Stability of Fishing Vessels

Real time simulations

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Stability of Fishing Vessels

Real time simulations

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1 INTRODUCTION

Following the accidents with the beam trawlers Lummetje and Spes Salutis, the Ministry of Infrastructure and the Environment had conducted research into the risk of capsizing of beam trawlers. This research executed by Conoship[1] shows that beam trawlers under 24 meters in particular run a high risk of capsizing while fishing.

The study suggest the following recommendations for further research:

- The study was based on only static stability, the impact of dynamic stability should be investigated in more detail, in particular the following subjects are suggested:
  - The impact of water on deck to the stability of the vessel
  - The effect of asymmetrical loads during fishing
  - Resonant beam waves
  - Longitudinal waves –> stability loss
- Bridge simulators for beam trawlers must be used for training, for scenarios such as:
  - Asymmetrical loading
  - Loss of fishing gear
  - Executing operations in wind and waves

This study is part of the 'Onderzoeksprogramma Scheepvaartveiligheid Noordzee 2024'. The main objective of this sub-programme is to increase the safety of fishing vessels

In this study we focused on the specific items in the dynamic stability such as the impact of resonance roll damping and sudden loss of load in the lines. This was done to verify how accurate the dynamic behaviour is captured by the GZ curve approach. Furthermore bridge simulation sessions were performed with crew members to study operational measures to mitigate capsizing in asymmetrical loading conditions and to evaluate the usefulness of simulations in general to understand the issues with stability in asymmetric loading conditions.

This document describes the execution and results of the bridge simulation study.

[1] Stability of beam trawlers RC22C003-1999-rev04 by Conoship International

2 OBJECTIVES AND APPROACH

Objectives
The aim of the bridge simulations is to contribute to the safety of beam trawling fishing. The main objectives are:

1. Present a realistic experience on a ship simulator of a ship with reduced stability, especially what the effect of asymmetric loads are.

2. Evaluate the realism and usability of simulations for training purposes with experienced fishermen. Hereby the focus is on contributing to the overall understanding of stability issues.

3. Experiment with emergency measures to prevent capsizing.

Approach
To reach the objective real-time manoeuvring simulations were carried with a dedicated model of a beam trawler. Scale model tests have been executed in the Seakeeping and Manoeuvring Basin and the results of these tests were used to tune the mathematical model for use on a simulator. The simulations were carried out by five experienced fishermen during two days. The Large Motion Simulator was used to provide a most realistic experience of heavy rolling and even capsizing. Various combinations of met-ocean conditions and different asymmetric loading conditions were tested. The results of these simulations are described together with conclusions and recommendations.

3 DESCRIPTION OF THE FISHING VESSEL MODEL AND DATABASE

3.1 Description of seakeeping and stability model

The simulations in this project make use of previous work in which MARIN developed a fishing vessel simulator model with the following capabilities:

- Calculation of static stability (righting moment) based on the actual submerged 3D shape of the vessel.
- 1st and 2nd order wave forces and moments. The stability model was improved with data from ship model tests. Hereby the focus was to better capture non-linear effects.
- It contains a physics model of the fishing booms, lines and blocks. The fishing lines, boom lines and safety lines can be controlled by a winch.
- Drag, weight and buoyancy of the fishing nets are modelled. This includes an adjustable friction (drag) with the bottom, that allows for simulating the nets getting stuck on the sea bed. It is also possible to adjust the weight in the nets, e.g. to simulate a net full of sand.
- The free surface effect of water on deck and inside the ship is included. It is possible to simulate the ingress of water in for example the engine room or fish holds. The model to include free surface effects of water on deck was further improved by using the results of the ship model tests.
- Various safety systems can be incorporated in the simulations (Marelec, Safety line)
- Winches are operated with physical winch controls. Three winches on port side and three on starboard side are available. Furthermore, the bridge is equipped with all the necessary navigation means, including an autopilot.

The mathematical model described amongst other the following effects:

- Manoeuvring properties in deep and shallow water;
- Effect of under keel clearance on manoeuvring characteristics;
- Effect of current including current gradients;
- Squat;
- Wind forces including effect of wind gradients and wind gusting;
- First order wave-induces motions;
- Mean wave drift forces and first order wave-induced motions computed with DIFFRAC.

The main dimensions and specifications of the fishing vessel are given in Table 3-1. The telegraph settings and corresponding speeds for the fishing vessel were modelled. The visuals of the fishing vessel are given in Figure 3-1.

Table 3-1: Main particulars of the fishing vessel

Description	Unit	Fishing vessel
Length over all	[m]	20.9
Length between perps	[m]	20.1
Beam	[m]	6.0
Draft	[m]	2.0
Propulsion power	[kW]	220
Frontal wind area	[m^2]	37
Lateral wind area	[m^2]	74
GM	[m]	0.72

KG	[m]	2.54
KB	[m]	1.24

The mathematical model was prepared taking into account the modelling aspects as given in Table 3-2. Hereby, the seakeeping behaviour of the model and the module to calculate the effect of water on deck (free surface) were updated with the results of the ship model tests.

Table 3-2: Preparation of mathematical model

Aspect	Source
Main dimensions and visual representation	General arrangement [Ref 3.]
Propulsion (location)	General arrangement [Ref 3.]
Propeller and rudder	Fixed propeller, rudder max angle 35 deg.
Windage area and coefficients	Stability booklet [Ref 1.]
GM	Stability booklet [Ref 1.]

For this project the seakeeping and manoeuvring model of the fishing vessel was improved using the results of model tests executed in MARIN's FMB (see MARIN report: Dynamic stability beam trawlers: Seakeeping model test [Ref. 1]). Since the fishing gear was not completely identical to the gear used in the model test campaign, the first version of the model was very instable. After the first four simulations the draught of the vessel was therefore reduced, from 2.0 to 1.9m and the KG (centre of gravity) was reduced from 2.3 to 2.1m. This resulted in a much more realistic behaviour.

Figure 3-1: Visual of the fishing vessel in the simulator [left] and picture of the scale model [right]

3.2 Description of simulator capabilities necessary to model fishing vessel operations

The fishing vessel model has a generic gear handling interface for the booms, fish line and safety line. In addition, the fishing nets can become stuck on the seabed and the weight of the fishing nets can be adjusted. Beside the fishing gear, the stability of the fishing vessel is affected by adding water into the fishing hold, engine room or on deck, creating a free surface moment.

The following sections describe the content of the user interfaces in more detail. The user interface was tested and validated on the simulator.

Fishing gear
The booms, fish line and safety line can be handled by a total of six winch levers. Three for portside boom, fish line and safety line and three for starboard beam, fish line and safety line. The port and starboard side boom can be raised and lowered independently. The fish line and safety line can be paid out and hauled in independently on the port and starboard side.

The safety line is also known as the ‘slip line’. With this line the center of pull can be adjusted toward the center of the vessel. This adjustment helps to reduce the critical moment acting on the fishing vessel’s stability under asymmetrical conditions.

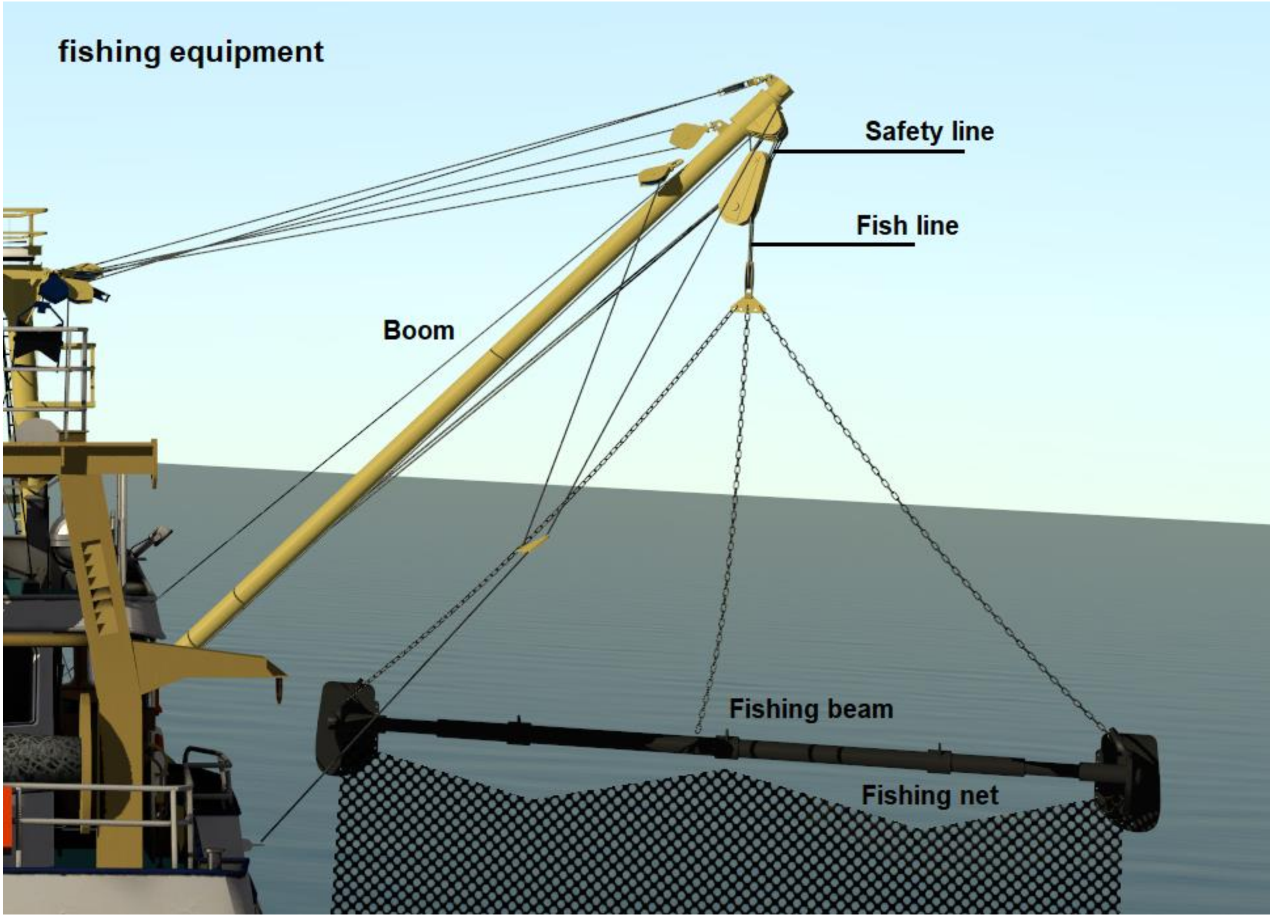


Figure 3-2 - Fishing equipment

Fishing net

The fishing nets can be adjusted in weight. Port and starboard side can be adjusted independently. Figure 3-3 shows the Dolphin control panel to adjust the fishing net weight. In addition, friction of the the fishing net can be adjusted and ultimately the fishing net can be fixed to the sea bed. This will be used to simulate a fishing net that is stuck to an object.

Figure 3-3: Dolphin fishing vessel control panel

Free surface moment

During several incidents, found during the desk study, open spaces were flooded with seawater which decreased the stability of the fishing vessel. To simulate these situations the fishing hold, engine room and deck were modelled as a box, that can be filled with water. The deck model includes outflow openings.

3.3 Description of database

A dedicated database for the fishing vessel simulations was prepared. The basis of the database contains the area and all relevant nautical aspects used for the simulations.

The simulator database contains the following elements:

- Area;
- Metocean conditions:
    - Uniform wind (including gustiness);
    - Wind waves;
    - Swell;
    - Current patterns.
- Ships;
- Scenarios.

The following sections will describe the content of the database in more details once the database is prepared.

Area

For the area database the Electronic Nautical Chart (ENC) of Den Helder was selected. This ENC contained the port of Den Helder and all relevant objects like the aids to navigation. Figure 3-4 shows the ENC used during the simulations. Water depths in this area are between 20 and 25m.

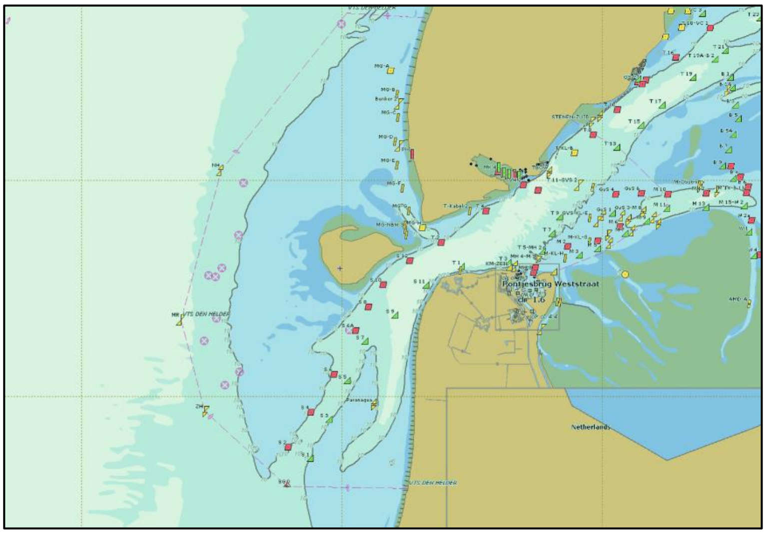


Figure 3-4: ENC of Den Helder

Metocean conditions

The wind, wave and currents are modelled as a uniform fields, meaning that each position in the database had the same value for direction and magnitude. Wind gusting is a standard effect in the simulator.

Two wave fields can be included in each simulation. Significant wave height and period can be set at the beginning of each run. Directions and magnitudes of wind, waves and current can be changed during the simulations, taking into account an adjustable transition period.

Scenarios

A scenario describes the vessel, the environmental conditions as well as the initial conditions. A matrix of conditions was prepared. These conditions were tested to see if capsizing occurs and if they could be used to find mitigating measures. Scenarios are based on regular fishing gear hauling procedures onboard beam trawlers and validated by the participants.

Table 3-3: Scenarios

Scenario	Acties	Weerscondities	Opmerkingen
Famil niet vissend	Snelheid netten aan grond	Scenario 1: Milde condities West 1.0 m Tp = 5s golven 10 kn wind (3 bft)	
	Snelheid netten omhoog		
	Rate of Turn		
	Algemeen gedrag kotter		
	Zicht naar buiten		
Famil vissend	Netten binnen halen	Scenario 1: Milde condities West 1.0 m Tp = 5s golven 10 kn wind (3 bft) Opbouwen naar Maximale condities 3.0 m golven 40 kn wind (8 bft)	Diverse koersen Aandacht voor autopilot, en handbediening winches
	Netten uitzetten		
	Bedienen		
Asymmetrische belading op zee	Bomen horizontaal, visgerei binnen, één net met troep.	Scenario 2: Matige condities	Acties uitvoeren op gunstige koers

Scenario	Acties	Weerscondities	Opmerkingen
Vangst + visgerei 2.2 ton Troep + visgerei 3.2	één boom op 45 , visgerei binnen, één net met troep	West 1.5 m Tp = 5.5s golven 20 kn wind (5 bft) Opbouwen naar Maximale condities 3.0 m golven 40 kn wind (8 bft)	Acties uitvoeren op ongunstige koers (dwarsgolven)
	Bomen op 45, binnen halen vangst + troep SB net		
	Bomen horizontaal, Een net vast op bodem en weer losschieten		
Achter inkomende golven	Bomen horizontaal, visgerei binnen, één net met troep	Scenario 3: Matige condities Zuid 1.6 m Tp = 4s golven 15 kn wind (4 bft)	
	één boom op 45 , visgerei binnen, één net met troep		
	Bomen op 45, binnen halen vangst + troep SB net		
	Bomen horizontaal, Een net vast op bodem en weer losschieten		

One of the objectives is to see if it is physically possible to perform the appropriate actions when the vessel is already under a large roll angle. Also unconventional actions (engine full astern, full rudder) could be tested in order to test their effect.

3.4 Simulator setup

MARIN's Large Motion Simulator (LMS) was used to simulate beam trawling operations. It was used to evaluate the usability for training to contribute to the overall understanding of stability issues and find mitigating measures to prevent capsizing.

Figure 3-5: Large Motion Simulator

Figure 3-6: View from the wheelhouse

More information on the LMS can be found here: [Large Motion Simulator | MARIN](). In the LMS it is possible to experience angles of up to 30°. Together with a further rotation of the visuals it is possible to give the sensation of actually capsizing.

For this project the console is equipped with regular navigational instruments (tiller for rudder control, telegraph and autopilot) and winch control handles to operate the fishing gear (see Figure 3-7).

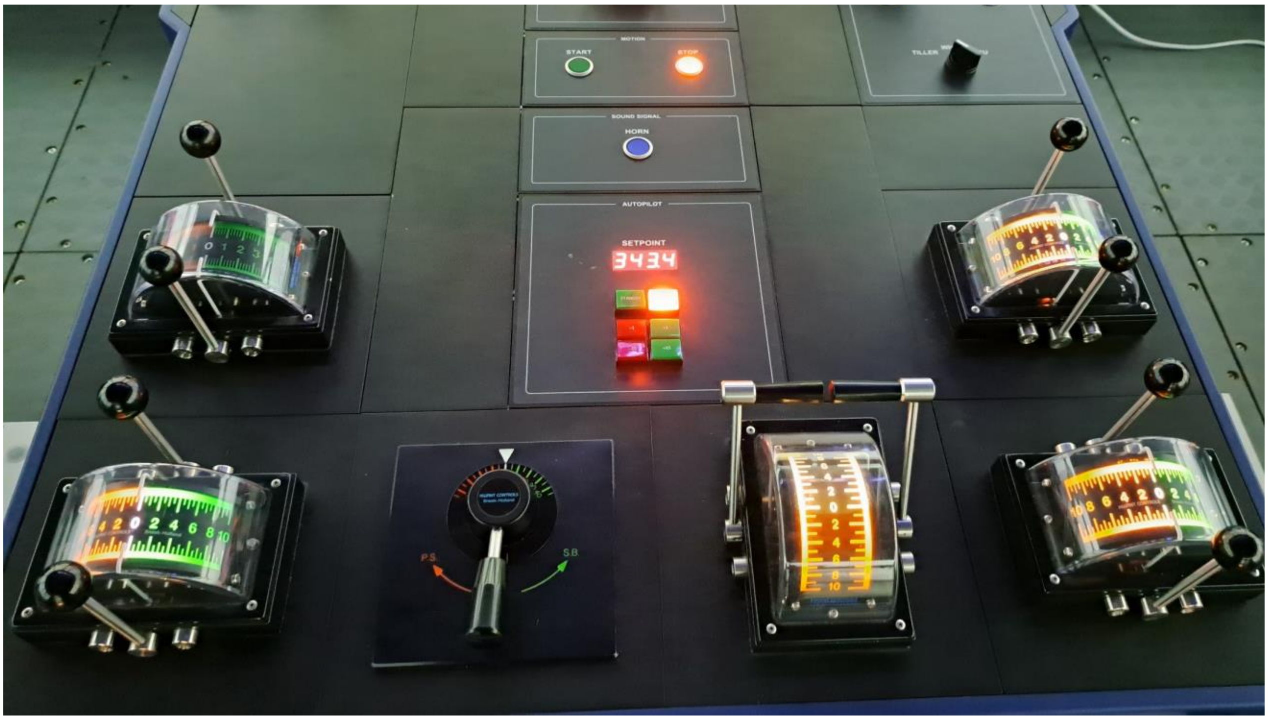


Figure 3-7: Control panel with autopilot, telegraph, rudder and winch controls

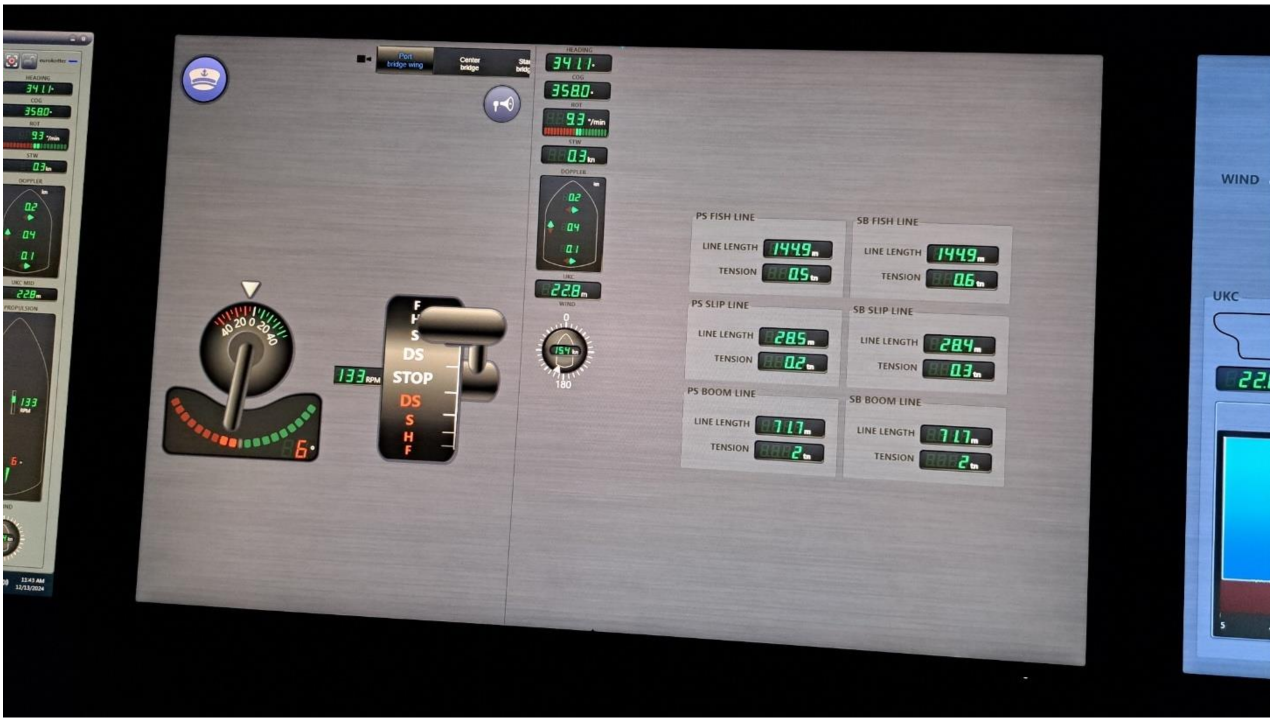


Figure 3-8: Revised conning display, showing line information (length and tension)

3.5 Execution of the simulations

On December 16 and 17 real-time manoeuvring simulations were carried out at MARIN's simulator facilities in Wageningen, The Netherlands. Participants in the simulations were:

Participant	Occupation	Years of experience as a skipper
Capt. Jacob van Urk	Fisherman	> 10 years
Capt. Dirk Kraak	Fisherman	> 10 years
Capt. Tjeerd de Boer	Fisherman, Lecturer Firda	8-10 years
Capt. Auke van Slooten	Fisherman, Lecturer Firda	4-6 years
Capt. Bertus Oost	Fisherman, Fleet Manager Ekofish Group	> 10 years

All fishermen reported onboard experience with asymmetrical conditions as a captain onboard beam trawlers. All fishermen were experienced and familiar with fishing gear handling in asymmetrical conditions onboard a beam trawler.

The simulations were supervised by:

Supervisor	Function	Role
Dimitri van Heel	Senior project manager MARIN	Instructor, Observer
Jelle Kaptijn	Project manager MARIN	Observer

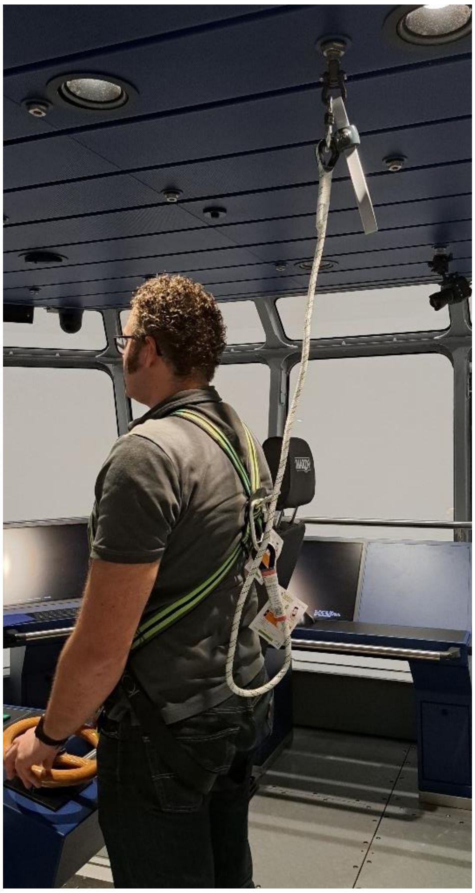
Before the start of the simulations the fishermen received two briefings:

1. A briefing regarding the project. In this briefing the objectives of the simulations were explained. The participants were informed on the simulation program and what is expected of them. This briefing included the set-up of the simulator, scenario overview etc.

2. A dedicated safety briefing regarding the use of the LMS. In this briefing the normal operation, but also emergency scenarios were explained. The operators were informed that their participation is voluntary and that they could stop their participation at any time. They were informed of the risk involved in the simulations. When everything was clear they were requested to read and sign the informed consent form.

The simulations were executed with the participant standing on the bridge behind the main console. This way the winch controls to control the fishing gear were in reach. Furthermore, the participant could reach telegraph, autopilot and rudder.

For the objective to study operational measures to mitigate capsizing in asymmetrical loading conditions participants were given instructions whilst being on the bridge by means of a microphone and speaker connection.



The bridge is equipped with an anti-slip floor, handholds on the ceiling and handrails around the consoles. During the simulations the participants were equipped with a fall arrest harness, connected to the ceiling in order to prevent injuries when balance is lost. For additional safety the possibility to wear a helmet was offered as well. However, after the first session the participants were happy to continue without it. No remarks were given about the fall arrest harness influencing or hampering normal equipment handling. The participants were requested to wear safety shoes (attention should be paid to high friction soles).

During the simulations different events were initiated that could lead to capsizing. The participants had instructions to deal with these events by applying various mitigating measures.

Figure 3-9: Operator equipped with fall arrest harness

3.6 Analyses and reporting

The simulations were stopped when all events were dealt with or the fishing vessel had capsized. After each simulation the run was debriefed with all participants, with the aim to collect lessons learned and to give input to the rest of the program. At the end of each day a debriefing took place to discuss the entire program with all participants and observers and the operators were asked to fill in a questionnaire.

For the objective to evaluate the usefulness of simulations in general and to understand the issues with stability in asymmetric loading conditions, participants were observed during the simulations in order to obtain their real-time attitude and remarks towards the scenarios and simulator. These notes were completed by information obtained from of the debriefing discussions and the questionnaires. This information is analyzed and given in the conclusions and recommendations (chapter 5).

4 RESULTS OF THE BRIDGE SIMULATIONS

In a two-days workshop various scenarios were simulated that in practice have led to capsizing of fishing vessels. Experienced skippers experienced the effect of asymmetric loads and had the opportunity to try out mitigating measures, varying from manoeuvring with the ship to the activation of safety systems. In this chapter the execution of the runs is described.

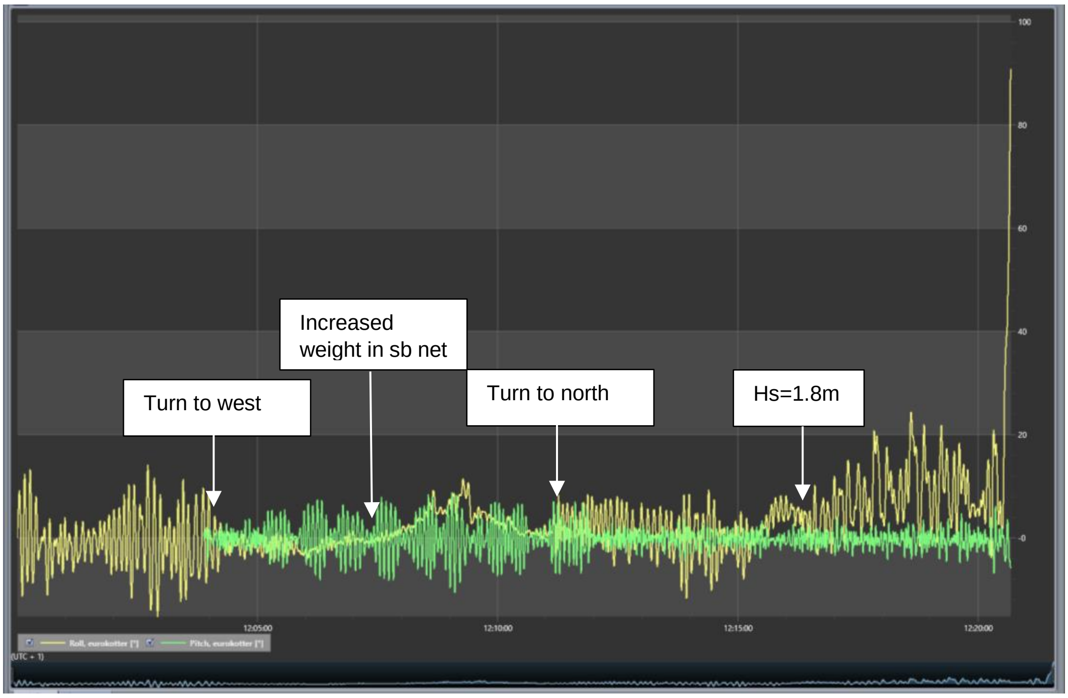
4.1 Description of the simulator runs

Run 1: Wind west 10 kts, waves west Hs=0.3m, Tp=5s, no current
This simulation was used to familiarize with the behaviour of the fishing vessel in mild conditions. The simulations started on a northerly heading in beam seas with the nets streamed to 125m. First the nets were hauled in and the booms were raised. In this condition the vessel reached a speed of 9.5 kts at Full Ahead. In steps of 30 degrees it turned to course 270 to experience head on conditions. The fishing nets were lowered again, and the speed of the vessel reduced to around 3 kts (at a drag setting of 0.75). Again the nets were hauled and a turn to course 180 was made. After some time the fishing boom on port side turned 90 degrees (bringing it parallel to the ship), which resulted in a large asymmetric load, and eventually capsizing.

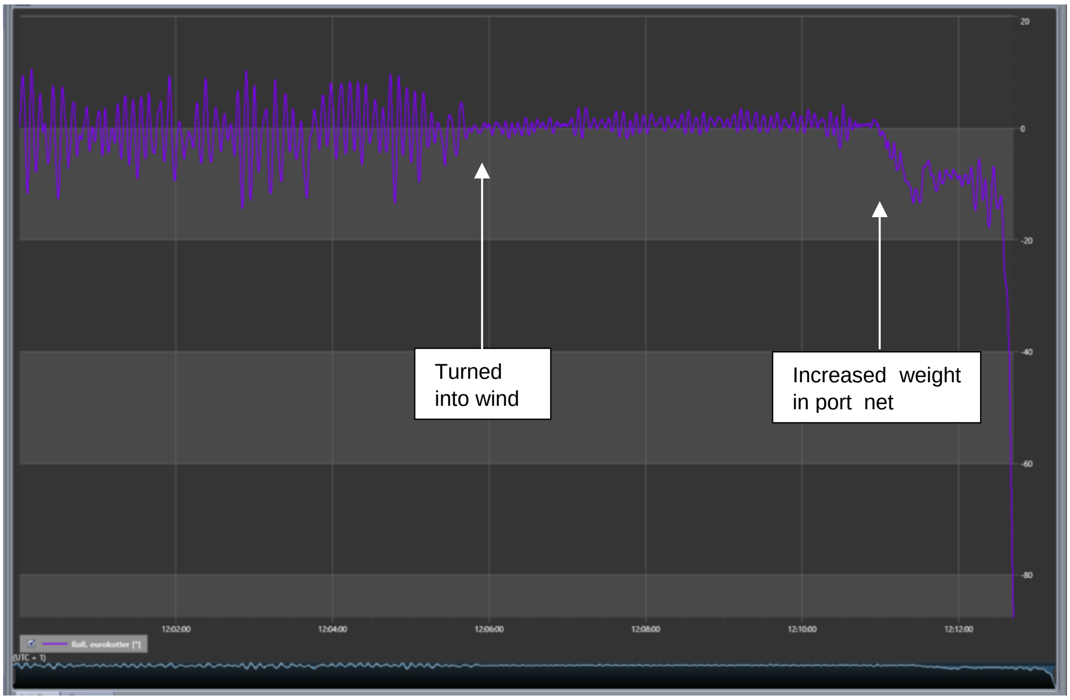
In the simulator the line length includes the part of the line from the fishing block to the winch, whilst in reality the fishermen are not used to include this part in the total line length. In general, the fishing lines are set to about 4 times the water depth.

Run 2: Wind west 10 kts, waves west Hs=1.0m, Tp=5s, no current
The simulations started on heading 000 in beam seas. A favourable course was chosen to haul in the nets. In this case the skipper turned to the west (against the waves). Very noticeable was the reduction in roll angles (from +/- 15° in beam seas to +/-2° in head seas) and the increase in pitch angles (from +/- 1° to +/-10°).

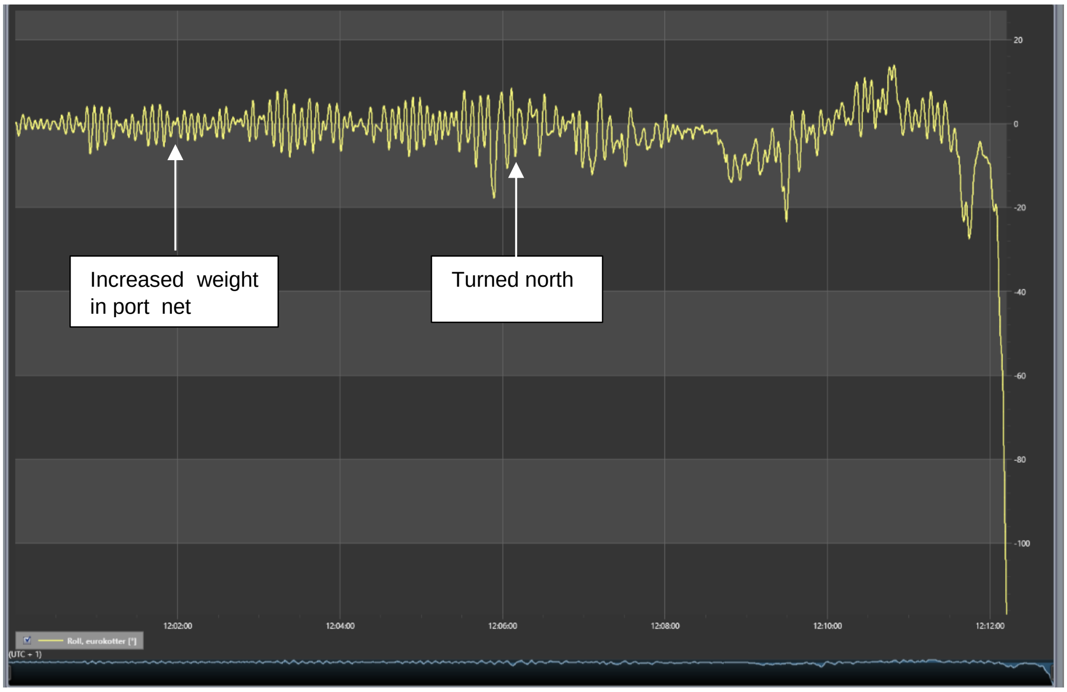
The weight in starboard net was increased to 3.5 tons. This resulted in a list of around 5°. The vessel was turned to course north and started to haul in the nets. Later the waves were increased to Hs=1.8m. This resulted in roll angles of up to 24 degrees. However, without changing the settings the vessel suddenly capsized. There was very little warning and no time to react.



Run 3: Wind west 10 kts, waves west Hs=1.5m, Tp=5s, no current
This run started with the fishing vessel actively fishing on course 000, beam seas. The ship turned to west to haul in the nets in head seas. The weight in the port side net was increased to 3.5 tons. This resulted in a list of around 10° when the net was pulled out of the water. Gradually the list increased even further until the vessel capsized. This result led to the belief that the stability of the vessel was too much compromised.



Run 4: Wind west 10 kts, waves west Hs=1.5m, Tp=6s, no current
In this simulation the vessel started with the sea head-on. The nets were hauled in, whilst the weight in port net was increased to 2.8 tons. The skipper reacted by paying out the safety line. This way the list could be compensated. After turning north the roll motion increased as expected. It was observed that the vessel started to turn into the wind with the nets on deck, while in such conditions it is expected that the vessel would turn the wind abeam. Capsizing was introduced by letting the weight fall out of the net.



Run 5: Wind west 20 kts, waves west Hs=1.5m, Tp=5.5s, no current

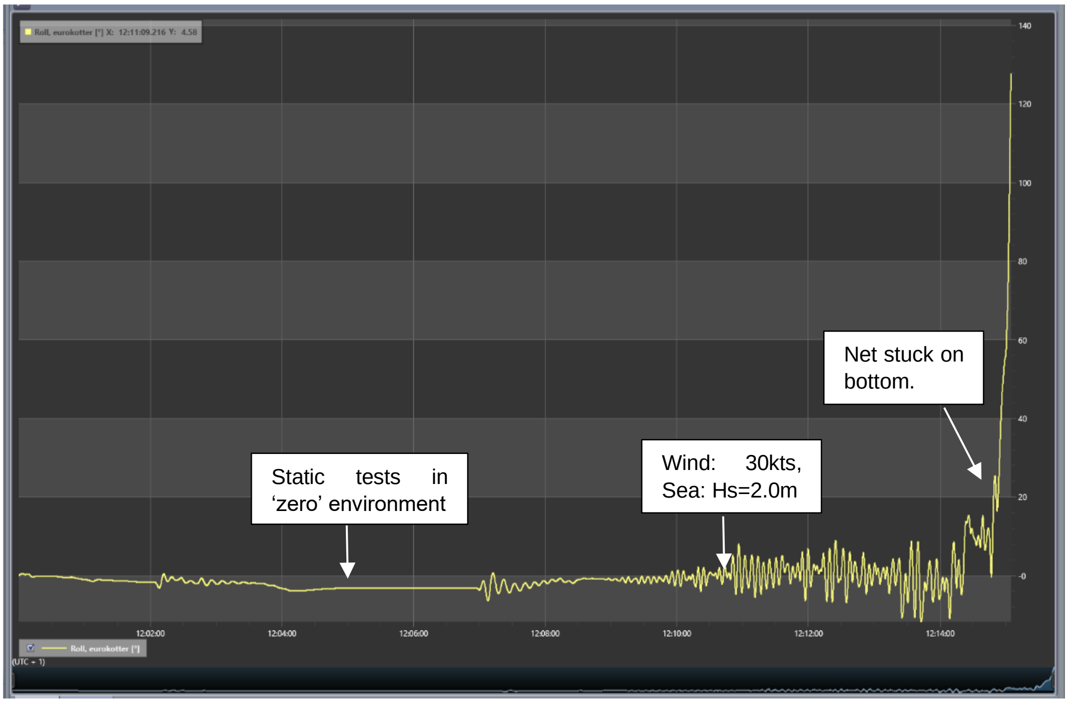
In the preceding runs it was too easy to capsize the vessel. Therefore, the draught of the vessel was adjusted from 2.0 to 1.9m and the centre of gravity (KG) was reduced from 2.3 to 2.1m to make the ship more stable. The waves were increased to 2.0m, whilst the nets were hauled in. The weights in the nets were 2.8 tons on port side and 2.0 tons on starboard side. This resulted in a list angle of around 10°. But this could be reduced by paying out the safety line.

Run 6: No wind, no waves, no current

This was a test condition to compare the simulations with the scale model tests. Both booms were set to 45°, with the nets hauled in. With a weight in portside net of 1.0 tons and 0.5 tons in starboard net, the observed list was 3.3°. This compared very well to the scale model test results.

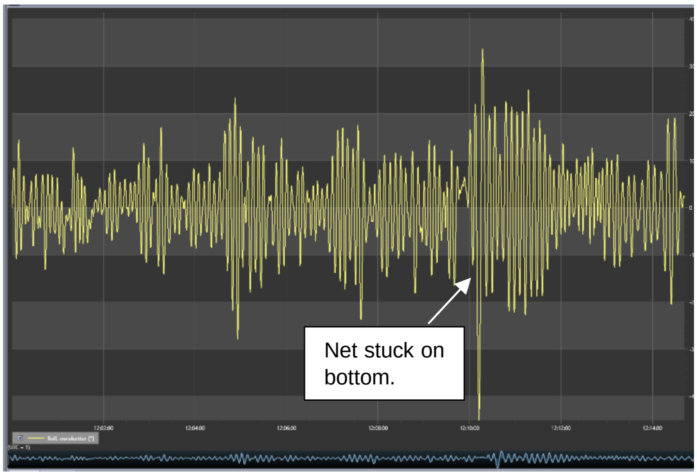
After the test, the simulation was resumed and the weight in the nets was equalized. The nets were set out and the fishing lines were paid out to 125m. The wind was increased to 30 kts and sea state was set to 2.0m coming from abeam.

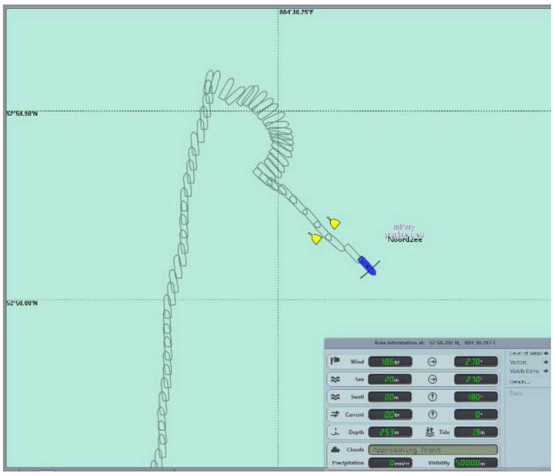
At 12.15 starboard net got stuck on the bottom. Initially this resulted in a roll angle of over 20°. There was no reaction and within a short time this resulted in capsizing.



Run 7: Wind west 20 kts, waves west Hs=2.0m, Tp=6s, no current

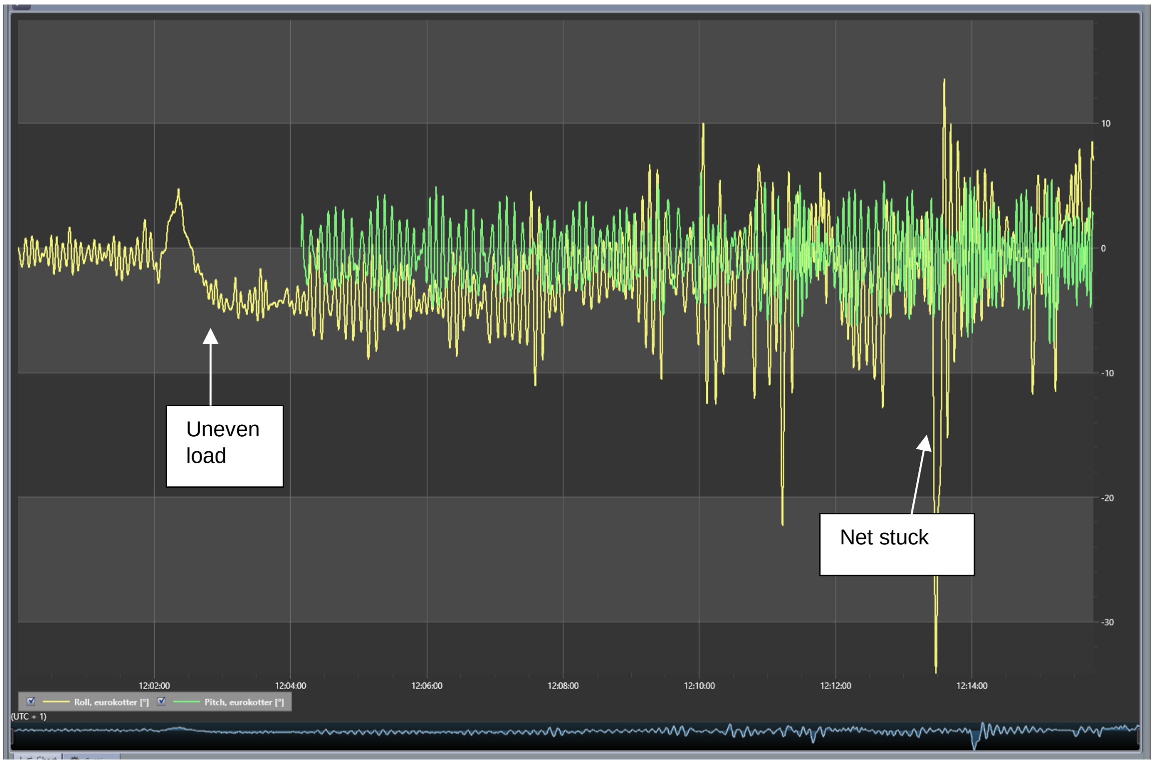
Prior to this run, the winch speed of the fishing line was adjusted. It was increased to 3 m/s. This was done to simulate the release of the winch brake more realistically. Unfortunately, this also meant that the maximum winch-in speed was unrealistically high. However, the skippers were well informed about this effect and this could be controlled with the handles. In beam seas roll angles of up to 25° were observed. At 12:10 SB net got stuck on the seabed, which resulted in a roll angle of 45°. The skipper reacted by stopping the engine, and releasing the fishing line. This was effective in preventing the vessel to capsize. After the fishing vessel had rotated approximately 120° the fishing line became unstuck and fishing was resumed in following seas.

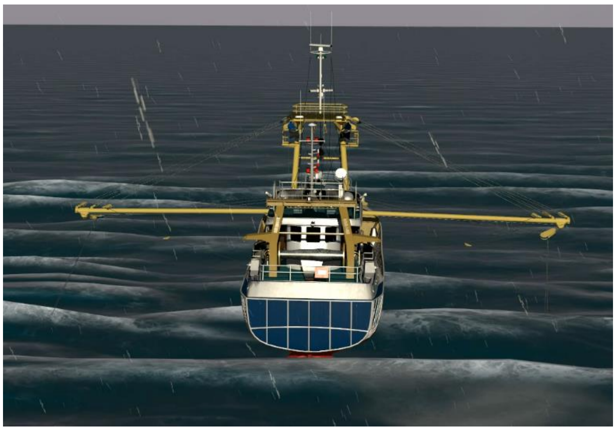




Run 8: Wind south 15 kts, waves south Hs=1.6m, Tp=4s, no current
In this simulation the environment came from astern. In these specific wave conditions the stability of the vessel is compromised. For this run the weight in the nets was set to 2.0 tons. When the nets were retrieved the weight of starboard net was increased to 2.8 tons. Quite suddenly the vessel capsized, without time to react.

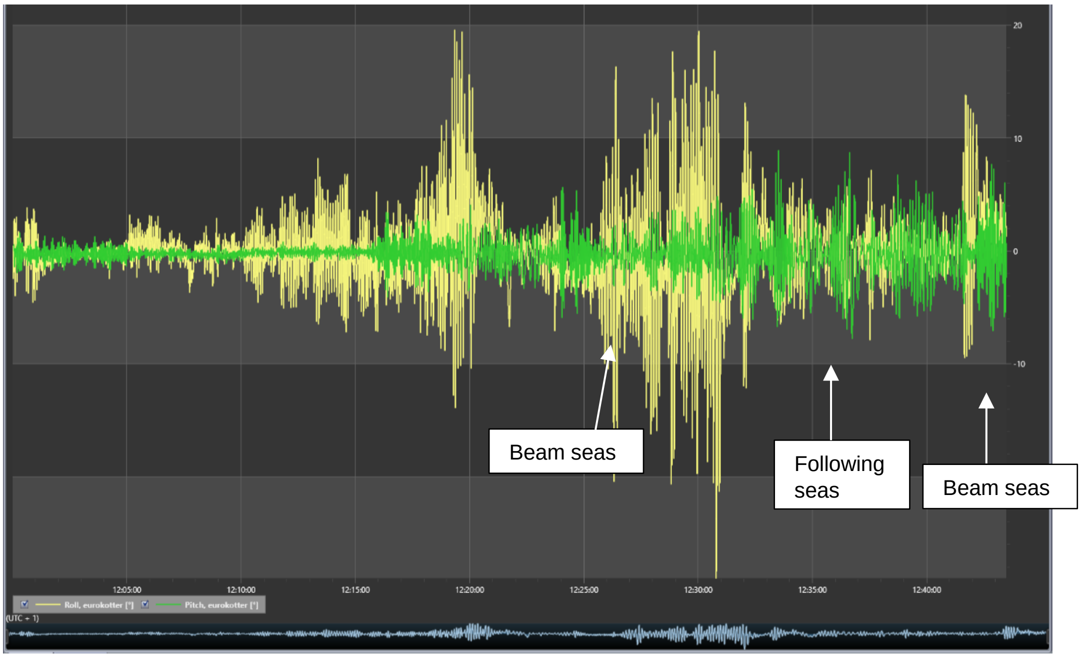
Run 9: Wind south 15 kts, waves south Hs=1.6m, Tp=4s, no current
In this scenario, the wind came from astern. An asymmetric load was created by setting port boom on a 45° angle, whilst starboard side was at 0° (horizontal). Furthermore the weight in the nets was unequally distributed (3.0 tons on portside and 2.0 tons on starboard). This resulted in a list of 5°. At first the ship was turned to course 045. Port boom was lowered and fishing was resumed. Later the course was changed to 090, bringing the sea abeam, which resulted in roll angles of over 20°. At 12.13 the portside net became stuck on the seabed. The speed was reduced immediately and the fishing line paid out, which was effective in preventing capsizing.



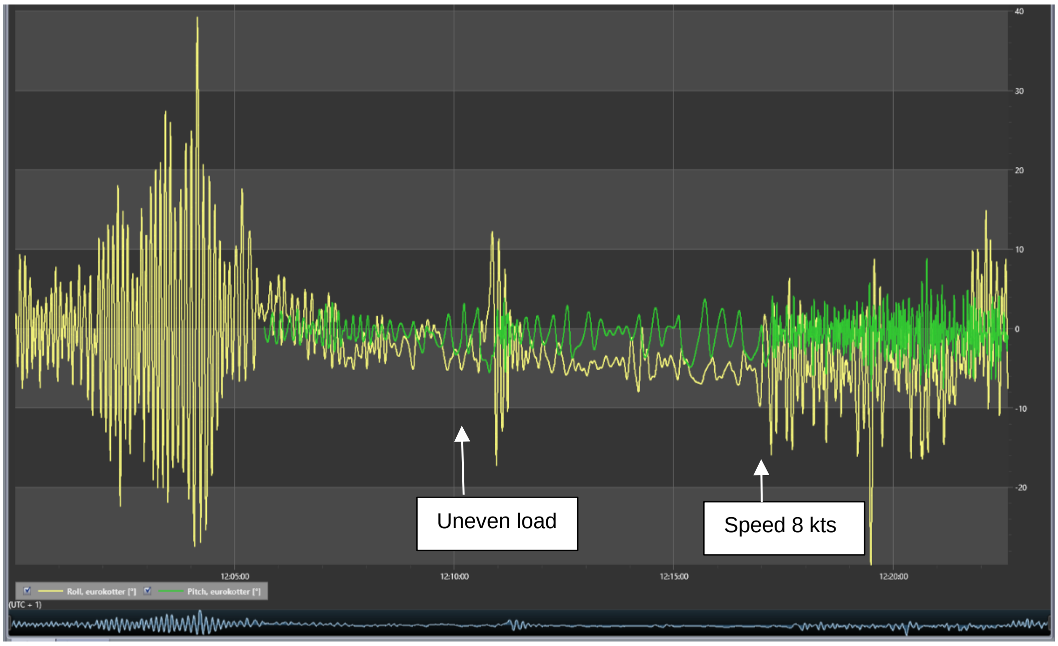


Run 10: Wind west 10 kts, waves west Hs=0.3m, Tp=5s, no current
This simulation was done on the second day with two new skippers. These captains had extensive experience with beam trawlers and explained that beam trawlers normally fish with 5 kts, whilst fishing for shrimp is done at lower speeds (3-4 kts). The simulation started with hauling in the nets. Once above water speed was increased to 8-10 kts to flush the sand from the nets. With the drag setting on 0.4 a speed of 4 kts was achieved in 1.0m waves.

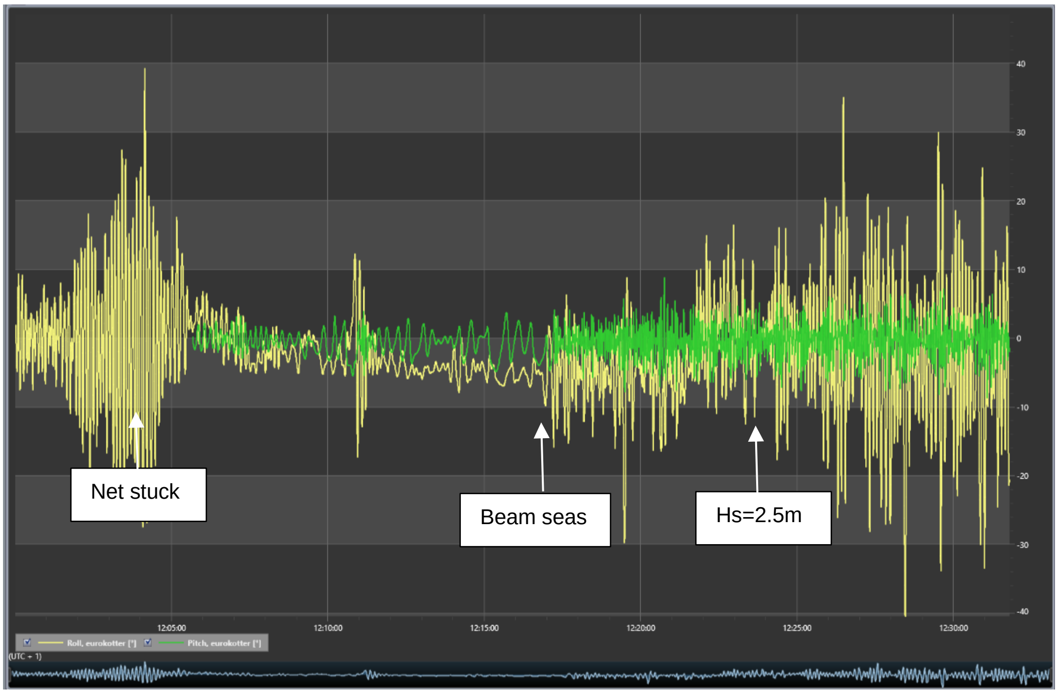
Both fishermen set and retrieved nets on various courses. The waves were experienced as a bit too short for the wave height.



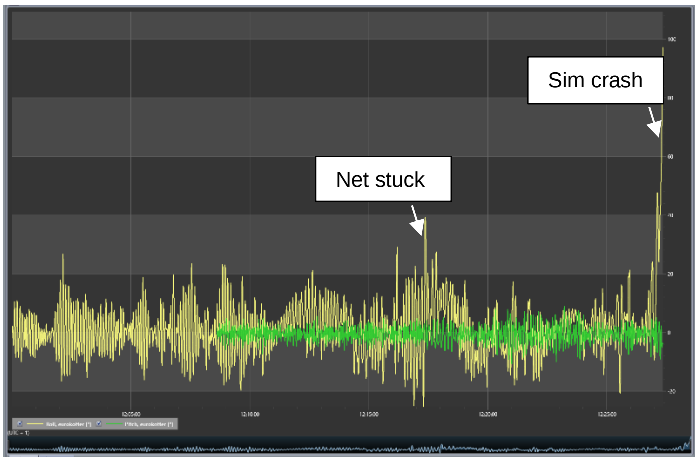
Run 11: Wind west 20 kts, waves west Hs=1.5m, Tp=5.5s, no current
Within the first five minutes, large roll angles were experienced (up to 40°) in 1.5m high beam waves. The vessel was turned to east to retrieve the nets in following seas. The motions were immediately a lot calmer. After retrieving the nets, the weight in portside net was gradually increased from 1.5 to 4.0 tons, resulting in a list of 7°. The speed of the fishing vessel was increased to 8 knots and the vessel turned on various courses to experience seas from different reactions.

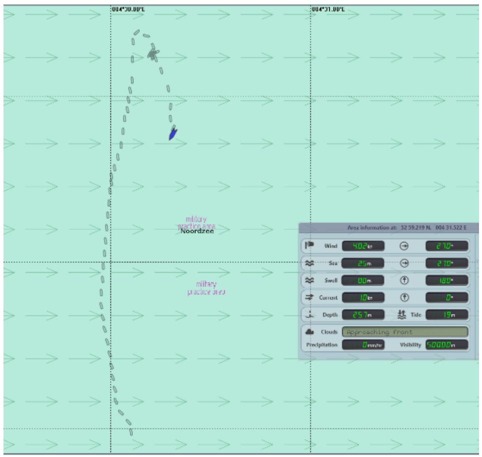


Run 12: Wind west 20 kts, waves west Hs=1.5m, Tp=5.5s, 1 kts current (to north)
These simulations were performed with 1 kts current. The fishing operation was performed with beam waves of Hs =1.5m. Waves were gradually increased to 2.0 m. Starboard net got stuck on the seabed. The skipper reacted immediately with reducing speed and releasing the fish line. A maximum roll angle of 45° was observed. The skipper maneuvered to sail with the waves. Starboard net came loose and was also hewed in. This net contained a heavy weight of 3 tons. In following seas the ship was much calmer, although the uneven load in the nets resulted in a list of approximately 5°.The booms were set to 45° and the course was set to south to create beam seas. The ship started rolling again.
Wind was increased to 35 kts wind, and sea state increased to Hs=2.5 m. After a few narrow escapes with roll angles up to 40°, the vessel eventually capsized. The skippers commented that the behavior is somewhat different (in reality the roll period is larger), but overall very realistic. They commented that such simulations should be included in the study program for sea fishing (SW5 or SW6).

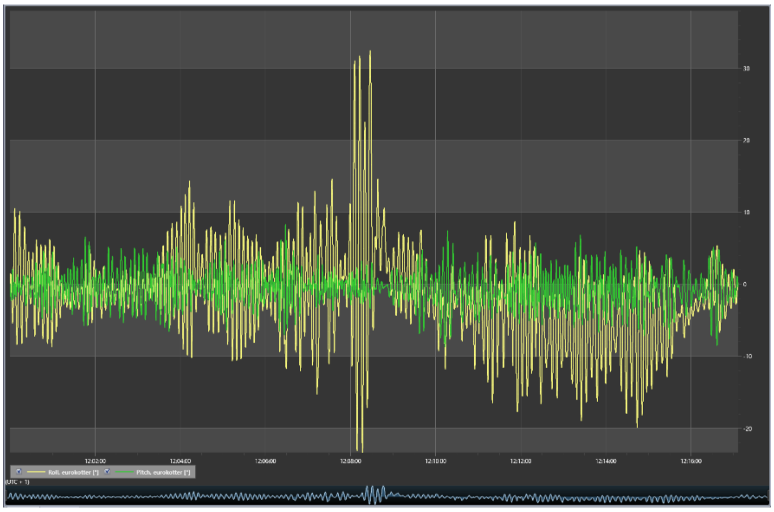


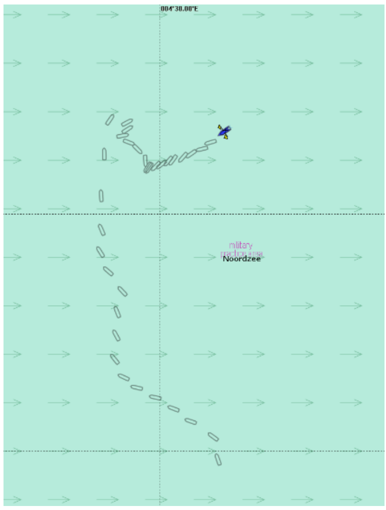
Run 13: Wind west 20 kts, waves west Hs=1.5m, Tp=5.5s, 1 kts current (to north)
This run was a simulation in beam seas with a 1 kts current from astern. Roll angles of 15° were observed. Starboard net got stuck to the seabed. This was immediately detected and appropriate action was taken (reducing speed and releasing the fishing line). Port net was retrieved just before starboard net came loose. Starboard net was also retrieved. In this process the slip line was released to reduce the arm of the force. Fishing was resumed by setting out the nets. However, due to a crash of the fishing gear module, the vessel capsized at the end of the run.





Run 14: Wind west 30 kts, waves west Hs=1.5m, Tp=5.5s, 1.0 kts current (to north)
First the skipper chose a course against the sea, whilst the fishing lines set to around 125m. Course was set to north, to create beam seas. The loads in the nets were uneven, with 1.5 tons weight in port net and 3.5 tons in starboards net. In beam seas maximum roll angles of 30° were observed, but by turning to starboard and creating following seas, this was brought under control. The speed was reduced and the nets were hewed in.

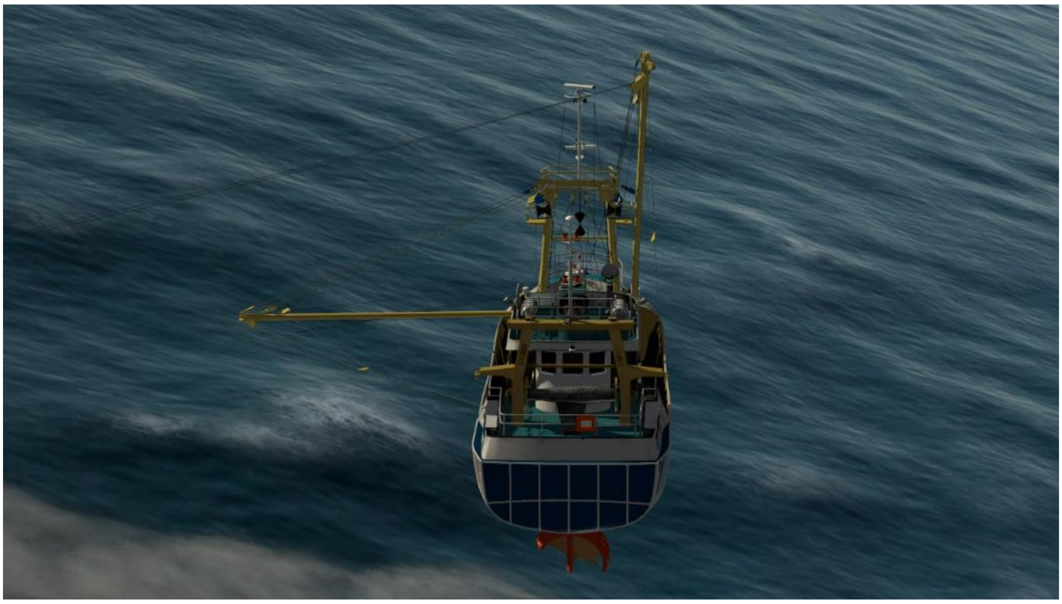




Run 15: Wind south 30 kts, waves south Hs=1.6m, Tp=4.0s, 1.5 kts current (to north)
Fishing started on a track in north east direction. Wind was increased to 40 kts and waves to Hs=2.5m. Startboard net got stuck on the seabed, which resulted in a large roll angle. However, this also resulted in a crash of the simulator.

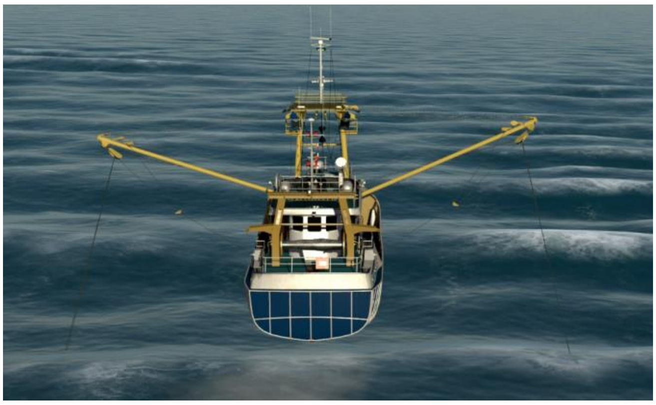
Run 16: Calm conditions wind south 10 kts, waves south Hs=0.5m, no current

The fishermen requested to simulate a scenario in which one of the booms was completely raised. At the start of the run starboard beam was fully raised fully and a turn to port was initiated. This resulted in both lines pulling to port as can be seen in the picture below. Consequently this resulted in a list of over 20°. It seems that every time one of the lines comes in contact with another object (e.g. line or hull) the fishing gear module crashes.



Run 17 Wind south 35kt, waves south Hs=2.0m, Tp=5.5s, no current

This simulation started with following seas and fishing with the booms on a 45° angle. A malfunction of the rudder was initiated (stuck hard to starboard) causing het vessel to turn quickly to starboard. The vessel turned more than 300 degrees, before the rotation was checked, which entangled the fishing lines. In the end this resulted in a crash of the ‘fishing gear module’.



Run 18 Wind west 35kt, waves west Hs=2.3m, Tp=6.0s, 2 kts current (to north)

In this scenario we tried to capsize the vessel. This was done by fishing in beam waves and let the starboard net get stuck. This resulted in a roll angle of 45°. However, the vessel righted itself again. The vessel also turned to starboard which resulted in following seas. This reduced the risk of capsizing. This shows that it might be more dangerous to get stuck whilst on a course against or with the sea. In these conditions the vessel may end up under a large roll angle in beam seas.

4.2 Results of questionnaires

At the end of the day each of the fishermen was asked to fill in a questionnaire. The results of the questionnaires are summarized in the table below, the complete questionnaires are included in appendix 2.

#	Question	Score on a scale of 1 to 5
	Questions regarding simulator realism	
1	I felt that I was immersed and could participate in the simulator environment.	4.6
2	I felt that my experience with sailing/fishing was simulated in a realistic manner.	4.0
3	I felt that the simulations replicated the seakeeping behavior of a fishing vessel in a realistic manner	4.0
	Questions regarding situational awareness of compromised stability	
1	Sufficient information was available to understand the situation.	4.2
2	I had sufficient information to deal with the simulated situations.	4.4
3	In case of capsizing, the moment of capsizing comes as a surprise.	4.4
4	See below	
5	The execution of different scenarios on the simulator provided insight in the stability of a fishing vessel during asymmetric loading conditions?	4.2
6	Having these simulations as a trainee fisherman would have helped me in practice to better understand the stability of a fishing vessel.	4.8

4. Which information did you use in the decision making process and during the execution of emergency actions?

- Sudden course change and roll angle
- Experience from the past
- Knowledge and understanding of the ship
- Force in fish line, slip line, boom, autopilot, rudder, roll angle and water on deck
- Speed/roll angle

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the simulations and the debriefings the following conclusions and recommendations are made regarding the objectives of this study:

1. **Present a realistic experience on a ship simulator of a ship with reduced stability, especially what the effect of asymmetric loads are.**

   Overall the fishermen were very positive about the simulator. The simulator was experienced as very realistic.

   Observations of the fishermen showed a quick familiarization with the simulator environment. Unprompted remarks and behaviours were in line with everyday practice onboard fishing vessels, e.g. “normally I would get some coffee”, and “I would send the deckhands to deck now”.

   It was observed that fishermen in some cases ‘felt’ (“It’s now pulling more heavy on starboard side”) before reading it from instruments (e.g. tension meter) that a load was added in one fishing net. Also noteworthy is how a fisher acted in a situation with reduced stability in extreme roll angles by continuously placing one hand on the telegraph so he could act quickly when necessary. In the debriefing the fishermen told that his behaviour was almost subconscious, like he would do when handling his own vessel.

   To summarize, observed realistic and intuitive responses, and self-reporting of the fishermen showed a realistic and immersed experience on a ship simulator of a ship with reduced stability.

2. **Evaluate the realism and usability of simulations for training purposes with experienced fishermen. Hereby the focus is on contributing to the overall understanding of stability issues.**

   Simulations of the different scenarios were received as realistic by the fishermen.

   There was overall consensus that the simulator is an excellent mean to learn things about stability. Even things you can’t learn in practice. Some of the quotes at the end of the simulations: “The safety of ship and crew is enhanced considerably, if unexperienced fishermen have followed a course like this on this simulator” and “Every student should do this!”.

   It was an eye opener that capsizing can occur really unexpected and fast. Some fishermen reported a blockage to take action in case of large roll angles or when a net gets stuck. In such situations a high mental load was experienced.

   To further enhance realism and usability of the simulations for training purposes, the following recommendations are made:

   - The speed for fishing should be around 5.0 kts for these ships. In the simulations the speeds were often lower, but by decreasing the drag of the fishnets, this can be adjusted as required.

   - The motions of the fishing vessel were experienced a bit too abrupt.

   - The rudder speed was considered too high. This was amended during the simulations. Also the working of the autopilot can be improved. It was noted that the rudder indicator is a good indicator for a net getting stuck (in such a case the autopilot will use hard over rudder to maintain the set course).

   - Include the Marelec history graph. Now the real time forces in the fishing lines were shown numerically, but in practice the trendline of a history graph is easier to interpret than the numbers.

- The winch in/out speed was difficult to control, this made it difficult to achieve equal winch speed in both fishing lines. For each line we used a winch, which was controlled by its own lever. An improvement would be to use one lever to control the winch speed, and separate levers to clutch in the appropriate line(s). These separate levers can have three setpoints:
    - Clutch in, the line is hewed in or paid out with the speed set by the winch speed lever.
    - Clutch out, the line is disconnected from the winch and on the brake.
    - Release, which releases the brake and allows the line to pay out freely.

With regards to a training course the following recommendations were made:

- Include simulation runs in fair weather conditions to let trainees become comfortable with the simulator set-up.
- The behavior and effect of the slip line was realistically included in the simulation. It would be interesting to include a simulation run in which the slip line blocks.
- Include the effect of current (this was done on day 2)
- Include simulations with a beam trawler equipped with a net reel on the aft deck.
- Include a scenario with two rigs intertwined.

3. Experiment with emergency measures to prevent capsizing.

When an asymmetric load is experienced, due to a difference in weight in the lines the subsequent lift can be compensated by paying out the slip line (safety line) on the heavy side. In a debriefing a fisher mentioned he never used the slip line like he used it in the simulator to regain stability.

It can be more dangerous to get stuck with the nets whilst on a course against or with the sea. In these conditions the vessel may end up under a large roll angle in beam seas.

The fishing gear module crashed on several occasions. It seems that this is related to the lines coming in contact with the hull or with each other. This needs to be further investigated. Overall further investment in the simulator software is required to make the simulator performance more reliable.

REFERENCES

[Ref 1.] MARIN Report, 77002-1-SMB Dynamic stability beam trawlers: Seakeeping model tests, November 2024

[Ref 2.] 04621b Stability Booklet Eurokotter.pdf

[Ref 3.] 21.145-0002-0000- Eurokotter General Arrangement - A0-REV.A.pdf

[Ref 4.] OSS LMS bedienings handleiding V1.6

[Ref 5.] Starvoorwaarden gebruik LMS als bewegende simulator [NL} v1.1

APPENDIX 1 INFORMED CONSENT FORM

You are being invited to participate in a simulation on the Large Motion Simulator (LMS) in MARIN's Seven Oceans Simulator Centre (image 1). The LMS is a motion based wheelhouse of 4x5m, placed on a hexapod, with 360 degrees projection in a large spherical dome of 16m. The simulation consists of operating the operation of a free sailing ship from the simulator bridge.

The simulation may include heavy motions, which can result in simulator sickness symptoms, such as nausea, headaches or dizziness.

The simulations will be executed with the operator standing on the bridge The bridge is equipped with an anti-slip floor, handholds on the ceiling and handrails around the consoles. During these simulations the operator will be equipped with a fall arrest harness, connected to the ceiling in order to prevent injuries when balance is lost. For additional safety a helmet is worn as well.

Please let the MARIN staff in charge of simulation know if your level of discomfort reaches your personal threshold. In this case, we will stop the simulation. If you feel any discomfort by the end of the simulation, it is advised you take a break before controlling any vehicle.

Please indicate beforehand to the MARIN staff operating the simulator if you have any physical conditions or limitations that might prevent you from safely participating in this simulation.

Image 1: large motion simulator (LMS)

I declare that to my knowledge I have no physical conditions or limitations that might prevent me from participating in a simulation on a motion platform.

I declare that I have read and understood the information provided in this consent form. I have had the opportunity to ask questions and received satisfactory answers. I voluntarily agree to participate in this simulation, understanding the potential risks involved.

Participant name: ___________________________________

Participant Signature:

Date: ______________________

I agree to having video recordings or photos being used for data collection and analysis purposes. *Encircle the answer that applies.*

YES / NO

I agree to having video recordings or photos being used for publication purposes. *Encircle the answer that applies.*

YES / NO

APPENDIX 2 INTERVIEW RESULTS

Debriefing vragenlijst - resultaten

Simulatorbeoordeling

1. Ik voelde dat ik kon opgaan en meedoen in simulatieomgeving.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld
	1	2	3	4	5	3
N = 5	0	0	0	2	3	4.6

Opmerkingen: "We kunnen alles inbrengen. Er wordt naar ons geluisterd"

2. Ik ervoer dat de simulatieomgeving op een realistische manier mijn ervaring van het varen/vissen uit de praktijk nabootste.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld
	1	2	3	4	5	3
N = 5	0	0	1	3	1	4

Opmerkingen: (Jelle: bij neutraal (dag1)) "Vond het simulatorschip best wel onstabiel"

3. Ik ervoer dat de simulatieomgeving op een realistische manier het zeegangsgedrag van een visserschip nabootste.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld
	1	2	3	4	5	3
N = 5	0	0	0	5	0	4

Opmerkingen: "Zeegang soms te schokkkerig. (Te)"
"Kwam redelijk overeen"
"Zitten nog wel harde bewegingen tussen"

Situatiebewustzijn bij een onstabiele situatie

1. Ik had genoeg informatie ter beschikking om een idee te krijgen van de situaties.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld
	1	2	3	4	5	3
N = 5	0	0	0	4	1	4.2

Opmerkingen: "Prima scenario's"

2. Ik had genoeg middelen ter beschikking om met de situaties om te gaan.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld:
	1	2	3	4	5	3
N = 5	0	0	0	3	2	4.4

Opmerkingen: "Alleen jammer dat we slipdraden niet gebruikt hadden"

(Jelle: bovenstaande is ingevuld in de ochtend)

3. In het geval van kapseizen kwam het moment van omslaan vaak geheel onverwachts.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld:
	1	2	3	4	5	3
N = 5	0	0	0	3	2	4.4

Opmerkingen: "Zeker de eerste keren. Was 1 moment"

"Geen tijd om te reageren"

4. Welke informatie gebruikte u bij het maken van beslissingen en bij het uitvoeren van (nood)maatregelen?

Opmerkingen: "Snelle koersverandering en hellingshoek."

"Ervaringen uit het verleden."

"Kennis en inzicht in het schip."

"Trekkracht, slipdraad, vislijn, giek, regulateur, wind&zeegang, roer, hellingshoek, water aan dek"

"Snelheid/helling."

5. Het uitvoeren van verschillende scenario's op de simulator gaven inzicht in de stabiliteit van een visserschip tijdens asymmetrische beladingstoestanden.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld:
	1	2	3	4	5	
N = 5	0	0	0	4	1	4.2

6. Deze simulaties zouden mij als leerling-visser geholpen hebben voor een beter besef van de stabiliteit van een visserschip later in de praktijk.

Deelnemers:	Sterk mee oneens	Oneens	Neutraal	Eens	Sterk mee eens	Gemiddeld:
	1	2	3	4	5	
N = 5	0	0	0	1	4	4.8

Opmerkingen: "Om beter inzicht te krijgen v/d realiteit wat ze vaak onderschatten."

"Ik denk dat als onervaren vissers op deze simulator een cursus doen dat dit de veiligheid voor schip en bemanning erg bevorderd."

"Dit moet elke student een keer doen."

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