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Results of the Icelandic part of the International Ecosystem Summer Survey in Nordic Seas (IESSNS) in 2018 on R/V Árni Friðriksson

Anna H. Ólafsdóttir and Sigurður þ. Jónsson

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Haf- og vatnarannsóknir
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Höfundur: Anna Heiða Ólafsdóttir og Sigurður Þór Jónsson

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Ágrip

Hafrannsóknastofnun hefur tekið þátt í alþjóðlegum sumaruppsjávarleiðangri í norðaustur Atlantshafi árlega síðan 2010. Leiðangurinn er skipulagður af vinnuhóp innan Alþjóðahafrannsóknaráðsins og önnur þáttökulönd eru: Noregur, Færeyjar, Grænland og Evrópusambandið. Sumarið 2018 þá var íslenski hluti leiðangursins farinn dagana 2.júlí til 2.ágúst á rannsóknaskipinu Árna Friðrikssyni. Rannsóknasvæðið var íslenska landhelgin, að undanskildum suðaustur hlutanum, svæði við Jan Mayen og alþjóðlegt hafsvæði í Noregshafi. Sigldar voru 6146 sjómílur og 259 stöðvar voru teknar.

Tilgangur leiðangursins er vistkerfisvöktun á uppsjónum, frá yfirborð niður á 500 m dýpi, þar sem næringarefni, frumframleiðni, hitastig, selta, birtustig, áta, magn og útbreiðsla markríls, kolmunna og síldar er mæld ásamt skráningum á hvölum. Magn og útbreiðsla makríls er mæld með stöðluðum yfirborðstogum á meðan kolmunni og síld eru mæld með bergmálsaðferð. Að auki er safnað sýnum fyrir ýmis rannsóknaverkefni eftir þörfum stofunarinnar og erlendra samstarfsaðila. Þar má nefna merkingar á hrognkelsum, söfnum umhverfiserfðasýna, söfnum á fisklirfum, og söfnum á fiskum og hryggleysingum úr miðsjávarlaginu.

Helstu niðurstöður leiðangursins er aldursgreind vísitala fyrir makríl sem notuð er í stofnmati, upplýsingar um útbreiðslu uppsjávarfiska að sumri, vöktun á umhverfis-aðstæðum, frumframleiðni og dýrasvifi. Kolmunna- og síldarvísitölur eru enn ekki notaðar í stofnmat en verða vonandi í framtíðinni þegar gagnaraðirnar verða orðnar lengri.

Heildaraflamagn makríls minnkaði mikið samanborið við fyrri ár og var einungis 32 % af heildaraflamagni 2017. Það voru merkt 253 hrognkelsi og skráðar voru 6 tegundir af hvölum.

Abstract

The Marine and Freshwater Research Institute (MFRI) has participated in the International Summer Survey in Nordic Seas (IESSNS) every summer since 2010. IESSNS is governed by ICES Working Group of International Pelagic Surveys and other participating nations are Norway, Faroe Islands, Greenland and the European Union. In summer of 2018, the Icelandic part of IESSNS was conducted from July 2nd to August 2nd on R/V Árni Friðriksson. The survey area

was the Icelandic exclusive economic zone, excluding the southeast part, and waters south of Jan Mayen and in the Norwegian Sea. The survey transects were 6146 nautical miles and a total of 259 stations were sampled.

The aim of IESSNS is to monitor the pelagic ecosystem, from surface to 500 m depth. The monitoring includes measurements of nutrients, primary production, temperature, salinity, ambient light, zooplankton, abundance and geographical distribution of mackerel, blue whiting and herring. Whale sightings are also recorded. Abundance and distribution of mackerel is measured using standardized surface trawling while blue whiting and herring are measured using acoustic methods. Furthermore, samples are collected for various research projects at MFRI and for collaborators, such sampling included tagging of live lumpfish, collection of environmental DNA, sampling of fish larvae and mesopelagic fish and mesopelagic invertebrates.

IESSNS major results include age-segregated abundance index for mackerel that is used for stock assessment by ICES. Furthermore, information on summer feeding distribution of pelagic stocks, annual changes in environmental condition, primary production, and in zooplankton communities. Blue whiting and herring index is not yet included in stock assessment which is the future aim.

Total catch of mackerel declined greatly, the catch in 2018 was only 32 % of the catch in 2017. 253 lumpfish were tagged, and six species of whales were recorded.

Lykilorð: *Makríll, kolmunni, síld, stofnmæling, útbreiðsla, áta, hitastig, sumaruppsjávarleiðangur. Mackerel, blue whiting, herring, stock index, geographical distribution, zooplankton, temperature, ecosystem summer survey*

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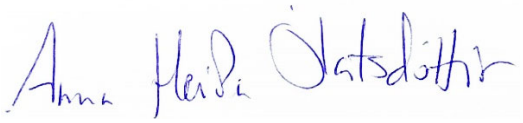	

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1. Introduction

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). 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. Additionally, samples are collected for various research projects.

IESSNS provides various data that are used in different ways. The survey provides age-segregated abundance index for mackerel that is used as tuning series in the analytical stock assessment, along with other survey and fishery data, within ICES Working Group on Widely Distributed Stocks (WGWIDE). The acoustical data provide information about distribution and quantity of herring and blue whiting, and the resulting age-segregated indices might become applicable later for stock assessment as the time-series gets longer. Hydrographical and zooplankton measurements are a long-term monitoring on the state of pelagic ecosystem during summer in the Northeast Atlantic.

This survey was first conducted in 2007 by two vessels from Institute of Marine Research (IMR) in Bergen, Norway, and annually from 2010 when 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 the European Union in 2018. Geographical coverage of the survey expanded as more nations joined from being limited to the Norwegian Sea in 2007, expanding to the west coast of Iceland in 2010, the east coast of Greenland to Cape Farewell in 2013, and the North Sea in 2018. In recent years, the survey coverage has been approximately 3 million km^2 of the Northeast Atlantic. Expansion of the survey was to follow the range expansion of mackerel 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 was until 2015 mainly determined by the mackerel distribution, but also to some degree by the distribution of NSSH. Thus, the

surveys have been considered to cover most of the mackerel and NSSH stocks while feeding in the NE-Atlantic in the summers since 2010. Since 2016 the objective of the surveys has also been to cover the summer distribution of blue whiting, which involved a slightly more survey coverage, southward to latitude 60 °N in the area south of Iceland, and dedicated trawling on acoustic registrations at greater depths 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-August 2018 included seven of thirteen IESSNS strata. Survey planning includes determining location of swept area surface trawl stations and survey transects for acoustic measurements. Stratified systematic transect design with random starting point within each stratum, and a distance that is nominally the same between all predetermined surface trawl stations and between all transects within each stratum. The distance is decided based on mackerel distribution and abundance in previous years, and available survey time (Table 1). Distance between stations is described as nominally the same as transects and stations cannot be equidistant using the current survey planning statistical method. 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 right 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 trawl Multpelt832, specifically design for the IESSNS, is employed according to a standardized IESSNS protocol (ICES, 2015). It is towed for 30 minutes at the speed of 5 nmi and turning the vessel 5° – 10° creating a “banana” shaped tow track. IESSNS participants would like to replace the “banana” tow with a straight tow where the vessel sails directly forward during towing. To replace “banana” shape tows with straight tows, catchability of the two trawl methods must be compared. Therefore, seven stations were selected for comparison towing where a straight tow was conducted directly after the “banana” tow.

R/V Árni Friðriksson departed from Reykjavik at 14 pm on the 2nd July and headed to the area northwest of Iceland (stratum 4) where the first station was taken. The survey then continued clockwise around Iceland. On July 17, crew change was in Reyðafjörður, a village on the east

coast of Iceland. The vessel arrived in Reyðafjörður at 9:30 and departed at 14:00, headed south to stratum south offshore, and continued from there westward. The vessel arrived in Reykjavik at noon on August 2nd. The total distance covered during these 32 days was 6146 nautical miles and 259 stations were sampled. The weather was calm for most of the survey excluding two days, including eight hours in the western stratum when all work was put on hold due to high winds. Fog was common in the survey area north of Iceland.

Samples were collected for six research projects at MFRI and for one project at IMR. Sampling for research projects expanded compared to previous years, and included tagging of live lumpfish, collection of environmental DNA (eDNA), sampling of mackerel gonads, registration of whale sightings, collection of mesopelagic fish and invertebrates from deep trawls, and sampling of fish larvae from surface to 100m. All sampling was executed according to plan and no transects were shortened due to zero mackerel catch for the first time. As in 2017, survey participants blogged about the research and life onboard (https://pelagicecosystemsurvey.wordpress.com/).

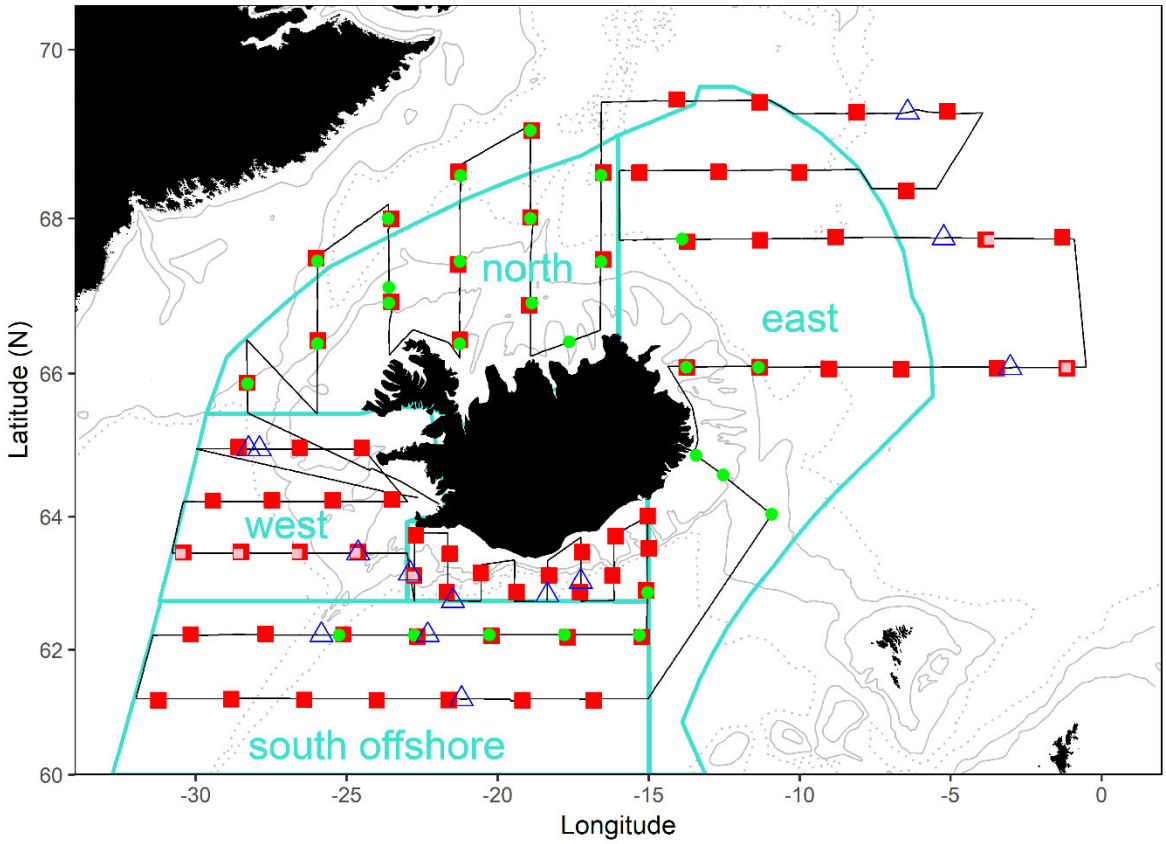


Figure 1. Predetermined surface trawl stations, including CTD and WP2-net (filled red rectangle), comparison surface trawling (filled pink rectangle), deep trawling on acoustic registrations (open blue triangle), and MIK net (filled green circle) stations stations sampled by R/V Árni Friðriksson in July and August 2018. 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.

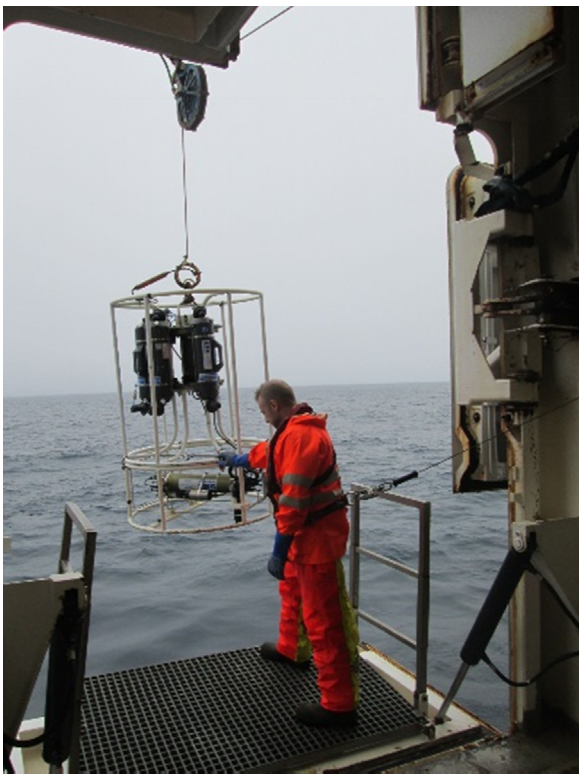
2.2 Acoustic and trawl sampling

Acoustic scatters were recorded continuously down to 500 m depth using a Simrad EK60 echosounder on four frequencies (18-38-120-200kHz). Data collected at 38 kHz were post-processed using the LSSS software (version 2.1) with a plankton sieve threshold of -72dB. The remaining echoes were then stored in their respective categories (categories used: herring, blue whiting and capelin) as 1 nautical mile s_A averages. Acoustic instruments and settings on R/V Árni Friðriksson are described in detail in Table 2. Sampling depth was from 15 m to 500 m. Dedicated trawl sampling on potential blue whiting acoustic registrations was executed at 13 stations. Trawl catch composition were used for species identification of acoustic registrations and for providing length distributions of fish targets. The echosounder was calibrated in April 2018.

The trawl hauled on deck with several tons of herring. Photo A.H. Ólafsdóttir.

The main trawl sampling was in the surface with a 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 Table 3. A total of 71 standardized surface hauls were conducted at the predefined IESSNS stations (Table 4). All tows were considered of appropriate quality, and thereby applicable for abundance estimation, both with respect to the trawl settings and to trawl operation. The total catch per all species and measurements per species is given in Table 5.

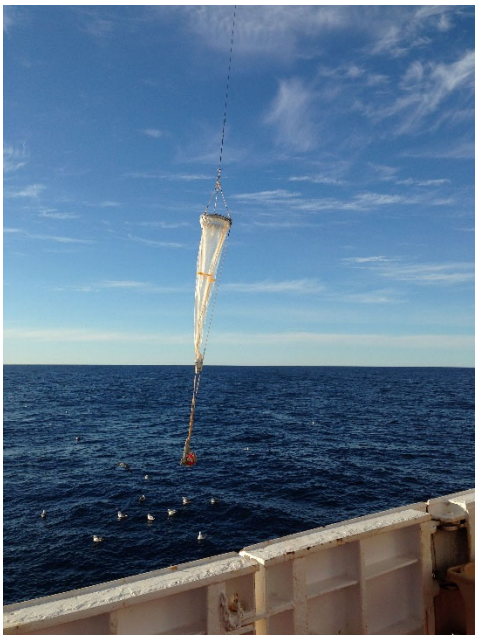
2.3 Sampling of hydrographic and plankton data



Guðmundur Svafarsson employs the CTD profiler. Photo A.H. Ólafsdóttir.

Hydrographic and plankton data was collected at all predetermined surface trawl stations, except plankton data was not sampled at one station 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 500m, for calibrating the salinity measurements, and at 50, 20, and surface, for calibrating chlorophyll measurements and to measure nutrient concentrations. A total of 73 CTD stations were taken, including two stations specifically in connection with MIK-net sampling.

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



WP2-net. Photo 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 primary production (chlorophyll).

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. 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 this survey report. During the survey a total of 164 mackerel, 97 herring, and 143 blue whiting stomachs were sampled. Sampling of stomachs is a part MFRI monitoring of the pelagic ecosystem during the summer feeding season.

Mackerel stomachs. Photo A.H. Ólafsdóttir.

2.4.2 Environmental DNA (eDNA)

eDNA samples were collected at 26 predetermined surface trawl stations (Table 5). At each eDNA station one litre of sea was filtered from five different depths: 0m, 20m, 50m, 200m, and 500m. The sampling was for a research project coordinated by Dr. Christophe Pampoulie

at MFRI. The samples will be analysed later in a laboratory on land and the results are not presented in the current report.

2.4.3 Tagging of live lumpfish

All lumpfish caught alive and longer than approximately 15 cm were tagged, with a plastic tag in the dorsal fin, and released. Maximum number tagged per station was 30 individuals. Tagging was done for a research project coordinated by Dr. James Kennedy at MFRI.

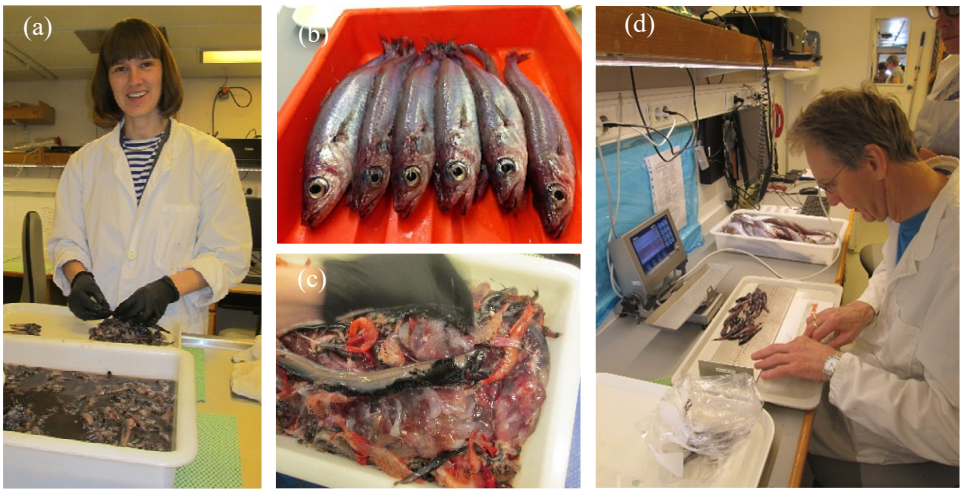
A tagged lumpfish. Photo J. Kennedy.

2.4.4 Mackerel gonads

Gonads were collected from mackerel females at predetermined surface trawl station. In each stratum 20 samples were collected and in total 100 samples. Sampling was done for a research project coordinated by Dr. Thassya C. dos Santos Schmidt at IMR, Bergen, Norway. The samples were shipped to Norway for analyses and the results are not presented in the current report.

2.4.5 Sampling of the mesopelagic layer

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. Sampling was done for an EU-funded Horizon 2020 project (SUMMER) which Dr. Christophe Pampoulie and Dr. Anna Ólafsdóttir at MFRI participate in. The samples will be analysed in a laboratory ashore later and the results are not published in the current report.



Catch from a mesopelagic trawl sample. Guðrún Finnbogadóttir identifies myxtopics to species (a), blue whiting (b), unsorted mesopelagic catch (c), Jóhann Gíslason measures myxtopics (d). Photo A.H. Ólafsdóttir.

2.4.6 Fish larvae

A midwater ring net (MIK; ICES, 2013), was used to sample fish larvae at selected stations located at predetermined surface stations or on acoustic transects. The MIK had an opening diameter of 2 m, the net was black and 13 m long with 2 mm meshes. A flowmeter was attached to the MIK opening. At each station, the MIK was hauled oblique from approximately 100 m depth to the surface at the speed of ~3 knots. Capelin larvae were sorted from the sample and stored in 70 % ethanol and other organisms were stored in 4 % buffered formalin. MIK-net samples were collected at 23 predetermined surface trawl stations and 4 location along the survey track, while other 24 planned trawl hauls on predetermined surface trawl stations had to be suspended as both MIK-nets were damaged. The samples will be analysed in MFRI laboratory later and the results are not published in the current report. The MIK sampling was done for MFRI project number "US10611_2017" which is coordinated Björn Gunnarsson at MFRI.

MIK-net sampling. The MIK-net hauled onboard (a). Sigurlína Gunnarsdóttir detaches the fish larvae bucked from the MIK-net (b). Sigurlína identifies the fish larvae to species (c). The MIK-net catch (d). Photo J. Kennedy.

2.4.7 Opportunistic marine mammal observations

For the first 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 in the IESSNS.

2.4.8 Parasite infection in Icelandic summer spawning herring

It is standard procedure on pelagic surveys conducted by MFRI to monitor parasite infection rates of the Icelandic summer-spawning herring stock by collecting the hearts from sampled herring. Icelandic summer-spawning herring were caught at ten trawl stations and 50 hearts frozen at each station. The samples will be analysed in MFRI laboratory later and the results are not published in the current report. Project coordinator is Dr. Guðmundur J. Óskarsson at MFRI.

3. Results

3.1 Hydrography

Sea surface temperature, at 10m depth, in 2018 ranged from -0.7°C to 11.7°C (Figure 2a-d). Surface temperature was below 7°C in most of the area north of Iceland and above in 7°C other strata. Mackerel presence is unlikely, but possible, in temperatures lower than 7°C (Olafsdottir *et al.*, 2018). Not a single mackerel was caught in the north stratum which was likely caused by the unusually cold waters in the area, compared to previous years.

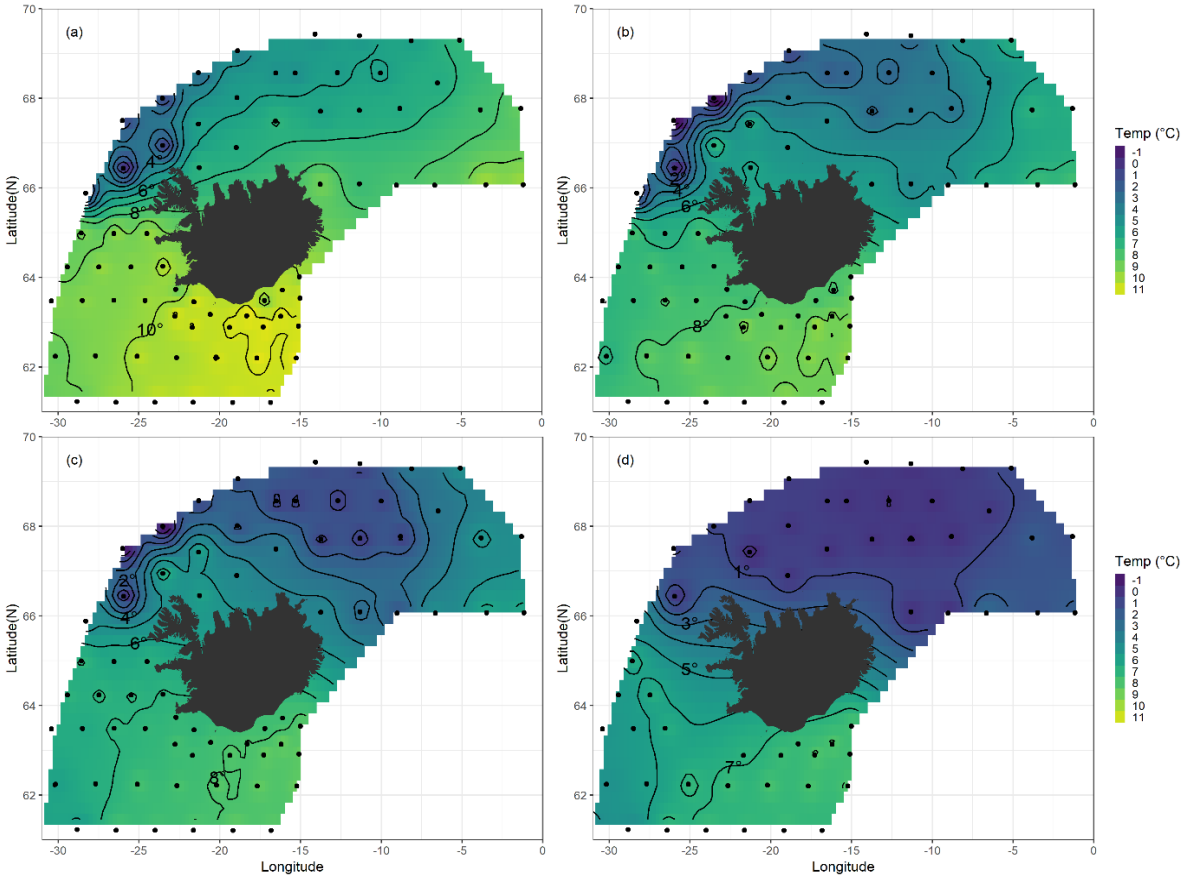


Figure 2. Ambient temperature at 10 m (a), 50 m (b), 100 m (c), and 400 m (d) depth using CTD data collected by R/V Árni Friðriksson in July and August 2018. Also displayed sampling station location (black solid circle). Same temperature scale used for all panels.

For the whole survey area, the average temperature at 10m depth was 0.9°C lower in 2018 compared to 2017. Average temperature difference between the two years declined with depth and was 0.9°C at 20m, 0.8°C at 30m, and 0.4°C at 40m.

3.2 Zooplankton

Zooplankton density, as indicated by dry weight, ranged from 1.6 g*m^{-2} to 48.7 g*m^{-2}. The highest density was in the Norwegian Sea, then in the Irminger Sea and off the shelf north of Iceland (Figure 3). Average zooplankton dry weight was 12.0 g*m^{-2} in 2018 compared to 10.1 g m^{-2} in 2017 and was among the highest annual averages recorded since 2010 (ICES, 2018a).

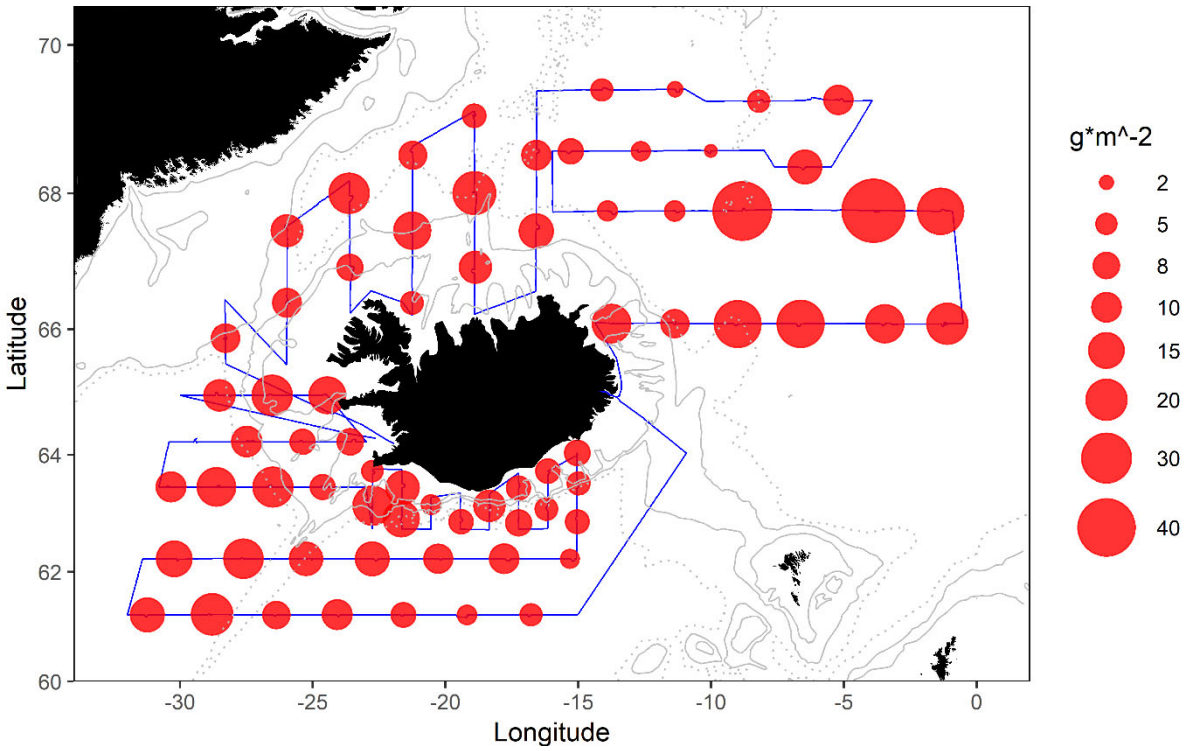


Figure 3. Zooplankton density at surface to 200 m depth, or to bottom when bottom depth was < 200 m, sampled by R/V Árni Friðriksson in July and August 2018. Survey track (blue line) and depth contours displayed for 200 m (grey solid line), 500 m (grey solid line), and 1000 m (grey broken line).

3.4 Mackerel

Mackerel was caught at 49 of 71 (70%) of predetermined surface trawl stations (Figure 4). Catch per station ranged from < 1 kg to 5311 kg, with a mean of 722 kg. The largest catches were in the Norwegian Sea, west of Iceland, and inshore south of Iceland. Offshore south of Iceland, only a few kg of mackerel was caught per station and not a single specimen was caught in the area north of Iceland. Zero mackerel boundary was established in all outskirts of IESSNS area covered by R/V Árni Friðriksson.

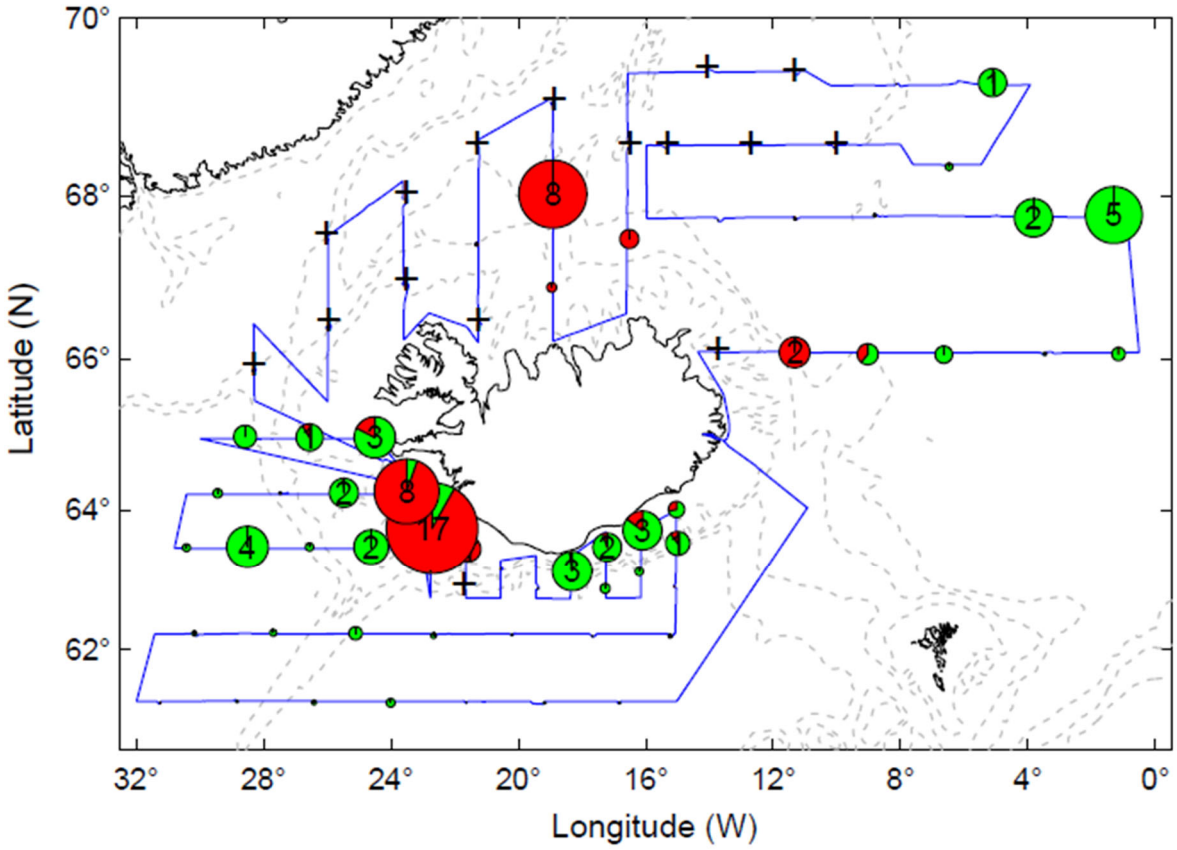


Figure 4. Mackerel (green) and herring (red) catch (tons) at predetermined surface trawl stations sampled by R/V Árni Friðriksson in July and August 2018. Displayed is catch in tonnes (circles), zero catch (+), the survey track (blue line), and the 200 m, 500 m, and 1000 m depth contours (grey broken lines).

Mackerel size distribution was similar in all areas except larger individuals were caught in inshore areas south of Iceland with peak length of 39 cm compared to 36-37 cm in other areas (Figure 5a). Weight-at-length was also similar between areas with two exceptions; lower weight in the west for length interval 35-39 cm, and for larger (37+cm) individuals in the south inshore (Figure 5b).

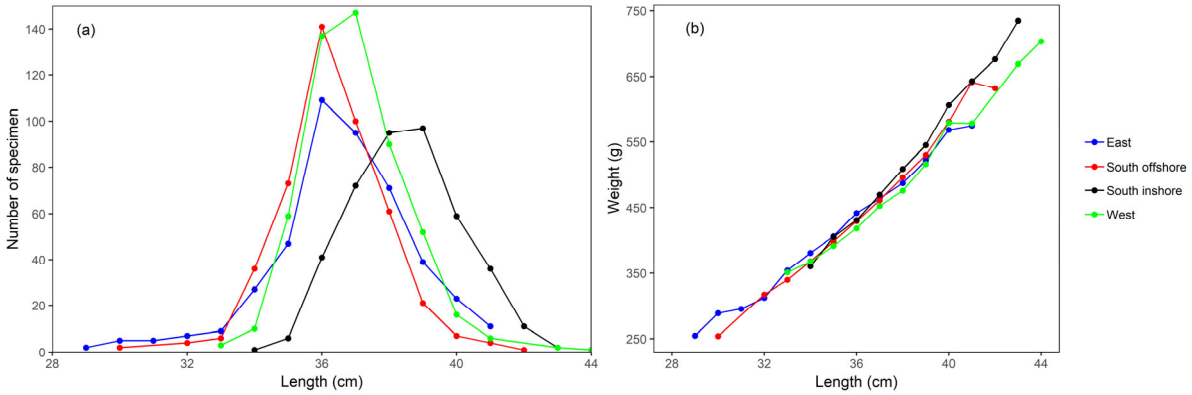


Figure 5. Mackerel numbers of specimen per 1-cm total length bin (a) and mean weight-at-length (b) for four different strata as measured from predetermined surface trawl stations sampled by R/V Árni Friðriksson in July-August 2018. Boundary of the different strata is displayed in figure 1.

No mackerel abundance estimate from predetermined surface trawl catches was made in the current report and referred to the 2018 IESSNS post cruise report (ICES, 2018a).

3.5 Herring

According to acoustic recordings, herring was distributed on the shelf of the west and south coast of Iceland, and offshore northeast and east of Iceland (Figure 6). 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. Herring was present from the surface to 280 m depth. Most of the herring was recorded in the upper 50 m of the water column where it was present during most hours of the day (Figure 7). Herring recordings below 100 m depth were most frequent in the afternoon compared to other hours of the day. It must be noted that the depth is relative to the transducer, which is mounted on a drop keel at ~8 m depth.

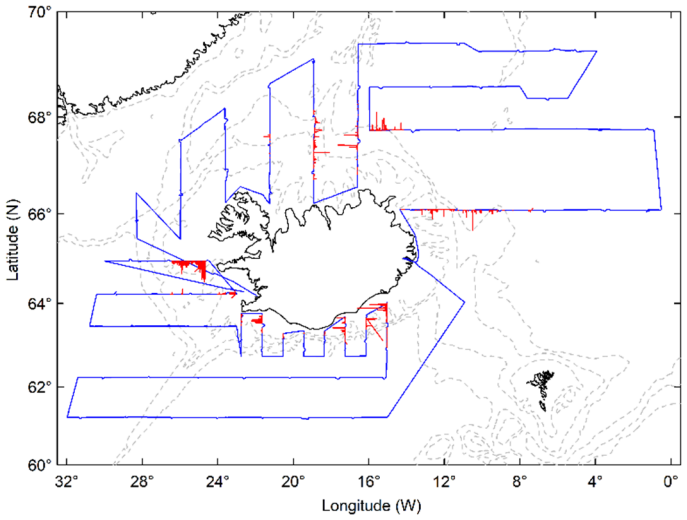


Figure 6. Herring acoustic backscatter values (sa: red bars) and survey track (solid blue line) in measured by R/V Árni Friðriksson in July and August 2018.

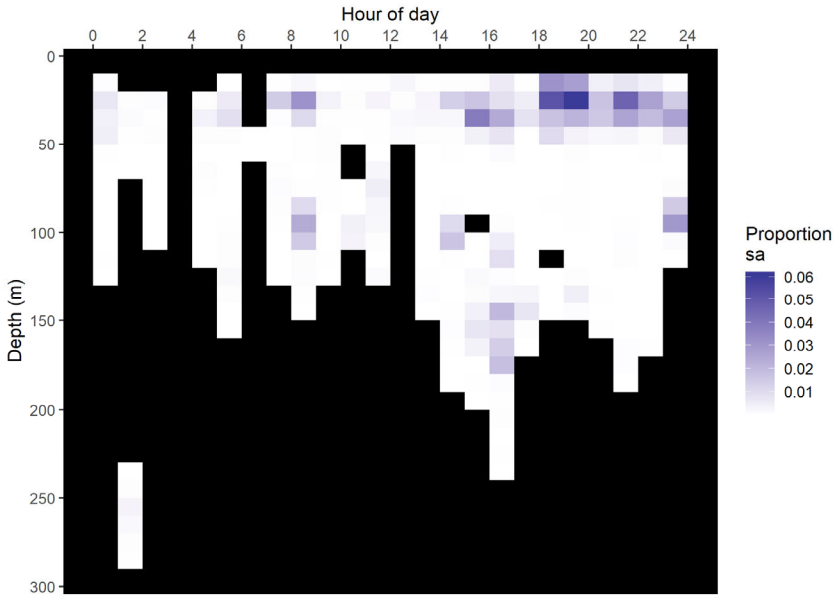


Figure 7. Proportion of herring backscatter by depth (10 m vertical bin) and by time of day (1-hour bin) as measured on R/V Árni Friðriksson in July and August 2018. Depth-hour bins with no herring registration are coloured black.

In the area offshore northeast of Iceland, high herring acoustic registration and high herring trawl catches overlapped. However, the highest acoustic densities did not completely overlap with the largest herring trawl catch. The largest trawl catch was on the shelf southwest of Iceland were acoustic registrations were low. On the shelf west of Iceland, acoustic registrations were high, but trawl catches small. It appears that acoustic registrations and trawl catch match well for NSSH but not for ISSH. This is expected as the ISSH spawns at this time of year and therefore has a patchy distribution whereas the NSSH is feeding and more evenly distributed.

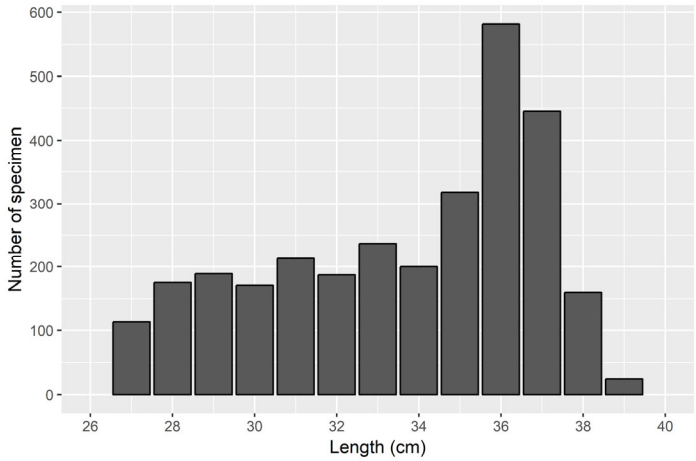


Figure 8. Herring length distribution from all trawl stations sampled by R/V Árni Friðriksson in July and August 2018.

Herring length ranged from 27 cm to 39 cm and the most common length was 35-37 cm (Figure 8).

No herring abundance estimate from acoustical measurements is made in the current report and referred to the 2018 IESSNS post cruise report (ICES, 2018a).

3.6 Blue whiting

Blue whiting was for the third year in a row one of the target species of IESSNS. Acoustic registrations and deep-water trawling indicate that blue whiting was widely distributed in part of the survey area that is dominated by warm Atlantic waters. This was in the Norwegian Sea, and on the shelf edge south and west of Iceland (Figure 9). Blue whiting registrations ranged from surface to 480 m depth and majority of registrations were below 200 m during all hours of the day (Figure 10). It appears that blue whiting moves deeper in the water column as the morning progresses into the afternoon. Blue whiting registrations were noticeably lower during the night compared to other times of the day.

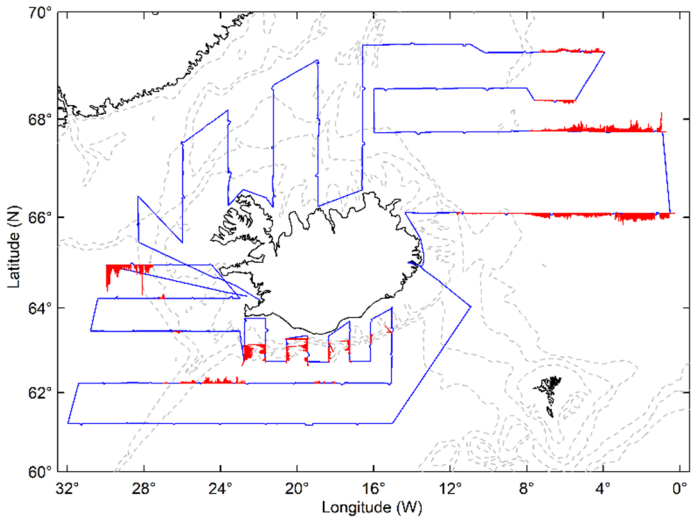


Figure 9. Blue whiting acoustic backscatter values (sa: red bars) and survey track (solid blue line) in measured by R/V Árni Friðriksson in July and August 2018.

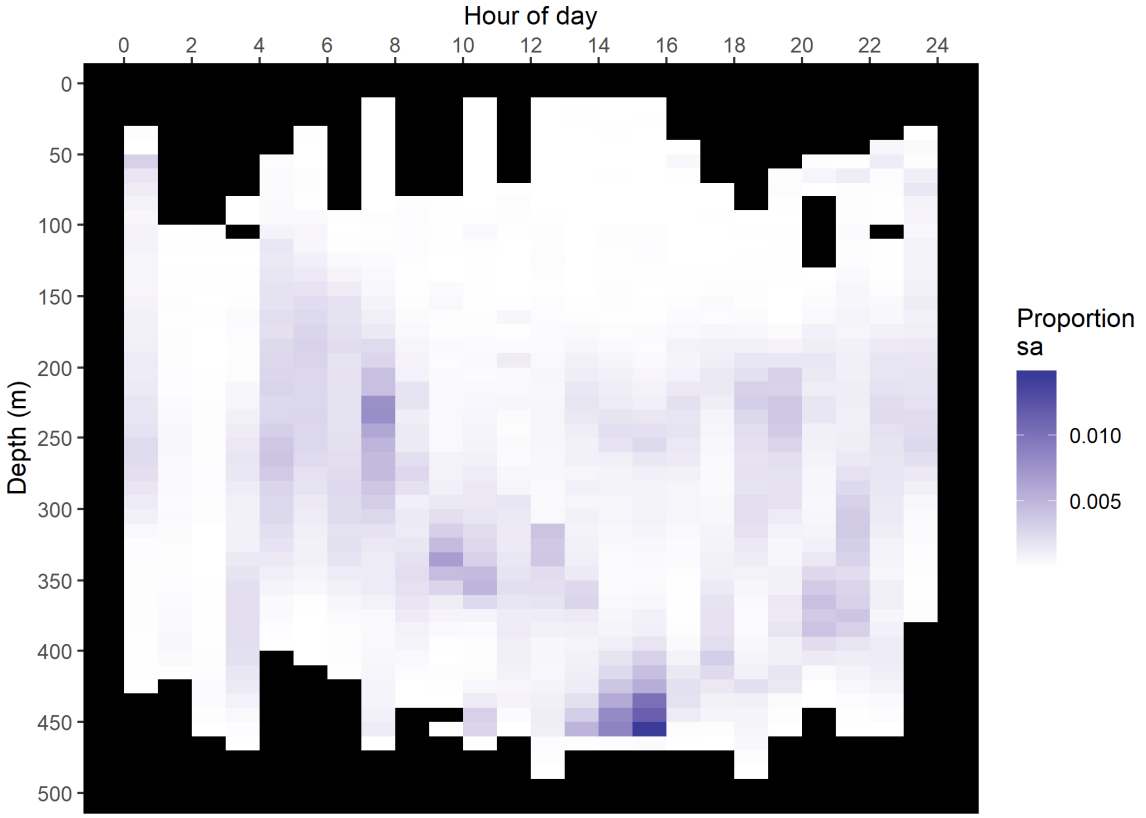


Figure 10. Proportion of blue whiting backscatter by depth (10 m vertical bin) and by time of day (1-hour bin) as measured on R/V Árni Friðriksson in July and August 2018. Depth-hour bins with no blue whiting registration are coloured black.

Blue whiting total length in trawl catches range from 27 cm to 36 cm and the most common length was 28-30 cm (Figure 11).

No blue whiting abundance estimate from acoustical measurements is made in this report and referred to the 2018 IESSNS post cruise report (ICES, 2018a).

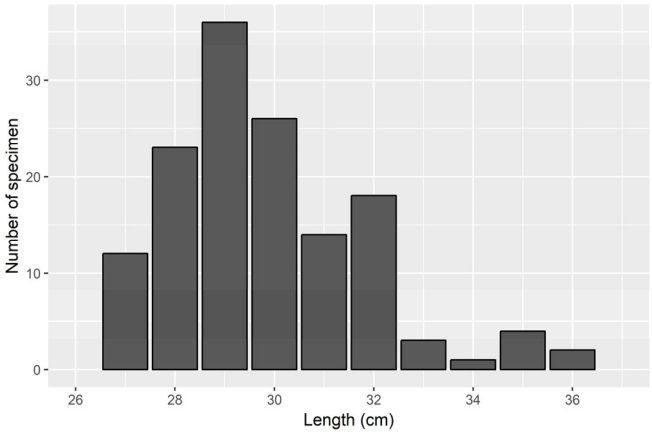


Figure 11. Blue whiting total length distribution from all trawl stations sampled by R/V Árni Friðriksson in July and August 2018.

3.7 Lumpfish

Lumpfish was caught at 54 of the 71 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 26 kg and the average was 6 kg (Table 5). Highest catches were north, northeast and west of Iceland.

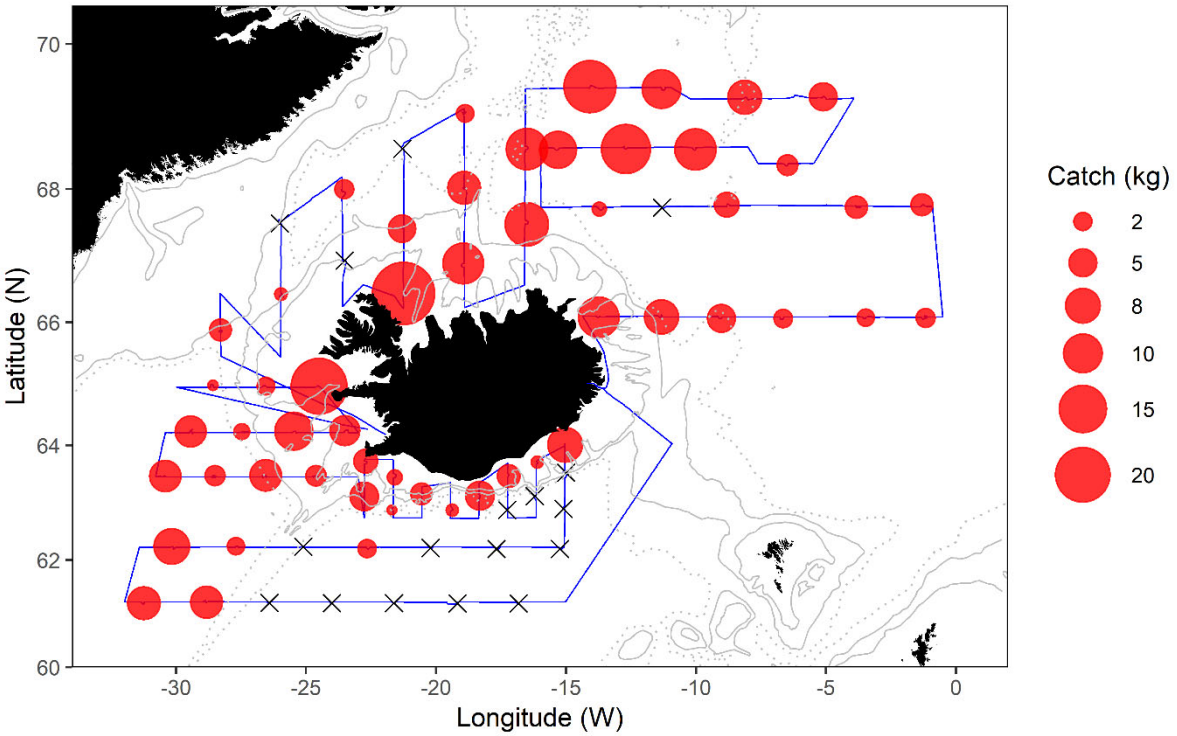


Figure 12. Lumpfish catch at predetermined surface trawl stations on R/V Árni Friðriksson in July and August 2018. Stations with no lumpfish caught are specifically labelled (black cross). Survey track (solid blue line) and depth contours displayed for 200m (grey line), 500 (grey line), and 1000m depth (dashed grey line).

3.7 Various research projects

3.7.1 Tagging of live lumpfish

Live lumpfish was caught at 51 of 71 predetermined surface trawl stations. A total of 253 lumpfish were tagged and released (Figure 13). The tagged fish range in size from 10 cm to 44 cm with majority of individuals ranging in length from 20 cm to 30 cm.

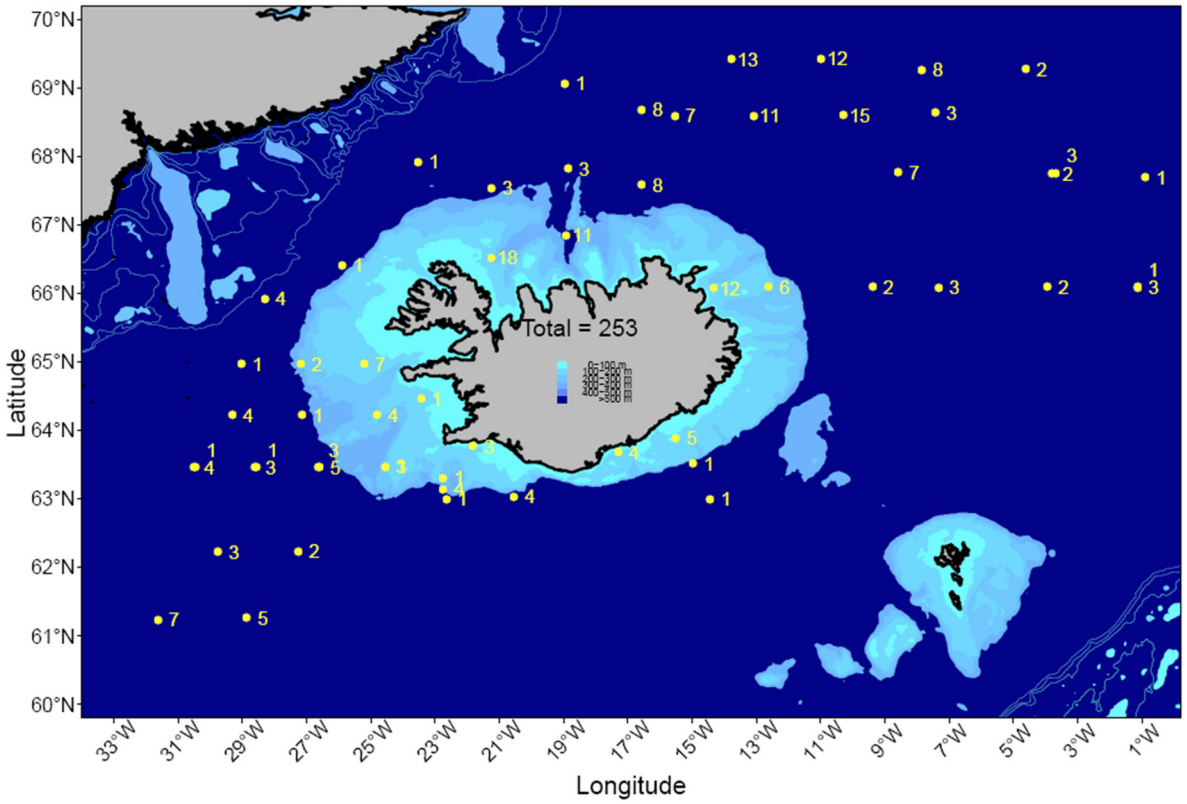


Figure 13. Number tagged and release location of lumpfish from R/V Árni Friðriksson in July and August 2018. Figure provided by James Kennedy at MFRI.

3.7.2 Opportunistic marine mammal observations

Six species of whales and dolphins were observed on 27 occasions (Figure 14). The species were fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), killer whale (*Orcinus orca*), pilot whale (*Globicephala spp.*), sperm whale (*Physeter marcocephalus*), and white-beaked dolphins (*Lagenorhynchus albirostris*). Pilot whales and white-beaked

dolphins were spotted in pods of several dozen animals. For other species number of animals per sighting ranged from one to five. One sighting could not be identified to species.

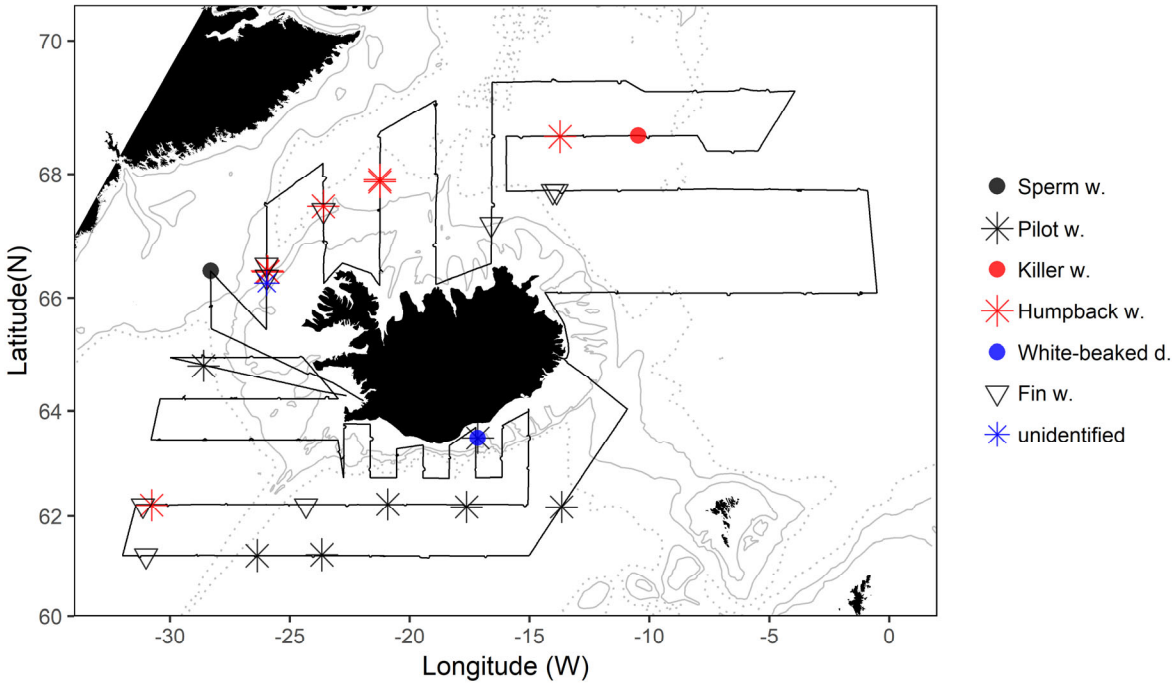


Figure 14. Opportunistic whale and dolphin sighting locations sampled on R/V Árni Friðriksson in July-August 2018. Pilot whales and white-beaked dolphins were spotted in pods of several dozen animals. Other species sighted ranged from 1 to 5 individuals. Depth contours displayed for 200m (grey line), 500 (grey line), and 1000m depth (dashed grey line).

4. Discussion

The survey successfully sampled all predetermined trawl stations and acoustic survey track with no modifications from the survey plan. 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, 2018a). The current survey plan approach was recommended by the 2017 IESSNS post cruise meeting at it was successfully applied in the previous two years.

The strata boundaries south and west of Iceland changed in 2018 to better reflect areas with similar mackerel densities as observed previous years. A new “south offshore” stratum was defined which includes the southern part of stratum “west” and the area southward of the shelf edge south of Iceland (Figure 1). A new “south inshore” stratum includes the shelf and shelf edge south of Iceland.

The discussion is limited, and we simply refer to the IESSNS 2018 post cruise report (ICES, 2018a). However, a few general discussion points about the survey are listed below.

In 2018, for the area surveyed by R/ V Árni Friðriksson, total weight of mackerel caught at predetermined surface trawl stations was 36,489 kg and was only 32% of mackerel total catch in 2017, despite similar number of surface trawl stations with mackerel present in both years. The high catches in 2017 were dominated by four stations with catches of 10, 12, 20 and 40 tons. Distribution also differed between years, with some mackerel caught north of Iceland in 2017, low density in the Norwegian Sea and no mackerel caught in stratum "south offshore". Both years had high density in strata "west" and "south inshore". These two strata have had the highest densities since the survey began in 2010.

For the whole IESSN survey area, mackerel biomass declined by 40% in 2018 compared to 2017 and was lower than estimated biomass in the last five years (ICES, 2018a). The biomass decline varied between different parts of the IESSNS area and was more pronounced in the west (westward of longitude 10W) compared to the Norwegian Sea. The cause of this decline in mackerel biomass in Icelandic waters in 2018 is not known. It is possibly related to a combination of declining mackerel stock size (ICES, 2018b) and colder waters (Olafsdottir *et al.*, 2018).

One new monitoring project and one new research project were added to the Icelandic part of IESSNS in 2018: opportunistic recording of marine mammal observations and tagging of lumpfish. We hope to make this new project a permanent feature of the IESSNS in the future.

5. 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, 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.

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7. Tables

Table 1. Sampling effort of predetermined surface trawl stations per strata on R/V Árni Friðriksson in July and August 2018.

Stratum name (stratum number)	Station interval (nmi)	Number of stations
IS-south shallow (6)	35	14
IS-south deep (12)	70	14
International East (1 & 7)		4
IS-east (3)	60	12
IS-north (4)	65	13
IS-west (5)	50	11
Jan Mayen (9)		3

Table 2. Acoustic instruments and settings for the primary frequency (boldface) for R/V Árni Friðriksson in July and August 2018.

Echo sounder	Simrad EK 60
Frequency (kHz)	**38**, 18, 120, 200
Primary transducer	ES38B
Transducer installation	Drop keel
Transducer depth (m)	10
Upper integration limit (m)	15
Absorption coeff. (dB/km)	10.6 -varies
Pulse length (ms)	1.024
Band width (kHz)	2.43
Transmitter power (W)	2000
Angle sensitivity (dB)	21.9
2-way beam angle (dB)	-20.81
Sv Transducer gain (dB)	
Ts Transducer gain (dB)	24.28
sA correction (dB)	-0.61
3 dB beam width (dg)	
alongship:	7.28
Athw. ship:	7.23
Maximum range (m)	500
Post processing software	LSSS v.2.3.0

Table 3. Trawl settings and operation details for R/V Árni Friðriksson in July and August 2018.

Properties	**Árni Friðriksson**
Trawl producer	Hampiðjan (Multpelt832#3)
Warp in front of doors	Dynex-34 mm
Warp length during towing	350 m
Difference in warp length port/starboard	16 m
Weight at the lower wing ends	2x400 kg
Weights on the foot-rope	Hampiðjan - footrope weight unknown as new trawl
Setback in metres	6 m
Type of trawl door	Jupiter
Weight of traw door	2200 kg
Area trawl door	7 m^2
Towing speed (GPS)	4.9 kn (4.5kn - 5.8kn)*
Trawl height (mean)	34.1m (28.5m-39.3m)*
Door distance (mean)	117m (106m – 127m)*
Trawl width*(mean)	66.1m (calculated)**
Turn radius	5 degrees
A fish lock in front end of cod-end	Yes
Trawl door depth (port and starboard)	4m-17m, 8m-20m***
Headline depth	0m
Float arrangements on the headline	Kite + 2 buoys on wings
Weighing of catch	All weighted

*Minimum and maximum values in bracket.

**Calculated using equation, (a) towing speed 4.5 knots: Horizontal opening (m) = 0.441 * Doorspread (m) + 13.094 or (b) towing speed 5.0 knots: Horizontal opening (m) = 0.3959 * Doorspread (m) + 20.094.

*** Minimum and maximum values

Table 4. Number of sampling stations per stratum for R/V Árni Friðriksson in July and August 2018.

Station type	Iceland west (5)	Iceland north (4)	Jan Mayen (9)	Iceland east (3)	Int. waters (1 & 7)	Iceland south shallow (6)	Iceland south deep (12)	*Total*
(a) Standard IESSNS sampling								
Predetermined surface trawl	11	13	3	12	4	14	14	*71*
"straight" comparison surface trawl	4	0	0	0	2	1	0	*7*
Deep water trawl	3	0	1	0	2	4	3	*13*
CTD*	11	13	3	12	4	14	14	*71*
WP-2	10+	13	3	12	4	14	14	*70*
(b) Additional research projects								
Mac, her and bw stomachs**	4mac, 1her	2her	1mac, 1her, 1bw	2mac, 4her, 2bw	1mac, 1her, 3bw	4mac, 3her, 4bw	5mac, 2bw	*17mac, 12her, 12bw*
Tagging lumpfish***	15 (41)	10 (58)	3 (13)	10 (81)	6(12)	10(28)	4(17)	*58(250)*
MIK-net	0	15	0	6	0	1	5	*27*
eDNA	5	5	1	5	0	3	7	*26*
Mackerel gonads***	1(20)	0	0	2(31)	0	2(20)	4(29)	*9(100)*
Mesopelagic fish and invertibrates	3	0	0	0	0	3	3	*9*
Length measured capelin larvae	0	0	0	0	0	1	2	*3*
Herring hearts frozen	4	0	0	0	0	6	0	*10*
Total‡	*72*	*71*	*17*	*67*	*27*	*84*	*77*	*415*

‡The trawl hauls, CTD, WP2 and MIK stations share the same station number in the database.
*nutrients and chlorophyll water samples collected at all CTD stations.
**Mac = mackerel, her = herring, bw = blue whiting.
***Number of tagged individuals in brackets.
+WP-2 not collected at 1 station due to high winds.

Table 5. Overview of the different species caught and measured in the Multpelt832 trawl, including predetermined surface stations, comparison straight surface stations and deep trawl stations by R/V Árni Friðriksson in July and August 2018. Target species displayed in bold.

Species name	Species id.*	Species NO**	Length measured (N)	Aged (N)	Counted (N)	Catch (kg)
Ýsa, haddock (*Melanogrammus aeglefinus*)	HAD	2	1	0	0	0.002
Skötuselur, monkfish (*Lophius piscatorius*)	MON	14	1	0	0	7.2
Síld, Herring (NSSH, ISSH)	**HER**	**830, 30**	**4561**	**1402**	**147151**	**52605.5**
Loðna, capelin (*Mallotus villosus*)	CAP	31	511	159	1268	317.8
Blue whiting (kolmunni)	**WHB**	**34**	**515**	**515**	**14368**	**2013.2**
Mackerel (makríll)	**MAC**	**36**	**5329**	**1918**	**168119**	**79427.0**
Smokkfiskur (*Ommastrephes sagittatus*)	SQE	44	117	0	103	1.1
Blágóma, Northern wolffish (*Anarhichas denticulatus*)	CAB	47	5	0	0	5.1
Hrognkelsi, Lump fish (*Cyclopterus lumpus*)	**LUM**	**48**	**355**	**106**	**37**	**486.4**
Ískóð, polar cod (Boreogadus saida)	POC	71	11	**0**	3	0.2
Laxsíldar ógr., laternfishes (*Myctophidae*)	MYX	75	1	**0**	1	0.008
Urrari, grey gurnard (*Eutrigla gurnardus*)	GUG	99	20	**0**	0	9.384
Litla geirsíli, (Notolepis rissoi kroyeri)	NRK	123	41	**0**	21	2.929
		130	7	**0**	60	0.065
Skjár, blálax, Goiter blacksmelt (*Bathylagus euryops*)	BBE	136	1	0	1	0.01
Svarthveðnir, rudderfish (*Centrolophus niger*)	CEO	151	19	0	1	7.565
Kolkrabbi, octopuse (*Octopus spp*)	OCZ	160	0	0	12	0.1
Sæsteinsuga, sea lamprey (*Petromyzon marinus*)	LAU	176	1	0		0.276
Marglytta, jellyfish (*Rhopilema spp*)	JEL	180	0	0	0	98.255
		186	0	0	0	7.794
Langalaxsíld, patchwork lampfish (*Notoscopelus kroeyerii*)	LAX	204	418	0	1607	26.292
Silfurbendill, elongate frostfish (*Benthodesmus elongatus*)	BDL	206	0	0	1	0.186
Ísalaxsíld, Glacier lanternfish (*Benthosema glaciale*)	BHG	209	180		349	0.442
Lax, salmon (*Salmo salar*)	SAL	210	3	2	0	2.7
Punktalaxsíld, spotted laternfish (*Myctophum punctatum*)	SPF	232	51		0	0.432
Digra geirsíli (*Duckbill barracudina*)	MNL	248	62		199	17.988
Fiskur ógreindur/fish unidentified		302	56		508	1.142
Rækja ógreind/shrimp unidentified		303	0		1	0.008
Grand Total			**12266**	**4102**	**333810**	**135038.9**

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

**In the Icelandic MFRI central database

8. Annex

Annex 1. Participants in the IESSNS onboard R/V Árni Friðriksson in July and August 2018.

2 - 17 July	**17 July – 2 August**
Scientific staff:	
Agnar M. Sigurðsson, plankton and biol. sampling	Agnes Eydal, plankton and biol. samples
Arnþór B. Kristjánsson, acoustics, technology	Anna Heiða Ólafsdóttir, cruise leader, acoustics
James Kennedy, acoustics and tagging	Björn Sigurðarson, acoustics, technology
Sigurður Þ. Jónsson, cruise leader, acoustics	George Haney, acoustics, technology
Sigurlína Gunnarsdóttir, plankton and biol. samples	Guðrún Finnbogadóttir, plankton and biol. samples
Sólrún Sigurgeirsdóttir, plankton and biol. samples	Jóhann Á. Gíslason, plankton and biol. samples
Svandís E. Aradóttir, plankton and biol. samples	Páll B. Valgeirsson, plankton and biol. samples
	Ragnhildur Ólafsdóttir, plankton and biol. samples
Captain:	
Ingvi Friðriksson	Heimir Örn Hafsteinsson

HAFRANNSÓKNASTOFNUN

Rannsókna- og ráðgjafarstofnun hafs og vatna