Cruise Report R/V Littorina, Cruise No. L01-22

Dates of Cruise: 06.02.2022 – 17.02.2022
Port Calls: Kiel – Heligoland – Kiel
Areas of Research: Marine Geophysics
Institutes: Institute of Geoscience (CAU), Institute of Geography (CAU), AWI Sylt
Chief Scientist: Dr. Jens Schneider von Deimling
Number of Scientists: 4
Projects: CDRmare sea4soCiety

This cruise report consists of 17 pages including cover.

Contents

1 Scientific crew

Name	Function	Institute
Schneider von Deimling, Jens, Dr.	Marine Geophysics / Chief Scientist	CAU
Hoffman, Jasper, Dr.	Marine Geophysics	AWI Sylt
Friedrich, Jenny	Marine Geophysics	CAU
Martius, Jakob	Geography	CAU

Chief scientist:
Dr. Jens Schneider von Deimling
Institute of Geosciences
Christian-Albrechts-Universität zu Kiel
Otto-Hahn-Platz 1, Room 108a
24118 Kiel, Germany
Phone: +49-431-880-5792
email: jens.schneider@ifg.uni-kiel.de
https://www.marinegeophysik.ifg.uni-kiel.de/

2 Research programme

A team from CAU with staff from the Institute of Geoscience and Institute of Geography, in cooperation with AWI Sylt set off from Kiel to Heligoland to precisely measure its underwater landscape with parametric and multibeam echosounding techniques. The main aim was to study the submerged aquatic vegetation with focus on acoustic kelp forests detection. The work is part of the DAM project sea4soCiety, in which CAU is driving forward optic and acoustic remote sensing of submerged aquatic vegetation in coastal areas. Regardless of the stormy weather episodes, we managed to acquire valuable data on a daily basis starting from the harbour of Heligoland. The acoustic seafloor and kelp mapping was successfully validated by underwater video camera recordings. We also performed several tests of optical radiation measurement underwater for later remote sensing by satellites.

Heligoland represents the only location in the German Bight at which hard rock material is exposed. The reason for this is an underlying salt diapir that lifted and tilted mesozoic strata, which are today apparent at the current sea level around Heligoland and its adjacent island “Dune”. On the main island of Heligoland, the red sandstone, whose most famous representative is the ”lange Anna”, is also a geological rarity under water. On the other side off the Dune outcropping chalk and shell limestone can be found. These hard substrates of outcropping Mesozoic hard rocks have formed an underwater landscape that is unique for Germany. Therefore, an exceptional underwater habitat has formed here.

The main objective of the trip was to adapt and further develop acoustic methods for visual and acoustic mapping of subaquatic vegetation, which have already proven to be viable for detection of underwater vegetation (Mielck et al. 2012, Heldt and Schneider von Deimling 2019, Schimel et al. 2020). In addition, the cruise allowed for first bathymetric measurements and video groundtruthing to learn under which morphometric setting kelp preferentially colonises.

3 Narrative of cruise with technical details

It was planned to include biologists and colleagues from sea4soCiety for water current velocity measurements, which were to be collected on a daily basis in the harbour of Heligoland. However, due to the current COVID restrictions, we performed the cruise with a permanent ship's crew. We focused on acoustic seafloor mapping and waited for short weather episodes to get out of the harbour, measure, and return.

We departured from Kiel on the 5th of February 12:00 UTC through the Kiel Canal, lashed all our equipment during the calm transit, and rested overnight in Cuxhaven. On the morning of the 6th there was a brief weather window that allowed us to get to Heligoland under rough weather conditions. As one of the few ships operating here in winter, we entered the harbour. We started rigging up the lab and were able to install our massive pole over the side, attached and connected our sonars and rigged up AWI's robust video camera frame. Finally, we tightened everything down, which was especially important in the prevailing wind. Station work started on the 8th in between Heligoland's main island and its Dune to start in a sheltered area, where we also ran some underwater test with optical radiance gear for later satellite observations. We successfully completed all acoustic and motion-sensing calibrations and started surveying. At dawn, we sailed back to port. In the following days we decided on a daily basis when to leave the harbour. We selected specific weather and swell windows to get out and survey. Occasionally, we faced significant ship motion, nevertheless succeeded in a lot of station work except on 13th and 14th, when the weather was too bad. On the very morning of the 16th we decided to call off all station work to avoid the approaching storm Ylenia. All equipment worked throughout the cruise without significant issues. We reached the port of Kiel on the 17th in the afternoon and demobilised the equipment on the 18th of February.

4 Scientific report and first results

4.1 Multibeam Echosounding

We installed the NORBIT shallow water iWBMS multibeam echosounder from the Marine and Hydroacoustic working group from CAU (https://www.marinegeophysik.ifg.uni-kiel.de/) via our massive side pole mounting on R/V Littorina. Our NORBIT iWBMS chirp multibeam system was operated with a protoype firmware kindly provided by NORBIT and we applied a frequency range between 150-410 kHz in various modes, using a 1x1° array. E.g. in multispectral mode with receiver picking 80 kHz-wide bands around 190 kHz and 370 kHz, respectively. This special setup limited the opening angle from 150° in single frequency chirp mode to 130° in multispectral mode for technical restrictions. In water column imaging (WCI) mode (Schneider von Deimling and Weinrebe 2014), and the new multidetect mode, that had been developed in the previous ECOMAP project with the aim to better identify SAV (Heldt et al. 2019). The MBES is coupled with an Applanix Wavemaster IMU and the dual Antenna GPS positions of the primary antenna is projected into the sonar head itself and written to s7k-files. The lever arms between MBES and the MRU are fixed, and we set the offsets between the primary antenna and the MBES flange (see Table 1).

Table 1: Installation offsets for the CAU Pole required for IMU calibration.

Offset from Flange to prim. Antenna	Offset [m]
+Fwd	0.685
+Stb	-0.145
+Down	4.987

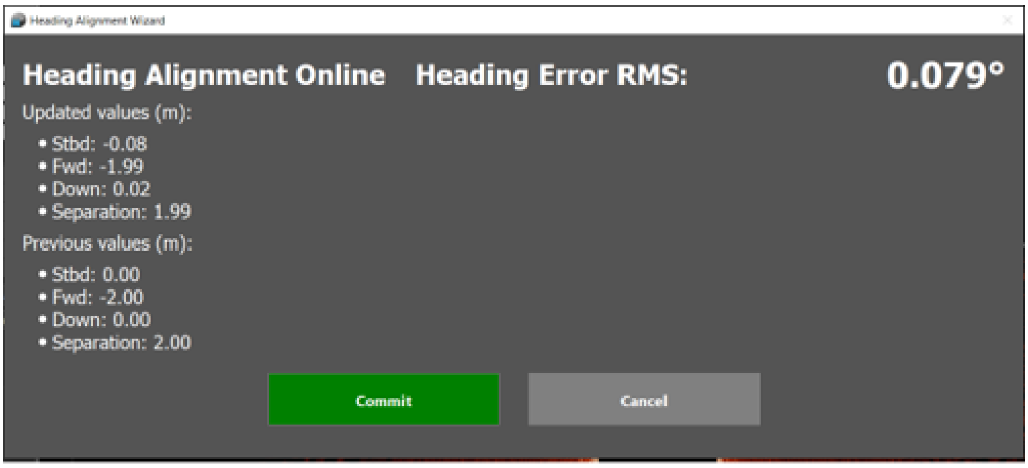


Figure 1: Screenshot of offset measurement system.

To keep the data consistent and backscatter comparable throughout the survey we fixed the pulse length and bandwidth, gains, and filter setting in the beginning of each working area as recommended (Lamarche and Lurton 2018). In addition, a parameter test was conducted with various modes including multifrequency, water column imaging, and multidetect for point cloud analyses.

An AML C-keel velocity probe is permanently mounted next to the transducer head in our system and measured c-keel on the fly. Sound velocity was found constant throughout die to the very well mixed water column, nevertheless we conducted two CTD profiles with a Sea and Sun CTD.

We connected the native NORBIT recording software, received GPS from approximately 15-20 satellites on each antenna and received corrections kindly provided by Axio-Net via the NTRIP protocol and Mountpoint 07 (GPS + GLONASS, VRS, ETRS89, ellipsoidal) using the on bord internet and achieved GPS RTK FIX status most of the times with accuracies ranging between 2 and 4 cm for positioning and height.The NORBIT offsets were determined earlier and we sailed figures of eights to calibrate the IMU system succeeding after a few minutes.

Figure 2: Installation of (left) the NORBIT MBES together with the (right) parametric INNOMAR on our massive over the side pole on R/V Littorina.

After full calibration the system performed excellently even during heavy roll operation of 20° to each side which we mainly attribute to very good motion sensing, the solid pole mounting, and deep position of the transducers.

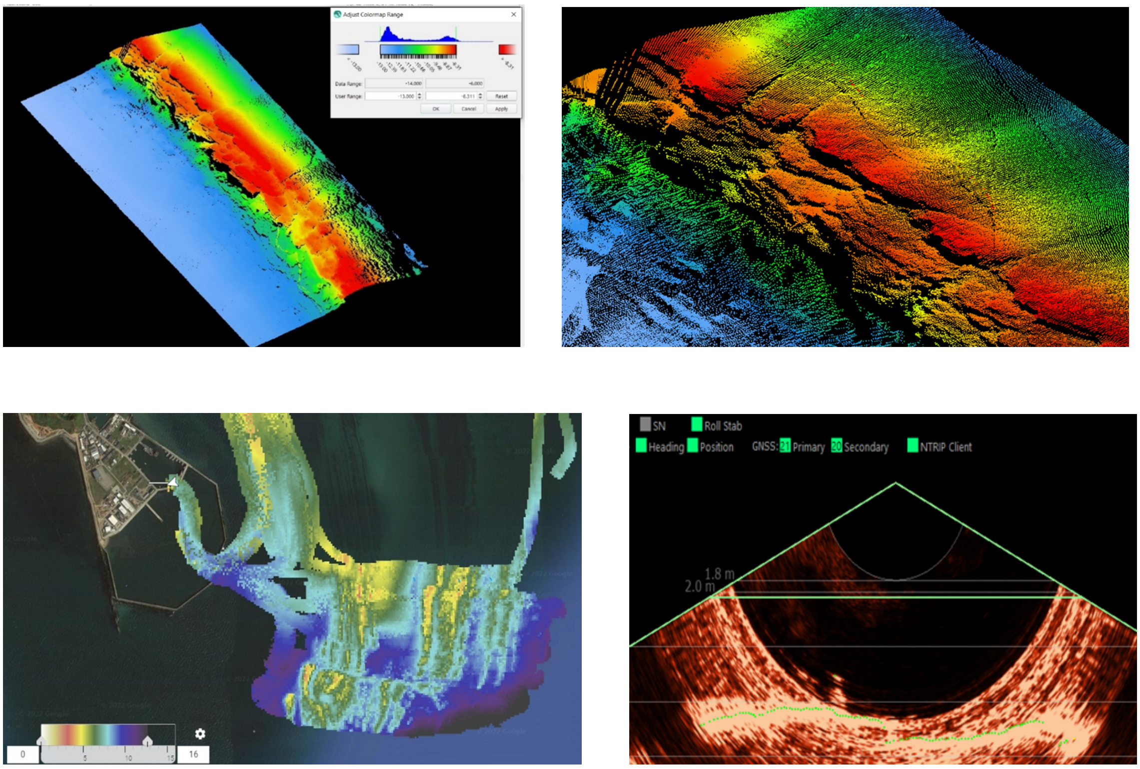


Figure 3: Raw MBES soundings (upper left) showing the complex morphology in the northern research area. The depth difference from the top of the ‘shoulder’ to the base comprises 5 m (upper right) close up representation of ‘upper left’ (lower left). Gridded bathymetry outlining the acoustic extension of optically visible strata striking north south (lower right) water column imaging plot showing SAV.

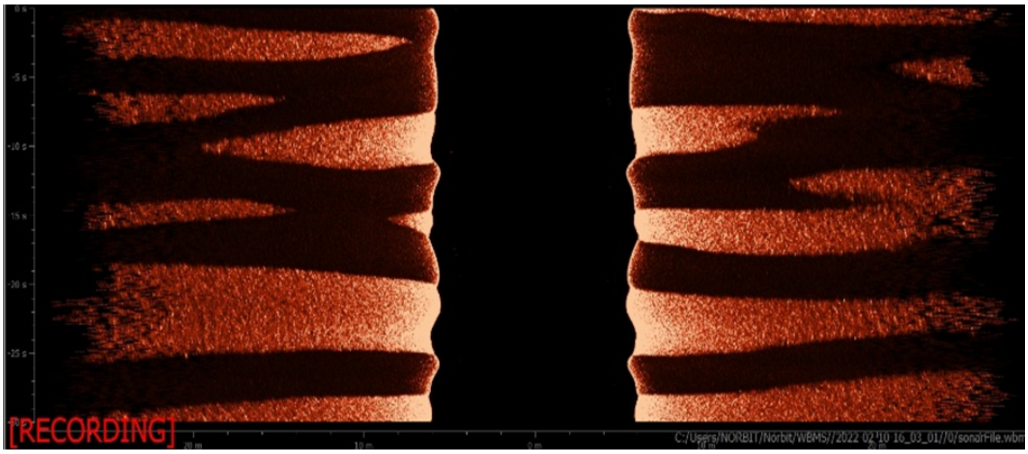


Figure 4: Sidescan plot acquired in parallel to bathymetry with our NORBIT system clearly showing sorted bedforms.

4.2 Parametric Echosounding

In parallel to the multibeam system we installed our INNOMAR SES2000 standard. Transmit and receive cycles between MBES and this system were successfully triggered by NORBIT being the master and INNOMAR being the slave. This parametric echosounder device operates with two primary frequencies centered around 100 kHz to form the parametric "difference frequency" with a corresponding wavelength of 0.1 m (approximated by the ratio of 1,500 m/s sound velocity and 15 kHz signal). The acoustic array generates a narrow ±1.8°, 3 dB transmit beam for primary and secondary frequencies, whereas the 3 dB receive beam width for the low secondary frequency is ±12.3°.

The advantage of a parametric system is that a small array is sufficient to generate narrow low-frequency beams having high horizontal and vertical resolution and very little side lobe cross-talk. For further technical information, the reader is referred to Wunderlich et al. (2005) and Wunderlich (2007). The given motion was compensated by a Seatex motion sensor installed right next to the transducer on the pole frame, and GPS was fed from the Applanix Wavemaster MRU. The INNOMAR has a forward lever arm offset of only approximately 25 cm (Figure 5). Therefore, positioning of the soundings can be assumed to be very accurate and should be identical to the MBES s7k positionings.

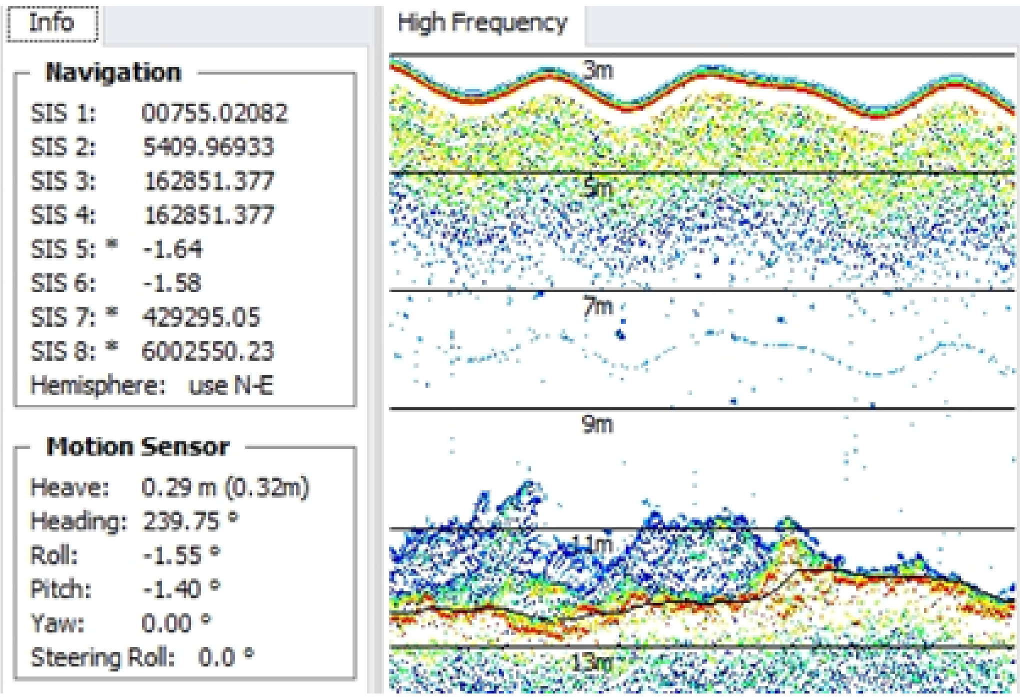
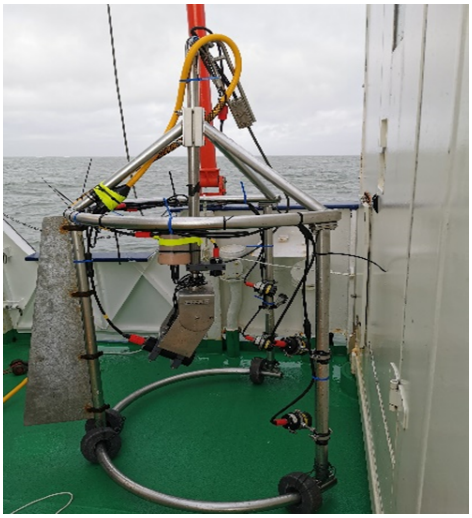


Figure 5: Echogram showing a second layer above the motion compensated seafloor most likely caused by scattering from Laminaria hyperborea.

The motion compensation worked well even under challenging conditions and we were able to clearly identify vegetation sticking out 1 until 2 m from the seabed in both frequencies. No penetration was observed except in some troughs filled with sediment. For unknown reasons we did not manage to feed UTC timestamps from GPS into the SIS 1 frame. Instead, we used synchronisation with PC Time, which itself was set to GPS UTC manually.

4.3 Camera

For ground-truthing of the hydroacoustic data and to obtain additional information on seafloor structure, colour, consistency and nature of the bottom substrate, we conducted six camera drift surveys. The camera system from AWI was equipped with two ahead-oriented cameras, artificial light sources and a laser scale reference. Positioning information during the recordings was received from the ships GPS. Recordings were taken while the ship was drifting (max. speed: 1 knot) and the camera system was kept as close to the seafloor as possible. Due to strong winds and high seas during the expedition the visibility around Heligoland was limited. Despite the relative turbid waters, different geologic regimes between Heligoland and Dune (red sand stone, shell limestone, and chalk) could clearly be distinguished and kelp forests as well as the substrate nature could visually be inspected. The highest densities of kelp forests were observed in the southern side of the Dune. Here, shell limestone, and chalk are exposed on the seafloor and therefore the hard substrate provides good settling substrate for the kelp. Due to the poor weather conditions the shallow parts in the north of the Dune and around Heligoland could not be investigated, but they are assumed to also hold large quantities of kelp forests.



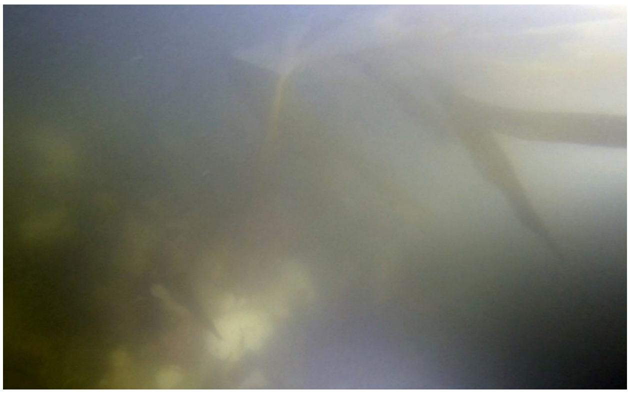


Figure 6: AWI camera system (left)and Laminaria hyperborea (right), that was found by video groundtruting on the chalk seabed.

4.4 RAMSES

Working group Earth Observation and Modelling (EOM) applied measurements of RAMSES spectral imaging radiometer on 8^{th} and 9^{th} of February 2022. The main goal of the measurements was to test the measurement setup under high sea conditions as RAMSES was mainly used in lake studies. Therefore, a T-shaped frame (see Figure 7, left) has been attached to the ships crane to position the two water sensors of RAMSES (downwelling radiance and upwelling radiance) in different water depths. The third sensor was placed on board to measure the reference downwelling solar irradiance (see Figure 7, right). RAMSES radiometer measures continuous spectra in a wavelength range between 280 and 950 nm (TriOS Optical Sensors). Empirical optical data of the water column are required to model optical parameters of the water. For instance, the index of refraction from different water depths can be derived from RAMSES in-situ measurements and used to fit optical models such as Mie theory (Boss 2021).

Figure 7: Left: T-shaped frame holding downwelling radiance and upwelling radiance water sensors.
Right: Mounting installed on upper deck of RV Littorina holding the incoming irradiance reference sensor of RAMSES.

The two measurement days enabled to gather helpful information and experience in order to further adapt the measurement setup to high sea conditions. To maximize the gain of knowledge data were collected at three different times under varying conditions, taking into account the limited time and weather conditions: In the harbour area of Heligoland to simulate a calm sea, in the mid time of accumulating water phase with strong water current and high waves and lastly about half an hour prior high tide when current had decreased nearly to a minimum. Measurement experience shows that the latter condition is required to gain useful data, otherwise the T-shaped frame with the water sensors tends to drift.

5 Acknowledgements

We very much appreciate the support of the ships' crew and the willingness of Captain Danny Flindt to sail in challenging survey conditions with strong winds, high currents, rocky shoals, and significant waves.

6 Appendices

6.1 Map

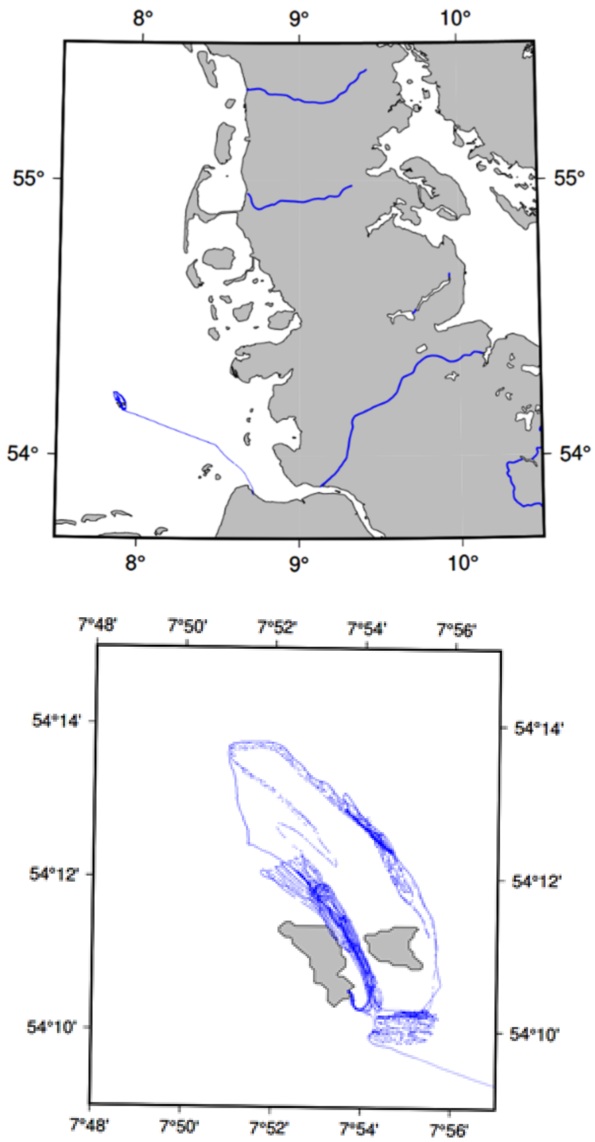


Figure 8: Top: Track chart of F/K Littorina Cruise L01-22 starting in Kiel, passing Kiel-Canal to Cuxhaven, and finally to Heligoland and back (WGS 84, UTM 32 N, ships antenna plot). **Bottom:** Track plot of acoustic surveying and station work within the 3 nm zone around the offshore island Heligoland.

6.2 Station list (all dates and times in UTC)

08.02.2022 – in between both islands 3-15m water depth

St. 1 09:00 UTC MBES start surveying

St. 2 11:06 UTC CTD

St. 3 12:00 UTC MBES continue

St. 4 13:30 RAMSES

St. 5 14:30 CAMERA on Patch 1 und 2 (54:11.461', 7:53.518'; 54:11.502'; 7:53.597')

14:40 in Water, no BoSi, abandon station

14:51 Adapt and set camera lower only 30cm above ground

14:53 now BoSi

14:57 kelp visible in Patch02

14:58 Drift, out of Patch, still kelp (Laminaria saccharia?)(no plants – have seen stalks…)

15:03 kelp

St. 6 15:20 continue MBES

09.02.2022 – north of the islands

St. 7: Jakob RAMSES Harbour

St. 8: 2nd RAMES between the islands

St. 9: Multibeam

St. 10 CTD (13.25)

St. 11: Multibeam

10.02.2022 – North/North East Düne

St. 12: Multibeam, multidetect

St. 13: Camera 14.55 Start, white clay at ground, sights of kelp, 3 camera transects

St. 14: continue Multibeam, multidetect

11.02.2022

St. 15 Multibeam Survey south of Heligoland

12.02.2022

Greifer über Galgen, backbords, gleiche Position wie Kamera

Area south off Düne/Area A: Position Ost, Greifer Position Area A Greifer 1–>

St. 16 Camera transect south off Helgoland (data for St. 15), roll 60° achtern, chalk on camera

St. 17, Ca. 07:15 Greifer A-1-1: kleiner Kreidestein, image greiferA-1-1.

St. 18, Ca. 07:30 Greifer A-1-2: großer Kreidestein, image greiferA-1-2

Position Mitte Greifer Position Area A Greifer 2–>

St. 19 Ca. 07:36: leerer Greifer, image greiferA-2-1

St. 20 07:38: leerer Greifer, image greiferA-2-2

St. 21 07:40 nicht ausgelöst, image greiferA-2-3

St. 22 07:42 leerer Greifer, image greiferA-2-4

Position West Greifer Area A Greifer 3–>

St. 23: 07:47:30, Greifer voll mit Muschelschalen, Kies, greifer with UTC stamp, image greiferA-3-1

Area east off Düne/Area B, Position north:

St. 24, 08:28:20 UTC Bottom contact, GreiferB-1-1 (no screenshot)

Position south:

St. 25, 08:35:33 UTC bottom contact, GreiferB2-1, image greiferB-2-1

St. 26 MBES multifrequency

11:22 UTC max roll values…

St 27 MBES calib roll

St 28 Video transect in between both islands

In water: 12:11:05 UTC

On Bord 12:27:50

13.02.2022

Bad weather, port call

14.02.2022

Bad weather, port call

Disembarkation of Jasper Hoffmann

15.02.2022

St. 29 Multiparameter survey south off islands

St. 30 ELAC ca. 08:10 UTC

St. 31 ca. 08:40 UTC Continue MBES Survey, ELAC off

St. 32 ca. 10-12 UTC NORBIT INNOMAR Interference Test

Ca. 12 UTC stop survey, end of scientific recording, demob

16.02.2022

07 UTC abandon station work off Heligoland to escape from arising severe storm Ylindia

7 References

Boss, E. (2021). Introduction to Optical Constituents of the Ocean. URL: https://www.oceanopticsbook.info/view/optical-constituents-of-the-ocean/introduction-to-optical-constituents-of-the-ocean. Last viewed 11.03.2022.

Held, P. and J. Schneider von Deimling (2019). New Feature Classes for Acoustic Habitat Mapping—A Multibeam Echosounder Point Cloud Analysis for Mapping Submerged Aquatic Vegetation (SAV). Geosciences, 9(5), 235.

Lamarche, G. and X. Lurton (2018). Recommendations for improved and coherent acquisition and processing of backscatter data from seafloor-mapping sonars. Marine Geophysical Research, 39(1), 5-22.

Mielck, F., Bartsch, I., Bürk, D. and H.C. Hass (2012). Detection of Kelpkelp Vegetation off Helgoland (SE North Sea) Using the Acoustic Ground-Discrimination System RoxAnn.

Schimel, A. C., Brown, C. J. and D. Ierodiaconou (2020). Automated filtering of multibeam water-column data to detect relative abundance of giant kelpkelp (Macrocystis pyrifera). Remote Sensing, 12(9), 1371.

Schneider von Deimling, J., and W. Weinrebe (2014). Beyond bathymetry: Water column imaging with multibeam echo sounder systems. Hydrographische Nachrichten, 31(97), 6-10.

TriOS Optical Sensors. RAMSES Hyperspectral radiometer manual. URL: https://docplayer.net/90782855-Ramses-hyperspectral-radiometer.html. Last viewed 11.03.2022.

Wunderlich, J., Kaestner, B., Sinova, J. and T. Jungwirth (2005). Experimental Observation of the Spin-Hall Effect in a Two-Dimensional Spin-Orbit Coupled Semiconductor System. Phys. Rev. Lett. 94, 047204.

Wunderlich, J. (2007). Mobile parametric sub□bottom profiler system for shallow and medium depth applications. J Acoust Soc Am 122(5): 2983.