ALKOR-Berichte

Deep-Ocean Validation of the LIGHTHOUSE System

Cruise No. AL568

11.11.21 – 22.11.21
Kiel (Germany) – Kiel (Germany)
LIGHTHOUSE-TEST III

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2021

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1 Cruise Summary

1.1 Summary in English

The objective of this cruise was to conduct the final and complete field test of the LIGHTHOUSE situational awareness system for remotely operated vehicles, developed in the HVF 0068 Project LIGHTHOUSE. This included three dives of the ROV PHOCA in the Norwegian Sognefjord, during which the optical and acoustic sensors were validated. Moreover, as part of the EU H2020 project iAtlantic (grant agreement 818123), we investigated the response of pelagic deep-sea fauna to warming and suspended sediment (which will be introduced to pelagic ecosystems by deep-sea mining activities). To this end, we captured the jellyfish *Periphylla periphylla* and conducted shipboard experiments.

1.2 Zusammenfassung

Ziel der Fahrt war ein abschließender und vollständiger Testbetrieb des LIGHTHOUSE Systems für Präsenzempfinden im Betrieb von Tauchrobotern, welches im HVF 0068 LIGHTHOUSE Projekt entwickelt wurde. In diesem Rahmen erfolgten drei Tauchgänge mit dem ROV PHOCA im norwegischen Sognefjord, während derer die optischen und akustischen Sensoren validiert werden konnten. Weiterhin wurde im Rahmen des EU H2020 Projektes iAtlantic (Fördernummer 818123) die Reaktion pelagischer Tiefseefauna auf Erwärmung und suspendiertes Sediment (wie es durch Tiefseebergbauaktivitäten in die Wassersäule gelangt). Hierfür wurde die Tiefseequalle *Periphylla periphylla* gefangen und an Bord Experimente durchgeführt.

2 Participants

2.1 Principal Investigator

Name	Institution
Kwasnitschka, Tom, Dr.	GEOMAR

2.2 Scientific Party

Name	Discipline	Institution
Kwasnitschka, Tom, Dr.	Principal Investigator / Chief Scientist	GEOMAR
Hauss, Helena, Dr.	Biologist, Co-Chief Scientist	GEOMAR
Stenvers, Vanessa	Biologist	GEOMAR
Rohleder, Marco	Chief Engineer	GEOMAR
Jahns, Oliver	Mechanical Engineer	GEOMAR
Pieper, Martin	Chief Engineer, ROV	GEOMAR
Cuno, Patrick	Software Engineer	GEOMAR
Bodendorfer, Matthias	Mechanical Engineer	GEOMAR
Huusmann, Hannes	Media Engineer	GEOMAR
Matthiessen, Torge	Mechanical Engineer	GEOMAR

Albiez, Jan Christian, Dr.	Software Engineer	Kraken

2.3 Participating Institutions

GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel
Kraken	Krakenrobotik GmbH, Bremen

3 Research Program

3.1 Description of the Work Area

The Sognefjord is the longest and one of the deepest of the Norwegian fjords. As such, it provides extremely sheltered, yet quickly accessible deep-water environments for the efficient testing of marine technology in development. It was planned to conduct the *Periphylla* work in the Lurefjord, which hosts a uniquely large population of this species, which is moreover distributed at shallower depths and comparatively easy to capture. Unfortunately, this fjord could not be entered (bad weather, narrow passage) and the entire time was spent in Sognefjorden instead (where *Periphylla* are much fewer and deeper).

3.2 Aims of the Cruise

The cruise was planned as a focused round of sea trials for the ROV-based situational awareness and mapping system LIGHTHOUSE. It is being developed under a federal venture capital grant from the Helmholtz Association through its Helmholtz Validation Fund (HVF). The goal of Project 0068, „LIGHTHOUSE – System zur Echtzeit-Visualisierung von Unterwasserumgebungen für Tauchroboter“ is to overcome limitations of most remotely operated vehicles (ROVs) which sensors are focused to one lateral sector, leaving the other sectors uncovered. This results in loss of intelligence for mission specialists and reduced situational awareness for the pilots. LIGHTHOUSE seeks to change this. The LIGHTHOUSE system generally consists of a suite of cameras, optical and acoustic seafloor shape acquisition devices, software to visualize their products as well as telemetry and hardware to accommodate the sensors on a remotely operated vehicle.

Within the EU project iAtlantic (WP4), a land-based expedition with twelve participants (including partners from HWU Edinburgh and UWC Cape Town) to Lurefjorden with the submersible JAGO was funded and planned for spring 2021. As this became impossible in the course of the SARS-Cov2 pandemic, we began to reach out to for shiptime. Since we did not have an approved cruise proposal, however, we were not eligible to apply for RV Alkor free time slots in 2021 (K. Lackschewitz, pers.comm.). We therefore downsized our plans considerably and accommodated some successful experiments on the already funded HE570 (H. Hauss/K.O. Möller, PhD student V. Stenvers joining on short notice) as well as co-applying for RV Alkor shiptime (two cruises) with T. Kwasnitschka as main proponent for additional experiments to achieve a suitable number of observations.

3.3 Agenda of the Cruise

To conduct the sea trials of the LIGHTHOUSE System, we used ROV PHOCA aboard ALKOR in the Sognefjord of central Norway. This water body is comparatively close to Kiel, requiring no shipping to an external port, water depths beyond 1200m but extremely calm since sheltered weather conditions, the type of which is necessary for controlled, experimental

deployments of novel equipment. We had planned to conduct four dives one day each, covering a cascade of functional and operational tests as well as calibration runs and collection of sample data. There were no plans to collect or publish any data of specific scientific relevance, though. The important feature of the working area is hard seafloor substrate for surface scans (i.e. rock walls) and the water depth beyond 1000m, which had been identified as an operational benchmark in the project. The cruise was planned as the last of a series of three rather identical cruises to this working area, each as an increment over the achievements of the former, with time in the workshop in between. Due to a series of unfortunate technical and logistical events in the LIGHTHOUSE project, this turned out to be the only of the three planned cruises to actually take us to the working area. Thus, the ROV deployments marked the first deep-water tests of the LIGHTHOUSE system.

For the *Periphylla* experiments, it was planned to spend two days in Lurefjorden to collect specimens with a large jelly net (WP3) for experimental incubations using different temperature and sediment load treatments. We planned to use a Hydrobios Multinet Maxi to determine their vertical distribution and thus *in situ* temperature. Water for incubations as well as baseline sampling (e.g. microbial community) was to be collected using the ship's CTD. During experiments, we prepared to determine oxygen consumption, ammonium excretion and collect samples for the microbiome, gene expression, and electron transport system (ETS) activity.

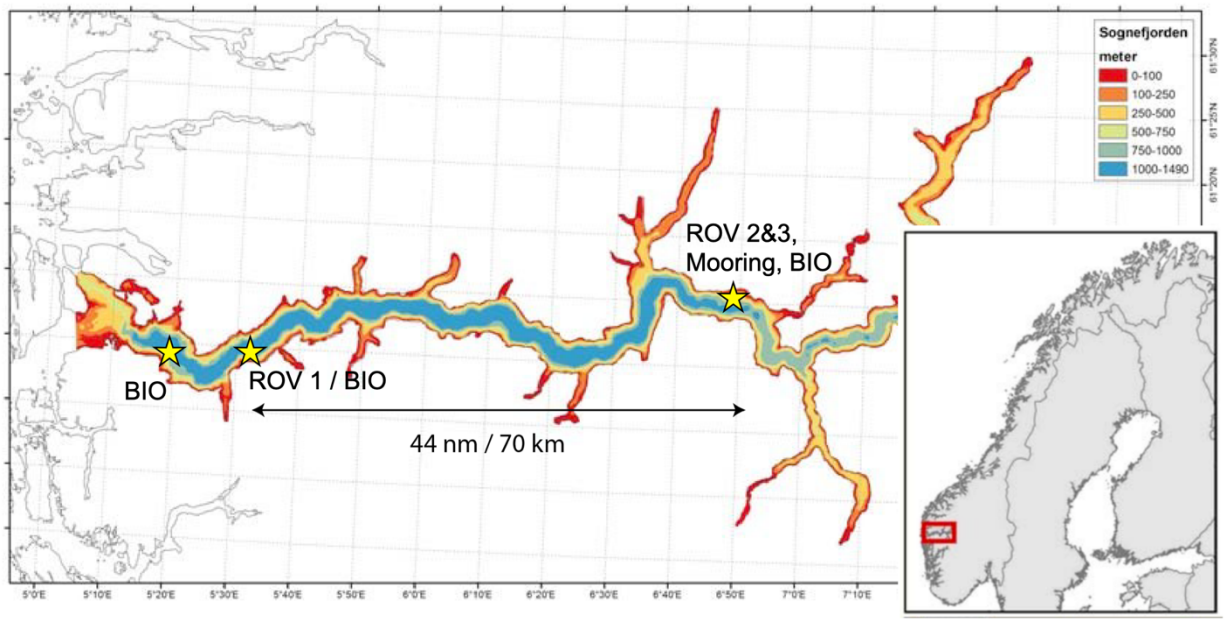

Fig. 3.1 Positions (asterisks) of R/V ALKOR Cruise AL568 stations within the Sognefjord. Compare the station list for details on biological sampling. Modified from Buhl-Mortensen et al, 2020.

4 Narrative of the Cruise

Thursday, 11-11-2021:

After loading and installation of the ROV the day before, the day started with a harbor test of the ROV itself, followed by a successful test of the ROV together with the LIGHTHOUSE system in the afternoon, during which the interplay with the ROV and the correct functioning of all subsystems was verified.

Friday, 12-11-2021:

Although the ship was to sail early in the morning, the unclear medical situation of two persons in light of the COVID pandemic needed to be clarified by a PCR test. Waiting for the test results, the Lighthouse team engaged in additional preparations, enjoying the availability of the quayside laboratory facilities. The vessel finally departed upon negative PCR results around 5.30 pm, with a delay of about 10 hours.

Saturday 13-11-21 - Monday 15-11-21

Despite rough weather, and with strong tail winds, the vessel safely passed Skagerrak on the 13th and arrived in the outskirts of Bergen in beautiful sunny weather on the evening on the 14th, when the weather turned rough with gusts of up to 10 Bft outside the shelter of the fjords. We had planned to first enter Lurefjord for biological sampling, yet its narrow inlet can only be passed during the day and at low tide. This plan was aborted in the morning of the 15th since the weather was too bad to risk entering Lurefjorden. We thus entered Sognefjorden to start with ROV work. The first dive was conducted on the southern slope of the outer fjord, at a small plateau at 900m depth. During the dive, the full functionality of the ROV and the LIGHTHOUSE System at depth was once more verified, and a first, minimal set of test data of the acoustic and optical sensors was gathered in case of unforeseen events during the course of the expedition.

The evening and the night served for CTD casts for vertical profiling and water collection, one Multinet tow (which however due to the low abundance of *Periphylla* did not contain any and therefore was not deployed again) and the collection of *Periphylla* specimens for the planned onboard experiments using repeated vertical hauls with the WP3 net. Since the weather forecast was not promising to allow a passage into Lurefjord, the biological sampling campaign was refocused on Sognefjord altogether. Unfortunately, continuous repeated net hauls only allowed to collect 26 intact specimens with which experiments were conducted, which is about a fifth of the number caught (in better condition, since distributed in the surface layer by night) on HE570 in Lurefjorden in fewer days.

Tuesday 16-11-21:

Following an overnight transit into the easternmost sector of the working area, maintenance on the ROV and LIGHTHOUSE fiberglass data link infrastructure was undertaken to improve on the available system bandwidth. Upon the successful completion of this work, a second ROV dive was conducted to the bottom of the Fjord at 980m depth. The purpose of the dive was primarily the further calibration of acoustic and laser cameras as well as the recording of test data.

The following night program once more served the harvest of jellyfish, but this far into the fjord, none could be acquired.

Wednesday 17-11-21

Shortly after 8 am, an optical and acoustic calibration target in the shape of a tetrahedral frame of 3m corner length was moored 5m above the seafloor in free fall from the ship, at the coordinate of the previous day's dive. Equipped with optical calibration charts (checkerboard, color board, Siemens star), this target serves to calibrate the scaling and geometric correctness of the 3D data acquired by the LIGHTHOUSE system. Following the deployment, a third ROV dive approached the target, calibrating the lasers and the front facing camer systems. After 2h of

complex maneuvers around the target, the ROV traversed to the southern slope of the fjord, largely formed by clean, vertical to subvertical rock face with ubiquitous glacial striations aligned to the valley axis. Most of this ascent was recorded with the LIGHTHOUSE cameras, interrupted by several stops to conduct laser scans of the sessile fauna on the rock face.

Concluding, this third and, due to the generally bad weather, final dive was highly successful, proving that the LIGHTHOUSE system could be operationally used, provided a thorough optimization of the topside control ergonomics. The only component which could not be deployed for technical reasons was the lighting system, yet this had been an optional step in favor of the sensor suite already since the cruise planning stage. Instead, the LIGHTHOUSE system had used the standard ROV lights in a reduced setup, which allowed to power the system through the lighting circuitry but proved enough to cover the frontal sector of the system.

Following the ROV ascent, the mooring was acoustically released and recovered after an ascent of about 1 hour.

Thursday 18-11-21:

The following night and all of Thursday served the sampling of *Periphylla*. Only two specimens had been visible in the ROV cameras in this remote inland locality, and all attempts to catch specimen remained fruitless. Thus, the vessel moved back to the first, western locality over night, where several individuals could be recovered for experiments.

Friday 19-11-21:

Between Friday at 4pm and Saturday at 8am, a final *Periphylla* sampling campaign was done and additional incubations started. Also, because there were still experimental tanks not occupied, we incubated some euphausiids (Meganyctiphanes norvegica) and polychaetes (Tomopteris sp.) using the same sediment concentration gradient as a pilot experiment regarding the impact on other pelagic taxa (which was however not proposed within the iAtlantic project).

Saturday 20-11-21 – Monday 22-11-21:

On Saturday morning we concluded the scientific station work and headed back through the fjords to Stavanger. Catching a southward moving calm weather window at this point, we safely made it back through Skagerrak and the Baltic Sea to Kiel, in time.

Tuesday 23-11-21:

Unloading of the scientific equipment and ROV shortly after 9 am concluded the cruise.

5 Preliminary Results

The HVF program is based on the idea first to validate a concept and then to monetize it with external industrial partners. This means that not only there is a requirement on extra tight control and protection of the intellectual property involved and developed, but also, in case of commercial success, an interest much in excess of the original funds received is due as revenue to the HVF. Consequently, since the assessment of innovation and the claiming of patents has not yet been finalized, we were legally advised not provide details on the system, the arrangement of its external components, nor photographs. We thus regret that extensive details cannot be part of this report. We expect such details to be publicly available by the end of 2022.

Altogether, we were able to verify the principal functioning of the system as intended, particularly with respect to the interaction with the ROV and the working of the central telemetry components. We were able to fine tune the navigation system and to link it with all sensors,

referencing their data. We recorded 3D acoustic scans of the seafloor and distal rock walls during descent and ascent. With the help of our external supplier Krakenrobotik, represented by Dr. Jan Albiez, we initiated a cluster of laser scanners, calibrated them, and recorded test data. Finally, we utilized our cluster of deep sea cameras, including a novel survey camera development together with Zeiss Industrieoptiken. First photogrammetrical reconstructions prove the accuracy and superiority of this optical system over previous industrial and own camera designs. Lastly, we could demonstrate that Sognefjord may prove a highly accessible, productive deep water test environment for ROV based technologies even if deployed from a comparatively small vessel like ALKOR.

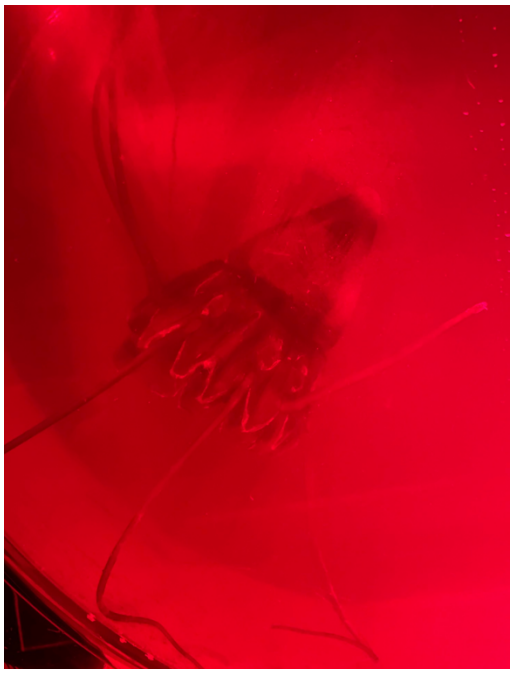

Fig. 5.1 *Periphylla* with visible mucus strings in response to sediment load.

The concentration of suspended sediment surrounding mining sites will be dependent on particle size, duration of the mining operation and dispersal by oceanic currents (Christiansen et al., 2020; Drazen et al., 2020). Therefore, a range of concentrations was therefore chosen to represent sediment suspensions in proximity of the mining site and in diluted state. The sediment treatments consisted of four concentrations and one control (0, 16.7, 33.3, 166.7, 333.3 $mg \cdot L^{-1}$), which were randomly assigned to kreisel tanks containing *P. periphylla*. abyssal plain sediment was obtained at 4427 m in the North Atlantic (47.250°N 10.105°W) onboard the *RV Sonne* during 4 December 2020– 5 January 2021 (SO279). Particle size ranged between 0.5–120 µm. Sediment plume incubations lasted 24 hours and the physical condition of *P. periphylla*, water temperature and sediment turbidity (Turb® 340 IR) were monitored throughout the incubations. Our first *Periphyll*a results are in line with previous data from HE570 and complement that dataset. While turbidity decreased over time, nominal suspended particle load showed a visible negative effect on P. periphylla at concentrations >33.3 mg·L-1. Particles started aggregating on bell and lappets after ~1.5 hours, which in response started producing excess mucus that slowly sloughed off. These Effects persisted throughout the entire incubation period. In the home lab, ETS activity was analyzed with the Iodonitrotetrazolium reduction assay according to Bode et al.

(2013), who followed protocols from Packard (1971) and Owens and King (1975) with slight modifications, and revealed increased respiratory activity at concentrations >166.7 mg L^{-1}. Extraction of samples for gene expression (transcriptome) has been completed, but sequencing is still pending. Vanessa Stenvers presented the results at the Ocean Science Meeting 2022.

6 Station List AL568

6.1 Overall Station List

Station No.		Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/ Recovery
AL568	GEOMAR	2021		[UTC]	[°N]	[°W]	[m]	
1-1	1	15.11.	CTD	12:30	61°05,277'	005°33,884'	1612	n.a.
1-2	2	15.11.	Multi Max	13:42	61°05,115'	005°33,417'	1249	n.a.
1-3	3	15.11.	CTD	14:45	61°05,110'	005°33,241'	1247	n.a.
1-4	4	15.11.	CTD	15:27	61°05,079'	005°33,259'	1613	n.a.
1-5	5	15.11.	Plankton Net WP3	15:56	61°05,076'	005°33,244'	1629	n.a.
1-6	6	15.11.	Plankton Net WP3	16:30	61°05,114'	005°33,161'	1560	n.a.
1-7	7	15.11.	Plankton Net WP3	17:00	61°05,127'	005°33,166'	1715	n.a.
1-8	8	15.11.	Plankton Net WP3	17:23	61°05,138'	005°33,122'	1205	n.a.
1-9	9	15.11.	Plankton Net WP3	17:46	61°05,136'	005°33,130'	1249	n.a.
1-10	10	15.11.	Plankton Net WP3	18:09	61°05,152'	005°33,113'	1251	n.a.
1-11	11	15.11.	Plankton Net WP3	18:37	61°05,163'	005°33,088'	1250	n.a.
1-12	12	15.11.	Plankton Net WP3	19:00	61°05,181'	005°33,113'	1690	n.a.
1-13	13	15.11.	Plankton Net WP3	19:25	61°05,188'	005°33,126'	1723	n.a.
1-14	14	15.11.	Plankton Net WP3	19:48	61°05,156'	005°33,145'	1732	n.a.
1-15	15	15.11.	Plankton Net WP3	20:12	61°05,142'	005°33,166'	1242	n.a.
1-16	16	15.11.	Plankton Net WP3	20:36	61°05,134'	005°33,160'	1574	n.a.
1-17	17	15.11.	Plankton Net WP3	20:58	61°05,140'	005°33,167'	1521	n.a.
1-18	18	15.11.	Plankton Net WP3	21:20	61°05,142'	005°33,178'	1453	n.a.
1-19	19	15.11.	Plankton Net WP3	21:41	61°05,128'	005°33,198'	1690	n.a.
1-20	20	15.11.	Plankton Net WP3	22:04	61°05,121'	005°33,244'	1558	n.a.
1-21	21	15.11.	Plankton Net WP3	22:27	61°05,129'	005°33,276'	1249	n.a.
2-1	22	16.11.	PHOCA	12:56	61°06,673'	005°39,384'	547	n.a.
3-1	23	16.11.	CTD	16:48	61°06,896'	005°39,991'	901	n.a.
3-2	24	16.11.	Plankton Net WP3	17:08	61°06,906'	005°39,812'	837	n.a.
3-3	25	16.11.	Plankton Net WP3	17:57	61°06,521'	005°42,593'	1229	n.a.
3-4	26	16.11.	Plankton Net WP3	18:29	61°06,408'	005°42,262'	1151	n.a.
3-5	27	16.11.	Plankton Net WP3	20:02	61°07,782'	006°03,667'	1252	n.a.
3-6	28	16.11.	Plankton Net WP3	20:28	61°07,693'	006°03,760'	1252	n.a.
3-7	29	16.11.	Plankton Net WP3	20:56	61°07,591'	006°03,853'	1252	n.a.
3-8	30	16.11.	Plankton Net WP3	21:08	61°07,534'	006°03,875'	1252	n.a.
3-9	31	16.11.	Plankton Net WP3	21:20	61°07,461'	006°03,903'	1252	n.a.
4-1	32	17.11.	Plankton Net WP3	07:58	61°09,393'	006°47,431'	985	n.a.
4-2	33	17.11.	Plankton Net WP3	08:43	61°09,390'	006°47,336'	986	n.a.
5-1	34	17.11.	PHOCA	11:40	61°09,370'	006°47,483'	984	n.a.

6-2	35	18.11.	PHOCA	07:59	61°09,339'	006°47,898'	980	n.a.
7-1	36	18.11.	Plankton Net WP3	23:14	61°05,336'	005°34,203'	1252	n.a.
7-2	37	18.11.	Plankton Net WP3	23:26	61°05,291'	005°34,207'	1252	n.a.
7-3	38	18.11.	Plankton Net WP3	23:59	61°05,232'	005°34,103'	1250	n.a.
7-4	39	19.11.	Plankton Net WP3	00:39	61°05,177'	005°33,800'	1250	n.a.
7-5	40	19.11.	Plankton Net WP3	01:19	61°05,223'	005°33,745'	1249	n.a.
7-6	41	19.11.	Plankton Net WP3	01:59	61°05,296'	005°33,907'	1249	n.a.
7-7	42	19.11.	Plankton Net WP3	02:41	61°05,287'	005°34,029'	1249	n.a.
7-8	43	19.11.	Plankton Net WP3	03:21	61°05,270'	005°34,214'	1250	n.a.
7-9	44	19.11.	Plankton Net WP3	04:04	61°05,241'	005°34,432'	1251	n.a.
7-10	45	19.11.	Plankton Net WP3	04:44	61°05,213'	005°34,619'	1252	n.a.
7-11	46	19.11.	Plankton Net WP3	05:32	61°05,189'	005°34,603'	1251	n.a.
7-12	47	19.11.	Plankton Net WP3	06:12	61°05,169'	005°34,636'	1251	n.a.
8-1	48	19.11.	CTD	14:53	61°05,290'	005°34,663'	1251	n.a.
8-2	49	19.11.	CTD	15:20	61°05,335'	005°34,655'	1249	n.a.
8-3	50	19.11.	CTD	15:45	61°05,397'	005°34,693'	1252	n.a.
8-4	51	19.11.	Plankton Net WP3	16:32	61°05,393'	005°34,695'	1251	n.a.
8-5	52	19.11.	Plankton Net WP3	16:43	61°05,372'	005°34,667'	1250	n.a.
8-6	53	19.11.	Plankton Net WP3	17:05	61°05,351'	005°34,621'	1250	n.a.
8-7	54	19.11.	Plankton Net WP3	17:39	61°05,318'	005°34,484'	1250	n.a.
8-8	55	19.11.	Plankton Net WP3	18:23	61°05,279'	005°34,361'	1250	n.a.
8-9	56	19.11.	Plankton Net WP3	19:03	61°05,280'	005°34,311'	1251	n.a.
8-10	57	19.11.	Plankton Net WP3	19:43	61°05,275'	005°34,262'	1251	n.a.
8-11	58	19.11.	Plankton Net WP3	20:27	61°05,320'	005°34,169'	1250	n.a.
8-12	59	19.11.	Plankton Net WP3	21:10	61°05,262'	005°34,090'	1250	n.a.
8-13	60	19.11.	Plankton Net WP3	21:50	61°05,256'	005°34,045'	1253	n.a.
8-14	61	19.11.	Plankton Net WP3	22:31	61°05,225'	005°34,011'	1252	n.a.
8-15	62	19.11.	Plankton Net WP3	23:15	61°05,229'	005°34,076'	1250	n.a.
8-16	63	19.11.	Plankton Net WP3	23:53	61°05,214'	005°34,189'	1250	n.a.
8-17	64	20.11.	Plankton Net WP3	00:47	61°05,316'	005°34,210'	1250	n.a.
9-1	65	20.11.	Plankton Net WP3	02:16	61°02,485'	005°25,180'	1241	n.a.
9-2	66	20.11.	Plankton Net WP3	03:01	61°02,514'	005°25,622'	1242	n.a.
9-3	67	20.11.	Plankton Net WP3	03:54	61°02,412'	005°24,534'	1236	n.a.
9-4	68	20.11.	Plankton Net WP3	04:35	61°02,400'	005°24,651'	1238	n.a.
9-5	69	20.11.	Plankton Net WP3	05:14	61°02,381'	005°24,689'	1238	n.a.
9-6	70	20.11.	Plankton Net WP3	06:02	61°02,483'	005°24,585'	1240	n.a.

7 Data and Sample Storage and Availability

Lighthouse test data was merely collected to validate the functioning of the equipment, and for calibration of sensor orientation. There is no scientific value in the data gathered, and no curated release of this data is planned. It should also be noted that the absolute georeferencing was unavailable due to a fault in the processing chain of the navigational sensors.

Data generated from the iAtlantic project (*Periphylla*) will be publicly available (PANGAEA, GenBank) upon publication of the manuscript.

Table 7.1 Overview of data availability

Type	Database	Available	Free Access	Contact
3D acoustic imagery	Local	Dec. 22	Dec. 22	tkwasnitschka@geomar.de
3D laser scans	Local	Dec. 22	Dec. 22	tkwasnitschka@geomar.de
Seafloor imagery and video	Local	Dec. 22	Dec. 22	tkwasnitschka@geomar.de

8 Acknowledgements

The project was funded through the HVF68 LIGHTHOUSE project, granted through the Helmholtz Validation Fund of the Helmholtz Association. *Periphylla* work was funded through EU H2020 project iAtlantic (grant agreement 818123). H. Hauss was funded through the BMBF-funded project CO_2MESO.
The scientific party would like to express their sincere appreciation of the excellent and hard work of the ROV engineers as well as the vessels crew and officers, making this short, focused expedition, at a challenging time of the year, a success.

9 References

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10 Abbreviations

ROV – Remotely Operated Vehicle

11 Appendices

11.1 Selected Pictures of Shipboard Operations

Fig. 11.1 ROV PHOCA with the LIGHTHOUSE modifications during the deployment.