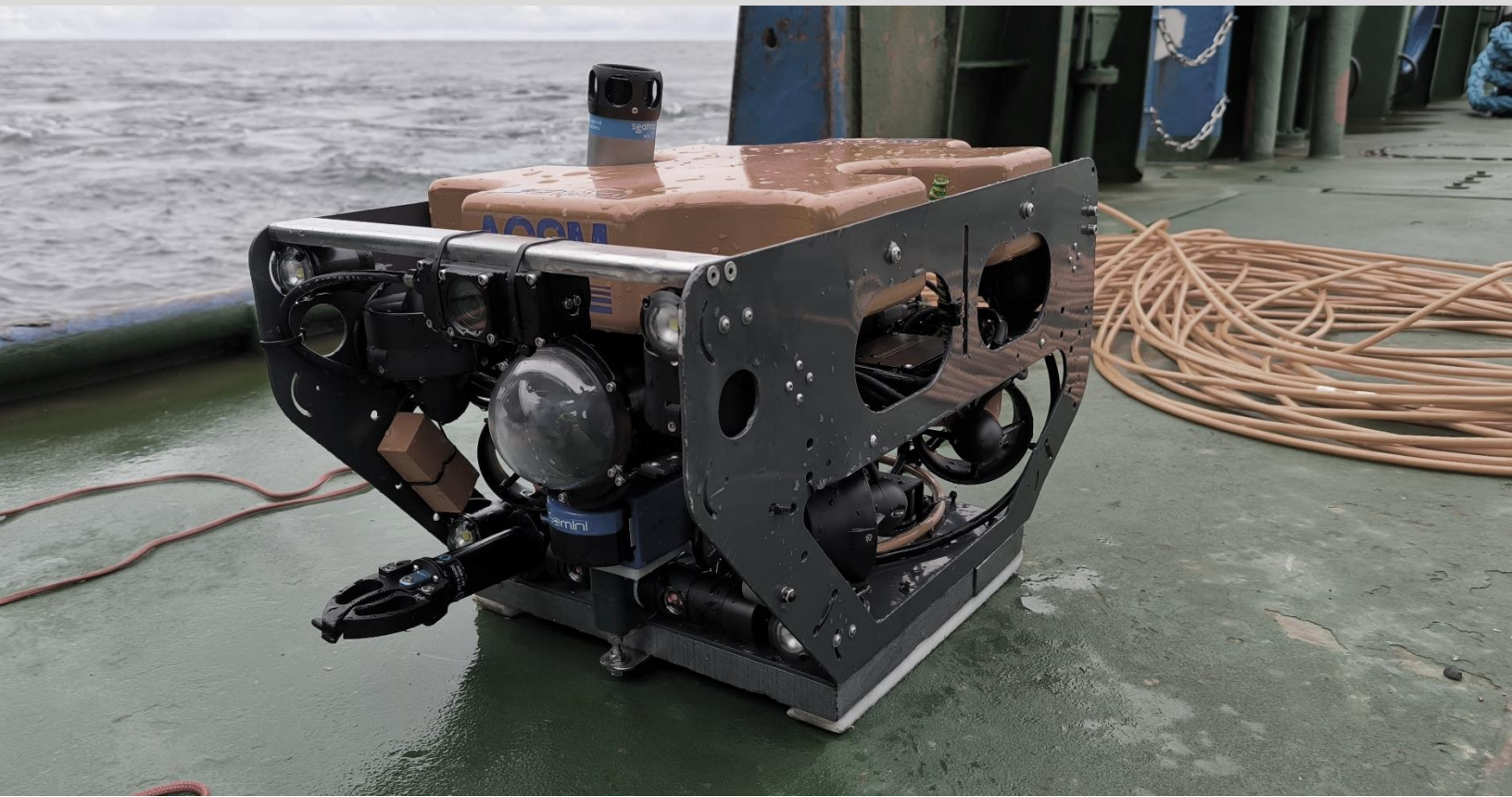




ROV VIDEO SURVEY OF THE SELECTED SONAR TARGETS ON THE SINKING TRACK OF MV ESTONIA ON THE BALTIC SEA JULY 1 TO JULY 4, 2024

PRELIMINARY ASSESSMENT
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Abbreviations

AIS	Automatic Identification System
DP	Dynamic Positioning
EMSA	European Maritime Safety Agency
ESIB	Estonian Safety Investigation Bureau <i>Ohutusjuurdluse Keskus</i>
HSVA	Hamburg Ship Model Basin <i>Hamburgische Schiffbau Versuchsanstalt</i>
JAIC	Joint Accident Investigation Commission of Estonia, Finland and Sweden
MAS	Multi Aperture Sonar
MV	Motor Vessel
ROV	Remotely Operated Vehicle
USBL	Ultra-Short Baseline



1. Introduction and Scope of Work

1.1. Safety Investigation Authority

The Estonian Safety Investigation Bureau (ESIB) is a structural unit of the Ministry of Economic Affairs and Communications of the Republic of Estonia. One of the main tasks of ESIB is to conduct safety investigations of very serious marine casualties; of serious marine casualties based on the decision of a preliminary assessment, and in the case of justified interest, any marine casualties or marine incidents.

The purpose of a safety investigation is to identify the circumstances, causes and consequences of a marine casualty or marine incident, and if necessary, to provide recommendations in order to prevent such marine casualty or marine incident in the future, and to improve maritime safety, but not to blame any party or assign liability.

A safety investigation is carried out in accordance with the legislation of the Republic of Estonia, the European Union, and the International Maritime Organization, as well as relevant international agreements.

1.2. MV Estonia Accident

The passenger ferry Estonia sank on September 28, 1994, during a voyage from Tallinn, Estonia, to Stockholm, Sweden. Of the 989 people on board, only 137 survived. The final report of the Joint Accident Investigation Commission of Estonia, Finland and Sweden (JAIC) was published in December 1997.

On September 28, 2020, a video recording was published, showing penetrating damage on the starboard side of the hull of MV Estonia. Based on this new evidence, ESIB initiated a preliminary assessment of the new information of the MV Estonia accident on October 2, 2020, along with its counterparts in Finland and Sweden.

The objective of the preliminary assessment is to identify the cause of penetrating deformations, to assess the validity of the conclusions presented in the final report of the JAIC and to assess whether the safety investigation of the accident should be re-opened.

1.3. Background

ESIB has considered it essential to conduct numerical simulations and analysis of the sinking scenarios of MV Estonia in the framework of the preliminary assessment to assess the possibility of various theoretical and/or hypothetical sinking scenarios of MV Estonia. The basis for assessing the probability and possibility of sinking scenarios is in a direct relationship with different evidence and factors, including the geographical area where the accident took place (i.e., the vessel's supposed track during the sinking).

To gain a better understanding of the flooded vessel's track during the accident and to document the seabed around the wreck in detail, ESIB launched a public procurement to conduct a high-resolution seabed imaging survey on the proposed sinking tracks of the vessel. This survey was conducted by the company Reach Subsea AS and was carried out in November 2023. As a result, about 300 presumably man-made objects were detected and located by the seabed imaging sonar survey in the vicinity of the hypothetical tracks of MV Estonia before its sinking.



A sonar image is typically a matter of interpretation – from the duotone image it is possible to see the size and shape of an object, but not its colour, material, or minor detail. Also, the object is typically imaged from fixed angles only and its shape and appearance from different points of view remain unknown. After analysing the results of the sonar survey, ESIB, together with its counterparts in Finland and Sweden, saw a need for an additional follow-up survey to identify some of the interpreted objects, verify whether these originate on MV Estonia and, if possible, from which part of the vessel. This identification would be carried out by observing and filming some of the objects with an underwater camera installed on a remotely operated vehicle (ROV).

As such, this survey was not planned and included in the additional funding application of autumn 2023 to the Estonian Government to continue and complete the preliminary assessment during 2024 and 2025. Nevertheless, it was possible to conduct the additional follow-up marine survey thanks to a cost-effective co-operation between ESIB, the Estonian State Fleet (*Riigilaevastik*), and the European Maritime Safety Agency (EMSA).

Estonian State Fleet multipurpose icebreaker EVA-316 was requested to use as a survey platform. This vessel was also used during the first marine surveys at the wreck site in July 2021. An ROV with competent personnel was requested from EMSA through its ROV service, which has been launched to support the Accident Investigation Bodies of EMSA Member States and other interested maritime stakeholders.

1.4. Scope of Work

Deliverables provided by Reach Subsea AS as a result of the high-resolution seabed imaging survey were used for planning and executing the ROV video survey. As it was not reasonable nor possible to visually check all the targets (altogether approximately 300 objects), a selection was made. Two sets of high-interest targets were compiled based on the available vessel and ROV time, considering conservative estimates of time necessary for each ROV dive.

The actual operational sequence and target priority were decided onboard the survey vessel considering available time (upcoming inclement weather conditions) and the results of prior dives.



2. Survey Equipment

2.1. Vessel

Estonian State Fleet multipurpose icebreaker EVA-316 (**Figure 1**) was requested to use as a survey platform. The vessel specifications are summarized in **Table 1**. An USBL beacon pole was installed to the vessel for positioning system of the ROV. Temporary survey room was set up in the vessel's workshop on main deck.



Figure 1. Multipurpose icebreaker EVA-316 in Pärnu harbour. Source: Tauri Roosipuu.

Table 1. Specifications of the survey vessel.

Specification	Value
IMO number	7917977
Flag	Estonia
Port of Registry	Tallinn
Year of Built/Rebuilt	1980/2006
Length overall	59,90 m
Breadth	12,20 m
Draught	3,80 m
Depth	5,00 m
Gross Tonnage	909
Deadweight	276 t
Ice Class	1A
Main Engines	Caterpillar, 3 × 1600 kW
Service Speed	11,5 knots
Special equipment	Crane, towing winch, firefighting and pollution control



2.2. ROV

ACSM Shipping CO SLU observation class LANAI Pro ROV, manufactured by Poseidon Robotics, was used for the video survey (**Figure 2**). The ROV specifications are summarized in (**Table 2**).

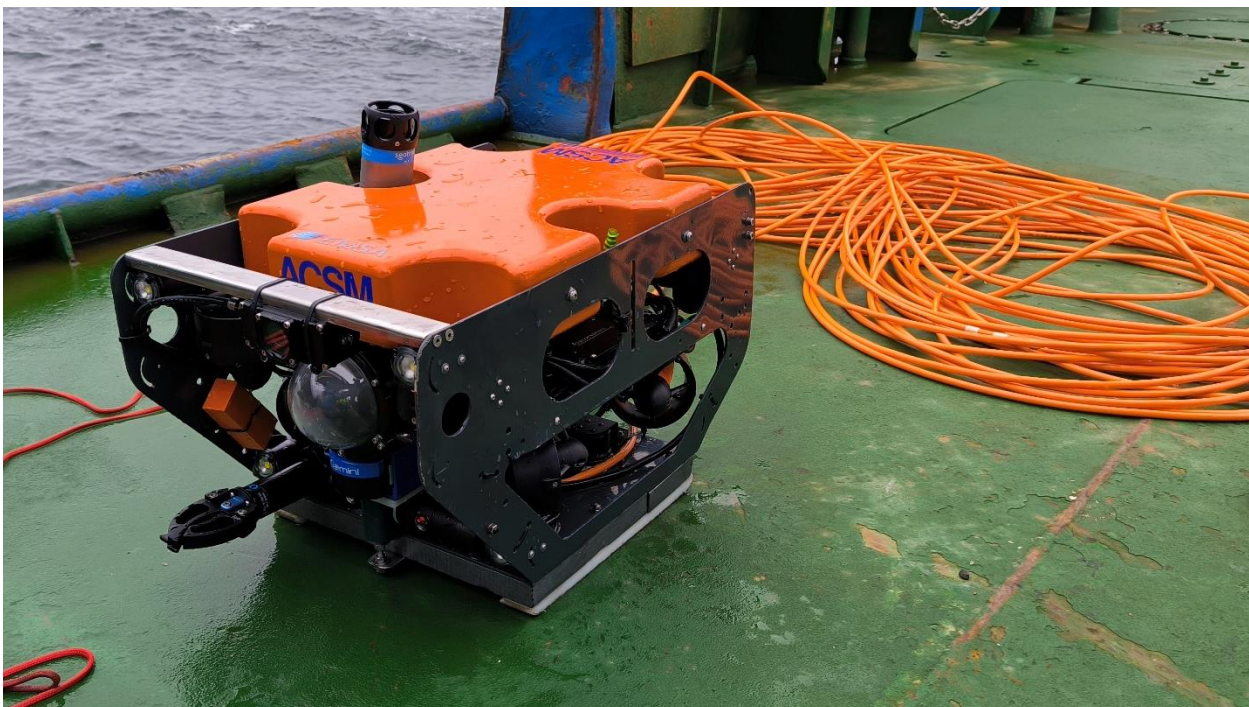


Figure 2. Observation class ROV LANAI Pro with tether on deck.

Table 2. Specifications of the survey ROV.

Specification	Value
Depth rating	400 m
Dimensions	559 × 356 × 305 mm (LWH)
Weight in air	14.7 kg
Payload capacity (fresh water)	2.5 kg
Thrusters	4 lateral (35 degrees), 4 vertical
Lights	6 × 1500 Lumens each
Tether:	Breaking strength 250 kg, Diameter 9.1 mm (neutral saltwater)
Camera	1080 HD IP camera with zoom and ± 180 degrees tilt
Additional equipment	Newton manipulator arm, scanning sonar, depth sensor, altimeter, laser, USBL positioning system



3. Operation

3.1. Execution

The mobilization of the ROV equipment and crew was conducted on Sunday, June 30, 2024. The wet test of the ROV was conducted on the same day. The departure of the survey vessel was postponed due to unfavourable weather conditions.

The survey vessel EVA-316 departed from the Estonian harbour Hundipea on Monday, July 1, 2024, at 23:10 and arrived at the wreck site of MV Estonia at 09:00 the following morning. The survey took place from 10:00 to 22:00 on Tuesday and from 06:30 to 18:30 on Wednesday. EVA-316 returned to Hundipea harbour on Thursday, 4 July at 03:45.

Altogether 17 dives were made with the ROV – seven on the first and ten on the second survey day (Figure 3 and Table 3). The survey started from the west and continued eastwards to the wreck. If the westward targets were mostly isolated – meaning one dive for one object – then the eastward dives covered also the main debris field southwest of the wreck where tens of objects could be seen during one dive.

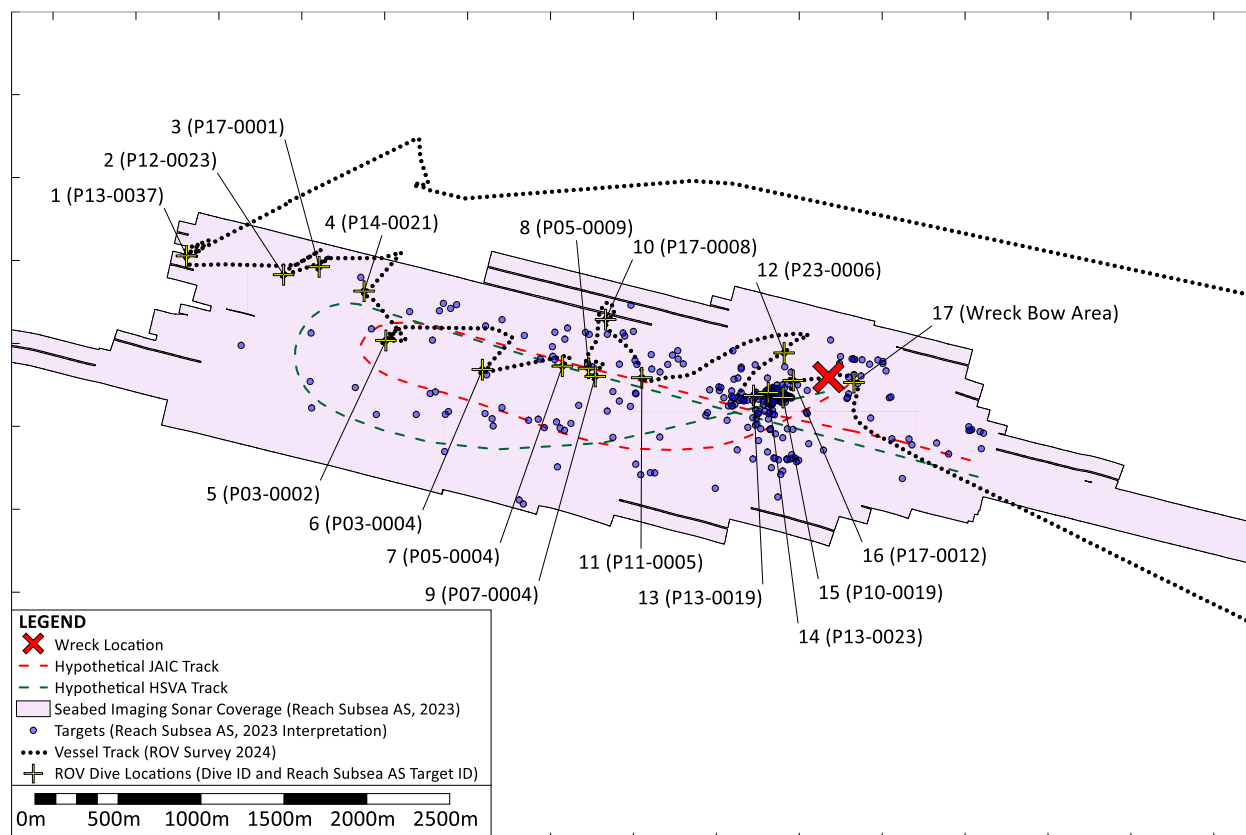


Figure 3. Sequence of the selected and inspected targets



Table 3. Dive locations

DIVE No	Date	Start Time (EET)	End Time (EET)	Reach Subsea AS Target ID	L (m)	W (m)	H (m)	Shadow (m)	Reach Subsea AS Target description	Descriptive summary of inspected objects (ROV)
1	02.07.2024	10:54	12:12	P13-0037	3.24	0.41	0.05	0.52	Elongated, part of cluster	Wood log, brown colour and few boulders
2	02.07.2024	12:50	13:22	P12-0023	2.61	0.33	0.15	0.40	Elongated, several similar in the area, isolated	Wood log, light colour, few isolated boulders and a boulder field
3	02.07.2024	14:42	15:20	P17-0001	2.53	0.51	0.11	0.71	Elongated, strong reflectivity, isolated	<u>Wood log, light colour</u>
4	02.07.2024	16:00	17:37	P14-0021	0.86	0.63	0.13	0.85	Possible debris	Large rectangular boulder and isolated boulder
5	02.07.2024	18:30	18:52	P03-0002	2.07	0.79	0.73	2.68	Irregular shadow, in till area	Large rectangular boulder and boulder field
6	02.07.2024	19:20	20:00	P03-0004	2.09	0.90	0.33	2.69	Rectangular shape, possible thin part sticking up	Rotatable part of the starboard side ramp railing
				P01-0002	3.37	0.27	0.14	0.68	Elongated, irregular shape, part of cluster	Possible metallic wire
7	02.07.2024	20:10	21:45	P05-0004	16.47	17.78	NMH	NMS	Sediment depressions from bow visor, picture 60x60m	Sediment depression from bow visor, one thin elongated object
8	03.07.2024	06:45	07:30	P09-0009	3.24	0.35	0.16	0.52	Elongated, several similar in the area, isolated	Wood log, brown colour
				P05-0009	1.37	1.04	0.15	1.19	Irregular shape	Several boulders
9	03.07.2024	07:52	08:58	P07-0004	5.42	0.31	0.32	1.42	Possible debris or scar	No object found, only metallic bowl
10	03.07.2024	09:28	10:13	P17-0008	2.58	0.92	0.05	0.47	Rectangular shape, possible life vest box	Life-saving appliance box
11	03.07.2024	10:32	11:02	P11-0005	3.57	0.30	NMH	NMS	Elongated, several similar in the area, isolated	Wood log, light colour, thick
12	03.07.2024	11:33	12:05	P23-0006	3.23	0.21	0.18	0.52	U shape, part of cluster	Panel, bent and twisted, two isolated boulders
13	03.07.2024	12:20	13:20	P13-0019*	4.29	0.41	1.95	22.4	Elongated, smaller and high object by the side, pronounced shadow, several similar in the area	Metallic beam with a capsule, several other objects
14	03.07.2024	13:39	15:07	P13-0023*	5.00	3.07	0.79	3.00	Thin construction with sharp edges, distinct shadow, possible metallic, associated with P13-0025	Main debris field SW of the wreck, many objects
15	03.07.2024	15:24	16:23	P10-0019*	0.91	0.69	0.16	0.97	Part of cluster	Main debris field SW of the wreck, many objects
16	03.07.2024	16:37	17:23	P17-0012*	2.59	0.35	0.09	0.21	Thin elongated, possible wire or rope, in till area	Boulder field area, several objects
17	03.07.2024	17:57	18:40	N/A - Wreck Bow Area	N/A	N/A	N/A	N/A	N/A	Starboard side of the forward bulkhead, area to the starboard side anchor, visor and ramp control station

* For the dives 13-16 only the initially selected target for vessel positioning is included in the table as these targets are located in highly clustered debris field



During the last dive, the area of the wreck previously masked by the ship's bow ramp, which was recovered from the seabed in July 2023, was filmed. The ramp recovery operation was completed by also filming this area, but video quality from this filming is poor due to the dredging works conducted (which resulted in suspended sediment) prior to the lifting. Also, the work-class ROV's camera was less capable. Therefore, it was decided to film this area again.

3.2. Personnel

In addition to the 10 crew members of the survey vessel, 4 persons were on-board to execute the survey:

- 1) ESIB Investigator – acting as an Offshore Manager of the survey and as a Coordinator of Requesting Authority (ESIB) for EMSA;
- 2) EMSA Project Officer – acting as an EMSA Service Manager (coordination between Requesting Authority (ESIB) and the Contractor (ACSM Shipping CO SLU) for EMSA);
- 3) ACSM Shipping CO SLU ROV Supervisor – acting as a Contractor for EMSA;
- 4) ACSM Shipping CO SLU ROV Senior Technician – acting as Contractor for EMSA.

3.3. Limitations

Due to prior drydocking, the survey vessel EVA-316 was made available for the operation from June 29 to July 7 following the collective leave of the vessel's crew. As the vessel's Dynamic Positioning (DP) capability is limited, weather also restricted the available time for operations (Figure 4). The survey was conducted during daytime only, as 12h operations, as there was only one shift of survey personnel available.

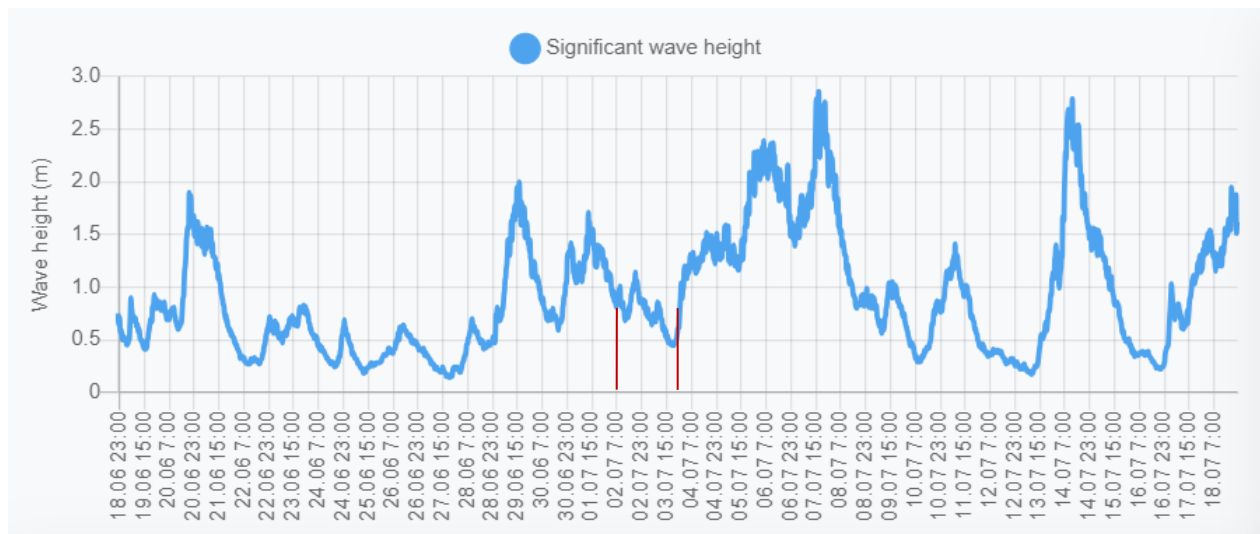


Figure 4. Significant wave heights on the Central Baltic Sea. Source: [Lainepeiss](#), 15 - BP Hiiumaa, LAT 59° 3'34.69" N, LON 21° 8'15.3" E. Actual period of survey is indicated by red lines.

Underwater visibility was considered mostly satisfactory. On some occasions visibility was reduced due to halocline. As the filming was conducted close to the seabed, sediment suspended during operations caused deteriorated visibility.

Erratic function of the ROV's USBL positioning system required additional time for locating the selected targets. An overboard vertical line with weight and buckets (for creating a reflection on ROV's sonar) was



used as an *ad hoc* solution to direct the ROV to the desired position on seabed. Although the joystick of the ROV's hand control failed during the operation, it could be replaced by a back-up hand control unit to continue the survey.



4. Results

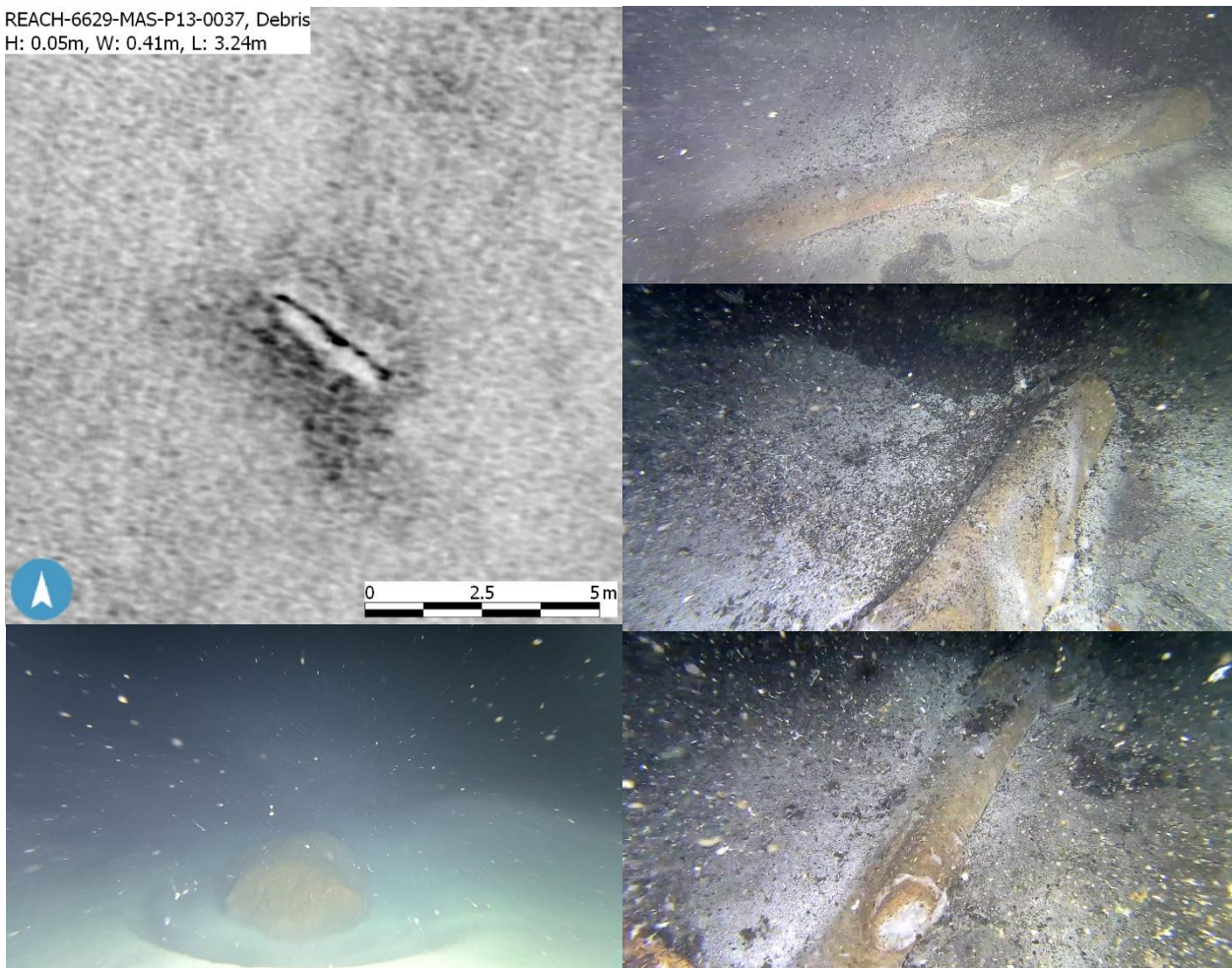
4.1. Overview of the Dives

Sonar images and video snapshots of the seabed and observed objects for each dive are presented in the following subchapters.

4.1.1. Dive 1

Some smaller boulders and one larger isolated boulder were in the area. Selected target turned out to be a brown colour wood log with remains of branches.

REACH-6629-MAS-P13-0037, Debris
H: 0.05m, W: 0.41m, L: 3.24m

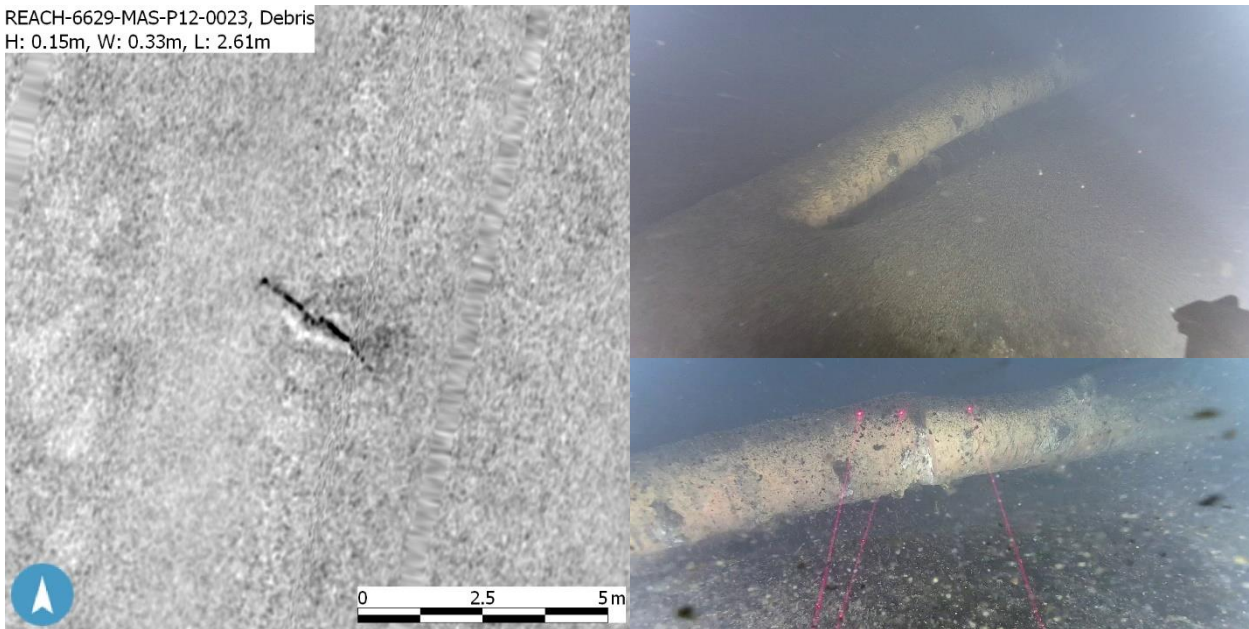




4.1.2. Dive 2

Some isolated boulders and a boulder field were visible in the area. Selected target turned out to be a light colour wood log with remains of branches.

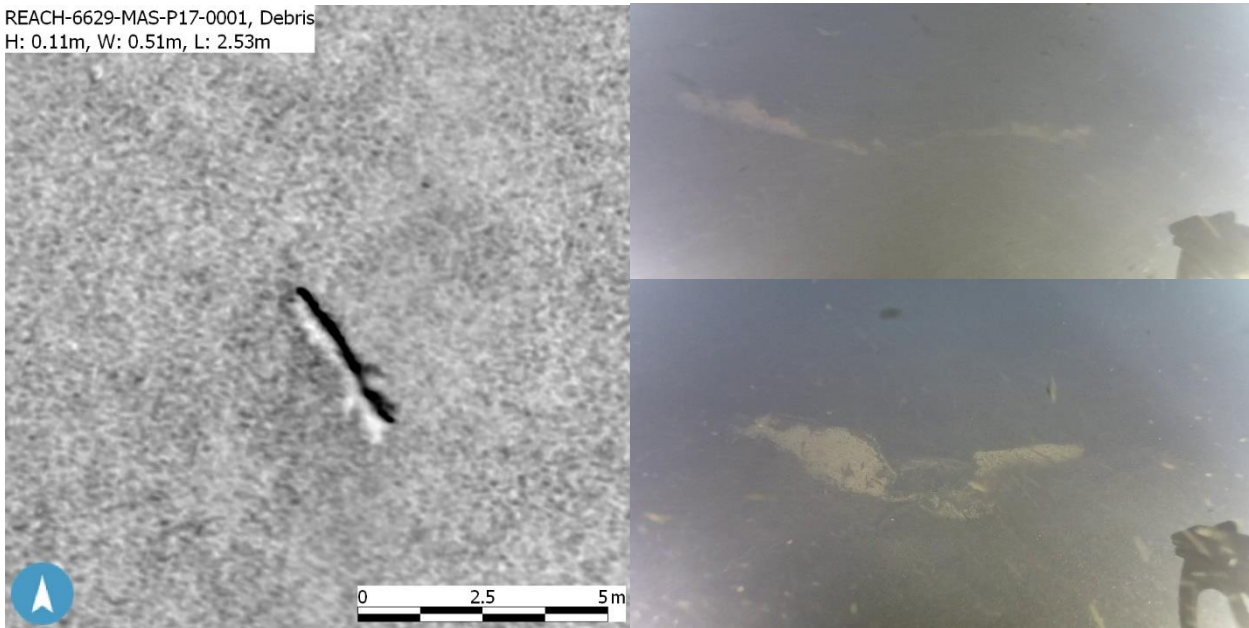
REACH-6629-MAS-P12-0023, Debris
H: 0.15m, W: 0.33m, L: 2.61m



4.1.3. Dive 3

Selected target turned out to be a light colour wood log with remains of branches. A lot of suspended sediment.

REACH-6629-MAS-P17-0001, Debris
H: 0.11m, W: 0.51m, L: 2.53m

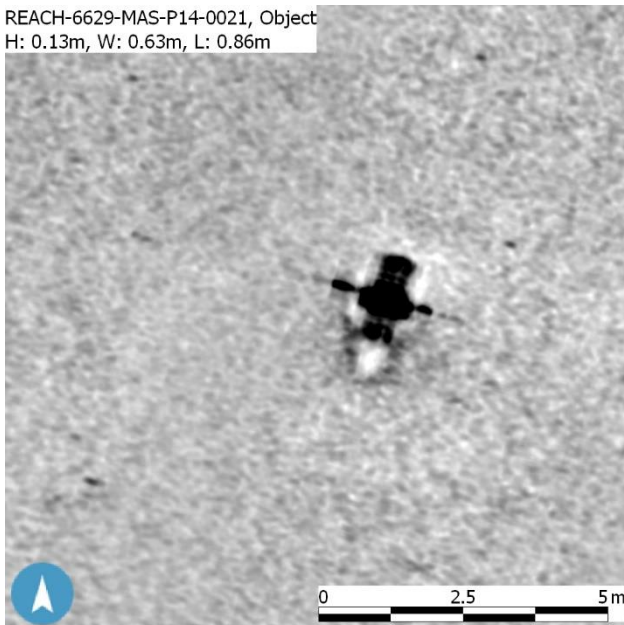




4.1.4. Dive 4

Selected target turned out to be a rectangular boulder, one isolated larger boulder was also visible.

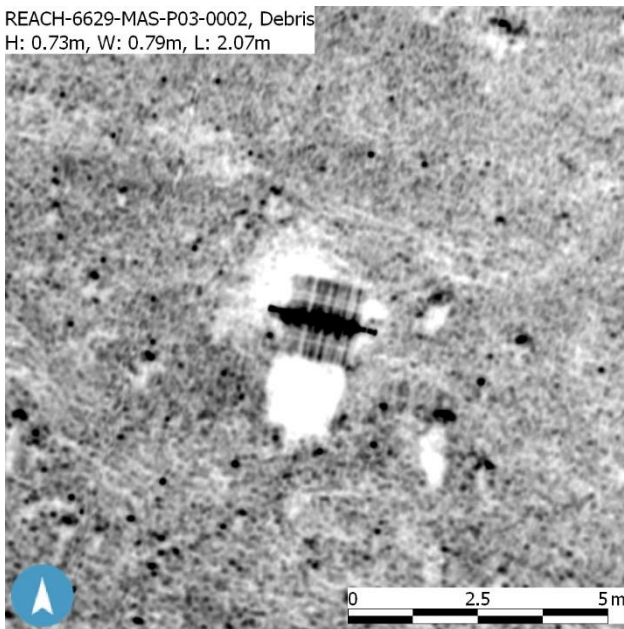
REACH-6629-MAS-P14-0021, Object
H: 0.13m, W: 0.63m, L: 0.86m



4.1.5. Dive 5

Selected target turned out to be a rectangular boulder, boulder field was also visible in the vicinity.

REACH-6629-MAS-P03-0002, Debris
H: 0.73m, W: 0.79m, L: 2.07m

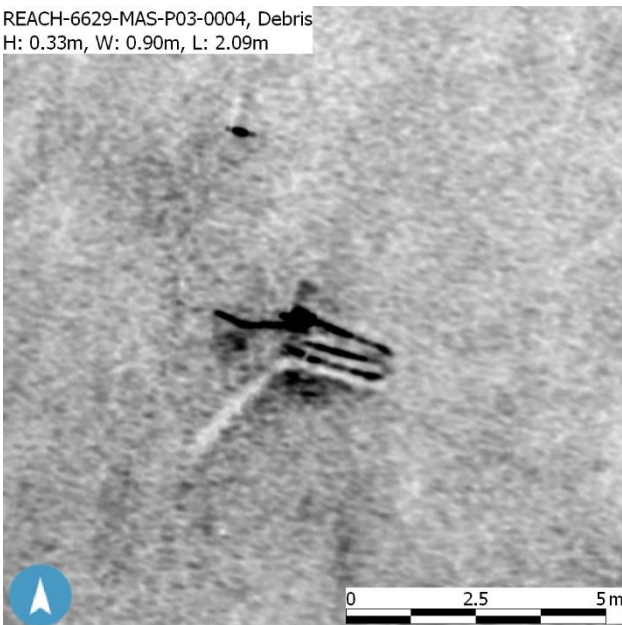




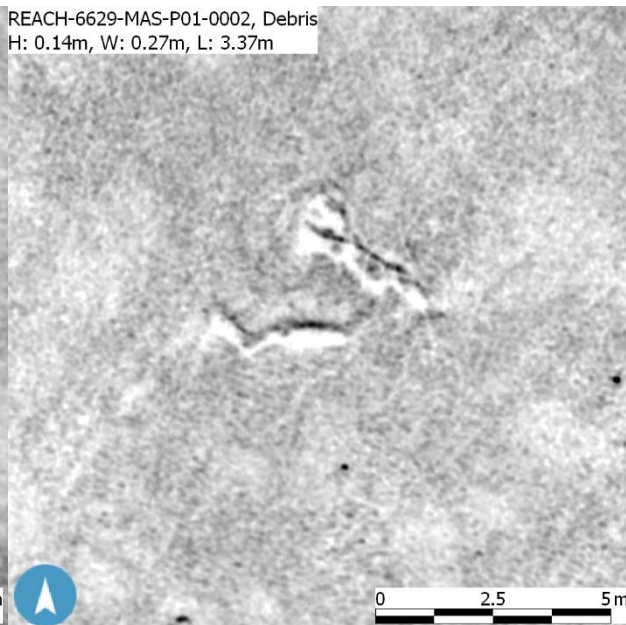
4.1.6. Dive 6

Selected target (P03-0004) turned out to be rotatable part of the starboard side ramp railing and second object (P01-0002) in vicinity possible metallic wire. The railing was recovered (the only object recovered from the seabed during the survey).

REACH-6629-MAS-P03-0004, Debris
H: 0.33m, W: 0.90m, L: 2.09m



REACH-6629-MAS-P01-0002, Debris
H: 0.14m, W: 0.27m, L: 3.37m

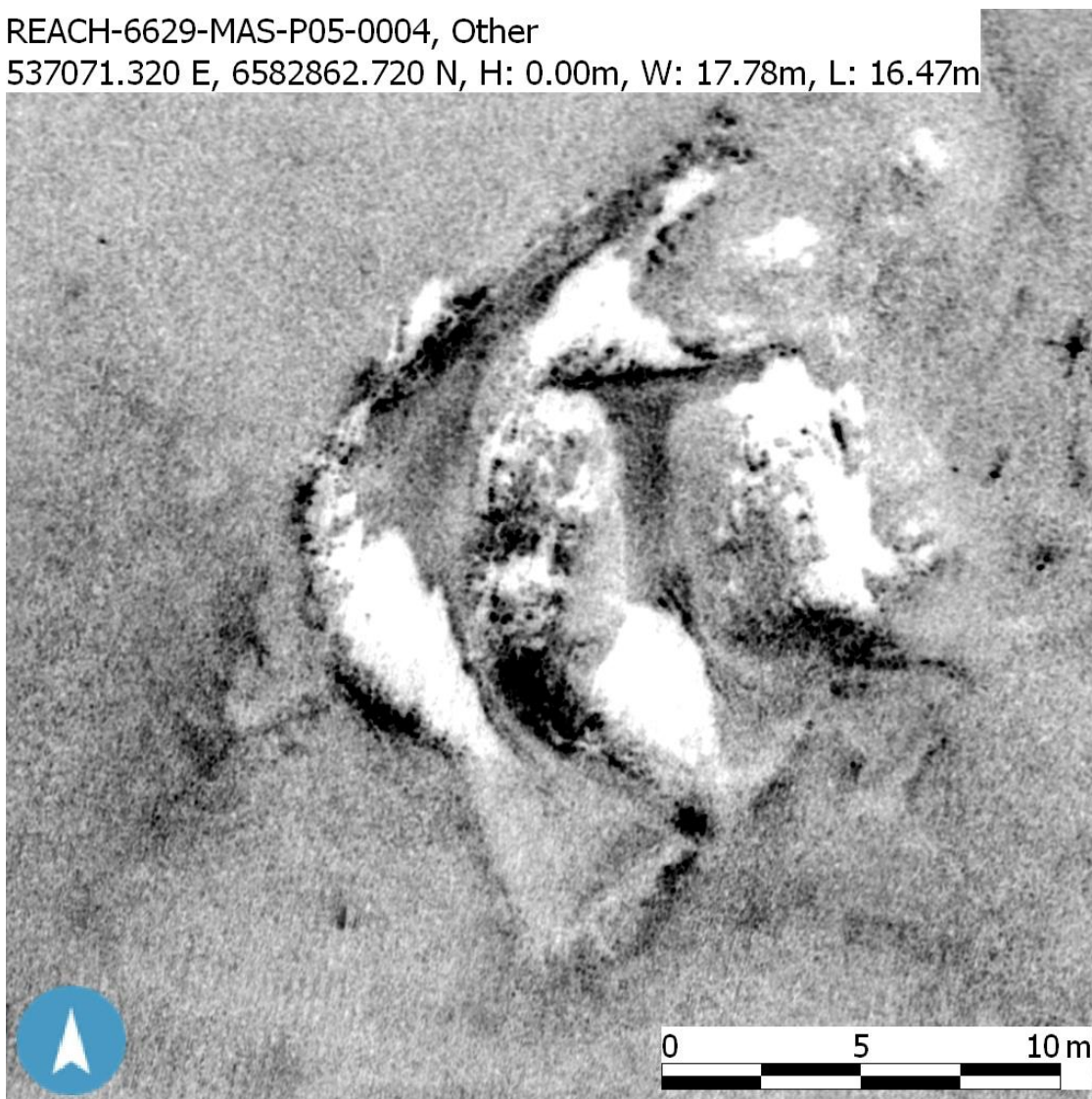




4.1.7. Dive 7

Sediment depression from bow visor was filmed, only one thin elongated object was detected.

REACH-6629-MAS-P05-0004, Other
537071.320 E, 6582862.720 N, H: 0.00m, W: 17.78m, L: 16.47m



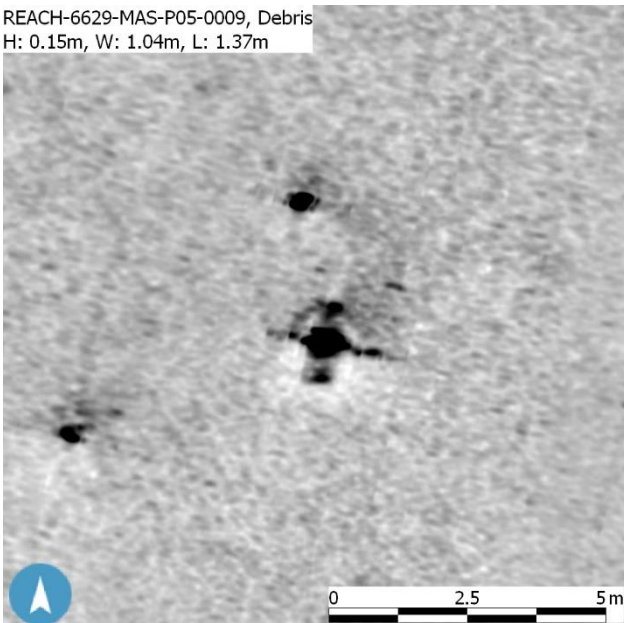




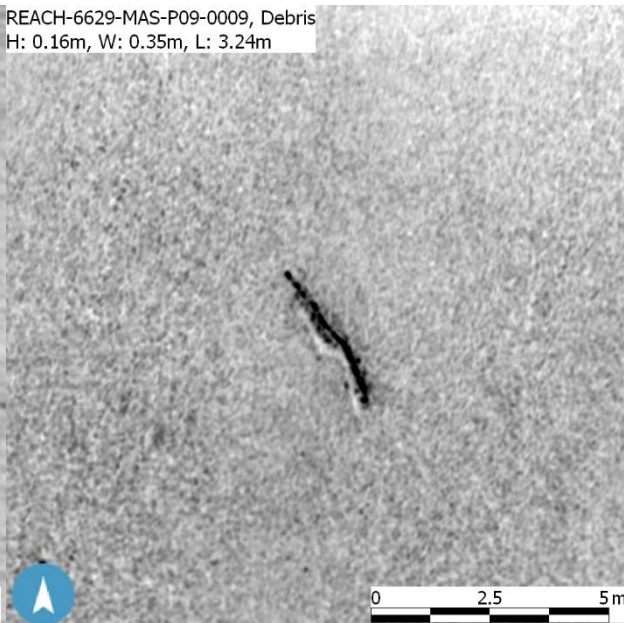
4.1.8. Dive 8

Selected target (P05-0009) turned out to be a boulder and another target (P09-0009) in the vicinity a brown colour wood log.

REACH-6629-MAS-P05-0009, Debris
H: 0.15m, W: 1.04m, L: 1.37m



REACH-6629-MAS-P09-0009, Debris
H: 0.16m, W: 0.35m, L: 3.24m

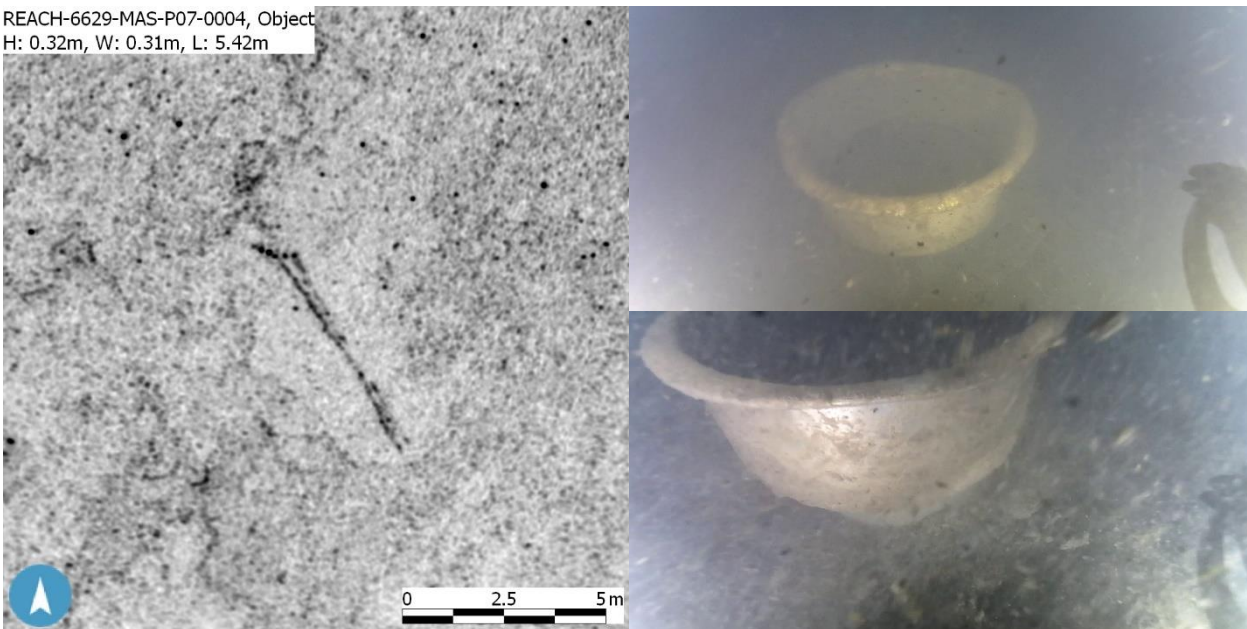




4.1.9. Dive 9

No object was found from the dive for the selected target, interpreted as possible debris or scar. Only a metallic bowl was found during the search.

REACH-6629-MAS-P07-0004, Object
H: 0.32m, W: 0.31m, L: 5.42m

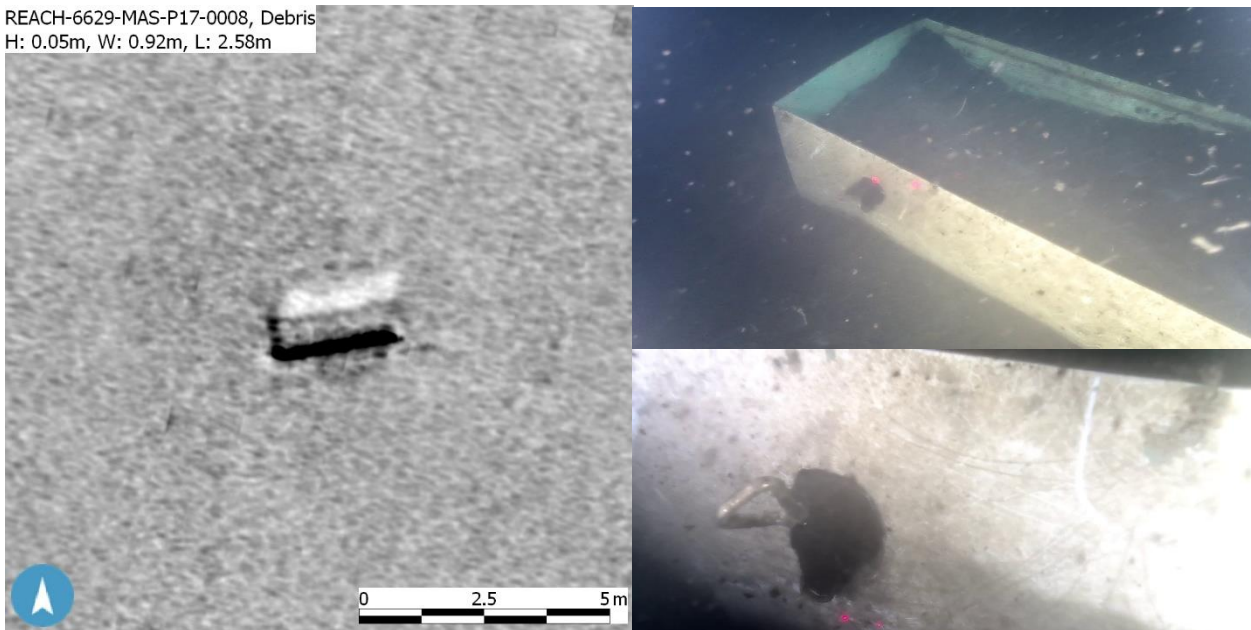




4.1.10. Dive 10

Selected target turned out to be a possible life-saving appliance box.

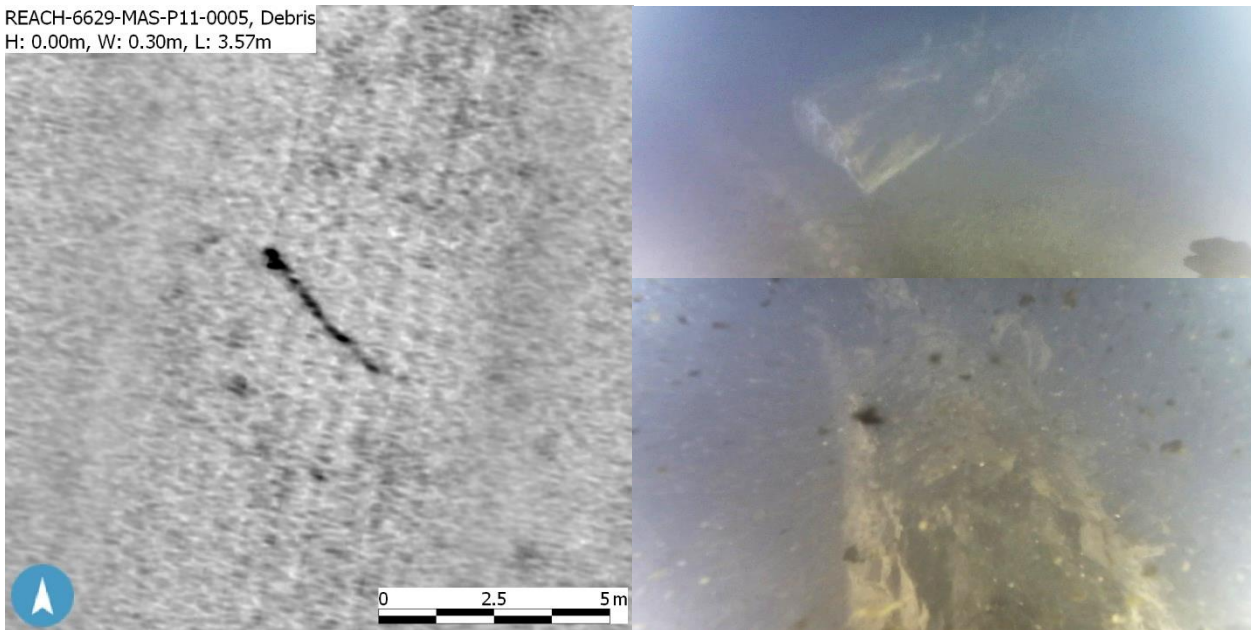
REACH-6629-MAS-P17-0008, Debris
H: 0.05m, W: 0.92m, L: 2.58m



4.1.11. Dive 11

Selected target turned out to be a light colour thick wood log, poor visibility.

REACH-6629-MAS-P11-0005, Debris
H: 0.00m, W: 0.30m, L: 3.57m

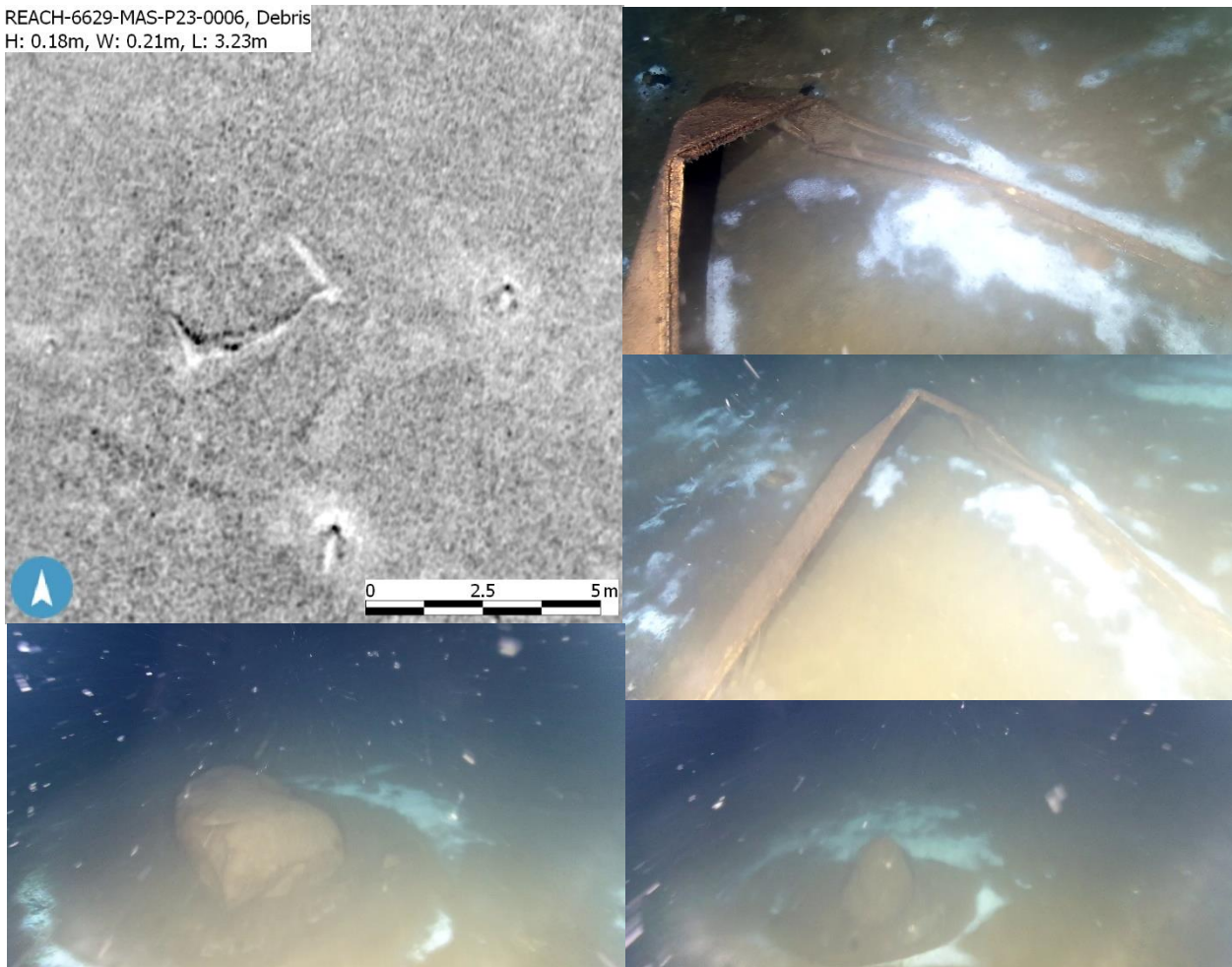




4.1.12. Dive 12

Selected target turned out to be a bent and twisted panel. Two isolated boulders were also visible in the area.

REACH-6629-MAS-P23-0006, Debris
H: 0.18m, W: 0.21m, L: 3.23m

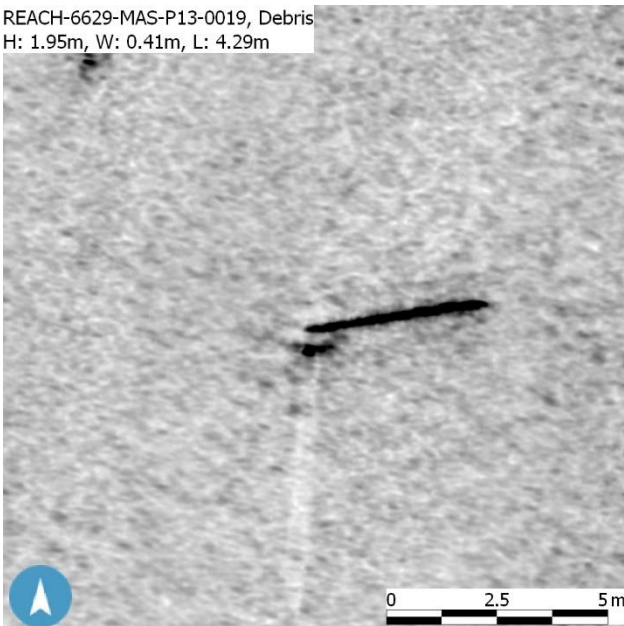


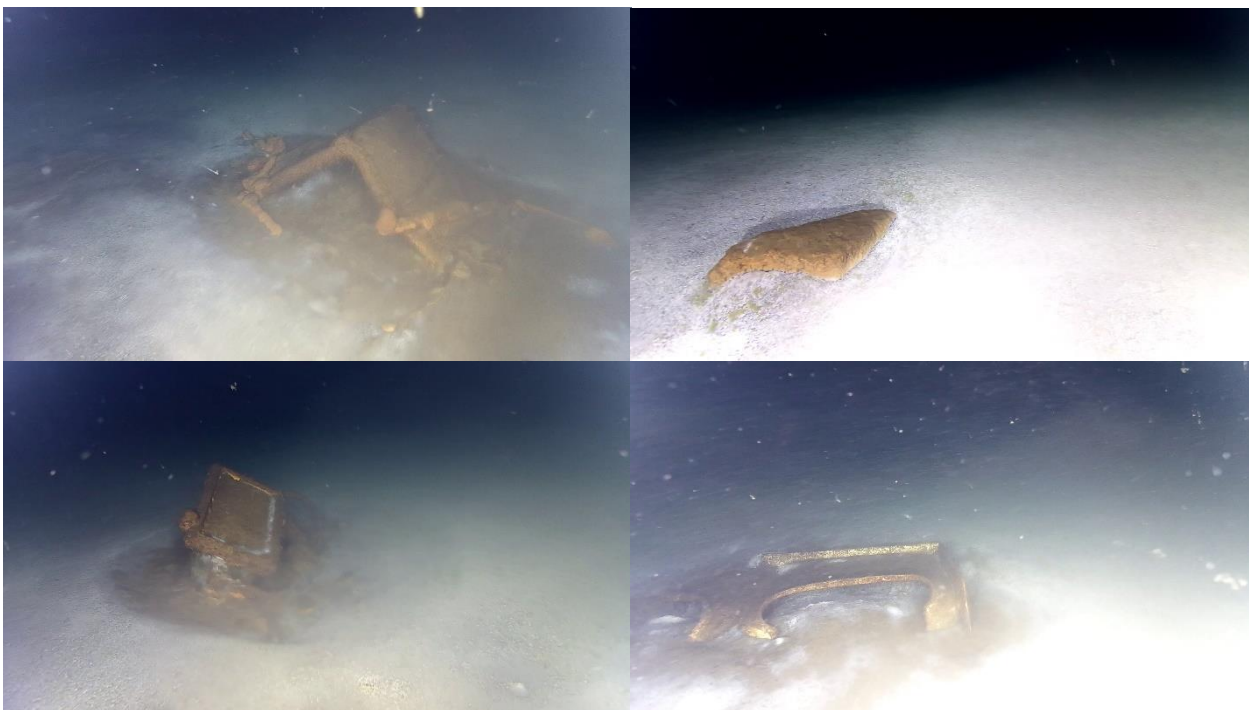
4.1.13. Dive 13

Selected target turned out to be a metallic beam with a capsule. In addition, many objects were seen in the vicinity, e.g., a box-shaped object (possibly ventilation housing from Deck 9), a cylindrical object, a metallic bowl, panels, a metallic object, a floodlight, and a part of a weather deck bench.



REACH-6629-MAS-P13-0019, Debris
H: 1.95m, W: 0.41m, L: 4.29m

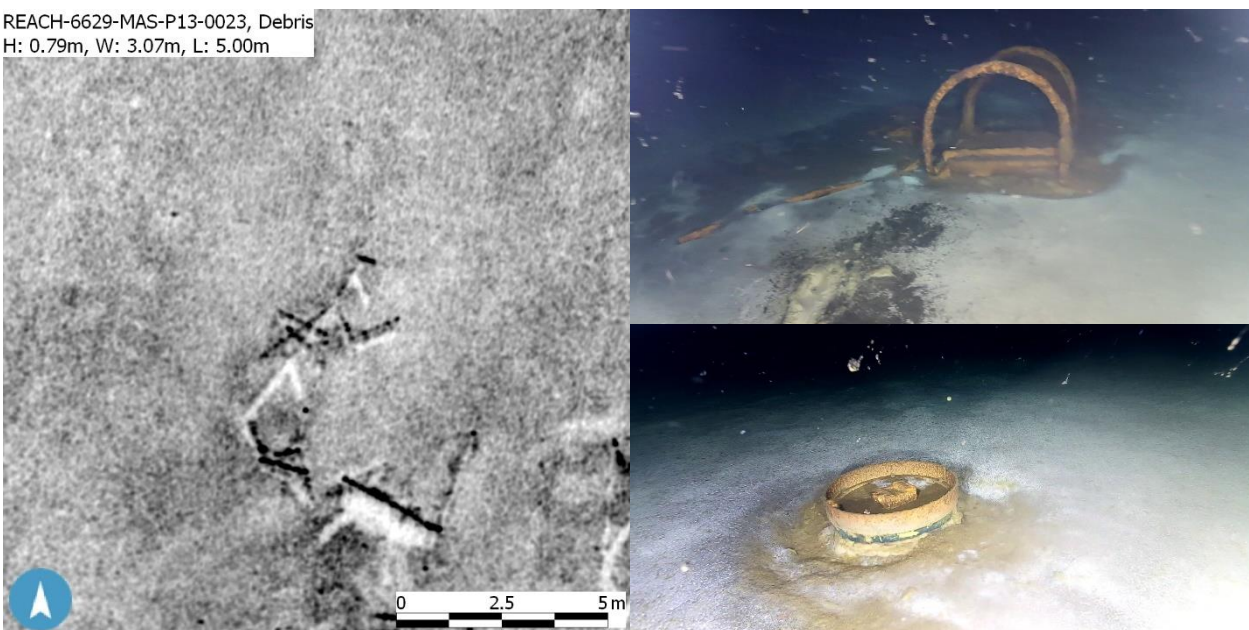




4.1.14. Dive 14

Dive 14 took place in the main debris field southwest of the wreck. Many objects were observed during the dive, e.g., different metallic objects, a box-shaped object (possible ventilation housing from Deck 9), panels, many remains of helicopter deck railings (without Plexiglas), many drawers (one having a plate inside), possible frames of portable chairs, a doorframe, a portable stair for lifeboat embarkation, a collapsed life raft (circular remains on seabed), a floodlight, and a TV monitor.

REACH-6629-MAS-P13-0023, Debris
H: 0.79m, W: 3.07m, L: 5.00m



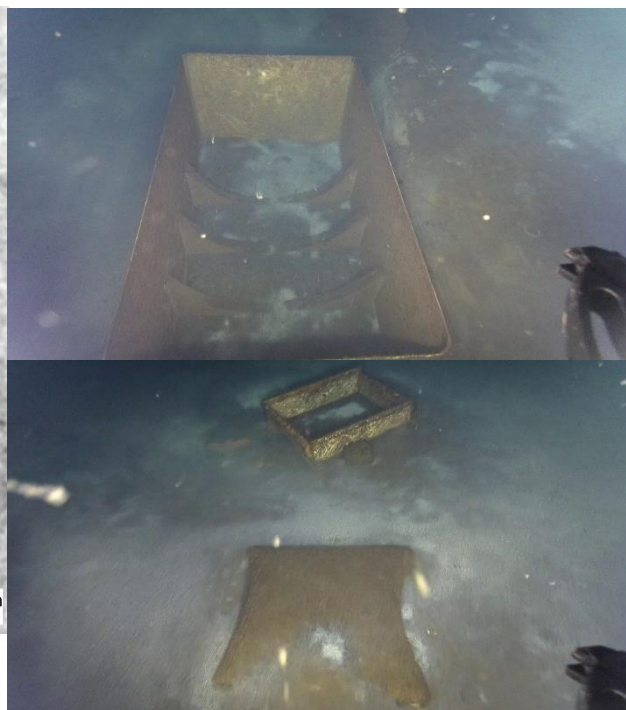
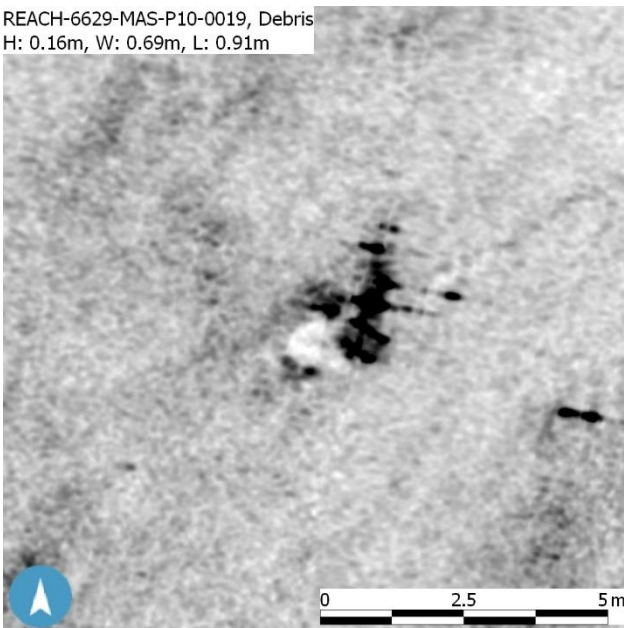




4.1.15. Dive 15

Dive 15 took place in the main debris field southwest of the wreck. Many similar objects were observed as described for Dive 14, in addition to which a pillow-shaped object and a plastic box, possibly for life-saving equipment.

REACH-6629-MAS-P10-0019, Debris
H: 0.16m, W: 0.69m, L: 0.91m

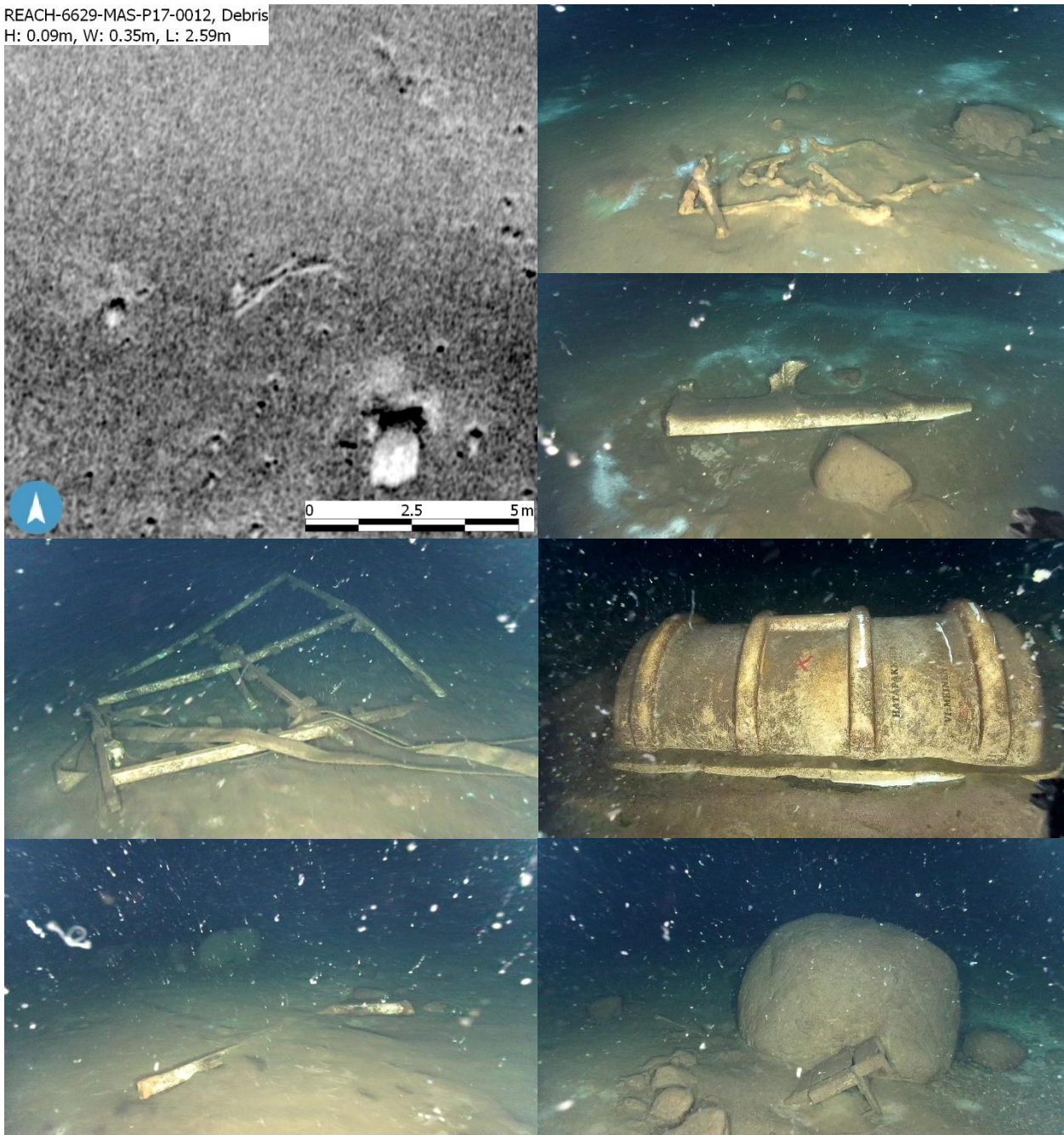




4.1.16. Dive 16

Dive 16 covered a boulder field. Several parts of weather deck benches and helicopter deck railings were observed. Also, an upper side of a life raft container, a fire hose, and a drawer were noted.

REACH-6629-MAS-P17-0012, Debris
H: 0.09m, W: 0.35m, L: 2.59m





4.1.17. Dive 17

During the last dive, the area of the wreck previously masked by the ship's bow ramp, which was recovered from the seabed in July 2023, was filmed. Filming covered the starboard side of the forward bulkhead next to the bow entrance and the area to the starboard side anchor. Also, the control station of the visor and ramp were filmed at the entrance of the car deck.



4.2. Part of the ramp railing

The rotatable part of the ramp railing which was found during Dive 6 was located 485 meters west (268°) from the visor recovery location (sediment depression mark on seabed) and the cross-track distance between the visor recovery location and the railing on the vessel's planned course (288°) was 165 meters. This object is the most westward object found on the seabed that undoubtedly originates from MV Estonia.



The part of the railing was recovered from the seabed (Figure 5). It was flushed with fresh water and cleaned on-board the survey vessel and later transported to Tallinn, Estonia (Figure 6).



Figure 5. Recovered part of the ramp railing on the aft deck of the survey vessel EVA-316. Source: Tauri Roosipuu, ESIB



Figure 6. Recovered part of the ramp railing after cleaning. Source: Tauri Roosipuu, ESIB

Further analysis showed that this item originates from the starboard side railing arrangement (Figure 7). Ramp railing arrangement was longitudinally symmetrical, but the lugs of the locking pins of the rotatable parts were aligned outwards. Comparing these details of the recovered part with the shipyard drawing made it possible to conclude from which side the object originates.

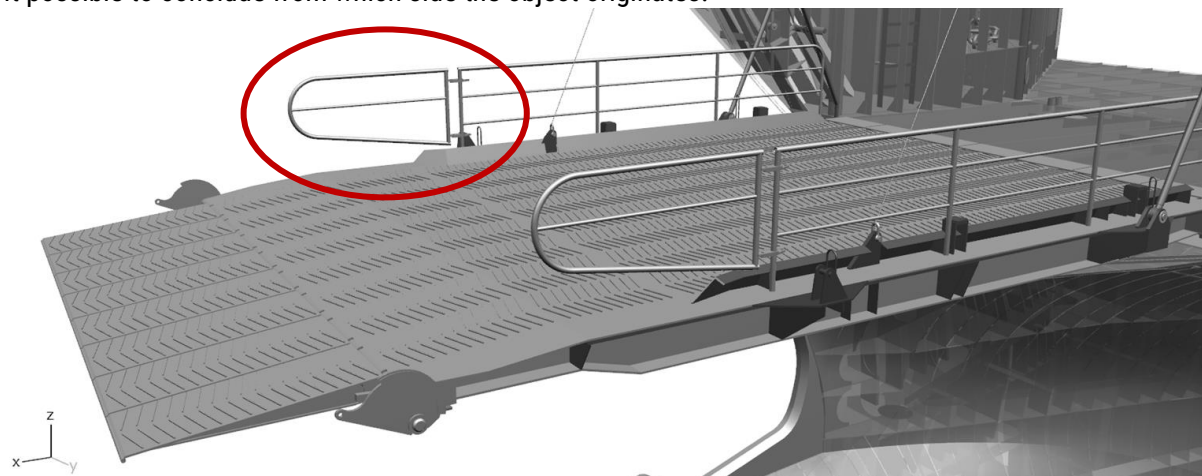


Figure 7. Railing arrangement on digital 3D model of the bow ramp of MV Estonia.

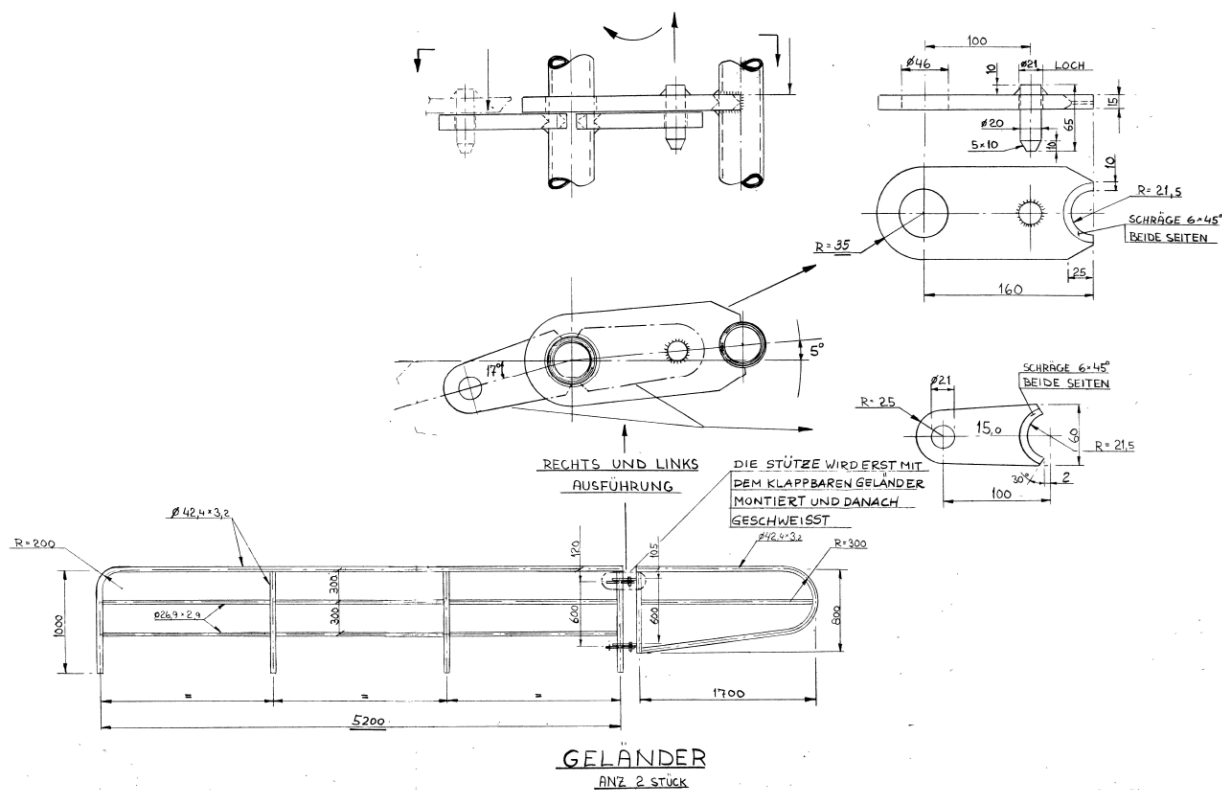
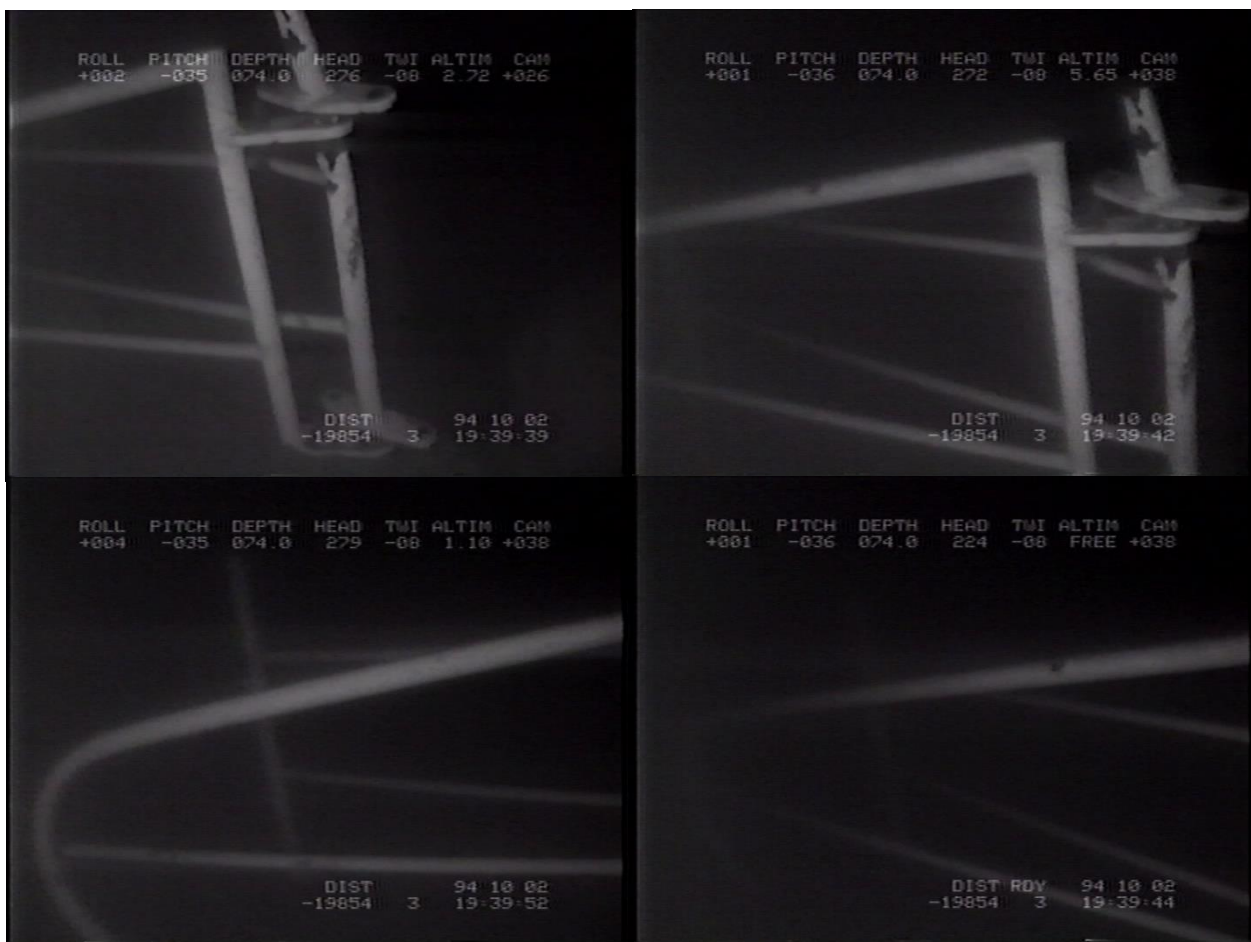


Figure 8. Original shipyard drawing of the ramp railings illustrating the rotatable part of the railing and the locking lugs and pins. VonTell drawing No 49111-302 'Details für Bugrampe'.

4.2.1. Part of the ramp railing seen on videos 1994

First ROV video survey of the wreck was conducted on October 2, 1994, from the oil spill response vessel Halli (owned by the Ministry of the Environment of Finland and operated by the Finnish Navy). Two ROVs were used which had the names Jutta and Simo. Among other areas and items filmed, part of the rotatable part of the ramp railing is also visible from the video tape from the ROV Jutta. The rotatable part is visible after filming the stern of the wreck and moving along the seabed approximately SW direction. Before and after filming the railing the ROV was heading eastwards.

On the video the railing is vertically upside down but not laying on seabed. It is considered to be port side railing according to the alignment of locking pin lugs and not having corresponding damage as the recovered starboard railing – fixed railing side has at least two horizontal bars attached to the forward railing post (starboard one has only one) and the locations of paint damage are different.



4.3. Reach Subsea AS density cloud of interpreted targets

Although there are several man-made objects that are not interpreted as targets and there are targets interpreted as a man-made object that are not, visualisation of the density of the target cloud reduces the possibility of overinterpreting information from any individual target. It is noted in the Final Report of Reach Subsea AS, that all targets from the Multi Aperture Sonar (MAS) data should be handled as the result of an interpretation until a visual inspection has been performed.

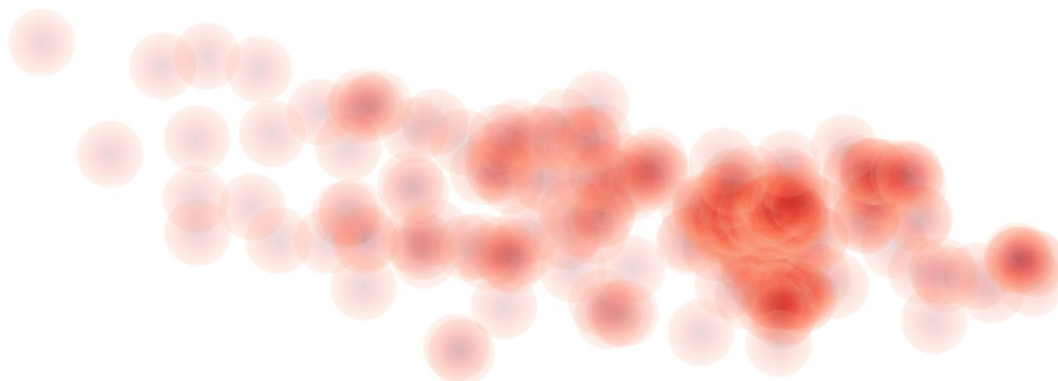


Figure 9. Reach Subsea AS density cloud of interpreted targets.



4.4. Elongated objects

At least 35 elongated objects were recognised from the MAS mosaic. The five visually inspected targets confirmed all of these as wood logs (**Figure 10**).

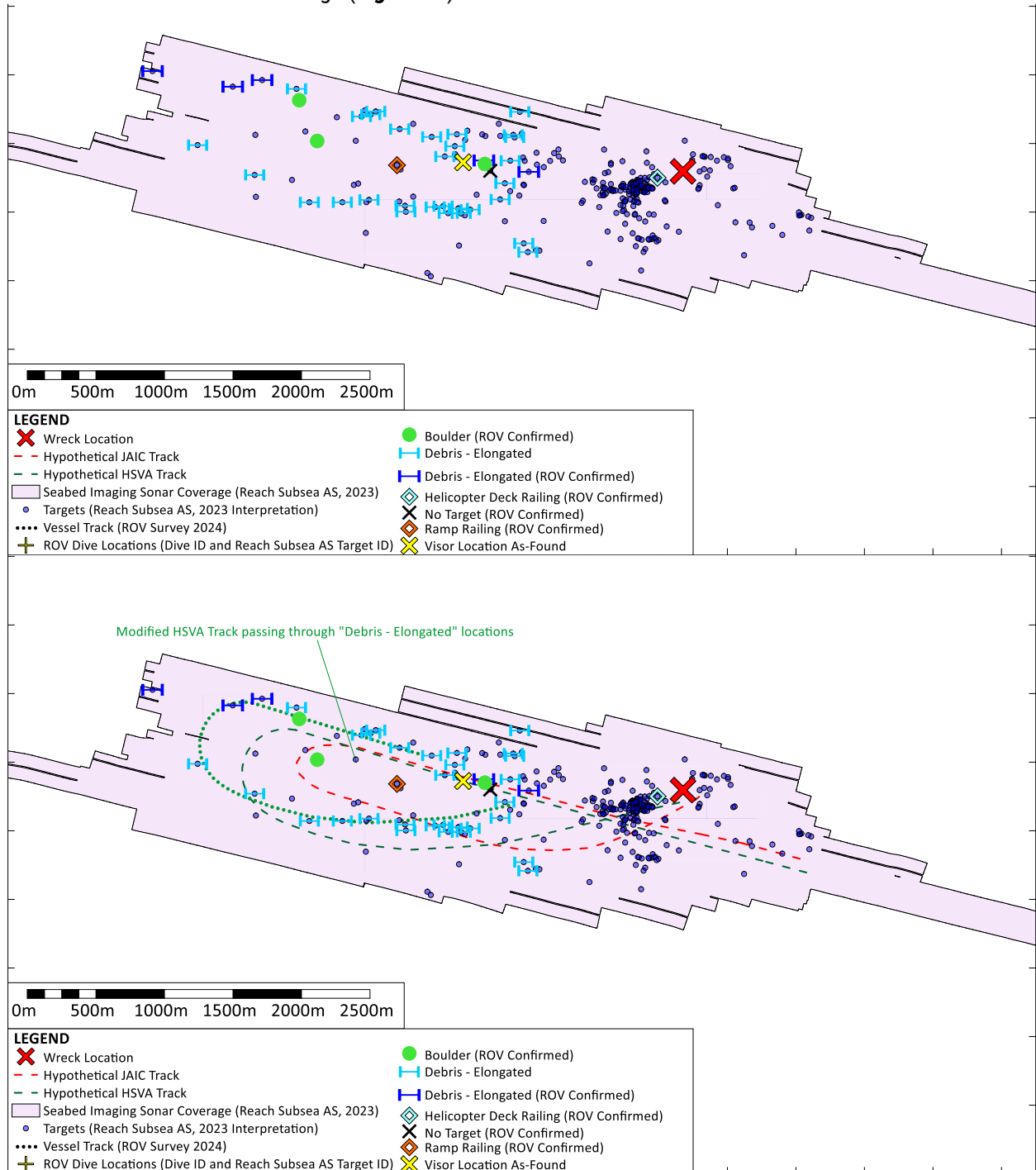


Figure 10. Elongated objects in the survey area with comparison to HSVA track.



4.4.1. Information related to wooden cargo

Cargo units carried on-board MV Estonia were recorded in the 'Cargo Manifest'. In this document there are six cargo units carrying either wood, timber, or lumber. According to the related custom declarations, half of these could be considered as raw material (**Table 4**).

Table 4. Cargo units on-board MV Estonia related to wooden cargo.

Ticket No	Vehicle(s)	Registration No	Cargo Description	Description in Customs Declaration
43740	Trailer	PUE 652	Wooden materials	Picture frames <i>Fotoraamid</i>
43741	Truck + trailer	GWD 695	Wood	Sawn timber, conifer 62 m ³ <i>Saematerjal okaspuit 62 m³</i>
43742	Truck + trailer	EPG 355	Timber	Sawn timber, conifer 68 m ³ <i>Saematerjal okaspuit 68 m³</i>
43747	Trailer	PZS 089	Wood	Garden houses, 2 sets <i>Aiamajad 2 komplekti</i>
43764	Truck + trailer	688 GAB	Timber	Longitudinally sawn or cut conifer <i>Pikikiudu saetud või lõigatud okaspuit</i>
43773	Truck + trailer	MOV 996	Lumber	Fiberboard <i>Puitkiudplaat</i>



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