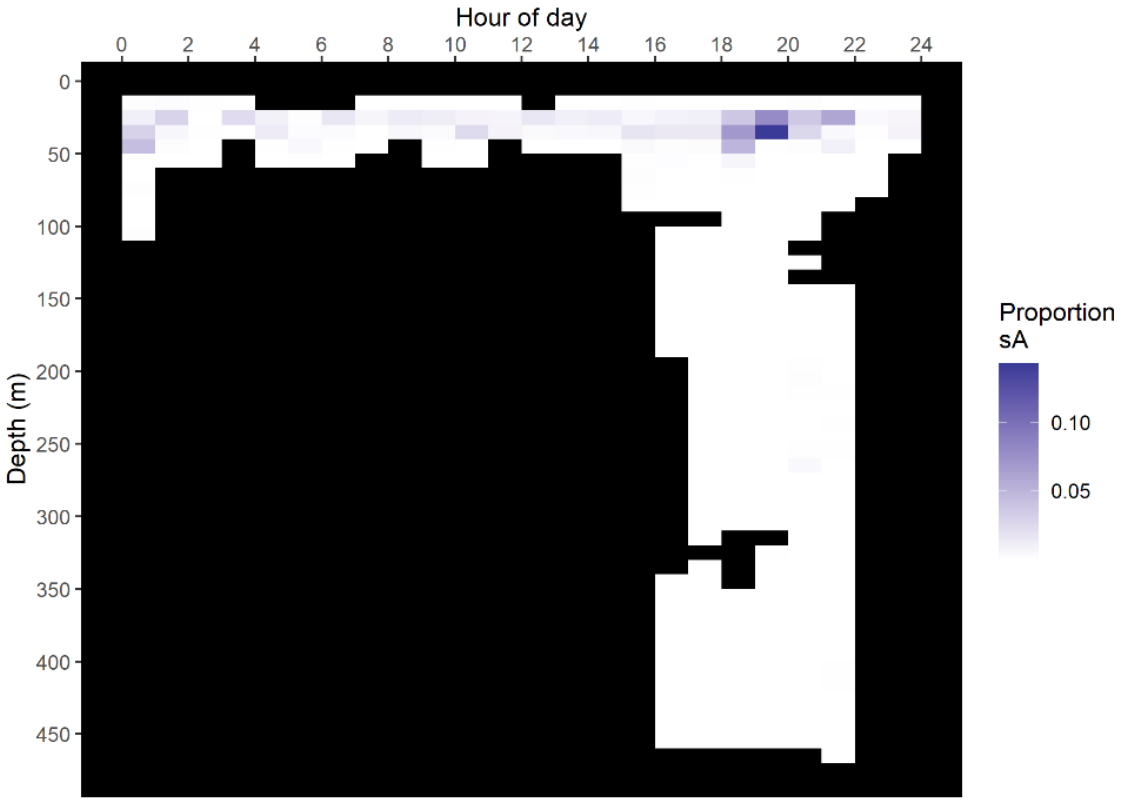

Figure 6. Proportion of NSSH backscatter (strata 3 and 4) by depth (10 m vertical bin) and by time of day (1-hour bin) as measured on R/V Árni Friðriksson in July 2020. Depth-hour bins with no herring registration are coloured black.

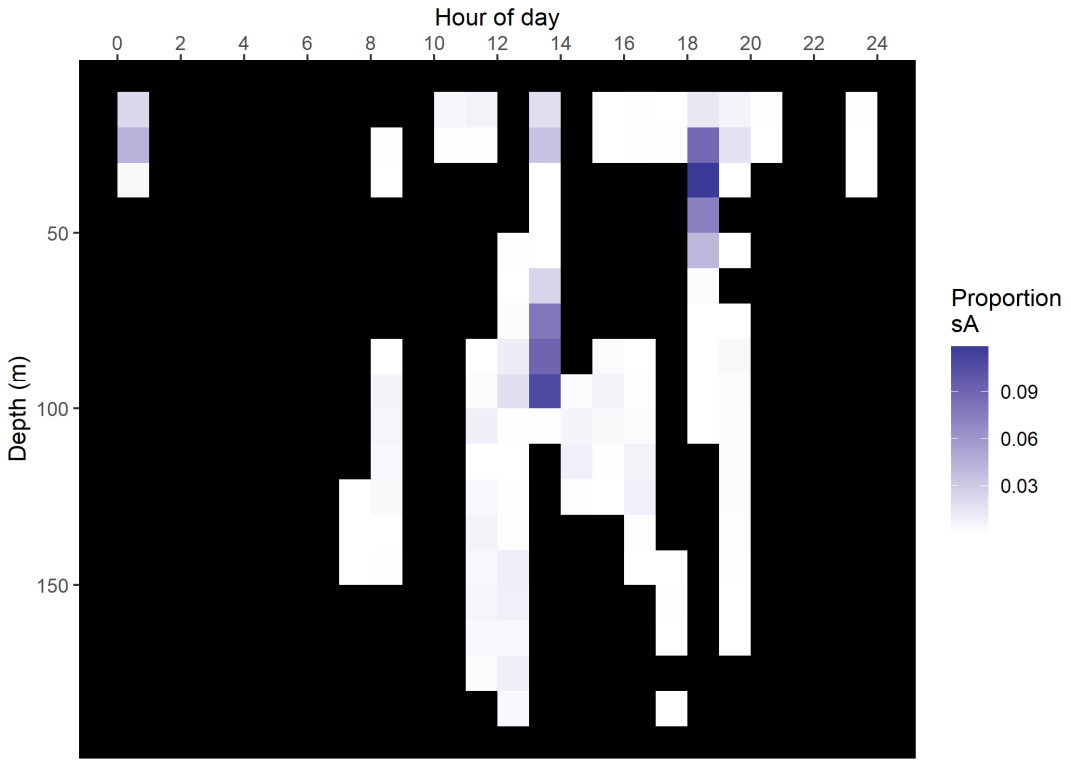

Figure 7. Proportion of ISSH backscatter (stratum 6) by depth (10 m vertical bin) and by time of day (1-hour bin) as measured on R/V Árni Friðriksson in July 2020. Depth-hour bins with no herring registration are coloured black.

Herring length ranged from 20 - 40 cm (Figure 8 top). Size varied between areas with the largest specimens being NSSH located north of Iceland (stratum 4). Smaller NSSH was located east of Iceland (stratum 3), size range 24 – 40 cm and peak length at 33 cm and 37 cm. This is expected as larger individuals have greater capacity for swimming and frequently migrate greater distances compared to smaller conspecific (Slotte, 1999). ISSH length distribution ranged from 20 cm to 39 cm, and had peak length at 25 cm, 33 cm and 36 cm (stratum 6). The shelf south of Iceland is both spawning ground and nursery area hence both small and large individuals are caught. NSSH had greater weight-at-length compared to ISSH (Figure 8 bottom). NSSH spawns in early spring and has been feeding for several months when measured in July compare ISSH which is mostly recently spent hence lower weight.

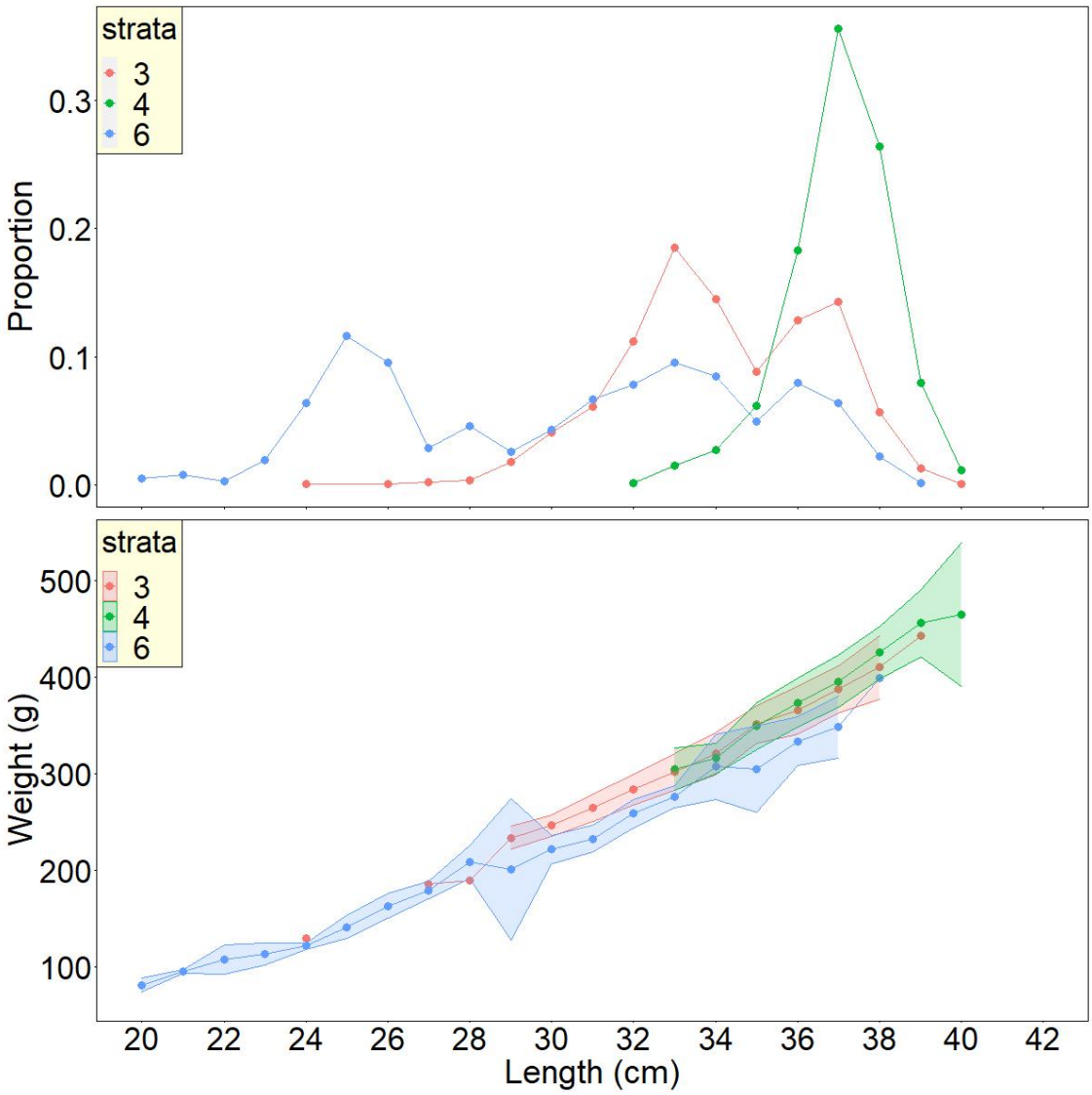

Figure 8. Proportion of herring (*Clupea harengus*) at each 1 cm length bin (top) and mean weight at length (bottom) in strata 3, 4 and 6 measured from predetermined surface trawl stations sampled by R/V Árni Friðriksson in July 2020. Different strata are displayed in Figure 1.

3.3 Blue whiting

As of 2020, blue whiting has been a target species of IESSNS for five consecutive years. Acoustic registrations and deep-water trawling indicate that blue whiting was only present in a small part on the northeastern survey area (Figure 9). Surprisingly, no blue whiting was recorded on the shelf edge south of Iceland as during the 2018 and 2019 surveys (Ólafsdóttir, 2019; Ólafsdóttir and Sigurðsson, 2018). No blue whiting abundance estimate from acoustical measurements is made in this report and referred to the 2020 IESSNS post cruise report (ICES, 2020).

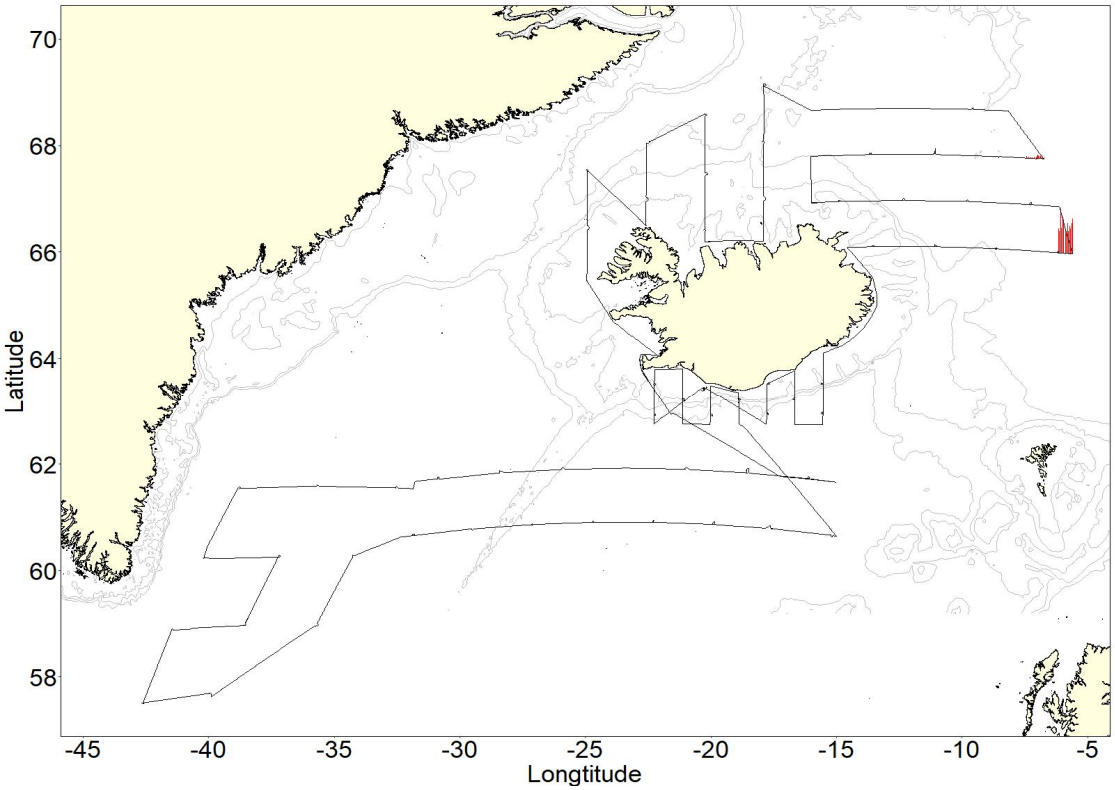

Figure 9. Blue whiting (*Micromesistius poutassou*) acoustic backscatter values (sA: red bars) as measured on R/V Árni Friðriksson in July 2020. Survey track (solid black line) also displayed.

Blue whiting registrations ranged from 100 m to 360 m depth, but vertical distribution of blue whiting is not displayed due to limited amount of data, blue whiting was only recorded for 33 nm of the survey track.

Blue whiting total length in trawl catches ranged from 7 cm to 36 cm (Figure 10). Length distribution was bimodal with juvenile fish, length 7 cm to 15 cm, caught in the basin south of Iceland (stratum 12) and mature fish, length 27 cm to 36 cm, caught east of Iceland (stratum 3). The juvenile blue whiting was caught during surface trawling and was not registered by the acoustic equipment whereas the mature fish was located deeper in the water column and recorded acoustically.

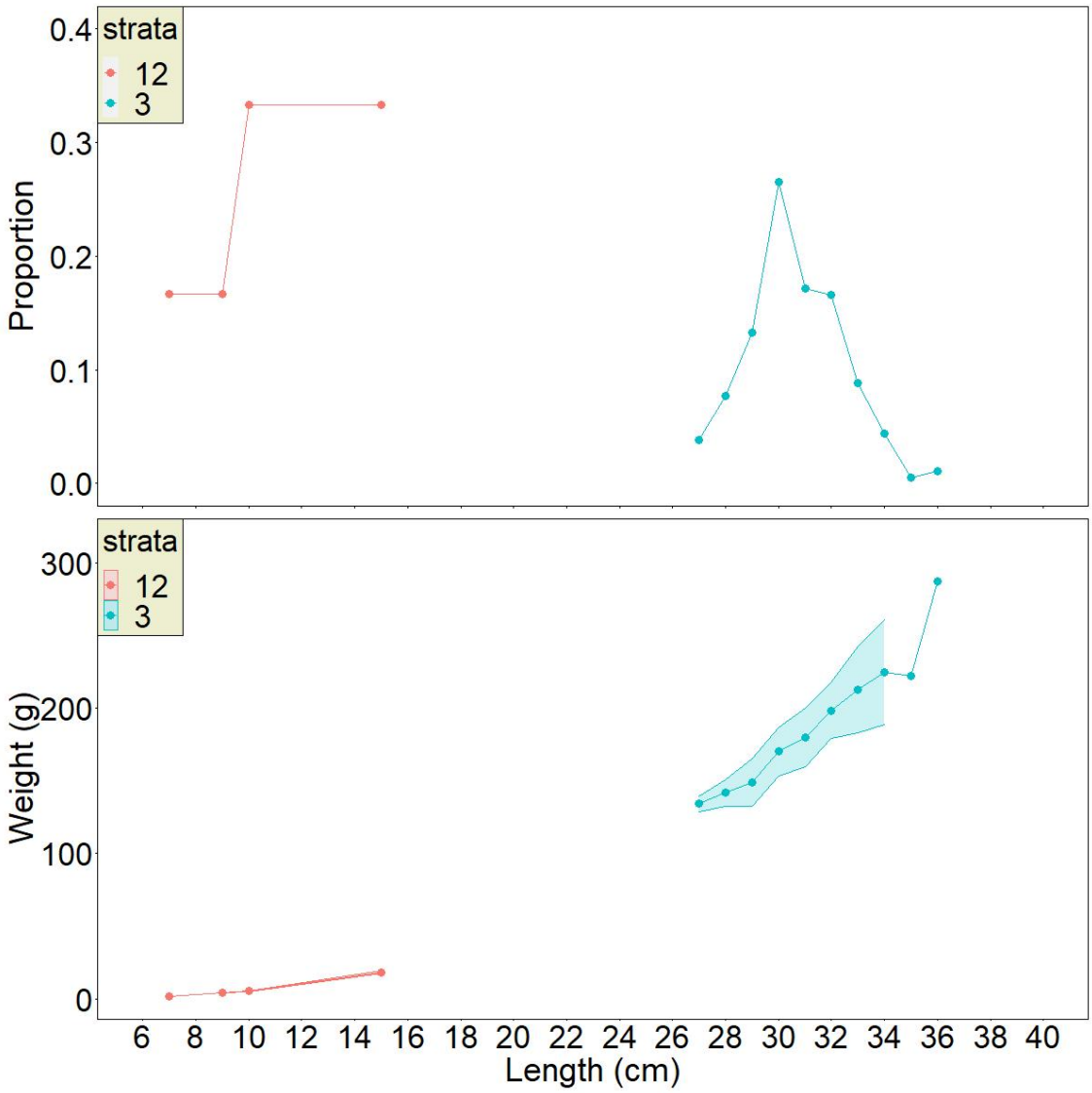

Figure 10. Proportion of blue whiting (*Micromesistius poutassou*) at each 1 cm length bin (top) and mean weight at length (bottom) in strata 3, and 12 measured from deep trawl stations deployed on acoustic registrations by R/V Árni Friðriksson in July 2020. Boundary of the different strata are displayed in Figure 1.

3.4 Lumpfish

Lumpfish were caught throughout the survey area, except the offshore area south of Iceland, at 46 of the 58 predetermined surface trawl stations (Figure 11). Catch per station ranged from < 1 kg to 78 kg with an average of 11.6 kg. Compared to 2019, lumpfish were caught at more stations (79% of the stations in 2020 versus 76% in 2019), the average catch per station was 3 kg higher, and more were caught on the shelf south of Iceland.

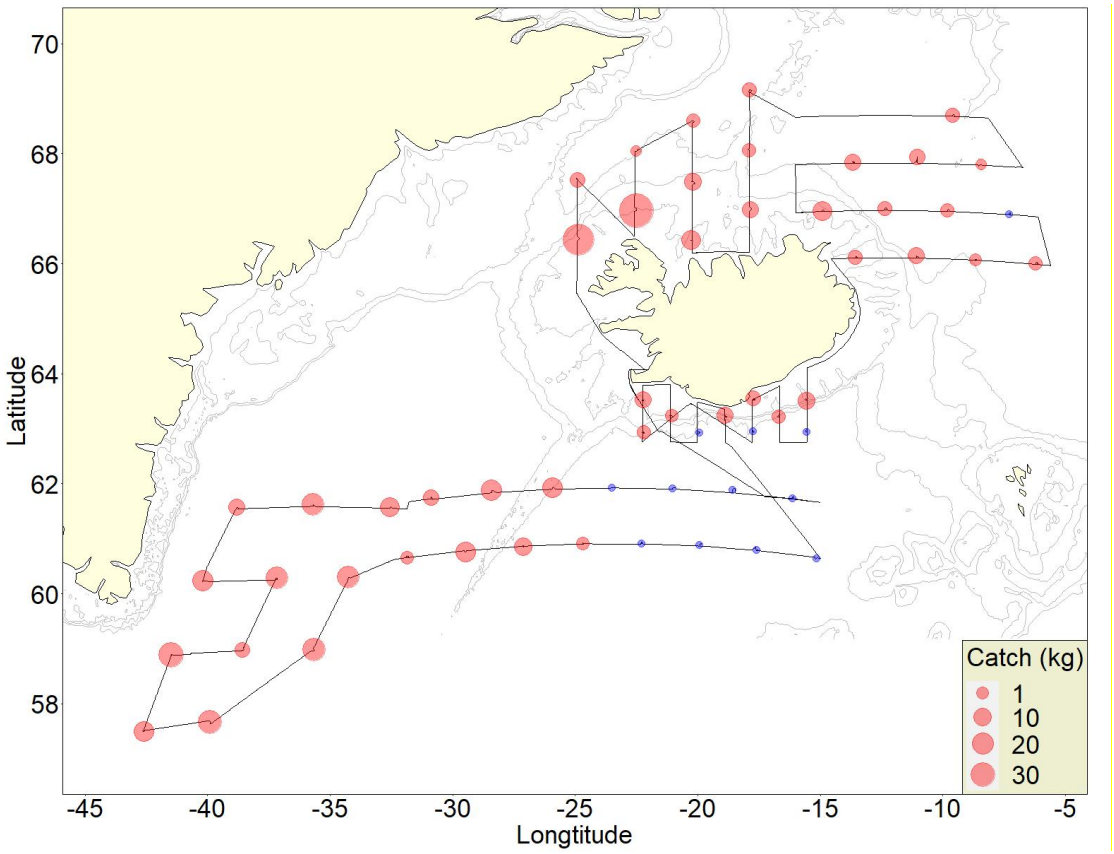

Figure 11. Lumpfish (*Cyclopterus lumpus*) catch at predetermined surface stations sampled by R/V Árni Friðriksson in July 2020. Blue circles represent zero catch. The survey track (black line) and depth contours at 200, 500 and 1000 m are also shown (grey lines).

3.5 Hydrography

Sea surface temperature, at 10m depth, ranged from 2.1 °C to 12.1 °C (Figure 12a) and was 1-2 °C lower compared to 2019 (Ólafsdóttir). As in previous years temperature was highest south of Iceland and lowest in Denmark strait. Temperature declined with increasing depth from the average of 8.6 °C at 10 m depth in the water column to 6.2 °C at 50 m, 5.1 °C at 100 m, and 4.0 °C at 400 m (Figure 12b-d).

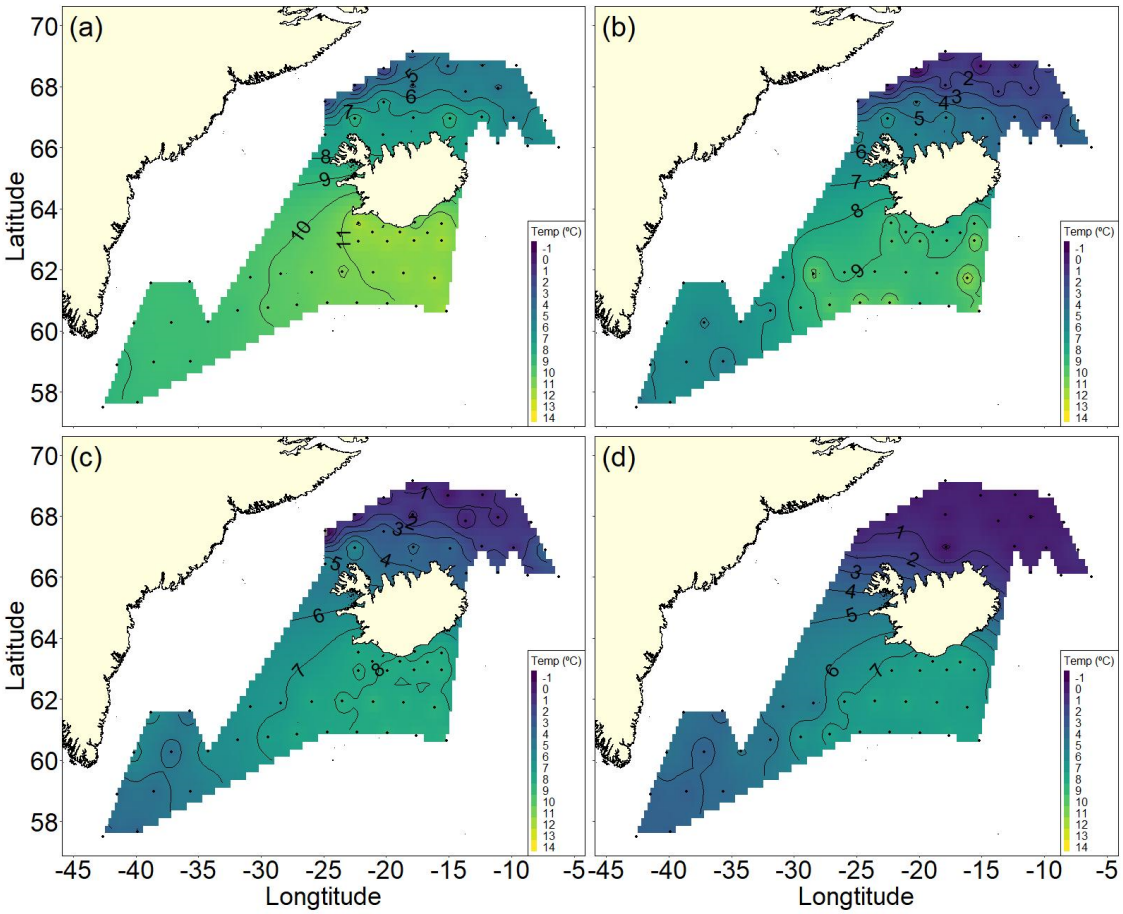

Figure 12. Ambient temperature at 10 m (a), 50 m (b), 100 m (c), and 400 m (d) depth using CTD data collected by R/V Árni Friðriksson in July 2020. Also displayed sampling station location (solid black circle). Same temperature scale used for all panels.

3.6 Mesozooplankton

Mesozooplankton density, as indicated by dry weight, ranged from 1.2 g*m^{-2} to 19.4 g*m^{-2} with a mean of 7.5 g*m^{-2} and a median of 6.4 g*m^{-2}(Figure 13). There is no clear pattern of higher or lower density in one part of the survey area compared to another one. No comparison is provided with average abundance in previous years due to differences in survey area. Unusually high number of stations were not sampled (12 out of 60) due to high winds.

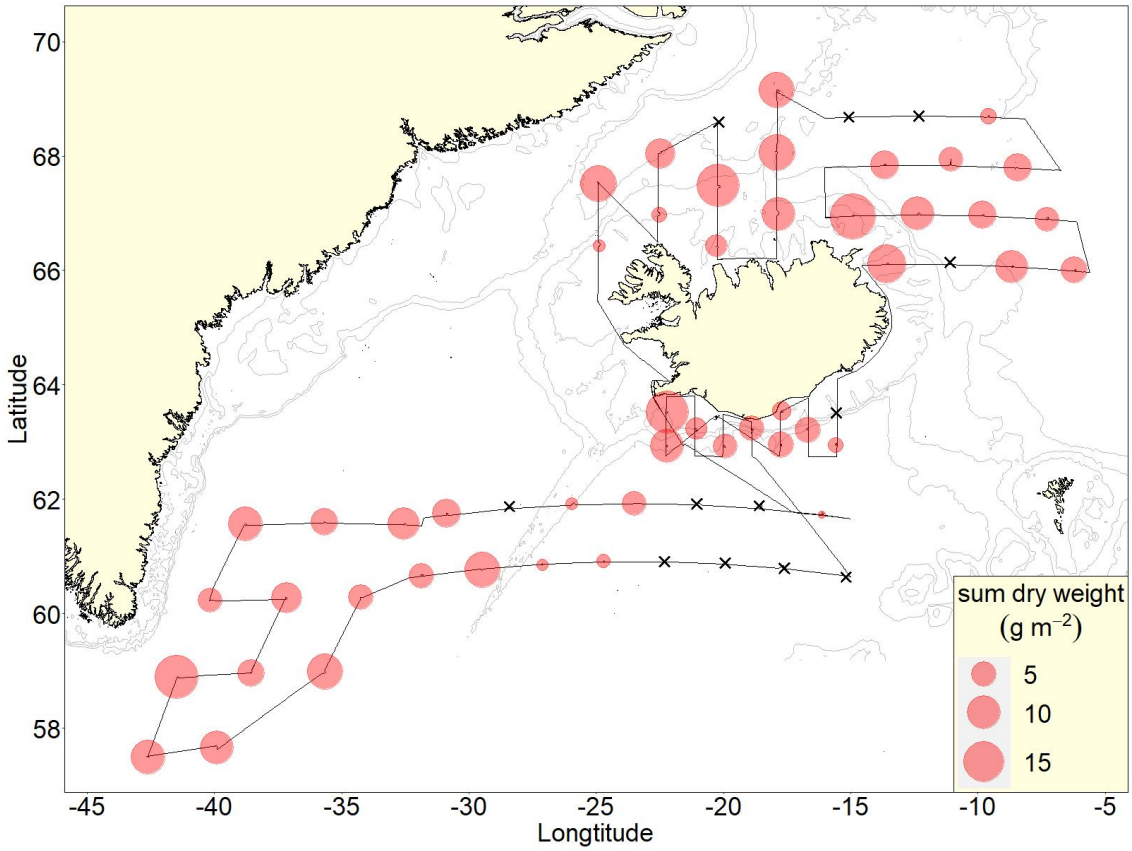

Figure 13. Mesozooplankton density at surface to 200 m depth, or to bottom when bottom depth was < 200 m, sampled by R/V Árni Friðriksson in July 2020. Survey track (black line) and depth contours displayed for 200 m, 500 m, and 1000 m (grey lines). Stations where mesozooplankton density could not be measured due to stormy weather are also displayed (black cross).

3.7 Various research projects

3.7.1 Tagging of live lumpfish

A total of 370 lumpfish were tagged and released at 45 of the 58 predetermined surface trawl stations. The tagged fish range in size from 17 cm to 45 cm with majority of individuals ranging in length from 20 cm to 30 cm (Figure 14).

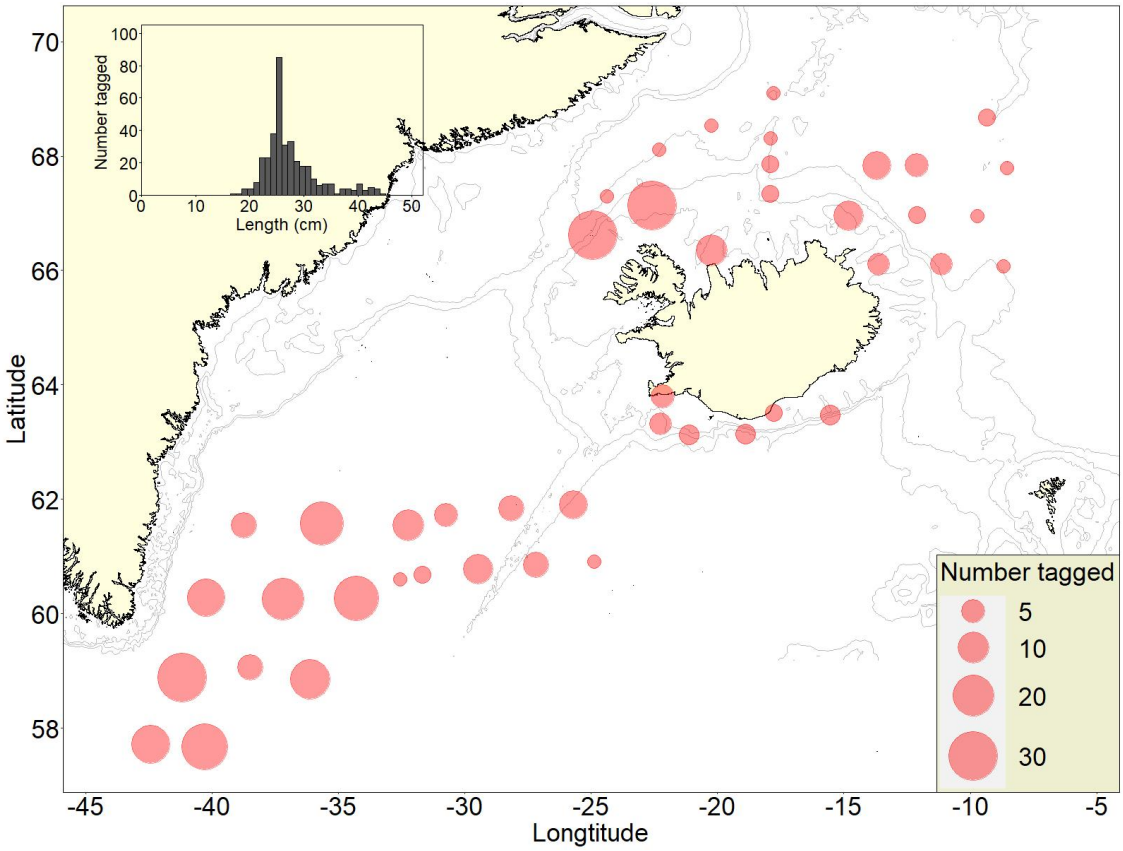

Figure 14. Number and location of lumpfish (*Cyclopterus lumpus*) tagged and released at predetermined surface trawl stations on R/V Árni Friðriksson in July 2020. Size distribution of tagged lumpfish is shown.

3.7.2 Opportunistic marine mammal observations

Marine mammals were sighted on 44 occasions (Figure 15). Ten species of whales and dolphins were identified, and one sighting could not be identified to species and were labelled as unidentified small toothed whale or dolphin. The identified species were blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), harbour porpoise (*Phocoena phocoena*), humpback whale (*Megaptera novaeangliae*), killer whale (*Orcinus orca*), long-finned pilot whale (*Globicephala melas*), minke whale (*Balaenoptera acutorostrata*), Northern bottlenose whale (*Hyperoodon ampullatus*), sperm whale (*Physeter marcocephalus*) and Atlantic white-beaked dolphins (*Lagenorhynchus albirostris*). One pod of long finned pilot whales consisted of ~150 individuals while another consisted of 8. One pod of Northern bottlenose whale consisted of 20 individuals, while on another occasion, a single individual was sighted. Two pods of white beaked dolphins were sighted which consisted of 7 and 15 individuals. The pod of killer whales consisted of 7 individuals. All other species consisted of 1 to 5 individuals.

Compared to 2019, there were twenty more mammal sightings with a higher number of species during the 2020 survey. In 2019, no harbour porpoise, killer whales, or Northern bottlenose whales were sighted, while in 2020, no sei whales (*Balaenoptera borealis*) were sighted but these were sighted in 2019. Fewer whale species were sighted south of Iceland and in the Irminger Sea compared to the area north and east of Iceland. This is possibly due to the presence of a dedicated whale observer on

the 1st leg of the survey north and east of Iceland, but a dedicated whale observer was no present during the 2nd leg of the survey which was south of Iceland and in the Irminger Sea.

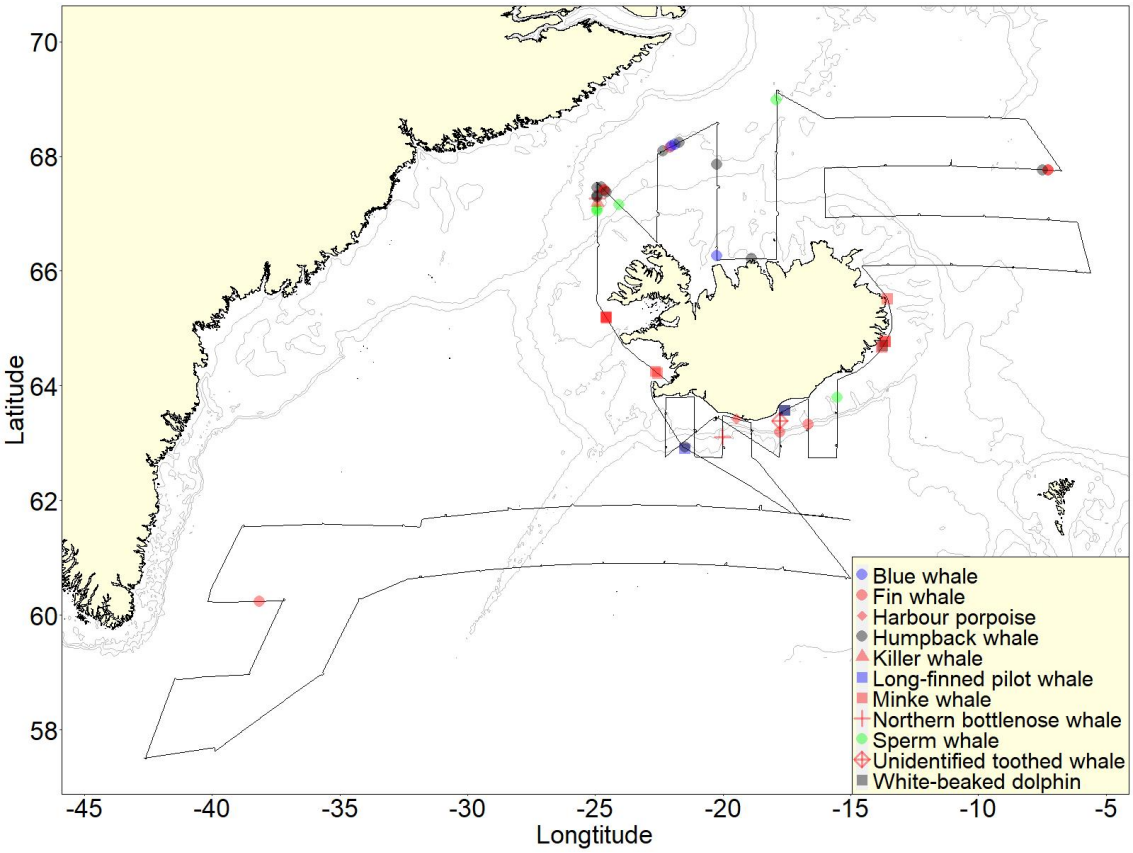

Figure 15. Dedicated and opportunistic whale and dolphin sighting locations observed on R/V Árni Friðriksson in July 2020. Pilot whales, northern bottlenose dolphins, white beaked dolphins and killer whales consisted of pods ≥7 individuals. Other species sighted ranged from 1 to 5 individuals. Survey track (black line) and depth contours displayed for 200 m, 500 m, and 1000 m (grey lines).

4. Acknowledgements

We sincerely thank survey participants and the crew of R/V Árni Friðriksson for their dedication to sampling for the many diverse research projects. Furthermore, we are grateful to Kristín Valsdóttir, Sigrún Jóhannsdóttir, Alice Benoit-Cattin, Magnús Daníelsson, Hildur Pétursdóttir, Kristinn Guðmundsson, Svandís Eva Aradóttir, and Bárður Jón Grímsson for their help during survey preparation, sample analyses, uploading of data to centralized data base and for data quality checking.

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6. Tables

Table 1. Sampling effort of predetermined surface trawl stations per strata on R/V Árni Friðriksson in July 2020.

Stratum name (stratum number)	Station interval (nmi)	Number of stations
IS-east (3)	60	12
IS-north (4)	65	10
IS-south shallow (6)	35	10
GL-south (11)	90	11
IS-south deep (12)	70	15

Table 2. Descriptive statistics for trawl operation during predetermined surface trawl stations on R/V Árni Friðriksson in July 2020.

Trawl descriptor	Average (min – max / st.dev)	Number stations included in average
Trawl door horizontal spread (m)	101(90 – 113 / 5)	58
Vertical trawl opening (m)	36 (28 – 45 / 4)	58
Horizontal trawl opening (m)*	60.6	58
Speed over ground (nmi)	5.1 (4.5 – 5.8 / 0.2)	58
Turn radius (degree)**	5	58
Port trawl door depth (m)	12 (5 – 24 / 4)	58
Starboard trawl door depth (m)	12 (4 – 31 / 4)	58
Headline depth (m)***	0 (0 – 0 / 0)	58

*Calculated using trawl door horizontal spread and trawling speed, see equation in ICES (2020).
**Tuning radius set to 5 degrees by captain during trawling. Not measured using trawl sensors during trawling.
***Headline and float visible in surface during trawling. Not measured using trawl sensors during trawling.

Table 3. Number of sampling stations per stratum for R/V Árni Friðriksson in July 2020. Targeted sampling for SUMMER projects is included but targeted sampling for MEESO projects is excluded from table.

Station type	Iceland east (stratum 3)	Iceland north (4)	Iceland south shallow (6)	Greenl. south (11)	Iceland south deep (12)	*Total*
(a) Standard IESSNS sampling[‡]						
Predetermined surface trawl	12	10	10	11	15	*58*
Deep water trawl	2	0	2	2	1	*7*
CTD[+]	14	10	12	11	17	*64*
WP-2[++]	11	9	11	11	10	*52*
(b) Additional research projects						
MAC, HER and WHB stomachs & somatic condition[*]	3 MAC, 5 HER, 2 WHB	4 HER	2 MAC, 2 HER			*5 MAC, 11 HER, 2 WHB*
Tag lumpfish[**]	10 (38)	10 (79)	6 (20)	12(196)	7(37)	*45 (370)*
eDNA	0	0	2	2	0	*4*
Froze mesopelagic fish and invertebrates^	4	3	5	6	10	*28*
MAC and WHB for microplastic research[***]	0	2 (40)	1 (20)	0	0	*3 (60)*
Herring hearts frozen	0	0	5	0	0	*5*
Polar cod[***]	4 (6)	5 (123)	0	0	0	*9 (129)*
Total	*67*	*53*	*58*	*55*	*60*	*293*

[‡]Trawl hauls, CTD, and WP2 stations share the same station number in the database.
[+]Nutrients and chlorophyll water samples collected at all CTD stations.
[++]WP-2 not collected at 12 stations due to high winds.
[*]MAC = mackerel, HER = herring, WHB = blue whiting. Stomachs frozen and somatic condition measured as described in chapter 2.4.2.
[**]Number of tagged individuals in brackets.
[***]Number of specimens sampled in brackets.
^For H2020 project SUMMER and for species identification by MFRI specialists.

Table 4. Catches of all species or higher classification level caught in the Multpelt832 trawl, including predetermined surface stations and deep trawl stations, by R/V Árni Friðriksson in July 2020. Survey target species displayed in bold.

Species names English	Latin	Icelandic	Deep trawling (kg)	Surface trawling (kg)	Total catch (kg)
Short snouted lancetfish	*Alepisaurus brevirostris*	Litli földungur		2.7	2.7
Malacostracan crustaceans	*Amphipoda^*	Sviflægar marflær		< 0.1	< 0.1
White barracudina	*Arctozenius rissoi*	Litla geirsíli	0.3	1.8	2.1
Bean's sawtooth eel	*Serrivomer beani*	Trjónuáll	< 0.1		< 0.1
Goiter blacksmelt	*Bathylagus euryops*	Skjár/blálax	< 0.1		< 0.1
Glacier lantern fish	*Benthosema glaciale*	Ísalaxsíld	3.5	< 0.1	3.5
Atlantic wolffish	*Anarhichas lupus*	Steinbítur		< 0.1	< 0.1
Northern wolffish	*Anarhichas denticulatus*	Blágóma	2.3		2.3
Capelin	*Mallotus villosus*	Loðna		7.8	7.8
Sloan´s viperfish	*Chauliodus sloani*	Slóans gelgja	0.2		0.2
Cephalapoda, decapoda	*Cephalapoda, decapoda^*	Smokkfiskar, kolkrabbar	0.8	4.1	4.8
Atlantic cod	*Gadus morhua*	Þorskur		< 0.1	< 0.1
Shrimp	*Natantia^*	Rækja	1.6		1.6
Silver/Arctic rockling	*Gaidropsarus argentatus*	Rauða sævesla		0.9	0.9
Grey gurnard	*Eutrigla gurnardus*	Urrari		1.1	1.1
Haddock	*Melanogrammus aeglefinus*	Ýsa		< 0.1	< 0.1
Herring	***Clupea harengus***	**Síld**	**201.3**	**40936.0**	**41137.3**
True jellyfish	*Scyphozoa^*	Hveljur og marglyttur	165.2	56.1	221.3
Sea lamprey	*Petromyzon marinus*	Steinsuga		0.7	0.7
Patchwork lampfishes	*Notoscopelus kroeyeri*	Langalaxssíld	12.9	0.2	13.1
Mirror lanternfish	*Lampadena speculigera*	Gljálaxsíld	< 0.1		< 0.1
Lumpfish	*Cyclopterus lumpus*	Hrognkelsi	0.8	531.3	532.1
Lanternfish	*Myctophidae^*	Laxsíld	0.1		0.1
Jewel lanternfish	*Lampanyctus crocodilus*	Fenrislaxsíld	0.1		0.1
Atlantic mackerel	***Scomber scombrus***	**Makríll**		**3466.1**	**3466.1**
Muller´s pearlside	*Maurolicus muelleri*	Norræna gulldepla	< 0.1		< 0.1
Duckbill barracudina	*Magnisudis atlantica*	Digra geirsíli		0.2	0.2
Monkfish	*Lophius piscatorius*	Skötuselur		0.4	0.4
Ocean sunfish	*Mola mola*	Tunglfiskur		80*	80*
Spotted lanternfish	*Myctophum punctatum*	Punktalaxsíld	0.5	0.1	0.6
reenland argentine	*Nansenia groenlandica*	Grænlandsnaggur	< 0.1		< 0.1
Sharpchin barracudina	*Paralepis coregonoides*	Stóra geirsíli		10.0	10.0
Polar cod	*Boreogadus saida*	Ískóð	< 0.1	1.9	1.9
Barracudinas	*Paralepididae^*	Geirsíli	0.1		0.1
Half-naked hatchetfish	*Argyropelecus hemigymnus*	Suðræni silfurfiskur	< 0.1		< 0.1
Beaked redfish	*Sebastes mentella*	Djúpkarfi	33.4		33.4
Atlantic salmon	*Salmo salar*	Lax		1.4	1.4
Sandlance	*Ammodytes marinus*	Sandsíli		< 0.1	< 0.1
Boa dragonfish	*Stomias boa*	Marsnákur	< 0.1		< 0.1
Squarenose helmetfish	*Scopelogadus beanii*	Kistufiskur		< 0.1	< 0.1
Deal fish	*Trachipterus arcticus*	Vogmær	4.9		4.9
Blue whiting	***Micromesistius poutassou***	**Kolmunni** Total catch	**48.1** 476.0	**0.1** 45023.1	**48.2** 45499.09
^higher classification level than species *visually estimated weight					

7. Annex

Annex 1. Scientific survey participants in the IESSNS onboard R/V Árni Friðriksson in July 2020, and participant work responsibilities during survey.

1 - 13 July	**13 - 30 July**
Ása Hilmarsdóttir, plankton and biol. sampling	Anna Heiða Ólafsdóttir, cruise leader, acoustics
Freyr Arnaldsson, plankton and biol. samples	Arnþór B. Kristjánsson, acoustics, technology
Georg Haney, acoustics,	Ástþór Gíslason, MEESO project
Jacek Sliwinski, acoustics, equipment	Birkir Bárðarson, plankton, biol. Samples, MEESO
James Kennedy, cruise leader, acoustics	Enrique G.A. Garcia, SUMMER project
Sigurlína Gunnarsdóttir, plankton and biol. samples	Guðrún Finnbogadóttir, plankton and biol. samples
Sólrún Sigurgeirsdóttir, plankton and biol. samples	Halldór Tyrfingsson, MEESO project
Sverrir Daníel Halldórsson, whales	Klara Jakobsdóttir, plankton, biol. Samples, MEESO
	Martina Blumel, SUMMER project
	Ragnhildur Ólafsdóttir, plankton and biol. samples
	Svanhildur Egilsdóttir, photographer
	Teresa S.G. da Silva, acoustics, MEESO project
Captain:	
Kristján H. Kristinsson	Heimir Örn Hafsteinsson

HAFRANNSÓKNASTOFNUN

Rannsókna- og ráðgjafarstofnun hafs og vatna