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Results of the Icelandic part of the International Ecosystem Summer Survey in Nordic Seas (IESSNS) in 2019 on R/V Árni Friðriksson

Anna Heiða Ólafsdóttir

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Ágrip

Hafrannsóknastofnun hefur frá árinu 2010 tekið þátt í alþjóðlegum uppsjávarleiðangri í norðaustur Atlantshafi. Tilgangur leiðangursins er vistkerfisvöktun að sumarlagi, frá yfirborði niður á 500 m dýpi. Meðal þess sem skoðað er eru næringarefni, hitastig, selta, áta, magn og útbreiðsla markríls, kolmunna, síldar og hrognkelsa. Sumarið 2019 þá var íslenski hluti leiðangursins farinn dagana 3.-27.júlí á rannsóknaskipinu Árna Friðrikssyni. Rannsóknasvæðið var íslenska landhelgin, að undanskildum suðaustur hlutanum og svæði fyrir vestan land. Sigldar voru 5525 sjómílur og athuganir gerðar á 194 mælistöðvum.

*Makríll veiddist í 48 % af stöðluðum yfirborðstogum og var mestur þéttleiki hans á landgrunninu og landgrunnsbrúninni fyrir sunnan og suðvestan landið. Enginn makríll veiddist fyrir norðan land. Á landgrunninu fyrir sunnan land var þéttleiki makríls tvöfalt hærri 2019 samanborið við 2018. Á öðrum svæðum var þéttleiki svipaður milli ára. Áta mældist á hverri stöð, magnið (þurrvigt) var á bilinu 0.6 – 25.9 g*m^{-2} og mest á landgrunninu norðan og sunnan við Ísland. Hitastig, í yfirborðslaginu, var á bilinu 0.6 – 13.5 °C. Yfirborðshitastig var yfir 9°C á öllu leiðangurssvæðinu fyrir sunnan og vestan Íslands en það hitastig er nægjanlega hátt fyrir makríl. Einungis mældist þó makríll á hluta af því svæði. Því er útbreiðsla og þéttleiki makríls háð fleiri breytum en hitastigi og átu. Síld mældist á 13 % af sigldum sjómílum og var dreifing hennar svipuð og sumarið 2018. Kolmunni mældist á 4 % af sigldum sjómílum sem er minna en 2018 og var áberandi að enginn kolmunni mældist fyrir vestan Ísland 2019.*

Abstract

The Marine and Freshwater Research Institute (MFRI) 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 2019, the Icelandic part of IESSNS was conducted from July 3rd to

29th on R/V Árni Friðriksson in the Icelandic exclusive economic zone, excluding the southeast part and small area west of Iceland. Survey transects were 5525 nautical miles and 194 stations were sampled.

Mackerel was caught at 48% of predetermined surface trawl stations and the highest density was on the shelf and shelf edge south and southwest of Iceland. No mackerel was caught north of Iceland. In the inshore waters of southern Iceland, mackerel density was approximately double compared to 2018. In other areas, the density was similar to 2018. Mesozooplankton , present at every station, dry weight ranged from 0.6 $g*m^{-2}$ to 25.9 $g*m^{-2}$, and its density was highest on the shelf north and south of Iceland. Temperature of the surface mixed layer, ranged from 0.6 °C to 13.5 °C. Areas with temperatures suitable for mackerel (> 9 °C) were found inshore and offshore, south and west of Iceland, however mackerel was only present in part of this area. Thus, presence and density of mackerel are dependent on more factors than temperature and mesozooplankton. Herring was present on 13 % of the survey track and had a similar distribution to previous years. Blue whiting was present for 4 %of survey track which is much less than is 2018, with a lack of blue whiting west of Iceland.

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

Undirskrift verkefnisstjóra:	**Undirskrift forstöðumanns sviðs:**
Anna Heiða Ólafsdóttir	Þorsteinn Sigurðsson

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1. Introduction

Mackerel, Norwegian spring-spawning herring and blue whiting. Photo J. Kennedy.

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 2019 (ICES, 2019). 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, and the aim is to include the age-segregated indices in stock assessment as the time-series matures. Hydrographical and zooplankton measurements that are an integrated part of long-term monitoring of the pelagic ecosystem during summer in the Northeast Atlantic.

Additionally, samples are collected for various research projects as requested by MFRI scientists or collaborators. During the 2019 IESSNS, samples were collected for ten research project and one graduate student joined the survey to collect data for his master project. Sampling for research projects included filtering seawater to collect environmental DNA (eDNA), tagging of live lump fish, opportunistic registrations of whale observations by crew and scientific staff, collection of herring biological samples for DNA analysis and parasite monitoring, sampling of capelin for gonad maturity research, sampling of mackerel and blue whiting to research microplastic presence in their stomachs, sampling of mesopelagic fishes and invertebrates for international collaborators in the SUMMER project, and finally,

measuring somatic condition and sample stomachs, for prey analysis, from mackerel, herring and blue whiting to research to research energy flow in the pelagic food wed.

This survey is conducted annually and commenced in 2007 by two vessels from Institute of Marine Research (IMR) in Bergen, Norway. In 2010, the Marine and Freshwater Research Institute (MFRI), Reykjavik, and the Faroe Marine Research Institute joined. Greenland Institute of Natural Resources, Nuuk, joined in 2013, and Denmark in 2018. The survey was originally limited to the Norwegian Sea but as more nations joined, geographical coverage expanded. The survey expanded to the west coast of Iceland in 2010, to the east coast of Greenland and south to Cape Farewell in 2013, and into the North Sea in 2018. In recent years, the survey coverage has been approximately 3 million km^2 of the Northeast Atlantic. The survey expanded in order to follow the expansion of the geographical range in mackerel distribution 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 spatial coverage of the survey, 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 distribution range 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

The survey area covered by R/V Árni Friðriksson in July 2019 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 design 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 (www.star-oddi.com) were attached to 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, and the same boundaries were used in 2019. Survey coverage was smaller in 2019 compared to 2018 as seven less predetermined surface trawl stations were sampled in international waters east of Iceland and the Greenland vessel sampled three predetermined surface trawl stations in the west stratum. When comparing survey results in 2019 to 2018, we focus on strata where most of the area was covered by R/V Árni Friðriksson and therefore exclude the east stratum.

R/V Árni Friðriksson departed from Reykjavik at 1600 on July 3rd 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 15, crew change was in Reyðafjörður, a village on the east coast of Iceland. Crew list is in Appendix 1. From Reyðafjörður, the vessel headed southwards to stratum south offshore and continued from there westward. The vessel arrived in Reykjavik at 1500 on July 29th. The total distance covered during these 27 days was 5525 nautical miles with 194 stations sampled (Table 3). The survey successfully sampled 61 of 65 predetermined trawl stations, located in five strata, and most of the predetermined acoustic survey track. Eight deep trawls were sampled to ground-truth acoustic backscatter. Drift ice was encountered at the northern part of four transects in the north stratum causing transect to be shortened and prevented sampling of four predetermined surface trawl stations.

The weather was exceptionally calm for most of the survey excluding few hours of moderate seas. Fog was common in the survey area north of Iceland.

Additionally, to the standard IESSNS survey protocol, samples were collected for ten research projects, eight at MFRI and two for international projects: 1) tagging of live lumpfish, 2) opportunistic registrations of whale observations, 3) whole frozen mackerel and blue whiting for analysis of microplastic in their stomachs, 4) measure somatic condition of mackerel, blue whiting and herring at selected stations, 5) freeze all female capelin > 14 cm long for a gonad research, 6) collection of surface water sample for species identification of algae bloom in Faxaflói, 7) collecting genetic samples from Icelandic summer spawning herring, and 8) sample hearts from Icelandic summer spawning herring to monitor parasite infection rate. Furthermore, two different types of samples were collected for international research project SUMMER (funded by the European Commission (Project number 817806): 9) collection of environmental DNA (eDNA), and 10) collection of mesopelagic fish and invertebrates. Finally, a student from University of Iceland joined the first part of the survey to research whale behaviour as part of his master research thesis. All sampling was executed according to plan and no transects were shortened due to zero mackerel catch for the second year in a row. As in previous years, survey participants blogged about research and life onboard

(https://pelagicecosystemsurvey.wordpress.com/).

We belief that risk of double and/or zero counting of mackerel is minimized with the current survey plan approach (*i.e.* going clockwise and start northwest of Iceland). Furthermore, synchronization with other vessels, participating in IESSNS, east of Iceland and west of Iceland was acceptable (ICES, 2019).

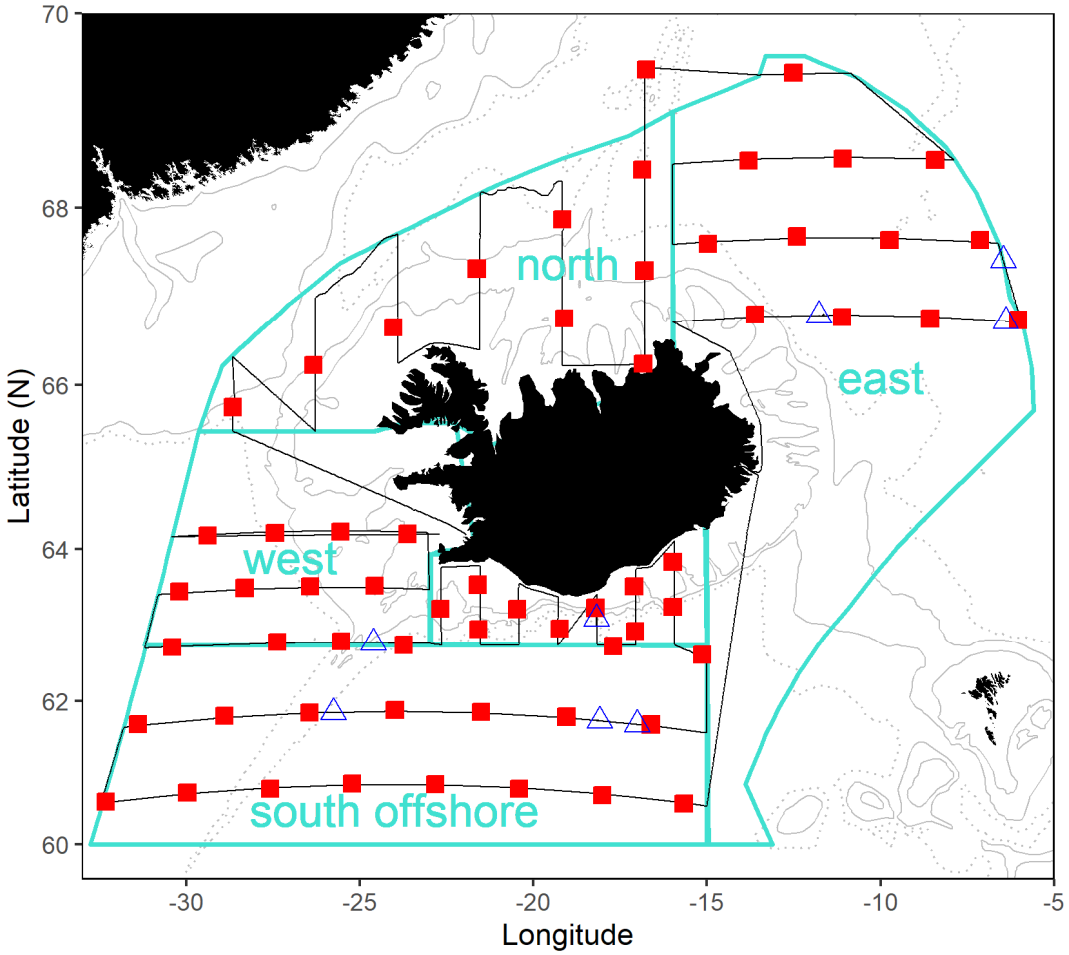

Figure 1. Predetermined surface trawl stations, including CTD and WP2-net (filled red rectangle) and deep trawling on acoustic registrations (open blue triangle) sampled by R/V Árni Friðriksson in July 2019. Also displayed is the survey track (black line), stratum boundaries (turquoise line), and depth contours at 200m, 500m and 1000m (grey lines). Stratum "south inshore" is located between stratum "south offshore" and the south coast of Iceland.

2.2 Acoustic methods and trawl sampling

Action on the trawl deck as Báður, Þorsteinn, Guðmundur and Björn haul in the pelagic trawl. Björn and Bárður empty the catch from the cod-end. Image A.H. Ólafsdóttir.

Acoustic scatters were recorded continuously from 15 m to 500 m or 750 m depth using a Simrad EK60 echosounder on four frequencies (18-38-120-200kHz). Sampling depth was limited to 500 m in strata north and east of Iceland and was 750 m in the south and west 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, 2019). Dedicated trawl sampling on potential blue whiting acoustic registrations was executed at 8 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 2019.

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, 2019). A total of 61 standardized surface hauls were conducted at predefined IESSNS stations. All tows were considered of appropriate quality, and thereby applicable for abundance estimation, both with respect to the trawl settings and to trawl operation.

Catch from a 30-min surface trawl at position 60°36 N and 15°37 W. Image A.H. Ólafsdóttir.

2.3 Sampling of hydrographic and plankton data

Hydrographic and plankton data was collected at all predetermined surface trawl stations, with the exception of one station 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; and at 500m, for calibrating the salinity measurements. A total of 65 CTD stations were taken, including four stations specifically in connection with eDNA sampling and algae bloom.

Þorsteinn ready to launch the hydrographic probe. Image A.H. Ólafsdóttir.

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-weighing in the laboratory on-shore. The second 50 m sample was preserved in formaldehyde for quantitative species identification later in a laboratory on land.

Björn and Guðmundur employ the WP2-net. Agnes and Guðmundur have the WP2-net on the deck and are disconnecting the bucket containing the sample from the net. Sólrún processing a plankton sample from a WP2-net. Plankton manually sorted to major groups. Sample of amphipods labelled in an aluminium tray and ready for drying and weighting ashore. Image A.H. Ólafsdóttir.

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 abundance.

2.4 Sampling for various research projects

2.4.1 Collection of stomach samples

MFRI monitoring of the pelagic ecosystem during the summer feeding season includes sampling of stomach samples to identify major prey species of commercially important fishes. This is done to better understand energy flow in the pelagic food web. 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. Blue whiting samples are collected at every station as much fewer trawling stations was sampled deep in the water column compared to predetermined surface trawl stations. During the survey, a total of 115 mackerel, 119 herring, and 50 blue whiting stomachs were sampled at 30 trawl stations (Table 3). The stomach samples were frozen on

board and will be analysed later at the MFRI laboratory to identify prey species and their amount, thus no results from these analyses are presented in the current report.

2.4.2 Measuring somatic condition of target pelagic fish species

To research annual variation in feeding condition of pelagic fishes during the summer feeding season, somatic condition of mackerel, herring and blue whiting were measured for the first time during the survey. Condition was measured for the same specimen that stomach samples were collected from. Goal of 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.

2.4.3 Environmental DNA (eDNA)

Páll filters seawater to collect environmental DNA. Image A.H. Ólafsdóttir.

eDNA is a new methodology that is being developed to monitor presence and abundance of species in the ocean ecosystem. To research fauna agreement between eDNA and trawl catch, eDNA samples were collected at 27 predetermined surface trawl stations, and at one opportunistic station in relation to interesting backscatter and distributed in all strata. At each eDNA station, one litre of sea was filtered from five different depths: 0m, 20m, 50m, 200m, and 500m. 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 second 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

Mesopelagic trawl sample from 350 m depth on the Reykjanes ridge. Image A.H. Ólafsdóttir.

At deep trawling stations, for acoustic ground truthing, mesopelagic fish and invertebrates were sorted to the lowest taxonomic rank possible, length measured, weighted and frozen. Samples were collected from five deep trawl stations. Additionally, rare invertebrates and rare fishes from six surface trawl stations were sampled and frozen. Sampling was done for the second year for the international research project SUMMER (funded by the European Commission (Project number 817806) in which Christophe Pampoulie and Anna Ólafsdóttir participate. The samples will be sent to SUMMER participants internationally for analysis and the results are not published in the current report.

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 an important research project. To initiate research on microplastic in prey of pelagic fish, two samples of ten specimens of mackerel and blue whiting were collected in the cold east Iceland current (stratum east) and in warm North Atlantic current south of Iceland (stratum south offshore). The samples will be analysed in a laboratory ashore later and the results are not published in the current report.

2.4.7 Opportunistic marine mammal observations

In an attempt to collect information on marine mammal distribution, between the official whale counting surveys which occur every seventh year, 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 *Ichthyophonus sp* parasite infection rates of the stock. Icelandic summer-spawning herring were caught at ten trawl stations and 50 hearts frozen at each station. In total, 370 hearts were sampled at 11 surface trawl stations in strata west and south inshore. The samples will be analysed in MFRI laboratory later and the results are not published in the current report. Project coordinator is Guðmundur J. Óskarsson at MFRI.

2.4.9 Capelin gonads

In recent years, MFRI has been investigating maturity staging of capelin from the Iceland-East Greenland-Jan Mayen stock (Bjarnason et al., 2019). Limited gonad samples were available from capelin > 14 cm sampled during summer. Hence, all capelin > 14 cm were individually frozen. 36 specimens were sampled at six station in strata north and east. The samples will be analysed in MFRI laboratory later and the results are not published in the current report. Project coordinator is Sigurvin Bjarnason at MFRI.

2.4.10 Sampling of DNA from Icelandic summer-spawning herring

DNA samples were collected from Icelandic summer-spawning herring, in maturity stage 5 or 6, by cutting a part of a gill and preserve in ethanol. Total of 34 specimens were sampled at 11 stations in stratum west and south inshore. The samples are for research project HER-SNP coordinated by Guðmundur Óskarsson at MFRI, and the results are not published in the current report.

2.4.11 Student participation

Emil Sölvi Ágústsson, a master student from University of Iceland, joined the first half of the survey to collect observations on whale sightings for his master thesis. He observed whales from the whale platform on top of the bridge for an average of 10 hours per day usually during the day from 9am to 7pm. The results of his research are not presented in the current report.

3. Results and Discussion

Total catch from the survey amounted to 58.8 tonnes which included 19 fish species identified to species level as well as unidentified lanternfishes (family Myctophidae) and sand lances (*Ammodytes* sp.). The catch also included unidentified jellyfish and cephalopods. Of the total catch, mackerel and herring were 38 (65%) and 20 (34%) tonnes respectively. Lumpfish and blue whiting made up ~1% with a catch of 0.31 and 0.25 tonnes respectively and the remaining ~240 kg being made up of other species (Table 4).

3.1 Hydrography

Sea surface temperature, at 10m depth, ranged from 1.6 °C to 13.5 °C and was the highest southwest of Iceland and the lowest northwest of the Westfjords (Figure 2a). Temperature declined with increasing depth from the average of 10.0 °C at 10 m depth in the water column to 7.0 °C at 50 m, 6.0 °C at 100 m, and 4.8 °C at 400 m (Figure 2b-d).

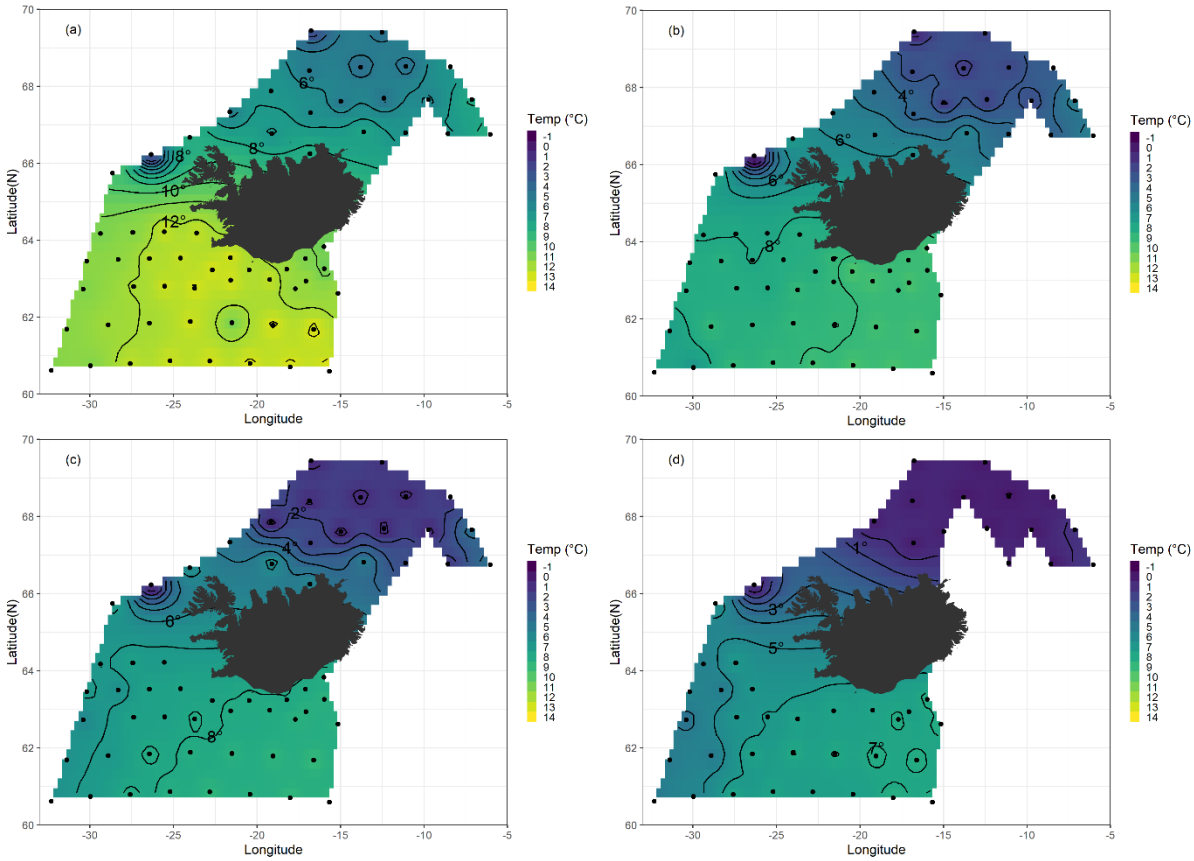

Figure 2. Ambient temperature at 10 m (a), 50 m (b), 100 m (c), and 400 m (d) depth using CTD data collected by R/V Árni Friðriksson in July 2019. Also displayed sampling station location (solid black circle). Same temperature scale used for all panels.

3.2 Mesozooplankton

Mesozooplankton density, as indicated by dry weight, ranged from 0.6 g*m^{-2} to 25.9 g*m^{-2} and the highest density was on the shelf north and south of Iceland (Figure 3). In 2019, for the entire survey coverage, average zooplankton dry weight was 7.2 g*m^{-2} which is 40% lower than the average in 2018, which was 12.0 g*m^{-2} (Ólafsdóttir and Jónsson, 2019). In strata west and offshore south of Iceland density was 2-3x higher in 2018 compared to 2019. However, a decline was not observed in all areas with density being similar in the north and on the shelf to the south of Iceland between 2018 and in 2019.

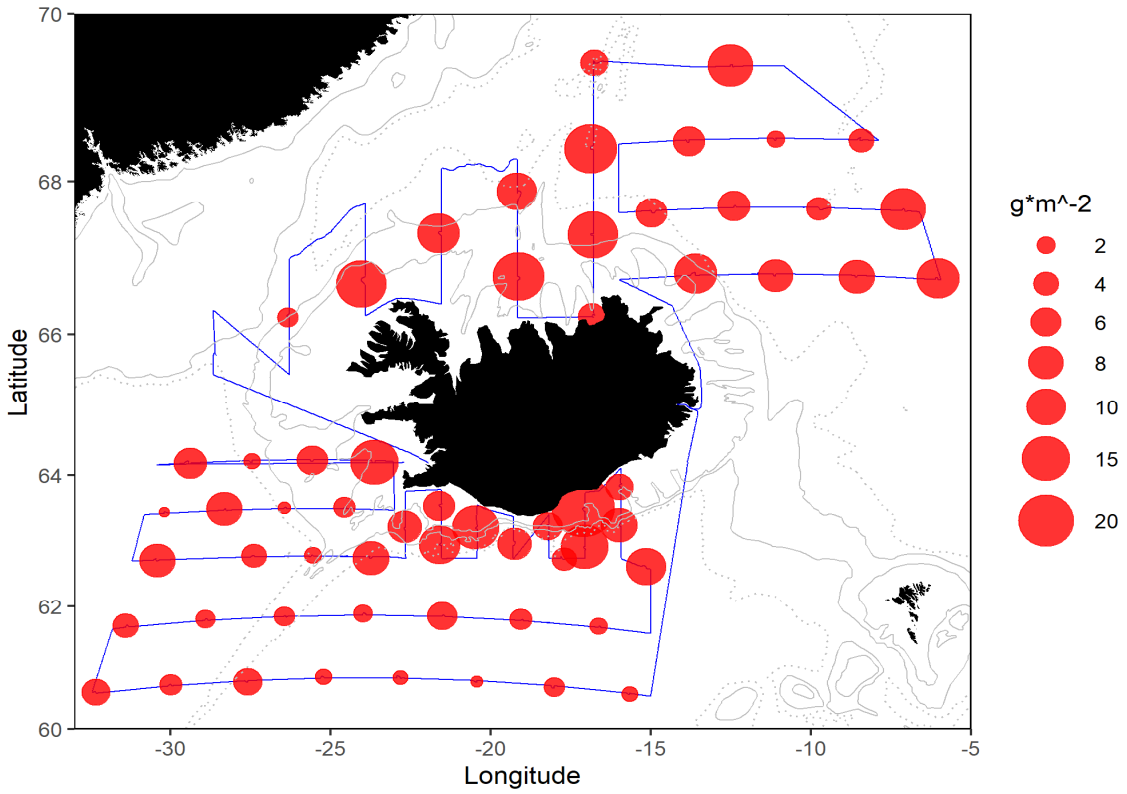

Figure 3. Zooplankton density at surface to 200 m depth, or to bottom when bottom depth was < 200 m, sampled by R/V Árni Friðriksson in July 2019. Survey track (blue line) and depth contours displayed for 200 m (grey solid line), 500 m (grey solid line), and 1000 m (grey broken line).

3.3 Mackerel

Mackerel was caught at 29 of 61 (48%) of predetermined surface trawl stations and the catch per station ranged from < 1 kg to 9 846 kg (Figure 4). The total weight of mackerel caught was 37 982 kg (Table 4). The largest catches were on the shelf and the shelf edge south and southwest of Iceland. Mackerel density in the west stratum was similar between 2018 and 2019, while it was approximately double in the south inshore stratum in 2019 compared to 2018. North of Iceland and on the southernmost transect south of Iceland not a single

specimen was caught establishing mackerel zero boundary in outskirts of the IESSNS area covered by R/V Árni Friðriksson. No mackerel abundance estimate from predetermined surface trawl catches was made in the current report and readers are referred to the 2019 IESSNS post cruise report (ICES, 2019).

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). However, temperature alone cannot fully explain the distribution of mackerel in the survey area as the surface mixed layer north of Iceland was >7°C and was >9°C in the offshore area south and west of Iceland yet mackerel was absent from these areas. 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.

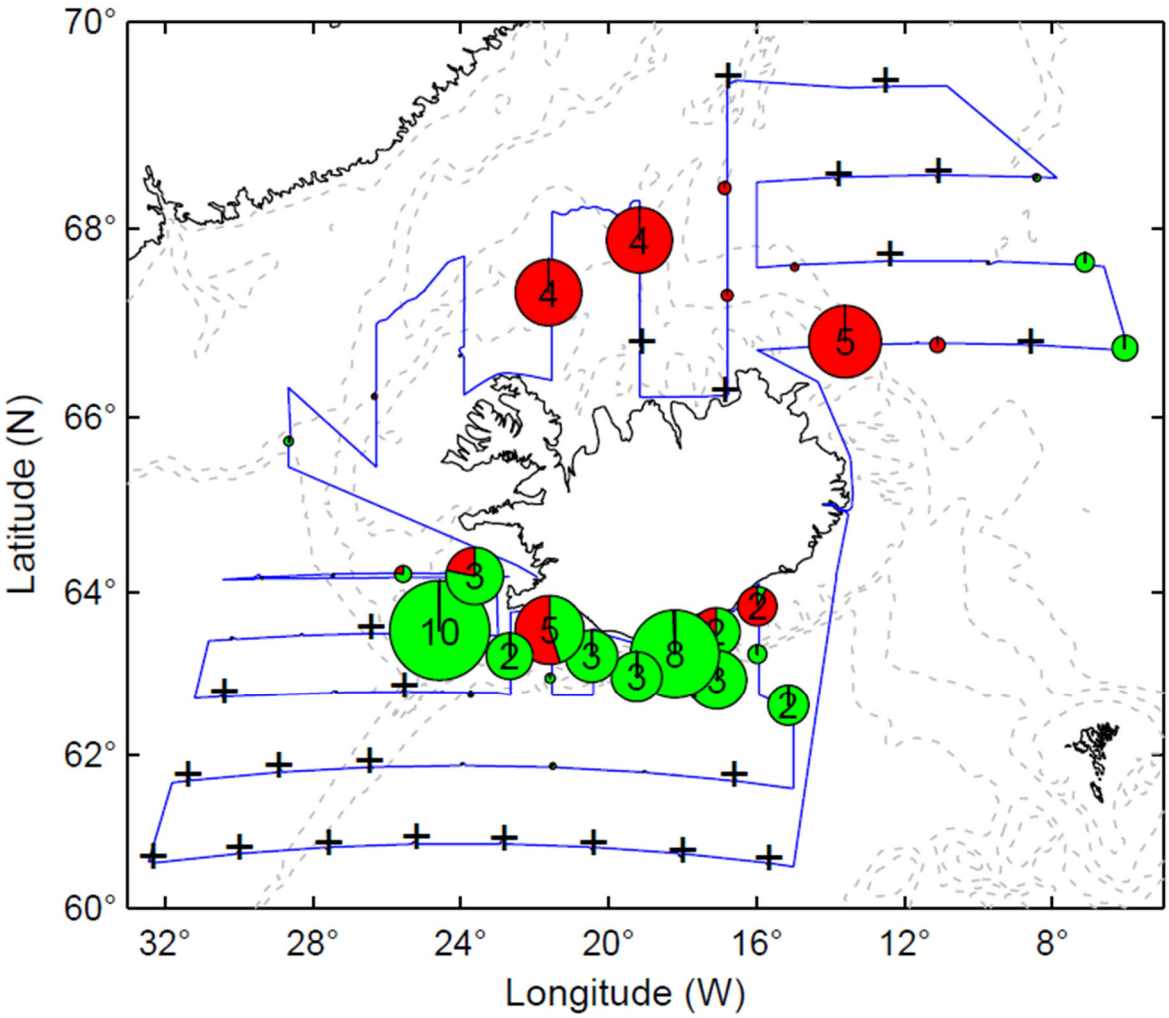

Figure 4. Mackerel (green) and herring (red) catch (tons) at predetermined surface trawl stations sampled by R/V Árni Friðriksson in July 2019. Displayed is catch in tonnes (circles), zero catch (+), the survey track (blue line), and the 200 m, 500 m, and 1000 m depth contours (grey broken lines).

Mackerel length distribution ranged from 32 – 43 cm and was slightly different between strata. Smaller specimens were caught inshore south of Iceland, peak length of 37 cm, compared to the east and west strata, peak length 38 cm (Figure 5a). Length distributions in the north and south offshore stratum should be interpreted with caution as only 1 sample and 2 samples were measured, respectively. Weight-at-length was also similar between strata.

Comparing mackerel length, by strata, between years suggests mackerel caught in 2019 was on average shorter in the south and longer in the west compared to 2018.

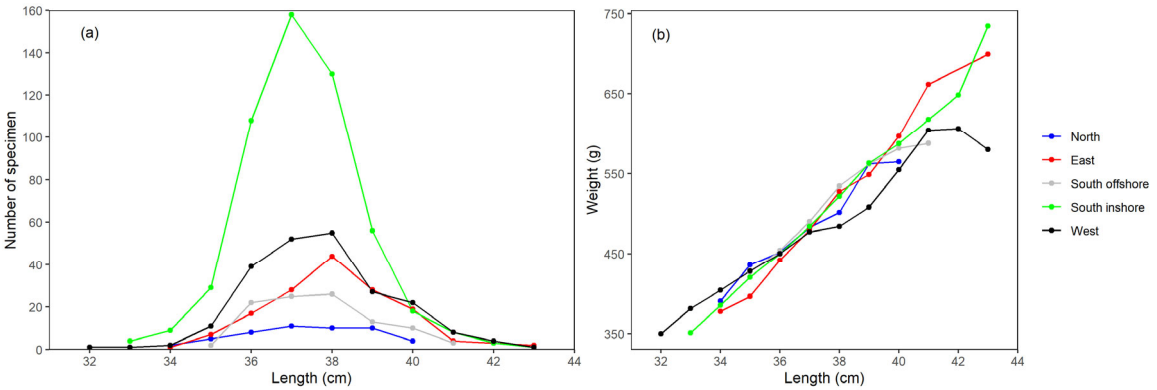

Figure 5. Mackerel numbers of specimen per 1-cm total length bin (a) and mean weight-at-length (b) for five different strata as measured from predetermined surface trawl stations sampled by R/V Árni Friðriksson in July 2019. Boundary of the different strata are displayed in figure 1.

3.4 Herring

According to acoustic recordings, herring was distributed on the shelf along the south of Iceland and this was also the area with the highest density of herring (Figure 6). Northwest, north, and northeast of Iceland, herring was distributed both over the shelf and the shelf edge into deeper waters. Herring was recorded for 741 nmi along the survey track. Herring was distributed in similar areas in 2019 compared to 2018, with the exception that herring were recorded north and west of the Westfjords in 2019 but not in 2018. No herring abundance estimate from acoustical measurements is made in the current report and readers are referred to the 2019 IESSNS post cruise report (ICES, 2019).

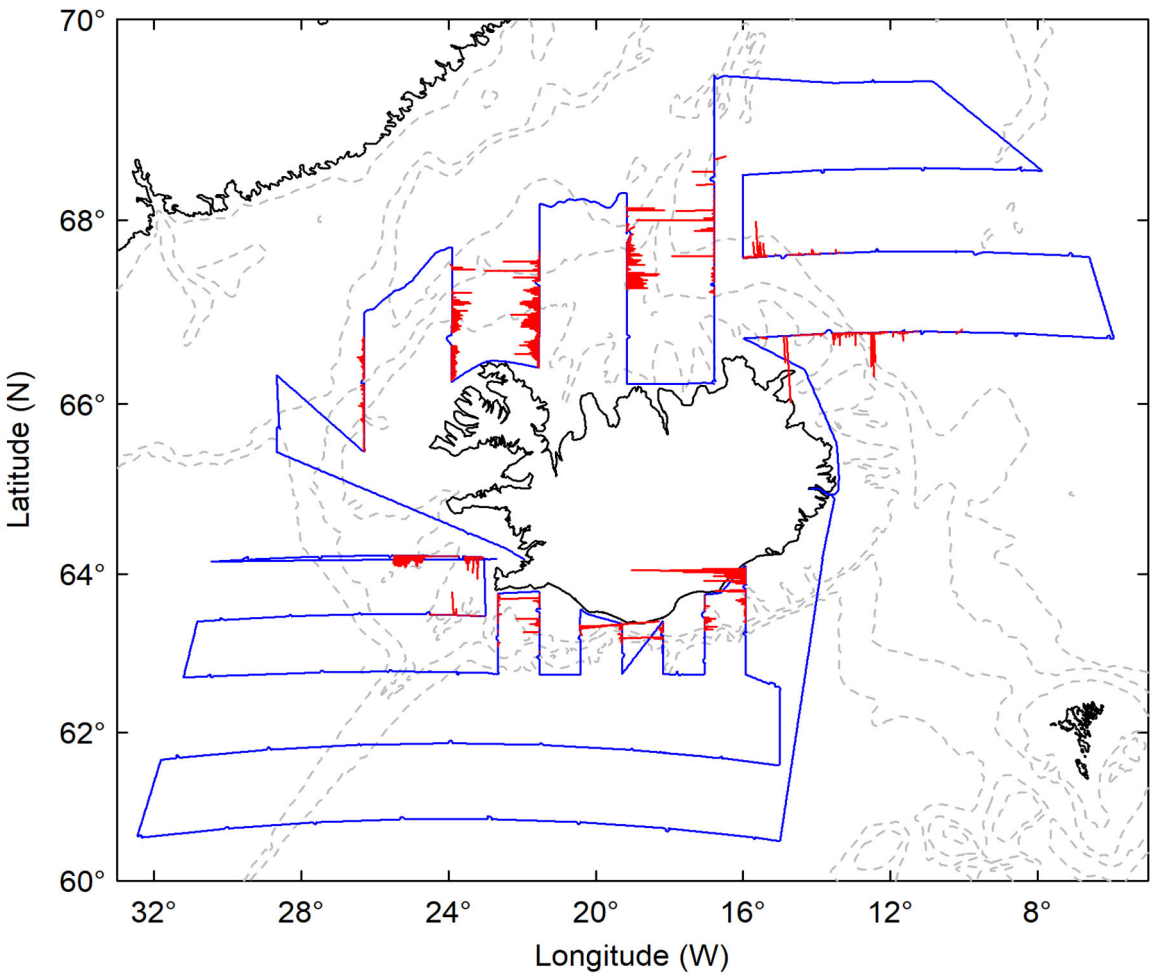

Figure 6. Herring acoustic backscatter values (log10 of sA: red bars) as measured on R/V Árni Friðriksson in July 2019. Survey track (solid blue line) also displayed. sA-values for "1 nmi horizontal by 10 m vertical" backscatter bins ranged from 0 to 35 179 with 0.4% of sA-values > 1000. For display purposes, all sA-values > 1000 were binned into one category with a sA-value = 1000.

Comparing herring density measured using acoustic registration and surface trawling (Figure 4) 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. ISSH spawn at this time of the year, and therefore they have a patchy distribution and are often distributed closer to the bottom instead of being in the surface mixed layer where the trawling occurs (0-35m). The NSSH is feeding during the survey period, is more evenly distributed horizontally and mostly located in the surface mixed layer.

Herring was present from the surface to 180 m depth (Figure 7). Herring was recorded in the upper 60 m of the water column during every hour of the day with the highest density between 20 m – 40 m, and in the afternoon compared to other times of day. There is a trend

of herring presence deeper in the water column during the afternoon and the evening, from noon to 11 pm, compared to other times of day. It must be noted that the depth is relative to the transducer, which is mounted on a drop keel at ~8 m depth.

Comparing herring vertical distribution in 2019 to 2018 reveals a shallower distribution pattern in 2019 when limited amount of herring is recorded between 100 – 200 m depth compared to 2018. We cannot explain annual variability in vertical distribution without more detailed analysis which is outside the scope of the current report.

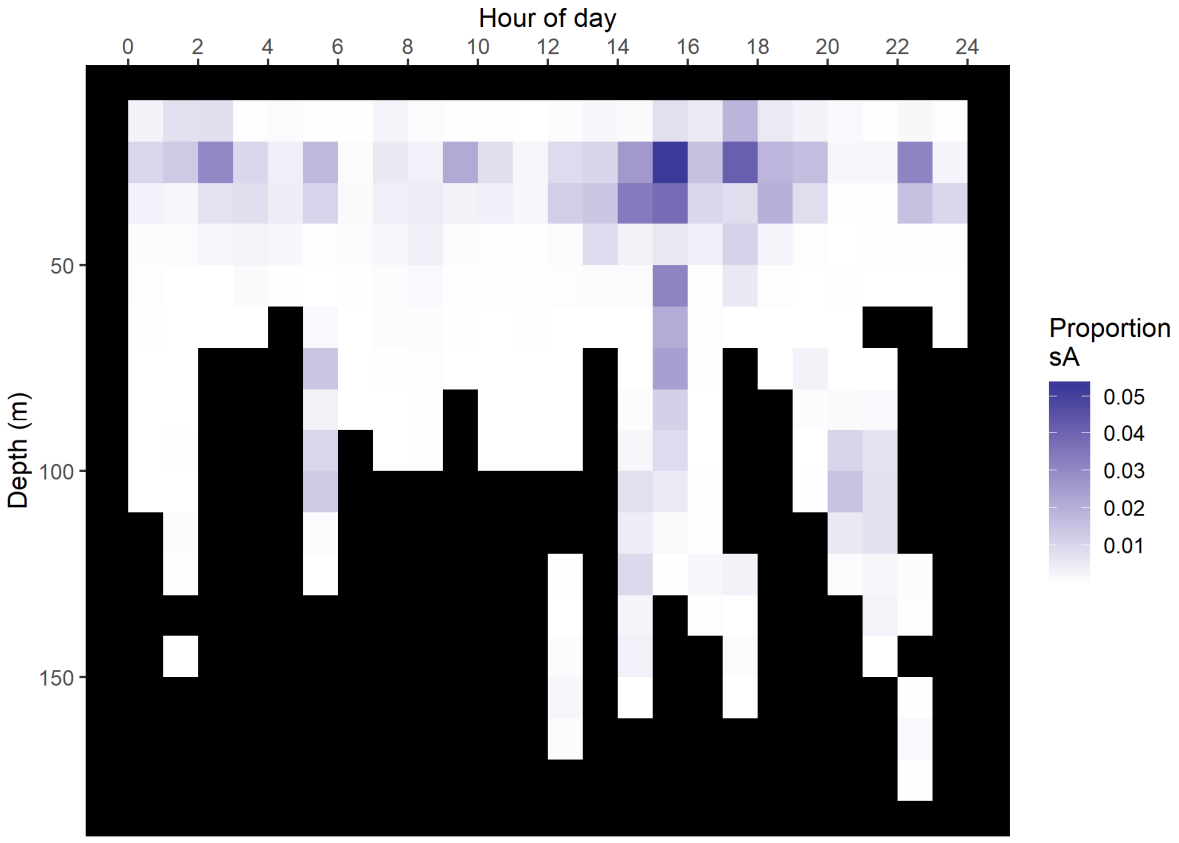

Figure 7. Proportion of herring backscatter by depth (10 m vertical bin) and by time of day (1-hour bin) as measured on R/V Árni Friðriksson in July 2019. Depth-hour bins with no herring registration are coloured black. sA-values for "1 nmi horizontal by 10 m vertical" backscatter bins ranged from 0 to 35 179 with 0.4% of sA-values > 1000. For display purposes, all sA-values > 1000 were binned into one category with a sA-value = 1000.

Herring length ranged from 16 cm to 40 cm, and the most common length was 36-37 cm (Figure 8). In comparison to 2018, peak length was similar between years however more small herring were caught in 2019, no herring < 27 cm was caught in 2018.

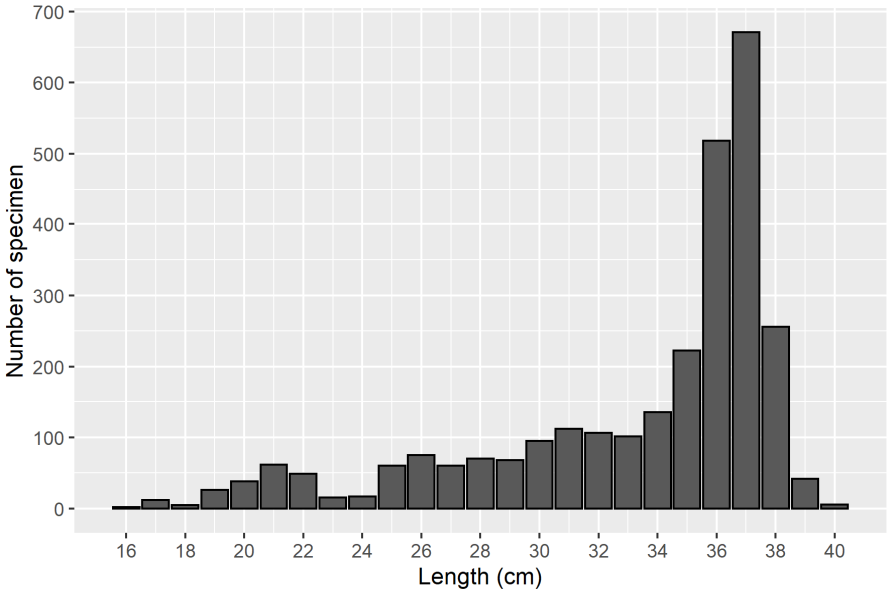

Figure 8. Herring length distribution from all trawl stations sampled by R/V Árni Friðriksson in July 2019.

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 separated by location 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.

3.5 Blue whiting

As of 2019, blue whiting has been a target species of IESSNS for four consecutive years. Acoustic registrations and deep-water trawling indicate that blue whiting was present in the Norwegian Sea and on the shelf edge south of Iceland (Figure 9). Surprisingly, no blue whiting was recorded west of Iceland where it was located during the 2018 survey (Ólafsdóttir and Jónsson, 2019; ICES 2019). Fewer blue whiting registrations were recorded in 2019 compared to 2018 with registrations recorded for 219 nmi along the survey track in 2019 compared to 848 nmi in 2018. No blue whiting abundance estimate from acoustical measurements is made in this report and referred to the 2019 IESSNS post cruise report (ICES, 2019).

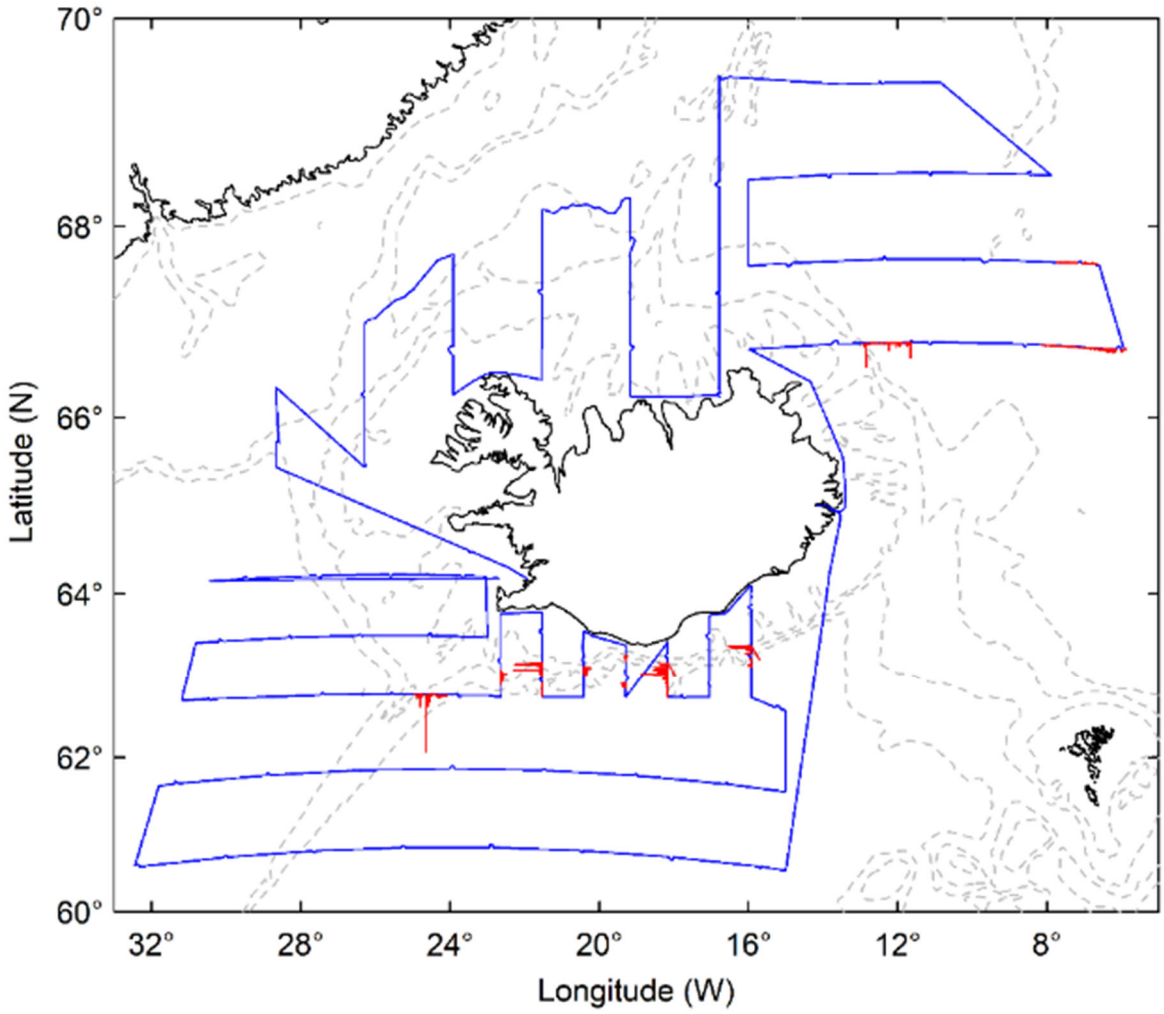

Figure 9. Blue whiting acoustic backscatter values (sa: red bars) as measured on R/V Árni Friðriksson in July 2019. Survey track (solid blue line) also displayed.

Blue whiting registrations ranged from 50 m to 480 m depth (Figure 10). Majority of registrations were recorded during the day, 8 am to 5 pm, and at depths below 300 m. Blue whiting registrations were lower during the late evening and night, 10 pm to 4 am, compared to other times of the day. Blue whiting vertical distribution, during large part of the day, was bimodal with no recordings between ~170 m – 300 m depth. Major difference in blue whiting vertical and time-of-day distribution in 2019 compared to previous year were limited registrations during evening and night, and lack of blue whiting registrations at intermediate depths (~170 – 300 m) during day. Relatively low number of registrations in 2019 probably contributed to the observed annual differences. Number of blue whiting registrations calculated per “hour-of-day–depth” bin was 2 947 in 2019 which is 20% of the 14 521 bins in 2018.

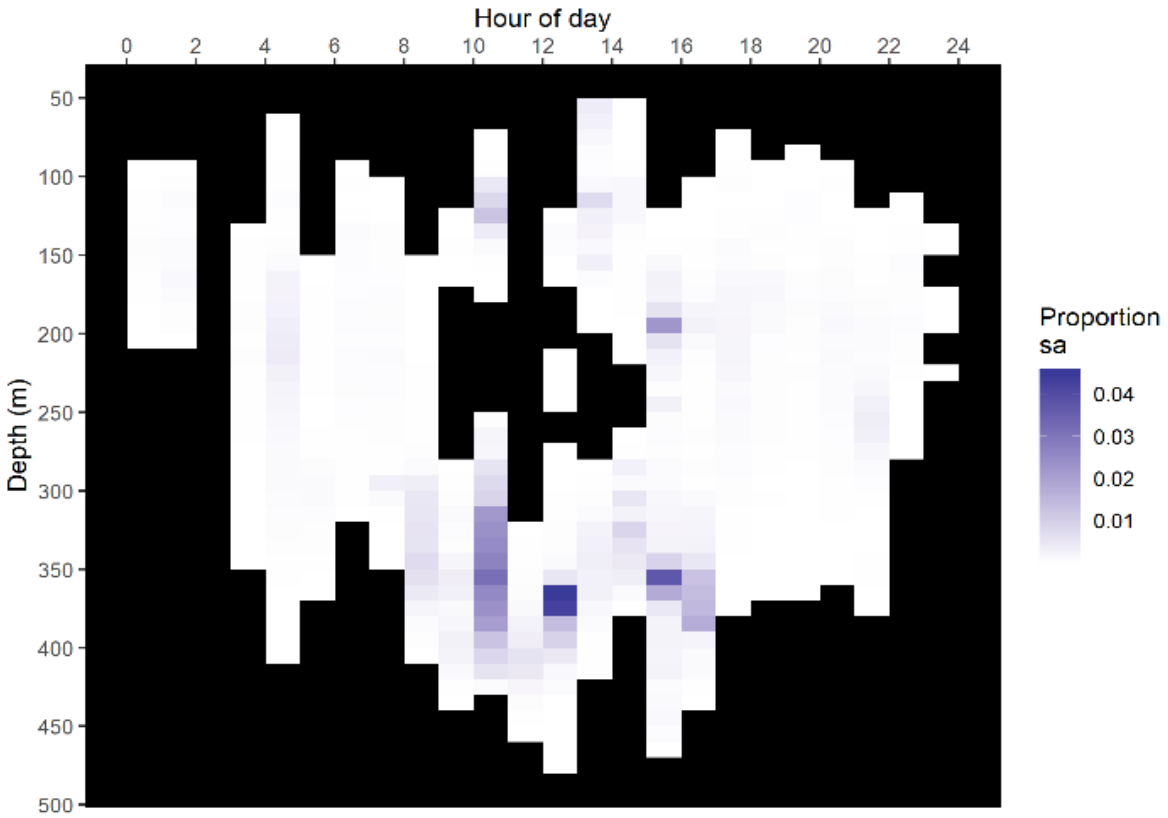

Figure 10. Proportion of blue whiting backscatter by depth (10 m vertical bin) and by time of day (1-hour bin) as measured on R/V Árni Friðriksson in July 2019. Depth-hour bins with no blue whiting registration are coloured black.

Blue whiting total length in trawl catches was bimodal and range from 7 cm to 14 cm and from 23 cm to 35 cm, and the most common length was 28-30 cm (Figure 11). Compared to 2018, the peak length range was the same and more small fish was caught in 2019, minimum length 2018 was 27 cm.

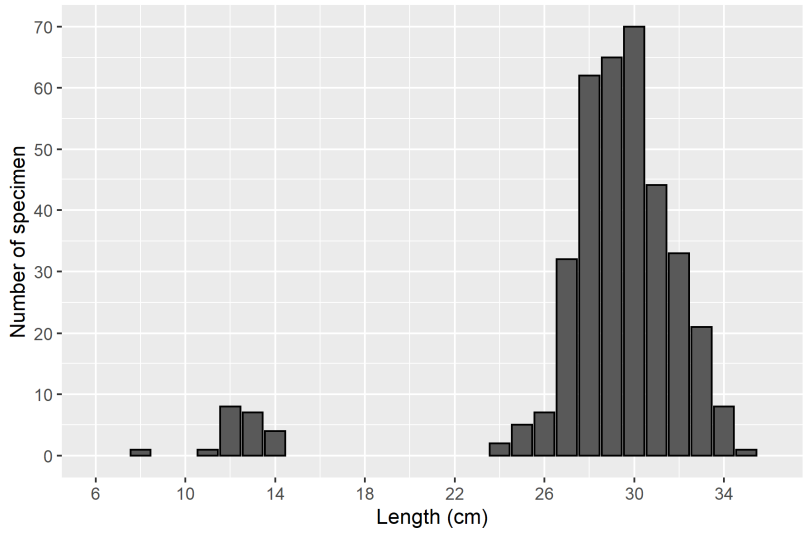

Figure 11. Blue whiting total length distribution from all trawl stations sampled by R/V Árni Friðriksson in July 2019.

3.6 Lumpfish

Lumpfish was caught at 36 of the 61 predetermined surface trawl stations and was caught in the whole survey area except offshore south of Iceland (Figure 12). Catch per station ranged from < 1 kg to 29 kg and the average was 9 kg. Highest catches were northeast of Iceland. Compared to 2018, lumpfish was caught at fewer stations (59 % versus 76 %), the average catch per station was 3 kg higher, and much less was caught on the shelf south and west of Iceland.

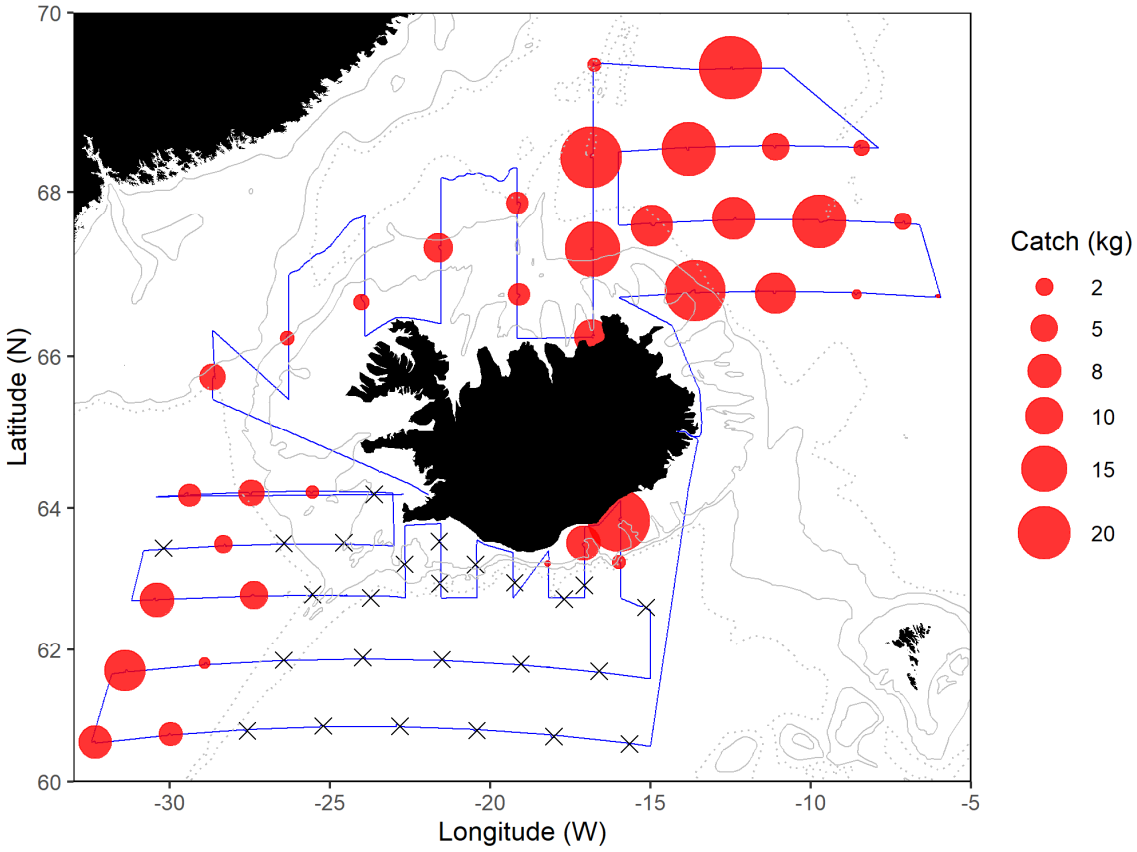

Figure 12. Lumpfish catch at predetermined surface trawl stations on R/V Árni Friðriksson in July 2019. Stations with no lumpfish caught are specifically labelled (black cross). Survey track (solid blue line) and depth contours displayed for 200m (grey line), 500 (grey line), and 1000m depth (dashed grey line).

3.7 Various research projects

3.7.1 Tagging of live lumpfish

Live lumpfish was caught at 34 of 61 predetermined surface trawl stations. A total of 217 lumpfish were tagged and released (Figure 13). The tagged fish range in size from 13 cm to 46 cm with majority of individuals ranging in length from 20 cm to 30 cm (Figure 13).

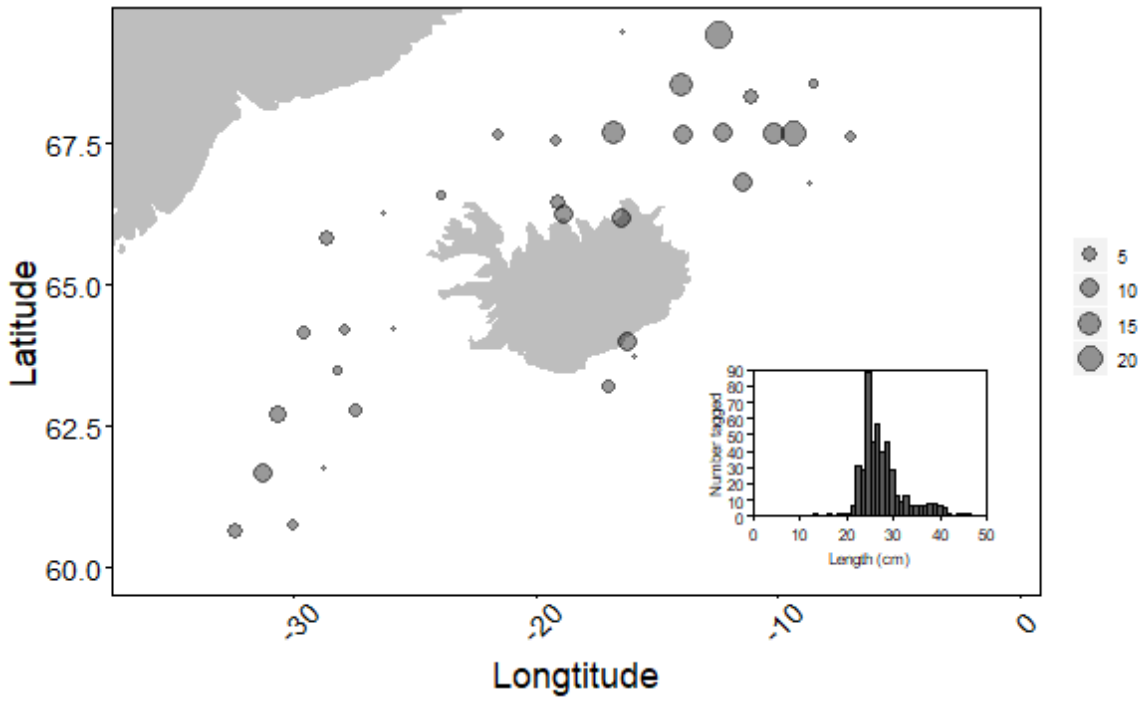

Figure 13. Number and location of lumpfish tagged and released at predetermined surface trawl stations on R/V Árni Friðriksson in July 2019. Size distribution of tagged lumpfish is shown.

3.7.2 Opportunistic marine mammal observations

Marine mammals were sighted on 22 occasions (Figure 14). Eight species of whales and dolphins were identified, and four sightings could not be identified to species and where labelled as unidentified small toothed whale or dolphin. The identified species were Atlantic white-beaked dolphins (*Lagenorhynchus albirostris*), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), pilot whale (*Globicephala melas*), sei whale (*Balaenoptera borealis*), and sperm whale (*Physeter marcocephalus*). Pilot whales and unidentified small toothed whales were spotted in pods of several dozen animals. For other species number of animals per sighting ranged from one to six.

Compared to 2018, five fewer mammal sightings were recorded, three new species were observed (blue whale, sei whale and mink whale), and one species was not seen (killer whale). Sighting distribution also varied between years with fewer whale sightings offshore south of Iceland and on the shelf edge around the Westfjords, and with more sightings on the shelf north and northeast of Iceland, in 2019 compared to 2018.

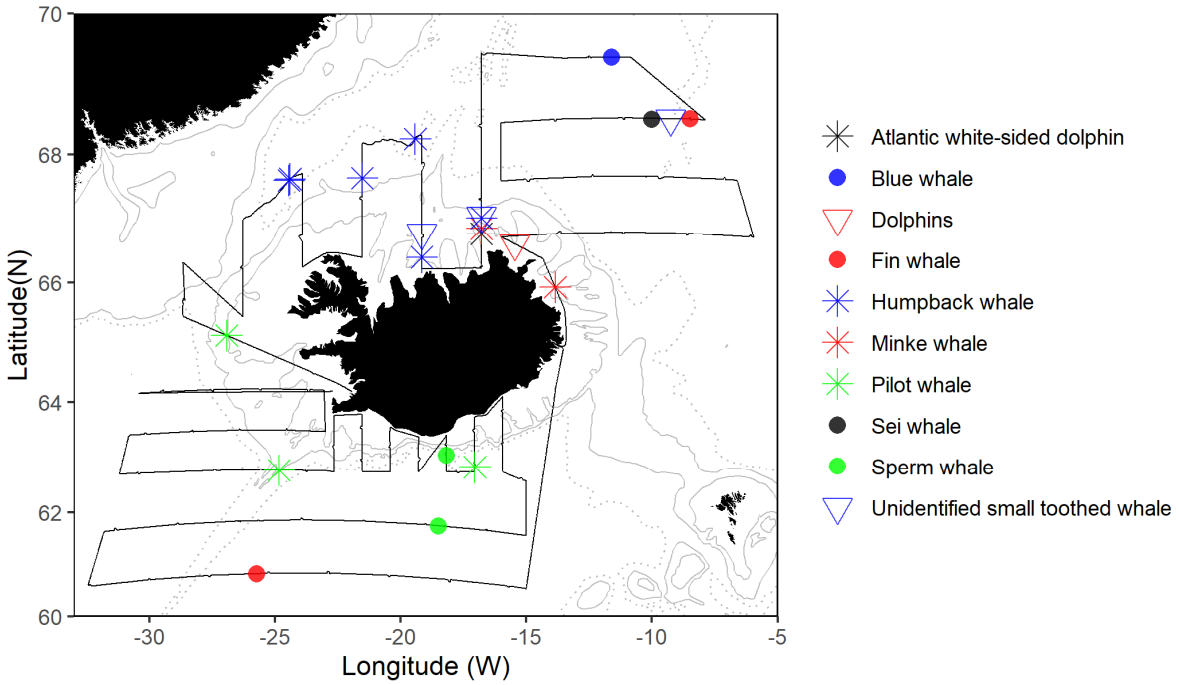

Figure 14. Opportunistic whale and dolphin sighting locations observed on R/V Árni Friðriksson in July 2019. Pilot whales and unidentified small toothed whales were spotted in pods of several dozen animals. Other species sighted ranged from 1 to 6 individuals. Depth contours displayed for 200m (grey line), 500 (grey line), and 1000m depth (dashed grey line).

Figure 15. Opportunistic whale and dolphin sighting locations observed on R/V Árni Friðriksson in July 2019. Pilot whales and unidentified small toothed whales were spotted in pods of several dozen animals. Other species sighted ranged from 1 to 6 individuals. Depth contours displayed for 200m (grey line), 500 (grey line), and 1000m depth (dashed grey line).

4. Acknowledgements

I wish to thank survey participants and the crew of R/V Árni Friðriksson for their dedication to sampling for the many diverse research projects. Furthermore, I am grateful to Kristín Valsdóttir, Sigrún Jóhannsdóttir, Alice Benoit-Cattin, Magnús Daníelsson, Hildur Pétursdóttir, Brynjólfur Már Þorsteinsson, and Bárður Jón Grímsson for their help during survey preparation, sample analyses, uploading of data to centralized data base and for data quality checking. Finally, I like to express my thanks to James Kennedy for his detailed and constructive review of the report.

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6. Tables

Table 1. Sampling effort of predetermined surface trawl stations per strata on R/V Árni Friðriksson in July 2019.

Stratum name (stratum number)	Station interval (nmi)	Number of stations
IS-south shallow (6)	35	10
IS-south deep (12)	70	17
IS-east (3)	60	12
IS-north (4)	65	10
IS-west (5)	50	12

Table 2. Descriptive statistics for trawl operation during predetermined surface trawl stations on R/V Árni Friðriksson in July 2019.

Trawl descriptor	Average (min – max / st.dev)	Number stations included in average
Trawl door horizontal spread (m)	103 (91 – 116 / 7)	60
Vertical trawl opening (m)	35 (27 – 41 / 2)	61
Horizontal trawl opening (m)*	59	60
Speed over ground (nmi)	4.9 (4.1 – 5.2 / 0.2)	61
Turn radius (degree)**	5	na
Trawl door depth (m)	(4 – 21 and 4 – 17)	60
Headline depth (m)***	0 (0 – 0 / 0)	61

*Calculated using trawl door horizontal spread and trawling speed, see equation in ICES (2019).
**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 2019.

Station type	Iceland west (5)	Iceland north (4)	Iceland east (3)	Iceland south shallow (6)	Iceland south deep (12)	*Total*
(a) Standard IESSNS sampling						
Predetermined surface trawl	12	10	12	10	17	*61*
Deep water trawl	1	0	3	1	3	*8*
CTD*	13	11	13	11	17	*65*
WP-2	11+	10	12	10	17	*60*
(b) Additional research projects						
MAC, HER and WHB stomachs & somatic condition**	4 MAC, 1 HER, 1 WHB	1 MAC, 3 HER	2 MAC, 4 HER, 2 WHB	3 MAC, 3 HER, 2 WHB	3 MAC, 1 HER	*13 MAC, 12 HER, 5 WHB*
Tag lumpfish***	6 (21)	10 (56)	11 (107)	3(14)	4(19)	*34 (217)*
eDNA	4	5	6	4s	8	*27*
Froze mesopelagic fish and invertebrates^	2	0	3	2	6	*13*
MAC and WHB for microplastic research^^	0	0	2 (20)	3 (20)	0	*5 (40)*
Herring hearts frozen	0	0	0	8	3	*11*
0-group capelin	1	4	2	0	1	*8*
Capelin > 14 cm^^	0	4 (12)	2 (24)	0	0	*6 (36)*
DNA from ISSH stock^^	5 (21)	0	0	6 (13)	0	*11 (34)*
Total‡	*55*	*54*	*66*	*58*	*76*	*339*

‡Trawl hauls, CTD, and WP2 stations share the same station number in the database.

*Nutrients and chlorophyll water samples collected at all CTD stations.

**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.

^For H2020 project SUMMER and for species identification by MFRI specialists.

^^Number of specimens sampled in brackets.

+WP-2 not collected at 1 station due to high winds.

Table 4. Overview of the different species caught and measured in the Multpelt832 trawl, including predetermined surface stations and deep trawl stations by R/V Árni Friðriksson in July 2019. Target species displayed in bold.

Species name in Icelandic, English, and Latin in brackets	Species id.*	Species NO**	Length measured (N)	Aged (N)	Maturity stage (N)	Catch (kg)
Ýsa, haddock (*Melanogrammus aeglefinus*)	HAD	2	1	0	0	1.0
Skötuselur, monkfish (*Lophius piscatorius*)	MON	14	21	0	0	0.6
Síld, herring (*Clupea harengus*)	**HER**	**830, 30**	**2825**	**884**	**897**	**20092.2**
Loðna, capelin (*Mallotus villosus*)	CAP	31	387^	0	0	1.0
Kolmunni, blue whiting (*Micromesistius poutassou*)	**WHB**	**34**	**371**	**213**	**200**	**254.2**
Makríll, mackerel (*Scomber scombrus*)	**MAC**	**36**	**2787**	**552**	**1051**	**37981.6**
Blágóma, Northern wolffish (*Anarhichas denticulatus*)	CAB	47	6	0	0	1.6
Hrognkelsi, lump fish (*Cyclopterus lumpus*)	**LUM**	**48**	**261**	**0**	**17**	**307.0**
Ískóð, polar cod (Boreogadus saida)	POC	71	53	0	0	0.9
Urrari, grey gurnard (*Eutrigla gurnardus*)	GUG	99	3	0	0	1.7
Sæsteinsuga, sea lamprey (*Petromyzon marinus*)	LAU	176	2	0	0	0.7
Marglytta, jellyfish (*Rhopilema spp*)	JEL	180	0	0	0	152.0
Langalaxsíld, patchwork lampfish (*Notoscopelus kroeyerii*)	LAX	204	50	0	0	7.6
Lax, salmon (*Salmo salar*)	SAL	210	1	0	0	1.4
Stóra geirsíli, lancet fish (*Paralepis coregonoides*)	PIR	141	72	0	0	4.9
Spærlingur, Norway pout (*Trisopterus esmarki*)	NOP	33	0	0	0	0.1
Litla geirsíli, white barracudina (*Arctozenius rissoi*)	ARZ	123	32	0	0	2.5
Svarthveðnir, blackfish (*Centrolophus niger*)	BKF	151	10	0	0	14.8
Laxsíld ógreind, lanternfishes (unidentified family *Myctophidae*)	LXX	75	50	0	0	0.4
Brúnalaxsíld, rakery beaconlamp/lanternfish (*Lampanyctus macdonaldi*)	LYO	243	20	0	0	5.3
Smokkfiskur ógreint, unidentified Cephalopod	CEP	44	342	0	0	11.3
Rauða sævesla, silver/arctic rockling (*Gaidropsarus argentatus*)	GDT	88	90	0	0	0.5
Síli (unidentified *Ammodytes* spp.)	SAN	301	50^^	0	0	< 0.1
Grand Total			**7434**	**1649**	**2205**	**58843.3**

* See in: http://www.ices.dk/datacentre/reco/reco.asp.

**In the Icelandic MFRI central database.

^361 specimens were 0-group and not weighted.

^^all 0-group and not weighted.

7. Annex

Annex 1. Participants in the IESSNS onboard R/V Árni Friðriksson in July 2019.

3 - 15 July	**15 - 29 July**
Scientific staff:	
Agnar M. Sigurðsson, plankton and biol. sampling	Agnes Eydal, plankton and biol. samples
Anna Heiða Ólafsdóttir, cruise leader, acoustics	Anna Heiða Ólafsdóttir, cruise leader, acoustics
Björn Sigurðarson, acoustics, technology	Arnþór B. Kristjánsson, acoustics, technology
Freyr Arnaldsson, plankton and biol. samples	Jóhann Á. Gíslason, plankton and biol. samples
James Kennedy, acoustics and tagging	Páll B. Valgeirsson, plankton and biol. samples
Sigurlína Gunnarsdóttir, plankton and biol. samples	Ragnhildur Ólafsdóttir, plankton and biol. samples
Sólrún Sigurgeirsdóttir, plankton and biol. samples	Tomas Didrikas, acoustics, mesopelagic fish
Captain:	
Heimir Örn Hafsteinsson	Ingvi Friðriksson

HAFRANNSÓKNASTOFNUN

Rannsókna- og ráðgjafarstofnun hafs og vatna