



F I N L A N D

Investigation report

C 5/1998 M

ms BALTIC MERCHANT, grounding in Puumala at Hätingvirta, April 21, 1998

This investigation report was written to improve safety and prevent new accidents. The report does not address the possible responsibility or liability caused by the accident. The investigation report should not be used for purposes other than the improvement of safety.

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Summary

The German general cargo ship ms BALTIC MERCHANT owned by Baltic Forest Line GmbH went aground on Lake Saimaa on April 21, 1998. Before the grounding the visibility deteriorated very quickly and there was no clear lead through the ice in the Hätingvirta sound. Ice floes disturbed the radar and the shoreline could not be discerned. The mate was acting as lookout and handled the searchlight. The pilot was steering the vessel and used the radar, which was disturbed by the sea clutter. The grounding occurred in the sound in the darkness at 00:15 and at a very low speed. As a result of the grounding there was a leak in the forepeak.

The grounding of the BALTIC MERCHANT was a result of the progressive reduction in the visibility. When the visibility deteriorated the cooperation between the pilot and the mate became difficult and was also reduced in direct relation to the visibility. The demands for the cooperation grew but were not met. Due to this, also the navigation and steering became more difficult when the pilot tried to cope simultaneously with the piloting and the steering of the vessel and using for this control equipment which was poorly suitable for the task.

A contributing factor to the grounding was also the fairway geometry, because the fairway through the Hätingvirta sound is a demanding one. The passage through it is especially difficult in a fog and without a passage plan. In the prevailing conditions and with the control equipment at hand there were no sufficient preconditions for piloting in any navigation method. Another contributing factor to the grounding was the lack of regulations and instructions, where the limitations for the piloting and for the continuation of piloting are dealt with in relation to the bridge equipment, manning and weather.

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Figure 1. General view of ms BALTIC MERCHANT

1 GENERAL DESCRIPTION AND INVESTIGATION OF THE ACCIDENT

1.1 The vessel

The data on the vessel is based on a brochure of Arminius Werke shipyard on the sister ships of the BALTIC MERCHANT, the BALTIC SKIPPER and BALTIC CARRIER. The data is supplemented with photographs taken from the bridge of the BALTIC MERCHANT which match the brochure published by the yard. At the time of the accident, the vessel was about six months old.

1.1.1 General data

Name of ship	ms BALTIC MERCHANT
Owner	Baltic Forest Line GmbH Schiffahrtsges. MgH &Co. KG. Peuterstrasse 67, 20539 Hamburg
Home port	Hamburg
Year of construction	1997
Registration	SSR 2220
Type	General cargo ship
Crew	7
Classification society	Germanischer Lloyd
Classification	100 A5 MG E2 + MC Aut E2
Ice class	Finnish ice class 1 B
Length	82,50m
Lpp	78,57m
Width	12,45m
Draught	5,02m in vessel data on the bridge
Freeboard	1345mm
Gross capacity	2280
Net volume	1244

Deadweight	3110 tons
Light ship	1236,76 tons
Displacement	4335
Hold	50,7m x 10,2m x 8,1m
Cubic volume	151,700 cubic feet
Unit volume	128 TEU (96 in hold / 32 on deck)
engine power	1360 kW MAK Diesel, type 8 M 20.
Speed	10,5 knots

The vessel had one propeller and bow thruster. The rudder was a Jastram flap rudder which improved the manoeuvrability of the vessel. The flap was connected mechanically to the rudder. It can be deduced from photographs that the propeller rotated clockwise from rear. On the vessel data table on the bridge this was stated as follows: 'Pitch propeller right rotation /left rotation effect'. According to this, the propeller creates a moment which turns the vessel to port.

1.1.2 Crew and traffic limitations

According to the maritime declaration the crew included the master, mate, three deck hands, engineer and cook totalling 7. According to the wharf brochure¹ there were 8 persons in the crew. The German/Rhein river traffic regulations request a crew of four². The manning document was not presented in the maritime declaration session and the alertness of the crew was not discussed.

The pilot had acted as canal pilot 10 years and as marine pilot a few years.

1.1.3 Cockpit and its equipment

The bridge had covered wings. Both wings contained

- equipment for aiming searchlights in the ceiling
- control equipment for main propellers
- control for bow thruster with pushbuttons and indicator lights for 70%, 85% and 100% to starboard and port.
- tachometer for main machine and tachometers and pitch indicators for propellers.
- NFU steering lever and rudder angle indicator.

There were two navigation posts in the middle of the bridge with radars. The console in between was occupied mainly by control equipment for the machinery. In addition it had the autopilot and NFU (Non Follow Up) emergency steering (Figure 2).

¹ Arminius Werke GmbH

² RheinSchUO 1995, 23.10 §.



Figure 2. Bridge view of ms BALTIC MERCHANT

Navigation equipment

GMDSS radio equipment, region A2
 Watch receiver R 501
 2 fixed Sailor VHF radiotelephones and VHF DSC receivers
 3 portable VHF radiotelephones
 Inmarsat C station
 Magnavox GPS receiver MX 200.
 Navtex and weatherfax receivers
 Furuno F 6060 depth sound
 Furuno DS 70 Doppler log
 EPIRB buoy
 2 SART radar transponders
 Cassens & Plath magnetic compass
 Battery free telephone
 Marine radar Kelvin & Hughes Nucleus 5000A
 River radar ELNA 3300 monitor
 Transmitter/receiver and antenna
 Manufactured by Kelvin & Hughes
 Gyrocompass Anschütz Standard 14
 Autopilot Anschütz Nautopilot D

There was no rate of turn indicator or autopilot based on rate of turn.

1.2 Accident events and preceding activity

1.2.1 Weather conditions

According to the pilot, there was no wind. The visibility was one kilometre on the approach to Hätinvirta but it dropped to 200 metres 4-5 minutes before the accident.

1.2.2 Preparation for piloting trip

The pilot collected the traffic information at the Mälkiä lock from the lock master. He does not mention in his report of having had a passage plan nor does he mention that there would have been any discussion about the piloted trip between him and the master.

In the maritime declaration the master stated that he had a conversation with the pilot concerning speed before the start of piloting. He does not mention having had a passage plan.

1.2.3 Accident voyage

The description of the accident voyage is based on the maritime declaration and the report of the pilot. General cargo vessel BALTIC MERCHANT was on her way from Zaandam to Varkaus on April 21, 1998 in ballast. The draught at the bow was 2,8 metres and at the stern 3,8 metres.

A canal pilot had piloted the vessel through the Saimaa canal. The pilot had been exchanged at the Mälkiä lock on April 20, at 20:50. At the time the master was on watch duty on the bridge. There was no helmsman or watchman. The master steered the vessel out of the lock. The pilot was manning the helm. The visibility was about 1 kilometre. One of the radars was in use.

General cargo ship PIA was travelling ahead preceded by tug PROTECTOR breaking the ice. After the canal, the engine power of the BALTIC MERCHANT was 90%. In the open the ice was broken but in narrow straits there was a clear lead. According to the pilot, the second radar was switched on after dark. One of the radars was on scale 1,5' NM and the other one on a smaller scale. The left searchlight was switched on and aimed to the edge of the lead in the ice. The watchman on duty was on deck and prepared to help the pilot board the vessel. According to the master it was normal to have only the mate on the bridge. There was no helmsman or lookout.

The PIA was passed at Rastiluoto half way between Lappeenranta and Puumala. Before the passing, the mate took over the watch. After the passing one VHF was left on channel 6 for radio traffic with the PIA. The pilot told that he and the mate took turns at the helm.

The visibility dropped to half a mile. The pilot telephoned the traffic officer on duty and reported that the BALTIC MERCHANT would arrive in Puumala after one and a half

hours provided that she did not have to anchor because of the bad visibility. He also asked the next pilot to report after waking up the visibility in the Puumala sound. The visibility dropped to less than half a mile. Ten minutes before the arrival of the BALTIC MERCHANT at the Hätingvirta ferry, the pilot reported on VHF channel 16 to the ferry operator and inquired about the visibility. The ferry operator said that the leading lights on the north shore of the sound were visible giving about 1100 metres as the visibility in the sound. The pilot reported to the pilot of the PIA on VHF channel six that he would begin to reduce speed for meeting the ferry. (Figure 3).

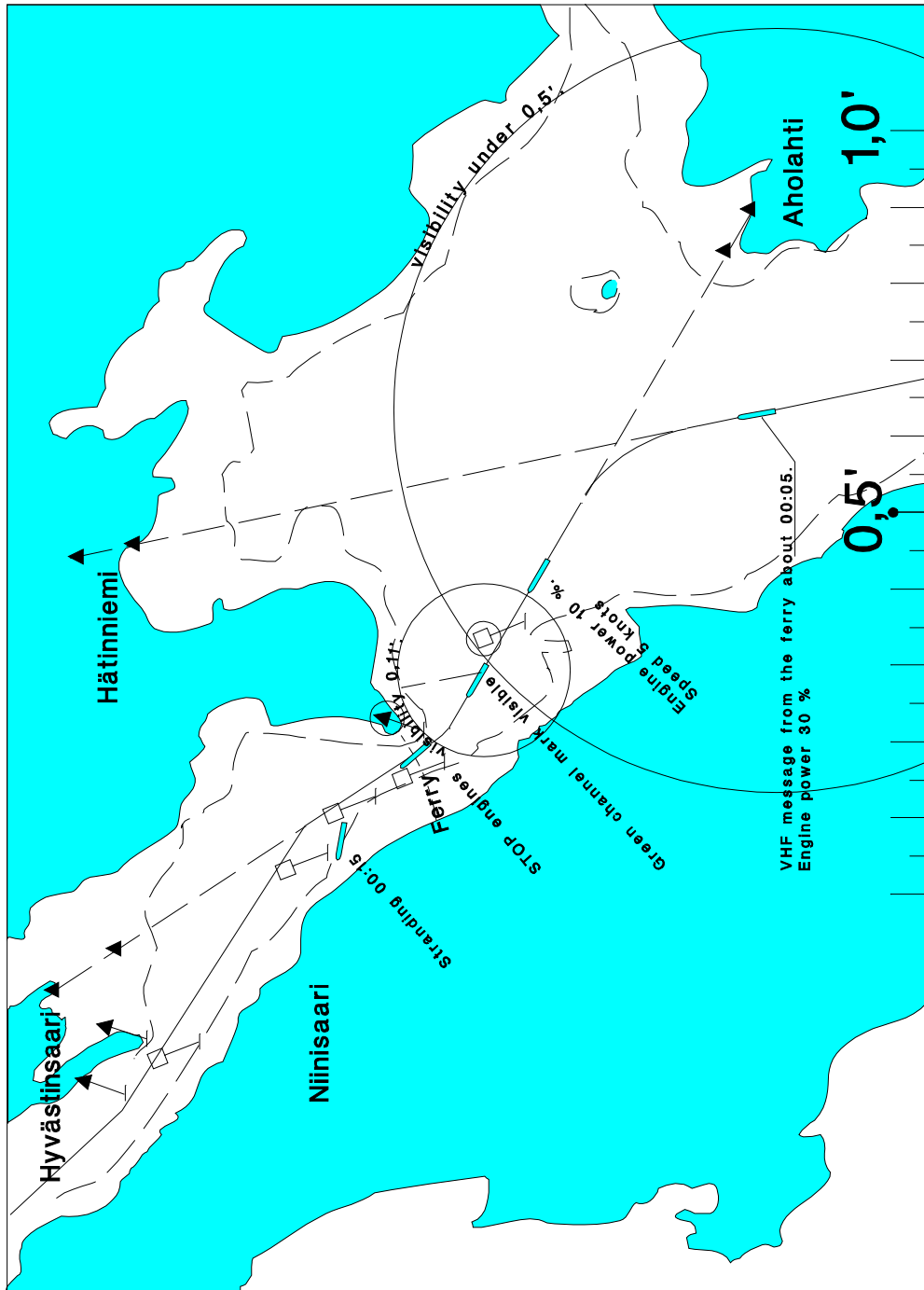


Figure 3. Events according to maritime declaration. Visibility deteriorated at crucial moment. Location of vessel at 00:15 and heading copied from chart based on unofficial soundings delivered by the maritime district to the Maritime Court in connection with the maritime declaration.

On arrival at the red lit buoy the pilot observed a visibility considerably less than half a mile. The speed was 5 knots and the engine power 30%. The pilot asked the mate to look for the next green lit buoy with binoculars and reduced the engine power to 10 per cent. The green buoy appeared at a distance of 200 metres. No leading lights were visible. The pilot asked the mate to search for the next red buoys with the searchlight. The pilot manned the helm. The mate used the searchlight on the port wing.

When the green buoy was passed, there were no red buoys nor leading lights in sight. There was open water at the site due to the currents. The radar image was flecked with ice floes. The pilot did not manage to produce the buoys on the radar by adjusting gain and sea clutter. The edge of solid ice and the shore line could not be distinguished. The radar did not help and the situation turned dangerous in the opinion of the pilot.

The pilot stalled the engine at the ferry and asked the mate to look for the next buoy with the searchlight. The only reliably identifiable radar target would have been the tip of Hyvästinsaari but even this was not visible on the radar. The intention was to glide through the sound and stop in the ice floes. The second red buoy appeared to port. It was passed at a distance of 2 metres. The third buoy materialised ahead starboard of the bow. The pilot immediately reversed the engine but this had no time to take effect and the vessel grounded. The pilot calculated from the force of the impact that the speed had been about 1-2 knots. The time was 00:15.

The shore lights of the ferry were visible 200 metres behind the stern. The shore was 50 metres ahead and faintly visible. The mate woke up the master and the pilot warned the PIA which remained south of the ferry waiting. The pilot in Puumala contacted the vessel reporting zero visibility and that the piloting would not be continued from Puumala.

1.3 Rescue activity

1.3.1 Alarms

The pilot reported to the traffic inspector and to the navigation inspector after the grounding.

1.3.2 Damage to the vessel and her rescue

The forepeak had sustained a leak. The master began the pumping of ballast from the bow. The police, fire brigade and Puumala pilot arrived on the vessel. The engine was running slowly forward all night in order to keep the vessel grounded. Fairway maintenance vessel KUMMELI arrived in the early morning.

Tug PROTECTOR arrived in the morning. After the rescue agreement, she drew the BALTIC MERCHANT afloat.

The pilot was exchanged at the Puumala changing post and the vessel was conducted to Savonlinna for repairs.



Figure 4. Damaged forepeak of ms BALTIC MERCHANT under repair at Savonlinna dock.

1.4 Accident investigation

Since several incidents where a foreign ship had grounded during piloting had taken place in the autumn of 1997, the Accident Investigation Board decided to launch a common investigation for several accidents on December 29, 1997. One of the accidents later included in this investigation was the grounding of general cargo ship ms BALTIC MERCHANT in Puumala at Hätinvirta on April 21, 1998.

These cases have not resulted in damage to persons or the environment and the damage sustained by the vessels has also remained relatively minor. The recurrence of such incidents, however, gives a reason to investigate the course of events and their causes in order to prevent similar occurrences in the future.

The master of the BALTIC MERCHANT provided a maritime declaration in a session of the Maritime Court in Savonlinna on April 29, 1998. The investigators acquired the minutes of the Maritime Court with enclosures.

Martti **Heikkilä**, Chief Accident Investigator and Risto **Repo**, Accident Investigator and Sea Captain, of the Accident Investigation Board were named as investigators of the grounding of the BALTIC MERCHANT. Permanent experts in the investigation were Kari **Larjo**, Sea Captain, Antti **Haapio**, Director, Sea Captain, of the Maritime Safety Training Centre, Leena **Norros**, Kristiina **Hukki** and Maaria **Nuutinen**, psychologists of VTT Automation, Matti **Hellevaara**, MSc (Tech.) of VTT Manufacturing Technology and Pirjo **Valkama-Joutsen**, Administrative Director of the Accident Investigation Board.

2 ANALYSIS

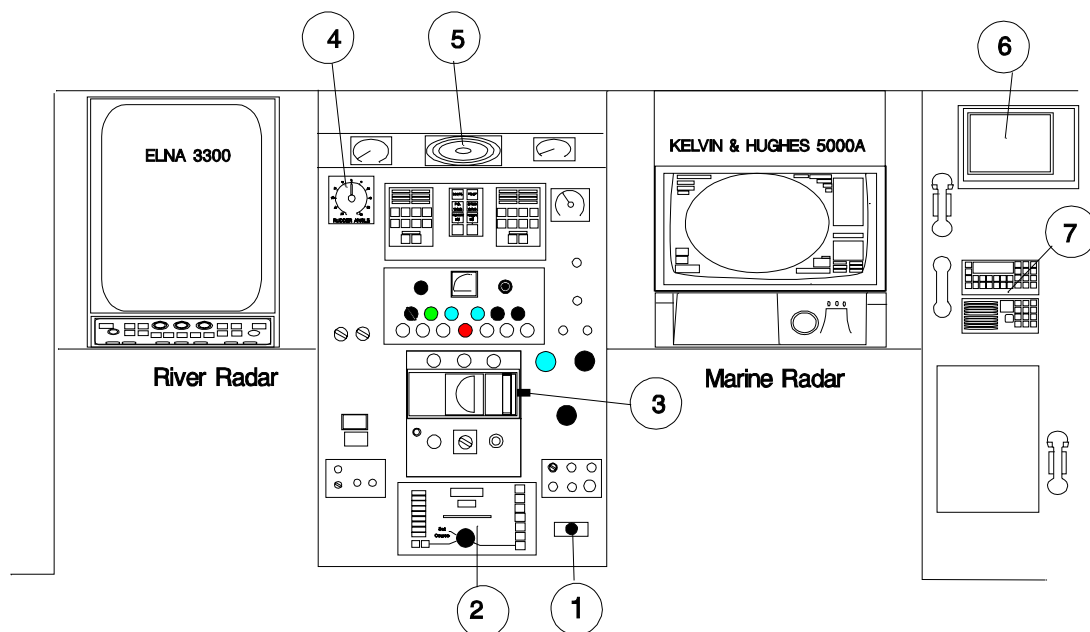
2.1 Conditions for navigation and piloting

2.1.1 Cockpit arrangements and conditions provided for piloting

The following presents an analysis of the cockpit arrangements of the BALTIC MERCHANT. The analysis addresses the suitability of the various control positions on the bridge for piloting on archipelago fairways in the light of the equipment situated in them. The analysis also discusses the usability of individual navigation instruments for the same purpose.

The drawings on the cockpit arrangements are based on photographs of the bridge of the BALTIC MERCHANT. Therefore, the pictures are not in scale.

Control positions in the cockpit. There were two control positions in the cockpit. The starboard navigation positions had the Kelvin & Hughes marine radar. The port navigation positions had the ELNA 3300 river radar. NFU manual steering was located on the right hand edge of the console and in the wings of the bridge.



- | | | | |
|---|------------------------|---|-------------------------------|
| 1 | Manual steering (NFU) | 5 | Compass |
| 2 | Autopilot | 6 | Echo sounder |
| 3 | Engine control | 7 | VHF or MF DSC radio equipment |
| 4 | Rudder angle indicator | | |

Figure 5. Navigation console of cockpit of ms BALTIC MERCHANT.



Figure 6. Kelvin & Hughes marine radar

Radars. The Kelvin & Hughes marine radar is not designed for piloting on archipelago fairways or inland waters. The user interface of this radar has been analysed in regard to piloting in the accident investigation of ms GERDA (Investigation C 4/1998 M). It could be determined that the user interface of the radar operated with a roller ball and menus is difficult for piloting. The problem is the complicated use of the electronic bearing line and variable range marker. During piloting, these controls are too complex and slow to use.

The user interface of the Kelvin & Hughes marine radar deviates considerably from the monitors of other manufacturers. This is problematic especially to pilots who do not have the same opportunities for practising the use of the radars as the ship's officers have.

In river radars this complexity is restricted by the Rhein river traffic regulations. The ELNA river radar allows the setting of bearing with one command. The same applies to range. The river traffic regulations forbid the connecting of the compass heading to the heading line of the river radar (gyrostabilised radar screen). The compass heading must be read from the daughter compass next to the radar (Figure 10). The heading line of the radar always points upward on the screen. Heading arc 000° - 360° stands for headings with regard to the bow. The river radar does not meet IMO open sea regulations concerning the compass connection.

The positive aspect of the ELNA river radar is the clear user interface. It is easy and quick to use. The pilot has clearly expressed this. The pilot preferred to use the river radar and he switched to that when the mate was looking for buoys with the searchlight.



Figure 7. ELNA river radar

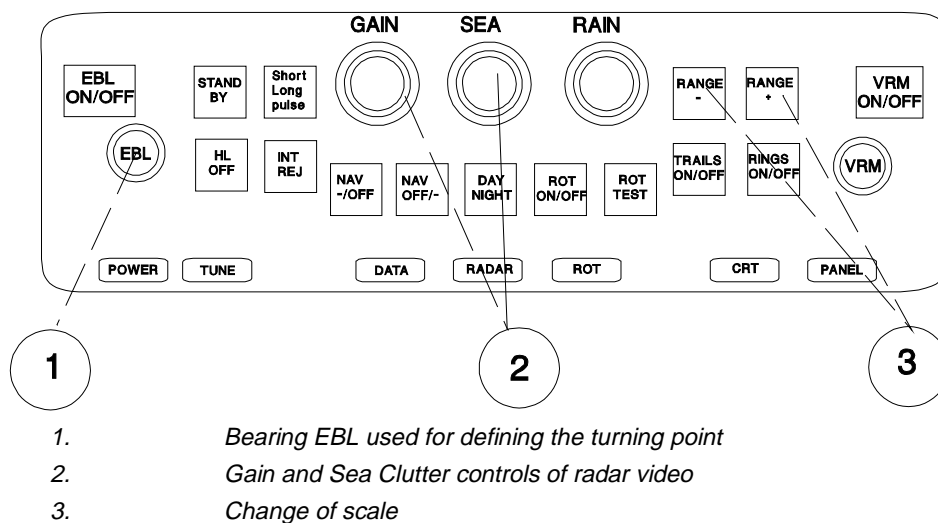


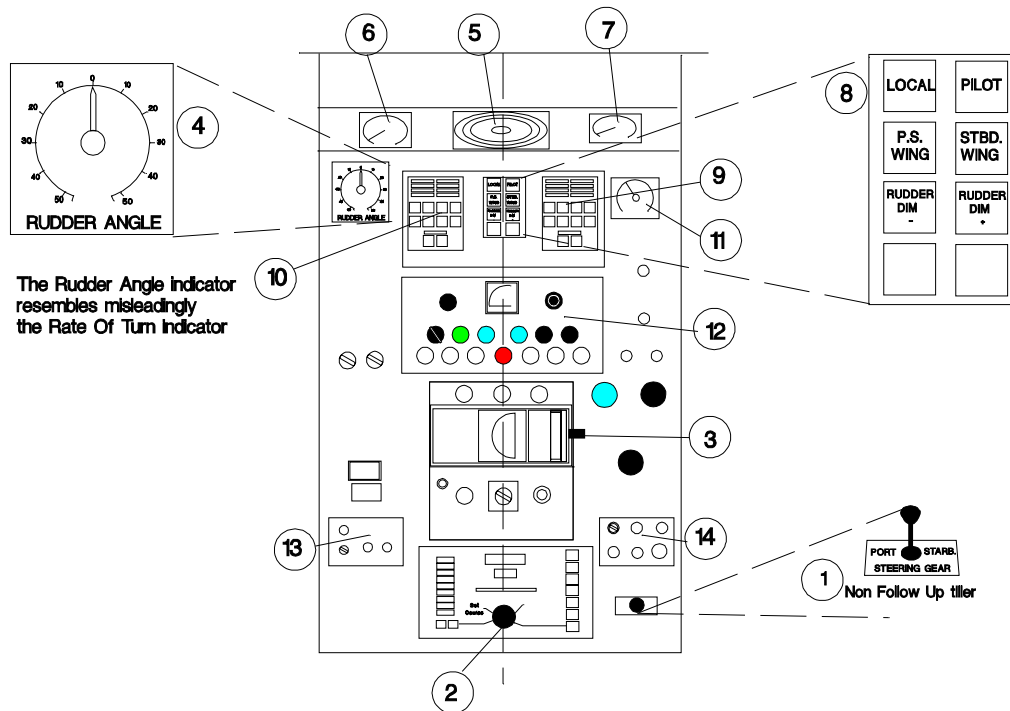
Figure 8. Keyboard of the ELNA 3300 radar was clear and user friendly. Controls 1, 2 and 3 would have been needed at Hätinvirta in the conditions during the grounding. Figure drawn from photograph.

Steering equipment. The BALTIC MERCHANT had only the autopilot and NFU steering. The steering place was selected with press buttons from the top edge of the steering console in the control unit for the rudder machine. The Nautopilot D automatic steering was not suitable for piloting on narrow winding fairways, because the BALTIC MERCHANT was not equipped with the ROT Tiller steering mode for the Nautopilot D system. This mode would have been suitable for demanding steering on narrow fairways.

The NFU (Non Follow Up) steering is commonly used as emergency steering because it is very reliable. It is difficult to steer with the NFU lever, since the position of the rudder is determined by the length of time the lever is pressed which means that the rudder angle indicator must be monitored constantly. It is not possible for the same person to navigate with the radar and steer the vessel in this mode at the same time. Another commonly used method for manual steering is the FU, (follow Up) steering, which the BALTIC MERCHANT did not have, however. The magnitude of the rudder angle command is felt with the lever of the FU steering and the rudder angle indicator need not be constantly monitored. This is an advantage if the radar image requires concentration when steering. There was no time for radar adjustment in the piloting situation at Hätinvirta.



Figure 9. *Steering console of the BALTIC MERCHANT*



- | | | | |
|---|---------------------------|----|--|
| 1 | Manual steering (NFU) | 8 | Steering selection panel |
| 2 | Anschütz autopilot | 9 | Rudder machine pump 2 |
| 3 | Engine Control | 10 | Rudder machine pump 1 |
| 4 | Rudder angle indicator | 11 | Starting air pressure |
| 5 | Anschütz daughter compass | 12 | Jastram rudder machine |
| 6 | Tachometer (propeller) | 13 | Emergency steering for propeller pitch |
| 7 | Tachometer (engine) | 14 | Propeller clutch |

Figure 10. Middle console of bridge of the BALTIC MERCHANT. Main steering equipment is marked on drawing. Figure is drawn from photographs. Width of middle console is about 80 cm.

Table 1. Key for equipment 8 in Figure 10

Text on press button	Explanation
P.S.WING	NFU lever in port wing
STBD WING	NFU lever in starboard wing
Local	NFU lever in middle console
PILOT	Nautopilot D automatic steering

As a summary it can be stated that the steering equipment of the BALTIC MERCHANT was not suitable for one man steering of the vessel on narrow fairways. The steering equipment of the vessel can also be evaluated according to the Rhein river traffic regulations which include detailed technical specifications on one man steering positions. It is possible that the BALTIC MERCHANT was intended for inspection according to these regulations, since the vessel carried a river radar. The equipment, however, was not fully consistent with the river traffic requirements.

The 1995 inspection manual of the central committee for the Rhein river traffic (ZKR) requests that the radar control position allows control of all steering equipment and meters sitting down and without losing track of the radar image³. The regulations require FU (Follow Up) steering for the rudder⁴. The BALTIC MERCHANT did not meet the requirement for river traffic concerning the latter. No corresponding requirements on technology and steering positions have been defined for Finnish canals and inland waters.

The autopilot based on rate of turn is not compulsory in river traffic but if it is missing, a rate of turn indicator and the use of a helmsman are required. There was no rate of turn indicator on the BALTIC MERCHANT. The rate of turn indicator can be replaced by the rate of turn information presented on the radar screen and the ELNA radar carried this in the upper section of the screen. With regard to the regulations, the steering equipment formed the economically most feasible unit.

Radar navigation requires a clear and easy to use steering system in order to manage the piloting, steering and radar adjustment at the same time without effort. The pilot used first the Kelvin Hughes radar and the mate used the ELNA river radar.

After the pilot had asked the mate to track the red buoys with the searchlight, the pilot moved to the river radar. The rudder angle indicator was to the right of this (Figure 10). The NFU steering lever was to the right but it had to be reached being about 1 metre way. The pilot had to follow simultaneously the green light of the buoy he was using as a steering mark and the rudder angle indicator. His role was more that of a helmsman than of radar navigator. The fact that there was no autopilot based on rate of turn or FU steering prevented the pilot from operating the radar. The possibilities of the pilot to maintain heading would have been significantly improved had a helmsman been called to the bridge.

2.1.2 Manning of the bridge

During the piloting there were two persons on the bridge, first the master and the pilot and at the time of the grounding the mate and the pilot. The crew of the vessel numbered 7. There should have been a lookout on the bridge in addition to the mate because the visibility was limited. Had the master been on the bridge, he or the mate could have acted as the lookout.

According to the international rule of the road, the bridge should have been manned by the officer on watch duty, the lookout, the helmsman and the pilot. The autopilot can replace the helmsman if it is suited for the situation at hand. The incompatible steering equipment would have required a manning of four on the bridge, including the pilot.

The Rhein river traffic regulations stipulate one man on the bridge as sufficient if there is a compatible autopilot on the bridge. The BALTIC MERCHANT did not meet the requirements for one man radar steering positions in the Rhein river traffic regulations, so

³ RheinSchUO 1995, 7.01§

⁴ RheinSchUO 1995, 7.04§

there should have been a separate helmsman on the bridge because of the missing FU steering. It is possible that the master interpreted the manning need of the bridge according to the river traffic regulations since traffic on the Saimaa canal and on the lakes resembles the river traffic in Central Europe.

It is difficult for the pilot to interpret manning issues and equipment standards without the support of instructions on the bridge manning, radar equipment and procedures in international traffic on inland waters. The pilot has the right to discontinue piloting but there are no guidelines on the criteria for the discontinuation.

Furthermore, the Piloting Decree states: "If the pilot for some reason considers himself unable to undertake the piloting, the master may continue it."

Based on the above it can be said that the manning in this situation was too small based on both rule of the road and river traffic regulations. The present practice dictated by the competition is to keep the vessel in traffic with minimum crew. In order to ensure the stipulated rest times, only the obligatory minimum manning is kept on the bridge at one time. The pilots have had to adapt to the situation in practice.

2.1.3. Passage plan

The recommendation on turns on fairways requires that the straight leg from the end of one turn to the start of the next turn should be at least five ship lengths if the heading change is between 20 and 30 degrees⁵. On the Hyvästinniemi line, this leg was only 220 metres. In the case of the BALTIC MERCHANT, this equals only 2,8 shiplengths. This is roughly the same as twice the advance required by the ship from the turning command to the even turn. The turning radius should be at least five shiplengths (0,22') according to the fairway recommendations. The geometry in the Hätingvirta bend does not comply with the fairway recommendations.

Passage plan. The steering of the vessel in the Hätingvirta sound was analysed in the light of the necessary passage plan. The direction of the line 327° was changed to direction 320° for the study. These were tested with simulation.

The new geometry based on the simulation is presented in Figure 11. This still does not comply with the fairway recommendations but steering is radically easier especially because of the longer turning radius.

The fairway geometry of Hätingvirta is difficult and therefore a passage plan is needed for the radar navigation. Since both marine and river radars are used in traffic on inland waters, the plan must be made for both types of radars.

⁵ TVH 1979 p.19 and PIANC 1994.

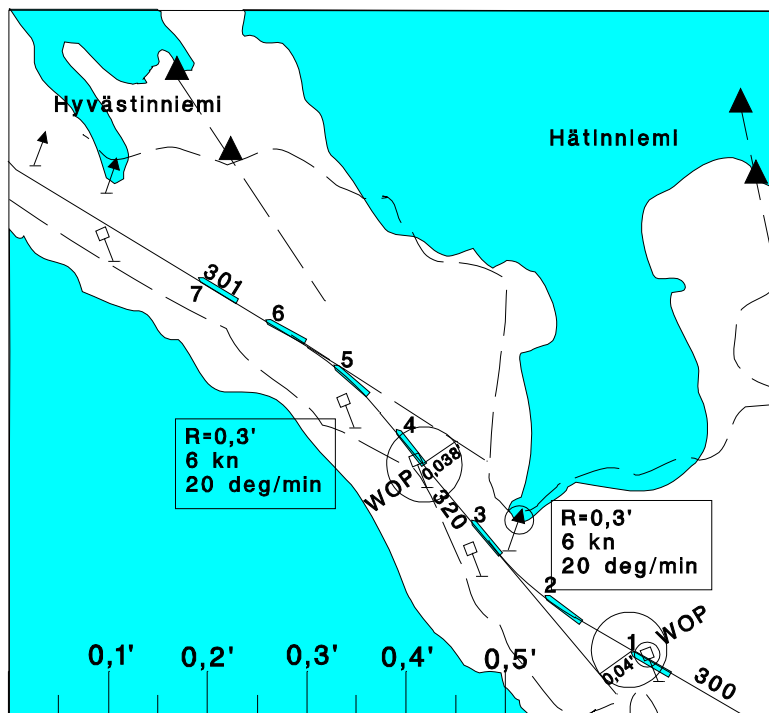


Figure 11. The new course based on simulation. Course changed by shifting Hyvästinniemi line 7° to port, which shifted the second turn northward.

The passage plan for open sea conditions is made on an enlarged chart copy only in one direction. There is too much information for the passage plan in both directions to fit on one chart (Figure 12). The turning points are marked as bearings which point to targets easily identifiable on the radar. The bearings are marked on the plan as close as possible to the new course in order to eliminate during the turn the lateral error on the approach course to the turn.

The Aholanti turn is initiated with the bearing 305° (marine radar) (Table 2). In the middle of the turn, steering is performed with the ROT indicator. If there is none, the vessel should be positioned on the new line by adjusting the rudder angle so that the lateral distance (225m) is realised (Figure 12).

On the Aholanti line, the bearing is set at direction 320° and the turn is begun in the same way as before. The rate of turn barely reaches 20° /minute during the turn. The lateral distance to the Hätinlempi ferry is about 90 metres (Figure 1).

The turn before Hyvästinniemi must be started with the variable range marker since according to the chart it is difficult to find a suitable radar target based on the new heading. The turn is begun when the distance to the point of Hyvästinsaari is 700 metres.

Table 2. *Passage plan in table format. Rudder angles apply to ship with conventional rudder.*

Turn	True course	River radar, bow heading	Marine radar, true heading	Helm angle	ROT	Speed
Aholanti	347°	318°	305°	20°	20°/min	6 knots
Ferry	300°	020°	320°	20°	20°/min	6 knots
Hätingvirta	321°	Distance to Hyvästinsaari 700 m	Distance to Hyvästinsaari 0,38'	20°	20°/min	6 knots

A passage plan is required for successful piloting in the Hätingvirta sound when the visibility is limited. The plan is important if it is not known beforehand whether the marine or the river radar has to be used. A concrete obstacle for passage planning is the acquisition of suitable chart enlargements. The nautical chart as such is not suitable for the planning.

As a summary it can be stated that the passage through the Hätingvirta sound is difficult in a fog and without a passage plan. In addition the ice complicates the execution of the passage plan. Visibility and ice limitations would be needed for this stretch of fairway.

- True courses in boxes are turn marks of the marine radar whereas the corresponding bow bearings of the river radar are marked with circles.
- The arrows point the heading line of the radar for different courses.
- Lateral distances are marked in the boxes in miles for the marine radar and in metres for the river radar.
- Turn marks are drawn by setting the EBL to point as close as possible to the heading identical with the new course.

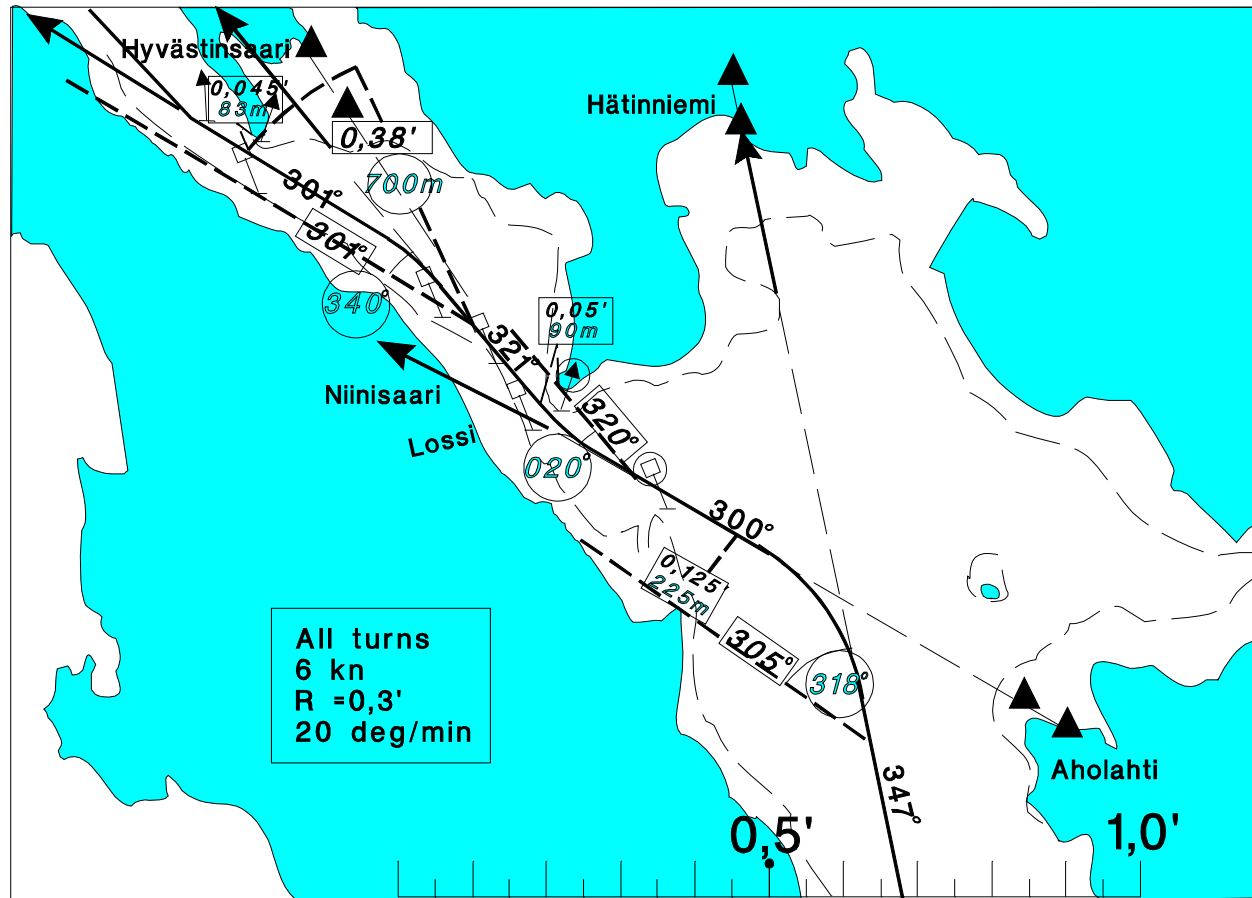


Figure 12. Passage plan for marine and river radar for open water conditions.

2.2 Flow of events of piloting trip

2.2.1 Events of accident based on simulation

The passage of the ship and the grounding were reconstructed based on the factual data from the investigation material. This was done by simulation on a desktop computer. The reconstruction has been used in the estimation of how the steering decisions affected the passage. The reconstruction describes the approach of the ship to the Hätinvirta sound during the 11 minutes before the accident.

The model used in the simulations is 10 metres longer than the BALTIC MERCHANT and has a conventional rudder. The BALTIC MERCHANT was equipped with an effective flap rudder which helped the steering especially at low speeds.

The visibility 10 minutes before arrival at Hätinvirta was about 1100 metres. According to the pilot, the turn to the Aholahiti line was initiated after he had finished a VHF call to the ferry operator. The estimated time was then 00:04. The heading of the vessel was 347° and the turn was made to heading 301° (Figure 13). On the nautical chart the turning radius of the fairway geometry is about 0,23 nautical miles. At a speed of 5 knots, the rate of turn must be 22° / minute in order to follow the turning radius on the chart. The turn started when the lower leading sign of Aholahiti was about directly abeam.

The vessel reached the Aholahiti line at about 00:08 (Figure 13). The visibility had deteriorated to less than half a mile based on the leading lights. The red lit buoy port of ship was passed at 00:09. The speed had dropped to 4,6 knots in the turn.

By simulation it was discovered that the turn on the Aholahiti chart is steep and at a low speed easily runs 2-3 degrees over. When the unintentional yawing is corrected there is no longer any point in following the course of the line, but a new heading of 306° - 309° must be adopted in order to come close to the green buoy. In other words, the vessel had already turned slightly for the next turn. According to the statement of the pilot, the engine power was cut to 10 per cent at the red buoy (see Tables 3 and 4).

The visibility continued to deteriorate. The green buoy appeared only at 200 metres at about 00:10:30. The speed was 4,2 knots. The bow reached the green buoy at about 00:11:30 and the vessel turned slowly to starboard. The speed was 4 knots. From the buoy, the vessel travelled on a straight course in heading 308°. The green buoy was at the bridge at about 00:12:10. The pilot stated that he had set the propeller pitch to zero at this stage. The vessel glided past the green buoy turning a few degrees to starboard and continued in heading 310° - 311° from the buoy.

At about 00:12:30 the second red buoy appeared in front of the bow slightly to port. The speed was 3,5 knots. The buoy was passed at about 00:13:30 at a distance of two metres. The third red buoy appeared starboard of the bow at about 00:14. The speed was about 2,7 knots. According to the pilot, he reversed at full astern as soon as he spotted the buoy but the BALTIC MERCHANT grounded at 00:15 at low speed.

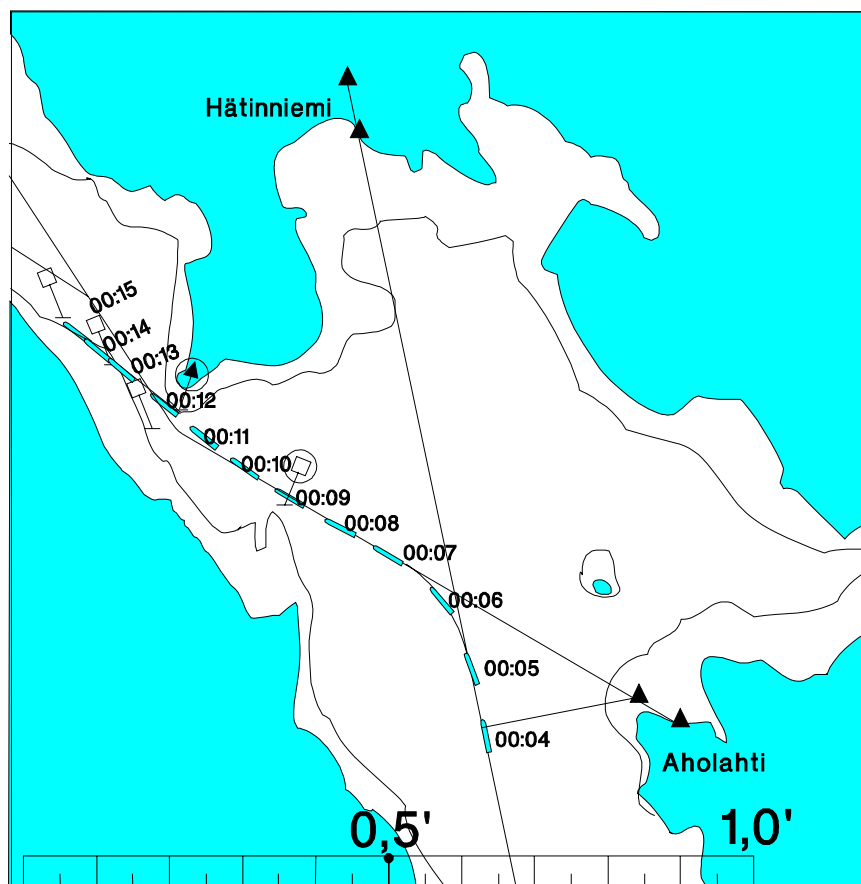


Figure 13. Piloting situation and grounding reconstructed by simulation.

Table 3. Simulations of the accident voyage 00:04-00:10. ROT=Rate of Turn in the simulations.

Simulation results						
Time	Speed	Compass	ROT °/min	Rudder angle	Propeller pitch	Comment
00:04	5 knots	347°	0	- 20°	+ 2,7	Turn begins
00:05	5 knots	340°	- 3 °/min	- 20°	+ 2,7	
00:06	4,9 knots	320°	- 21 °/min	- 5°	+ 2,7	Constant ROT
00:07	4,7 knots	301°	- 14 °/min	+ 27°	+ 2,7	Counter helm
00:08	4,6 knots	297°	0	+ 11°	+ 2,7	
00:09	4,6 knots	300°	+ 5 °/min	+ 5°	+ 1	Red buoy
00:10	4,3 knots	305°	+ 4 °/min	- 24°	+ 1	No visibility

The adjustable pitch propeller had evidently turned the ship to port at the low speed, which has been further enhanced by the propeller reversal at the final stages. It is impossible to simulate reliably the last minute before the grounding. The simulated vessel strayed slightly to starboard because the previous turn was slightly to starboard and the propeller pitch had been set to zero immediately after that.

The reconstruction showed that the BALTIC MERCHANT had travelled almost straight during the last three minutes before the grounding.

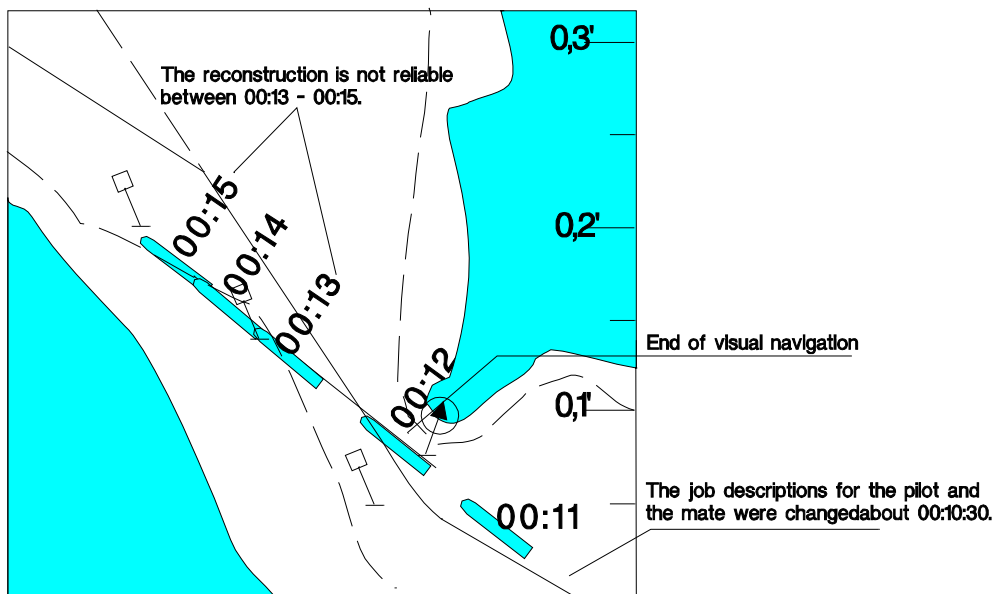


Figure 14. Grounding of the BALTIC MERCHANT. The vessel has apparently headed almost straight during the last minute before grounding. Situation in the picture was reconstructed by simulation. In reality, the vessel has turned slightly to port during the last minute.

Table 4. Four last minutes before the grounding. Table values are simulated.

Simulation results						
Time	Speed	Compass	ROT °/min	Rudder angle	Propeller pitch	Comment
00:11	4,0 knots	308°	+ 2 °/min	+ 1°	+ 1	Pilot steering
00:12	3,8 knots	309°	+ 1 °/min	0°	0	Green buoy
00:13	3,1 knots	311°	+ 1 °/min	- 24°	0	Second red buoy
00:14	2,6 knots	310°	- 1 °/min	- 35°	0	Third red buoy visible
00:15	1,5 knots	307°	- 3 °/min	0°	-10	Grounding

2.2.2 Steering and navigation method during piloting

The manning on the bridge was changed about half way through the intended piloting trip. The mate took over the watch and the master went to rest. The mate and the pilot were alone on the bridge since no helmsman was used. The pilot was using the Kelvin & Hughes radar on the starboard side of the bridge and the mate was using the ELNA river radar to the left of the control equipment. They took turns at the NFU steering which requires constant monitoring of the rudder angle. This complicates simultaneous radar monitoring and adjustment of the radar. The mate had the opportunity for visual monitoring when the visibility was about 1 kilometre.

When the vessel was approaching the Hätinvirta sound (Figure 13) the pilot cut the engine power to 10 per cent at the red buoy of the Aholanti line and asked the mate to look for the next green lit buoy on the starboard side of the fairway with the binoculars. Since the pilot was steering and simultaneously following the rudder angle indicator, the compass and the buoy gate in the sound with the radar, his task became a demanding one (Figure 15).

When the visibility sank to about 200 metres, the working methods changed. The pilot asked the mate to aim the searchlight and look for the red unlit buoy of the buoy gate on the port side of the fairway. The mate moved to the port wing and switched on the searchlight, and the pilot moved to the river radar because he preferred its user interface to the Kelvin & Hughes radar he had been using. The heading line on the river radar points always upward. In this respect, the image on it is similar to the views opening from the bridge. This factor may also have contributed to the pilot's wish to change the radar.

The use of the searchlight prevented the mate from monitoring the radar and when the visibility deteriorated he also lost the visual sight and positioning. The role of the mate changed to that of a lookout. The navigation and steering were left entirely to the pilot. The ice disturbed the radar image and simultaneously the pilot also lost the visibility due to the fog. The task of the pilot changed into that of a helmsman only. Because of the manning deficiency a situation where the professional skills of neither the mate nor the pilot could be used arose on the bridge.

After the starboard green lit buoy of the buoy gate in the Hätinvirta sound had been passed (Figure 14) the only visual steering mark was lost. The mate could not find the portside left buoy of the buoy gate with the searchlight. The pilot presumed it had been covered by the ice. There was only a curtain of fog ahead. The situation had turned dangerous and the pilot set the propeller pitch to zero.

The radar was no help any longer. The intention of the pilot was to use the point of Hyvästinniemi as a heading reference on the radar after the first turn. However, it was not visible on the radar. The pilot tried to adjust the radar image but this failed. This proves the unsuitability of the used steering equipment (NFU) because it required an unreasonable share of the pilot's attention.

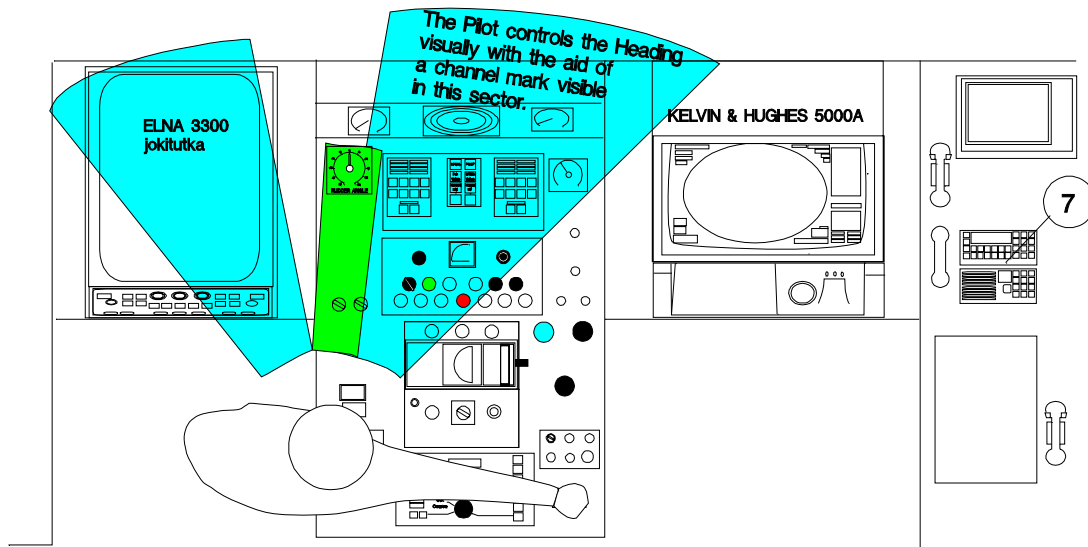


Figure 15. After the pilot had manned the river radar, he had to monitor three sectors while steering with the NFU lever, the radar, the rudder angle indicator and the green buoy ahead, diagonally to starboard. The pilot steered towards the green buoy using the NFU lever and monitored the rudder angle indicator. He relied on visual navigation because concentrating on the radar would have made the steering more difficult.

The echos from the buoys blended with the echos from the ice floes and the radar screen was spotted with ice. The pilot asked the mate to direct the searchlight towards the next red buoy which was expected to appear port of the ship. In a moment the buoy in fact appeared where it was expected.

After this, the mate tried to locate the third red buoy in the sound in front of the ship to port, but the buoy appeared starboard of the bow. The reversal at full astern which was performed as an emergency measure did not stop the vessel from grounding.

As a summary of the piloting and navigation method, it can be stated that no headings, rudder angles or turn marks have been memorised from the piloting situation. The fact that these could not be recalled afterwards indicates that visual navigation was used in the piloting and the commands were based on the fairway markings. These features point to the prevalence of the traditional navigation method in the piloting. The existing circumstances and the available equipment would have not provided sufficient conditions for piloting in any navigation method.

2.2.3 Cooperation on the bridge

The cooperation and situational management on the bridge are evaluated in relation to the demands placed by safe execution of the piloting task. This approach brings to light issues which should be considered in the organisation of pilotage, development of regulations and training. These demands have not been addressed in the regulations on piloting or professional competence of bridge officers, so the cooperation cannot be ex-

pected to meet these requirements. In this case, the demanding navigation situation and deficiencies in the cockpit arrangement together with the small manning of the bridge placed special demands on the cooperation.

Preparation for piloting. During the preparation for piloting, each party creates the conditions for success of his own activities and for execution of the piloting task. The most important factor affecting the piloting during the preparation is the drafting of the passage plan. The passage plan supports navigation and steering activity by describing the conditions for safe execution of the critical phases of the passage, such as demanding turns. It also promotes a common understanding of the steering and navigation method on the route and thereby promotes the cooperation.

There is little information on the preparation of the pilot of the BALTIC MERCHANT for the piloting. It does not become obvious from the material whether the pilot brought charts with him and whether these charts possibly contained a passage plan marked on them. For the pilot, this was the first piloting of the spring to Puumala. There is no data on the preparation of the ship's officers for the piloting or of their knowledge of the route. Based on the investigation material it appears that the pilot did not discuss the route with the master or the mate. The stretch of fairway at Häätinsalmi does not comply with the fairway planning recommendations for a ship of this size. A passage plan could have given support for the demanding steering task expected. The information points to the piloting not being jointly planned, at least not with the help of a passage plan. When the pilot started to pilot, he had estimated the development of the weather conditions and observed visibility of about one kilometre. The pilot tried to create conditions for successful piloting concerning his own activity but apparently not concerning the cooperation.

The available steering and navigation equipment as well as the weather all have an effect on the minimum need of manning on the bridge and a feasible sharing of tasks. The adopted navigation methods have an effect on how the available personnel and the navigation and steering equipment can be utilised.

At an earlier stage of the analysis it was shown that the steering equipment of the BALTIC MERCHANT did not meet the requirements of the piloting. The manning on the bridge with regard to the equipment and the circumstances was not adequate according to the criteria set in international regulations. The pilot told that he had acquainted himself with the equipment on the bridge of the vessel, which he considered important since the vessel was new to him. However, it is obvious that there was no discussion about the manning needs for the piloting in this context. The master either misinterpreted the manning requirements of the piloting situation in question (Section 2.1.2) or ignored them, and the pilot did not either appeal to these.

Cooperation in piloting. The sharing of tasks had formed along the usual lines in the beginning of the piloting. The pilot started to steer and the master - after the change of watch the mate - monitored the surroundings visually. Later, the mate and the pilot took turns at the steering.

The pilot followed the changes in the visibility well during the piloting and himself initiated precautions called for by the situation (requested information about the development of the visibility, prepared for anchoring). However, the pilot and the mate did not prepare for the increase in the manning need on the bridge. The visibility deteriorated after the decision, that was based on the available information on visibility, was already made about proceeding to the Hätingvirta sound thereby passing the possible anchoring point.

When the visibility deteriorated the visual steering based on the traditional navigation method became more difficult. The situation could have been controlled better if the re-sharing of tasks had been done. Instead, the pilot centred model of activity was strengthened. Even the mate could not break the traditional model of activity, instead he himself promoted the change in his role in a difficult piloting situation by taking – at express request from the pilot – gradually the role of a lookout. Changing one's own activity, the re-sharing of tasks or the improving cooperation cannot be done in a demanding situation unless the content of the tasks, the responsibilities and the possibilities of the sharing of tasks have been specified. Knowledge of the ship's position and heading was difficult to maintain when even the radar visibility deteriorated due to the disturbance caused by the ice and the pilot's attention was required by the steering task.

The sharing of tasks was based on the traditional navigation method. This navigation method is a (historically evolved) strong point of the pilot which should be supported with appropriate navigation and steering equipment. Professional competence derived from experience and its only partial conceptualisation are features of the traditional navigation method. This may explain why the pilot of the BALTIC MERCHANT did not request a separate helmsman on the bridge to help in the steering nor did he prepare to use the mate as helmsman in case of an eventual fog.

It is difficult to use modern navigation equipment within the framework of the traditional navigation method, because in this the sea area and the ship's motion are viewed from the birdseye perspective and from the perspective of the planned passage of the ship. It is also more difficult to utilise the passage plan in the traditional navigation method, because the general framework for execution method of turns is described in geometrical terms in it. The pilots are not used to utilising these in the navigation. In bad visibility, deficient use of the navigation equipment and the passage plan creates a problem, because it results in complicating the visual steering used in the traditional navigation method.

In piloting situations, the safe passage of the ship is considered to require that another person than the person steering and navigating **monitors** or ensures the success of the piloting. The basic requirement for monitoring is the detectability of activities and the vessel's passage along the course, which is influenced by the joint effect of the use of the navigation method and the navigation equipment. The less vocal communication there is about the intentions and actions concerning steering and the more difficult it is to detect the independently performed steering actions, for instance on the autopilot, the less opportunities there are for monitoring the activity. Based on the analysis of the navigation method in the grounding of the BALTIC MERCHANT it can be deduced that

the detectability of the activities was not particularly good in this case, which meant that the chances for monitoring were inadequate.

The passage plan can be used as a reference in the monitoring. Modern integrated steering and navigation equipment with two navigation and steering positions also facilitates the monitoring. This is achieved by creating a common description of the situation to the persons responsible for the steering and navigation and the monitoring. Neither of these facilitating factors existed in this case. When the piloting progressed the amount of the available information decreased and its quality deteriorated. This was not realised in time. The monitoring was completely abandoned when the mate moved mainly to the role of a lookout. The weakening of the cooperation on the bridge can also be seen in the chart describing the activities and decision making in the grounding, in Figure 16.

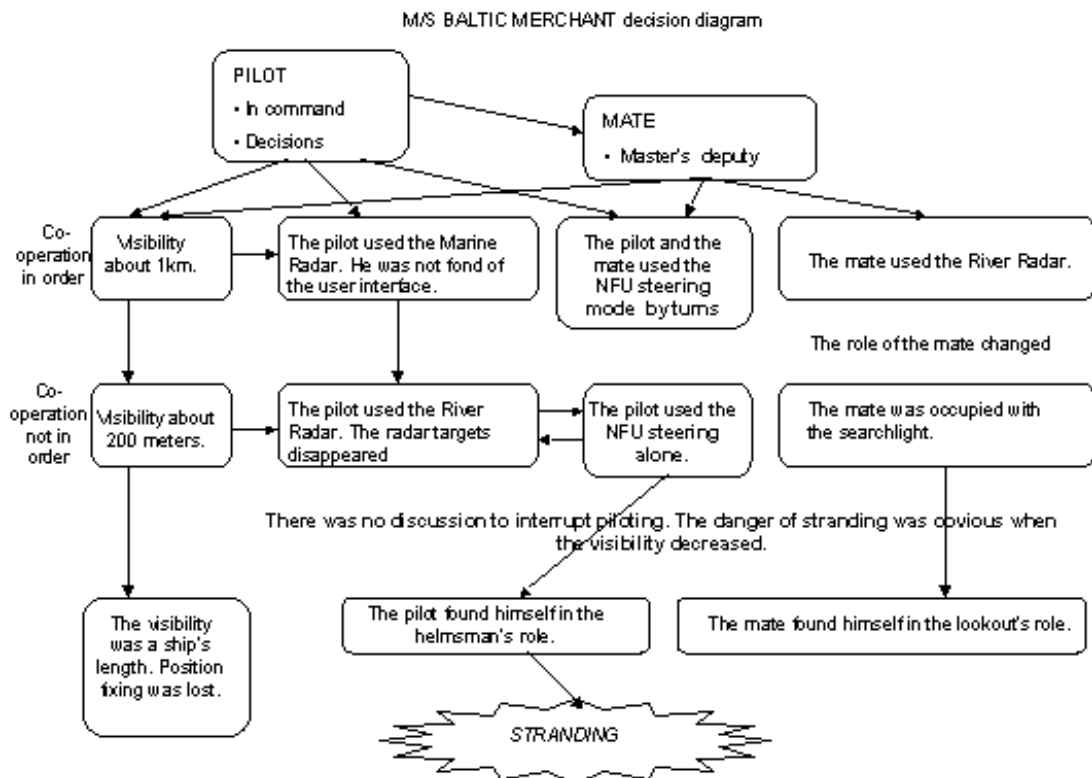


Figure 16. Activity and decision making chart of the grounding of the BALTIC MERCHANT.

Responsibilities and power relations. It would be advantageous for the safe execution of the piloting task to be able to combine optimally the fields of expertise of the pilot and the ship's master (or his deputy the mate) with an appropriate sharing of tasks. Each party carries the responsibility for his own task according to the sharing. The requirements arising from the task or the equipment concerning the division of labour do not receive enough attention in the daily work. There were flaws in the navigation and cooperation methods formed in the grounding of the BALTIC MERCHANT. They resulted in the weakening of activity in a demanding situation because the sharing of tasks developed in a bad direction considering the situation.

The responsibility appointed by the sharing of tasks and tied to the task is not in principle in violation with the overall responsibility and power of decision of the master. In this sense, there is no controversy either with the regulations concerning piloting. Unspecified division of tasks results in confusion concerning the power of decision. In the case of the BALTIC MERCHANT, the mate was on the bridge at the time of the accident. When the tasks accumulated on the pilot, also the commanding authority transferred on him in practice. The situation does not correspond to the regulations concerning the piloting activity.

Rules guiding the activity. The overall operation of complex safety critical systems and safe management of dynamic situations require the use of rules on the activities. Rules improve the predictability of the system and facilitate the control of complex situations. The correspondence of the rules and the actual situation is a complex issue, since general regulations or guidelines cannot be applied directly to a particular situation. The person must interpret the situation and evaluate the significance of the rules with regard to the situation. Rules should facilitate practical activity by providing foundations for the solutions made in different situations.

If the rules are very general in nature, they do not have real significance in the guiding of activities. The pilot is left in a difficult position. He must make decisions that apply to a particular situation without rules and practical instructions guiding the activity. It was difficult for the pilot of the BALTIC MERCHANT to interpret the manning questions and the equipment requirements in a situation where there were no general regulations or previously drafted guidelines concerning the cooperation and sharing of tasks in piloting (manning on the bridge, radar and steering equipment and procedures). The guidelines could also have facilitated the organisation of the sharing of tasks in a demanding situation. The pilot also had the right to discontinue the piloting as stipulated in the Piloting Decree. The pilot had prepared for the discontinuation but the visibility deteriorated at the crucial moment. In the present practice, the discontinuation of piloting is based on personal judgement. Since there are no commonly agreed criteria for the discontinuation, it is considered an extreme measure.

3 CONCLUSIONS

3.1 Chain of events leading to the grounding

The grounding of the BALTIC MERCHANT in the Hätinvirta sound was a result of progressive deterioration of the visibility. When the visibility deteriorated, the cooperation between the pilot and the mate on the bridge became more difficult and weakened in direct proportion. Although the demands of the cooperation increased they could not be met. This also resulted in complication of the navigation and steering, when the pilot tried to cope simultaneously with the piloting and steering of the vessel with steering equipment poorly suitable for the situation.

The chain of events was as follows:

- Cooperation on the bridge was functioning before the Hätinvirta sound when the visibility was about one kilometre.
- The cooperation became more difficult when the visibility deteriorated to 200 metres on approach to the Hätinvirta sound. The role of the mate changed from that of the officer of the watch to that of a lookout when he manned the searchlight.
- The cooperation on the bridge ceased when the fog suddenly became dense and the visibility dropped to one shiplength. This took place at the narrowest point of the sound. The pilot concentrated on the duties of a helmsman. The radar visibility was also poor. The pilot could not distinguish the buoys and the edge of the solid ice and the shoreline from each other on the radar. This resulted in the loss of the heading references he had been using and in the grounding of the BALTIC MERCHANT after driving straight in the first turn of the sound.

3.2 Contributing factors to the grounding

3.2.1 Conditions for navigation and piloting

Steering equipment and manning on the bridge. The steering equipment of the BALTIC MERCHANT can be considered a contributing factor to the accident. This steering system does not provide the necessary clarity and user friendliness needed in radar navigation for easy simultaneous piloting, steering and adjustment of the radar.

The NFU (Non Follow Up) steering for the rudder was the only manual steering method on the vessel. This method requires simultaneous focusing on the rudder angle indicator and heading information from the pilot, which complicates the navigation

The Rhein river traffic regulations include specifications for a one man radar steering place. These requirements, which were not fulfilled by the BALTIC MERCHANT stipulate either an autopilot based on rate of turn or a rate of turn indicator and FU rudder

steering and, if the latter is not available, a separate helmsman. The role of the pilot in the grounding of the BALTIC MERCHANT resembled more that of a helmsman than radar navigator. An autopilot based on rate of turn or FU rudder steering would have increased the pilot's opportunities for radar operation.

The possibilities of the pilot to maintain the course would also have improved radically if a helmsman had been called on the bridge according to the river traffic regulations. Corresponding demands on the technology and steering places have not been defined for Finnish inland waters and canals. The grounding of the BALTIC MERCHANT demonstrates that there would be grounds for introducing similar requirements also in the Finnish conditions.

Fairway geometry. The fairway leading through the Hätingvirta sound is demanding. Passage through it is especially difficult in a fog and without a passage plan.

In the case of the BALTIC MERCHANT the combined effect of the ice floes and the fog created a situation which would have required a visibility limitation. Fog itself does not form an obstacle to piloting, but combined with the ice floes, the visibility should have been at least four cables or about 700 metres in order to have the fairway markings of both turns in the sound visible.

3.2.2 Navigation method and cooperation on the bridge

The pilot was using the **traditional navigation method** where the chart is memorised and the radar viewed in the same way as the scenery. His intention was to use the point of Hyvästinniemi as a heading reference after the first turn. However, this was not visible on the radar. There was no passage plan available nor were any courses given. The conditions would not have been sufficient for piloting in any navigation method in the existing circumstances and with the available equipment.

Manning and sharing of tasks. The present practice in piloting does not include preparation that would promote the cooperation nor was there any such activity in this case. In the case of the BALTIC MERCHANT the tasks accumulated on the pilot instead of reaching an efficient sharing of tasks. As is typical of the traditional navigation method, the pilot centred model of activity was further enhanced when the situation became more demanding and the mate went to act as lookout. The monitoring, which for many reasons had inadequate conditions, was altogether neglected.

Regulations and procedural guidelines. Because of the general nature of the regulations concerning piloting, the pilot has to decide which fairways are navigable under which circumstances. He has to estimate the largest possible vessel size for the various fairways, the minimum manning of the bridge and evaluate the suitability of the navigation and steering equipment for the piloting.

Another contributing factor to the grounding of the BALTIC MERCHANT can be found in the fact that there are no regulations or procedural guidelines which would clearly define the limitations placed by the equipment and manning on the bridge and the weather on

the piloting and continuation of the piloting. In the present practice, the judgment on whether it is safe to pilot the vessel in the existing situation is based on a personal decision. In the absence of commonly agreed criteria on piloting and discontinuation the decision not to pilot or to discontinue piloting is considered an extreme measure.

This case brought to light the fact that it is difficult to change the usual pilot centred method of cooperation when the situation becomes more difficult. Regulations on cooperation and practising a new way of cooperation during training could facilitate the organisation of the division of labour in a difficult situation.

4 RECOMMENDATIONS

4.1 Discontinuation of piloting and traffic limitations

The ambiguous wording of the Piloting Decree does not sufficiently emphasise the discontinuation of piloting and the criteria for discontinuation is left at the pilot's own discretion. A clear minimum level should be defined for manning of the bridge and steering equipment. This level forms the foundation for feasible cooperation in piloting.

In winter traffic, the ice conditions require a good radar image and a searchlight in the dark. The ice can shift the floating navigation marks when it moves. This requires minimum visibility for certain fairway buoys at some points of the fairway in order to ensure safe piloting. The pilot stations should define such fairway points and the necessary visibility limits for them to be confirmed by the maritime district.

It is the recommendation of this investigation that:

- 1 *The Finnish Maritime Administration drafts the criteria for discontinuation of piloting including:*
 - *manning on the bridge*
 - *acceptable manual steering equipment*
 - *acceptable autopilot modes.*
- 2 *The maritime districts issue visibility limits on the fairways applicable to winter traffic and control their observation.*

4.2 Equipment training of pilots

The limitations of the steering equipment should be considered when sharing the tasks on the bridge. The pilot may not use the NFU steering of the rudder himself if the navigation is performed solely with the radar (for example in a fog or in heavy rain). A separate helmsman may use the NFU steering in these conditions.

It is the recommendation of this investigation that:

- 3 *The Finnish Maritime Administration warns pilots about the dangers of the NFU steering and issues directions for its use.*

4.3 Development of cooperation on the bridge

In this case the deficiencies in the cooperation method were direct causes of the accident. The background to these lies in the fact that piloting is not considered a joint task but separate individual performances by the ship's officers and the pilot. In practice, the

steering and navigation tasks accumulate on the pilot and the verification of activities linked to the overall responsibility of the master remains quite general. The supporting means for the cooperation, such as a passage plan, mutual communication and properties of the equipment that promote cooperation cannot be utilised.

It is the recommendation of this investigation that:

- 4 *The Finnish Maritime Administration develops in cooperation with maritime training institutions a cooperation model for Finnish conditions. Knowledge of this model should be required in the competence requirements of the pilot and the officers.*

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