DMAIB
Danish Maritime Accident Investigation Board

RIGI

Marine accident report on foundering

23 APRIL 2018

MARINE ACCIDENT REPORT ON THE FOUNDERING OF RIGI ON 23 APRIL 2018

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Photo: RIGI in Faxe Bay
Source: Private photo

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The investigations are carried out separately from the criminal investigation, without having used legal evidence procedures and with no other basic aim than learning about accidents with the purpose of gaining and promoting an understanding of safety. Consequently, any use of this report for other purposes may lead to erroneous or misleading interpretations.

Content

Board statement

On 23 April 2018, the German recreational craft RIGI, a small motorboat, sank in Faxe Bay on the southeast coast of Zealand, Denmark, approx. 1 nm from shore. On board was a team of three scientists who were conducting marine biotic research, and an observer representing the contractor of the research.

The persons escaped the sinking boat and ended in the water. They stayed by the boat in the hope that rescue assistance would arrive, but after a while they realised that their best chance of survival was to swim to shore and alert the rescue services there. The team leader and the observer swam towards the shore, but only the team leader made it to shore, where passing local residents contacted the emergency call centre. A rescue operation was launched and the remaining two scientists, who were still by the sunken boat, were rescued. The observer was later found and recovered from the sea by a rescue helicopter, approx. 2 nm from the boat. Despite receiving treatment both in the rescue helicopter and in hospital, she died as a result of the accident.

DMAIB was notified by the police while the events were still unfolding, and immediately launched an investigation, due to the very serious nature of the accident. The investigation comprised, inter alia, interviews with the surviving scientists, examination of the boat and its equipment, analysis of emergency preparedness, interviews and data collection from the organisations involved in the project, authorities, rescue services, witnesses etc.

The research that was being conducted on board RIGI on the day of the accident was part of a large scale project, involving several companies, such as research institutes, contractors, consulting engineers and management consultants. The investigation showed that the choice of boat, its equipment, its operation, and its manning influenced the events on the day of the accident. Therefore, the investigation found it relevant to address the question of how and why such large, professional project organisation chose to conduct the commercial research in Faxe Bay using a small recreational craft manned by four non-professional mariners. The accident investigation report therefore focuses on both the technical and organisational circumstances leading to the foundering of the boat and the fatality that occurred as a consequence.

Narrative

The narrative is a description of the accident as the involved persons perceived it to unfold and is based on their recollection of the sequence of events.

The narrative covers the sequence of events from the time that RIGI departed Faxe Ladeplads on 23 April 2018 until the search and rescue operation was ended approx. ten hours later.

Background

During the period from 19 March to 15 May 2018, the German company Institut für Angewandte Ökosystemforschung[1] (IfAÖ) was conducting ichthyofauna[2] surveys in Faxe Bay (fig. 1), Denmark as a part of a larger offshore gas pipe project with the Danish consulting engineering company Rambøll Danmark A/S as the overall contract holder. IfAÖ was contracted by through one of Rambøll's subcontractors working on the project. The surveys in Faxe Bay comprised seine fishing carried out from the shore, and gillnetting conducted at sea, using a motorboat named RIGI, which IfAÖ had chartered in Germany (fig. 2).

The IfAÖ survey team consisted of three fish biologists, one of them is referred to in this report as the *team leader*, and the other two are referred to as *scientists*. As a condition for obtaining permission from Danish authorities to conduct the surveys, Rambøll was obliged to have one of their employees, a Danish citizen, on board the boat during the surveys. In this report, the appointed Rambøll employee is referred to as the *observer*.

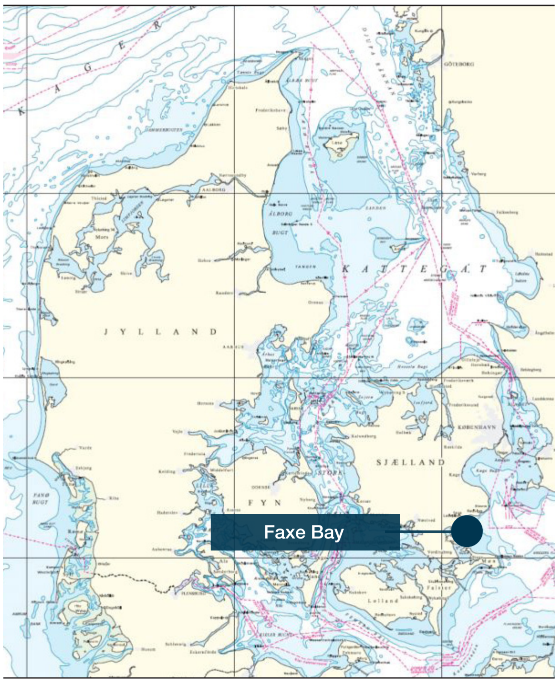

Figure 1: Location of the accident, Denmark
Source: Danish Geodata Agency/DMAIB

1 Institute for Applied Ecosystem Research
2 Regional fish life

Figure 2: RIGI
Source: Private photo

The accident

Time is stated as local time in Denmark, CEST (UTC+2), unless otherwise specified.

Some time statements in this report are approximations, based on the recollections and estimates of the involved parties. Other time statements are accurate, based on AIS time stamps, official logs etc.

It should be noted that emergency and crisis situations affect people's perception of time. Therefore, the involved persons' recollections of the time and duration of events may not be entirely accurate or consistent with other data.

On Monday 23 April 2018, at approximately 0600 in the morning, the three scientists met with the observer in the port of Faxe Ladeplads, where they boarded the boat RIGI. The task for the day was to haul the gillnets that they had set in Faxe Bay the previous day (fig. 3).

On the day of the accident, the weather forecast predicted a deterioration in the weather conditions from around noon, so it was agreed that they would start the day's work at 0600 so they could return to port around 1100, before the weather worsened. When RIGI left the port, the weather was calm and sunny with a light to gentle breeze and glassy sea.

After stowing their equipment and personal items on RIGI and starting up, there were some problems turning the engine on, which were quickly resolved when the team leader called the boat owner for advice.

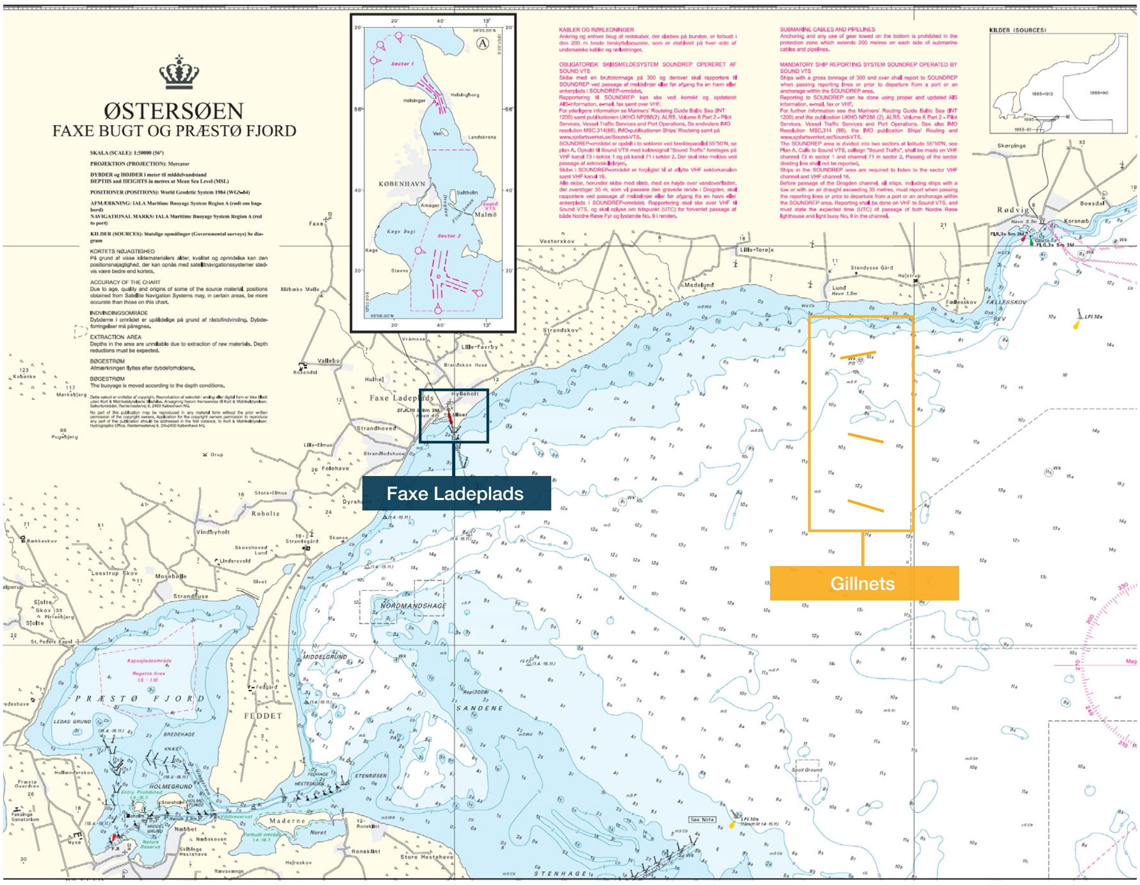

Figure 3: Gillnets in Faxe Bay
Source: Danish Geodata Agency/DMAIB

In accordance with the terms of the permission to conduct the survey, the observer made a call to the Danish Fisheries Agency to report the time of departure and the expected time of return. They then conducted a test run in the harbour basin to confirm that the engine was working properly and then left the port of Faxe Ladeplads at approximately 0635, and headed for the first gillnet net position (fig. 4), which was the southernmost of the three net stations.

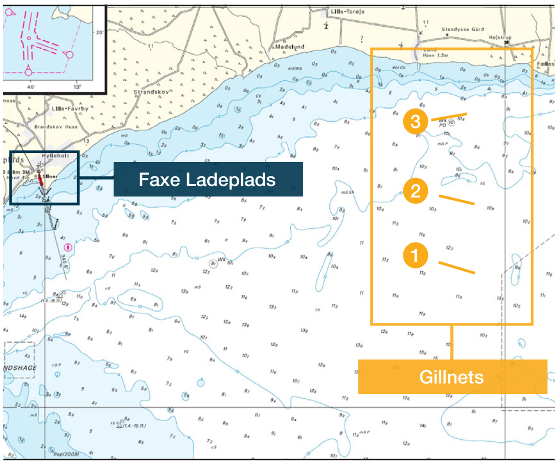

Figure 4: Gillnets in Faxe Bay
Source: Danish Geodata Agency/DMAIB

During the voyage from Faxe Ladeplads to the gillnets, the team leader was steering the boat, sitting in the chair behind the helm. The other two scientists and the observer were either on the benches in the cabin or on the open aft deck area (fig. 5). The voyage to the first net position lasted approx. 45 minutes at 6-7 knots speed, and they started hauling the first gill nets at 0726.

The scientists followed their normal method of work for hauling nets: The team leader was at the helm and controlled the propulsion, while one of the others hauled the net from the port side of the deck area, with the second scientist assisting.

The nets were hauled by hand with the boat's port side towards the direction of the nets, while the team leader kept the boat's speed at 0-1 knots, just sufficient to keep the direction.

Usually, the scientists would clean the nets and remove the catch as the nets were hauled. However, on this particular day, because the weather was expected to deteriorate and they wanted to finish the job before that, they just hauled the nets and moved on to the next location. The intention was to collect all the nets and then return to shore, where they would examine the catch. Hauling the first net took about 35 minutes after which they continued to the other two locations. They finished hauling the third and last net at around 0951.

Towards the end of the last haul, the weather worsened, earlier than they had expected. The wind quickly picked up and changed direction from southeast to southwest, and the waves rose to a height of about 1.0-1.5 m with a direction that was different to the swell direction, resulting in chopping seas. As soon as the last net was hauled, the course was set for the voyage back to the port of Faxe Ladeplads at a speed of 4-5 knots. All four persons stayed in the cabin during the return voyage, with the sliding door to the cabin open.

As a result of the change in weather conditions and the direction and magnitude of the waves, which were now abeam (perpendicular to the boat's direction) it became very uncomfortable to be on the boat due to the boat's motion in the sea. At around 1015, 20-25 minutes after hauling the last net, the team leader decided that they should alter their course and instead proceed to the small harbour Lund Harbour, which was much closer, just to the northeast of their current position.

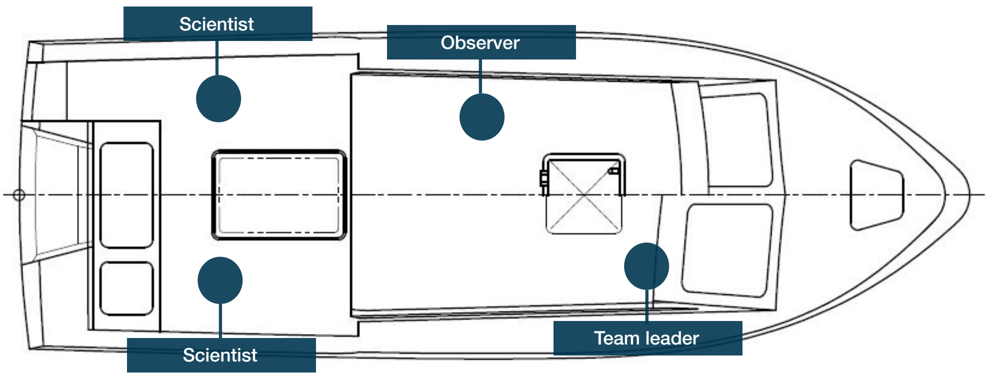

Figure 5: Sketch of RIGI
Source:YA-RO/DMAIB

The scientists were familiar with Lund Harbour, because they had used it during previous campaigns for lunch breaks, cleaning nets etc. The team leader also knew from experience that sailing in following sea, i.e. the wave direction being the same as the boat's heading, would be much smoother, and in his opinion also safer.

Shortly after they had changed course towards Lund Harbour, a wave lifted the aft end of the boat, and as it moved downwards again, another large wave came over the aft. The sea water filled most of the open deck area and flooded into the cabin, where it stood about ankle level. The engine stuttered and then stopped. The team leader immediately activated the boat's bilge pump, ordered that everybody should don immersion suits and lifejackets, and started handing out the suits, which were stowed in the forward part of the cabin.

Only himself and the observer had time to don the suits because, as soon as the first wave entered the boat, the other two scientists went outside onto the deck, where they attempted to bail out water using a bucket and a pail, and began dumping equipment overboard to reduce the boat's weight. The team leader threw immersion suits towards them from the cabin, and one of them managed to partly don a suit. One scientist managed to throw one of the net bags overboard and had just lifted another onto the railing when a second wave came over the stern and completely flooded the deck and cabin.

The team leader grabbed the observer, who was still in the cabin, and pushed her out onto the deck, before following closely behind. Just as all four arrived outside on the deck area, the boat sank by its aft end and came to a position where only approx. one metre of the bow was above the water.

The last AIS-signal from RIGI was received at 1029 (fig. 6).

Just as the boat was sinking, the team leader shouted that everybody should stay by the boat. None of them had time to get hold of a lifejacket or any personal items before they ended up in the water.

Once the boat sank and settled in an upright position (fig. 7), the four persons held on to it, and tried to position themselves as best as they could. Initially, the observer and the scientist who had no immersion suit on were placed at the foremost part of the boat, which was partly above the surface of the water. After a short while, the other scientist, whose suit was not properly zipped, switched places with the observer to allow him to get out of the water as much as possible. It required several attempts and assistance from the others for him to climb to the new position because his suit was heavy from being full of water.

The location of RIGI, after it sank, was within visual range of the coastline and Lund Harbour, and the scientists and the observer were able to observe activity in the port and on the beach nearby. Based on their sea survival training, they all agreed that their best option was to stay together and hold on to the boat until help arrived. The scientists had brought inflatable lifejackets fitted with AIS-SARTs. Since the lifejackets were stored inside the foundered boat's cabin, they were not sure if the AIS-SARTs had been activated. They did however believe so, because the transmitters were designed to activate when in contact with sea water. Since the cabin had been flooded, they hoped the sea water had reached the transmitters, and that rescue services therefore would be on their way within an hour.

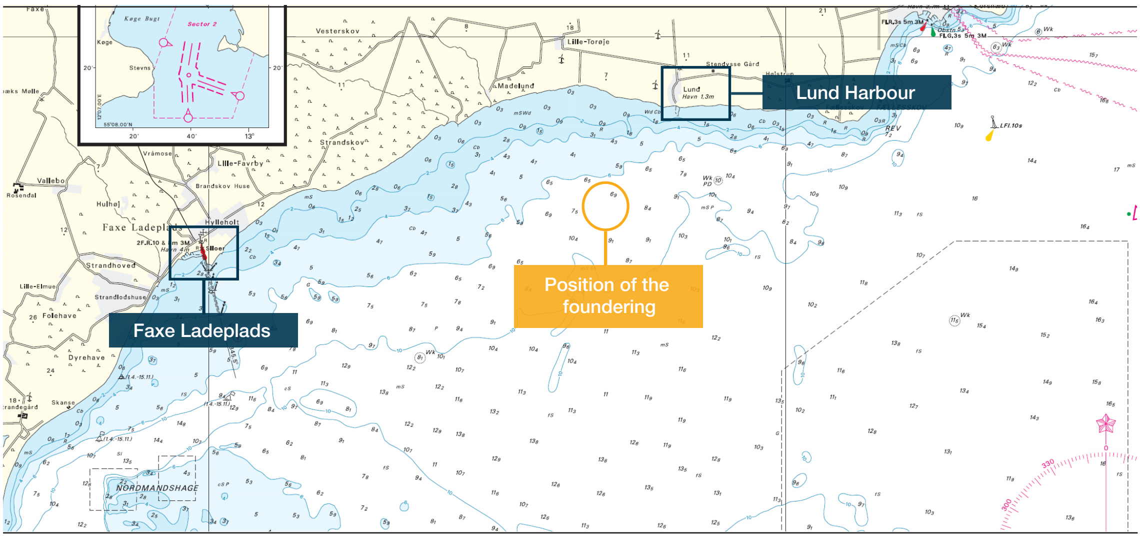

Figure 6: Position of the foundering of RIGI in Faxe Bay
Source: Danish Geodata Agency/DMAIB

Figure 7: RIGI foundered in Faxe Bay
Source: Klintholm Coastal Rescue Service

At some time, probably between 1130 and 1200, when the four persons had been in the water for one to two hours, they became worried that no help had arrived. The team leader noticed that his two colleagues were beginning to shiver uncontrollably due to the cold, and he decided that he should attempt to swim to shore and get help.

Because he was familiar with the area, he knew that between their location and Lund Harbour there was a fyke net installation, mounted on pillars rammed into the sea bed (fig. 8). He also knew, due to his profession, that fyke nets were usually connected by ropes and nets all the way to the coast. Therefore, his plan was to swim until reaching the fyke nets and then use the connecting ropes to haul his way to shore until he could call for help.

The observer stated that he should not go alone, and insisted on going with him, as she felt relatively warm, and considered herself a capable swimmer. The team leader on the other hand, argued that getting the others to safety was his responsibility. The team leader however accepted the observer's offer to go together as this would improve their chances of getting help. He then grabbed one of the boat's fenders and secured it to his suit to use as a floatation aid, and he and the observer connected their buddy lines and started swimming towards the fyke nets.

After swimming for approx. two hours the team leader and the observer reached the fyke nets. The observer said that she was completely exhausted and was unable to continue. The team leader noted that she was low in the water, and that it was difficult to communicate with her. They decided that she should stay at the fyke nets, while he continued towards the shore. At this time, he also felt very cold and exhausted, and noted water was flooding into his immersion suit at the neck.

After instructing the observer to hold on to the fyke net pillars, he then pulled himself hand over hand along the upper edge of the nets, until the fyke net ended, approx. 200 m from the pier south of the harbour. At this point, only the fender that he held under his left arm kept him afloat, the wind and waves carried him away from shore, and he was certain he was not going to survive. Just then, he felt the seabed under his feet and stumbled towards shore, shouting for help.

Figure 8: Fyke net installation pillars.
Source: DMAIB

Search and rescue

A woman walking her dogs along the shore just east of Lund Harbour spotted the RIGI team leader struggling in the water to reach shore while yelling for help, approx. 100-200 m from shore. She had not brought her mobile phone with her, so as soon as she saw the distressed man, she rushed back towards the village to get help. At the car park in Lund Harbour, she encountered a man who phoned the emergency operations centre (112). The call was placed at 1508. The two then returned to the shore, where they saw the team leader still struggling to reach the coast.

They observed how he kept slipping and falling over, submerging his head, taking longer to get up again each time. The assisting man then decided that he should go into the water to help him to shore. Having retrieved the team leader, the woman comforted the distressed man while they waited for the ambulance, which arrived 8-10 min. later. He was exhausted and barely able to speak, but was able to provide information about his name, and that a boat had sunk, leaving three other persons in the bay, one of whom had no immersion suit on.

The assisting man, who was in constant contact with rescue services, relayed this information. At that time, the team leader may have briefly lost consciousness. When he came to, he was close to the ambulance and told the assisting man that there was one person at the fyke nets and two others at the sunken boat.

When the phone call was received at the emergency operations centre, a number of measures were initiated by the emergency services:

The emergency operations centre contacted the police and emergency service who dispatched police patrols and ambulances to Lund Harbour. They also contacted the Joint Rescue Coordination Centre (JRCC), which then coordinated the rescue efforts.

JRCC scrambled two search and rescue (SAR) helicopters, RES502 and RES504. The Coastal Rescue Service in Klintholm deployed their rescue boat FRB20. Østsjællands Beredskab (Regional emergency service) deployed their fast rescue boat (FRB). The navy patrol vessel FREJA P521 was appointed on-scene coordinator of the operation by JRCC.

The two scientists who stayed at RIGI had been able to maintain visual contact with the team leader and the observer as they made their way towards the shore, but after about an hour they could no longer see them. While waiting for help, they saw people going to and from the nearby beach, and at one point a helicopter passed over them. They waved and shouted but the helicopter did not react, and as no other help arrived, this added to their growing concern about what had happened to their two colleagues. At 1554, the search and rescue crew located the two scientists in the water, still holding on to the boat. After helping the rescue boat crew secure the rescue boat to RIGI, the two men let go of RIGI and were brought on board the rescue boat at 1601. They became increasingly concerned about their two other colleagues' wellbeing when the rescue boat crew asked them where the other two persons were.

At 1627, one of the rescue helicopters located the observer lying face down in the water, some 1.8 nm east-southeast of the fyke nets, and three minutes later, at 1630, she was brought on board the helicopter. While the two scientists recovered from RIGI were brought to Lund Harbour and then to hospital by ambulance, the observer received medical treatment in the helicopter, while she was flown to the trauma centre at Rigshospitalet (National hospital in Copenhagen). She was pronounced dead at 1705. The three scientists survived, but sustained various degrees of hypothermia and psychological stress as a result of the accident.

Investigation

This section describes the results of DMAIB's investigation of the factual circumstances of the accident. The purpose of the investigation of RIGI was to clarify the circumstances of the foundering of the boat and the circumstances of the fatality occurring subsequently.

Method

DMAIB investigated the sinking of the ship and the fatality as two separate events. The fatality occurred hours after the boat sank. Hence, the fatality did not happen as a direct result of the foundering of the ship, but is linked to the emergency situation following the foundering of the vessel. The aim of the investigation was to answer the following questions:

- What caused RIGI to founder?
- Why did the foundering lead to the death of the observer?

RIGI's presence and operation in Faxe Bay on the day of the accident was a part of a large-scale project, and DMAIB found it crucial to understand the background for the choice of RIGI as a survey vessel and the manning of the boat, to answer the investigation questions above. Therefore, DMAIB drew the conclusion that an understanding of the accident could not be reached by limiting the investigation to the sequence of events on RIGI on the day of the accident.

The investigation section is therefore structured in three parts: The background, the casualty stage and the emergency stage (fig. 9). Each part of the investigation section contains investigation topics, which cover the circumstances that DMAIB has found to be significant to the emergency situation and the outcome of this accident.

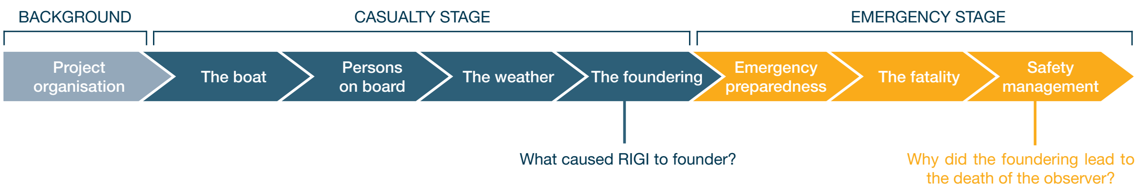

Figure 9: Structure of the investigation section.
Source: DMAIB

Project organisation

Project and organisation
The Baltic Pipe Project was an infrastructure project carried out as a collaboration between the Danish gas and electricity transmission system operator Energinet and the Polish gas transmission system operator GAZ-SYSTEM. The goal of the project was to establish a gas supply corridor from Norway to Poland via Denmark, which would make it possible to commence the transmission of gas between the countries in 2022 (fig. 10). In 2017, the consulting engineering company Rambøll was contracted by GAZ-SYSTEM to obtain the applicable permits and administrative approvals for the construction of an offshore pipeline in the Baltic Sea which were a vital part of the Baltic Pipe Project.

To obtain the environmental permits for the establishment of the offshore pipeline in the Baltic Sea various surveys of the marine environment in different areas of the Baltic Sea were to be carried out in 2018, one of these areas being Faxe Bay in Denmark. Rambøll did not have in-house expertise to carry out these surveys. Hence, Rambøll outsourced all the marine biotic surveys to a subcontractor - a consortium comprising Polish research institute Maritime Institute Gdansk (MIG) and the Polish company MEWO who specialise in seabed surveys and offshore development works. MIG mainly took care of the technical project management of the surveys, while MEWO focused on logistics.

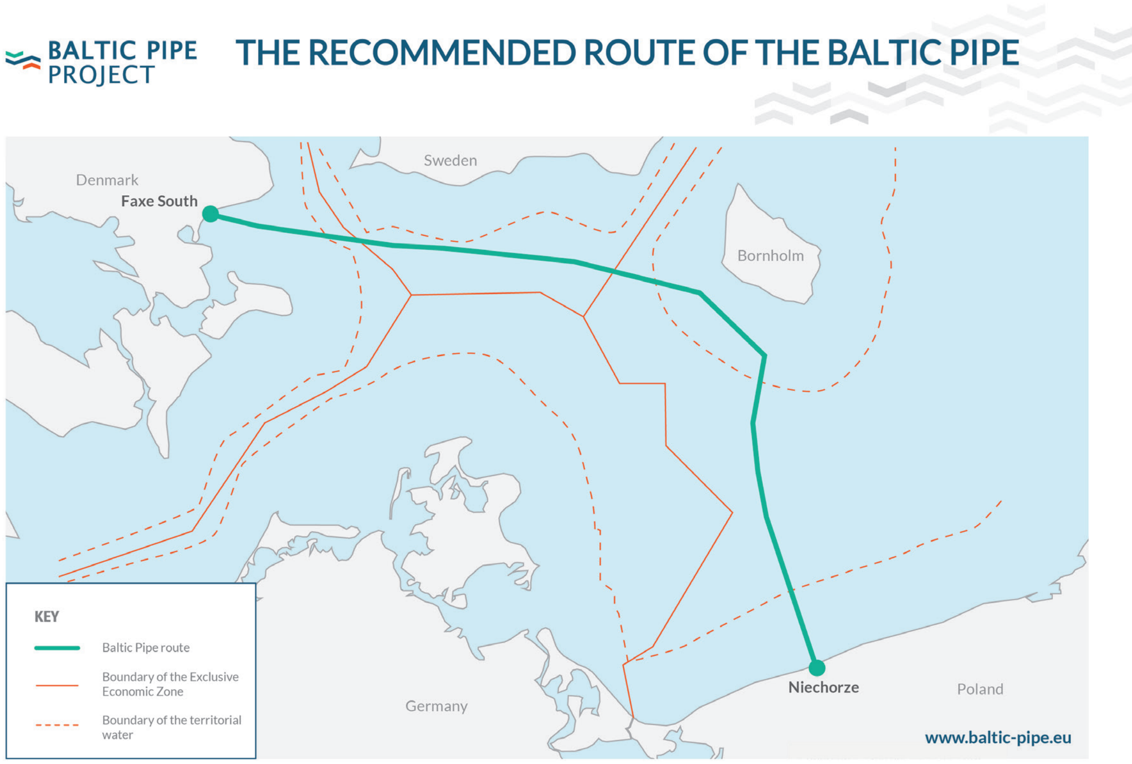

Figure 10: Recommended route for the establishment of the offshore pipeline
Source: Baltic Pipe Project

Neither MIG nor MEWO had resources, such as ships and crew, to carry out the surveys. Therefore, they subcontracted the Polish National Marine Fisheries Research Institute (NMFRI) and the German research institute Institute for Applied Ecosystem Research (IfAÖ) to carry out different surveys for the project.

IfAÖ became responsible for the coastal marine biotic surveys in Faxe Bay. IfAÖ chartered the vessel RIGI unmanned from the German company Yachtagentur Rostock (YARO, henceforth called the owner) for the surveys, as IfAÖ was able to man the boat with their own personnel. The surveys in Faxe Bay, which IfAÖ were to carry out, consisted of scientific fishing using a beach seine and gillnets. RIGI was used for setting and hauling gillnets. The survey was carried out over the course of four campaigns spread over one year: a winter, spring, summer and autumn campaign. The accident occurred at the end of the spring campaign. RIGI had also been used during the winter campaign.

An overview of the organisations and companies involved in the marine environment surveys which RIGI was participating in on the day of the accident in Faxe Bay can be seen in figure 11.

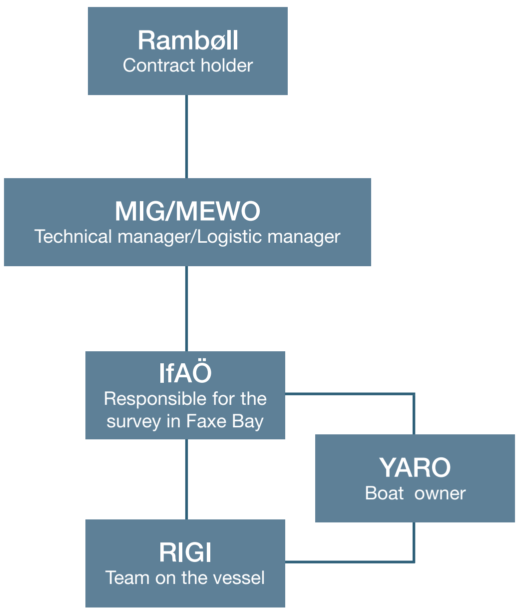

Figure 11: Chart showing the structure of the project organisation in connection to the marine biotic surveys
Source: DMAIB

Boat and on-board personnel

It was a prerequisite for obtaining permissions for the project from authorities that the vessels used for the marine biotic surveys in connection with the Baltic Pipe Project were specified by name in the project description documents. For this type of survey, MIG and MEWO preferred to hire professional research vessels with all necessary equipment, a professional crew, accommodation and other facilities for researchers etc. In the cases where such a vessel was not available or not feasible for a particular part of research, the second choice was to hire a smaller fishing vessel, usually with a crew of one or two professional fishermen. Chartering an unmanned vessel to be used by researchers alone without professional crew was generally avoided as to avoid potential goal conflicts between safe navigation and the research work.

For the Faxe Bay survey, a large professional research vessel was not expedient because of the proximity to the shore and the low water depth. Within MIG and MEWO's project management group, the possibility of hiring local fishing vessels with crew was considered, however it proved difficult to find a vessel suitable for the survey in Faxe Bay, which also had the facilities to carry researchers on board. MIG and MEWO had collaborated with the German research institute IfAÖ on previous projects and knew that they were experienced in carrying out the type of survey which was to be conducted in Faxe Bay.

IfAÖ could provide both researchers and a vessel for the survey, and therefore IfAÖ was contracted by MIG and MEWO to do the scientific fishing in Faxe Bay. The previous collaboration with IfAÖ had not included the chartering of a vessel, but only the use of the institute's researchers. However, MIG and MEWO trusted IfAÖ's selection and manning of the boat. A group of three fish biologists from IfAÖ was assigned to do the scientific fishing in Faxe Bay. The group had previously conducted similar surveys close to shore with the small recreational craft RIGI, and the fish biologist were considered experienced in navigating the boat themselves. RIGI was to be used for the survey in Faxe Bay, and was transported on a trailer to Fakse Ladeplads.

The Danish Fisheries Agency had granted Rambøll permission to fish as part of research in Danish waters with three named vessels, one of which was RIGI. For fishing within 3 nm off the Danish coast, it was required by the Danish Fisheries Agency that the vessels carried Danish researchers, specified by name. Rambøll therefore had appointed eight Danish employees, whose names were stated in the permit. Since the survey in Faxe Bay was carried out within the 3 nm zone, a Rambøll representative was required to join the IfAÖ researchers on board RIGI on each voyage where fishing was carried out.

Rambøll had outsourced the survey because they did not have expertise in the field in-house. Hence, the appointed Rambøll representatives were geologists and engineers with neither maritime nor marine biologist backgrounds. This did not present a problem, as the Rambøll representatives were solely on board as observers to comply with the permit. The criterion for the selection of the Rambøll representatives was that all of them carried a basic sea survival certificate, which they had obtained in connection with previous offshore-based work.

IfAÖ did not know that a Rambøll representative was to join them during the survey, before RIGI had been appointed as the survey vessel. However, RIGI had capacity for six persons, and therefore carrying one extra person besides the three fish biologists was not a problem. Three different Rambøll representatives joined RIGI as observers during the spring campaign.

The boat

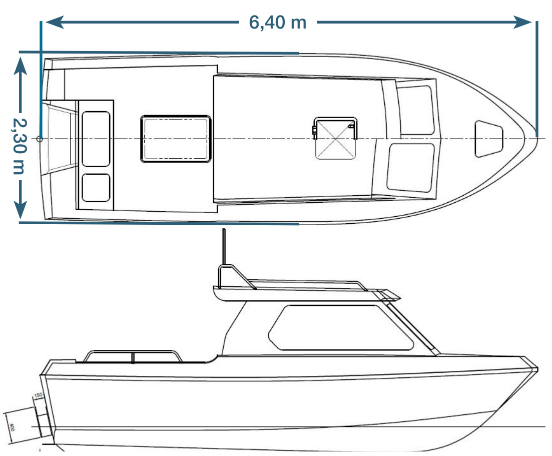

Figure 12: Drawing of RIGI
Source: YARO/DMAIB

The motorboat RIGI (fig. 12) was of the type Loon Fishing 642, produced in 2011 by the Swiss company Loon-Yachts. It was built and certified as a recreational craft intended for angling and leisure trips. At the time of the accident, the boat was owned by Yachtagentur Rostock, a company that designed, built, traded and hired out boats. The boat was hired by the company IfAÖ and brought to Denmark for the Faxe Bay research project.

Construction

RIGI had a length overall of 6.40 m, a breadth of 2.30 m, and a design draft of approx. 0.35 m. The hull was made of aluminium with a fibreglass accommodation and a wooden interior. The cabin at the forward part of the boat contained a small storage space under the fore deck, a steering console and chair on the starboard side, and a storage bench along each side of the cabin. The cabin was enclosed by the fibre glass accommodation with acrylic glass windows and a sliding door towards the deck area, which was raised above the cabin floor. On the port side of the aft end, the boat had an opening towards a swimming platform fitted on the transom. The opening was fitted with a non-watertight acrylic glass door.

Below deck (fig. 13), RIGI consisted of what was essentially one single compartment, which extended from the transom, all the way to the bow of the boat. There were three transverse bulkheads: one at frame 2 (B1) that was the forward part of the transverse bench on the deck, one at frame 6 (B2) just below the sliding door between the cabin and the deck, and one in the foremost part (B3), which constituted the aft bulkhead of the anchor compartment.

The transverse bulkhead, that separated the storage and equipment compartment/bench (C1) aft from the compartment containing the fuel tank (C2), had several penetrations that connected it to both the open deck area forward of the compartment, and to the fuel tank compartment under deck (fig. 14, next page).

The bulkhead that separated the tank compartment from the area under the cabin (C3) had a large cut-out where the aluminum structure had been removed. Forwards of the cut-out, a plywood panel had been fitted as part of the cabin's wooden interior (fig. 15, next page).

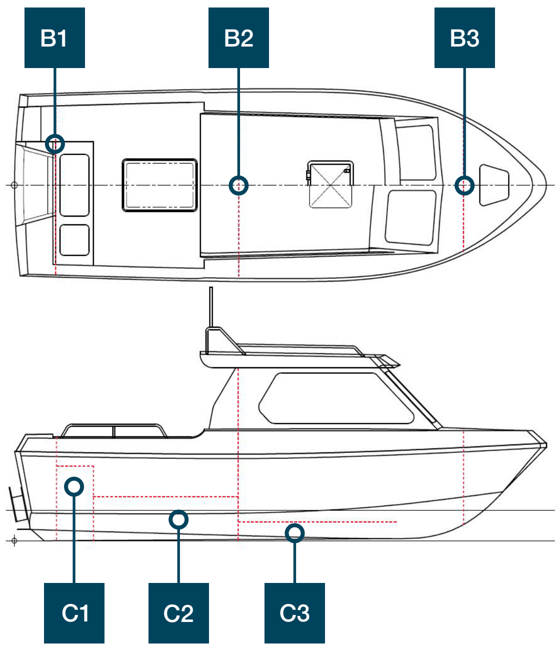

Figure 13: Sketch of compartments and bulkheads under deck
Source: YARO/DMAIB

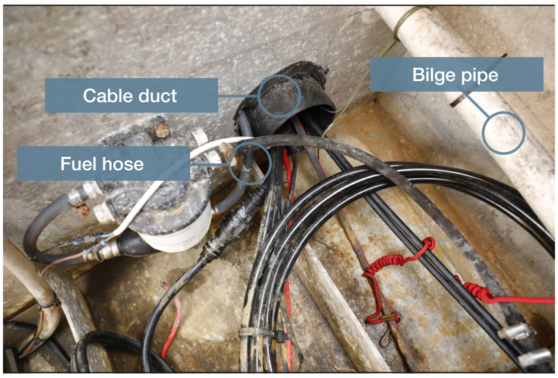

Figure 14: Penetrations in bulkhead between tank compartment and aft storage/equipment compartment.
Source: DMAIB

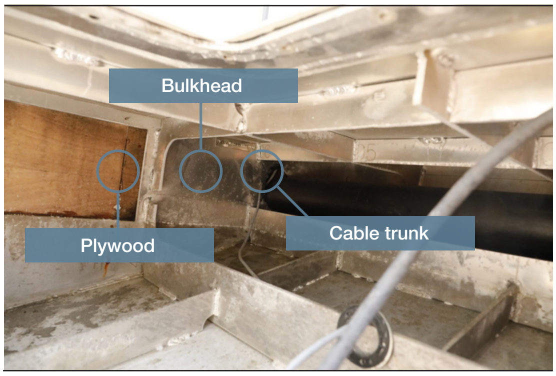

Figure 15: Penetrations in transverse bulkhead, frame 6 between cabin and tank compartment.
Source: DMAIB

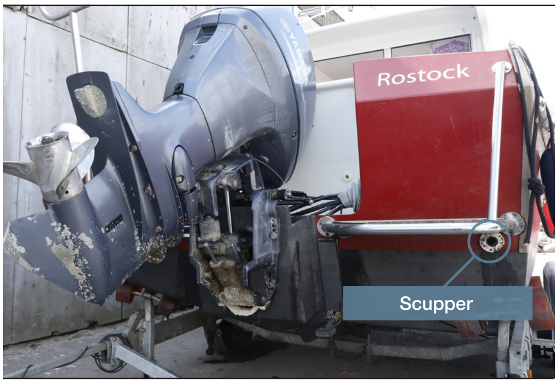

Figure 16: Self-bailing arrangement. Note the absence of non-return flaps on the scuppers outside.
Source: DMAIB

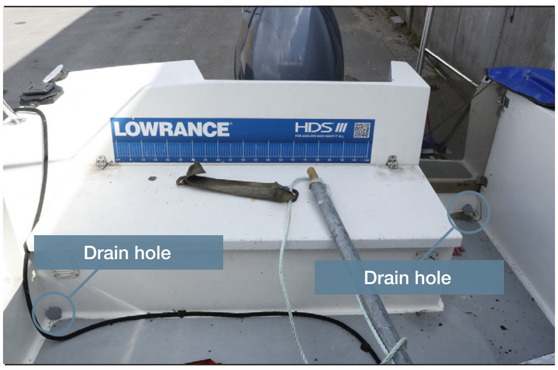

Figure 17: Self-bailing arrangement, plugged drain holes
Source: DMAIB

The deck area aft of the cabin was designed to be partly self-bailing as it had bilge or drain holes in each corner of the aft end (fig. 16 and 17). The intended use of the self-bailing arrangement was that, when the boat passed at speed through the water, bilge water would be ejected through the drain holes, through a pipe in each side, and finally exit through scuppers with non-return flaps in the transom.

Previously, the scientists had experienced that the non-return flaps would become clogged and did not close properly when sailing for instance in areas with a lot of seaweed. Therefore, the flaps had been removed, in agreement with the boat owner. This resulted in unintended water ingress through the scuppers when the boat was reversed, stopped, or was moving forward slowly, for example when hauling nets. On these occasions, water would enter the deck area through the drain holes. To counter this, the scientists had adapted two rubber plugs, which were fitted into the drain holes when such operations took place. The intention was that the plugs should be removed when the boat moved at speed, thus bailing the deck area. On the day of the accident, the plugs were found mounted in the drain holes.

Equipment
The boat was equipped with a 115 HP outboard petrol engine, mounted on an electric/hydraulic remote control system in an engine recess aft. The deck area consisted of an open area with a storage locker/bench placed across the aft end, just forward of the engine recess. The locker contained a bilge pump, a battery, fuel hoses, a filter and electrical cables for the mechanical engine steering and trim controls. An electric net hauler was installed on the port side of the deck area. An approx. 100 l petrol tank was placed under the deck, beneath a flush hatch in the deck.

The standard equipment on board RIGI, which was supplied by the owner comprised: Navigation lights, an anchor and chain, a tool box, fenders, foam-type lifejackets, a first aid kit, a flashlight, day signals, and a harbour guide book. The IfAÖ scientists brought additional equipment with them onto RIGI to supplement the standard equipment provided by the owner. The main safety and emergency items included: Inflatable lifejackets, fitted with PLBs (personal locating beacons), immersion suits with insulating inner suit, and pyrotechnical distress flares. All of these items were packed individually and stored in compartments in the boat's cabin. In addition to the safety equipment, the scientists brought three large bags of gillnets, anchors, marker buoys, a water sample kit, various work clothes and boots, personal items, tools, provisions, laptops etc.

Alterations

In a cooperation between the boat owner and IfAÖ, who had hired RIGI for previous projects, some alterations were made to the boat in order to make it better suited for IfAÖ's research purposes. On the port side of the open deck area, an electric net hauler had been installed, on the port side swimming platform aft a fork for setting nets had been mounted, and in the cabin a second chart plotter had been installed. In addition, an AIS system had been installed, consisting of an antenna and an AIS transmitter.

Approval and certification

RIGI was issued with a ship license by the German Federal Waterways and Shipping Administration who had certified the boat as a recreational craft, limited to a navigational area of max. 3 nm from the coastline, during daytime, in weather conditions up to Beaufort 4-5, with a visibility of no less than 3.000 m.

The boat was certified in accordance with the EU recreational craft directive 94/25/EU . The directive sets the minimum requirements for the design and construction, as well as the trade of boats, personal watercraft, propulsion engines and components. Further, the directive sets out minimum safety and environmental requirements for recreational craft between 2.5 m and 24 m and personal watercraft, which enables them to be sold or used within the European Union.

A recreational craft certified in accordance with the directive should provide two main sources of information to the user and/or owner of the craft: A CE-marking that indicates that the craft has been constructed in accordance with the directive, and which sets the main limits of operation, and an owner's manual that provides the user of the boat with information about safe operation, maintenance etc. of the craft. The boat is with regard to stability and freeboard, buoyancy and floating ability, calculated in accordance with EN ISO 12217-3. From that, the number of persons and loading capacity has been established.

In RIGI's case, the CE-marking plate installed in the cabin next to the steering console, stated the following (fig. 18):

CE-MARKING PLATE	
Manufacturer:	Loon-Yachts
Boat type:	Loon Fishing 642
Design category:	C
Max. allowed no. of persons:	6
Max. allowed load, incl. persons:	740 kg
Max. engine power:	225 HP

Figure 18: RIGI's CE-marking plate
Source: DMAIB

The boat's CE manual was not found on board the boat when examined by DMAIB, and the IfAÖ employees operating the boat were not familiar with the contents of the manual. Similarly, it is unknown whether they were aware of the limitations stated in the official recreational craft certificate.

RIGI's owner's manual (In German: Handbuch für den Bootsführer), which was obtained by DMAIB from the owner, included the following information stated in figure 19:

TECHNICAL DATA	
Length overall:	6.40 m
Breadth overall:	2.30 m
Draught:	Ca. 0.25 m
Weight of the boat:	Ca. 900 kg exl. engine, fuel tank and battery
Max. allowable engine power:	225 HP
Max. allowed no. of persons on board:	6
Max. allowed total load on board:	740 kg
Design category:	C (large lakes and coastal waters)

Figure 19: Technical data from RIGI's manual
Source: YARO

In addition, the owner's manual offered operational advice to the user, such as the following statements (translated from German):

"Because of the light construction, it is recommended that excess load is always stowed in the lower part of the boat. In addition, all persons should be seated on the benches during sailing."

"In its normal operating condition, due to its relatively high freeboard and its good stability, the boat can practicably not capsize or become flooded. This is only possible in the case of inexpedient or incorrect operation. Attention is brought to the fact that, even though the boat in flooded condition is unsinkable, it is only partially suitable as a means of rescue."

This section in the manual explicitly states that the construction of the boat provides enough residual buoyancy so that it will stay afloat after flooding. The text in the manual does not elaborate on whether the boat's residual buoyancy will be sufficient to keep the people on board out of the water, and thus render a liferaft unnecessary. The DMAIB examination of the boat found that its underwater hull consisted of one large compartment, had no watertight divisions, and had no extra means of buoyancy such as foam-filled or closed, void compartments. Therefore, the boat was not unsinkable.

With regard to weather criteria and area of operation, the manual stated that the boat was "Designed for operation in coastal waters, larger bays, estuaries, lakes and rivers, where weather conditions of maximum wind force 6 and 2 m wave height are prevalent". In DMAIB's estimation, on the day of the accident, the boat was operating within the formal limitations stated with regard to wind and wave conditions, and the distance from the shore (see p. 21, Weather). According to the information provided on the owner's web page, RIGI's trade area was within Warnow, Mecklenburger Bucht and Fischland-Darß, and a German 'Sportbootführerschein See' was required to operate the boat.

Loading conditions

Because the boat sank in an undamaged condition, it was relevant to examine the displacement (i.e. the weight of the boat), which determines the freeboard. DMAIB examined the loading conditions of the boat, both in the condition in which it was handed over from the owner to the IfAÖ scientists and the likely condition it was in on the day of the accident.

Displacement

The owner provided two different numbers for the boat's displacement. On the owner's webpage, the displacement of the boat was stated as 1,400 kg, presumably representing the weight of the boat in operative condition when it was handed over to the client, including the standard equipment. In the documentation for the CE-marking of the boat, as well as on the CE-marking plate installed in the cabin, the boat's weight was stated as 'ca. 900 kg, excluding motor, tank and batteries.'

Following the accident, DMAIB weighed the boat with the engine and a full fuel tank. The total weight showed that the boat's displacement was 1,800 kg, i.e at least 400 kg more than stated by the owner.

Payload

In the CE-manual and on the marking plate displayed on board, it was stated that the maximum payload was 740 kg. However, there was a discrepancy between the number stated in the manual and on the plate: According to the plate, the payload was 740 kg excluding fuel tank contents (approx. 100 kg), whereas in the manual it was stated that the tank contents were included in the 740 kg. In other words, the marking plate indicated a payload that was 100 kg higher than indicated in the manual. It is unclear, which of the two payloads is correct.

To assess the payload that was likely on board RIGI when it foundered, DMAIB weighed all the items that were recovered and also those that were on board at the time. For persons, and items, which were not recovered, such as personal belongings, fishing gear etc., conservative estimates were made. DMAIB's calculations suggested that the load on board was likely in the region of 900 kg, some 50 kg more than the maximum allowed payload stated on the boat's CE-plate.

DMAIB can conclude that the combination of a higher displacement and a higher payload meant that, on the day of the accident, RIGI's displacement was at least 450 kg higher than the displacement stated by the owner.

German regulatory requirements

With regard to construction and equipment there were no German regulatory requirements governing RIGI, because the boat was below 8 metres in length. As RIGI was being used in Danish waters there were no German mandatory rules governing the crew's training and certification, as those regulations for these kinds of vessels are only applicable, when engaged in domestic voyages. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) is also not applicable, because RIGI is not a seagoing ship with the meaning of STCW. According to STCW, a seagoing ship is a ship navigating in areas not close to inland or sheltered waters or where port regulations apply."

Persons on board

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On the day of the accident, there were four persons on board RIGI: Three IfAÖ employees, and one Rambøll employee. None of the four were professional mariners, and they had been appointed their tasks primarily based on their key competencies, education and experience as scientists and researchers, and secondarily because of their previous experience at sea. It was however the opinion of both the company IfAÖ and the team, that the recreational craft and safety training certificates they held, and the previous experience from other projects, were sufficient for tasks like the Faxe Bay research.

The IfAÖ scientists were a team of fish biologists that worked together on a daily basis. One of these biologists was the team leader, both in the office and on research projects like the one on the day of the accident. Although the team leader was formally the manager of the other two scientists, in their day to day work, they preferred a more informal work relationship where they divided the tasks between them as they saw fit. On the day of the accident, the team leader was the one steering the boat most of the time, mainly because he was the most experienced.

The IfAÖ team leader held a recreational craft certificate for German waters (Sportsbootführerschein), and he had approximately 20 years of experience operating recreational craft, both for leisure and work related. He also held a BOSIET certificate (Basic Offshore Safety Induction and Emergency Training), which is often a minimum requirement when working on, for instance, off-shore installations such as wind farms. He had been with IfAÖ for approx. nine years, during which he had participated in several research projects similar to the Faxe Bay campaign. The other two scientists held similar recreational craft and BOSIET certificates, and had been with IfAÖ for approx. nine and eight years respectively. They also had extensive experience with research projects at sea.

The observer had been employed by Rambøll as a geologist since 2015. One of the requirements from the Danish authorities for granting permission to conduct the surveys was that a Rambøll employee, a Danish citizen, should participate as an observer during all surveys. Rambøll had therefore appointed eight employees to take turns for the task, one of them being the geologist on board RIGI at the time of the accident. She held a BOSIET certificate, an additional offshore safety certificate, and a health certificate for mariners and fishermen.

The observer, as well as the other Rambøll employees, had mainly been appointed for the task based on availability and their varying degrees of previous experience from other projects, which were of a more or less similar nature. Apart from observing the work and reporting to authorities at the beginning and at the end of each survey, she had no other task on board the boat. She had participated in previous research trips on board RIGI earlier in the campaign.

The weather

Project organisation | The boat | Persons on board | | The foundering | Emergency preparedness | The fatality | Safety management

Preparing for the day's work, the team leader had consulted the weather and marine forecasts on the webpage of The Danish Meteorological Institute (DMI). For the morning of the day of the accident, 23 April, the forecasts predicted light wind and waves of up to 0.5 m. The weather was expected to worsen around noon, with stronger wind, and a wave height of approx. 1-1.5 m. In the scientists' experience, it was difficult and uncomfortable – but not unsafe - to work on the boat in conditions where the wave height exceeded 0.5-1.0 m. Therefore, this had in the past been the limit for when work would be cancelled or postponed, and was also the reason for the intention to start and finish work early on the day of the accident.

The scientists' perception of the development in weather conditions on the day of the accident corresponded well with the predictions, except for the fact that the increase in wind speed and change of direction occurred earlier than anticipated.

They had expected the change to happen around noon when in fact, just after hauling the last nets at around 0950, they experienced a rapid increase in wind speed and a change of direction of waves and wind. In their perception, the wave height at this time also rose from approx. 0.5 m to 1.0-1.5 m. This was the reason for the decision to change course towards Lund Harbour instead of returning to Faxe Ladeplads.

Following the accident, DMAIB acquired and analysed weather data from DMI. This included data which was available during the time leading up to the day of the accident, updates during 23 April, and observation and model data from the same period. DMAIB's examination of the forecasts available prior to the accident, and DMI's observations and model calculations after the accident, showed that the conditions in the area largely corresponded with the scientists' perceptions, except the model data showed no significant increase in wave height during the day, as perceived by the persons on board RIGI. The data showed an average wave height in the period from 0500 to 1700 of 0.65 m, with only a slight increase towards the late afternoon.

The difference between the scientists' perception and the available data has two likely explanations:

- DMI's model data is the result of computer calculations, based on observational data that are not from the exact position of the accident. Therefore, it is possible that larger waves than those calculated may have occurred locally.

- The perception of how high waves are, is influenced by the boat, its freeboard, its speed, direction of impact, and the interaction between waves, current and swell.

When a significant change in wind direction occurs, a period will follow where the direction of wind, waves, current and swell will interfere, resulting in choppy, irregular sea. Experienced from a small boat, close to the surface of the sea, such waves can appear quite forceful, and perhaps higher than they are. Figure 20 illustrates the approximate changes in the directions of wind, waves and current at the time of departure, after hauling the last nets, and around the course change towards Lund.

The air temperature at the time of the accident was 13-14°C, and the water temperature was 8°C.

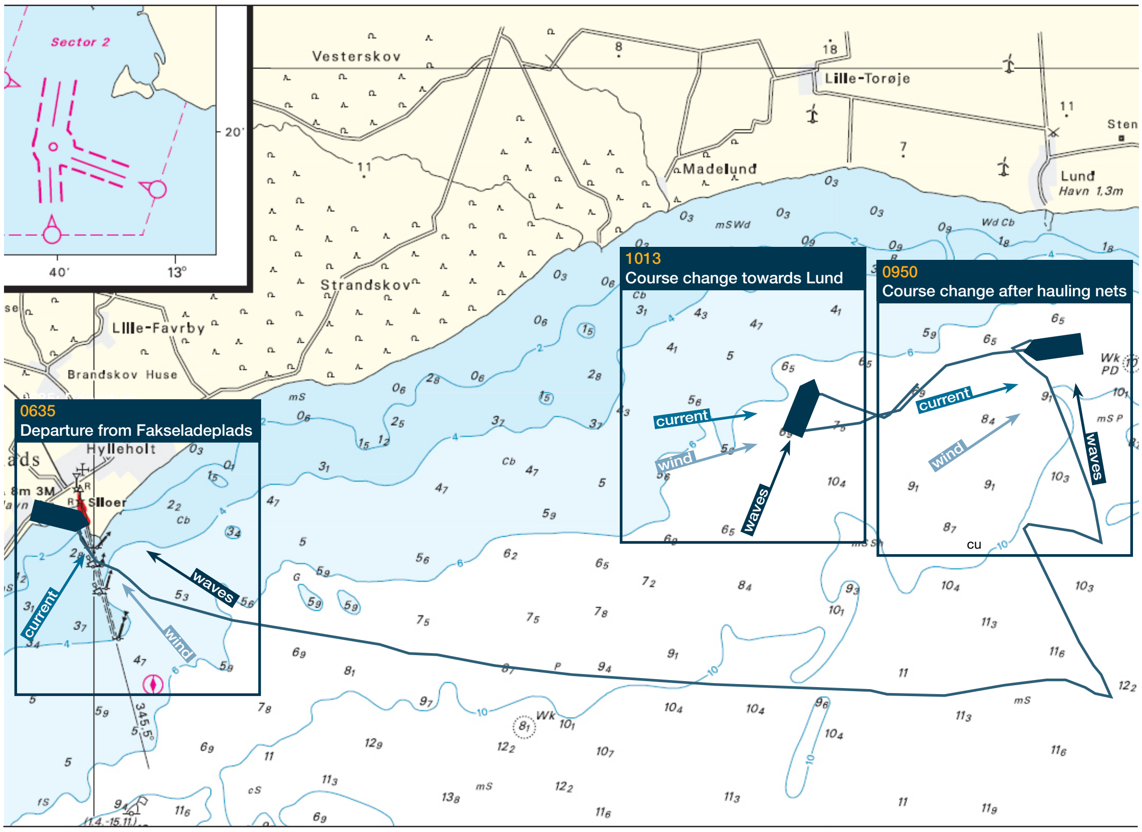


Figure 20: Weather and sea changes on the day of the accident
Source: Danish Geodata Agency/DMAIB

The foundering

In the period immediately leading up to the flooding, the scientists had decided to change course towards Lund Harbour because the weather meant that it was uncomfortable to be on board RIGI. Lund Harbour was much closer than the original destination, Faxe Ladeplads, but the course change also meant that the boat was now sailing in following sea. When RIGI sailed in following sea, the persons on board felt that the boat's motions were reduced, and the team leader considered it safer than sailing with the sea abeam.

There are potential challenges associated with sailing in following sea, i.e. waves moving in the same direction as the boat:

- Waves coming from behind the boat can overtake the boat, lift up the aft end and capsize the boat.

- When the boat rides down a following wave, there is a risk that the bow will plough into the sea and/or that the aft end will set heavily in the sea.

- If the aft end is lifted out of the water, or if the aft end sets in the sea, the boat can lose speed, which in turn increases the risk of the waves catching up with the boat, thus flooding it from the aft.

In RIGI's case, sailing in the following sea, after the course change, allowed the waves to catch up with the boat and flood it from the aft. The overload, and the fact that the persons on board, as a natural response to the situation, rushed to the aft deck, meant that RIGI's aft end settled even deeper into the sea, making it easier for the next wave to enter the boat because of the lower freeboard. When the first wave came over the aft end, the engine stuttered and then stopped, either because water entered the air intake or because water affected the electrical installations. Once the boat had been flooded, it was a matter of seconds before it lost buoyancy and sank.

RIGI was flooded when two large waves came over the stern within a short timeframe, probably one or two minutes. The first wave flooded the deck area and flowed into the cabin, filling it to ankle level. The next wave flooded the boat entirely, which caused it to sink immediately by the port aft side first. Subsequent examination of the boat revealed no external damage to the boat, which could have contributed to the sudden flooding.

The boat was constructed with no watertight subdivisions, which meant that in essence the boat's hull was one large compartment. Therefore, once one compartment was flooded, there was no residual buoyancy to keep the boat afloat. RIGI was not equipped with emergency bilge pumps or other means of quickly bailing the boat. Although the boat had a self-bailing system fitted in the open deck area, and a bilge pump, neither of these arrangements were intended for emergency bailing, but rather for removing smaller quantities of water that entered the boat when for instance hauling nets, during rain showers, or when wind and waves would cause seawater to spray over the boat. Therefore, it was not significant for the foundering that the bilge holes were plugged when large quantities of water entered the boat.

The owner's manual stated: *"In its normal operating condition, due to its relatively high freeboard and its good stability, the boat can practicably not capsize or become flooded."* DMAIB found no indication that the boat was in fact constructed with for instance foam-filled or air and watertight compartments to a degree that could justify the claim that the boat was unsinkable.

As discussed in the previous section, RIGI's displacement was higher than the displacement stated by the owner, and in addition, at the time of the accident, the boat was loaded heavier than the CE certification and marking recommended. The overload, while not crucial in itself, meant that the amount of water necessary to flood and sink the boat was lower than it would have been, had the requirements been met.

When the first wave entered RIGI, the persons on board did not consider the situation an emergency. Two of the scientists went on to the open deck and began bailing and throwing weight overboard to remedy the situation. Meanwhile, the team leader, as a safety precaution, ordered that they should all begin donning immersion suits and lifejackets. While they were preparing for a possible, but in their minds still unlikely, evacuation, more water entered the boat within a short time, and the situation was suddenly an emergency. When the boat started to sink, they were in the process of donning their immersion suits. Thus, the abandoning of the boat was not an intentional action, but rather a matter of the boat sinking under them.

Emergency preparedness

RIGI was equipped with emergency equipment for different types of emergency situations. In this section the emergency equipment relevant in connection to the foundering and subsequent evacuation of RIGI will be described. Furthermore, the deployment of this equipment on the day of the accident will also be described.

Some of the emergency equipment was on board RIGI as a part of the boat's standard equipment, and other equipment was brought on board by the IfAÖ scientists as personal safety equipment.

Emergency equipment on board RIGI

Immersion suits

The IfAÖ scientists had brought four immersion suits of the type Ursuit RDS Wind Energy on board RIGI in the sizes L and XL. The immersion suits were kept in their designated storage bags and were stowed in the compartment left of the helm inside RIGI's cabin and underneath the seat at the helm.

The immersion suits on RIGI were constant wear immersion suits designed for wind farm transit and were to be worn as a working suit (fig. 21).

Figure 21: Immersion suit from RIGI
Source: DMAIB

Figure 22: Thermal underwear for immersion suit from RIGI
Source: DMAIB

In case of accidental immersion in water, this type of suit provides thermal protection with the purpose of reducing the risk of cold shock and delaying the onset of hypothermia. The suits' protection time for water temperatures between 5-10° C is estimated to be 2.5 hours. The suit is a watertight, non-insulated shell without integrated buoyancy.

In order to provide protection, it is required that warm underwear is worn underneath the immersion suit, that the suit is of the right size, that it is donned correctly, and that it is used in combination with a lifejacket. Four thermal suits of the type Ursuit X-Tex Finnfill Light in the sizes L and XL were also brought on board by the IfAÖ scientists and were stored together with the immersion suits (fig. 22, previous page).

The size recommendations were similar for the immersion suit and the thermal inner suit. Size L was recommended for persons with a height of 170-182 cm and a chest circumference of 104-112 cm. Size XL was recommended for persons with a height of 182-194 cm and a chest circumference of 112-120 cm.

On board RIGI, the immersion suits primarily had the function of being emergency equipment and not working suits. The suits were intended to be donned in the event that an emergency arose which required the persons on board to leave the boat while being at sea.

Lifejackets

There were two types of lifejacket on board RIGI: six lifejackets of the type Plastimo Storm 2 150 N and four of the type Secumar Alpha 275 TWZ PLB SOLAS (fig. 23 and 24). Both jackets had the purpose of being a floating aid to keep the respiratory passages above the surface of the water .

The Plastimo Storm 2 type is floatation block lifejacket. These lifejackets were a part of RIGI's standard equipment and were stowed in the locker benches in the cabin. DMAIB found four of the lifejackets on board RIGI after the boat had been salvaged.

The Secumar Alpha 275 TWZ PLB SOLAS lifejackets were brought on board by the IfAÖ scientists as a part of their personal safety equipment. The Secumar lifejackets were kept in storage bags and were stowed in the locker benches in the cabin.

This type of lifejacket features automatic inflation when the lifejacket is immersed in water. A spray hood was fitted on the lifejacket to reduce the risk of drowning in waves. Furthermore, the lifejacket was equipped with an AIS-SART (fig. 25, next page) of the type Weather Dock easyRESCUE-A, which is also automatically activated when immersed in water. When the AIS-SART is activated it transmits a distress signal and a GPS position to all AIS receivers within range.

Figure 23: Plastimo Storm 2 lifejacket
Source: DMAIB

Figure 24: Secumar Alpha lifejacket - inflated.
Source: DMAIB

Figure 25: AIS-SART attached to Secumar lifejacket
Source: DMAIB

The distress message does not include information on the type of distress. The AIS-SART is a passive emergency communication form, as it does not facilitate two-way communication.

The inflatable Secumar lifejacket is designed to be worn during work, while the Plastimo Storm is not ergonomically designed for the purpose of work. Both lifejackets are passive emergency aids designed to minimise the risk of drowning until rescue arrives, facilitate the visual location of the distressed person wearing the lifejacket, and aid in the recovery of the person from the water. They are not designed to facilitate the distressed person actively engaging in their recovery from the water. This means that the vests are not designed for swimming.

To provide protection it is crucial for both the floatation block vest and the inflatable lifejacket that the straps are fitted tightly to the person wearing the vest. If the vest is not donned correctly and the straps are not fitted tightly, the vest may counteract its purpose of keeping the respiratory passages out of the water.

On RIGI, the IfAÖ scientists and the observer did not wear lifejackets while the survey in Faxe Bay was being carried out. The lifejackets were meant to be donned if an emergency requiring the persons to leave the boat at sea occurred. The scientists expected that the rescue services would arrive within 60 minutes of one of the lifejacket's distress signals being transmitted.

The lifejackets were not worn during fishing, as the risk of falling over board was considered to be low and it was also considered easy to recover a distressed person from the sea.

Mobile phones
The scientists and the observer carried their personal mobile phones on board. One of the phones was stored in a watertight box which was stowed in a locker bench in the cabin. If an emergency situation occurred, the persons on RIGI were to call for help by means of a mobile phone. A laminated flowchart (fig. 26) showing who to contact in a prioritised sequence was situated next to the wheel. As the mobile phones were not waterproof, the emergency communication by phone was only possible in dry conditions on board the boat.

Traditionally, VHF radio is used for emergency communication at sea. This was not deemed necessary on RIGI as the survey was carried out close to the shore and within coverage of mobile phone signal. Furthermore, the persons on board did not have a certificate for VHF radio communication.

Distress flares
A distress signal flare was stowed in the locker benches in RIGI's cabin. In case of emergency, the flares could be launched from the boat or by a person in the water to signal the need for help. The distress flare was kept in its package and was of the type NICO Signal (fig. 27, next page). The flare has a shot height of 80 m, a burning time of 6 seconds, and has the capacity for six shots.

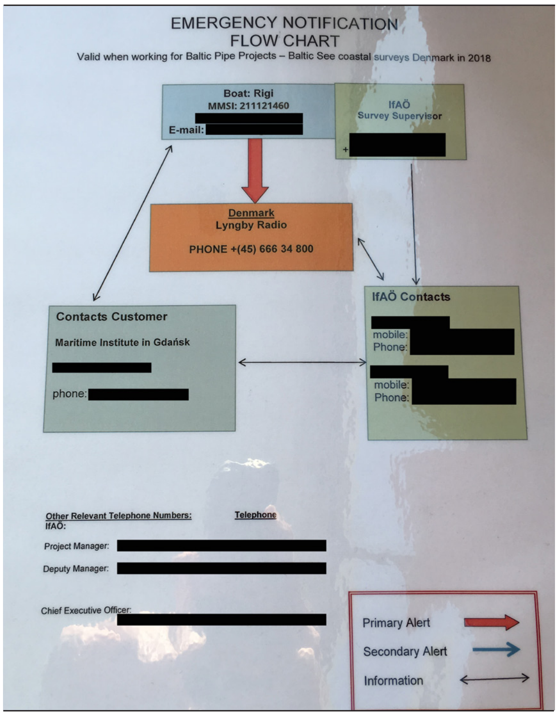


Figure 26: Instruction for emergency notification on RIGI. The flowchart has been anonymised by DMAIB.
Source: Private photo

Figure 27: Distress flare
Source: DMAIB

Use of the emergency equipment on the day of the accident

In case of evacuation, the persons on board RIGI had to find and don the thermal inner suits, the immersion suits and the inflatable lifejackets and then phone the emergency contacts and collect the emergency flare before leaving the boat. On the day of the accident, there was a very short time span between the first wave that gushed into the boat and made the team leader suggest that the others should don the immersion suits, and the second wave that made the boat sink and required the persons to leave the ship immediately. Due to a lack of time, it was not possible for the persons on board to utilize all the emergency equipment as intended. In the following, the use of the different types of emergency equipment on the day of the accident will be described:

Emergency communication

When the second wave gushed into the boat shortly after the first and the boat started to sink rapidly, the first impulse of the persons on board was to don their immersion suits. As the boat sank rapidly, there was no time to use the mobile phone to call for help before leaving the boat to avoid getting trapped in the flood of water in cabin. All phones were lost in the water, except for the mobile phone that was kept in a watertight container in a bench. It was not possible to retrieve this phone after the boat had sunk. Therefore, the main emergency contact Lyngby Radio did not receive information regarding the emergency situation.

No persons on board had the time to locate distress flares in the tightly packed locker benches in the cabin. Therefore, the scientists could not fire the distress flare to signal for help when they had left the ship. The scientists trusted that the AIS-SART on the lifejackets inside the cabin would transmit a distress signal, and that help would arrive within 60 minutes. However, as the lifejackets were inside the boat, it was not possible for them to verify whether the AIS-SART had been activated or not.

The scientists were trained to stay at the boat in the water and wait for help. Approx. 1.5-2 hours after the boat sank, two of the scientists were shivering uncontrollably from the cold, and they realised that their survival depended on getting help quickly. From the water by the boat, the scientists could see cars and persons moving at Lund Harbour. They had tried to shout and wave for help, but were not seen or heard, so the team leader and observer decided to swim to shore and call for help, as they were in the best condition. As they could see persons walking on the shore, the distance seemed manageable. The shortest distance from the foundered boat to the shore was approx. 0.9 nm.

The forward movements of their swimming were obstructed considerably by the waves, and the current made them drift east of the closest point to the shore, the pier at Lund Harbour, which made the distance longer. It took approx. 3 hours for the team leader to swim the distance of approx. 1.1 nm to shore where he received help from passing persons, who contacted the emergency services (fig. 28, next page).

Because the scientists were unable to call the rescue services by phone, the scientists were dependent on the AIS-SART to send a distress message to AIS receivers nearby. Because the scientists lacked distress flares they could not signal for help. Therefore, their only option was to swim to shore in order to alarm persons. Due to their trust in the AIS-SART and the subsequent wait at the boat, followed by the time it took to swim for help, the rescue services were not notified of the emergency until 3½-4½ hours after the foundering.

DMAIB has concluded that the AIS-SART was in working order, however it was not activated until the boat was towed during salvage.

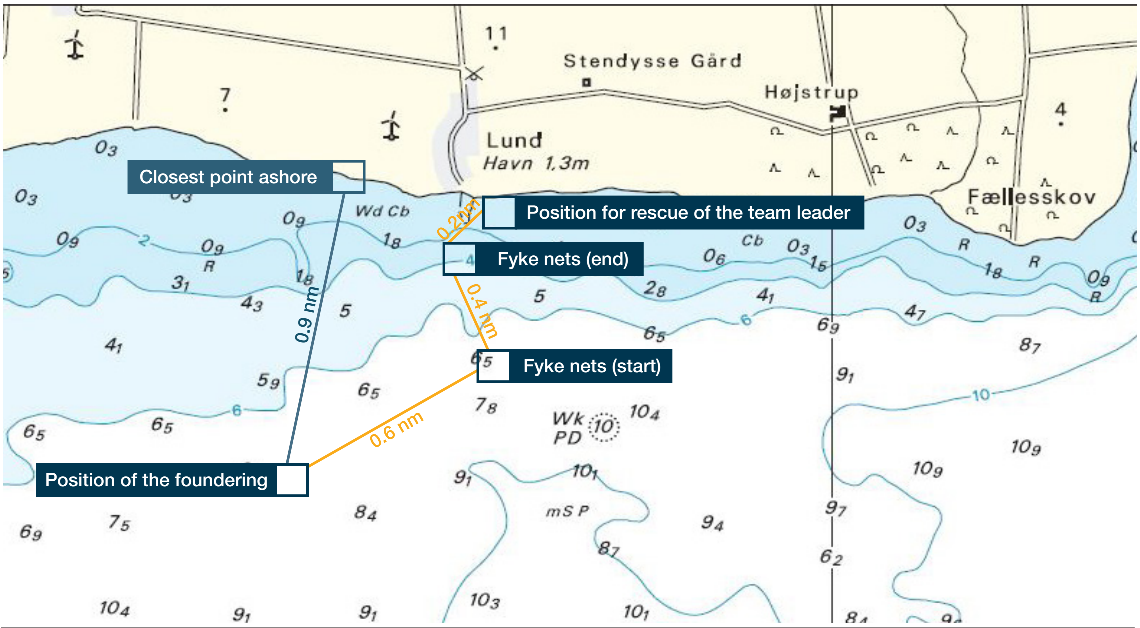


Figure 28: Distances for swimming for help. Team leader's route marked in yellow.
Source: Danish Geodata Agency/DMAIB

Emergency equipment for immersion

The emergency equipment for immersion consisted of three parts: thermal suit, immersion suit and the lifejacket. Due to the rapid sinking of the boat, the immersion suits were the only equipment used on the day of the accident, because the scientists had to escape the water flooding into the cabin. The observer was wearing the thermal suit underneath the immersion suit. The immersion suits were donned in a hurry. The zipper on the team leader's suit broke at the neck making it impossible to close the immersion suit entirely. The observer's suit was not closed entirely at the neck either.

One scientist did not get the immersion suit on, and one did not manage to zip up the suit before being immersed in water. As the immersion suits were partially open, they filled with water at different rates depending on how open they were. The scientist who got a suit, but did not manage to zip it up, found that the suit filled with water as soon as he was immersed in water. The water made the suit so heavy that he was not able to move without assistance, and his body was quickly affected by the cold water. The team leader's and the observer's suits which were not closed entirely at the neck, were slowly filled with water while they were swimming to shore.

As water entered the suits, they became heavier, which made movement more difficult and their body temperature decreased. As the suit got heavier and colder, the task of reaching the shore became more difficult.

The immersion suit was to be worn with a lifejacket and warm underwear and needed to be entirely closed to protect the wearer from hypothermia and drowning. When the immersion suit is not used according to the instructions, it can start to work against you in an emergency situation. If water enters the suit, it will become heavy and obstruct the movements of the person wearing it. If worn without lifejacket and water comes into the suit, the risk of drowning will increase as the suit will keep the person floating low in the water requiring great effort to keep the respiratory passages out of the water.

The immersion suits on RIGI were non-insulated and without buoyancy. As it needed to be donned along with two more pieces of equipment to provide protection from hypothermia and drowning, it was not compatible with the very short response time that is characteristic for emergency situations on board small vessels.

The fatality

When RIGI sank, and the four persons on board ended up in the sea, three of them survived and one – the observer – perished. As discussed in the previous section, the contingency plans for RIGI in case of abandoning the boat in broad terms consisted of two measures: 1) To don immersion suits as thermal protection and lifejackets to protect against drowning, and 2) To rely on external rescue assistance. On the day of the accident, both parts of the plan failed. The persons on board did not have time to properly don the immersion suits because the boat sank suddenly, and they did not have time to don lifejackets at all. The second part of the plan, external rescue, failed because the scientists had no effective means of informing others about the emergency.

For a period of time, probably 1-1½ hours, the four persons stayed passively by the boat, expecting help to arrive. When they realised that help was not coming, their status changed to actively seeking to rescue themselves. The team leader and the observer considered themselves having the best prerequisites for swimming towards shore, as they felt relatively dry and warm, having managed to don the immersion suits. When they started swimming, the observer's suit provided buoyancy because it was air-filled, and water had not yet entered the suit. However, as the two had fought their way towards the shore, the observer's suit gradually filled with sea water through the neck collar. The team leader noted that during the first stages of swimming, the observer gradually began to lie lower in the water and, as a result, it became harder to swim. When they approached the fyke nets, the team leader noted that the observer had become increasingly more difficult to communicate with, and she herself stated that she was exhausted and could not go on. The team leader, himself also exhausted from the strenuous long swim in cold sea water, therefore left the observer at the fyke net pillars, and instructed her to stay there and hold on while he continued towards the shore. Although she wasn't swimming anymore, she was still exposed to the cold water, the wind and the waves.

What happened while the observer stayed at the nets, and the team leader continued towards shore, is unknown. The observer was located by the rescue helicopter crew approx. 1 hour and 20 minutes later, after the team leader had reached the shore and made contact with the assisting persons. They in turn had initiated the search and rescue operation by alerting the emergency services. The observer was found lifeless, approx. 1.8 nm east-southeast of the fyke nets, upright in the water with her face near the surface (fig. 29).

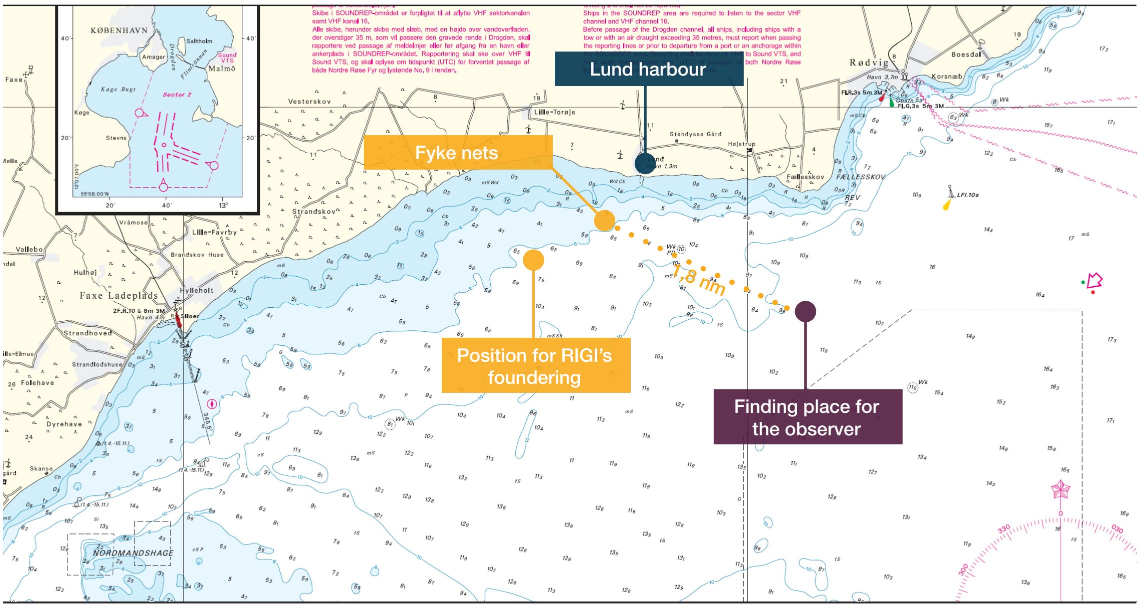


Figure 29: Finding place for the oberserver during the SAR operation
Source: Danish Geodata Agency/DMAIB

She was brought on board the helicopter and received first aid on the way to the hospital, where she was later pronounced dead.

Examination of the observer's clothing showed that her immersion suit contained a minimum of 40 litres of water. Just as the team leader's observations indicated, the suit had not been entirely closed at the neck. The observer wore a size XL inner suit and a size L outer suit, which would have made it uncomfortable or impossible to close the suit at the neck, which meant that sea water gradually filled the suit. Wearing a water-filled immersion suit will not drag the person under water but will rather cause the person to become heavier and become suspended in a natural equilibrium (Danish: "malflyde"), deep in the water, which is consistent with the observer being found in an upright position with her head and face close to the surface.

When a person is immersed in cold water, a state of hypothermia can occur, which means that the body's core temperature drops below 35°C. There are different stages in the body's response to hypothermia. Initially the body starts to shiver to raise the body temperature. After this, the blood supply to the muscles in the extremities will minimise to slow down the lowering of the core temperature and protect the vital organs.

At this stage, the hypothermic person will experience impaired body movements and increasing confusion, and they will begin to slur their speech.

In water at a temperature of 8°C, it is estimated that a person of average build will experience exhaustion and become unconscious within 30-60 minutes provided that an aid to keep the respiratory passages above the water level, such as a lifejacket, is used. If the person is physically active, e.g. swimming, the blood from the cooled extremities will begin to circulate, causing the core temperature of the body to drop at a faster rate.

The exhaustion caused by hypothermia makes it increasingly difficult to keep the respiratory passages above the water and can hence lead to drowning. In broad terms, drowning can occur in two ways. When a person is submerged in water, i.e. entirely under the water, there is a natural reflex to hold one's breath until eventually they can hold their breath no longer and water is then inhaled into the lungs. When a person is immersed, i.e. in the water but with the head and airways above the surface, drowning can occur as a result of small amounts of water reaching the larynx, which causes a reflex where the vocal cords seal the airways, making breathing difficult or impossible.

Safety management

Each of the organisations involved in the marine biotic survey conducted on RIGI on the day of the accident had implemented a quality management system (QMS) which was the main instrument for ensuring a certain level of safety for the organisations' employees, who were on board RIGI. The QMSs contained, among other, equipment requirements, risk assessments and emergency procedures. DMAIB has found it relevant to investigate how the quality management systems were used, in connection to the marine biotic surveys prior to the accident, to establish whether the safety standard described in the QMS was maintained across the project's organisations.

Purpose of the QMS

Rambøll had implemented a QMS with the purpose of establishing and describing the level of quality of the deliveries and outcome of the project, as well as standards for safe execution of the project.

Furthermore, the QMS had an incorporated work process for how to verify that the described level of quality and safety was is in place. The QMS was based on the ISO 9001 standard, and in order to ensure that their quality level was maintained, when parts of the project were outsourced to subcontractors, Rambøll chose to collaborate only with ISO 9001 certified subcontractors. This was preferred, as the ISO certified subcontractors were able to document their level of quality, and furthermore the ISO 9001 standard worked as a common language between contractor and subcontractor. Both MIG, MEWO and IfAÖ had implemented QMS systems, which were in accordance with the ISO standard.

Subcontractor audits as a tool for control

As the ISO certification indicated that the organisations performed on a professional level, this resulted in a high degree of trust between the contractors and the subcontractors, e.g. between Rambøll and MIG/MEWO and between MIG/MEWO and IfAÖ. This level of trust was enhanced as the subcontractors were hired to provide an expertise which the contractor did not possess in-house. The contractors, Rambøll and MIG/MEWO, carried out audits of their subcontractors as an integral part of their quality management system, to verify that the subcontractor met the agreed level of quality. The subcontractor audit had the purpose of verifying that the subcontractor's quality management system was in place and was implemented.

By means of the subcontractor audit, the contractor could check that a certain standard was maintained by the subcontractor. Hence, the subcontractor audit made it possible for the contractor to control the process and the quality of the project management as well as work carried out outside the contractor's own field of expertise. This was useful when tasks were outsourced to specialists. In this respect, the subcontractor audit was supposed to work as a safety barrier against a drift towards lower standards.

On the Faxe Bay project, Rambøll carried out a subcontractor audit of their subcontractor MIG/MEWO, and MIG/MEWO carried out an audit of IfAÖ. Furthermore, Rambøll also carried out a subcontractor audit on RIGI as Rambøll employees were being sent to work on board the vessel. On figure 30, a flowchart shows the various audits and inspections carried out on different levels across the organisations involved in RIGI's operation in Faxe Bay.

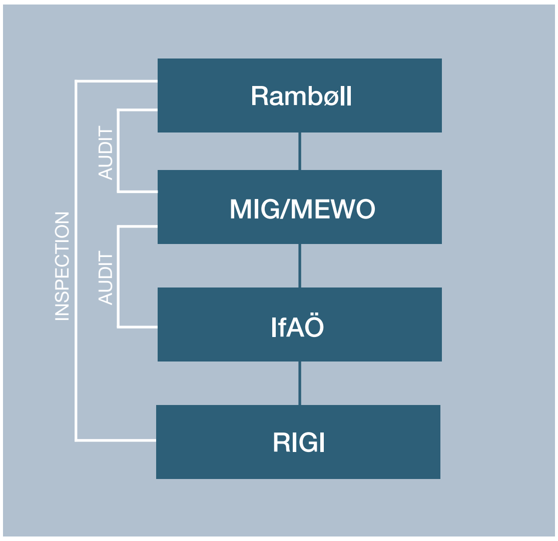
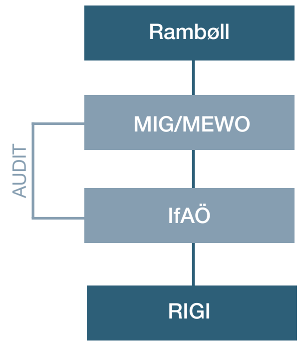


Figure 30: Chart of audits and inspections carried out in connection to RIGI's participation in the surveys
Source: DMAIB

DMAIB found it relevant to investigate the subcontractor audits to establish whether the organisations' QMS standards were adhered to, when the organisations passed on parts of the project to subcontractors. The investigation focused on the safety relevant topics, such as emergency procedures, risk assessments and emergency equipment. DMAIB revealed relevant findings concerning the use of the quality management system in MIG/MEWO's subcontractor audit of IfAÖ, and in Rambøll's subcontractor audit on board RIGI. These will be described in the following subsections.

MIG/MEWO - Subcontractor audit of IfAÖ



As a part of the contract between Rambøll and their subcontractor MIG/MEWO, MIG/MEWO provided an implemented HSEQ management system which comprised, inter alia, risk assessments and emergency procedures. The HSEQ management system was to be described in a method statement, which was prepared by MIG/MEWO and approved by Rambøll.

The risk assessments and the emergency procedures in the HSEQ section of the method statement were generic. This meant that the risk assessments and emergency procedures were not vessel specific, but reflected a general perception of the risks that were relevant for working on board a ship, while the emergency procedures were based on commonly used best practises in the industry. For the emergency procedures it was stated that the procedures could vary on board the individual vessels, according to the size of the vessel and the required equipment. The emergency procedure for evacuation stated in the method statement can be seen in figure 31, next page.

Methods statement — Ichthyofauna

10.4.13.5 Evacuation

Function	**ABANDON SHIP** **ALARM** **Alarm bell – single long signal**
Captain	Whenever necessary, the Captain transmits the emergency signal by radio (DSC on the UKF and DSC on the HF/MF), providing the coordinates of the vessel and the type of emergency. The Captain coordinates the actions from the bridge. The Captain raises the general alarm, gives the order to abandon the ship. The Captain is the last person to leave a ship and enter a lowered lifeboat. The Captain collects pyrotechnic articles, the VHF portable radio, and Aldis lamp with the battery transponder.
Watch-keeping officer	On the Captain's order, the watch-keeping officer collects the vessel documents, first-aid kit, and the second UKF EPIRB radio system. The officer maintains constant radio contact with the captain at 17 UKF channel. The officer checks whether the crew and other people on board had put on their survival suits and safety belts correctly. The officer takes his/her place in a lifeboat.
Engineering officer	Stays in the machine-room throughout the action. Having secured the machine-room, the engineering officer collects the documents, shuts all the hatches, and heads to one of the lifeboats on the Captain's order. Together with the bosun and the seaman, the engineering officer launches the lifeboat(s) onto the water.
Able body/bosun	The able body/bosun collects the blankets. Having obtained information from the seaman; he/she shuts the outer door and on-board hatches. The able body/bosun releases the lifeboat(s) specified by the Captain. Together with the engineering officer and the seaman he/she launches them into the sea, and after it/they are open, he/she secures and helps the watch-keeping officer in managing the abandon the ship action.
Seaman/cook	Seamen/cook checks whether everyone had left the cabins, informs the bosun about the completed action, after which he/she collects food and drinking water, goes to the upper deck and helps the bosun in making the life-saving equipment ready for use.
AFTER THE GENERAL ALARM IS RAISED, EVERYONE PUTS ON THE SURVIVAL SUITS AND SAFETY BELTS.	
MEETING POINT FOR THE SURVEY TEAM – THE OPEN PART OF THE MAIN DECK AT THE STERN.	

Figure 31: Emergency procedure for evacuation in the method statement
Source: Rambøll/MIG/MEWO

The emergency procedure for evacuation in the method statement was prepared for a larger vessel with a designated professional crew on board. In the procedure, tasks are delegated to each crew member in advance, and the procedure presupposes the availability of standard emergency equipment such as lifeboats and VHF radio. RIGI was a small boat without a professional crew on board, without VHF and without lifeboat or liferaft. Hence, the procedure described in the method statement was not possible to implement on RIGI.

MIG/MEWO had verified that IfAÖ had a quality management system in place which was certified according to ISO 9001 and OHSAS 18001.

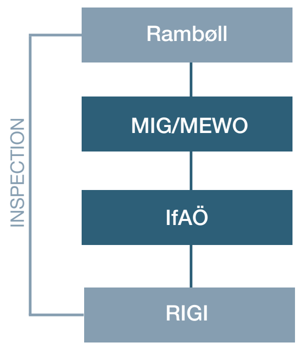
MIG/MEWO had received a German version of this system but they were not sufficiently proficient in the German language to fully understand the contents of the documents. As MIG/MEWO trusted the OHSAS certification and that the company had implanted their own system on board, it was not verified whether emergency procedures equivalent to the standards in the method statement were provided on RIGI. Besides the trust in the IfAÖ's quality management system, MIG/MEWO did not find it applicable to have emergency procedures on a small vessel like RIGI. Although the method statement promised that the HSEQ standards were implemented, MIG/MEWO did not ensure that emergency procedures for RIGI were in place.

DMAIB has found no documented emergency procedures for RIGI other than a flowchart of who to contact in case of an emergency. No written guidelines on how to act in different emergency situations was prepared for RIGI. DMAIB found that the phone numbers for the Danish coastal radio Lyngby Radio and the Danish Navy's rescue services in the list of emergency contact points in the method statement and the flowchart on emergency contact were outdated.

Furthermore, the recommended way to alert the Danish rescue services for vessels without VHF is to call 112. If the connection is lost, the emergency call centre is able to locate the signal of the mobile phone, and calls to 112 are ensured better coverage.

RIGI had no VHF on board and no liferaft or lifeboat, and the employees on board were dependent on their mobile phones, lifejackets and immersion suits in case of an emergency. DMAIB considers this to be a considerable lowering of the safety standards from what the method statement describes.

Rambøll - Inspection on RIGI



According to Rambøll's own policy, the company took responsibility for the safety of their employees when working on board a ship or a boat, as well as in all other work settings. To ensure that a HSE system was in place to provide the safety of the persons on board according to the agreement between Rambøll and their subcontractors, audits were carried on board by Rambøll employees when ships served as a work setting. Furthermore, Rambøll's quality management system required that a risk assessment was carried out and approved by a project manager.

Prior to the survey's spring campaign, an audit had not been carried out on RIGI, and therefore it was not verified whether a safety system was in place on board. It had been discussed, internally in Rambøll, whether it was necessary to carry out audit on RIGI, as RIGI was only a small boat, and the marine biotic survey was being carried out close to shore. During the survey's spring campaign, Rambøll however decided to conduct a simplified inspection instead of an audit. A formal risk assessment was not carried out and approved for the work on board RIGI.

On 20 April 2018, three days before the accident, one of the Rambøll observers carried out a simplified inspection on board RIGI to check whether the ship was in compliance with the HSEQ chapter in the method statement provided by MIG/MEWO.

The reason for conducting only a simplified inspection, was that there was a perception that the method statement was prepared for larger ships than RIGI, and therefore it did not make sense to audit the boat on these terms, as RIGI was only a small boat. Rambøll did not provide other instruments for the inspector other than instructing him to use the method statement as guidance, though it was recognised that it did not fully apply to a boat like RIGI, and using his own sound judgement. The inspection on RIGI therefore focused on the items in Rambøll's genereic template for ship audits which were possible to inspect on RIGI.

1) Training
The inspector checked the IfAÖ employees' certificates and found that all had valid BOSIET certificates and medical certificates. These were Rambøll's requirements for the scientists participating in the survey. The report did not include inspection of the IfAÖ employees' certificates concerning their navigational or maritime skills. The inspector had no basis for verifying whether the persons from IfAÖ had the required certificates and training for navigating the boat for this type of operation.

2) Emergency procedures
The inspector was introduced to the emergency procedures on board. This consisted of familiarisation with a flowchart of who to contact by phone in case of an emergency, and an instruction on how to react in case of an emergency. The inspector was instructed to alert a crew member in case of an emergency and wait for instructions. The IfAÖ scientists explained how they would handle two specific emergency scenarios; fire and man over board. The inspector was told that there was a dry powder extinguisher on board which the scientists were trained to use in case of fire. In the event of a man over board, the inspector was told that it was easy to turn the boat around and haul the person back on board.

The method statement comprised emergency procedures for three emergency scenarios: man over board, fire and evacuation. How to act in case of evacuation was not directly a part of the instruction given by the IfAÖ personnel nor was the question raised during the inspection. The IfAÖ personnel indirectly addressed this subject by pointing out where the lifejackets and immersion suits were stowed on board.

The inspector did not check whether the phone numbers on the emergency contact flowchart were up to date.

3) Emergency equipment
The inspector was informed that there were lifejackets with AIS-transmitters and immersion suits on board, and it was pointed out to him where these were stowed. The inspector saw the bags in which the lifejackets and suits were stowed, but did not see what type of lifejackets and immersion suits they were. Furthermore, he did not receive instruction on how to don them or how the AIS-transmitter was activated.

The inspector asked the IfAÖ employees whether the lifejackets should be worn when the nets were set or hauled. He was told that since the boat had railings there was little risk of falling over board. Furthermore, it would be very easy to recover a person who had fallen over board. Therefore, it was unnecessary to wear a lifejacket on RIGI.

The conclusion of the inspection was that:

"No non-conformities or observations were observed during the inspection. The inspector experienced a tidy ship and a good HSE-culture, where the QHSE-provisions of the Method Statement document is complied with where applicable for a small boat vessel."

The inspector who carried out the inspection on RIGI was not a maritime professional. The quality management system allowed for persons without branch expertise to carry out a subcontractor audit to verify whether the quality management system was implemented by verifying that the described standards were in place. When Rambøll decided that only a simplified inspection of RIGI was to be carried out, the Rambøll employee had to use his own judgement on which parts of the method statement were applicable for RIGI to comply with and to what extent. As the inspector did not have professional maritime expertise, he trusted the IfAÖ employees' professionalism and experience. This judgement was dependent on the IfAÖ personnel's opinion. The IfAÖ employees' perception of the marine biotic survey on board RIGI was that it was a low risk operation and that it would be easy to recover from emergency situations, because the boat was small and the survey was carried out close to the shore.

Though Rambøll was aware that it was not possible to audit RIGI on the basis of the method statement, because this required a ship with different features to RIGI, this incongruity was not perceived as a nonconformity. Instead, it was perceived that the quality management system did not cover a ship type similar to RIGI, rather than RIGI was unable to meet the safety level established in the quality management system. In other words, it was concluded that the QMS did not fit RIGI, and not that RIGI did not comply with the QMS. Therefore, Rambøll's procedures for handling nonconformities were not initiated. The subcontractor audit as a control measure for ensuring that a certain safety level was in place to ensure the safety of Rambøll's employees on RIGI was, hence, not in effect.

Common traits in the use of QMS
The implementation of quality management systems was a prerequisite for both Rambøll and MIG/MEWO when both organisations outsourced the execution of marine biotic surveys to their subcontractor(s), who had expertise within this type of work. Rambøll and MIG/MEWO showed a high degree of trust in the subcontractors' judgements and working methods, because the subcontractors has implemented a QMS, which indicated a level of professional project management, and because the subcontractors were hired to provide expertise concerning these types of surveys that Rambøll and MIG/MEWO did not have in-house.

When deviations were found during subcontractor audits, this did not lead to a response according to the described workflow concerning nonconformities in the quality management system. The deviations were not perceived as nonconformities in MIG/MEWO's subcontractor audit and in Rambøll's inspection of the boat, but rather as a symptom of the quality managements systems not being able to cover the specific operation. In both cases, there was more trust in the subcontractor providing an adequate alternative solution as the subcontractor was perceived to have more knowledge and practical experience, and had less trust in the quality management system in place to control the standard.

In other words, both Rambøll's and MIG/MEWO's quality management system were bypassed when the inconsistencies between the described standard and the conditions found on board RIGI were encountered. Hence, both MIG/MEWO and Rambøll's quality management systems were in effect absent on board RIGI and did not ensure the agreed safety level for the employees on RIGI as described in the QMS. The subcontractor audit as a control tool did not lead to any corrective actions when deviations were detected and hence did not work as a safety barrier against lowered safety standards as the project was divided between several project organisations. Instead the lower standards were accepted, because the survey carried out on RIGI was perceived as a low risk operation due to the ship's size and proximity to the shore.

Analysis

In this section the narrative and the investigation data will be analysed to establish the circumstances and underlying factors for the foundering of RIGI and the subsequent fatality.

The foundering

When RIGI foundered, it happened because the boat became flooded and lost buoyancy within a short timeframe. The boat foundered, not just because of its constructional changes, the way it was loaded, and the weather conditions, because these factors were within the boat's normal operational conditions.

On the day of the accident, the team leader in consultation with the others, decided to alter course towards Lund Harbour because that made the voyage significantly shorter following the change in weather conditions. The course change meant that the boat came to sail in a following sea, and this was, in the team leader's perception, an advantage because, the boat was more stable in the water, and therefore it was also safer.

However, sailing in a following sea actually worsened the situation. The factors that were previously within normal operation – the boat's constructional changes, loading and the weather conditions – now became crucial:

The weather and the sea state in combination with the boat's heading now meant that the waves could catch up with the boat. The load on board and the low aft freeboard made it possible for the waves to break over the aft end and flood the boat. The boat's construction, with no watertight divisions or extra buoyancy, meant that once the boat was flooded, it quickly sank. Thus, the decision to alter course became a determining factor for the foundering of RIGI.

The group of people on board RIGI were skilled professionals within their fields of biological and geological research. The three scientists all held recreational craft certificates, but none of them were professionally trained mariners. Therefore, they did not have a detailed insight into the factors that became crucial for the foundering, i.e. the boat's construction and loading, its manoeuvrability, etc. Thus, the non-professional approach to the seagoing part of the research contributed significantly to the foundering.

Emergency preparedness

An emergency preparedness with the purpose of ensuring the survival of the persons on board RIGI in case of an emergency situation, e.g. foundering, was provided by IfAÖ. The Rambøll observer was, as per agreement with the subcontractor, covered by the emergency preparedness provided by IfAÖ, and she did not carry personal emergency equipment on board, nor was she under specific instructions provided by her own employer, Rambøll.

The emergency preparedness on RIGI relied mainly on calling for external assistance and having equipment for surviving in the water until help arrived. When RIGI foundered, the preparedness was not capable of alerting and summoning assistance, nor ensuring the survival of the observer until the rescue services arrived at the scene of the accident.

The emergency preparedness provided by IfAÖ consisted mainly of equipment, but no drills in case of emergency scenarios were prepared or exercised. The persons on RIGI were familiar with the necessity of drills and emergency procedures when they were boarding larger ships, but there was an understanding between the IfAÖ scientists and the entire project organisation that this was not necessary or applicable on board a small vessel like RIGI. The reason for this was that there was expected to be sufficient time to work out an action plan and call for help on the mobile phone, if an emergency situation occurred. Emergency communication by means of mobile phone and the lack of exercises does not meet the standards for what is expected on a professionally operated ship.

RIGI was a recreational craft and the persons on board were not maritime professionals, and therefore did not have the equipment and competence to provide a professional standard for emergency preparedness.

For the emergency preparedness to function as intended, several pieces of equipment had to be utilized in combination. In total, a minimum of 12 items (4 inner suits, 4 immersion suits and 4 lifejackets) had to be found in the different compartments and tightly packed locker benches inside the cabin. Each person had to don three pieces of equipment correctly, and tighten the straps on the lifejacket. Furthermore, emergency communication by mobile phone would have to work while being on board the vessel. Hence, it was a prerequisite for the emergency preparedness that the ship remained a stable platform during the process of calling for assistance and donning the immersion suits. As this process had not been exercised, the scientists did not have a realistic perception of the time it would take to utilise the emergency equipment as a total package and had not addressed the fact that the emergency equipment was intended to be used in a situation where the ship failed to remain a stable platform.

RIGI foundered with a speed that did not render sufficient time to don the immersion suits correctly or call for assistance. The observer lost her life while attempting to compensate for the ineffective contingency plan of calling for emergency assistance by attempting to swim to shore to call for rescue assistance for the two scientists who remained at the foundered boat. As the observer's immersion suit was not entirely closed and the lifejacket was missing, it was not able to protect her sufficiently. Instead, as water started to fill the suit during the swim, the suit enhanced the observer's exhaustion and the difficulties of keeping the respiratory passages free of water.

Safety management

The previous two sections have discussed how the non-professional approach to the seagoing part of the survey, had a significant impact on the sequence of events and the outcome of the accident. Therefore, the following section will examine how and why the professional organisations who contracted the surveys accepted and contributed to the non-professional setup of the Faxe Bay survey.

When Rambøll subcontracted MIG/MEWO, the two companies had already agreed on the terms of the work to be carried out, including quality and safety aspects, as these were included in the method statement.

When IfAÖ and in turn RIGI was subcontracted, MIG/MEWO did not consider it necessary to review the safety procedures and requirements against the method statement. This was mainly because MIG/MEWO were confident that since IfAÖ had a QMS which was ISO9001 and OHSAS18001 certified they would also be able to ensure compliance with the requirements of the method statement. Secondarily, MIG/MEWO did not believe that most of the safety requirements in the method statement were applicable for a small boat like RIGI. In other words, MIG/MEWO chose to trust that IfAÖ would ensure compliance with the QMS, but they did not attempt to verify it.

During the previous campaigns in Faxe Bay, in which Rambøll observers also participated, Rambøll had not deemed it necessary to conduct audits of RIGI and its personnel as prescribed by the QMS, although there had been internal discussions about the topic. In April 2018 however, it was decided to carry out a simplified inspection of the safety equipment on RIGI in lieu of a full audit. The purpose was to verify the compliance with the QHSE section of the method statement.

When the inspecting Rambøll observer was faced with a boat, equipment, crew and procedures that did not match the audit template and checklists, which were prepared for large, commercial vessels, the decision from Rambøll's side was that it was up to the inspector's discretion to evaluate whether or not RIGI and its equipment and personnel met the expected safety standard. As the inspector did not have a professional maritime background he had to trust in the expertise of IfAÖ, and accepted things as they were. The verification or control function that should uphold the professional standard was thereby absent.

There were some traits that were shared among the stakeholders Rambøll, MIG/MEWO and IfAÖ: None of them were professional mariners or had any particular insight into commercial shipping or the safety aspects of seagoing operations. They all shared the perception that a small boat required fewer safety precautions and less emergency preparedness, because a small boat, operating close to the shore, would be easier to abandon and it would be easier to recover a person if they fell overboard, easier to reach the shore, and easier to call for assistance etc.

They did not realise that there was a discrepancy between their risk perception and their assumptions about safety on smaller boats. The stakeholders were all familiar with the safety and emergency procedures on larger ships, such as muster lists, drills, exercises, and safety equipment and familiarisation, but they did not consider such measures relevant or applicable to a small boat like RIGI.

Seen as a whole, the stakeholders underestimated the potential risks that were present when operating the small boat, and overestimated the possibility of recovering from a threatening situation. The accident, and the events that preceded it, show that the quality and safety management systems they had all prepared were not understood and/or did not work as intended. Thus, the professional standard that was needed to ensure a safe operation was not present.

Conclusion

The marine biotic survey carried out on RIGI by the three fish biologists from IfAÖ, was a small part of a large scale project concerning the preparation for the establishment of a new gas pipeline in the Baltic Sea. Normally, project's surveys of this type were carried out by scientists from commercial ships with a professional crew on board. However, the survey in Faxe Bay was to be carried out close to the shore and did not require a large ship. Instead, it could be carried out by biologists from a small recreational craft, with the biologists operating the boat themselves. Hence, no maritime professionals were on board for the marine survey carried out by RIGI. Because the survey was carried out by a foreign vessel close to the Danish coast, it was however required that a Danish observer was on board during the survey.

The project organisation conducting the marine biotic surveys in connection with the Baltic Pipe Project consisted of several affiliated organisations organised in subcontractor relationships. The organisations were joined by a quality management document with the purpose of ensuring a professional standard throughout the surveys, also concerning the management of the employees' safety. RIGI was however not able to meet the standards described in the document, but this was not considered a non-conformity as there was a trust that the subcontractor operating RIGI would provide a sufficient solution.

On 23 April 2018, RIGI foundered in Faxe Bay approx. 0.9 nm from the shore. One of the four persons on board perished in an attempt to swim to shore for assistance. An inexpedient manoeuvring of the boat due to a lack of maritime competence was decisive for the foundering's occurrence. An ineffective emergency response on RIGI consequently made it impossible for the persons on board to call for assistance and don the necessary equipment before being immersed in the water. As the only option for notifying the rescue services was to swim to shore, it took hours before the rescue services received information on the persons in distress, and one of the persons swimming for help died as incomplete donning of the immersion suit caused water to fill the suit and made it hard to move. Exhaustion from moving through the water in the heavy suit, exposure to cold water and difficulties keeping the respiratory airways clear of the water were decisive circumstances for the fatality.

The focus of the emergency preparedness on board RIGI was on the presence of individual pieces of equipment and did not consist of action plans comprising the process of how the equipment was to be utilised. There was a perception that this could be improvised if and when an emergency situation arose. The lack of maritime knowledge meant that the persons on board did not have insight into how the boat would react in case of flooding, and hence they did not have a realistic perception of the response time available for emergency communication and preparation for abandoning the ship. Furthermore, the lack of exercises meant that the persons on board did not know how long it would take to utilise the emergency equipment. Hence, there was an unrecognised discrepancy between the time needed to put the emergency preparedness into force, and the available time for response in the emergency situation, which the preparedness was a response to.

Across the project organisation there was an acceptance that the emergency preparedness on RIGI differed from the standard described in the shared quality and safety management documents. The acceptance was based on the assumption that it was impossible for a small boat like RIGI to meet the same standards as those for larger commercial ships, and the perception that a small boat like RIGI operating close to the shore did not require the same scale of emergency preparedness. Hence, the acknowledged deviation from QMS became an acceptance of a lower safety standard by means of a reduced emergency preparedness instead of ensuring that an alternative emergency preparedness of an equivalent standard was provided. Therefore, the management of the safety for the employees of the project organisation on board RIGI did not correspond to a professional maritime standard.

Actions taken

Following the the investigation, DMAIB has received information on actions taken from IfAÖ, MIG/MEWO and Rambøll in connection to the foundering of RIGI as preventive measures in the future. These statements are quoted below:

IfAÖ - Preventive measures

- ”*Further improvement of emergency message chain/call service*
- *Use of EPIRB for all boats used*
- *Demand for radio on all boats used (minimum SRC ->short range certificate)*
- *Use of work boats and not pleasure boats*
- *Explicit training on modes of action of AIS, EPIRB, Personal Locator Beacon*
- *Explicit training on emergency signal means*
- *Preparation of operating instructions for the storage of life-saving appliances and emergency signal means.”*

MIG/MEWO - Preventive measures

”RIGI misadventure accident has tremendous impact for way of thinking of consortium comprising MIG/MEWO and approach to operations carried out by small crafts.

First of all this kind of activities are considered as high risk areas which required vessel specific risk assessment for each activity taken to identify all potential risk they may occur during operation and actions to reduce the risk.

Immediate After RIGI accident MIG/MEWO decided to check properly once more all subcontractors. MIG/MEWO decided to send to Denmark own Surveyors as QHSE Inspectors who were responsible for watching safety manners on board during works. In operations on board vessels provided by subcontractor instead RIGI MIG/MEWO provide all needed safety equipment accordingly to MIG/MEWO standards which are higher than rules in Denmark.

MIG/MEWO consider safety as most important company core value and therefore in regards to safety MIG/MEWO implemented limited trust rule in relation with clients and subcontractors leading to own inspections of all vessels employed in projects managed by company.
To make sure that RIGI lesson will be learned and never forgotten following actions has been taken to provide equal, ultimate safety level of offshore operations on the vessels regardless of their size:

- *To supervise offshore operations QHSE department has been established with professional Master Mariner Unlimited as an Superintendent to provide necessary expertise. Department is responsible for vessel inspections and audits, developing of procedures and improving Safety Management System covering all offshore operations.*
- *Each vessel used in company project must posses vessel specific safety instruction and updated Emergency Contact list.*
- *Each small craft must be certified as workboat / commercial craft.*
- *Crew certification must be appropriate with requirements described in the vessel safety certificate.*
- *On all vessels use of life jackets is compulsory when at sea and if water temperature is below 12 deg. C all personnel wearing immersion suits.*
- *As a minimum communication equipment required to be on board small craft an portable VHF is considered and personnel must be properly certified to operate it and fluent in distress communication.*
- *On the vessels without EPIRB all personnel is equipped in Personal Locator Beacons.*
- *During inspections special care is taken to seek for evidence of training drills carried out on board vessels.*
- *QHSE department is working on developing inspection checklist for small boats.*
- *At least one waterproof mobile phone is planned to be on board small craft.”*

Rambøll - Preventive measures

”Ramboll’s Group health and safety risk management framework is continuing to develop in line with the Three Lines of Defense model . We are utilizing this model in order to improve our governance framework and enhance clarity among the various roles and responsibilities in risk management and control across the Ramboll organization. Our corrective and preventive actions to address the root causes of the foundering accident are organized along this risk management model.

First Line of Defense: Ramboll Operational and Project Management

Overall, the first line of defense “owns” the risk. It is the responsibility of operational and project management to identify, assess, control and mitigate health and safety risks on a day-to-day basis. Following guidance provided by Group Health, Safety & Security (HSS); Quality; and Compliance (Second Line of Defense), operational and project management define and implement detailed processes that control and supervise execution of those processes/ procedures used by employees.

Specific corrective/preventive actions that are being taken by Operational and Project Management includes:

- *Integration of health and safety:*
  - Integrating health and safety requirements into existing and newly developed systems and processes, in particular Management of Change and Contractor Management.

- *Risk Assessment Process:*
  - Specifying project task activities in each risk assessment;
  - Having Ramboll employees conduct the risk assessment, rather than a contractor;
  - Discussing the risk assessment in the project health and safety kick-off meetings.

- *Communication:*
  - Report incidents in timely manner, per company requirements;
  - For high risk projects, project Steering Committee now includes health and safety as part of the evaluation criteria;
  - Increase frequency of health and safety communications with employees (e.g. safety talks, safety moments, lessons learned).

- *Training:*
  - *Ensure employees are current on training modules.*

Second Line of Defense: Group Health, Safety and Security (HSS); Quality and Compliance
Overall, the second line of defense builds and monitors the controls used by the first line of defense. It is the responsibility of this group to provide internal guidance to operations and project management based on applicable regulatory/legal requirements, client requirements, industry best practices and Ramboll policies. This responsibility includes continuing to develop and communicate the Group-wide health and safety management system, which is based on the ISO 45001:2018 "Occupational Health and Safety Management Systems" specification.
Specific corrective/preventive actions that are being taken includes:

- *Risk Assessment Process:*
  - *Developing guidelines and checklists specifically for high risk projects and vessel inspections; and*
  - *Improving the ease of access of the risk assessment template to project managers.*

- *Communication:*
  - *Adding health and safety Key Performance Indicators as a benchmark which is routinely communicated to management; and*
  - *Integrating health and safety into the Ramboll Crisis Management process and work flow.*

- *Training:*
  - *Developing and implementing safety leadership training for executive and operations management;*
  - *Developing new training modules on:*
    Induction to Health, Safety and Security (including Behavior Safety)
    Stop Work Authority
    Water Safety
    Lone Work
    Other modules under development

- *Incident Reporting:*
  - *Implementing Group-wide electronic incident reporting system for all employees using smartphone, tablet or computer; and*
  - *Incorporating triggers of high severity events in order to effectively manage the event.*

- *Management of Change:*
  - *Integrating health and safety into the Project Excellence Management of Change process.*

- *Contractor management:*
  - *Assessing and improving contractor retention, evaluation and audit processes.*

Third Line of Defense: Internal Auditing (Independent)
The internal audit function provides independent assurance and is currently developing an assurance framework to evaluate whether risk management processes and controls are being effectively implemented. The scope will include health, safety and security as well as other risk management topics. The framework will define a risk-based audit process for projects as well as offices and operational units. This assurance framework is currently being developed and is expected to be implemented in 2019."

Appendix

SHIP PARTICULARS	
Name of vessel:	RIGI
Type of vessel:	Pleasure craft – motor boat
Flag state:	Germany
Port of registry:	Rostock
Official no.:	HST 111-3
Year built:	2011
Shipyard/yard number:	Aazopf Bootswerft AG, Switzerland
Classification society:	(unclassed)
Length overall:	6.40 m
Breadth overall:	2.30 m
Displacement:	1.4 t
Draught max.:	0.90 m
Engine rating:	86 kW (115 HP)
Service speed:	15 knots (27 knots max.)
Hull material:	Aluminum
Hull design:	Single hull

VOYAGE PARTICULARS	
Port of departure:	Faxe Ladeplads, Denmark
Port of call:	Lund harbour, Denmark
Type of voyage:	Coastal
Manning:	3 fish biologists, 1 observer
Pilot on board:	No

WEATHER DATA	
Wind – direction and speed:	WSW – 9-10 m/s
Wave height:	0.5-1.0 m
Visibility:	20-23 nm
Light/dark:	Daylight
Current:	East-going, 0.4 knots

MARINE CASUALTY OR INCIDENT INFORMATION	
Type of marine casualty/incident:	Foundering
IMO classification:	Very serious
Date, time:	23 April 2018, approx. 11:00 LT (UTC+2)
Location:	Faxe Bay (Faxe Bugt), Denmark
Position:	55°14.20’ N 012°18.10’ E
Ship’s operation, voyage segment:	Underway
Place on board:	-
Human factor data:	Yes
Consequences:	One person perished, three persons rescued, the boat sank and was later salvaged.

SHORE AUTHORITY INVOLVEMENT AND EMERGENCY RESPONSE

Involved parties:	JRCC/JOC, Rescue services, police, Royal Danish Navy
Resources used:	Rescue boats, helicopters, navy patrol vessel
Speed of response:	3-4 min. from alarm call to first responders on site. 46 min from alarm call to first two persons rescued. 1h 25m from alarm call to all persons recovered.
Actions taken:	Rescue personnel, ships, boats, divers and helicopters scrambled.
Results achieved:	4 persons recovered from sea, 3 survived, 1 perished. Found-ered boat was re-covered.

PERSONS ON BOARD

Team leader:	38 years old, fish biologist. Held a German ‘sportsbootfüh-rerschein’ (pleasure craft certificate for German waters), and a BOSIET certificate (Basic Offshore Sa-fety Induction and Emergency Training). Had approx. 20 years’ experi-ence with operating pleasure craft. Had been with the company IfAÖ for 9 years.
Scientist:	42 years old, fish biologist. Held a German International Certifi-cate for opera-tors of pleasure craft in inland waters, and a BOSIET certificate. Had approx. 15 years’ experience with operating pleasure craft, had been with the company IfAÖ approx. 9 years.
Scientist:	37 years old, fish biologist. Held a German ‘sportsbootfüh-rerschein’ (pleasure craft certificate for German waters), and a BOSIET certificate. Had been with the company IfAÖ approx. 8 years.
Observer:	35 years old, geologist. Held a BOSIET certificate, a certificate of Further Offs-hore Emergency Training, certificate of Additional Training for Norwegian offshore territory, and a Health Certificate for Seafarers and Fishermen. Had been with the company Rambøll since 2015 .