HEINCKE-Berichte

DAM pilot project: Exclusion of bottom trawl fishery in marine protected areas of the German EEZ (North Sea) – DAM MPA Geo 1

Cruise No. HE588

October 24 – November 4, 2021
Bremerhaven (Germany) – Bremerhaven (Germany)
DAM MPA Geo 1

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2022

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1 Cruise Summary

1.1 Summary in English

During HE588, data were collected in five research areas in the south-eastern part of the German Bight as part of the DAM *Pilotmission* on the exclusion of mobile bottom-contact fishing in the North Sea (*www.mgf-nordsee.de*). The cruise started on October 24, 2021, and had a duration of twelve days at sea. The conducted tasks consisted of seafloor mapping with hydroacoustic devices, multicoring and grab sampling from the seafloor surface, lander deployments for the study of current characteristics, and video and diving surveys of benthic fauna. Despite the unstable weather conditions, all scientific tasks could be conducted successfully within the allocated time.

1.2 Zusammenfassung

Während HE588 wurden Daten in fünf Untersuchungsgebieten in der süd-östlichen Deutschen Bucht erhoben. Die Untersuchungen fanden im Rahmen der DAM-Pilotmission zum Ausschluss mobiler, grundberührender Fischerei in der Nordsee (*www.mgf-nordsee.de*) statt. Die Ausfahrt begann am 24. Oktober 2021 und hatte eine Dauer von zwölf Tagen auf See. Das Messprogramm bestand aus Meeresbodenkartierungen mit hydroakustischen Geräten, Multicorer und Greiferbeprobungen der Meeresbodenoberfläche, Landereinsätzen zur Untersuchung der Strömungseigenschaften, sowie Video- und Taucheruntersuchungen der benthischen Fauna. Trotz der instabilen Wetterbedingungen konnten alle wissenschaftlichen Aufgaben im verfügbaren Zeitrahmen erfolgreich durchgeführt werden.

2 Participants

2.1 Scientific Party

Name	Discipline	Institution
Sander, Lasse, Dr.	Coastal Geology/Chief Scientist	AWI
Hoffmann, Jasper, Dr.	Coastal Geology	AWI
Bartholomä, Alexander, Dr.	Coastal Geology/Dep. Chief Scientist	SaM
Hochstein, Mara	Coastal Geology	SaM
Rohde, Sven, Dr.	Biology/Scientific Diver	ICBM
Helber, Stephanie, Dr.	Biology/Scientific Diver	ICBM
Küppers, Lisanne (ICBM)	Biology/Scientific Diver	ICBM
Hans, Katharina (ICBM)	Biology/Scientific Diver	ICBM
Bonthond, Guido, Dr. (ICBM)	Biology	ICBM
Neumann, Andreas, Dr. (Hereon)	Biogeochemistry	Hereon
Müller, Frieda	Coastal Geology	CAU

2.2 Participating Institutions

AWI	Alfred-Wegener-Institute, List/Sylt
SaM	Senckenberg am Meer, Wilhelmshaven
ICBM	Institut für Biologie und Chemie des Meeres, Wilhelmshaven
CAU	Christian-Albrechts-Universität, Kiel

3 Research Program

3.1 Description of the Work Area

During cruise no. HE588 of RV "Heincke", work was conducted in five research areas (*Arbeitsgebiete*, AG) located in the south-eastern part of the German Bight (Fig. 3.1). Water depths in the investigated areas range between 12 – 32 m and seafloor sediments are dominated by sands, with the presence of gravels and hard substrates (both individual stones and boulder reef complexes). Areas within the Borkum Reef Ground (AG1) and Sylt Outer Reef (AG4 and AG5) have been determined as focus areas for the DAM *Pilotmission* on the exclusion of mobile bottom-contact fishing in the North Sea (*www.mgf-nordsee.de*) and have already been surveyed during HE576 (May 2 – 23, 2021). Planned investigations on the Doggerbank, a further focus area of the project, could not be conducted due to the unfavorable weather conditions during HE588. Offshore Sylt (AG2), an additional research area was added for a long-term lander deployment as a near-shore site, with habitat properties comparable to the Sylt Outer Reef (AG4, AG5). Furthermore, a site at Amrumbank (AG3) was added to the work program of HE588. As a consequence of recent political developments, entailing the exclusion of bottom-contact fishing in this area, a baseline survey of the seafloor properties prior to exclusion was conducted. At two additional locations, multicorer (MUC) samples were taken in transit.

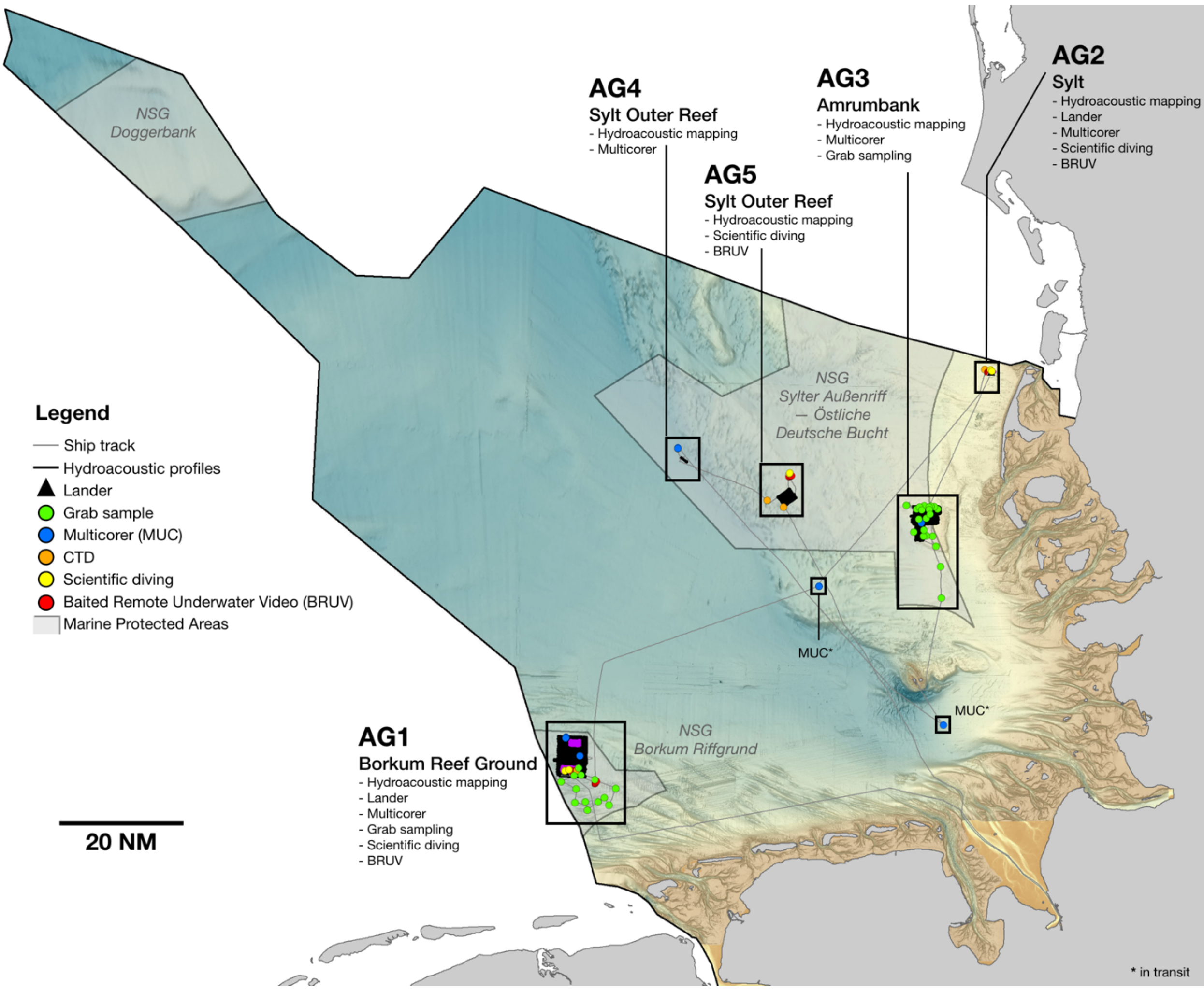

Fig. 3.1: *Overview of the ship track, work areas (AG,* Arbeitsgebiete*), and tasks conducted during HE588.*

3.2 Aims of the Cruise

The cruise was conducted as part of the DAM *Pilotmission* on the impact of mobile bottom-contact fishery. The main aim of cruise was to extend the current knowledge on seafloor habitats and to assess the impact of bottom trawling in relevant areas of the North Sea. We thereby focused on three main aspects: A. properties and dynamics of the seafloor and visual impacts of bottom-contact fishing, B. seafloor biogeochemistry along gradients of disturbance, and C. community composition of cryptic benthic and pelagic fish species. The main aim of A ("seafloor mapping") was the repeated survey of the focus areas to further determine the environmental characteristics (e.g. current properties) at the sites and to detect spatio-temporal changes in seafloor properties (sediment distribution, geomorphology, trawl marks) since the baseline study conducted during HE576 in May 2021. The work was primarily based on the acquisition of hydroacoustic data, Acoustic Doppler Current Profiler (ADCP), Side-Scan Sonar (SSS), MultiBeam Echo-Sounder (MBES) and parametric subbottom profiler (SES) (see section 5.1), from lander deployments and ship-based surveys. The main aim of B ("biogeochemistry") was to investigate exchange processes at the seafloor/water column interface in areas of different habitat properties and fishery intensities, in order to pin-point the role of mobile bottom-contact fishing on e.g. nutrient fluxes and mineralization processes (see subsection 5.2.2). In a similar fashion, the aspect C ("communities") investigated species composition with a focus on bacterial communities and fish, based on environmental DNA (eDNA) from sediment samples and video observations (see 5.2.1 and 5.3).

3.3 Agenda of the Cruise

The work order of the research areas (AG) was chosen based on the predicted conditions of wind, waves, and daylight hours, as well as the necessary transit times, in order to ensure the most efficient use of the allocated ship time. At each site, all possible research tasks were conducted in a consecutive order, and adjusted based on safety considerations and methodological requirements primarily based on the above parameters. Hydroacoustic mapping was the least critical task in that regard and was primarily conducted at night or when other tasks were either finished or on stand-by due to poor weather conditions. Mapping phases typically started and ended with a manual CTD-profile measurement and the deployment/recovery of the sidescan tow fish. Locations for grab sampling were chosen based on the hydroacoustic data and in accordance with locations from a predefined sampling strategy (for eDNA). Lander deployments were conducted at the earliest time possible at each site to allow the longest possible duration for deployment (at least one full tidal cycle). Scientific diving was conducted during daylight hours at a point in time close to slack water and the duration of the diving missions was dependent on the water depth at each site. Diving started/ended with the deployment/recovery of the shot line and the boat. Both tasks require a calm wave state. The video stations were deployed for at least 2-3 hours along a transect with a lateral spacing of a few hundred meters between each station.

4 Narrative of the Cruise

The scientific party of the cruise arrived over the course of the early afternoon of October 24 at the berth of RV "Heincke" at Fischkai 27 in Bremerhaven and all materials were loaded on board. Large equipment (such as the lander) were setup and fixed on deck for transport, while all other boxes were placed in the respective laboratories or stowed in the hangar. The afternoon was used to arrange the equipment in the laboratories and to finalize the lander before the ship left port in the evening.

Due to the prevailing south-westerly winds and the weather forecast for the coming days, AG1 at Borkum Reef Ground was chosen as the first area of investigation for HE588. The transit was accomplished overnight and we arrived on site in the early morning of October 25. The scientific tasks of the cruise commenced at daybreak with the first diving mission in the southern part of AG1 (Fig. 4.1), followed by the deployment of the four underwater video stations (BRUV). After that, MUC samples were taken in the northern part of AG1. The final preparations for the deployment of the lander were made over the course of the morning and the lander was placed in the southern part of AG1 in the early afternoon of October 25. After the retrieval of the BRUV station, the tow fish was launched and the mapping of AG1 commenced. The line spacing was identical with the survey lines of HE576 and chosen to allow a full spatial coverage with the towed SSS system, MBES, SES, and ADCP data were likewise logged. The mapping continued overnight.

In the morning of October 26, the mapping was interrupted for a few hours during slack water for the second diving mission. Before returning on the survey profiles, additional MUC samples were taken in the southern part of AG1.

The mapping of the main area of AG1 was concluded in the morning of October 27. The tow fish was recovered prior to continuing with the full-coverage MBES mapping of the two subareas within AG1 (Fig. 4.1). These areas were likewise surveyed during HE576 and the new mapping followed the identical profile lines.

In the early morning of October 28, the MBES survey was finished. At daybreak, the lander was recovered and all data downloaded and stored. As the last tasks at AG1, the BRUV stations were deployed again at a different location. A number of 13 grab samples were taken in the meantime (for eDNA and grain-size analysis), while the video stations were recording video data from the seafloor. The recovery of the BRUV finalized the work at AG1 in the afternoon of October 28. During the following transit to AG2, the MUC was deployed in the late evening at an individual location in the southern Sylt Outer Reef (see Fig. 3.1).

In the early morning of October 29, the work at AG2, an area of sandy seafloor adjacent to an isolated hard-substrate reef offshore Sylt, was commenced. A CTD profile was measured and a small patch of seafloor surveyed (MBES) to bathymetrically map the area where the lander would be deployed. At daybreak, the four BRUV stations were deployed and MUC samples taken, while the final preparations for the lander were made. The lander was placed at 55°02,370'N/8°13,764'E and will remain at this position until February/March 2022, when it will be picked up during the second leg of this cruise (HE592). As the next task at AG2, the boat was launched and the third diving mission conducted. Amongst other things, the divers controlled the proper orientation of the lander. The pick-up of the BRUV station concluded the works at AG2 in the early afternoon.

After a short transit, work at Amrumbank (AG3) began in the late afternoon with the deployment of the MUC. After that, the SSS tow fish was launched and a baseline mapping of the planed fisheries exclusion zone was conducted for the following ~37 hours. The mapping was concluded in the morning of October 31. To obtain ground truthing information for the interpretation of the SSS data and for biological analysis, a number of 19 grab samples were taken at Amrumbank, along with two additional samples in transit to Helgoland. RV "Heincke" arrived on Helgoland in the afternoon of October 31, where we weathered the passage of a storm system.

In the early morning of November 2, we left the harbor in a southerly direction to take MUC samples in the Helgoland Mud Area, before heading in a northwesterly direction towards AG4 in the western part of the Sylt Outer Reef (SOR). Work in the area commenced with the deployment of the MUC, before continuing with the SSS survey of a trawl mark produced by FRV "Solea" (von-Thünen-Institute, Bremerhaven) during HE576 in May 2021. We investigated the site along a few predefined profiles in order to investigate the temporal development of a defined physical disturbance of the seafloor as a reference for comparison with dredge marks of unknown origin and age. This short task concluded work at AG4 and was followed by a brief transit to AG5 in the central part of the SOR.

Work at AG5 commenced with the measurement of CTD profiles, before the launch of the SSS tow fish. The main task at AG5 was the repeated hydroacoustic survey of an area investigated during HE576 with SSS, SES, and MBES (with full spatial coverage; see Fig. 4.1) with the aim of detecting spatio-temporal seafloor dynamics. Mapping begun in the afternoon of November 2 and continued for ~16 hours. In the morning of November 3, the BRUV stations were deployed and the diver boat launched for the final diving mission of this cruise. After the divers, boat, and BRUV were taken safely back on deck, the SSS tow fish was launched again in the early afternoon to complete the mapping at AG5. A last CTD cast at 19:30 UTC terminated the scientific tasks of HE588 and RV "Heincke" started back for Bremerhaven. We arrived back in the harbor at Fischkai 27 in the morning of November 4.

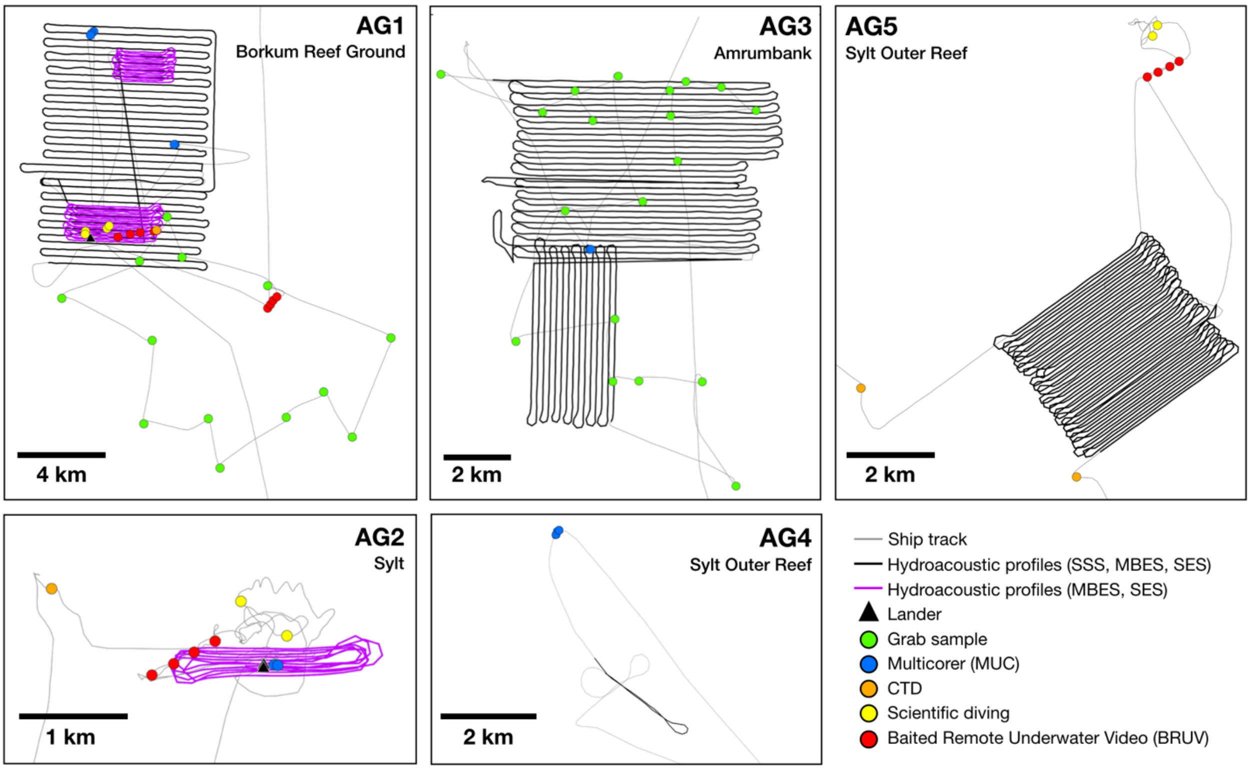

Fig. 4.1: *Details of the works conducted in the different areas of investigation*

5 Preliminary Results

5.1 Hydroacoustics

(Bartholomä, Hochstein, Hoffmann, Sander)

In order to survey seafloor properties and current characteristics in the five research areas of HE588, measurements were conducted with a suite of ship-based hydroacoustic sensors. In addition, observations were conducted from sensors mounted on a stationary lander placed on the seafloor in AG1 and AG2.

5.1.1 Side Scan Sonar (SSS)

Two different SSS systems were used during HE588, an EdgeTech 4200 MP and a Klein System 4000 (Table 5.1). The SSS were towed at a survey speed of 4.5 kn and connected through the conductor cables of the ship and placed in the water via the small deck crane on the starboard side of RV "Heincke". The range of the SSS was set to 200 m on each side in AG1, 75 m in AG5 and 100 m in AG3. This resulted in a line spacing of 360 m in AG1, 75 m in AG5 and 180 m in AG3 which assured a good coverage and overlap of the resulting mosaics. Data were recorded in the respective manufacturer's software (EdgeTech Discover, Klein SonarPro). All processing was conducted in SonarWiz 7 (Chesapeake Technology), including the bottom-tracking, layback correction, gain normalization, and mosaicing of the data.

Table 5.1: *Overview of the used SSS systems and specifications*

SSS system	Frequency (kHz)	Horizontal beam width (°)	Vertical beam width (°)	Areas surveyed	Across track resolution (cm)	File formats
EdgeTech 4200 MP	300	0.5	50	AG3, AG5	3	.jsf, .xtf
	600	0.26			1.5	
Klein 4000	100	0.7	50	AG1, AG4	9.6	.sdf, .xtf
	400	0.3			2.4	

5.1.2 Multibeam Echo Sounder (MBES)

MBES data were recorded with the hull-mounted Kongsberg EM710 system. Frequency ranges between 40 and 100 kHz with a ping rate of up to 30 Hz. The EM710 acquires 400 soundings per swath reaching a range of up to 140 degrees. To ensure a correct beam forming, surface sound velocity was measured continuously by a stationary sound velocity probe (SVP; Valeport Mini SVP) and supplemented with data from regular CTD casts (Sea & Sun M48) to correct for vertical differences and stratification in the water column. The movements of the ship were compensated for with data from the PHINS II (iXSea) motion reference unit (MRU) installed onboard RV "Heincke". All MBES data including the raw backscatter data ('snippets') were stored in Kongsberg multibeam processing format (.all) using the Kongsberg SIS acquisition software.

MBES data were recorded with full spatial coverage in AG2, AG5, and in the two subareas of AG1 (Fig. 4.1).

The data were quality controlled and postprocessed using QPS software packages including Qimera, Fledermaus and FMGT. The data was manually cleaned for erroneous soundings and sound velocity profiles were assigned according to their time of acquisition. All data was tide corrected using backwards modeled sea surface height data provided by the Federal Maritime and Hydrographic Agency of Germany (BSH). The final bathymetrical grids were exported with a cell width of 1 x 1 m while the corrected backscatter mosaics have resolutions of 0.25 m.

5.1.3 Parametric Echo Sounder (SES)

Data on the properties of the shallow subsurface of the seafloor was collected with the hull-mounted parametric sediment echosounder (SES-2000 medium, Innomar) installed on RV "Heincke". The system operates at frequencies between 3.5 and 22 kHz. Data were recorded in .ses and .raw (full waveform) formats in the SESWIN system software. Signal penetration was typically low and rarely exceeded a depth of 10 m below the seafloor. The movements of the ship were compensated with data from the ship's MRU (see 5.1.2).

Table 5.2: *Overview of specifications and configurations of the used ADCP*

Parameter	Nortek Signature 500				Nortek Signature 250		Nortek AWAC 1 MHz	Teledyne Workhorse Mariner
	AG1		AG2		AG1	AG2	AG2	AG1, AG3, AG5
Deployment mode	Lander				Lander		Lander	Hull-mounted
Orientation	Vertical (up-looking)				Horizontal (Y-axis up)		Vertical (down-looking)	Vertical (down-looking)
Frequency [kHz]	500				250		1000	614.4
Measurement mode	Avg	Avg	Burst	Wave	Avg		Avg	Avg
Number of beams	4	4	1	4	4		3	4
Measurement interval [s]	120	300	3600	7200	120	300	300	3.26
Average interval [s]	30	90	n/a	n/a	30	30	90	3.26
Burst duration [s]	n/a	n/a	0:17:04	0:17:04	n/a		n/a	n/a
Blanking distance [m]	0.5	0.5	0.5	14.5	0.5		0.4	1.73
Cell size [m]	0.5	0.5	1	1.5	2.0		0.4	0.5
Number of cells	71	43	32	12	82		5	80
Horizontal precision [cm/s]	2.17	1.25	n/a	4.91	3.32		2.9	n/a
Vertical precision [cm/s]	0.72	0.41	3.25	1.62	0.86		1	14

5.1.4 Acoustic Doppler Current Profiler (ADCP)

During most survey phases of HE588, ADCP data were constantly logged with the hull-mounted Teledyne RDI Workhorse Mariner 600 kHz system onboard RV "Heincke". Data acquisition (in mobile mode) and processing have been carried out in the software packages Teledyne RDI VmDas. Stationary measurements were conducted with three different ADCP systems installed on a lander: an upward-looking Nortek Signature500 (500 kHz), a horizontal-looking (Y-axis up) Nortek Signature250 (250 kHz), and with a downward-looking Nortek AWAC 1 MHz. The configurations and specifications of these three ADCPs are shown in Tab. 5.1. The measurement plans for the lander deployments are shown in Fig. 5.1. Post-processing and data visualization of the stationary ADCPs were achieved using Ocean Contour V2.1.4 and MATLAB R2021a. Processing steps included manual data selection, removal of side lobe interference, and averaging to improve data quality and remove areas of poor data quality. Slack water times were calculated as the local extrema of the water pressure data from the up-looking ADCP.

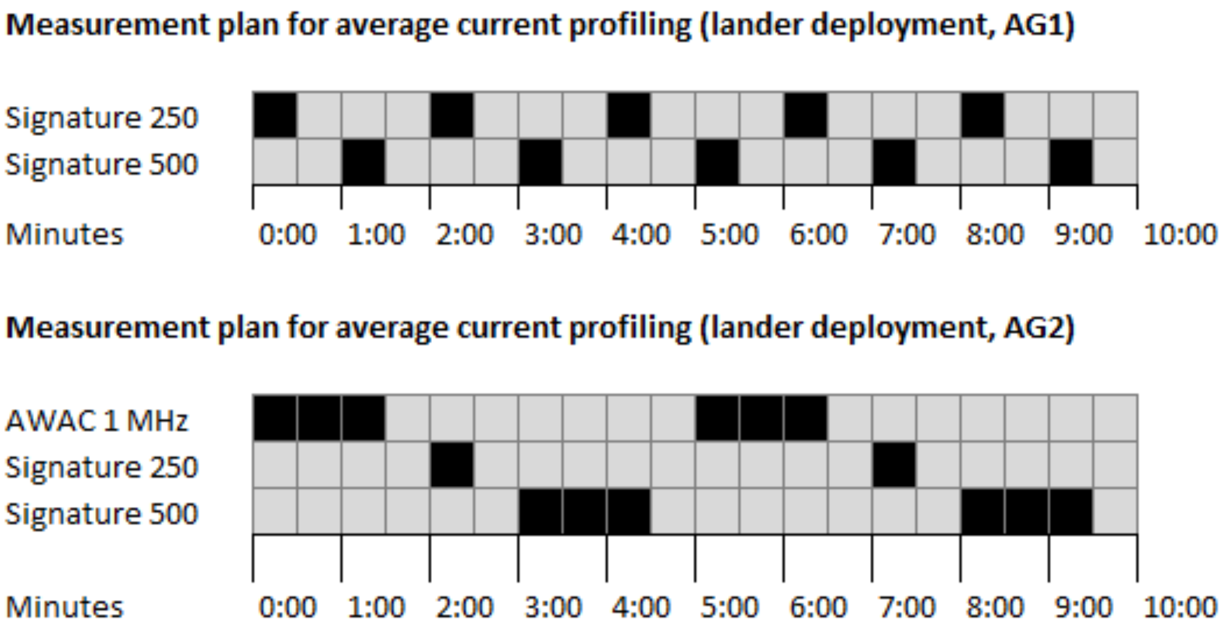

Fig. 5.1: *Measurement plans for average current profiling in AG 1 and AG 2.*

5.1.5 Rotation Scanner

The Imagenex 881A is a digital multi-frequency, 360° rotating side scan sonar. This programmable system is connected to an IRIS datalogger unit to acquire and store high resolution images of the surrounding of the lander. The system operates at frequencies between 310 and 1000 kHz and covers a range of up to 200 m. The pulse length is also adjustable between 10 and 530 µs. For the short-term deployment in AG1 the system was set up to acquire four sequences at different frequencies every hour. For the long-term lander deployment in AG2, we also acquire four sequences at different frequencies but only every 12 h. The specifications of both deployments are listed in Table 5.3.

***Table 5.3:** Programmed specifications for the rotation scanner at the two lander deployments sites.*

	Frequency [kHz]	Range [m]	Pulse length [µm]	Absorption [dB]	Gain [Db]
AG1-S1	1000	5	20	0.6	17
AG1-S2	675	8	40	0.2	17
AG1-S3	675	20	100	0.2	15
AG1-S4	310	100	540	0.1	13
AG1-S1	1000	5	20	0.6	27
AG1-S2	675	10	60	0.2	12
AG1-S3	675	20	100	0.2	15
AG1-S4	675	50	260	0.2	21

5.2 Seafloor sampling

5.2.1 Sediment Grab Sampling

(Bonthond, Bartholomä, Hochstein, Hoffmann, Sander)

Sediment samples were taken from the seafloor with a Van-Veen-type grab sampler extracting material from an area with a size of ~0.1 m² (HELCOM standard). Photos of the undisturbed grab sample were taken and small volume of material from the surface was sampled for grain-size analysis. In addition, three small sediment cores (10 cm x 1 cm diameter) were taken from each grab to characterize microbial communities. These cores were immediately stored at -80°C to preserve DNA and RNA. After transport to the laboratory at the ICBM in Wilhelmshaven, nucleic acid extractions will be performed on the top centimeter, followed by PCR and high-throughput amplicon sequencing to characterize microbial communities associated with the sediment. The remaining part of these sediment cores will remain in storage for potential later nucleic acid extraction.

5.2.2 Multicorer (MUC)

(Neumann, Bonthond)

We retrieved virtually undisturbed sediment cores with the sediment water interface at six sites (Tab. 5.4). The sampled areas include sites, which were previously studied by the NOAH project to enable us to connect the results of this cruise with previous observations. Four cores from each site were subject of a whole-core incubation method in the ship's laboratory to measure fluxes of oxygen and nutrients. Additional cores were sliced immediately after retrieval in 1 cm intervals to collect samples for DNA and sediment characteristics (grain size, chlorophyll, TOC). For preserving DNA, small subsamples (~500 µg) were taken from the slices with a sterile spoon and transferred to 2mL tubes with molecular grade ethanol. These tubes were stored at -80°C. Similar to the grab samples, these tubes were transferred to the laboratory at ICBM in Wilhelmshaven where they will be subjected to DNA extraction, PCR and amplicon sequencing.

Table 5.4: *Summary of sites samples with Multicorer.*

D-Ship ID	Latitude (deg)	Longitude (deg)	Area
3	53.996131	6.248191	Borkum Reefground
8	53.948979	6.319435	Borkum Reefground
28	54.439025	7.424846	NOAH-E
31	55.039357	8.231006	Sylt
35	54.619236	7.904269	Amrum Bank
59	54.060503	8.023045	NOAH-C
60	54.810323	6.734283	Sylt Outer Reef

5.3 Surveys of benthic communities

(Rohde, Helber, Küppers, Hans)

Sidescan sonar and multibeam echosounder data were analysed to identify reef structures or stony habitats in order to assign stations for the benthic surveys. Stations were assigned at water depths ranging from 28-30 m (see Table 5.5). An additional station was set at the site where the Lander was deployed at a water depth of 14 m.

Table 5.5: *Station site overview of benthic surveys*

Date	Time	Lat	Long	Depth (m)	Operation
25.10.2021	9:00h	53°54.295	6°15.411	30.6	ARMS
25.10.2021	10:30h	53°54.313	6°16.688	27	BRUVs
26.10.2021	9:30h	53°54.276	6°15.399	30	Video transects
28.10.2021	9:30h	53°52.821	6°24.267	29	BRUVs
29.10.2012	8:15h	55°02.302	8°12.777	18	BRUVs
29.10.2012	11:34h	55°02.306	8°12.781	16	ARMS
29.10.2012	13:00h	55°02.306	8°12.781	14	Lander check, Video transects
03.11.2021	12:00h	54°44.807	7° 16.036320	29	ARMS, Video transects

Benthic communities were surveyed using three different methods.

1. Autonomous Reef Monitoring Structures (ARMS) are standardized 3D collectors of marine species. They comprise of stacks of PVC plates that mimic the complex structure of the sea bottom and were attached at the sea floor with steel pegs by scientific divers. These settlement plates will be recollected after 6 months and analysed for community composition.

2. Video transects: A diver guided stereo-video system including two HD video cameras and a light system was used to record at least three 30 m transects of the benthic communities at each station. This setup not only allows the identification of species and abundances, but also to estimate the size and biomass of specimens to gather information on the population structure of abundant species.

3. Baited remote underwater video systems (BRUVs) are a technique primarily used to unobtrusively sample carnivorous fishes and invertebrates. It is favoured where traditional diver surveys are impractical and as a means to eliminate diver-positive or

diver-negative behavioural responses that generate unwanted sampling bias. The array consists of a stereo HD video system combined with a light system. The standard bait are sardines. Video data allow the analyses of abundance and size of populations.

5.4 Preliminary and expected results

5.4.1 Hydroacoustics

Seafloor Mapping (SSS & MBES)

The repeated SSS mapping revealed that there are no large-scale changes in the properties and spatial distribution sediment and seafloor features at Borkum Reef Ground (AG1), when compared to the SSS data from May 2021 (Fig. 5.2). With a third data set recorded in May 2020 (cruise HE548), a small-scale comparison can be made for the occurrence of changes over a longer period of time. In areas, where the data quality is sufficient, blocks with a diameter of around 2 m or more are clearly visible (Fig. 5.3). These surveys provide robust information on seafloor properties in the focus areas of the DAM *Pilotmission*, at different spatial and temporal scales.

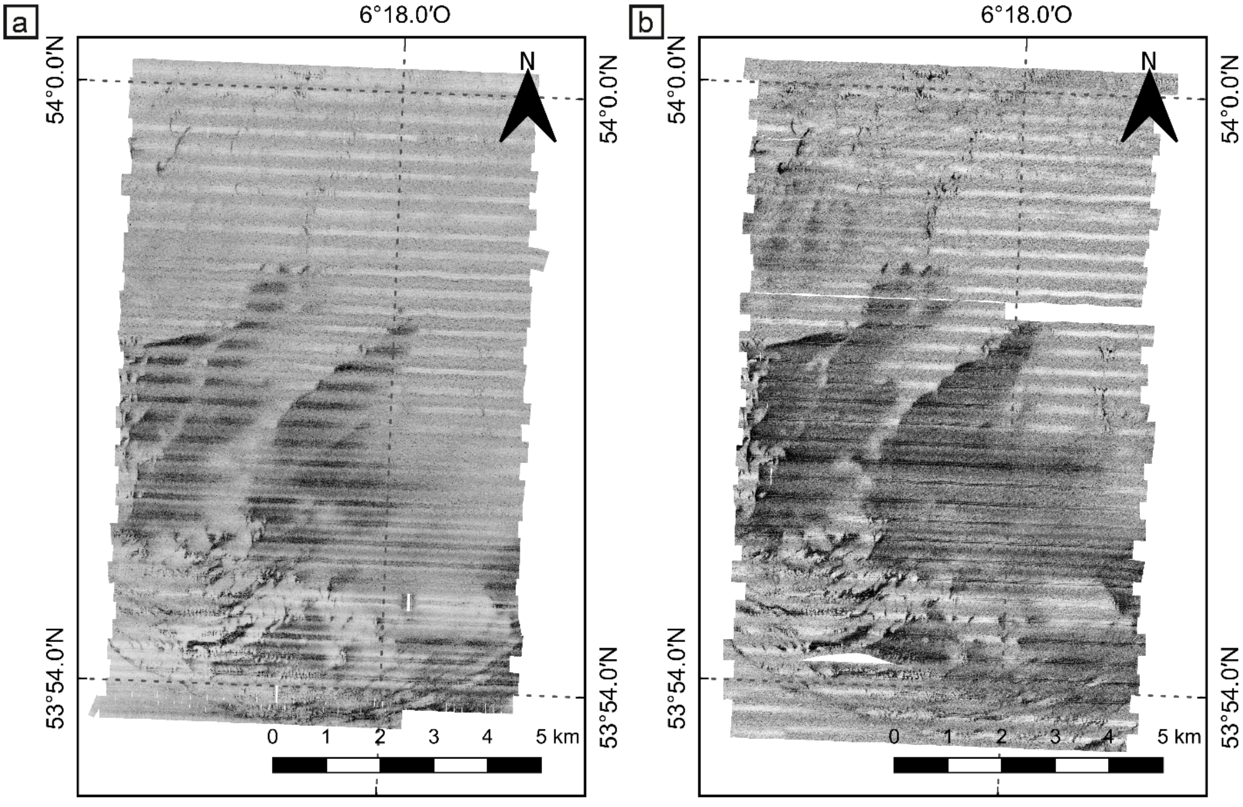

Fig. 5.2: *Sidescan sonar mosaic of Borkum Reef Ground (AG1) surveyed with Klein 4000 SSS; resolution = 25 cm; frequency = 100 kHz. a – May 2021 (HE576). b – October 2021 (HE588).*

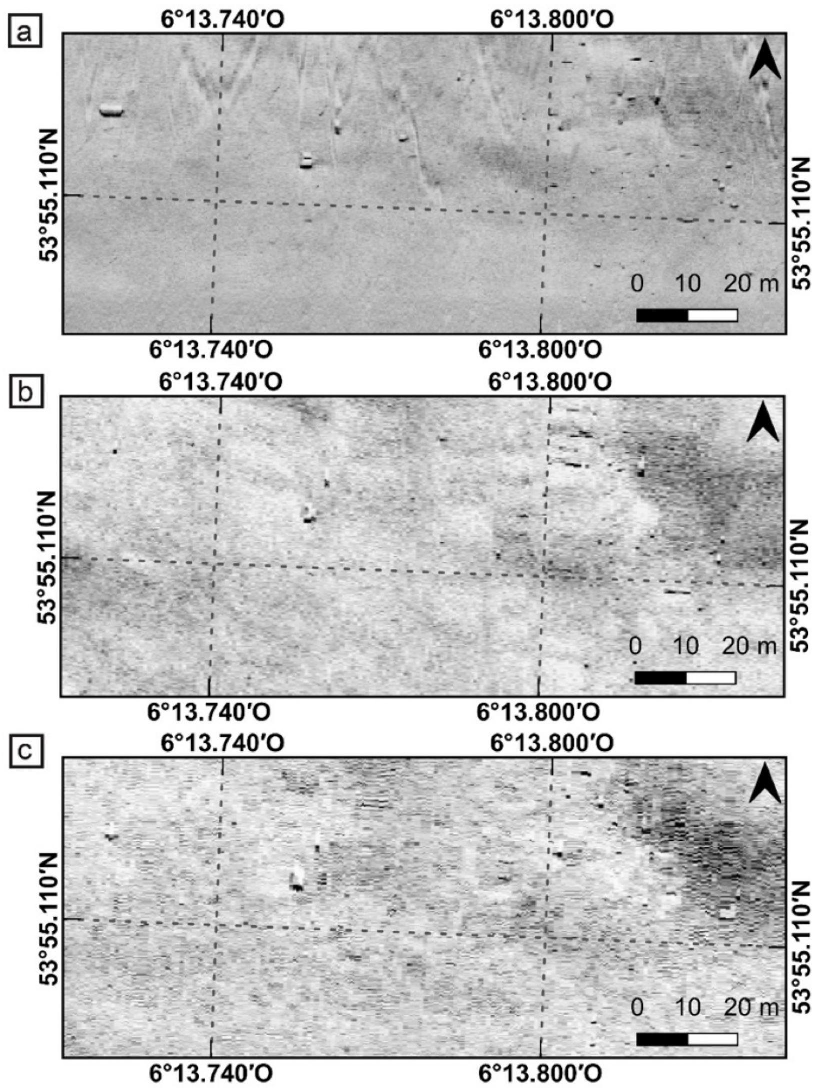

Fig. 5.3: Detail from sidescan sonar mosaic of Borkum Reef Ground (AG1) surveyed with Klein 4000 SSS; resolution = 25 cm; frequency = 400 kHz. a – May 2020 (HE548). b – May 2021 (HE576). c – October 2021 (HE588).

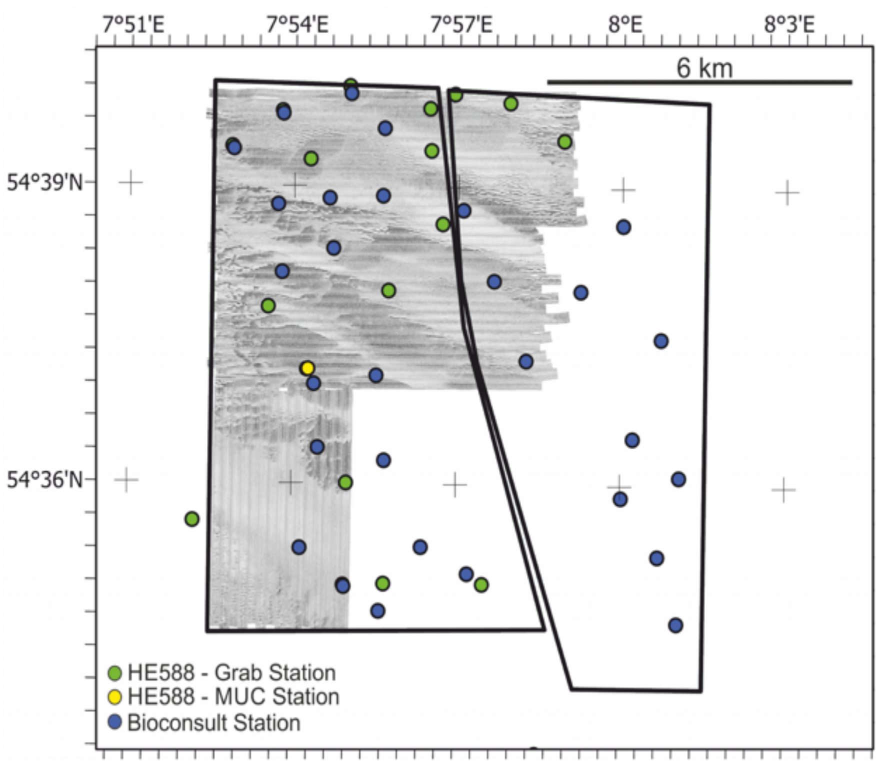

Fig. 5.4: Amrum Bank (AG3): A new baseline sonar mosaic from the area of fishery exclusion (left frame) that will serve as a reference for later surveys after the exclusion has been implemented.

On the Amrum Bank (AG3) ~190 NM of sidescan sonar data were recorded in an area proposed for the exclusion of bottom trawl fishery indicated by the left frame in Fig. 5.4. The right frame presents an outline for a reference area, and the sampling location for benthic fauna surveys (conducted by BioConsult) are indicated along with the positions of the grab and MUC station sampled during HE588. Due to the shallow water depth in the eastern part of Amrum Bank, no sidescan sonar data could be recorded. Overall, the new dataset will serve as a reference for later surveys to assess the effect of reduced disturbance on seafloor properties. However, no trawl marks were detected during HE588 suggesting that the hydrodynamics and resulting high sediment transport rates rapidly mask the effect of bottom contact gear.

At Sylt Outer Reef (AG4) trawl marks were likewise rarely observed, likely suggesting that these are of short-lived persistence on the seafloor (given that fishery activities are documented in at least some of these areas). As shown in Fig. 5.5, the artificial trawl marks, which were drawn by the FRV "Solea" (cruise SOL791) in May 2021, could not be detected in this cruise (Fig. 5.6, frames [c] and [d]), in contrast to the cruise in May (HE576; Fig. 5.6, frames [a] and [b]). Also, other trawl marks in the surrounding area were no longer visible, but new ones, some of which had a similar course as previously detected ones (compare light blue lines in Fig. 5.6 [b] with green lines in Fig. 5.6 [d]).

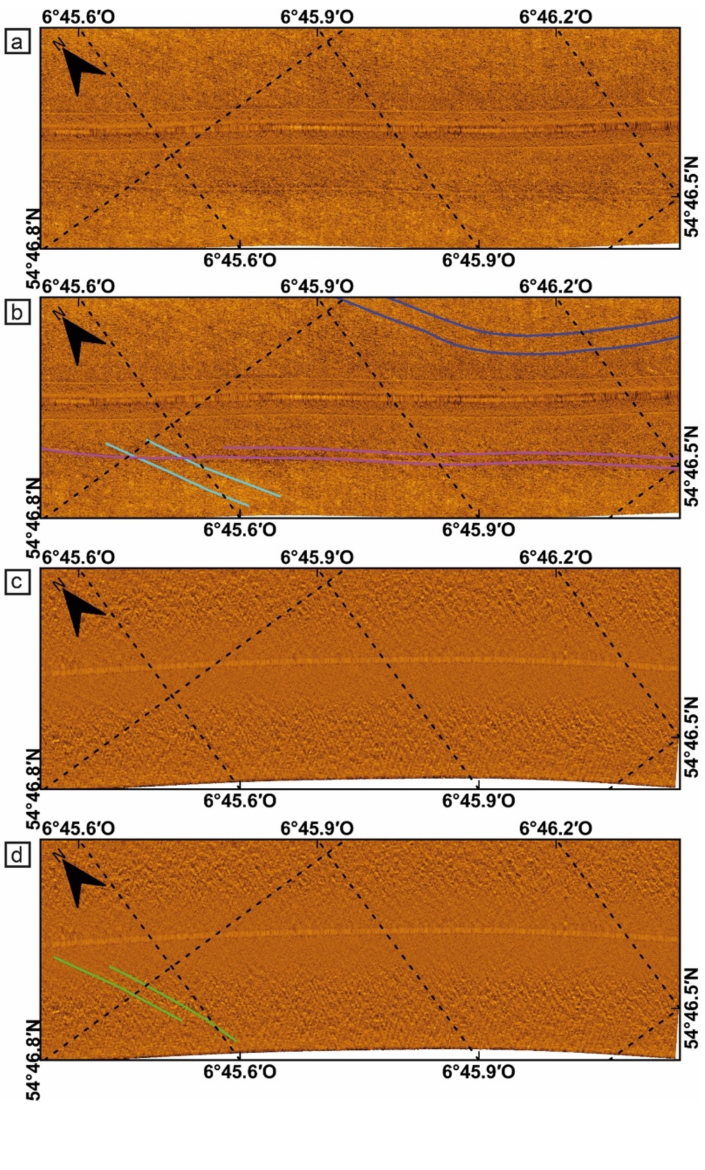

Fig. 5.5: *Sidescan sonar mosaic from Sylt Outer Reef (AG4) surveyed with Klein 4000 SSS; resolution = 25 cm; frequency = 100 kHz. Frame [a] and [b] show experimentally drawn trawl marks of FRV "Solea" (pink) and other recognizable ones (light and dark blue) from May 2021 (cruise HE576). Frame [c] and [d] show that trawl marks visible May are no longer recognizable in our sidescan sonar data from November 2021 (HE588), but a new mark with similar location as before (green) appeared in the meantime.*

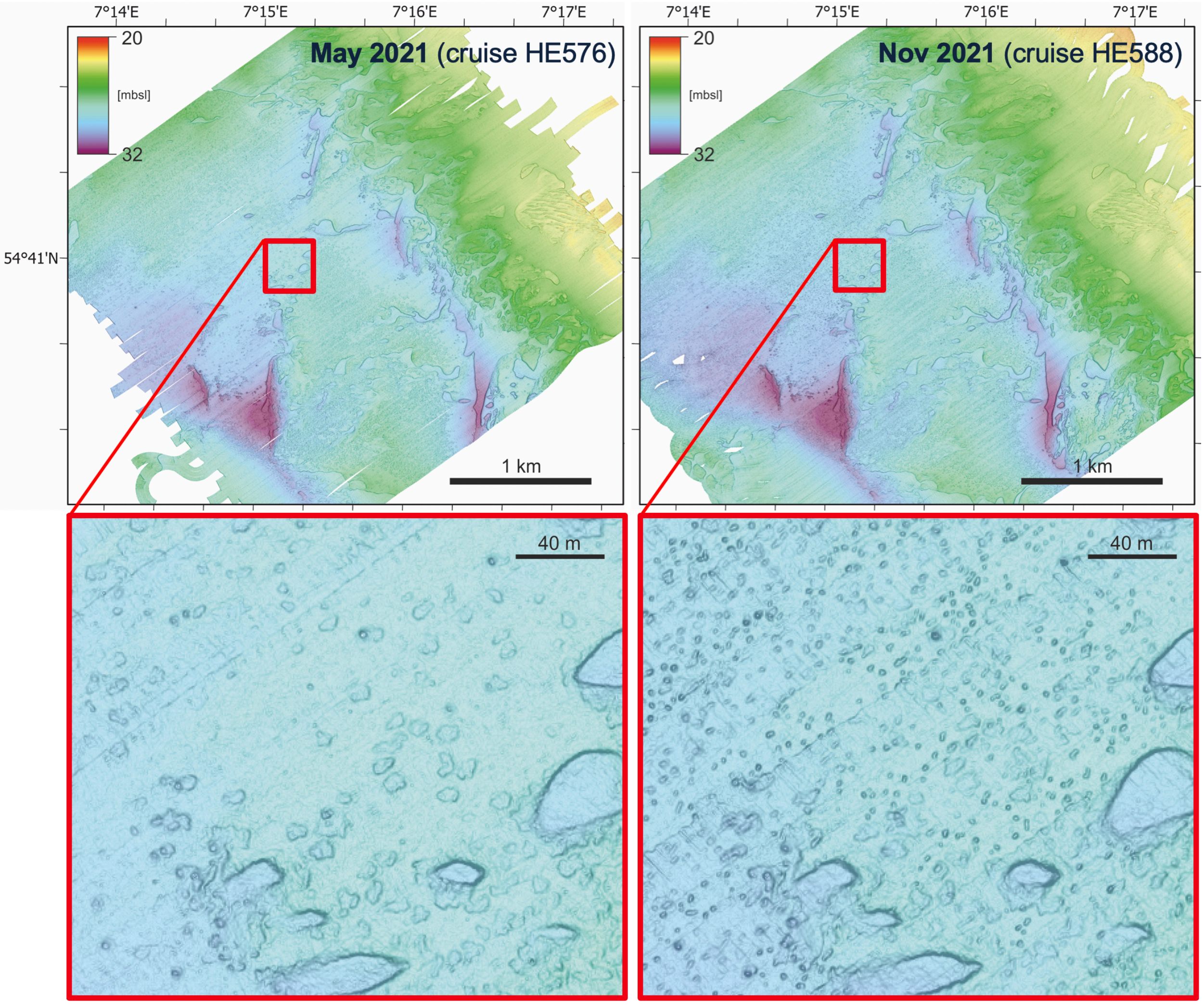

Fig. 5.6: *Sylt Outer Reef (AG5): Comparison of MBES data from May 2021 (HE576) and November 2021 (HE588). While the seafloor remains relatively unchanged at the large scale (top), significant changes occur in small-scale observations (bottom).*

The full-coverage MBES mapping of selected subarea at Borkum Reef Ground (AG1) and Sylt Outer Reef (AG5) established that sediment transport and the overall bathymetric patterns of the areas are the result of long-term fluctuations around a quasi-steady state, that is maintained over extended periods of time. Large-scale changes in seafloor features are hence barely detectable between the two surveys (Fig. 5.6, top), but the occurrence of small-scale changes in surface structure were widely observed in AG5 (Fig. 5.6, bottom).

ADCP

Due to the partly bad weather conditions, not all data from the hull mounted ADCP could be used, as some data contain too much errors. The usable data from the Borkum Reef Ground (AG1) could be compared with the measurements taken by the deployed lander at the same time. The water velocity data show the same trends for both ADCP's, whereby the data from the lander (Fig. 5.7, lower plot) contain significantly fewer errors and offer better resolution than the data from the ship- mounted ADCP (Fig. 5.7, upper plot). The highest current velocities occurred in the time slot from one to three hours before slack high water, but lowest five hours before and one hour after slack high water. The same pattern could already be observed in May (cruise HE576) for this working area. Modeled sea surface height data provided by the Federal Maritime and Hydrographic Agency of Germany (BSH) show the same trend as the variation of pressure values recorded by the stationary ADCP (see black curves in Fig. 5.7).

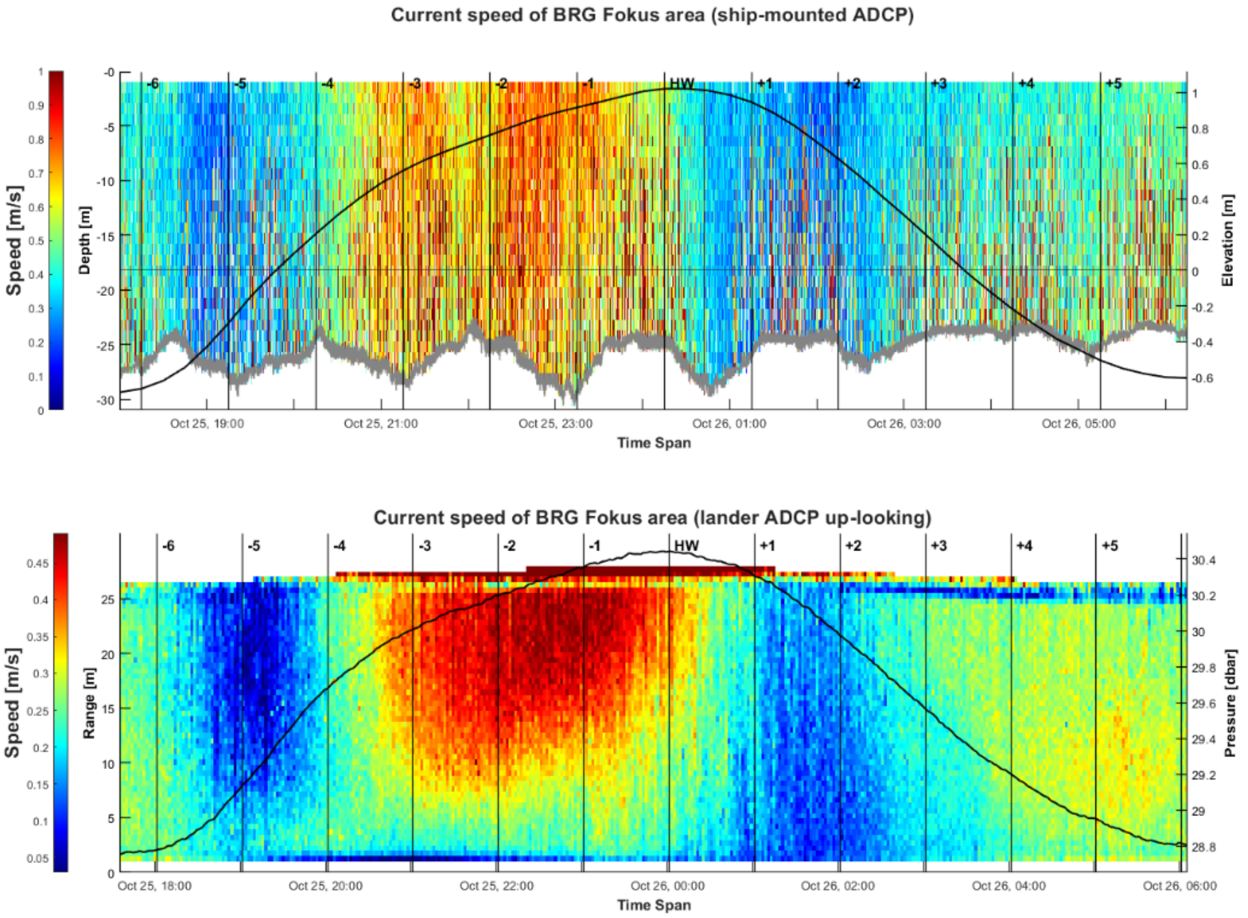

Fig. 5.7: *Comparison of current speed for one tide in AG1 collected during HE588 with the ship-mounted (top) and the up-looking lander-mounted ADCP (bottom).*

The backscatter intensities measured by the different ADCP systems show no clear correlation. The ship data (Fig. 5.8, upper plot) show a regular increase in amplitude at an interval of about 1¾ hours, which is not evident in the lander data (Fig. 5.8, lower plot). So far, there is no evidence, that this is caused by natural factors, but is probably due to the ship's direction or orientation (due to the profile direction during the measurement). However, the lander data show a significant increase where the water velocities are close to zero. On one hand, this may be related to the fact that the sediment load from the land increases at low tide. But on the other hand, a large amount of organic load in the water can be seen in the videos of the divers. These particles can accumulate at low water velocities, which could result in an increase in backscatter intensities.

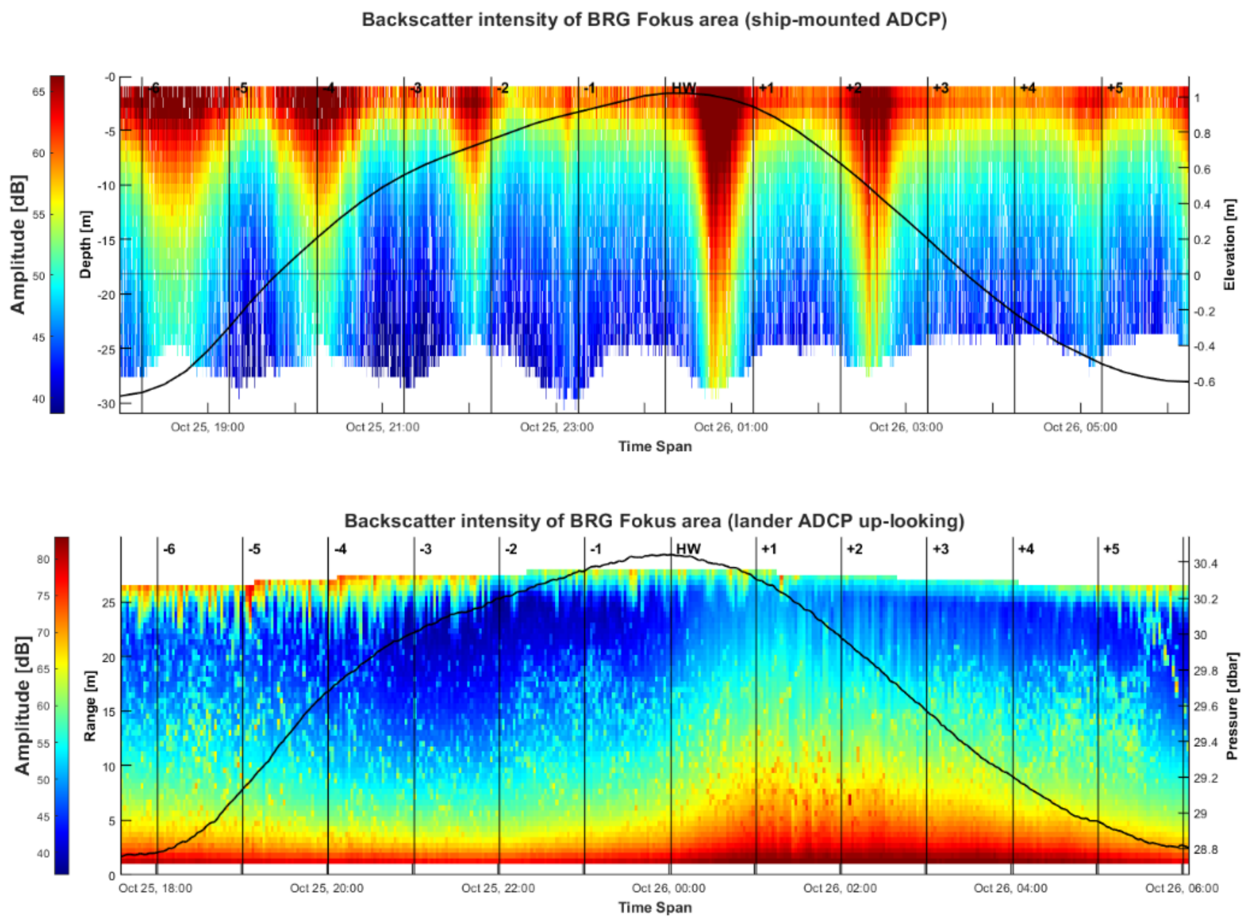

Fig. 5.8: *Comparison of backscatter intensities for one tide in AG1 collected during HE588 with the ship-mounted (top) and the up-looking lander-mounted ADCP (bottom).*

Rotation scanner

The rotational scanner operated well during the first deployment in AG1 (Fig. 5.9). Small scale sedimentary structures like ripple features and individual stones on the seabed were well imaged. At long ranges (at ~60 m) the sea surface was visible which masks any further geological features. No distinct changes over the course of the deployment were observed.

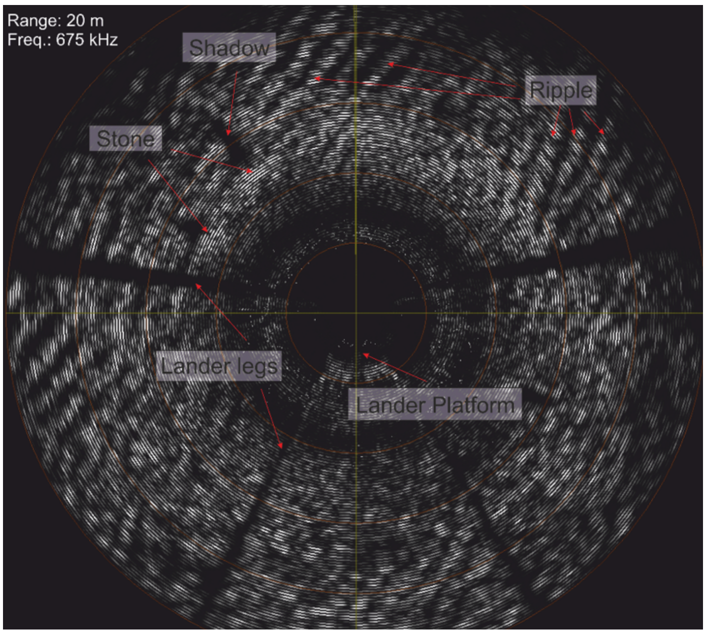

Fig. 5.9: *Rotational sidescan data, obtained at an hourly interval during the lander deployment in AG1, can visualize smaller features (such as stones and bedforms) and their mobility over time.*

5.4.2 Seafloor sampling

The granulometry of the grab samples taken from the seafloor was determined using the CILAS 1180 laser-diffraction grain-size analyser at AWI Sylt. The results show that all samples are composed of sands with variable proportions in the fine, medium, and coarse sand fractions (a few samples contained material >2 mm) and thus reflect typical conditions for the investigated parts of the North Sea. The data will be used along with the photos of the grab sample for the ground-truthing of the sidescan sonar data.

In the MUC samples, oxygen fluxes were measured directly on board and were in the range of 9 – 23 mmol m^{-2} d^{-1} and thus fall well within the range of oxygen fluxes that were previously observed by the NOAH project (see Fig. 5.10). The sediment samples and the water samples from the incubations are currently analyzed in laboratories at hereon and ICBM, and will become available in the near future. The combined results will be incorporated into the data base of the MGF-Nordsee Project.

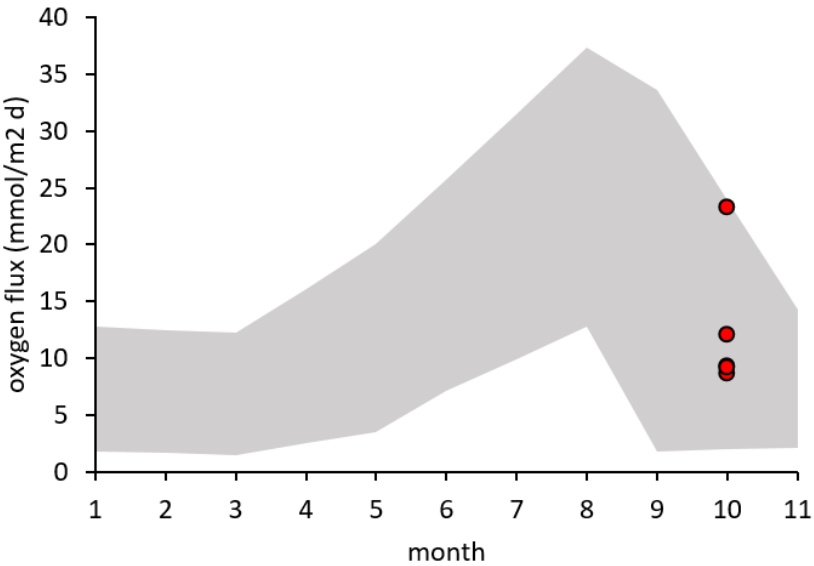

Fig. 5.10: *Average benthic oxygen fluxes as measured during HE588 (red circles) in comparison to previous results from the NOAH project (grey polygon).*

Sediment samples from the MUC and Van-Veen grabs, were further used to assess the ecological effects of bottom trawling at the microbial level. Most research on the effects of bottom trawling has focused on invertebrate communities and little is known about the impact on microbial communities and the metabolic processes mediated by microbes. In order to study these effects taxonomically, DNA will be extracted from the preserved sediment samples and analysed by PCR targeting a fragment of the 16S rDNA region and by using high throughput amplicon sequencing. We aim to characterize communities of microbial taxa and use these data to model how different microbial taxa, linked to specific metabolic processes, vary with depth, granulometry, fishing intensity and with space in general. Due to increased mortality of bio-irrigating invertebrates in heavily trawled areas, we expect that the abundance of anaerobic taxa correlates positively with trawling intensity. In addition, due to a higher degree of bottom disturbance which may interfere with microbial succession, we also expect trawling may decrease alpha diversity (species richness) and increase beta diversity.

5.4.3 Benthic surveys

ARMS

We could successfully deploy ARMS at two stations and we plan to recover them in 6-12 months in order to analyze the cryptic invertebrate communities (Fig. 5.11).

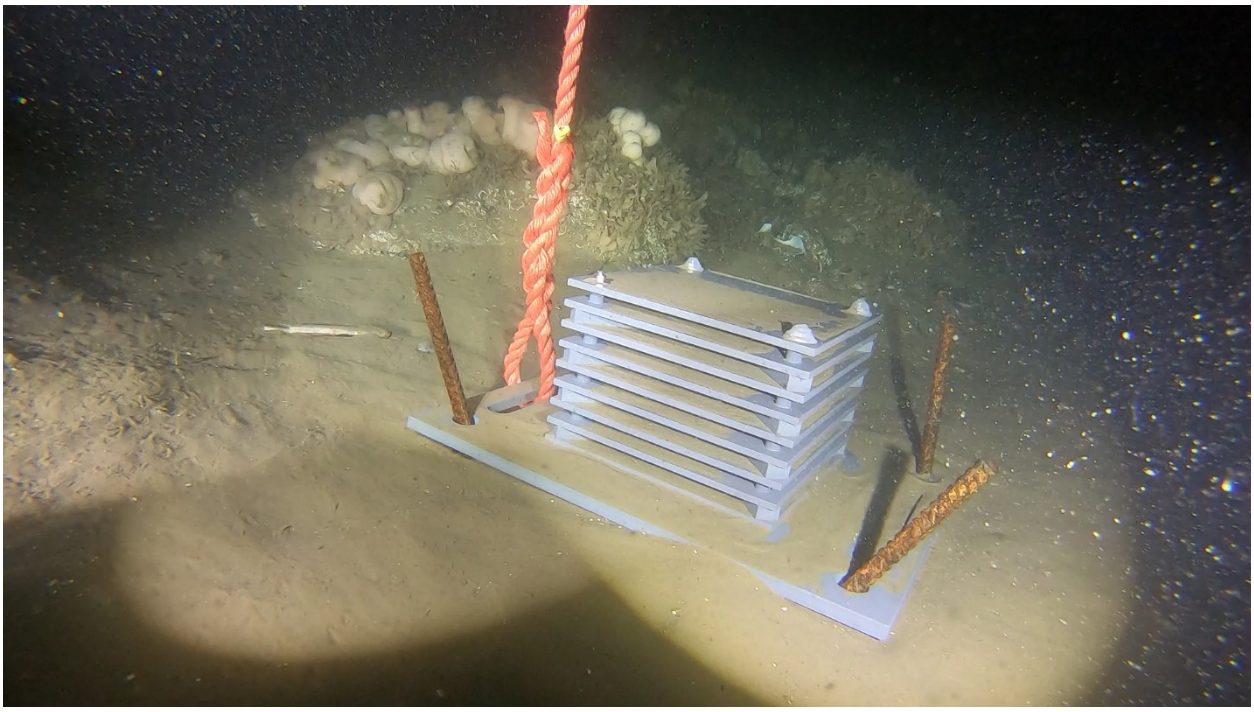

Fig. 5.11: *A deployed ARMS next to a reef area on the Sylter Outer Reef.*

Diving profiles

Two diving transects could be recorded at the Borkum Reefground (26.10.2021) and offshore Sylt (AG2; 29.10.2021) on the way to the Lander and in the hard substrate area of the Sylt Outer Reef (03.11.2021; Fig. 5.12). The analysis of those transects is still in progress.

BRUVs

The BRUVs could be deployed in hard substrate habitats (reef structures) and up to now we could record 11 different species: *Liocarcinus* sp., Gobiidae, *Callionymus* sp., *Asterias rubens* different species: *Liocarcinus* sp., Gobiidae, *Callionymus* sp., *Asterias rubens*, *Astropecten irregularis*, *Cyanea lamarckii*, *Merlangius merlangus*, *Limanda limanda*, *Buglossidium luteum*, *Pagurus bernhardus* and schools of *Trachurus trachurus* (Fig. 3).

Fig. 5.12: *Outtake of a survey transect on the Sylt Outer Reef. On the left is a stone overgrown with* Metridium senile *and on the right upper side are three red/purple anemones of the genus* Urticina.

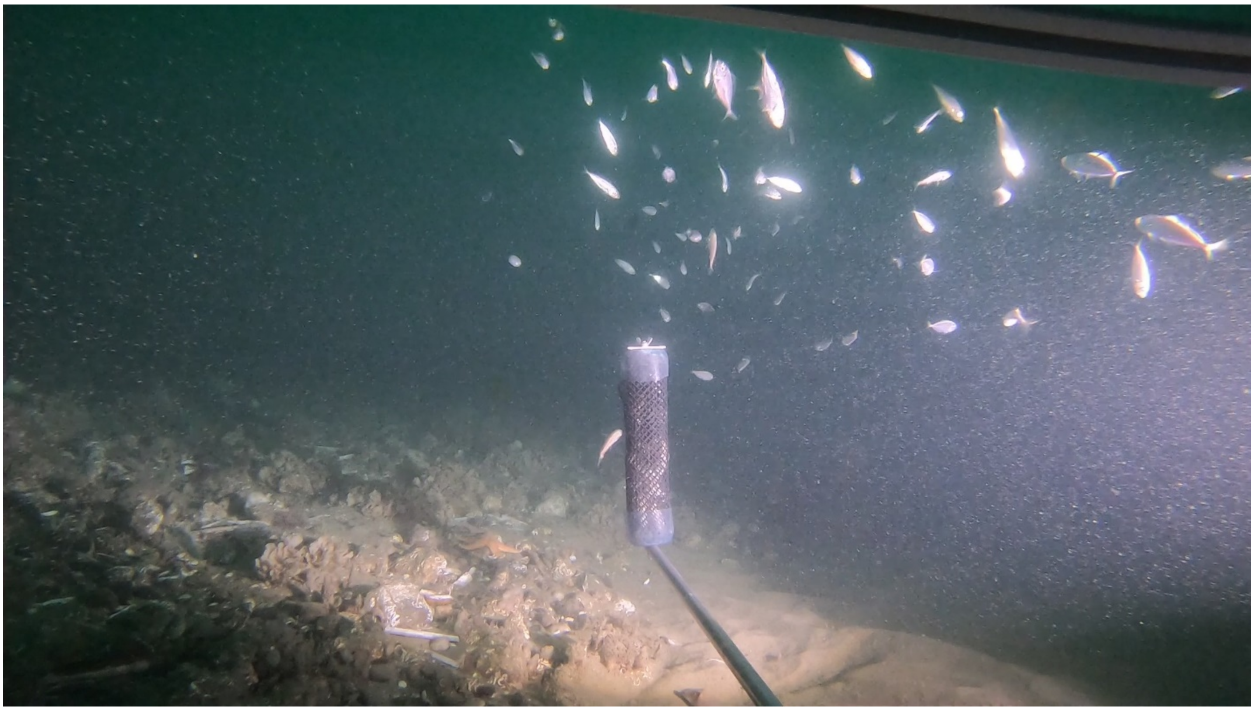

Fig. 5.13: *Hard substrate area of the Sylt Outer Reef with a school of* Trachurus trachurus.

6 Station List HE588

Station No.	Date	Time	Latitude	Longitude	Gear	Remarks
HEINCKE	**2021**	**[UTC]**				
HE588_1-2	25.10	6:15	53° 54,295' N	006° 15,411' E	BOAT	shot line (deployment)
HE588_1-2	25.10	6:35	53° 54,441' N	006° 15,153' E	BOAT	boat in the water
HE588_1-2	25.10	7:55	53° 54,541' N	006° 16,166' E	BOAT	boat on deck
HE588_1-2	25.10	8:00	53° 54,464' N	006° 16,295' E	BOAT	shot line (recovery)
HE588_2-1	25.10	8:21	53° 54,313' N	006° 16,688' E	BOP	BRUV 1 (deployment)
HE588_2-1	25.10	8:35	53° 54,403' N	006° 17,271' E	BOP	BRUV 2 (deployment)
HE588_2-1	25.10	8:44	53° 54,463' N	006° 17,723' E	BOP	BRUV 3 (deployment)
HE588_2-1	25.10	8:59	53° 54,514' N	006° 18,378' E	BOP	BRUV 4 (deployment)
HE588_3-2	25.10	11:24	53° 59,986' N	006° 15,183' E	MUC	MUC 1
HE588_3-2	25.10	11:36	53° 59,926' N	006° 15,076' E	MUC	MUC 2
HE588_3-2	25.10	11:48	53° 59,876' N	006° 15,028' E	MUC	MUC 3
HE588_4-1	25.10	13:33	53° 54,276' N	006° 15,399' E	LANDER	Lander (deployment)
HE588_5-1	25.10	14:06	53° 54,357' N	006° 16,850' E	BOP	BRUV 1 (recovery)
HE588_5-1	25.10	14:23	53° 54,428' N	006° 17,429' E	BOP	BRUV 2 (recovery)
HE588_5-1	25.10	14:38	53° 54,492' N	006° 17,841' E	BOP	BRUV 3 (recovery)
HE588_5-1	25.10	14:54	53° 54,538' N	006° 18,434' E	BOP	BRUV 4 (recovery)
HE588_6-1	25.10	15:00	53° 54,543' N	006° 18,499' E	CTD	
HE588_6-2	25.10	16:00	53° 53,526' N	006° 13,391' E	SSS	profile start
HE588_6-2	26.10	6:10	53° 56,234' N	006° 20,476' E	SSS	profile end
HE588_7-1	26.10	7:00	53° 54,378' N	006° 15,139' E	BOAT	boat in the water
HE588_7-1	26.10	8:50	53° 54,611' N	006° 16,265' E	BOAT	boat on deck
HE588_8-1	26.10	9:24	53° 56,942' N	006° 19,205' E	MUC	MUC 1
HE588_8-1	26.10	9:36	53° 56,939' N	006° 19,166' E	MUC	MUC 2
HE588_9-1	26.10	10:33	53° 56,436' N	006° 20,460' E	SSS	profile start
HE588_9-1	27.10	8:26	53° 56,029' N	006° 13,209' E	SSS	profile end
HE588_10-1	27.10	8:49	53° 55,153' N	006° 14,835' E	MBES	profile start
HE588_11-1	28.10	2:54	53° 58,625' N	006° 16,579' E	MBES	profile end
HE588_12-1	28.10	6:34	53° 54,284' N	006° 15,427' E	LANDER	Lander (recovery)
HE588_13-1	28.10	7:33	53° 52,494' N	006° 23,846' E	BOP	BRUV 1 (deployment)
HE588_13-1	28.10	7:43	53° 52,601' N	006° 23,973' E	BOP	BRUV 2 (deployment)
HE588_13-1	28.10	7:53	53° 52,715' N	006° 24,090' E	BOP	BRUV 3 (deployment)
HE588_13-1	28.10	8:03	53° 52,821' N	006° 24,267' E	BOP	BRUV 4 (deployment)
HE588_14-1	28.10	8:22	53° 53,120' N	006° 23,815' E	GRAB	
HE588_15-1	28.10	9:00	53° 51,797' N	006° 29,690' E	GRAB	
HE588_16-1	28.10	9:27	53° 49,006' N	006° 28,038' E	GRAB	
HE588_17-1	28.10	9:54	53° 50,231' N	006° 26,624' E	GRAB	
HE588_18-1	28.10	10:21	53° 49,486' N	006° 24,907' E	GRAB	
HE588_19-1	28.10	10:55	53° 48,016' N	006° 21,897' E	GRAB	
HE588_20-1	28.10	11:13	53° 49,373' N	006° 21,256' E	GRAB	
HE588_21-1	28.10	11:40	53° 49,161' N	006° 18,238' E	GRAB	

HE588_22-1	28.10	12:02	53° 51,480' N	006° 18,483' E	GRAB	
HE588_23-1	28.10	12:30	53° 52,554' N	006° 14,168' E	GRAB	
HE588_24-1	28.10	12:54	53° 53,670' N	006° 17,748' E	GRAB	
HE588_25-1	28.10	13:13	53° 54,924' N	006° 18,966' E	GRAB	
HE588_26-1	28.10	13:28	53° 53,818' N	006° 19,736' E	GRAB	
HE588_27-1	28.10	14:00	53° 52,828' N	006° 24,252' E	BOP	BRUV 1 (recovery)
HE588_27-1	28.10	14:12	53° 52,717' N	006° 24,068' E	BOP	BRUV 2 (recovery)
HE588_27-1	28.10	14:20	53° 52,591' N	006° 23,946' E	BOP	BRUV 3 (recovery)
HE588_27-1	28.10	14:26	53° 52,492' N	006° 23,831' E	BOP	BRUV 4 (recovery)
HE588_28-1	28.10	19:49	54° 26,342' N	007° 25,491' E	MUC	MUC 1
HE588_29-1	29.10	3:01	55° 02,736' N	008° 11,880' E	CTD	CTD
HE588_29-2	29.10	3:30	55° 02,439' N	008° 13,118' E	MBES	profile start
HE588_29-2	29.10	5:55	55° 02,352' N	008° 13,577' E	MBES	profile end
HE588_30-1	29.10	6:12	55° 02,302' N	008° 12,777' E	BOP	BRUV 1 (deployment)
HE588_30-1	29.10	6:23	55° 02,361' N	008° 12,970' E	BOP	BRUV 2 (deployment)
HE588_30-1	29.10	6:32	55° 02,421' N	008° 13,148' E	BOP	BRUV 3 (deployment)
HE588_30-1	29.10	6:43	55° 02,478' N	008° 13,333' E	BOP	BRUV 4 (deployment)
HE588_31-1	29.10	7:08	55° 02,361' N	008° 13,860' E	MUC	MUC 1
HE588_31-2	29.10	7:15	55° 02,358' N	008° 13,892' E	MUC	MUC 2
HE588_32-1	29.10	7:42	55° 02,370' N	008° 13,764' E	LANDER	Lander (deployment)
HE588_33-1	29.10	8:40	55° 02,490' N	008° 13,628' E	BOAT	shot line (deployment)
HE588_33-1	29.10	8:54	55° 02,590' N	008° 13,701' E	BOAT	boat in the water
HE588_33-1	29.10	12:05	55° 02,509' N	008° 13,970' E	BOAT	boat on deck
HE588_33-1	29.10	12:26	55° 02,488' N	008° 13,603' E	BOAT	shot line (recovery)
HE588_34-1	29.10	12:47	55° 02,484' N	008° 13,352' E	BOP	BRUV 1 (recovery)
HE588_34-1	29.10	13:01	55° 02,426' N	008° 13,117' E	BOP	BRUV 2 (recovery)
HE588_34-1	29.10	13:10	55° 02,360' N	008° 12,933' E	BOP	BRUV 3 (recovery)
HE588_34-1	29.10	13:17	55° 02,303' N	008° 12,766' E	BOP	BRUV 4 (recovery)
HE588_35-1	29.10	16:45	54° 37,154' N	007° 54,256' E	MUC	MUC 1
HE588_35-2	29.10	16:53	54° 37,156' N	007° 54,284' E	MUC	MUC 2
HE588_36-1	29.10	17:46	54° 40,480' N	007° 50,655' E	SSS	profile start
HE588_37-1	31.10	7:00	54° 34,463' N	007° 54,993' E	SSS	profile end
HE588_38-1	31.10	7:22	54° 33,291' N	007° 58,506' E	GRAB	
HE588_39-1	31.10	7:43	54° 34,999' N	007° 57,506' E	GRAB	
HE588_40-1	31.10	7:56	54° 34,996' N	007° 55,707' E	GRAB	
HE588_41-1	31.10	8:07	54° 34,981' N	007° 54,969' E	GRAB	
HE588_42-1	31.10	8:21	54° 36,011' N	007° 55,000' E	GRAB	
HE588_43-1	31.10	8:40	54° 35,616' N	007° 52,208' E	GRAB	
HE588_44-1	31.10	9:02	54° 37,781' N	007° 53,545' E	GRAB	
HE588_45-1	31.10	9:17	54° 37,952' N	007° 55,738' E	GRAB	
HE588_46-1	31.10	9:37	54° 40,013' N	007° 54,988' E	GRAB	
HE588_47-1	31.10	9:51	54° 39,398' N	007° 52,854' E	GRAB	
HE588_48-1	31.10	10:08	54° 39,995' N	007° 49,947' E	GRAB	
HE588_49-1	31.10	10:28	54° 39,759' N	007° 53,765' E	GRAB	

HE588_50-1	31.10	10:39	54° 39,273' N	007° 54,285' E	GRAB	
HE588_51-1	31.10	11:02	54° 39,481' N	007° 58,920' E	GRAB	
HE588_52-1	31.10	11:14	54° 39,859' N	007° 57,925' E	GRAB	
HE588_53-1	31.10	11:25	54° 39,941' N	007° 56,912' E	GRAB	
HE588_54-1	31.10	11:34	54° 39,792' N	007° 56,460' E	GRAB	
HE588_55-1	31.10	11:44	54° 39,370' N	007° 56,492' E	GRAB	
HE588_56-1	31.10	11:54	54° 38,630' N	007° 56,713' E	GRAB	
HE588_57-1	31.10	12:54	54° 29,963' N	007° 59,969' E	GRAB	
HE588_58-1	31.10	13:33	54° 24,718' N	008° 00,290' E	GRAB	
HE588_59-1	2.11	4:04	54° 03,630' N	008° 01,383' E	MUC	MUC 1
HE588_60-1	2.11	10:31	54° 48,619' N	006° 44,057' E	MUC	MUC 2
HE588_60-1	2.11	10:45	54° 48,581' N	006° 44,058' E	MUC	MUC 3
HE588_60-1	2.11	10:52	54° 48,553' N	006° 44,042' E	MUC	MUC 4
HE588_61-1	2.11	11:13	54° 48,352' N	006° 43,961' E	SSS	profile start
HE588_61-1	2.11	12:41	54° 46,519' N	006° 44,683' E	SSS	station end
HE588_62-1	2.11	14:36	54° 40,354' N	007° 10,112' E	CTD	
HE588_62-2	2.11	15:10	54° 41,090' N	007° 13,369' E	SSS	profile start
HE588_62-2	3.11	6:48	54° 41,178' N	007° 17,265' E	SSS	profile end
HE588_63-1	3.11	7:37	54° 44,371' N	007° 16,174' E	BOP	BRUV 1 (deployment)
HE588_63-1	3.11	7:46	54° 44,435' N	007° 16,410' E	BOP	BRUV 2 (deployment)
HE588_63-1	3.11	7:55	54° 44,509' N	007° 16,664' E	BOP	BRUV 3 (deployment)
HE588_63-1	3.11	8:03	54° 44,578' N	007° 16,864' E	BOP	BRUV 4 (deployment)
HE588_64-1	3.11	8:26	54° 44,788' N	007° 16,071' E	BOAT	shot line (deployment)
HE588_64-1	3.11	8:38	54° 44,890' N	007° 16,272' E	BOAT	boat in the water
HE588_64-1	3.11	10:23	54° 45,026' N	007° 16,370' E	BOAT	boat on deck
HE588_64-1	3.11	11:00	54° 44,728' N	007° 16,081' E	BOAT	shot line (recovery)
HE588_65-1	3.11	11:14	54° 44,575' N	007° 16,862' E	BOP	BRUV 1 (recovery)
HE588_65-1	3.11	11:28	54° 44,494' N	007° 16,610' E	BOP	BRUV 2 (recovery)
HE588_65-1	3.11	11:35	54° 44,434' N	007° 16,361' E	BOP	BRUV 3 (recovery)
HE588_65-1	3.11	11:44	54° 44,367' N	007° 16,138' E	BOP	BRUV 4 (recovery)
HE588_66-1	3.11	12:29	54° 41,234' N	007° 17,456' E	SSS	profile start
HE588_66-1	3.11	19:28	54° 39,590' N	007° 15,268' E	SSS	profile end
HE588_66-2	3.11	19:37	54° 39,306' N	007° 14,851' E	CTD	

7 Data and Sample Storage and Availability

Once processed and quality controlled, all data will be submitted to the PANGAEA database.

8 Acknowledgements

We would like to thank Captain Haye Diecks and the entire crew of RV Heincke for their support during HE588. The cruise was conducted as part of the DAM *Pilotmission* on the impact of mobile bottom-contact fishing in marine protected areas of the North Sea (MGF-Nordsee; https://www.mgf-nordsee.de/), funded by the Federal Ministry of Education and Research (BMBF; contract no. 03F0847A).

9 Abbreviations

ADCP: Acoustic Doppler Current Profiler
AG: *Arbeitsgebiet* (research area)
ARMS: Artificial Reef Monitoring Structure
AWI: Alfred-Wegener-Institute
BMBF: *Bundesministerium für Bildung und Forschung* (Federal Ministry of Education and Research)
BOP: Bio-optical platform
BRUV: Baited Remote Underwater Video
CAU: Christian-Albrechts-Universität, Kiel
CTD: Conductivity-Temperature-Depth probe
DAM: *Deutsche Allianz Meeresforschung*
Deg: degree
DNA: Deoxyribonucleic acid
eDNA: environmental DNA
FRV: Fishery Research Vessel
HELCOM: Baltic Marine Environment Protection Commission (Helsinki Commission)
ICBM: Institut für Biologie und Chemie des Meeres
MBES: Multibeam Echo Sounder
MUC: Mulicorer
NOAH: North Sea Observation and Assessment of Habitats
PCR: Polymerase chain reaction
RNA: ribonucleic acid
RV: Research Vessel
SaM: Senckenberg am Meer
SES: Sediment Echosounder
SSS: Sidescan sonar
TOC: Total Organic Carbon