HV 2021-40
ISSN 2298-9137

HAF- OG VATNARANNSÓKNIR

MARINE AND FRESHWATER RESEARCH IN ICELAND

Benthic Habitat Mapping of the Seafloor 2019 – Cruise report B8-2019

Steinunn H. Ólafsdóttir, Julian M. Burgos, Fine Brendtner, María R. Þrándardóttir

HAFNARFJÖRÐUR - JÚLÍ 2021

Benthic Habitat Mapping of the Seafloor 2019 – Cruise report B8-2019

Steinunn H. Ólafsdóttir, Julian M. Burgos, Fine Brendtner,
María R. Þrándardóttir

Haf- og vatnarannsóknir
Marine and Freshwater Research in Iceland

HAFRANNSÓKNASTOFNUN
Rannsókna- og ráðgjafarstofnun hafs og vatna

Upplýsingablað

Titill: Benthic Habitat Mapping of the Seafloor 2019 – Cruise report B8-2019		
Höfundur Steinunn H. Ólafsdóttir, Julian M. Burgos, Fine Brendtner, María R. Þrándardóttir		
Skýrsla nr: HV 2021-40	**Verkefnisstjóri:** Steinunn H. Ólafsdóttir	**Verknúmer:** 9224
ISSN 2298-9137	**Fjöldi síðna:** 48	**Útgáfudagur:** 12. júlí 2021
Unnið fyrir: Hafrannsóknastofnun	**Dreifing:** Opin	**Yfirfarið af:** Eric dos Santos

Abstract

The eighth survey for benthic habitat mapping (Kortlagning búsvæða á hafsbotni, KBH) project was conducted between June 24 and July 3, 2019. This is an ongoing project within the Marine and Freshwater Research Institute (MFRI) with the aim of describing the composition of the epifauna and habitats of the seabed in selected areas, mapping vulnerable benthic species and vulnerable marine ecosystems (vmes) and recommending conservation measures. The areas mapped in this survey included Jökuldjúp, an area east of Eldey, Kötlugrunn and various locations along the south slope of Iceland between Háfadjúp and Hornafjarðardjúp. Observations were obtained with an underwater camera system that filmed the seabed along 70 transects, each approximately 600 m long.

Preliminary observations indicate the presence of several habitats characterized by different key species. Among these habitats are relatively homogenous soft bottoms characterized by the presence of sea cucumbers, sea urchins, sea pens, bamboo corals or sea pens. More complex habitats consisted of a mixture of soft and hard sediments with fields of sponges or coral gardens or accumulations of boulders with sea anemones and orange-footed sea cucumber (brimbútur in Icelandic). High density of coral indicates coral reefs off Síðugrunn and Mýragrunn. Sea pens were observed in high densities on the shelf and *Swiftia* garden was found in Kötlugrunn. New observations of known reefs were also obtained. A known area with geothermal activity east of Eldey was surveyed, characterized by the outflow of hot water and the presence of bacteria mats growing on sandy sediments.

Ágrip

Áttundi leiðangur verkefnisins Kortlagning búsvæða á hafsbotni (KBH) fór fram 24. júní til 3. júlí 2019. KBH er langtímaverkefni á vegum Hafrannsóknastofnunar þar sem markmiðið er að lýsa samfélagsgerðum botndýra og búsvæðum á hafsbotni ásamt því að kortleggja viðkvæmar tegundir og vistkerfi og meta þörf á verndun þeirra. Svæðin sem kortlögð voru að þessu sinni voru Jökuldjúp, lítið svæði austur af Eldey, Kötlugrunn og nokkrir staðir í kantinum

milli Háfadjúps og Hornafjarðardjúps. Rannsóknin fór fram með neðansjávarmyndavélum þar sem myndað var á 70 sniðum sem hvert um sig var um 600 m langt. Frumniðurstöður sýna nokkrar gerðir af ólíkum búsvæðum sem einkennast af mismunandi lykiltegundum. Til að mynda eru einsleit búsvæði á mjúkum botni sem einkennast af sæbjúgum, ígulkerum, bambuskóral eða sæfjöðrum. Flóknari búsvæði samanstóðu meðal annars af blöndu af mjúku og hörðu seti með svömpum og kóralgörðum eða grjóthrúgum með sænellikum og brimbútum. Hár þéttleiki kórals bendir til að kóralrif séu úti fyrir Siðugrunni og Mýragrunni. Swiftia kóralgarður sást á Kötlugunni. Athuganir voru einnig gerðar á þekktum kóralrifum. Þekkt svæði með jarðhitavirkni austur af Eldey var kannað og uppstreymi af heitu vatni og bakteríumottur sáust á sandbotni.

Lykilorð: *Habitat mapping, coral, sponges, VME, underwater images, ecosystem, benthos*

Undirskrift verkefnisstjóra:	**Undirskrift forstöðumanns sviðs:**
Steinunn H. Ólafsdóttir	

Benthic Habitat Mapping of the Seafloor 2019

Cruise report B8-2019

Steinunn H. Ólafsdóttir, Julian M. Burgos, Fine Brendtner, María R. Þrándardóttir

I stare at the shimmer and inhale the sunshine. My essence has become one with the movements of the ship. Deep inside it dances with the waves. The body follows and finds the source of the sound. Back and forth yet sometimes with a slant up and down. Eyes - which do not let in the light except when it is bright outside - surround me. I miss you like I miss the sun at night. She travels periodically from left to right unless we turn in another direction. I am restless and destitute until I fall asleep on the watch and breakfast awaits me. The fog hides the expanse, but I know it also waits alongside the breakfast. It waits for me to look at it longwise and I try to reach its length. Infinity is always finite. I am nauseous at sea but not as much when I watch the horizon level everything out and leaves me be for a short while. Black birds cut through the sky and their reflection cuts the waves. They observe the green skin behind the black locks. She lives on and becomes an animal in the darkness. She is sipping on the sea in a cup made of silk that satisfies her hunger. No one knows and no one cares and no one was and no one is and no one may and no one has my heart any longer. I do not miss you, not so much, except sometimes when I stare at the shimmer.

María Rún Þráinsdóttir

Table of Contents

Table of figures

1 Introduction

The seafloor around Iceland is highly diverse and is comprised of many different habitats. Habitats on the seabed are shaped by the topography and type of sediment, depth, temperature, salinity, currents, and the organisms present in each area (Mortensen et al. 2009). Benthic communities are strongly influenced by local geological and oceanographic conditions (Bluhm et al. 2011; Piepenburg et al. 2001). Bottom trawling can also have a strong influence on the abundance and diversity of benthic organisms (Hiddink et al. 2006; Mazor et al. 2021). The species composition of benthic fauna around Iceland differs depending on environmental factors and location. Whether they are in the cold seas north of Iceland, including species that are associated with the Arctic, or in the warmer seas south of Iceland. All of this contributes to the diversity of the ecosystem (Meiβner et al. 2014, 2018). Habitat mapping is the basis for being able to assess the impact and/or changes on the ecosystem so that the ocean's resources can be used responsibly and the areas that need special protection can be protected.

Benthic Habitat Mapping (Kortlagning búsvæða á hafsbotni, KBH) has been ongoing at the Marine and Freshwater Research Institute (MFRI) since 2004. The project has two main objectives. The first is to locate and map vulnerable habitats, including cold-water coral areas, that are at risk of being impacted by commercial fishing. The second objective is to map and describe other habitats, increasing the knowledge and understanding of the communities and ecosystems of the seafloor mainly in deep waters around Iceland. Data is collected with underwater videos and photographs of the seafloor. In this way, data is collected without damaging the specimens or breaking the vulnerable structure of habitat forming species like cold-water corals. This method also provides valuable information on the status of benthic habitats and gives insight into the species associations *in situ*.

The eight KBH cruise was carried out by the r/v Bjarni Sæmundsson from June 24th to July 4th, 2019. The areas mapped included Jökuldjúp, an area east of Eldey, and various locations along the south slope of Iceland between Háfadjúp and Hornafjarðardjúp. This area has partly been surveyed earlier with the focus to locate and document cold-water coral reefs (Sigmar A. Steingrímsson and Sólmundur T. Einarsson 2004; Steinunn H. Ólafsdóttir et al. 2020), produce a habitat map (Óðinsson et al. 2019) and to evaluate the association between fish and cold-water coral (Ragnarsson and Burgos 2018). In this survey we aimed to “fill the gaps”, adding sampling stations to obtain a more complete coverage to produce habitat maps and validate the prediction

of habitat suitability models. Based on density, the species composition (complexity, VME indicator species), distance from fishing grounds and thus risk of damage, vulnerable areas will be evaluated.

2 Material and methods

2.1 Objectives and focus for the survey in 2019:

1 Obtain baseline information on the composition and distribution of benthic communities and habitats.
2 Revisit cold-water coral reefs first observed in 2004, which were included within marine protected areas (MPAs) in 2005, with the objective of identifying signs of recovery.
3 Sample soft sediments to ground-truth multibeam backscatter measurements. For this a small grab was attached to the camera rig.
4 Register the presence of vulnerable species.
5 Verify possible cold-water coral reefs observed in new bathymetry data. In 2017 an area on the Kötlugrunn was mapped with a multibeam echosounder. The high-resolution bathymetry revealed the presence of circular formations similar to others that have been proven to be coral reefs.
6 Obtain observations to validate the predictions of habitat suitability models for VME indicator species (Burgos et al., 2020).

2.2 Study area and survey design

2.2.1 Selection of study areas

The selection of the study areas was based on several factors, the main one being the availability of high-resolution bathymetry and backscatter data obtained with a multibeam echosounder. Multibeam data is essential for mapping habitats, not only because it allows for the safe navigation of the camera rig near the seabed, but also because it provides information on the morphology and structure of the seafloor. This information is used first to plan the survey and later to provide context to the observations. Multibeam data is also used in later stages to extrapolate the observations into full coverage maps by using species or habitat distribution models. Within the areas where the multibeam data is available, the maximum depth that can be reached with the current camera system is approximately 700m. This limitation is due to the

length of the axial fibre optic cable that connects the camera platform to the vessel. Given these two constraints, the study areas were selected based on several criteria, including the location of previously studied areas, the presence of interesting bathymetric features, fishing pressure and the existence of records of vulnerable habitats or species from various sources, including historical data and information provided by fishermen.

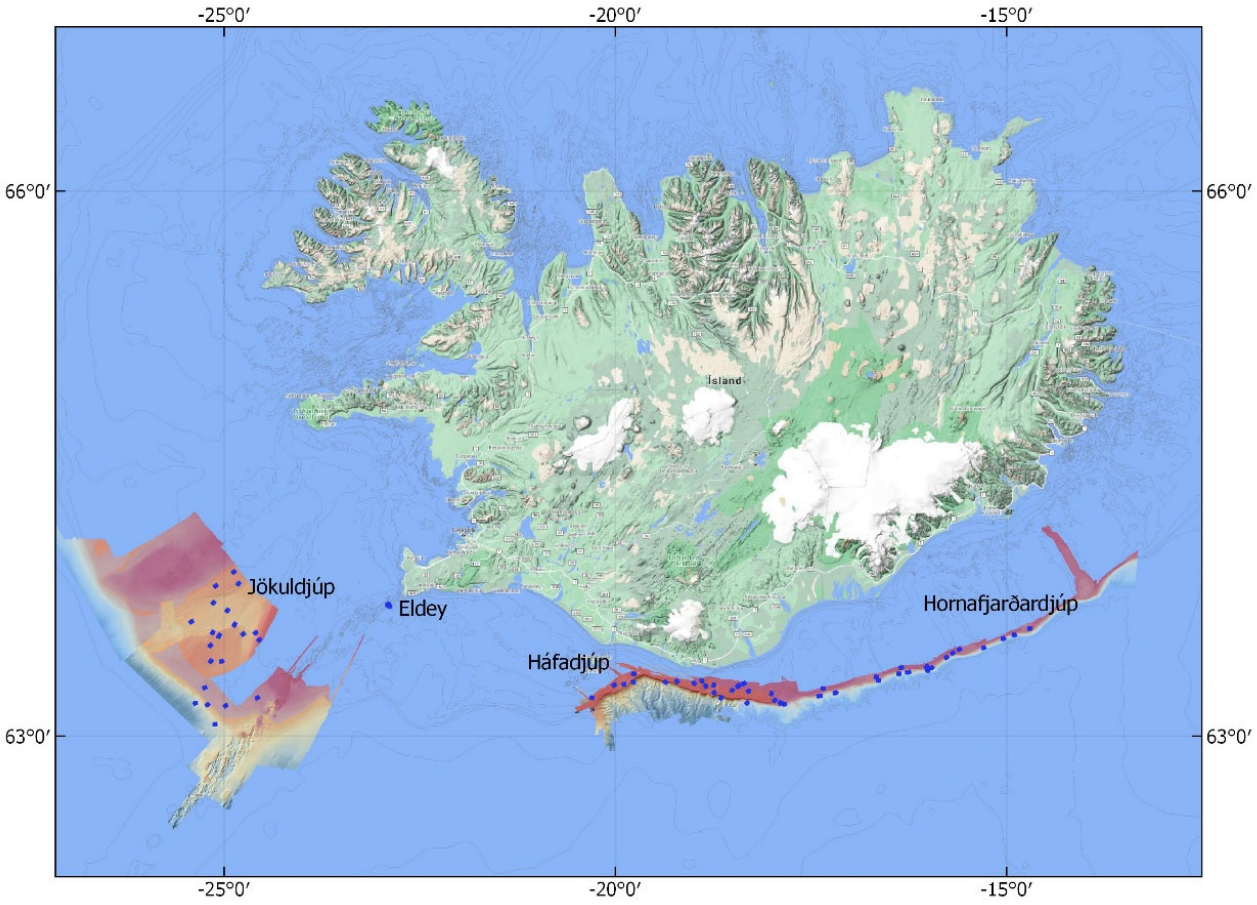

Figure 1. Study area. The sampling stations (blue dots) are within the multibeam areas.

1. mynd. Rannsóknasvæðið. Snið (bláir punktar) voru tekin innan fjölgeislamældra svæða.

The selected study areas included Jökuldjúp, a small area (2.5 km^2) west of Eldey, and several locations along the shelf and the slope from Háfadjúp to Hornafjarðardjúp (figure 1). Jökuldjúp is a broad underwater valley that runs in a NE-SW direction approximately 35 NM west of the Reykjanes peninsula. The multibeam data available covered an area of 2943 km^2 in the deeper areas of the valley close to the shelf break. This area included Faxadjúp, a depression in the centre

of Jökuldjúp that reaches a depth of 470 m, and the relatively steep slope known as Suðurkantur. From Háfadjúp and to Hornafjarðardjúp the available multibeam data covered an area of 3958 km^2.

2.2.2 Survey design

The survey design for Jökulsárdjúp and the area along the southern slope was based on a) seabed segmentation to identify areas with similar conditions, and b) selection of sampling sites, defining the location of the sampling stations in each segment using a Generalized Random Tesselation Stratified (GRTS) approach (Stevens and Olsen 2004).

2.2.3 Seabed segmentation

Within each of the tree main study areas, clustering analysis was used to classify the seabed based on the following environmental descriptors:

Depth	derived from multibeam data at a resolution of 50 m.
Backscatter	obtained from multibeam data and serving as an indication of the relative hardness of the bottom.
Bottom slope	calculated from depth values, using a 9-cell moving window.
Average near-bottom current speed:	derived from the CODE oceanographic model (Logemann et al. 2013).
Average near-bottom temperature	derived from the CODE oceanographic model (Logemann et al. 2013).
Fishing effort	derived from Vessel Monitoring System (VMS) data from bottom trawlers, including otter trawlers, *Nephrops* trawlers, shrimp trawlers and dredges from the period 2012-2017. Logbook data and a vessel speed criterion was used to identify the VMS records that corresponding to fishing activities

All variables were resampled to match the resolution and origin of the bottom depth grid. In this way, we obtained values for all descriptors for each cell in the grid. These values were clustered into ten groups or strata, a number considered high enough to identify distinct regions with

different environmental settings while at the same time low enough to allow for multiple dives in each region. Cluster analysis was performed using the CLARA (Clustering Large Applications) algorithm (Kaufman and Rousseeuw 1990) implemented in the R package "**cluster**" (Maechler et al. 2019). The geometric complexity of the resulting areas was reduced by calculating the median value with a 10-cell moving window. The result of this analysis is a segmentation at a 50m resolution, where each category represents a portion of the seabed with similar environmental descriptors.

2.2.4 Selection of sampling stations

We aimed to place, on average, one sampling station per 100 km^2. This sampling density is based on the density used in the MAREANO programme in Norway (Buhl-Mortensen et al. 2015). The number of stations allocated to each stratum was proportional to the square root of the total area occupied by each stratum. The position of the sampling stations in each stratum was selected using a Generalized Random Tesselation Stratified (GRTS) approach (Stevens and Olsen 2004), using the R package "spsurvey" (Kincaid and Olsen 2016). GRTS is a spatially balanced sampling design, similar to a stratified random sampling design, but with the advantage that it avoids placing sampling stations in close proximity to other stations and thus avoids issues with spatial correlation. The resulting positions were adjusted to avoid having sampling stations in the proximity of the boundaries between seabed segments, to place stations in locations with geomorphic features of interest (e.g., banks, troughs, canyon walls), or when bad weather reduced the amount of time available in a particular area.

2.3 Data collection

2.3.1 Towed video platform

Data was collected with the Campod, a towed video platform designed for habitat mapping (figure 2). The Campod consists of a tripod frame equipped with a high-definition colour video camera (Kongsberg OE 14-502) and a 12 megapixel digital still camera (Sony UMC-S3C A7 II) mounted on a pan and tilt frame. The Campod also had an SBE 19 plus V2 SeaCAT Profiler CTD to

measure conductivity, temperature, and pressure, two parallel lasers for scaling (DeepSea), six SeaLite LED lights, and a Tritech Sea King sonar as a navigation aid. The Campod was also equipped with a set of thrusters that provide some manoeuvrability. This configuration has been used for habitat mapping in KBH since 2009.

For this survey, a small grab was attached to the Campod, built with the purpose of obtaining sediment samples. The grab was equipped with a release mechanism controlled from the ship. The grab could only be used in soft sediments. Due to a failure in the motor, the grab was only used early in the cruise.

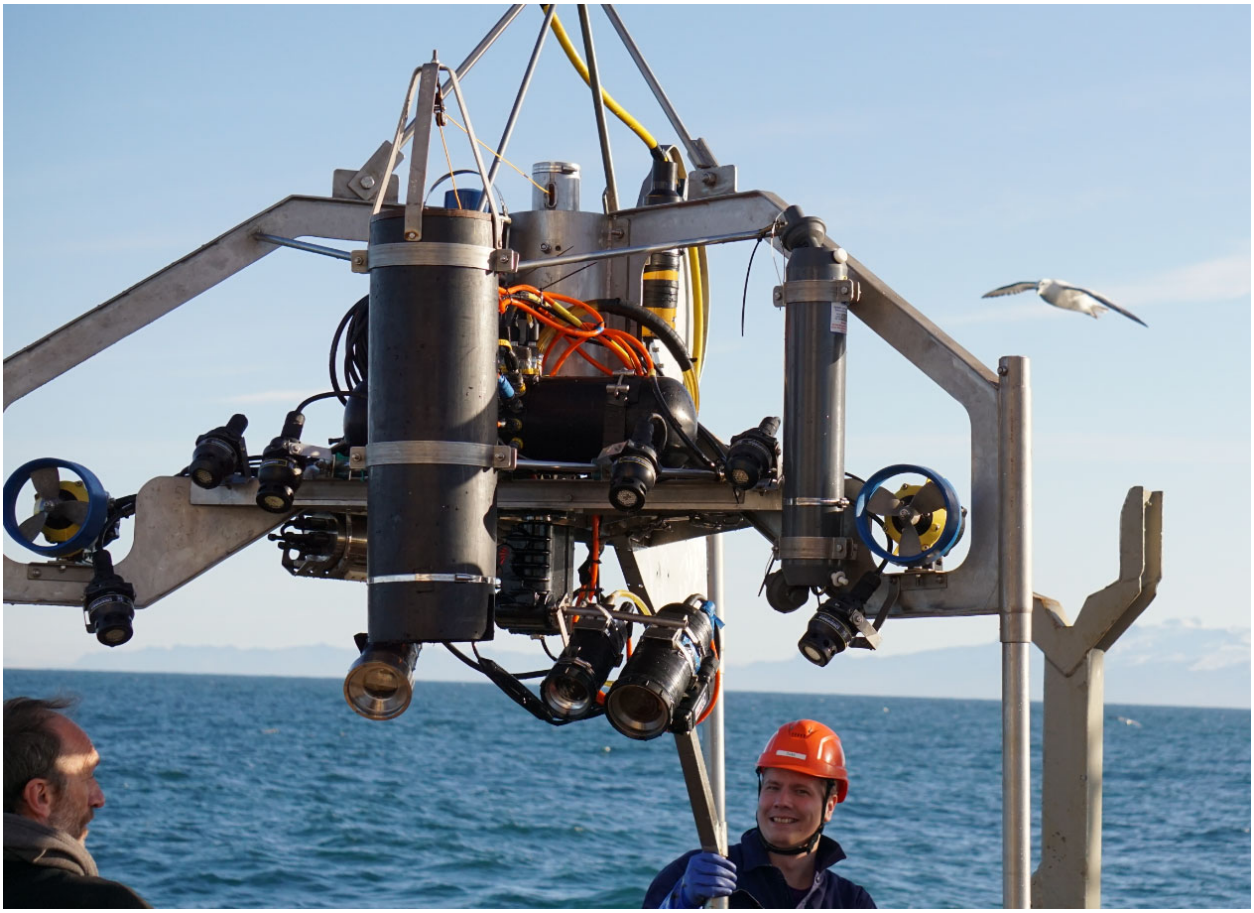

Figure 2. The Campod. Cameras, lights, thrusters, and sonar are visible in the image. The grab is located within the black cylinder on the front.

2. mynd. Myndavélagrindin (Campod). Myndavélar, ljós, hreyflar og sonar sjást á myndinni. Botngreip er innan í svarta hólknum framan á grindinni.

2.3.2 Sampling method

In each station we carried out a video transect of approximately 600 m in length. The transect was conducted while the research vessel was drifting at speeds between 0.1 to 1 knot, as at higher drifting speeds the videos obtained would be too blurry and could not be used for analysis. Waves are also a critical factor in the sampling process. If waves are too high, the camera rig cannot be manoeuvred safely in proximity to the seabed. Perfect conditions can be hard to meet.

At the beginning of each transect the Campod was lowered to the seabed and landed to obtain an initial view of the seafloor and the fauna. Next, the transect was initiated. The Campod was kept at safe distance above the seabed, about 1-2 m. Depending on the conditions, the Campod was landed regularly to get better view of the sediment and the fauna. The Campod was also landed if interesting species or features were observed. Still images were taken manually based on the live feed from the cameras.

Figure 3. The onboard control station. Video is displayed in real time. The Campod is controlled based on what is seen on the video feed. Digital stills are taken manually.

3. mynd. Stjórnsvæði um borð í skipinu. Myndefni er streymt upp í rauntíma. Myndavélagrindinni er stjórnað út frá því sem sést á skjánum. Ljósmyndir eru teknar handvirkt um borð.

The grab was deployed occasionally when the sediment was considered soft enough for the grab to operate. Sediment samples were only collected in the first half of the survey, due to the

subsequent mechanical failures of both the primary motor and the spare motor that drive the grab inhibiting further sediment sampling.

2.3.3 Video and image annotation

The material was analysed with the annotation software “Hafmynd” developed at MFRI by Björn Darri Sigurðsson. Hafmynd allows the user to make annotations of fauna, sediment types and other items of interest observed in underwater video and photographs (figure 4). The software holds an updated list of all taxa from the World Register of Marine Species (WoRMS Editorial Board 2019), which ensures that the records have up-to-date taxonomic information. Hafmynd also stores a timestamp of each record, as well as the navigation data (time, latitude, and longitude) of the Campod that is used to assign a location to each record. During the survey, the software was improved and modified.

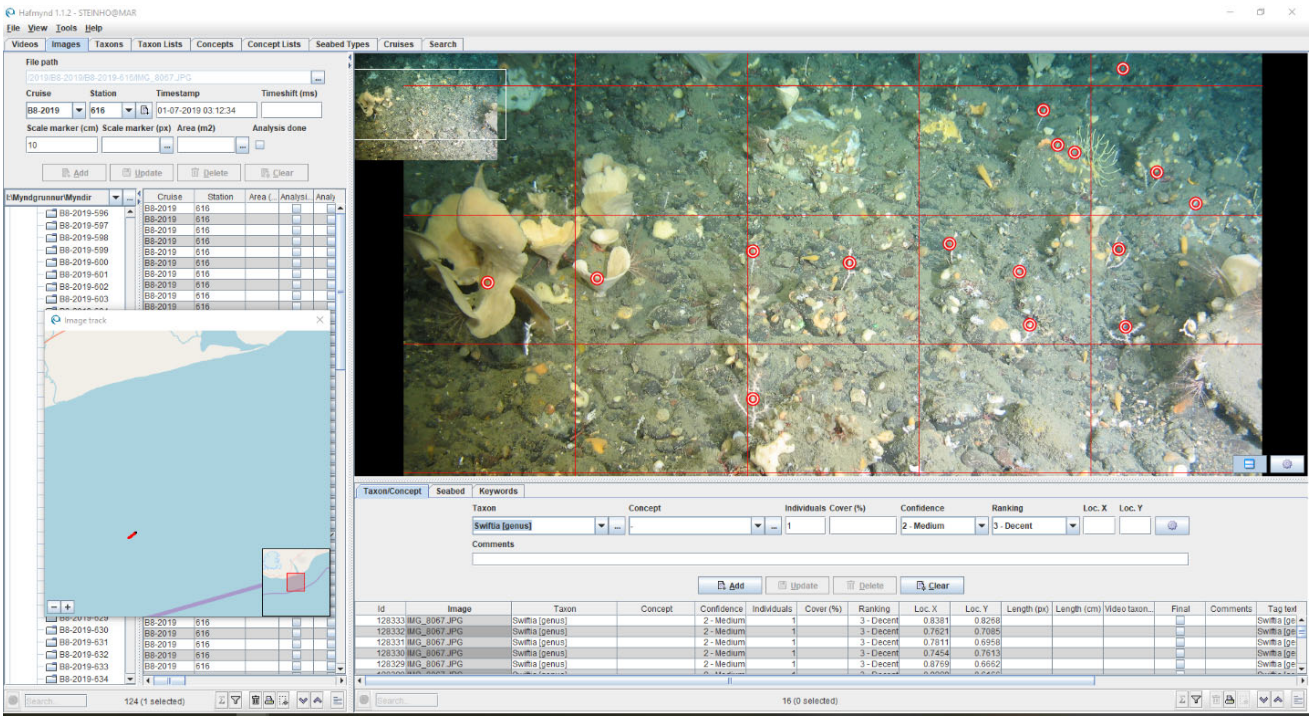

Figure 4. Screen shot of the Hafmynd software, which is used to record species and bottom types.

4. mynd. Skjáskot af Hafmynd hugbúnaðinum sem er notaður til að skrá tegundaheiti og botngerð.

The following modifications were made to the software during the cruise:

- Navigation log files were connected to each video/image file, creating a transect profile connected to the annotations.
- User-friendly features were developed to facilitate annotation.
- Live stream annotation options were created.
- Station table with cruise, time, lat., lon.
- Import and view the Campod track of individual transects.
- Location of individual photograph shown on the track.
- Thumbnails of images from each folder.
- Hierarchy of concepts in the concept list.

Part of the video material collected was analysed onboard during the cruise. The annotations were uploaded into the Oracle database at MFRI after the survey. Annotation of the remaining video and image material was then carried out.

3 Results

A total of 70 transects were conducted west and south of Iceland (figure 1), at depths between 65 and 640 m. Weather conditions were poor the first two days, hindering operation of the camera system. Thereafter, the survey went well.

3.1 Jökuldjúp

A total of 21 transects (stations 574-594) were conducted in Jökuldjúp (figure 5). Most of the seabed was a mixture of sand and mud. A single holothuroid species, cf. *Laetmogone violacea* (fjólufætla, figure 6 and 7), was the most abundant epibenthic species in this area. It was sometimes joined by the "lollipop" sponge *Stylocordyla borealis* and the sea urchin *Gracilechinus* sp. In some locations, the bottom was somewhat harder and characterized by sponge aggregations of the genera *Iophon* and *Haliclona*.

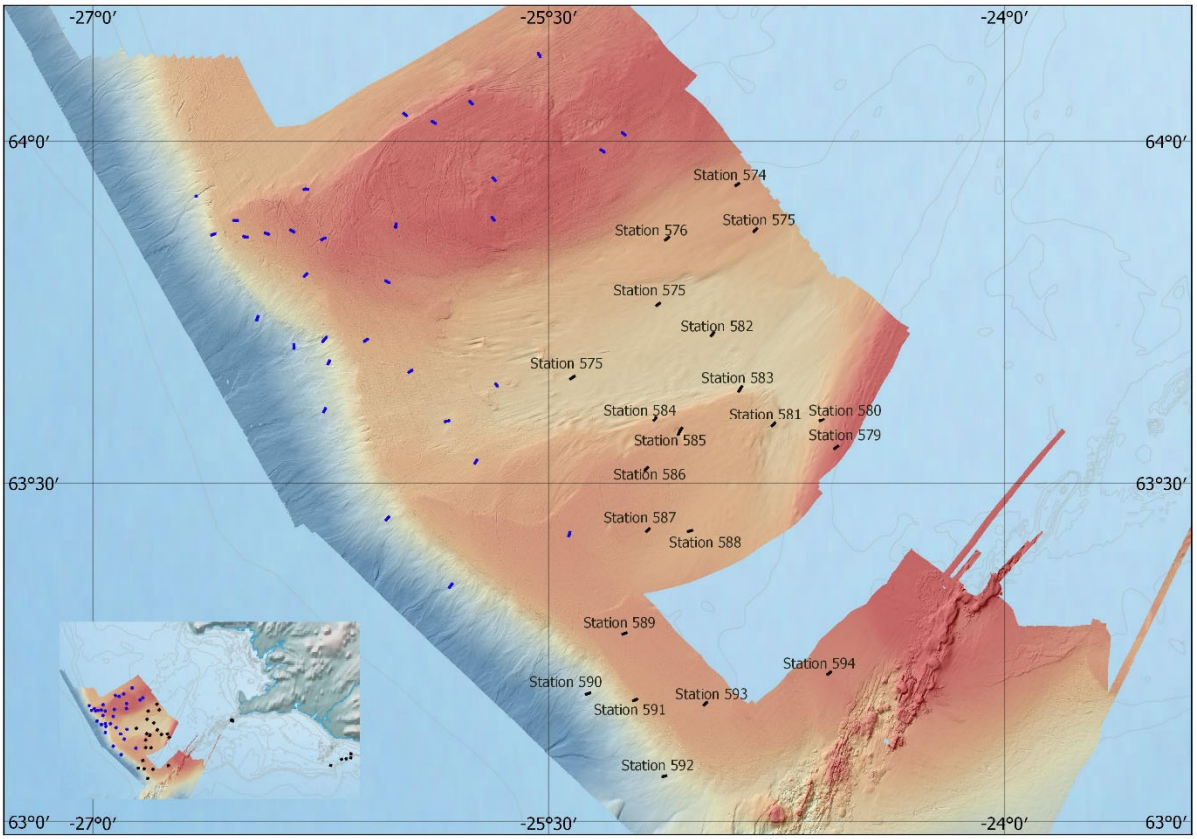

Figure 5. Location of transects (black) in Jökuldjúp area and the slope and shelf west of Reykjanes Ridge. Transects from the 2017 KBH survey are blue.

5. mynd. Staðsetning sniða (svört) í Jökuldjúpi og á brúninni og kantinum vestur af Reykjaneshrygg. Blá snið eru frá leiðangri KBH 2017.

Figure 6.Fjólufætla, cf. Laetmogone violacea on the soft seafloor.

6. mynd. Fjólufætlur á mjúkum botni.

Figure 7. Stamp showing Fjólufætla Laetmogone violacea and red Pennatula sp. sea pen photographed during an earlier KBH cruise. Stamp designer Örn Smári Gíslason / Marine Research Institute (Photo).

7. mynd. Frímerki sem sýnir fjólufætlu og rauða Pennatula *sæfjöður. Myndin var tekin í fyrri leiðangri KBH. Frímerkið var hannað af Erni Smára Gíslasyni fyrir Póstinn.*

On the slope (stations 590-592) the seabed was firm sand. Transect 591 was characterized by the presence of Crinoidea (sea lilies), while transects 590 and 592, by a thin layer of fine sediment covered a denser sandy layer with scattered epifauna of echinoderms, sponges, and brachiopods. Similar communities were observed in 2017 in an adjacent area north of this study area (figure 5). Furthermore, a similar sponge community with *Iophon* sp*., Haliclona* sp*.* and *Asconema foliatum* was observed on Látragrunn, near the south end of *Brjálaði hryggur* during the 2011 habitat mapping cruise (Steinunn H. Ólafsdóttir and Julian Burgos 2018).

3.2 Eldey - Evidence of hydrothermal activity

Stations 595-600 were located east of Eldey (figure 8), where we examined two known sites with hydrothermal activity. The transects here were not the standard length used for habitat mapping purposes (600 m), as the objective of these dives was to examine the different geomorphological

features in the area. The longest transect (596) was about 1.4 km long, ranging from the north to south of the area.

The Campod is not the optimal tool to locate relatively small structures on the seabed, as it has a limited navigational capability. However, it confirmed active outflow of hot water, as evidenced by the yellow mineral deposits and white mats of thermophilic bacteria on the sandy seafloor and on the pumice observed in station 600 (figure 9).

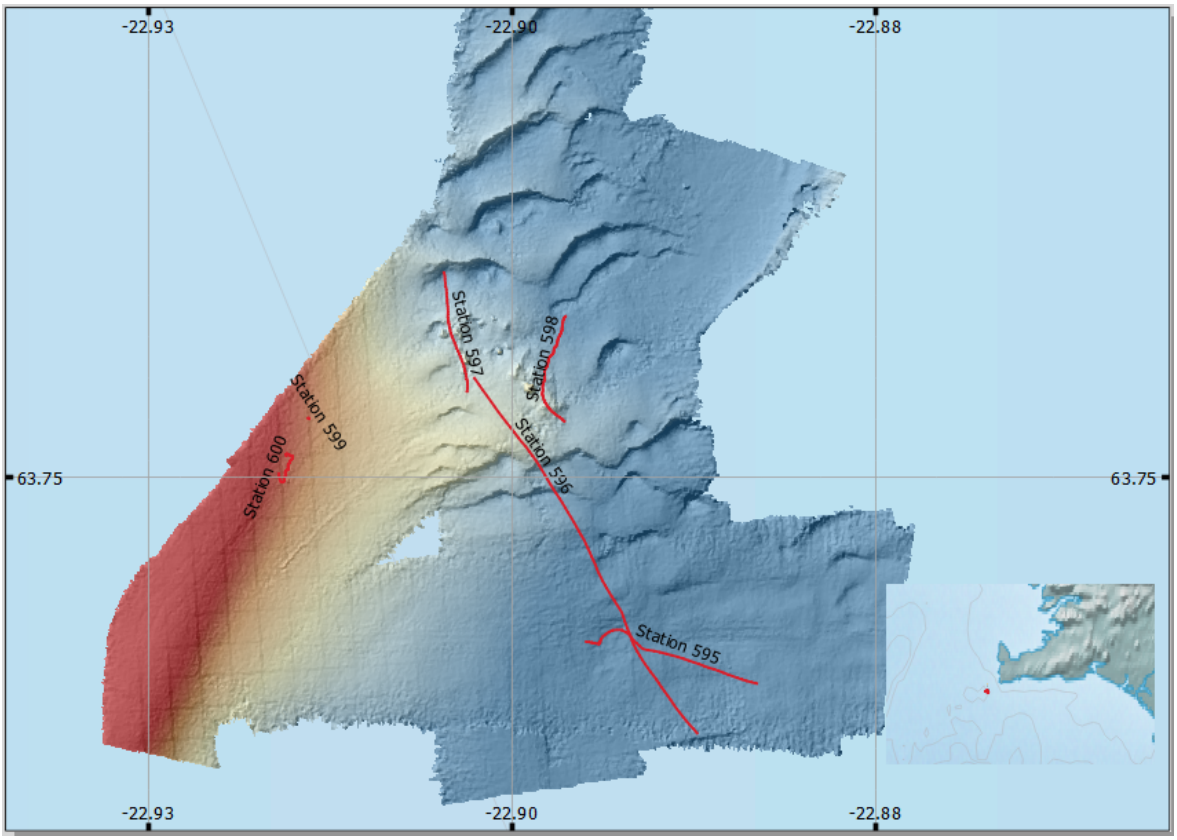

Figure 8. Study area east of Eldey. The transects are red.

8. mynd. Rannsóknasvæðið austur af Eldey. Rannsóknasniðin eru rauð.

Transects 597 and 598 crossed rough circular formations on the seafloor, covering an area of approximately 8.2 ha. These formations were built up by boulders or lava surrounded by black sand, pebble and shell debris or pumice seabed. Dense aggregations of clonal plumose anemones (likely *Metridium senile*), the edible sea cucumber *Cucumaria frondosa* and hydrozoa (likely Tubularia) were observed on the boulders (figure 10).

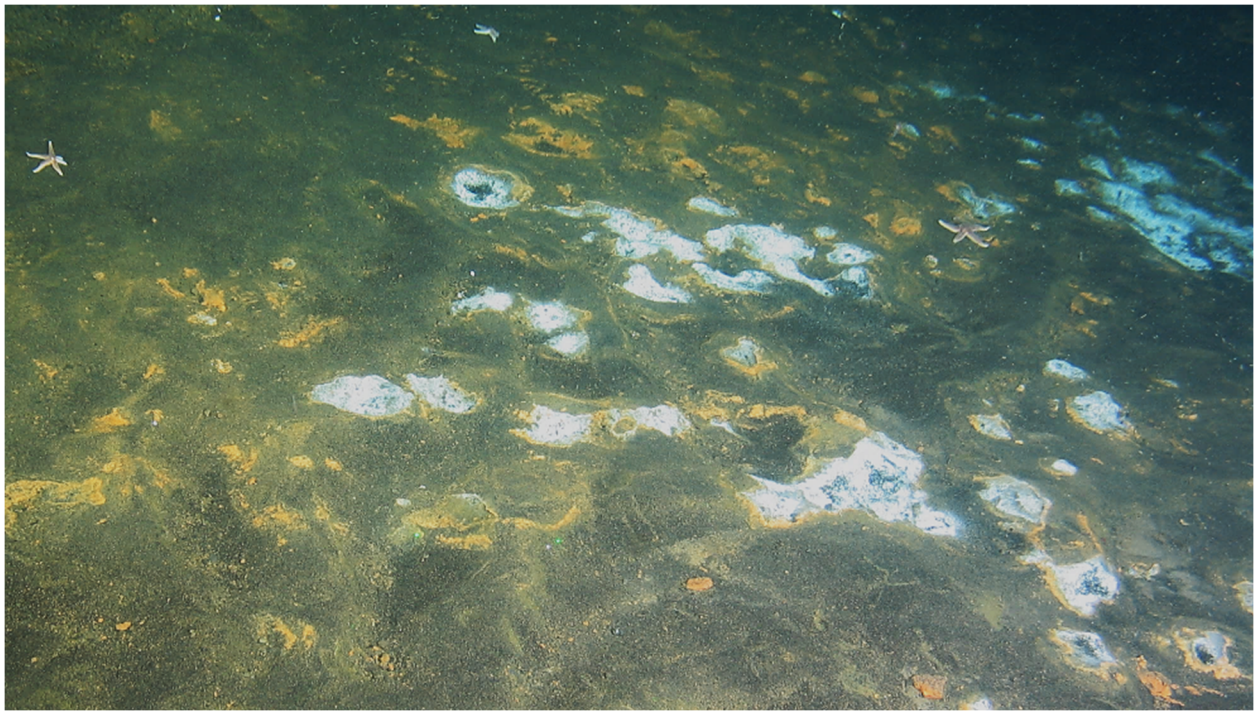

Figure 9. Yellow precipitate and white bacterial mat around the openings of the hot water flow.

9. mynd. Gular útfellingar og hvít bakteríuskán við uppstreymisop þar sem heitt vatn seytlar út.

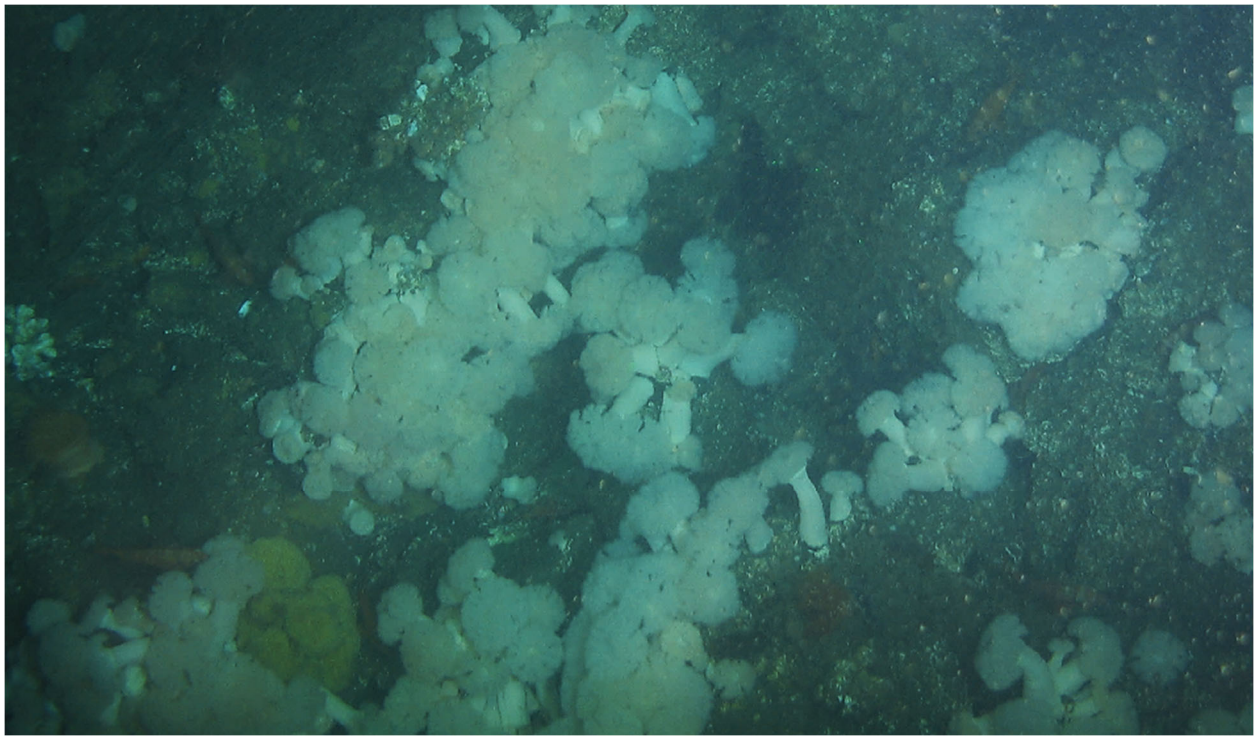

Figure 10. Dense aggregation of cf. Metridium senile on the circular boulders/lava features.

10. mynd. Þyrping af sænellikum á grjóti/hrauni.

3.3 Háfadjúp

Stations 601-607 were located from the shelf west of Háfadjúp and along the shelf towards Reynisdjúp. Two (605 and 606) were on the slope at depths 350-440 m (figure 11). This area was previously surveyed in 2012 (Óðinsson et al. 2019, Steinunn H. Ólafsdóttir et al. 2020).

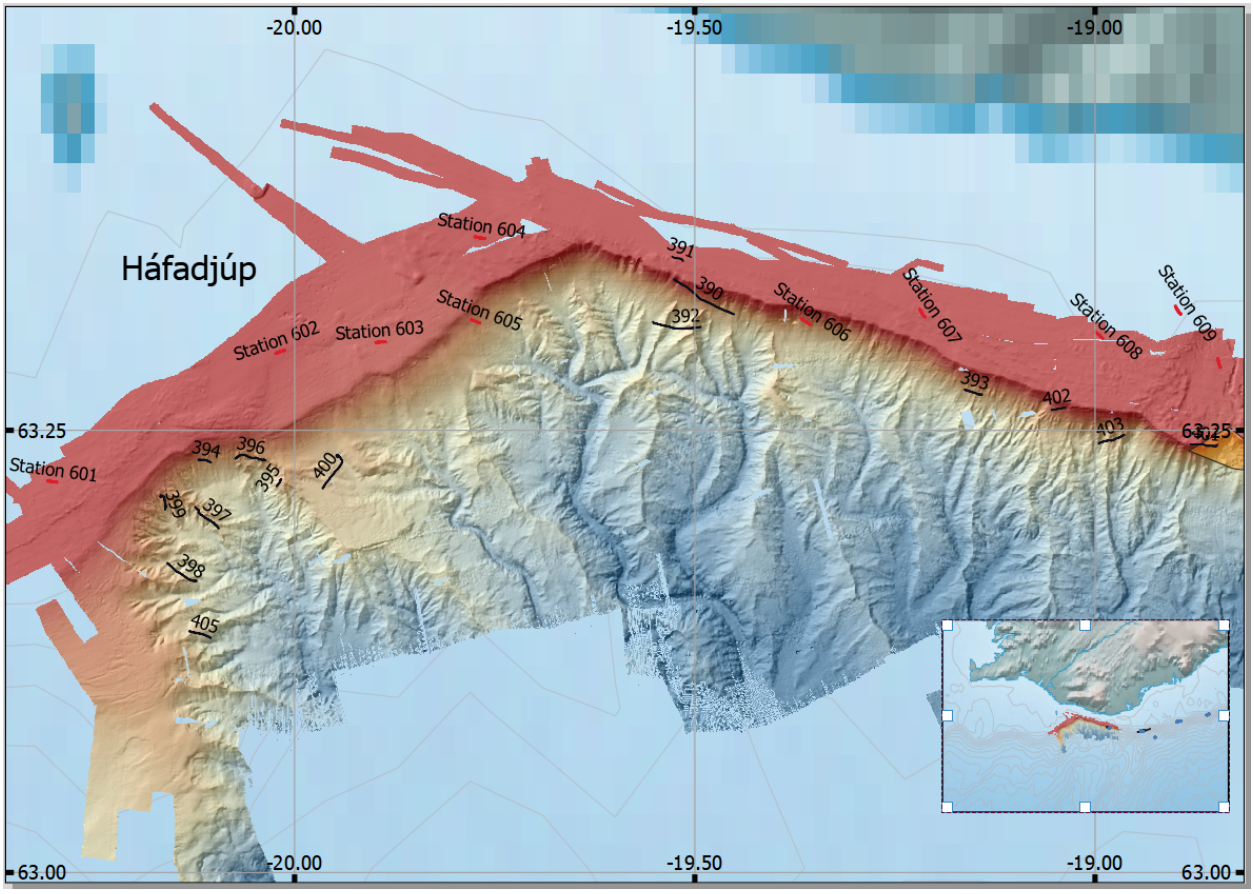

Figure 11. Háfadjúp. The red lines are the transects from this survey and the black lines are the transects from a KBH survey in 2012.

11.mynd. Háfadjúp. Rauðar línur eru snið tekin í þessari rannsókn og svartar línur sýna snið tekin í leiðangri KBH 2012.

Muddy sand was the main sediment type observed on the shelf and down to the slope off the Háfadjúp trough. The sea pens *Kophobelemnon*, Virgulariidae and *Pennatula* sp. were abundant along transects 602 to 605, and the tube dwelling polychaeta *Ditrupa* sp. was abundant at transect 601. In the slope at transect 606 we observed hard ground, gravel, and broken shells with small sponges. Transect 607 on the shelf was characterized by hard bottom, with gravel and boulders inhabited by sponges, crinoids, brachiopods, Nephtheidae soft corals and Bryozoa (figure 12).

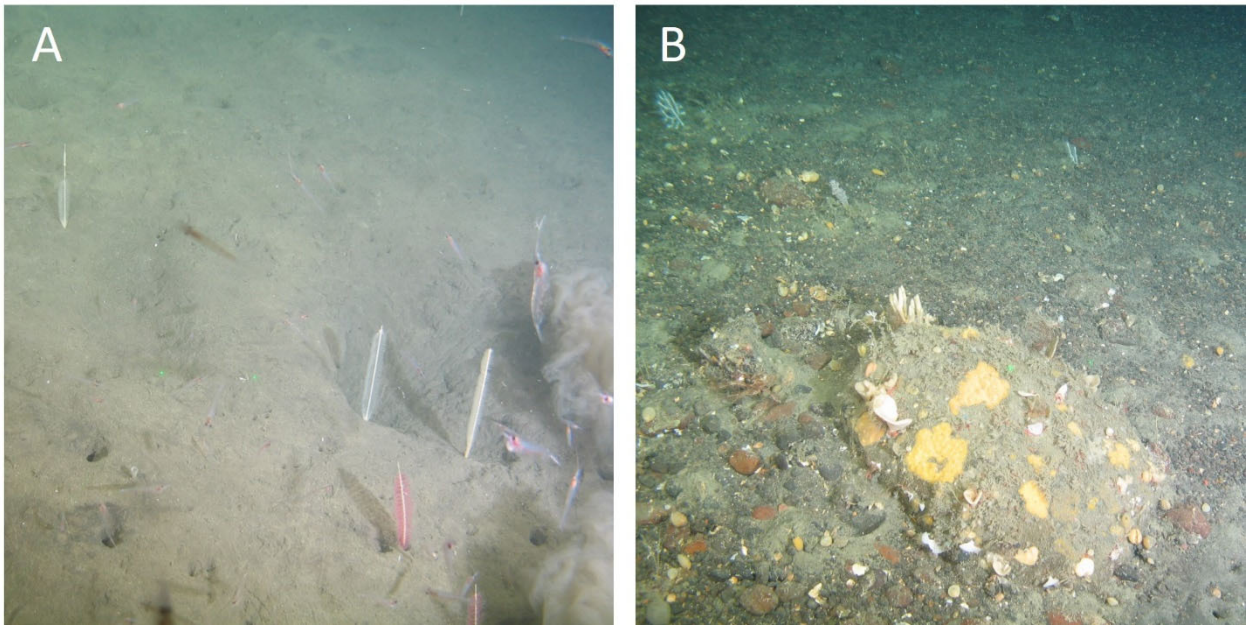

Figure 12. A) Sea pens on soft bottom in transect 602. B) Diverse fauna in transect 607.

12. mynd. A) Sæfjaðrir á mjúkum botni á sniði 602. B) Fjölbreytt lífríki á hörðum botni á sniði 617.

3.4 Reynisdjúp

Stations 608-612 were located on the shelf and in the Reynsidjúp trough, while station 613 was on the slope (figure 13). Previous observations in Reynisdjúp were obtained during a single dive in 2004 (Sigmar A. Steingrímsson and Sólmundur T. Einarsson 2004) and two dives in 2012 (Steinunn H. Ólafsdóttir et al. 2020). Based on the observation of coral habitats in 2004, the area was protected in 2005 (Anon 2005).

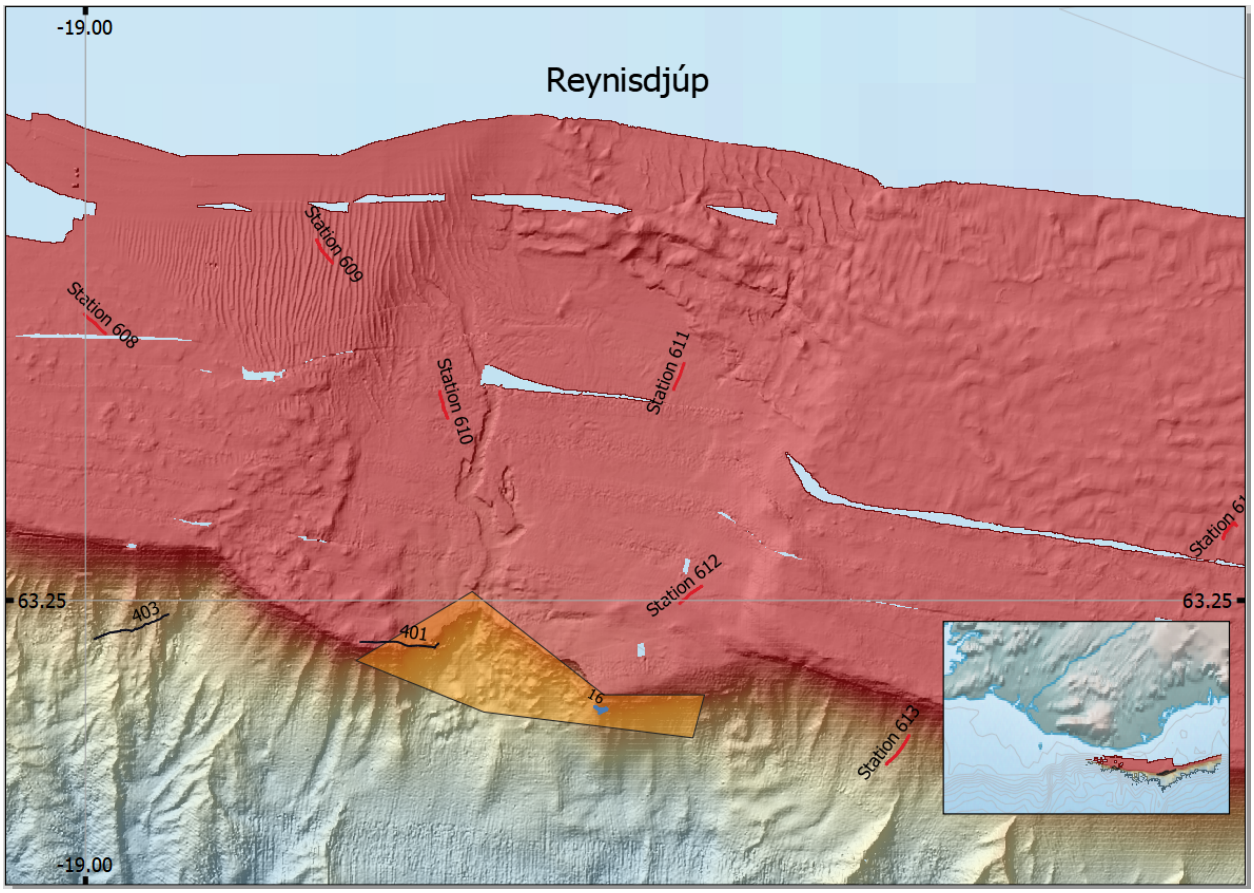

Figure 13. Reynisdjúp. The red lines are the transects from this survey. The black lines are the transects from the KBH survey in 2012 and the blue dot is a dive from the KBH in 2004. The orange polygon is the closed area established in 2005 to protect coral.

13. mynd. Reynisdjúp. Rauðar línur eru snið tekin í þessari rannsókn. Svartar línur sýna snið tekin í leiðangri KBH 2012 og blár punktur er snið tekið í leiðangri KBH 2004. Appelsínuguli reiturinn er friðað svæði lokað árið 2005 til að vernda kórala.

Transect 608 was characterized by hard bottom with boulders, gravel, and cobbles. Plexauridae and Stylasteridae coral branches were attached occasionally to the boulders that otherwise were mostly covered with sediment or hydrozoans. Large sand ripples are evident from the multibeam data west of Reynisdjúp and transect 609 was placed in the centre of this area, with the video track crossing over four of these features (figures 13 and 14). Few benthic organisms were observed. Sand, hardened sediment and gravel were observed at transect 610. Fan-shaped sponges, hydrozoans, the starfish *Ceramaster granularis*, brachiopods, ophiuroids, branched bryozoans with hard skeleton, and sea anemones were observed on the hard substrate. Clay deposits and sand ripples characterized transect 611 (figure 15), where very little epifauna was observed. Muddy sand and some boulders were observed on transect 612.

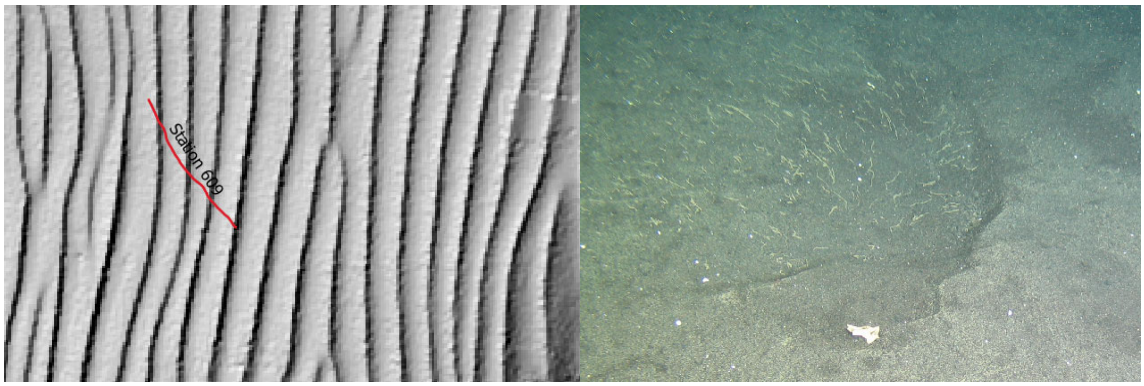

Figure 14. The transect at station 609 crosses over four large sand waves. The image to right shows the sediment.

14. mynd. Snið á stöð 609 sem fer yfir fjórar sandöldur. Myndin til hægri sýnir setgerðina.

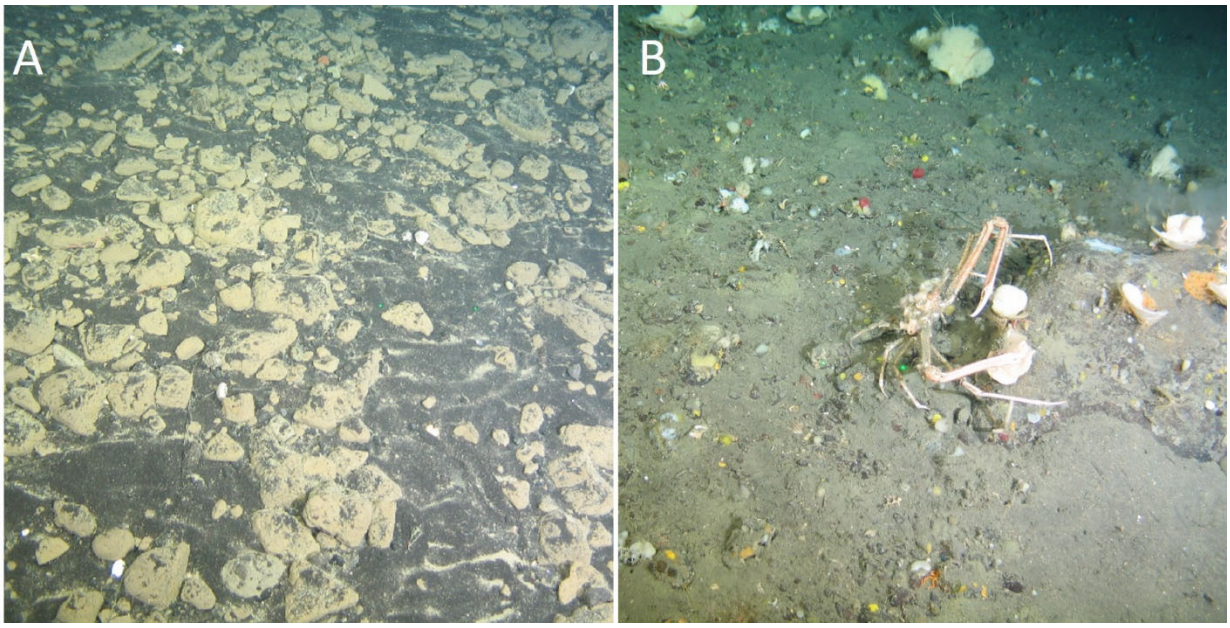

Figure 15. A) Clay deposits at station 611. B) Scyramathia carpenter with various sponge species and other benthos at transect 613.

15. mynd. Leirkögglar á sandbotni á stöð 611. B) Gaffalkrabbi ásamt ýmsum svampategundum og fleiri botnlífverum á sniði 613.

Station 613 was located on the slope (figure 13). Higher biodiversity was observed in this station compared to stations on the shelf. It had a diverse community of sponges, including species of the genera *Tethya* or *Craniella*, *Asbestopluma*, the bright yellow *Aplisylla*/*Hexadella*, the red *Aplysilla rosea, Quasillina brevis* and various fan-shaped sponges. Corals were observed, including *Acanthogorgia armata*, *Paramuricea,* a single *Desmophyllum pertusum (Lophelia pertusa)* colony on a boulder, and the sea pen *Pennatula* sp. Other taxa observed included the

"fork" crab *Scyramathia carpenteri*, galatheoidea, hydrozoans, ophiuroids, bright red Ophiomyxa, crinoids, stylasterids, and echinothuriinae soft sea urchin (figure 15).

3.5 Kötlugrunn

Stations 614-618 were located on Kötlugrunn, while station 619 was on the slope (figure 16). The landscape shows hummocky moraine terrain and at transects 614 and 618 a mixture of hard muddy sand, gravel, cobble, and boulders was observed. The fauna was comprised mainly of sponges, hydrozoans, and brachiopods.

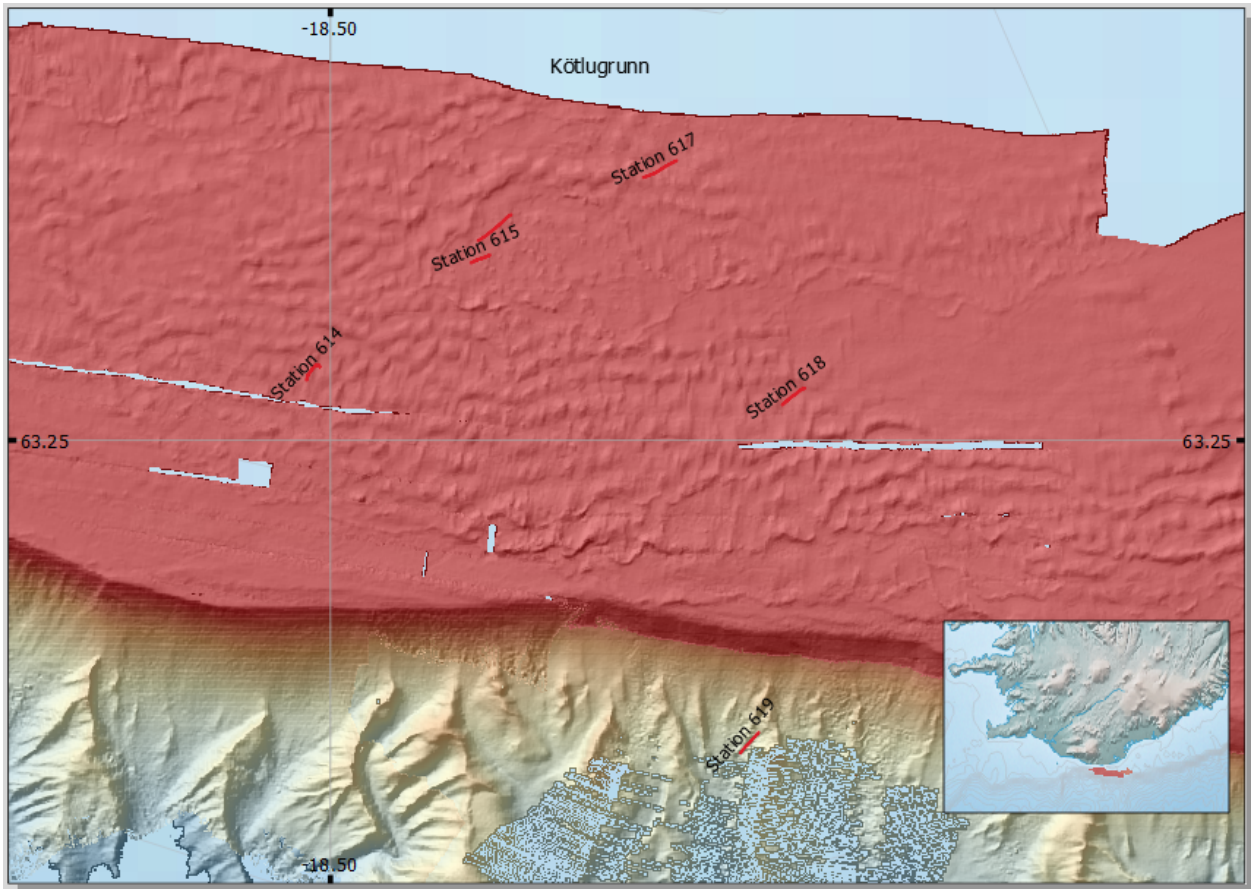

Figure 16. Kötlugrunn area. Transects are red.

16. mynd. Rannsóknasnið á Kötlugrunni.

Circular forms on the seafloor in Kötlugrunn (figure 16 and 17) were suspected to be coral reefs as they show similar size and shape as coral reefs present along the southern shelf (see Sigmar A. Steingrímsson and Sólmundur T. Einarsson 2004; Steinunn H. Ólafsdóttir et al. 2020).

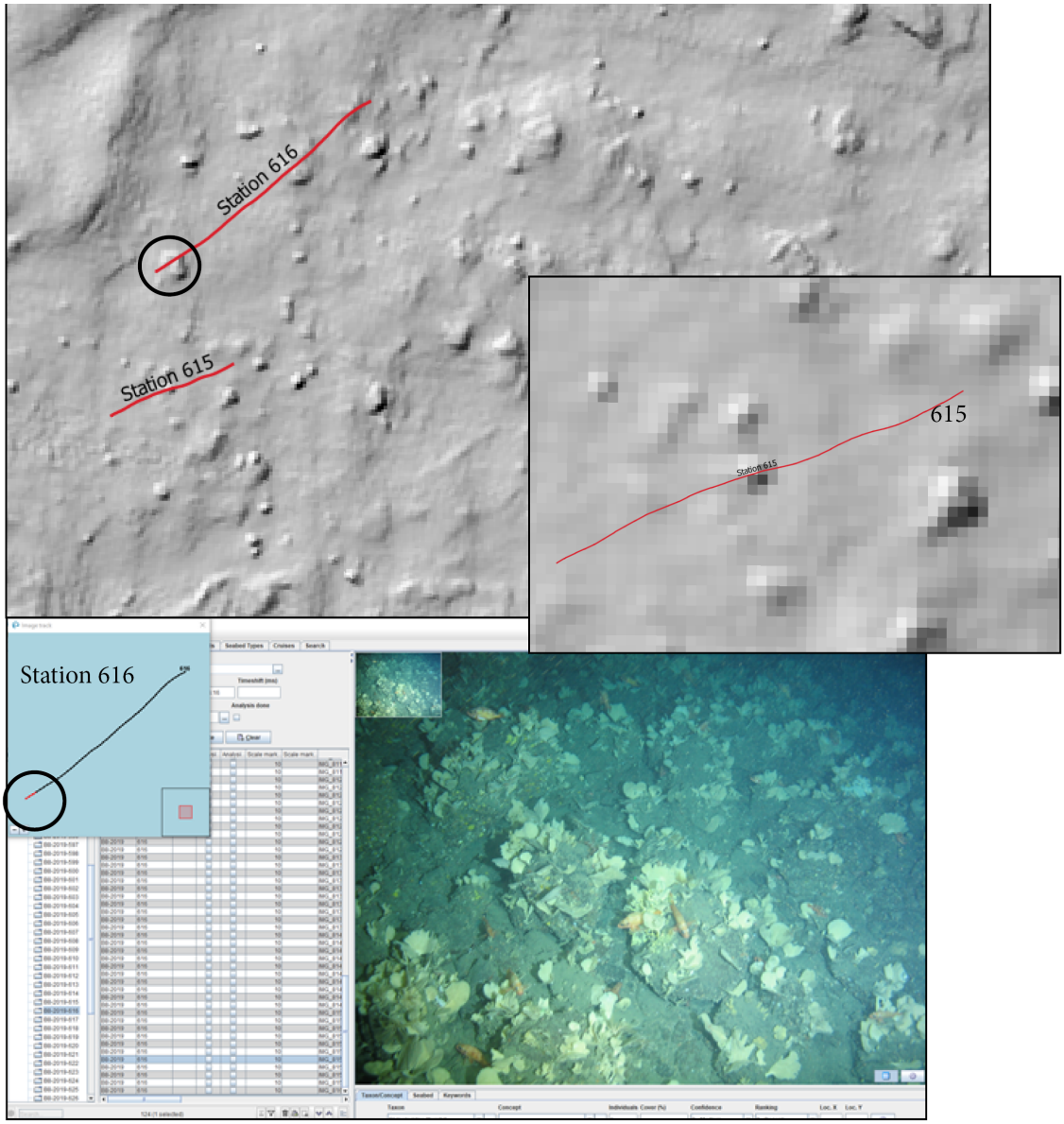

Figure 17. Transect at stations 615 and 616 above. The black circle shows a circular formation that is observed in transect 616. Transect 615 crosses over one circular feature. The image below shows dense aggregation of Axinellidae sponge community observed on boulders/lava within the black circle in transect 616.

17. mynd. Efri mynd sýnir snið 615 og 616. Svarti hringurinn sýnir hringlaga myndun sem mynduð var á sniði 616. Fyrir neðan sést þyrping af Axinellidae svömpum sem sitja á grjóti/hrauni á sniði 616. Innfellda myndin sýnir betur snið 615.

Inspection however showed that these circular forms are built up by boulders or lava. Porifera aggregations, mostly Axinellidae, were observed on these boulder features, which attracted a large number of redfish (*Sebastes* sp.). Gravel and sand bottom mixed with empty shells and brachiopods were observed between these boulder features.

Transect 617 was similar to 615 and 616 regarding the seabed, but it also included lithified sediment crusts along with sand, gravel with dead shells, cobbles and boulders. Sponges were settled on the boulders, which were covered with more sediments than in the other transects. In the second half of the transect we observed branches of the coral *Swiftia* sp. attached to cobbles and boulders on the gravelly-sandy bottom. Towards the end of the transect, the density of these *Swiftia* sp. corals (figure 18 B) increased to approximately 20 branches per m^2. Such high densities of this coral have not been observed previously in Icelandic waters.

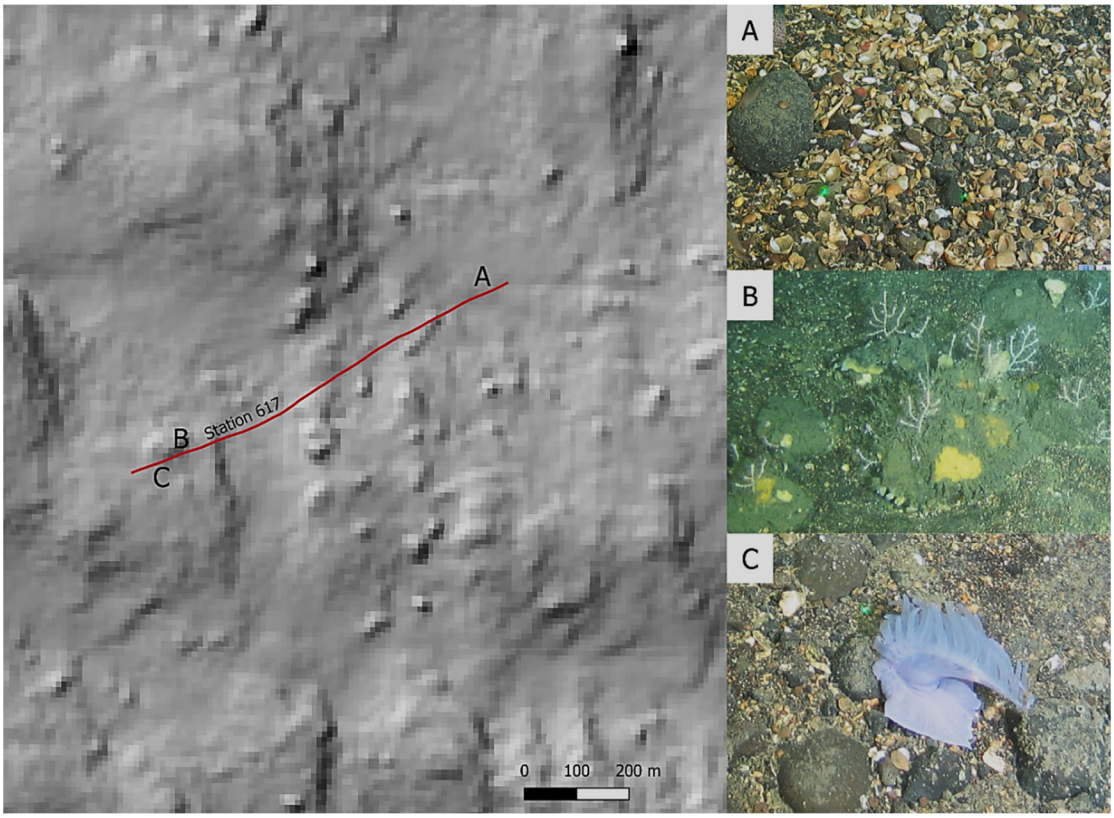

Figure 18. Transect for station 617 at Kötlugrunn. A) Gravel and dead seashells. B) Dense occurrence of Swiftia corals C) An unknown blue organism.

18. Mynd. Snið á stöð 617 á Kötlugrunni. A) Möl og dauðar skeljar. B) Swiftia *kóralgreinar. C) Óþekkt bláleit lífvera.*

An unusual organism was photographed at 113 m depth on transect 617 (figure 18 C). The organism was light blue in colour, with comb like tentacles and a foot or a flat base. Its taxonomic status cannot be confirmed as collecting specimens is not possible with the Campod. Transect 618 was characterized by gravelly muddy sand with scattered cobbles, inhabited by hydroids, brachiopods and *Quasillina brevis* sponges. Station 619 was located on the slope at 600-660 m depth. The seabed was muddy sand with fields of bamboo coral *Acanella arbuscula* and sea pens *Pennatula* sp., with up to 6 individuals per m^2 (figure 19).

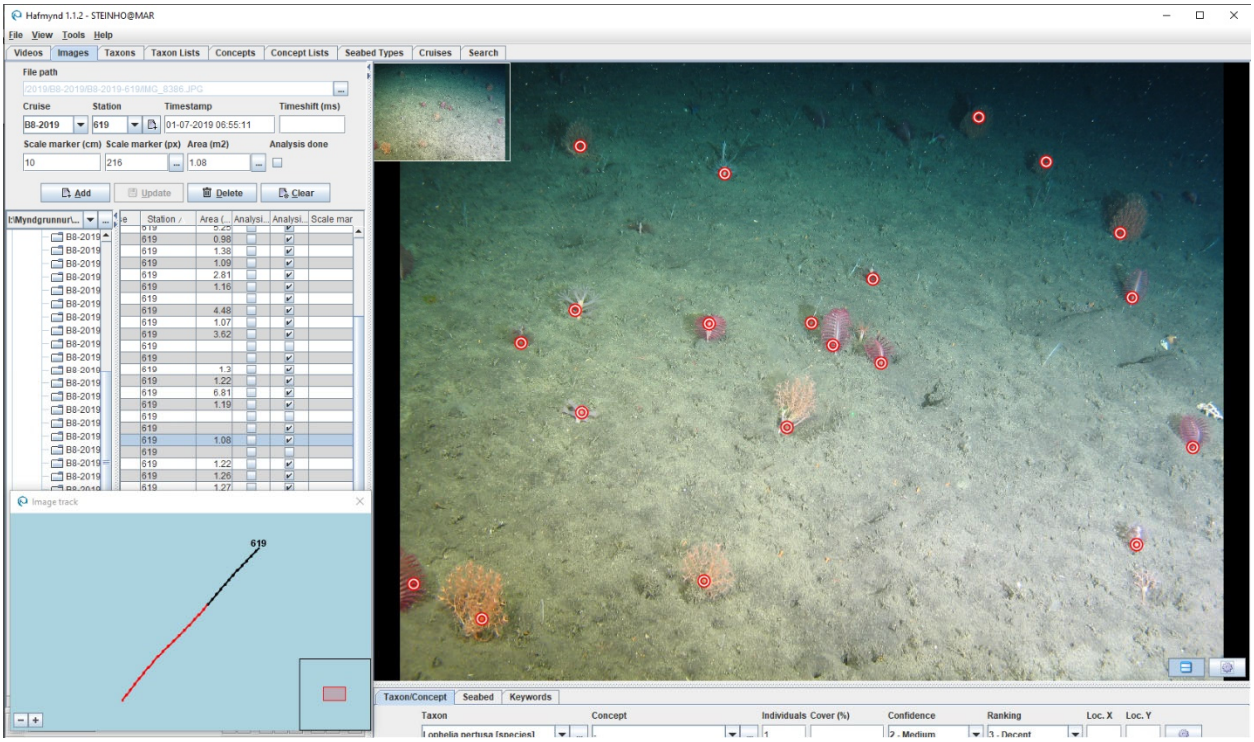

Figure 19. Field of bamboo coral and sea pens on soft bottom observed at transect 619.

19. mynd. Sæfjaðra- og kóralgarður á mjúkum botni á sniði 619.

3.6 Skaftárdjúp

Stations 620-624 were located on the shelf of Skaftárdjúp (figure 20). Like on the shelf of Háfadjúp, the seabed was mostly muddy sand, with few epibenthic taxa, of which the sea pen *Kophobelemnon* sp. was most common. In this area, live *D. pertusum* colonies were observed in 2004 (Sigmar A. Steingrímsson and Sólmundur T. Einarsson 2004). Based on these findings the area was protected in 2005 (Anon 2005).

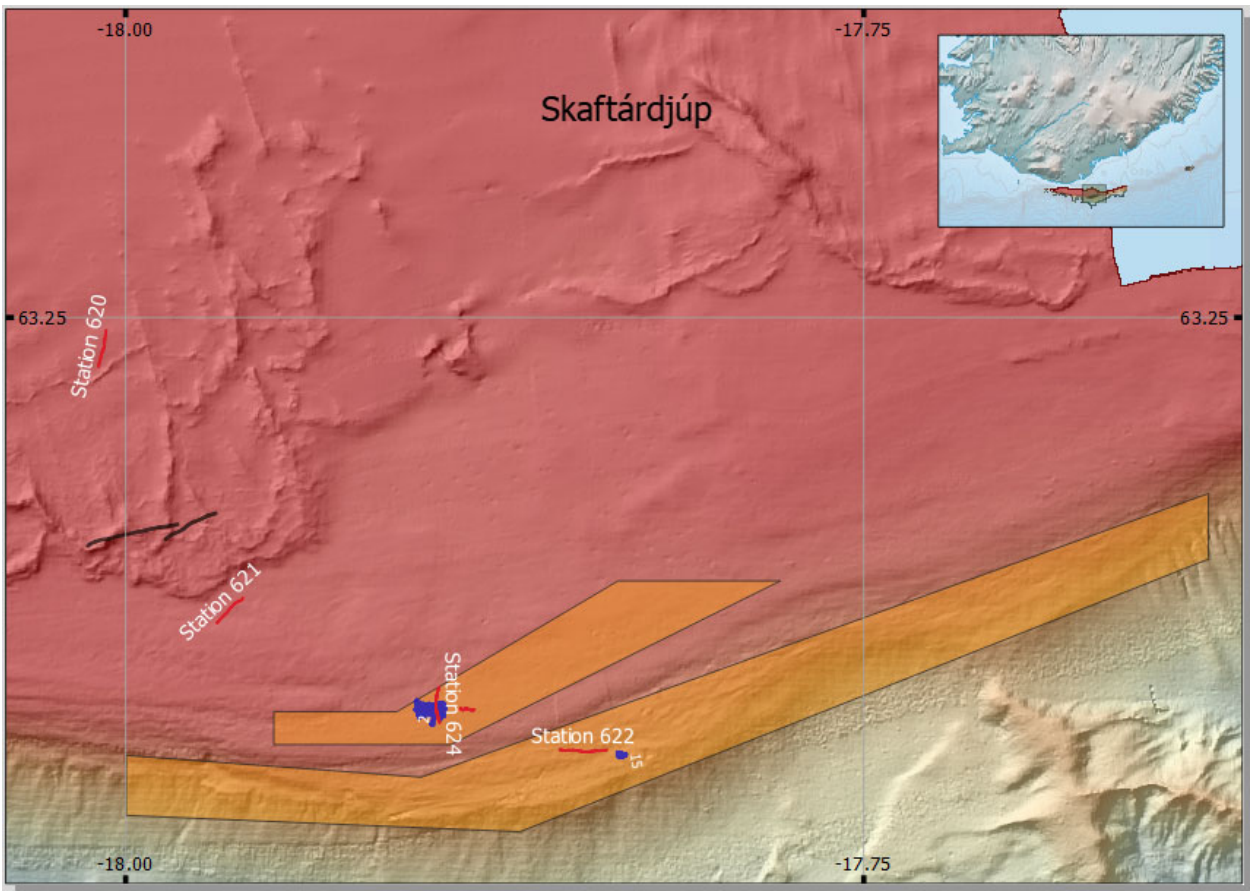

Figure 20. Skaftárdjúp. The orange polygons are the areas closed in 2005 to protect corals. The red lines are the transects from this cruise, the blue and black lines are transects from KBH surveys in 2004 and 2010.

20. Mynd. Skaftárdjúp. Appelsínugulir fletir sýna verndarsvæði frá 2005. Rauðar línur sýna snið frá þessum leiðangri, bláar línur eru snið frá KBH 2004 og svartar línur eru frá KBH 2010.

Here we revisited the coral area within the closed area to evaluate if the live coral cover had increased during this time. The coral reefs are easily visible on the multibeam maps, but it is difficult to target specific features on the seafloor with the Campod. The camera crossed over a single coral reef, which was one of the same reefs observed in 2004 (figure 21). There was little sign of recovery, and the coral framework was covered with sediment and colonized by other organisms than coral (figure 22).

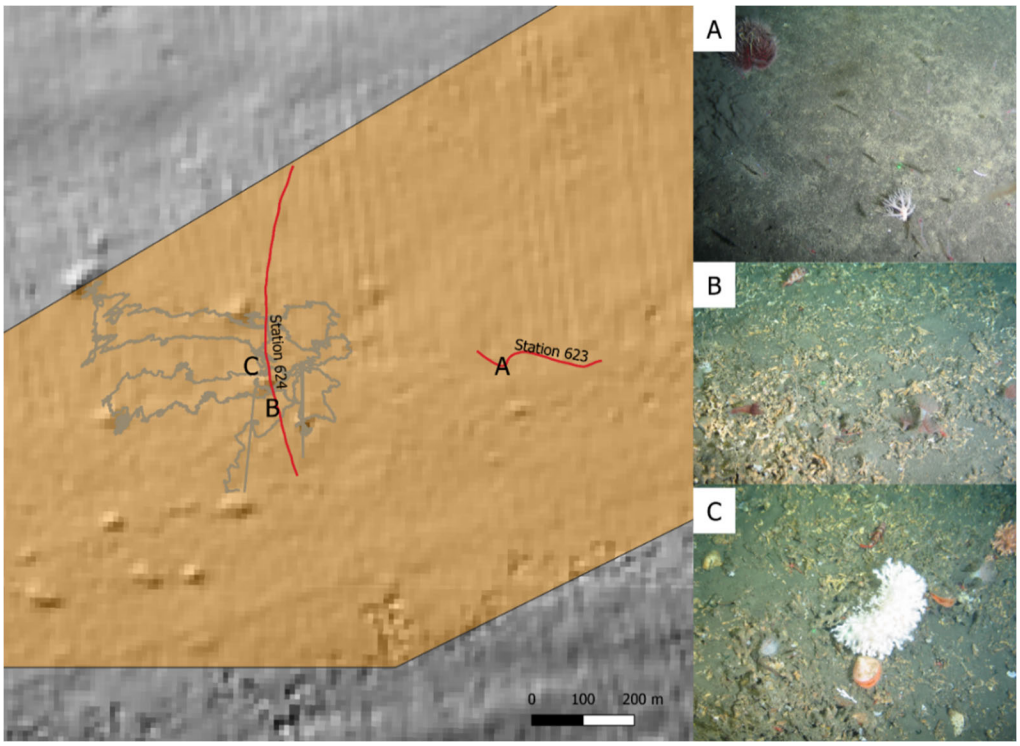

Figure 21. Circular coral-reefs can be seen in the large image within the closed area (yellow). The grey line is the transect from 2004 and the red lines are transects 623 and 624 from this survey. A) Transect 623 was on sandy bottom with Kophobelemnon sea pens. B) Dead coral rubble observed in transect 624. C) Most of the reef was dead, but two live colonies were found, one seen here.

21. mynd. Hringlaga kóralrif sjást á stóru myndinni innan við friðað svæði (gult). Gráa línan er ferill ROV frá 2004. A) Sandbotn með Kophobelemnon *sæfjöður á sniði 623. B) Dauð kóralbrot á sniði 624. C) Stærstur hluti rifsins var dauður, en tvö lifandi kóralsambýli sáust. Hér sést annað þeirra.*

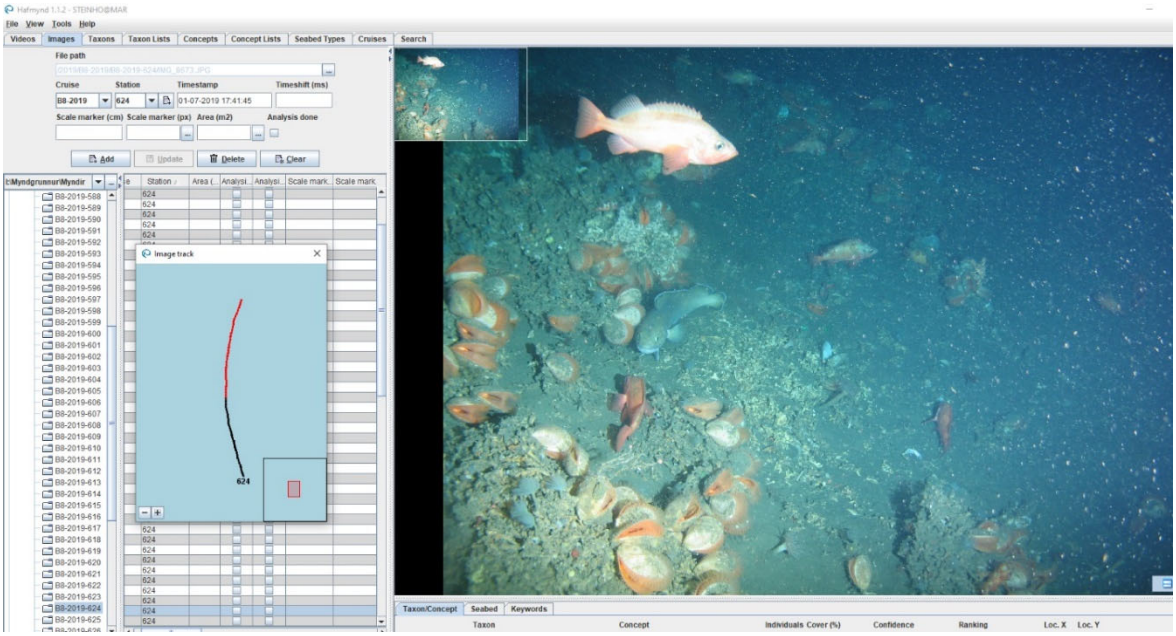

Figure 22. Dead coral reef inhabited by Acesta excavata, polychaeta and fish at transect 624.

21. mynd. Dautt kóralrif sem ægisdrekkur, burstormar og fiskar nýta sér á sniði 624.

3.7 Síðugrunn

Stations 625 and 627 were on the slope off Síðugrunn, while station 626 was on the shelf (figure 23). Transect 625 was at depths between 420 and 500 m. It crossed over three gullies, all with corals on the flanks, and sea pen fields on the soft bottom in the valley between. We observed scattered coral, and a coral reef composed of *M. oculate* and *D. pertusum* with *Primnoa resedaefomis*, *Paramuricea* sp. and Anthothelidae associated.

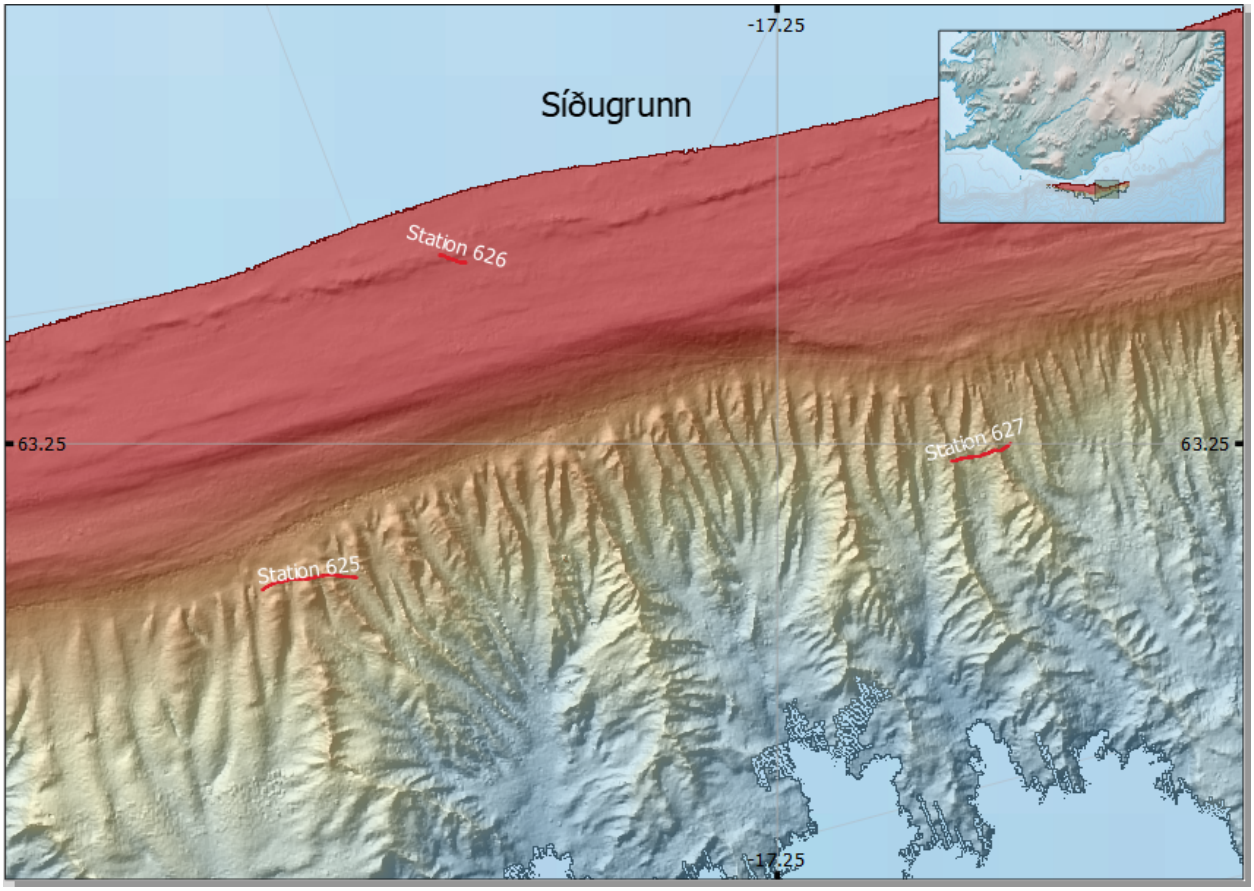

Figure 23. Síðugrunn. The red lines show the transects from this survey.

23. mynd. Síðugrunn. Rauðar línur sýna rannsóknasniðin úr leiðangrinum.

Station 626 was located on the shelf at 150-160 m depth. Muddy sand was observed along the transect with very little epifauna. Some sponges were on boulders but most of the boulders had a layer of sediment. Transect 627 was on the slope at 515-580 m depth and crossed over two

gullies. Coral reefs or patches were on the flanks and summit of the gullies while sea pens and bamboo corals were on the soft bottom between the coral patches (figure 24).

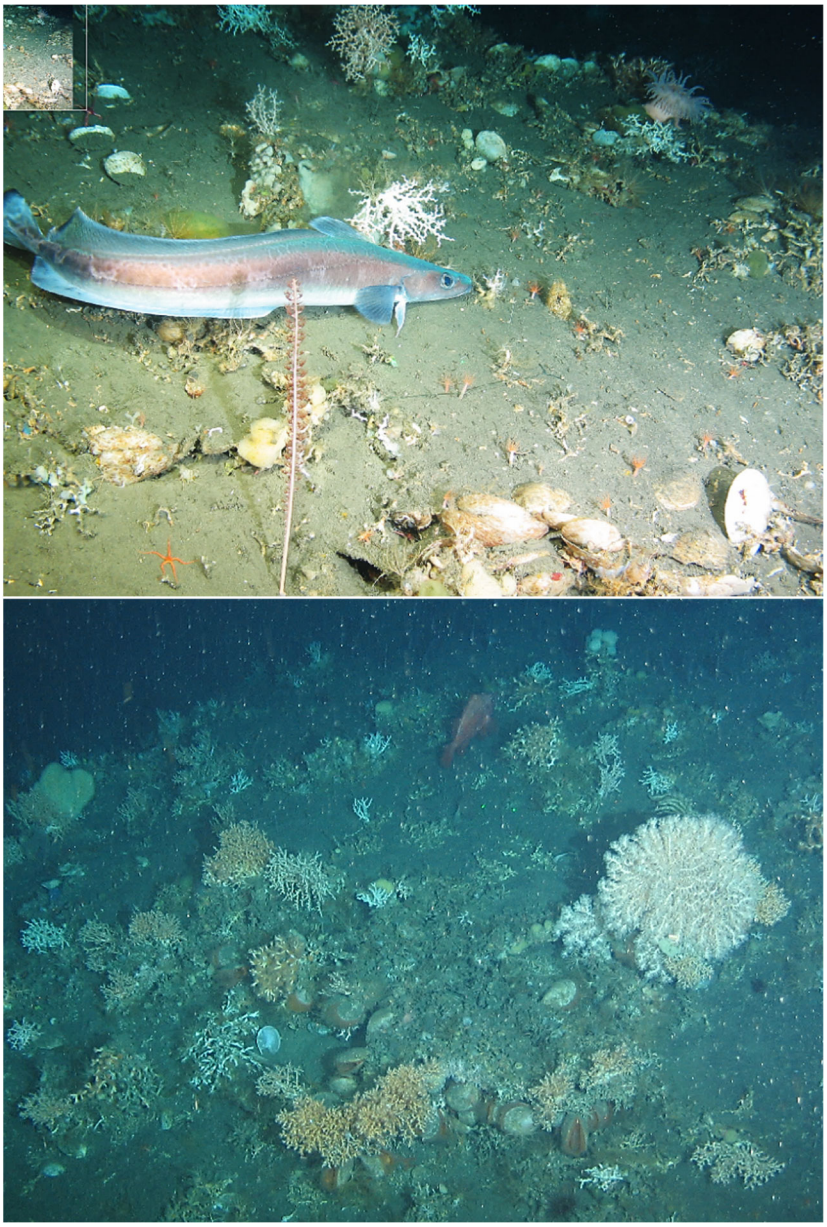

Figure 24. Coral patches and reef from the slope off Síðugrunn. Above, blue ling among coral and sea pens and other benthic animals. Below, coral reef observed in transect 627.

23. mynd. Kóralflekkir og kóralrif í kantinum út af Síðugrunni. Efri mynd sýnir blálöngu innan um kóralgreinar, sæfjöður og fleiri botnlífverur. Neðri mynd sýnir kóralrif á sniði 627.

3.8 Skeiðarárdjúp

Skeiðarárdjúp was previously investigated in 2004, and corals were confirmed (Sigmar A. Steingrímsson and Sólmundur T. Einarsson 2004). Additional observations were carried out in 2009 and 2010 (Steinunn H. Ólafsdóttir et al. 2020). Following these surveys, the western part of the area was closed to protect the coral in 2011 (Steinunn H. Ólafsdóttir and Julian Burgos 2012). In this survey, two transects were added on the slope and in the eastern part of the area (figure 25). Transect 628 was conducted over muddy sand bottom with *Kophobelmnon* sp. as the most frequent species. Transect 629 was located on the slope at 400 m depth, where the bottom was firm, sandy gravel with cobbles. Axinellidae sponges were spread along the transect and scattered colonies of *D. pertusum* and *M. oculata* were also observed (figure 26).

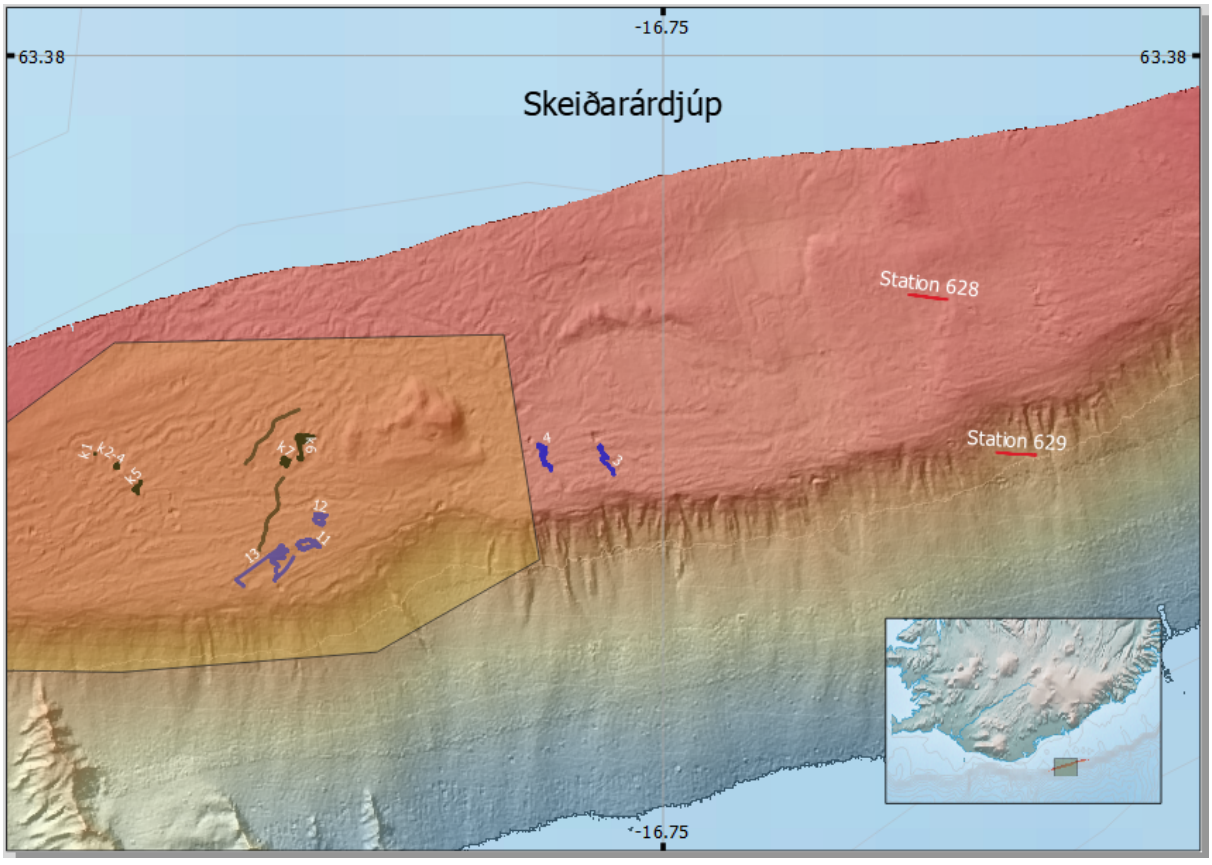

Figure 25. Skeiðarárdjúp. The blue transects are previous dives of KBH in 2004 and the black transects are from KBH in 2009 and 2010. The red transects in the eastern part are from this survey. The orange polygon is a part of the closed area from 2011 to protect coral.

25. mynd. Skeiðarárdjúp. Bláar línur eru snið frá KBH 2004 og svartar línur eru snið frá KBH 2009 og 2010. Rauðar línur eru snið úr þessum leiðangri. Appelsínuguli flöturinn er svæði sem var lokað árið 2011 til verndar kórölum.

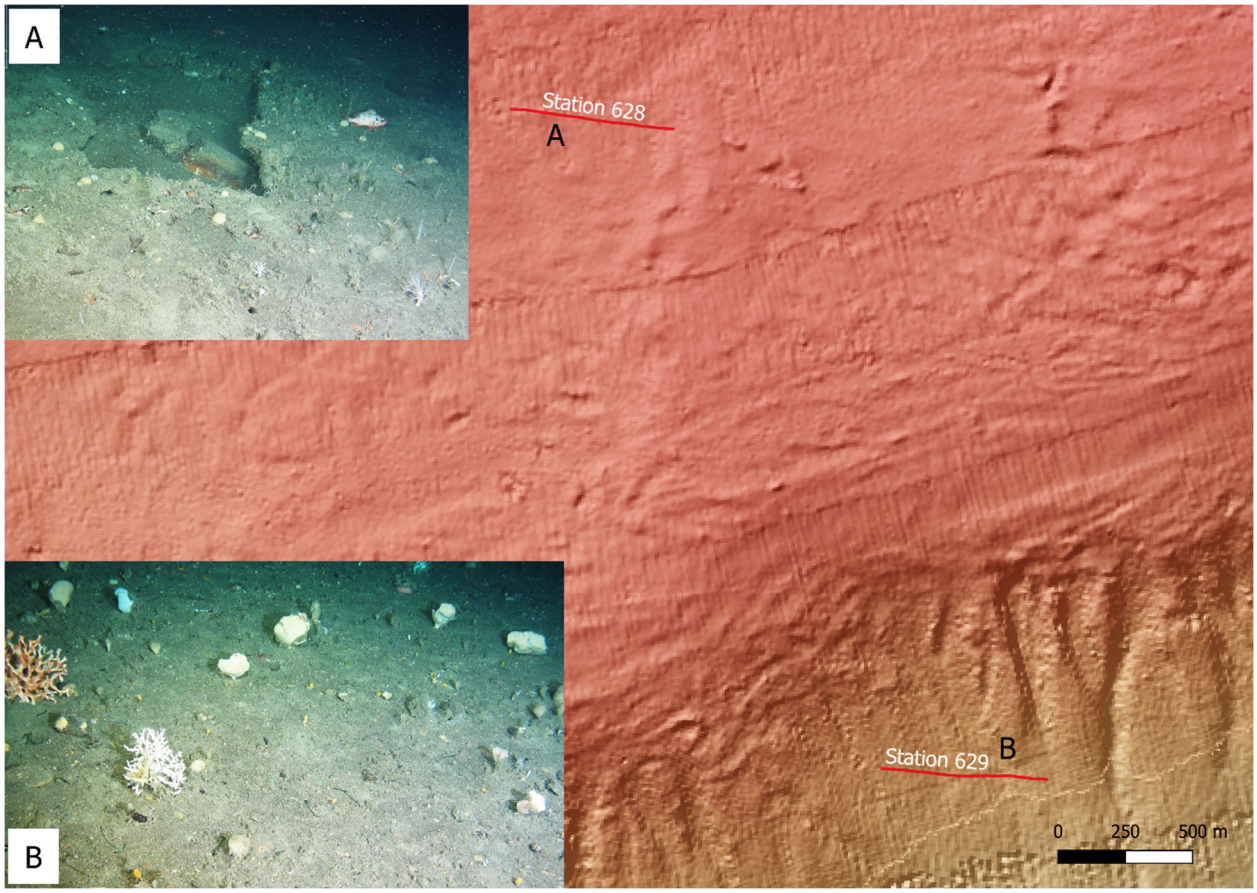

Figure 26. A) Firm sandy sediment at station 628. B) Coral colonies and Axinellidae sponges in the slope off Skeiðarárdjúp at station 629.

26. Mynd. A) Þétt sendið set á sniði 628 B) Kóralgreinar og Axinellidae svampar á sniði 629 í kantinum út af Skeiðarárdjúpi.

3.9 Öræfagrunn

Stations 630, 632, 635 and 637 were on the slope off Öræfagrunn at 350-600 m depth, while stations 631, 634, 636 and 638 were on the shelf (figures 27-29). In 2004, three transects were carried out on coral reefs in Öræfagrunn. Images obtained with an ROV confirmed the presence of coral reefs, but they also confirmed that these reefs were demolished and therefore the area was not closed for protection (Sigmar A. Steingrímsson and Sólmundur T. Einarsson 2004).

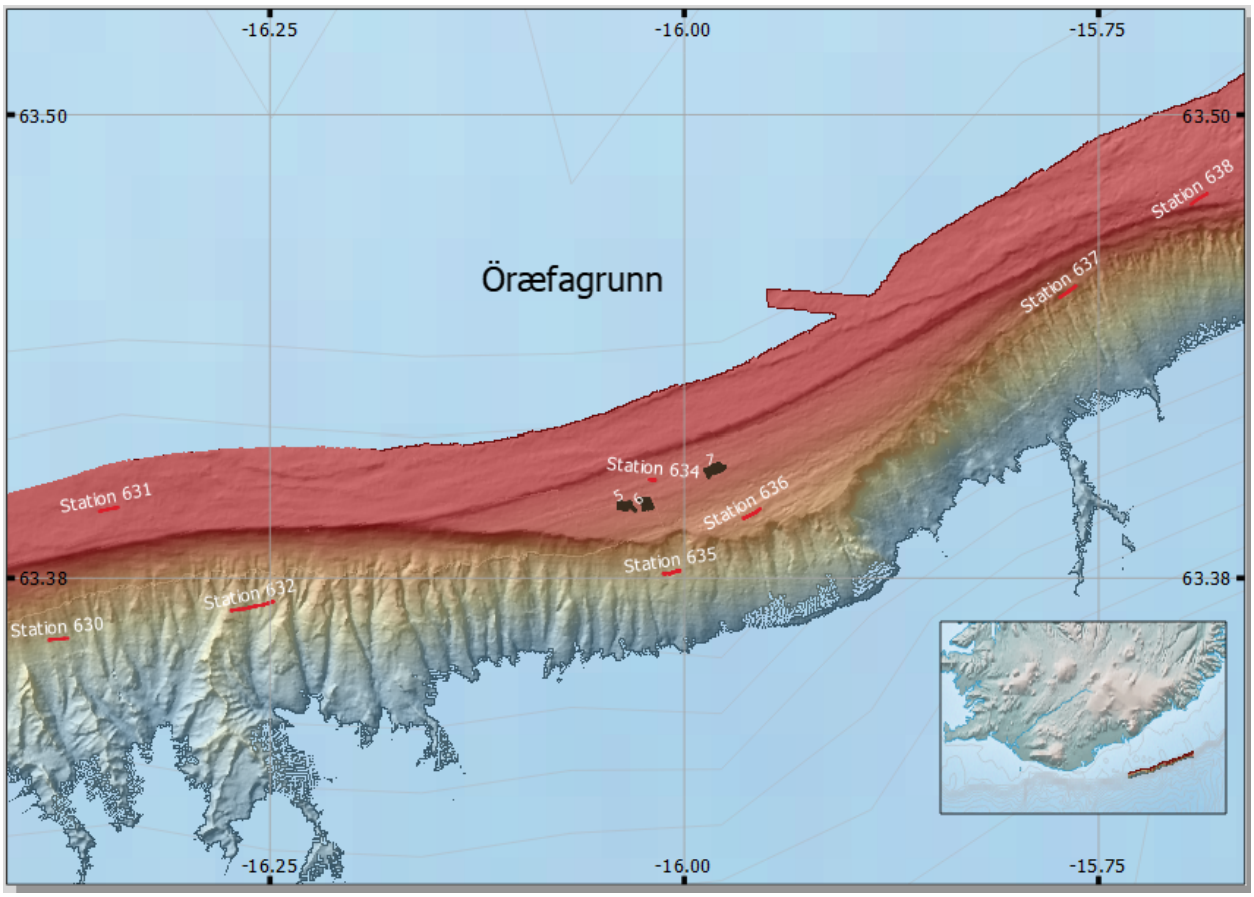

Figure 27.Öræfagrunn. The red lines are the transects from this survey and the black lines are transects are from 2004.

27. Mynd. Öræfagrunn. Rauðar línur eru snið tekin í þessum leiðangri og svörtu línurnar eru snið tekin í leiðangri KBH 2004.

Although transects 633 and 634 targeted coral reefs in particular, no live coral was found, and only coral rubble and dead framework were observed (figure 30 and 31). Scattered coral branches were found at transect 632. Transect 636 was located close to the shelf break and we observed hard bottom with diverse fauna, including *Paramuricea* sp. (figure 29). Transects 635 and 637 were located at the slope on hard bottom with sea pens, sponges, crabs, and scattered coral colonies.

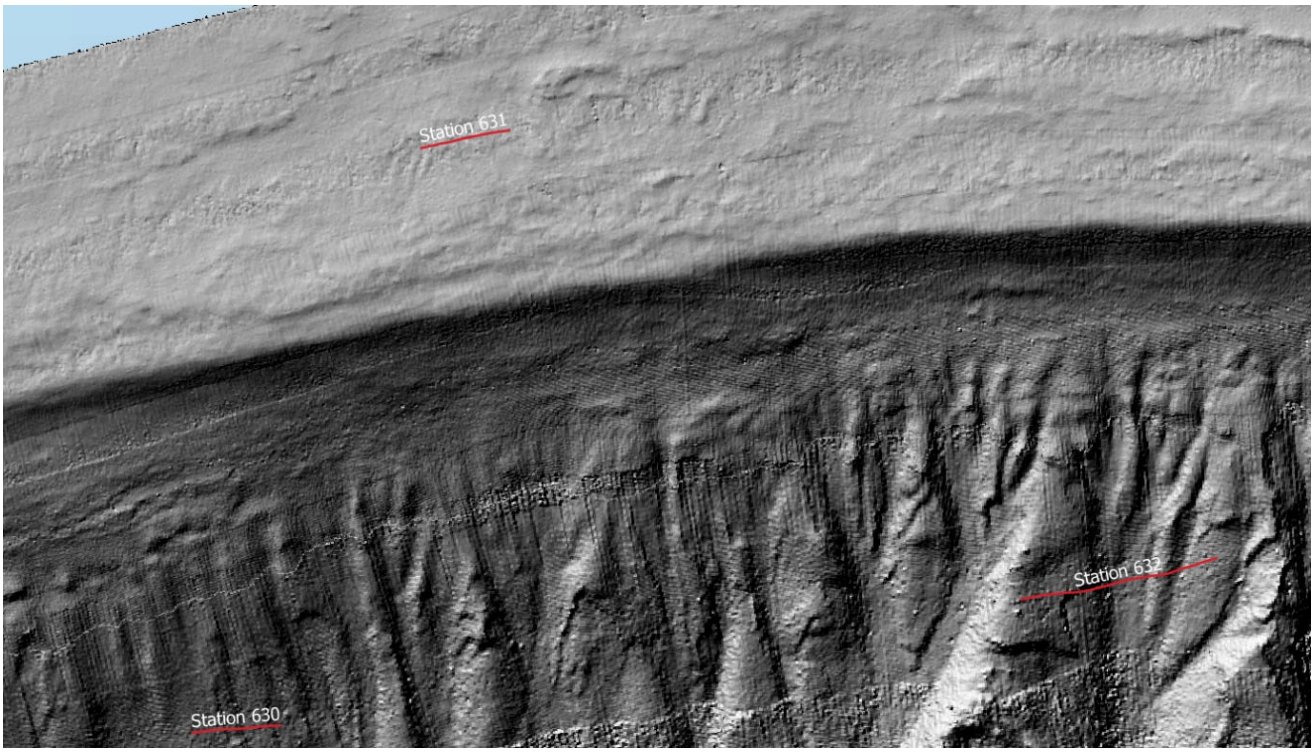

Figure 28. Transects 630-632 in Öræfagrunn.

28. mynd. Snið 630 til 632 við Öræfagrunn.

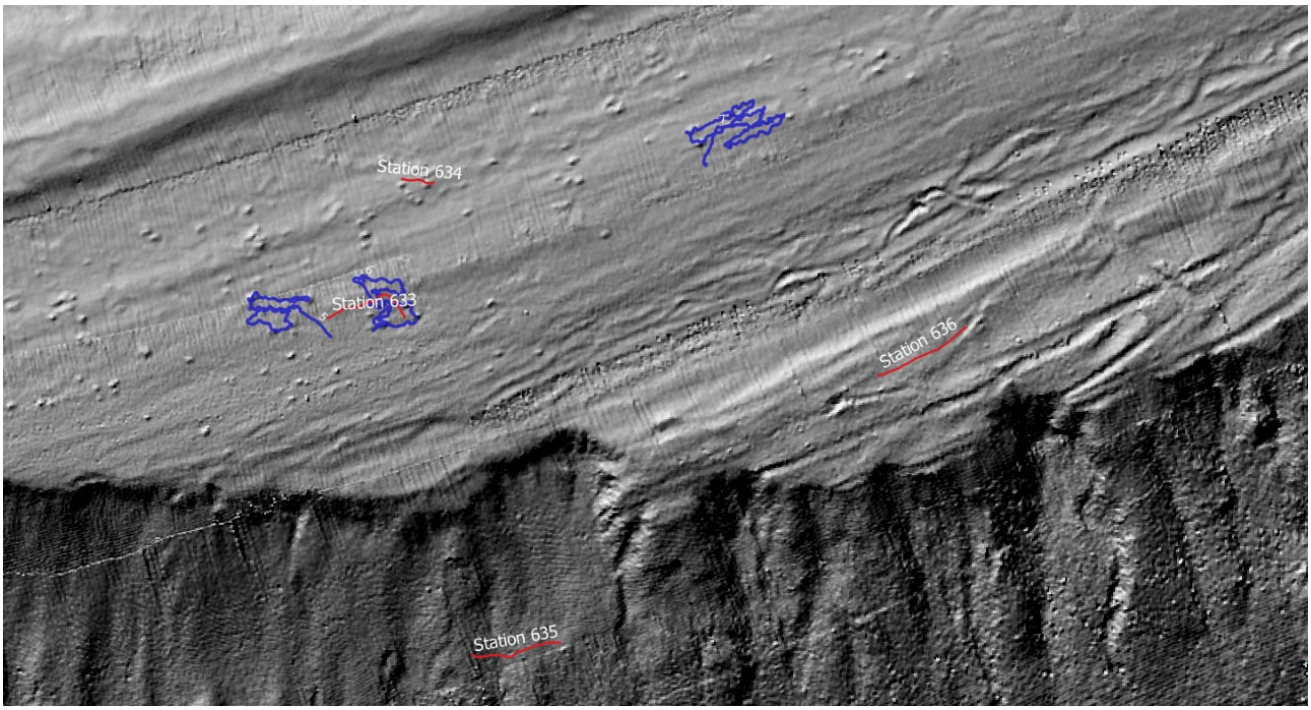

Figure 29. Transects 633-636 in Öræfagrunn. Red lines are transects from this survey and the blue lines are from KBH in 2004.

29. mynd. Snið 633 til 636 við Öræfagrunn. Rauðar línur eru snið tekin í þessum leiðangri og bláar línur er frá leiðangri KBH 2004.

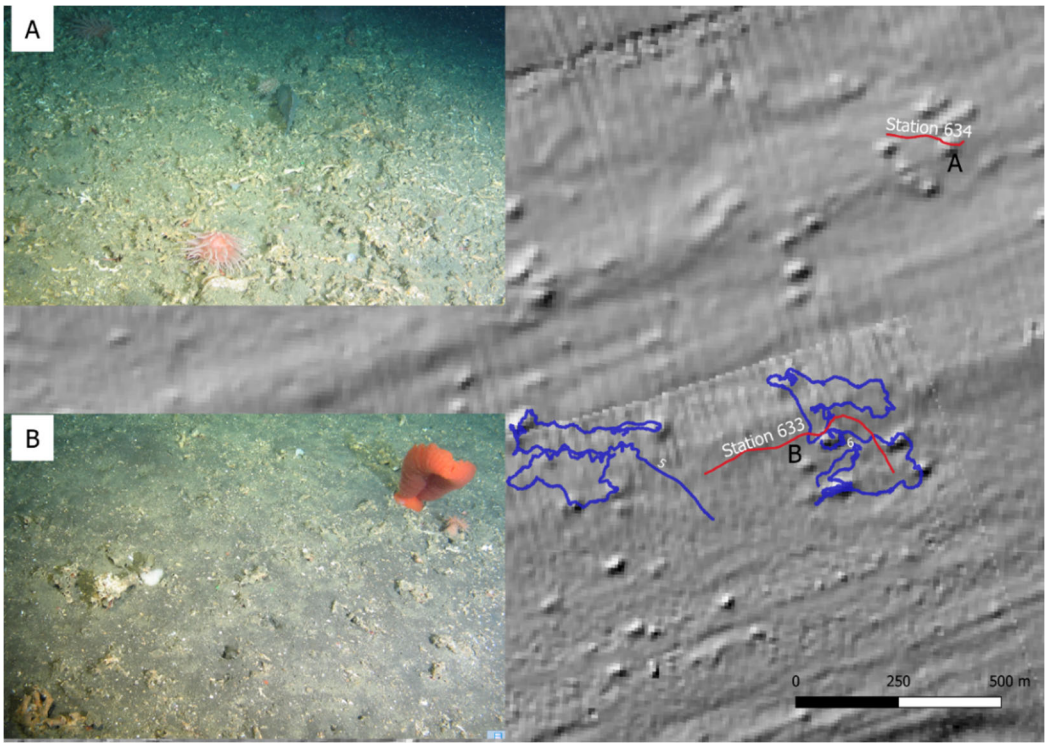

Figure 30. Close up of stations 633 and 634. The circular coral-reefs are easily seen on the multibeam map to right. The red lines are from this survey and the blue lines are from KBH survey in 2004. A) Dead coral reef. B) Coral rubble with the orange sea pen Ptilella grandis.

*30. mynd. Nærmynd af sniðum 633 og 634. Hringlaga kóralrif sjást vel á fjölgeislakortinu til hægri. Rauðar línur eru snið frá þessum leiðangri og bláar línur eru snið frá KBH leiðangri 2004. A) Dautt kóralrif. B) Kóralmulningur ásamt appelsínugulri sæfjöður (*Ptilella grandis*).*

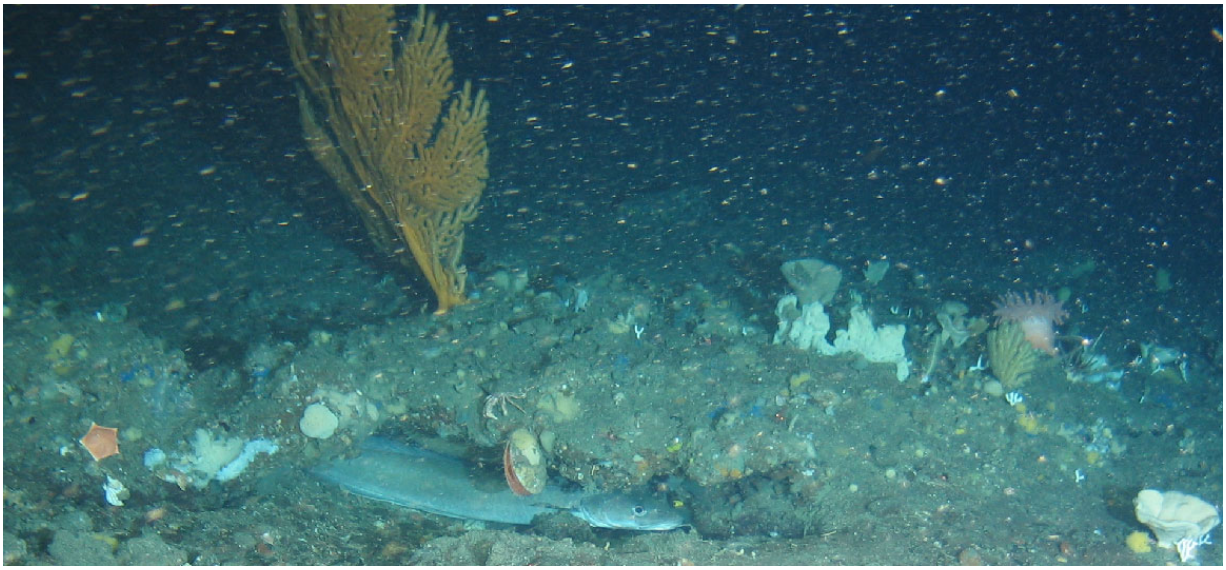

Figure 31. Hard bottom at transect 636. Various species of benthic fauna, including a large branch of Paramuricea sp. and ling hiding in a crevice.

31. mynd. Harður botn á sniði 636. Ýmsar botnlífverur, meðal annars Paramuricea *kóraltré og langa í felum.*

3.10 Breiðamerkurdjúp/Mýragrunn

Stations 638 to 640 were in Breiðamerkurdjúp to Mýragrunn (figure 32). Transect 638 was close to the shelf break, where the bottom was hard sand, gravel and cobbles with *Actinauge* sp. sea anemones and Ophiuroidea. Transect 639 crossed iceberg plough marks. The bottom type was comprised of boulders, consolidated crust, coral rubble, and dead coral reefs. A torn fishing net full off dead coral was observed on one of the dead coral reefs (figure 33). Plexauridae and Stylasteridae occurred along the transect, perhaps indicating recovery as these are vulnerable to trawling because they rise above the seabed.

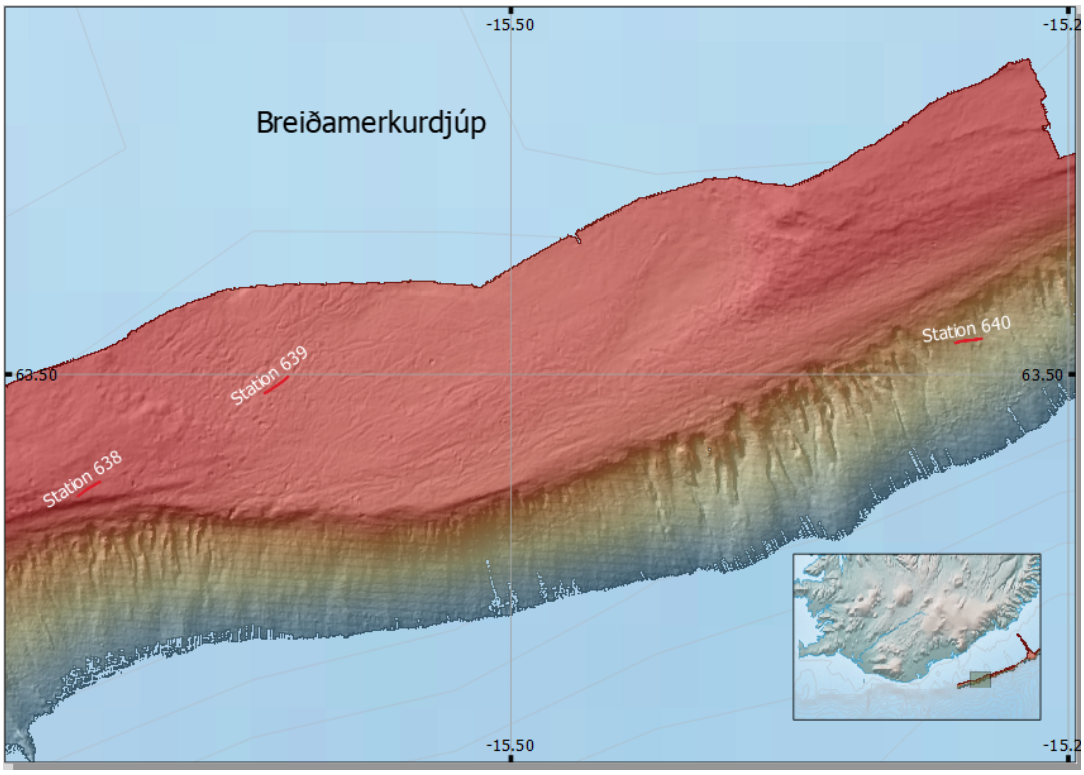

Figure 32. Breiðamerkurdjúp and the three transects.

32. mynd. Rannsóknasnið á Breiðamerkurdjúpi.

Transect 640 was located at 500 m depth on the slope off Mýragrunn (figure 32). Here we observed a complex habitat comprised of diverse sponges, mainly flabellate sponges, Plexauridae coral, branches of *D. pertusum*, *M. oculata* and Stylasteridae. Coral thickets were observed at 512 m depth (figure 35).

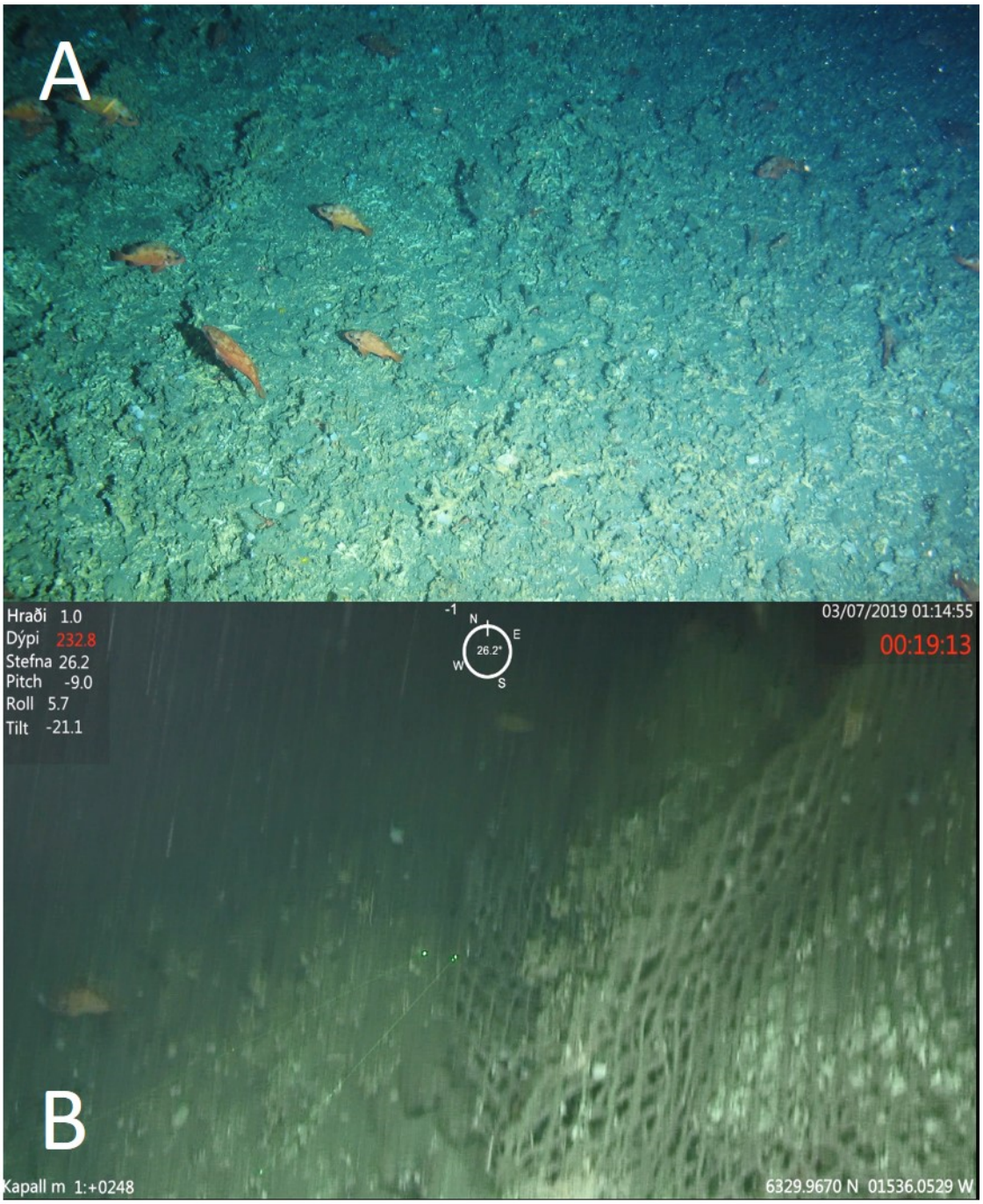

Figure 33. A) Dead coral reef. B) Torn fishing net on dead coral reef with dead coral inside at station 639.

33. mynd. A) Dautt kóralrif. B) Drauganet full af kóral á sniði 639.

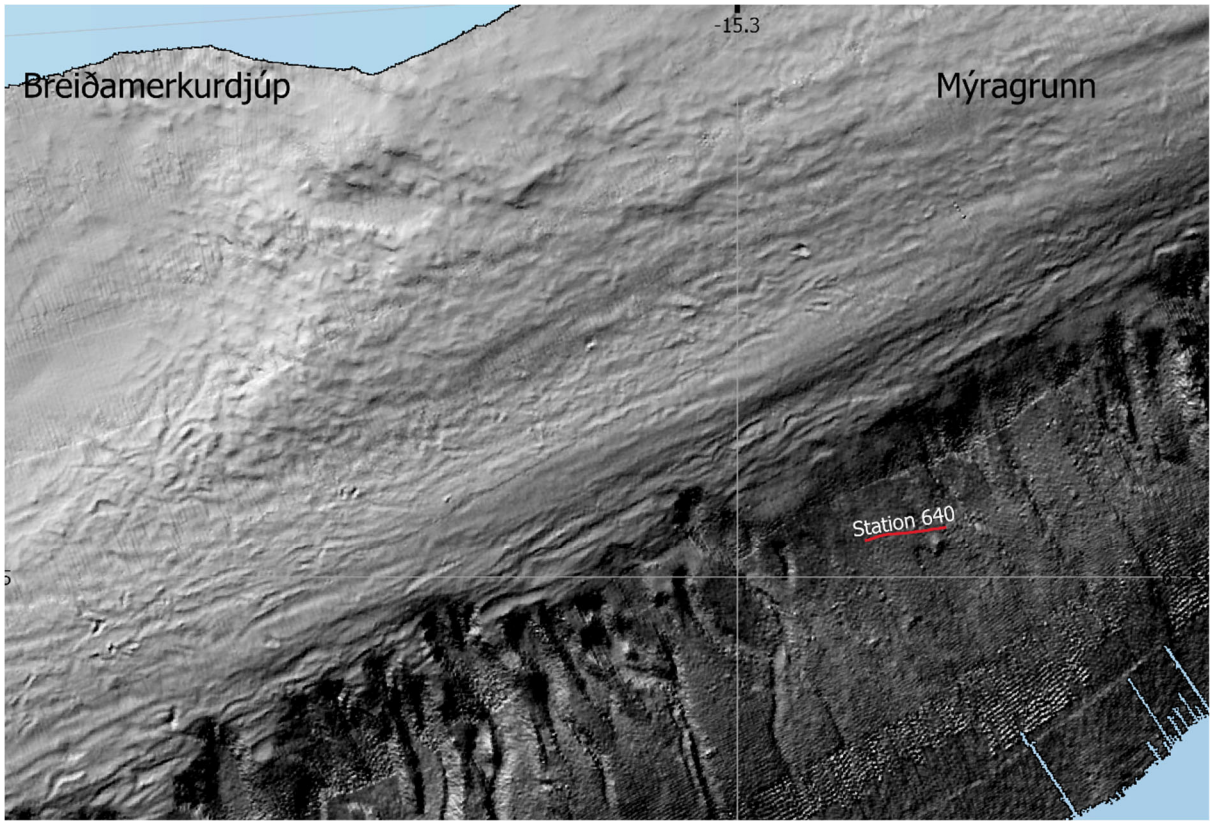

Figure 34. Transect 640 in the steep slope off Mýragrunn.

34. mynd. Snið 640 í kantinum út af Mýragrunni.

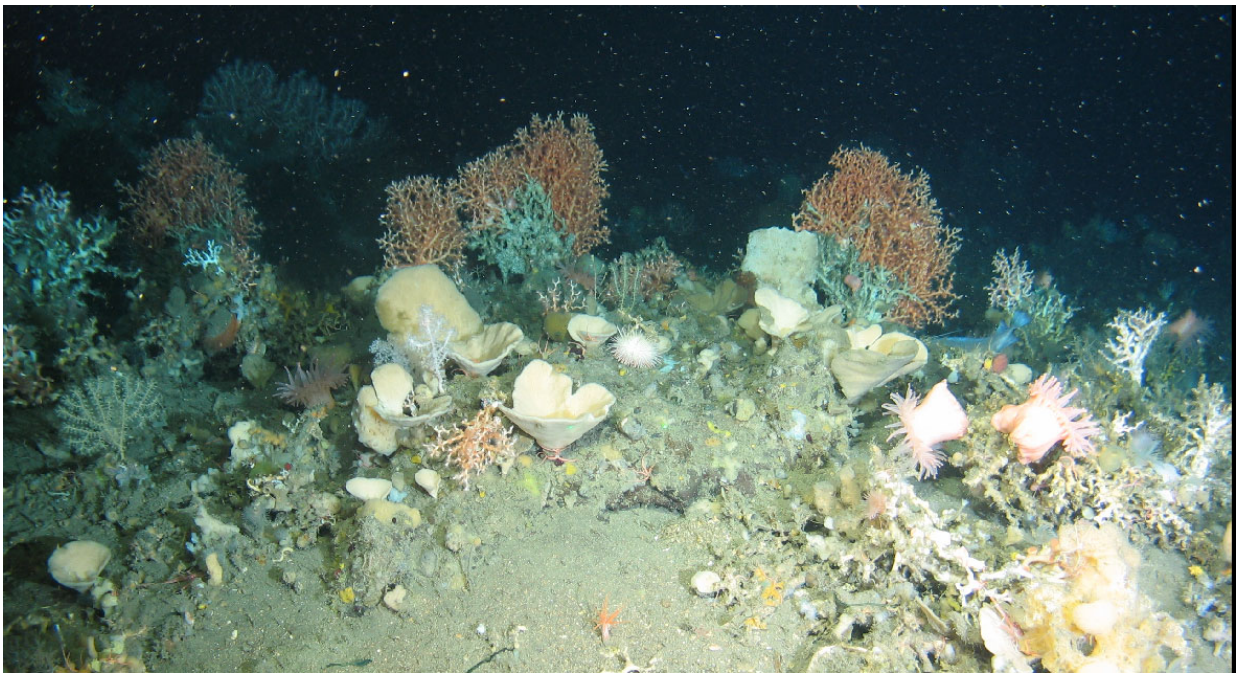

Figure 35. Coral thickets at transect 640 in the slope off Mýragrunn.

35. mynd. Kóralbreiða í kantinum út af Mýragrunni á sniði 640.

3.11 Stokksnesgrunn

On the slope off Stokksnesgrunn stations 641 and 642 were located at 470-545 m depth (figure 35). Scattered coral branches and thickets of *D. pertusum*, *M. oculata* and Stylasteridae were located on the hard seabed comprised of firm sand and gravel bottom. Live and thriving coral reefs were observed at 470 m depth and again at 485 m depth. Similar to the slope off Mýragrunn, we observed a complex habitat comprised mainly by flabellate sponges, Plexauridae, colonies of *D. pertusum, M. oculata* and Stylasteridae.

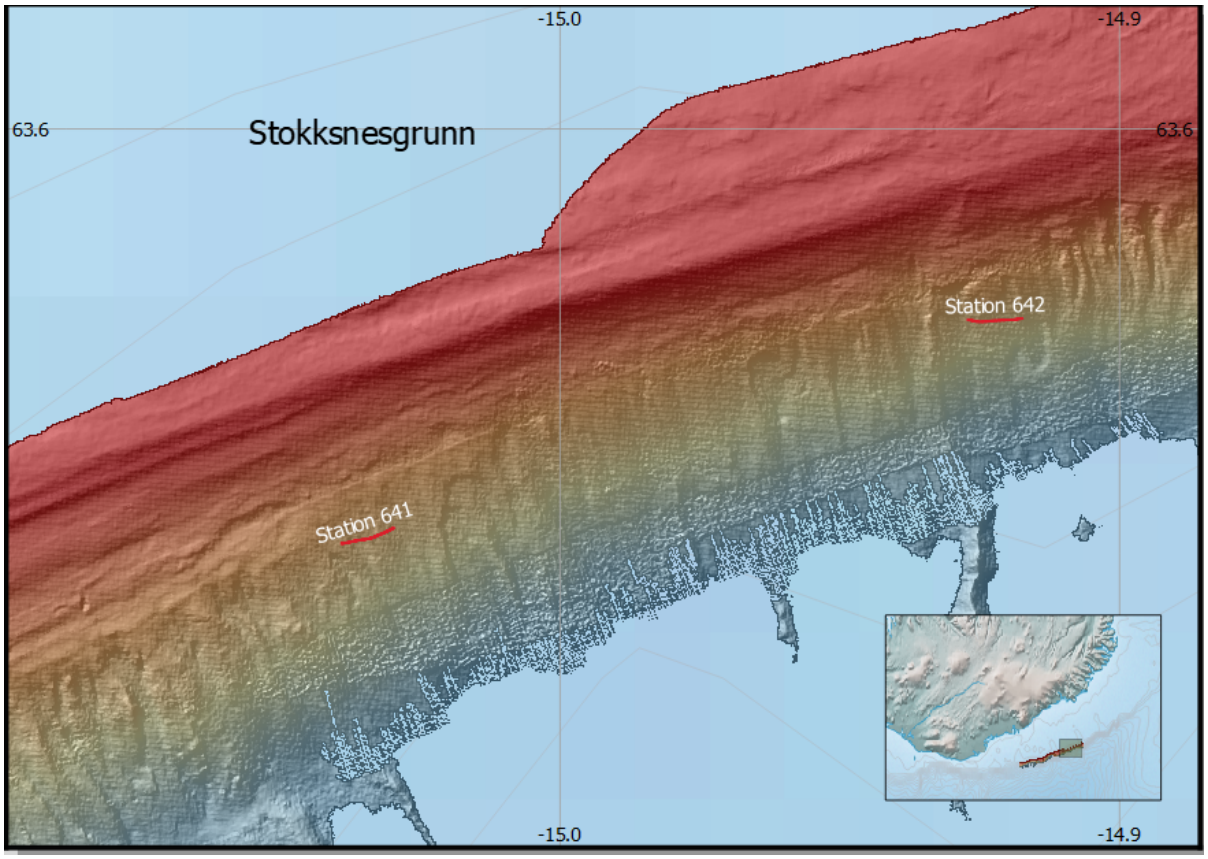

Figure 36. Transects located in the steep slope off Stokksnesgrunn.

36. mynd. Snið í kantinum út af Stokksnesgrunni.

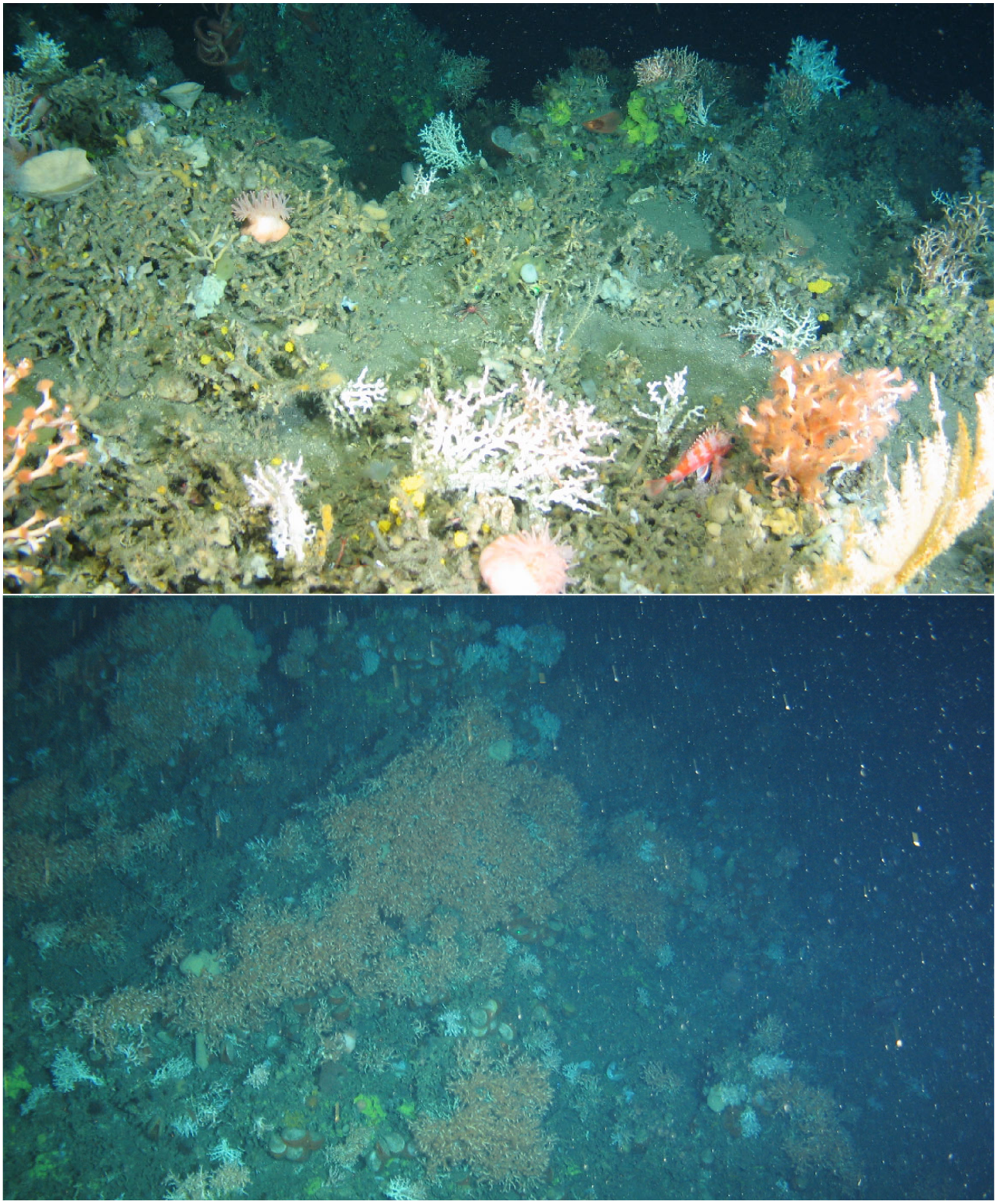

Figure 37. Coral reef in the slope off Stokksnesgrunn.

37. mynd. Kóralrif í kantinum út af Stokksnesgrunni.

3.12 Hornafjarðardjúp

A single transect was carried out at station 643 in Hornafjarðardjúp (figure 38). Live coral reefs were observed in 2004, and as a result two fishing closures were established in 2005 to protect the reefs (Sigmar A. Steingrímsson and Sólmundur T. Einarsson 2004; Anon 2005). Transect 643 was located at the margin of the closed area. Dead coral rubble was observed at this site. Further studies within the protected area were not possible due to the lack of time.

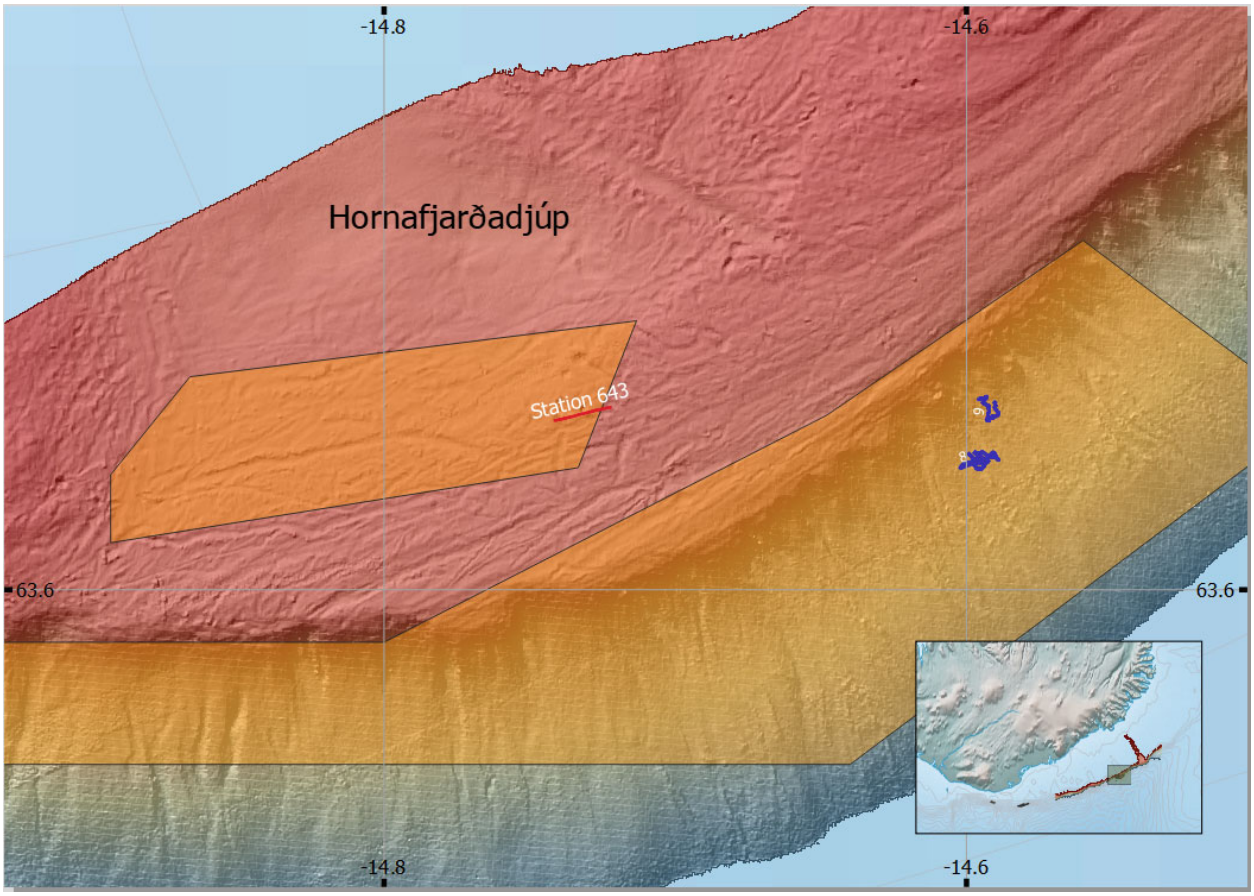

Figure 38. Hornafjarðardjúp. Red transect are from this survey and the blue lines are transects from survey KBH in 2004. Yellow polygons show closed areas.

38. mynd. Hornafjarðardjúp. Rauð lína sýnir snið frá þessum leiðangri og bláar línur sýna snið frá KBH 2004.

3.13 Vulnerable marine ecosystems (VMEs)

Based on density, species composition, VME indicator species, distance from fishing grounds and thus risk of damage, vulnerable areas will be evaluated. Vulnerable species and VME indicator

species were recorded based on the definition by the Working Group of Deep-Water Ecosystems (WGDEC/NAFO) within the International Council for the Exploration of the Seas (ICES 2016, 2020). Records of Alcyonacea, Pennatulacea and Scleractinia corals are shown in figure 39.

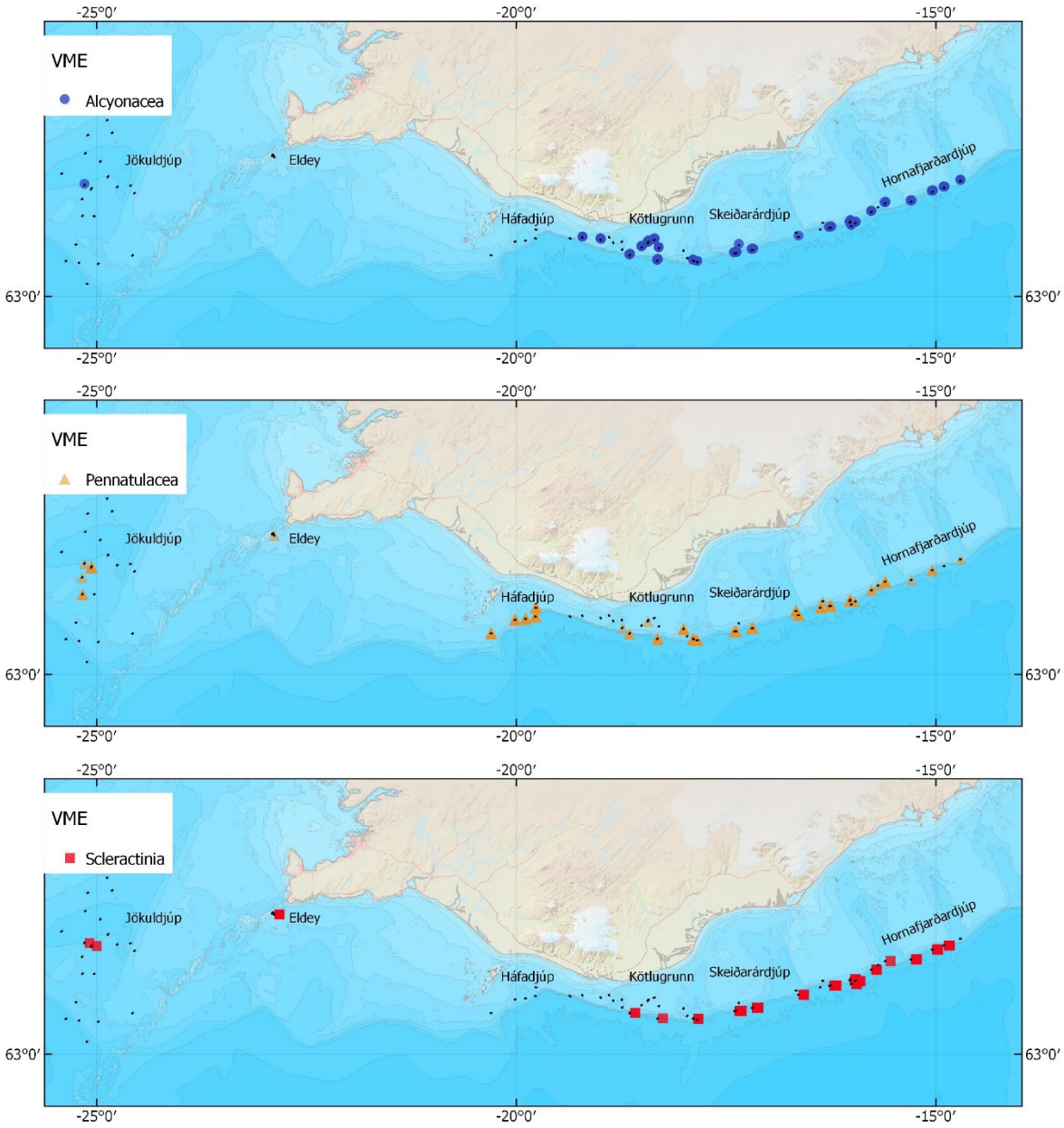

Figure 39. Maps showing the distribution of the three Cnidaria orders Alcyonacea, Pennatulacea and Scleractinia. The black dots are the transects that these groups were not observed.

39. mynd. Kort sem sýna skráningar á mjúkum kóral, sæfjöðrum og steinkóral. Svartir punktar sýna snið þar sem þessir hópar voru ekki skráðir.

On muddy sand at the south shelf, the sea pens *Kophobelemnon* sp., Pennatula sp. and Virgulariidae were very common. *Swiftia* sp. (Alcyonacea) was observed in high density on hard bottom in the Kötlugrunn. This is the first time a dense garden of *Swiftia* sp. is observed in Icelandic waters. Coral colonies were normally counted but in cases where it was difficult to count, the density was estimated as cover of coral framework. High cover indicates coral reefs, and this was observed off Síðugrunn, off Mýragrunn and Hornafjaðardjúp. Dead coral reefs were observed on the shelf in Skaftárdjúp, Öræfagrunn, Breiðamerkurdjúp and Hornafjarðardjúp.

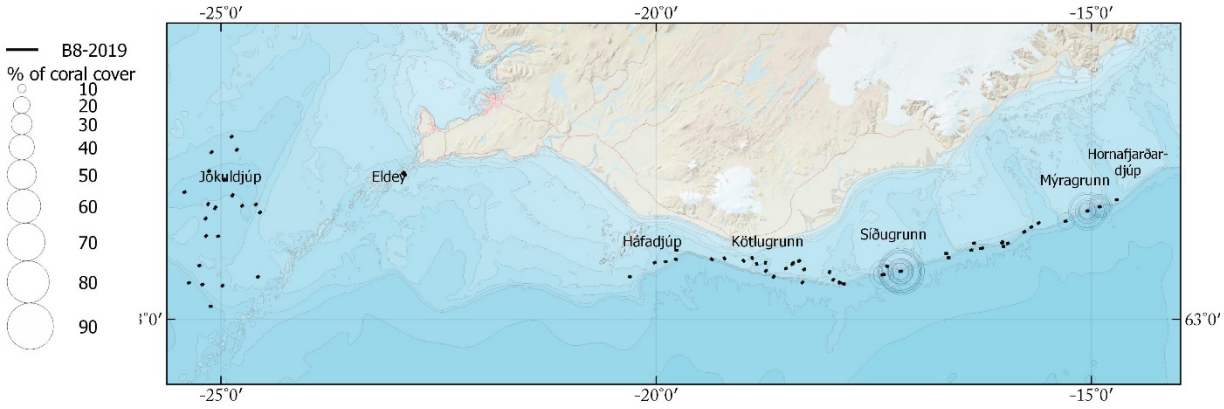

Figure 40. Coral cover estimated from the images. In most cases coral was counted but in some cases the cover was estimated.

40. mynd. Þekja kórals metin frá ljósmyndum. Kórall var í flestum tilfellum talinn en þar sem þéttleiki var mikill var þekja metin.

Revisiting the coral reefs in Skaftárdjúp and Öræfagrunn.

Marine protected areas (MPAs) were established in 2005 and in 2011 to protect coral areas (Anon 2005; Steinunn H. Ólafsdóttir and Julian M. Burgos 2012). These closures were based on the confirmed presence of live coral reefs observed near fishing grounds and therefore considered at risk. During this cruise we attempted to revisit some of the coral reefs inside the protected areas. We were only able to film across a single reef within the protected area in Skaftárdjúp. The video material showed a small amount of live reef-building *Desmophyllum pertusum,* and none of the associated corals usually found in healthy reefs.

3.14 Marine litter

Marine litter was recorded in ten of the 70 transects carried out during the survey (14 % figure 40). In most cases, the litter was remnants of longlines. We also observed nets, plastic containers, ropes, wire, and unidentified plastic material.

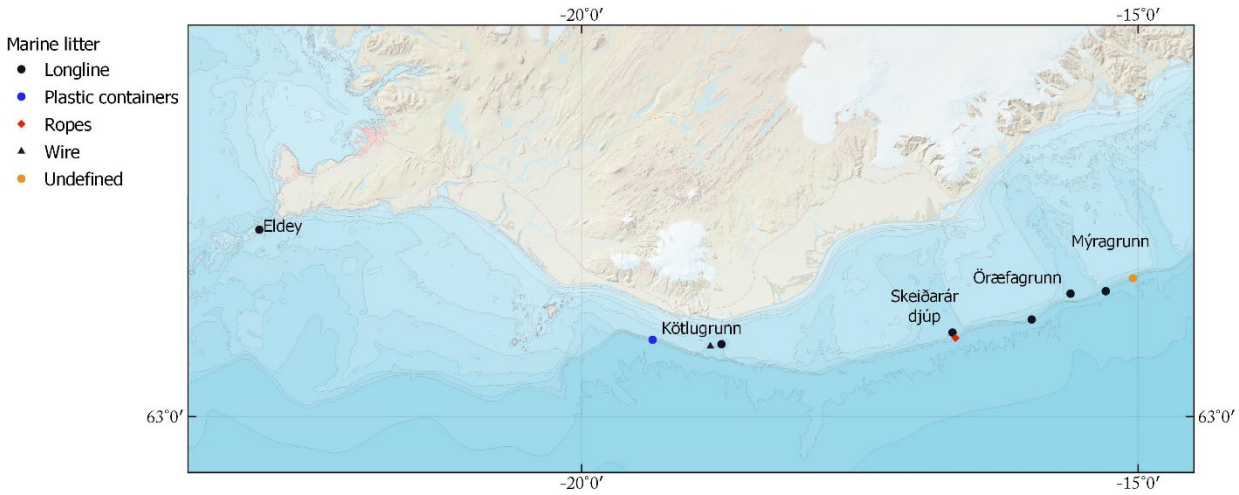

Figure 41. Locations where marine litter was observed.

41. Mynd. Fundarstaðir rusls sem sást á myndefni.

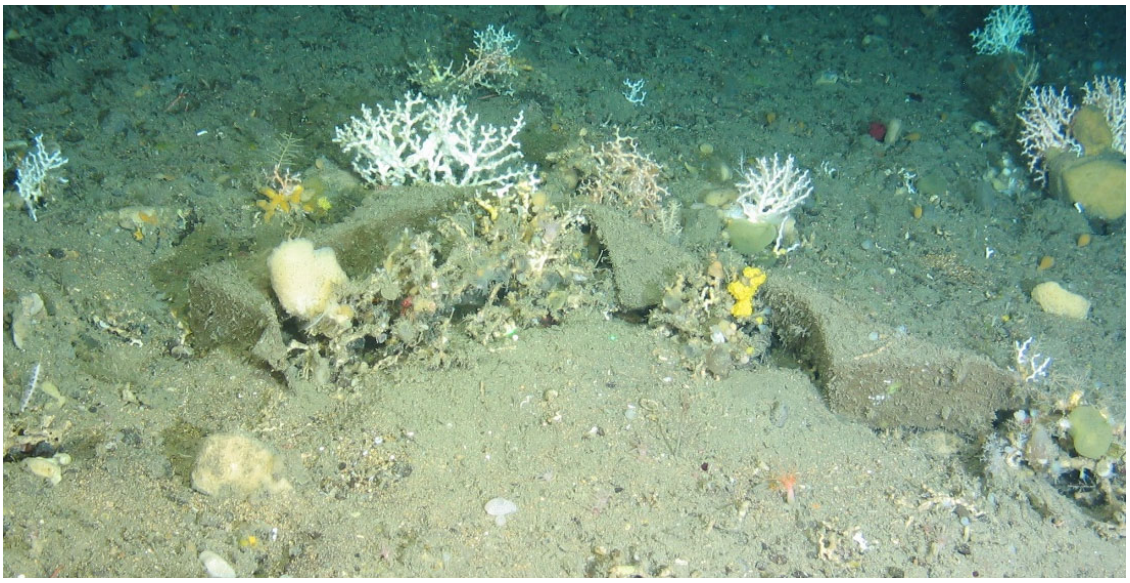

Figure 42. Unidentified marine litter.

42. mynd. Ógreint rusl.

3.15 Contribution of guests

Two students were on board as guests: María Rún Þrándardóttir, an art student from the Iceland University of Arts, and Fine Brendtner, an exchange student at the University Centre of Westfjords from Aarhus University.

3.15.1 Shimmer. The inspiration of the sea, live at sea and physiology in modern time

(María Rún Þrándardóttir)

For María Rún Þrándardóttir an Art student, the cruise experience was expressed through poetry where the ocean and humans are jointed. Her poem *Shimmer* is the introduction to this report.

3.15.2 Epistemologies of marine science, information-visualization and image-based research tools

(Fine Brendtner)

This section presents the objectives of a Master thesis by Fine Brendtner, MSc student of visual anthropology at Aarhus University. Her academic focus lies in environmental humanities and science and technology studies with a special interest in marine issues. This summer, she was an exchange student at the Háskólasetur Vestfjarða.

"It was my ambition to accompany the habitat mapping survey as a student researcher and observe the way in which it is conducted. This would allow me to understand the real-life conditions and application of visual surveys. With a personal interest in marine conservation practices, I applied for this survey in particular, to better comprehend the meaning of benthic habitats for broader marine ecosystems."

Joining the cruise gave the opportunity to learn first-hand about the value and nature of benthic habitats and vulnerable marine ecosystems in Iceland. This insight would not have been possible form reading papers or even conducting interviews. Being there and witnessing the interplay of bodies, senses, and technology in generating marine scientific knowledge was an exceptional opportunity. Participating in onboard analysis of the video material obtained in the survey and learning the basic skills in photo analysis and computational identification was one of the tasks of the field work.

"Being able to directly discuss questions that arose during my observations with the natural scientists aboard, allowed me an informed biological education. I witnessed the motion, the bodily challenges and weather dependency of ship-based research. I learned about the teamwork, sleep/work schedules and the excitement involved in obtaining images of the seabed. I got to look at the campod up close and get a feeling for the implicated technology. The importance and properties of the cables, the physical remote controlling practice and live-stream observations gave me a clue of the technological objects at work".

It is crucial to bridge disciplinary gaps between social and life sciences when exploring the conservation practices and techno-scientific imaginaries at sea from a humanities perspective.

4 Summary - Discussion

Analysis of the video and photographs is in progress; however, this report presents the initial annotations of the main epibenthic species of the images of the 70 transects taken from Jökuldjúp to Hornafjarðardjúp and provides maps of the coral records. The preliminary results show areas of soft sediment with different fauna were observed the sea cucumber "Fjólufætla" in Jökuldjúp and the sea pen field in Háfadjúp. Coral habitats were found along the slope, including both coral reefs and coral gardens. A mix of gravel, sand, and boulders creates substrate for epibenthic species like sponges, sea anemones, sea lilies, bryozoans, and many more species. The species composition and densities vary between locations and even within individual transects.

The video from a revisited coral reef within a protected area in Skaftárdjúp did not show signs of recovery after 14 years of closure. This leads to questions like a) has the protection induced recovery? b) what is the timeframe for recovery? c) have the conditions in the area changed and are not favourable any longer? d) are there other disturbances that hinder the recovery, like disturbance from the nearby fishing grounds? or lastly, e) are the conditions on other reefs in the area different? This reflects the slow regrowth process and low resilience that underline the vulnerability of these areas.

5 Participants

Research team: Steinunn H. Ólafsdóttir, Julian M. Burgos, Hjalti Karlsson, Arnþór B. Kristjánsson, Hlynur Á. Þorleifsson, Bylgja S. Jónsdóttir and Darri Sigurðsson

Guests: María R. Þrándardóttir art student from Listaháskóli Íslands, Fine Brendtner MSc student of visual anthropology at Aarhus University.

The crew on RV Bjarni Sæmundsson and the captain Ásmundur Sveinsson.

Figure 43. The research team and the crew on R/V Bjarni Sæmundsson.

43. mynd. Rannsóknateymi og áhöfn á Bjarna Sæmundssyni.

6 References

Anon. (2005). *Friðun viðkvæmra hafssvæða við Ísland*. Atvinnuvega- og nýsköpunarráðuneyti 21. september 2005.

Bennecke, S., Metaxas, A. (2017). Effectiveness of a deep-water coral conservation area: Evaluation of its boundaries and changes in octocoral communities over 13 years. *Deep-Sea Research II* 137: 420–435.

Bluhm, B.A., Ambrose, W.G., Bergmann, M., Clough, L.M., Gebruk, A.V., Hasemann, C., et al. (2011). Diversity of the arctic deep-sea benthos. *Marine Biodiversity* 41(1), 87–107. doi: 10.1007/s12526-010-0078-4

Buhl-Mortensen, L., Buhl-Mortensen, P., Dolan, M.F.J., Holte, B. (2015). The MAREANO programme--A full coverage mapping of the Norwegian off-shore benthic environment and fauna. *Marine Biology Research* 11: 4–17

Hiddink, J., Jennings, S., Kaiser, M., Queirós, AM, Duplisea, D., and Piet, G. (2006). Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences* 63(4), 721–736.

Huvenne, V.A.I., Bett, B.J., Masson, D.G., Le Bas, T.P., Wheeler, A.J. (2016). Effectiveness of a deep-sea cold-water coral Marine Protected Area, following eight years of fisheries closures. *Biological conservations* 200: 60–69.

ICES. (2016). *Report of the Workshop on Vulnerable Marine Ecosystem Database (WKVME),* 10–11 December 2015, Peterborough, UK. ICES CM 2015/ACOM:62. 42 pp

ICES. (2020). *ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC).* ICES Scientific Reports. 2:62. 171 pp. doi: 10.17895/ices.pub.6095

Kaufman, L., Rousseeuw, P.J. (1990). Finding Groups in Data: An Introduction to Cluster Analysis. Wiley, New York.

Kincaid, T.M., Olsen, A.R. (2016). spsurvey: Spatial Survey Design and Analysis. R package version 3.3.

Logemann, K., Ólafsson, J., Snorrason, Á., Valdimarsson, H., Marteinsdóttir, G. (2013). The circulation of Icelandic waters - a modelling study. *Ocean Science* 9: 931–955

Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., Hornik, K. (2019). cluster: Cluster Analysis Basics and Extensions. R package version 2.1.0.

Mazor, T., Pitcher, C.R., Rochester, W., Kaiser, M.J., Hiddink, J.G., Jennings, S., Amoroso, R., et. al. (2021). Trawl fishing impacts on the status of seabed fauna in diverse regions of the globe. *Fish and Fisheries* 22 (1) 72–86.

Meiβner, K., Brenke, N., Svavarsson, J. (2014). Benthic habitats around Iceland investigated during the IceAGE expeditions. *Polish Polar Research 3*5(2): 179–204.

Meiβner, K., Brix, S., Halanych, K.M., Jażdżewska, A.M. (2018). Preface-Biodiversity of Icelandic waters. *Marine Biodiversity* 48: 715–718.

Mortensen P.B., Buhl-Mortensen, L., Dolan, M., Dannheim, J., Kröger, K. (2009). Megafaunal diversity associated with marine landscapes of northern Norway: a preliminary assessment. *Norwegian Journal of Geology* 89, pp. 163-171, Trondheim 2009. ISSN 029-196X.

Óðinsson D.Þ., Ólafsdóttir S.H., Burgos J. (2019). *Characterization of the geomorphology and biotopes of the Háfadjúp canyon, south Iceland*. In Seafloor Geomorphology as Benthic Habitat: GeoHab Atlas of seafloor geomorphic features and benthic habitats -2nd Edition. Eds: Peter Harris & Elain Baker. 1076 s.

Piepenburg, D., Brandt, A., von Juterzenka, K., Mayer, M., Schnack, K., Seiler, D., Witte, U., Spindler, M. (2001). *Patterns and determinants of the distribution and structure of benthic faunal assemblages in the northern North Atlantic*. In: The Northern North Atlantic: A Changing Environment. Edited by P. Schafer, W. Ritzrau, M. Schluter and J. Thiede. (pp. 179–198).

Sigmar A. Steingrímsson, Sólmundur T. Einarsson. (2004). *Kóralsvæði áÍslandsmiðum: Mat á ástandi og tillaga um aðgerðir til verndar þeim.* Fjölrit no. 110. Marine Research Institute, Reykjavík.

Steinunn H. Ólafsdóttir, Julian M. Burgos. (2012). *Friðun kóralsvæða við Ísland og í Norður Atlantshafi /Cold water coral conservation in Iceland and the North Atlantic*. In: Þættir úr vistfræði sjávar 2011, Environmental conditions in Icelandic waters 2011. Hafrannsóknir no. 162. Marnie and Freshwater Research Institute, Reykjavík.

Steinunn H. Ólafsdóttir, Julian Burgos. (2018). *Kortlagning búsvæða við Ísland – Rannsókn B6-2011*. Haf-og vatnarannsóknir HV 2018-48. Marnie and Freshwater Research Institute, Reykjavík.

Stevens, D.L., Jr., Olsen, A.R. (2004). Spatially-balanced sampling of natural resources. *Journal of American Statistical Association* 99(465): 262–278.

WoRMS Editorial Board. (2019). World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ. Accessed 2019-09-25. doi:10.14284/170

HAFRANNSÓKNASTOFNUN

Rannsókna- og ráðgjafarstofnun hafs og vatna