Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation

Summary Investigation Report 284/21

Other Casualty/Incident

Allision with a Pier Involving the Use of an Automatic Steering Control System by the Motor Yacht SANTA CECILIA in the Port of Hamburg on 5 September 2021

as well as Four other Accidents of Recreational Craft in Conjunction with Automatic Steering Control Systems

15 November 2023

This summary report in accordance with Article 27(5) of the Law on Improving Safety at Sea by Investigating Marine Accidents and Other Incidents (German Maritime Safety Investigation Law, “Seesicherheits-Untersuchungs-Gesetz” SUG) is a simplified report pursuant to Article 14(1) sentence 2 of Directive 2009/18/EC of the European Parliament and of the Council dated 23 April 2009, establishing the fundamental principles governing the investigation of accidents in the maritime transport sector.

The investigation was conducted in accordance with the above law. Accordingly, the sole objective of the investigation is the prevention of future accidents. The investigation does not serve to ascertain fault, liability, or claims (Article 9(2) SUG).

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 34(4) SUG.

The German text shall prevail in the interpretation of this investigation report.

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Amendments

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Acronyms Used

AE	Acceleration error
AHRS	Attitude heading reference system
BSH	Federal Maritime and Hydrographic Agency
CEST	Central European Summer Time
COLREGs	International Regulations for Preventing Collisions at Sea
Dev	Deviation
DMYV	German Motor Yachting Association
GE	Gyro error
GFRP	Glass-fibre reinforced plastic
GNSS	Global navigation satellite systems
IMO	International Maritime Organization, also short for IMO number
NMEA	National Marine Electronics Association
NOK	Kiel Canal
OCI	Other casualty/incident
Ref.	File reference
ROC	Restricted operator's certificate
SE	Steaming error
SeeSchStrO	German Traffic Regulations for Navigable Maritime Waterways
SKS	International certificate for operators of pleasure craft in coastal waters not exceeding 12 nm
SOG	Speed over ground
SUG	Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law)
Var	Variation
WSA NOK	Waterways and Shipping Office Kiel Canal
WSP	Waterway police
WSPK	Waterway police department
WSV	Federal Waterways and Shipping Administration

1 FACTUAL INFORMATION

1.1 Photograph of the Vessel

Figure 1: Photograph of the SANTA CECILIA[1]

1.2 Ship Particulars

Name of ship:	SANTA CECILIA
Type of ship:	Motor yacht / Salongsbåt[2]
Flag:	Germany
Port of registry:	Hamburg
Year built:	1938
Shipyard:	Moranäs shipyard, Saltsjöbaden, Sweden
Length overall:	11.17 m
Breadth overall:	2.95 m
Draught (max.):	0.7 m
Displacement:	About 6 t
Engine rating:	255 BHP
Main engine:	Yanmar six-cylinder turbo-diesel, 4.16 l cyl. capacity
Service speed:	18 kts
Hull material:	Wood (mahogany, ash), every third frame and floor plates made of steel

1.3 Voyage Particulars

Port of departure:	Wedel, Germany
Port of destination:	Hamburg (HafenCity), Germany
Type of voyage:	Private voyage, national
Crew:	1
Draught at time of accident:	0.7 m
Number of passengers:	5

[1] Source: Owner.
[2] Swedish name for a so-called commuter from the early 20th century.

1.4 Marine Casualty/Incident Information

Type of marine casualty:	Other casualty/incident (OCI)[3], allision with pier; two people injured; yacht heavily damaged
Date, time:	5 September 2021, 1603 (CEST)
Location:	Port of Hamburg level with Athabaskakai 8
Latitude, longitude:	φ = 53°32.2'N, λ = 009°54.3'E
Voyage segment:	Restricted waters
Consequences:	Two people with minor injuries; heavy damage to the vessel's structure

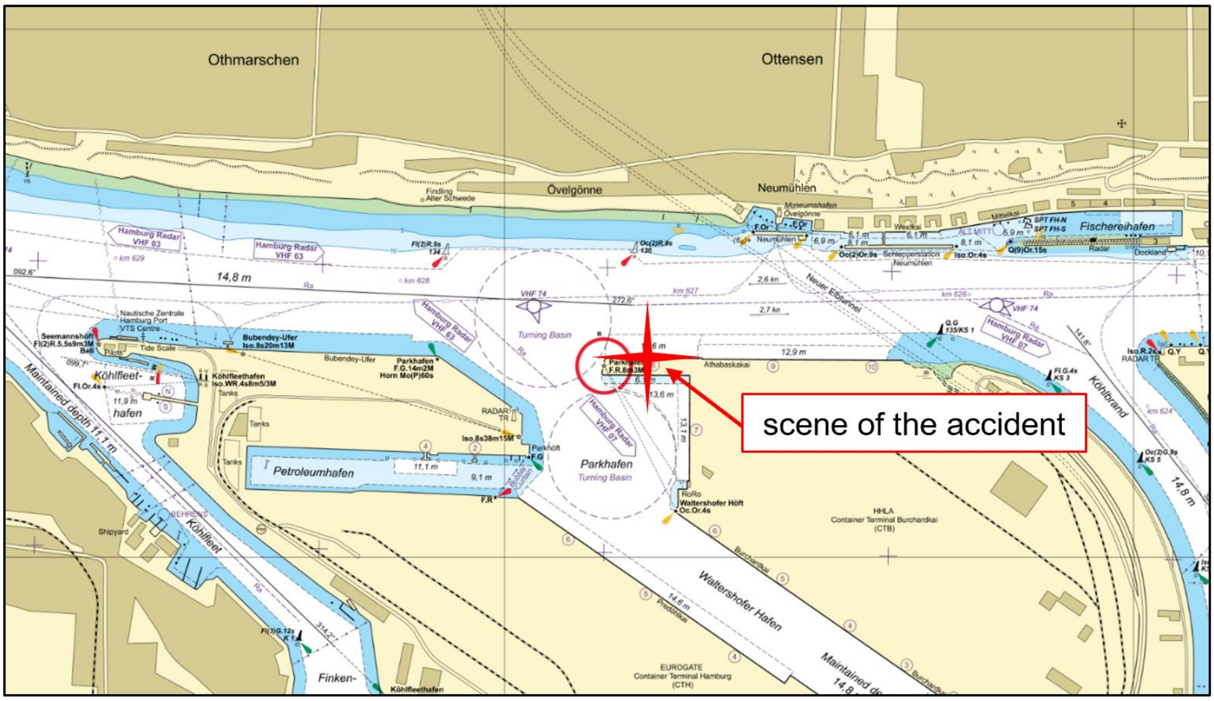

Figure 2: Extract from Navigational Chart DE48 (INT 1455) River Elbe, Lühesand to Hamburg[4]

[3] Marine casualties involving only non-commercial recreational craft do not fall within the scope of Section 1 SUG. This marine casualty was therefore classified as 'other casualty/incident' rather than as 'serious marine casualty'.
[4] Source: BSH.

1.5 Shore Authority Involvement and Emergency Response

Agencies involved:	Heavy harbour patrol vessel WS35 from Hamburg waterway police department (WSPK) 1, heavy harbour patrol vessel WS37 from Hamburg WSPK 2, tug HOFE (call sign: DA9578), Vessel Traffic Centre Hamburg (vessel traffic service)
Resources used:	Anchor with anchor line, additional line, liferaft
Actions taken:	Boat engine switched off; anchor with extended anchor line dropped; liferaft launched and inflated; initial care for the casualties; recreational craft towed by a harbour tug

2 COURSE OF THE ACCIDENT AND FINDINGS OF THE INVESTIGATION

2.1 Course of the Accident

The course of the accident set out below is based mainly on the skipper's eyewitness account and the report of Hamburg WSPK 1 to the BSU dated 6 September 2021. On 21 and 29 September 2021, face-to-face discussions were held by videoconference between the skipper and the BSU's investigation team. The skipper's statements were verified using radar images from around the time of the accident made available by the vessel traffic centre.

On 5 September 2021, the skipper sailed from Wedel towards the port of Hamburg with five other people on board (family members). They were heading for the City Sporthafen marina. Before reaching the port of Hamburg, the SANTA CECILIA continuously sailed outside the fairway next to the green buoy line. The River Elbe was heavily frequented by commercial shipping and recreational craft.

At the entrance into the Parkhafen harbour between Bubendey-Ufer and Athabaskahöft, the container ship IDA RAMBOW (IMO 9354478), also bound for Hamburg, slowed down in front of the SANTA CECILIA so as to turn around there and then proceed astern to berth 10 at Athabaskakai. To the skipper of the SANTA CECILIA, the turning manoeuvre initially looked as if the IDA RAMBOW was entering the Parkhafen harbour. The skipper found it difficult to assess the difference in speed between the container ship and the motor yacht. At the beginning of the IDA RAMBOW's turning manoeuvre he altered course to port to the middle of the Elbe fairway, so as to overtake the container vessel and leave her on his starboard side.

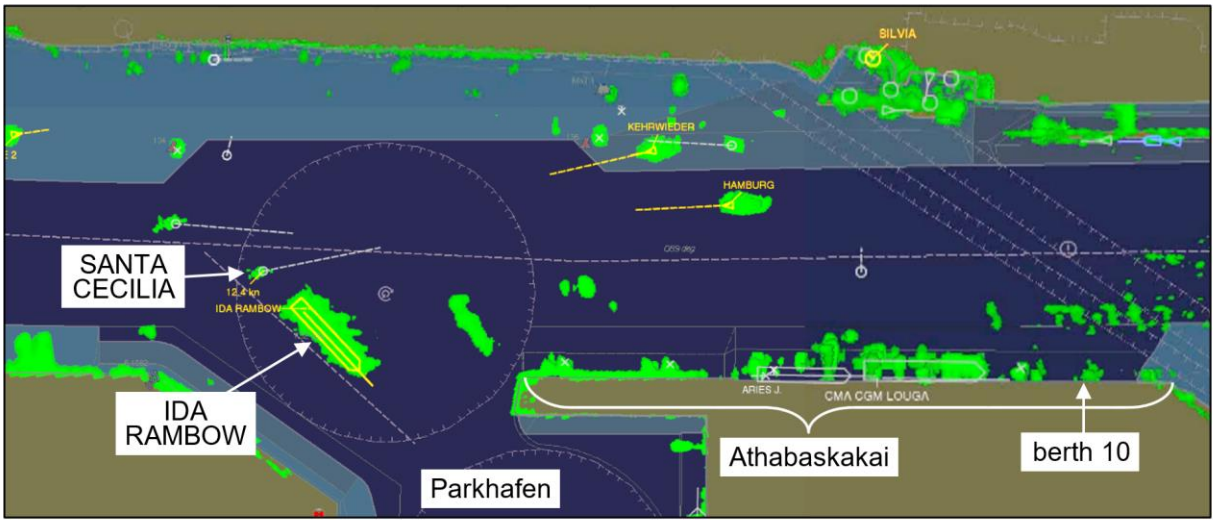

Figure 3: SANTA CECILIA Passes the Stern of the IDA RAMBOW at 12.4 kts SOG[5]

[5] Source: Vessel Traffic Centre Hamburg; screenshot at 160130 on 05/09/2021; notes by the BSU.

After passing the IDA RAMBOW, the SANTA CECILIA's skipper altered course to starboard to about 135° so as to then return to the southern side of the fairway. At this point, Athabaskakai was about 0.15 nm ahead (or just short of 280 m). While on this course, the skipper's mobile phone fell from the bevelled control console onto the floor. He instinctively switched on the automatic steering control system (autopilot) with the remote control, which was still within reach, before picking up his phone. The remote control was within reach because the autopilot had previously been used where there was less traffic and more manoeuvring space.

The skipper intended to switch off the autopilot using the remote control a few moments later, so as to alter course to port manually and follow the fairway in the direction of City Sporthafen marina. This was unsuccessful. After repeatedly operating the remote control, he intended to switch off the autopilot via the fuse box to be able to steer by hand again. However, he did not immediately find the relevant one among the some 30 fuse switches installed in the fuse box near the wheel. The autopilot's main control unit was not easy for the skipper to reach at this point because it was to the right just below the seat of the helmsman's chair and he was standing to the left of the chair.

The quay wall of the Athabaskakai was now immediately in front of the SANTA CECILIA and from the perspective of the skipper it was no longer possible to prevent an allision. To reduce the impact, he set the engine lever to stop. He recalled that he definitely did not put the lever to full astern because he reportedly always used the engine lever carefully. Even in the emergency situation, he reportedly was unable to act differently and set the engine lever to full astern. In hindsight, the skipper believed that a full astern manoeuvre would have been appropriate.

The SANTA CECILIA's starboard side struck the quay wall at a speed of some 7-9 kts. The forward superstructure was almost completely destroyed from above by a cylindrical fender that was suspended from the pier in an elevated position. A female passenger standing behind the skipper suffered an injury to her head caused by the control position's staved in roof and was bleeding profusely. For his part, the skipper suffered minor injuries in the form of lacerations caused by the panes of glass that had shattered.

Figure 4: SANTA CECILIA on 07/09/2021 – Side View[6]

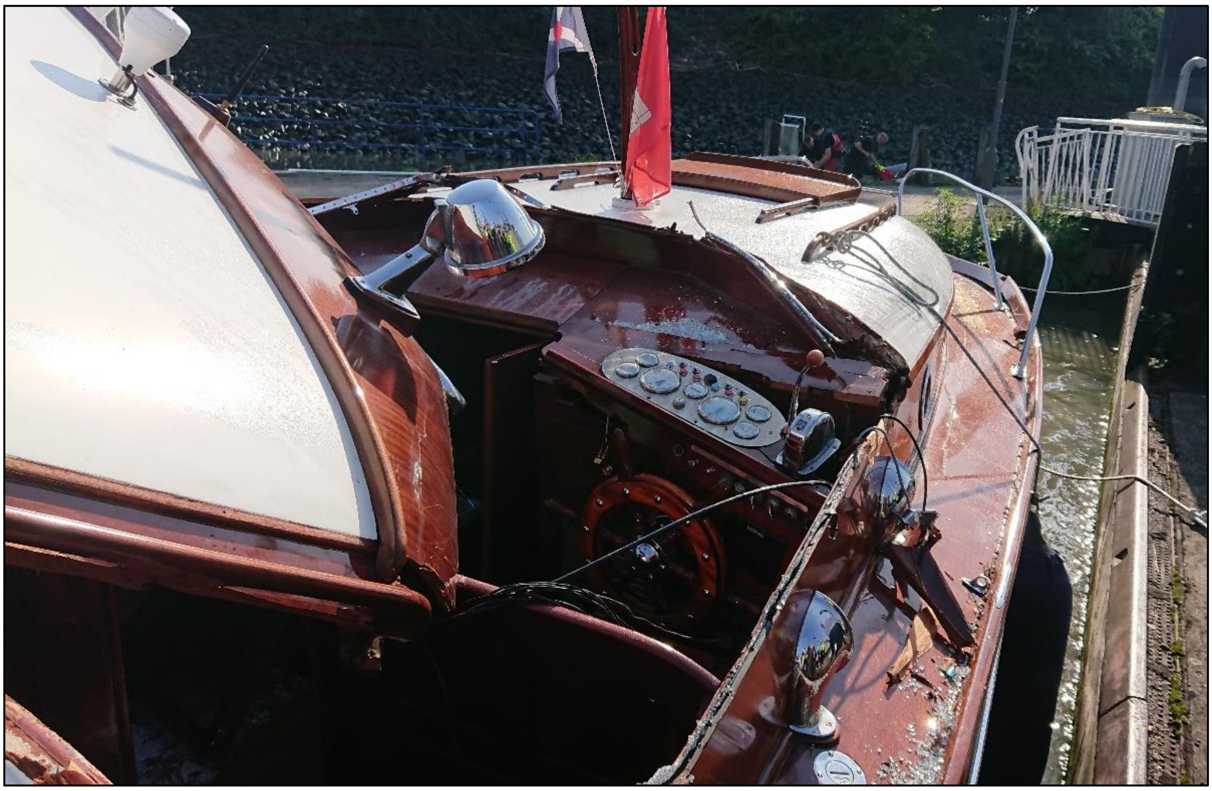

Figure 5: SANTA CECILIA on 07/09/2021 – Superstructure and Control Position[7]

[6] Source: BSU.
[7] Source: BSU.

After the allision the SANTA CECILIA's engine was idling and later switched off. Since the tide was still rising, the yacht drifted towards the container vessel ARIES J (IMO 9514767) moored at berth 9. The rudder could no longer be operated, on the one hand due to the still activated autopilot and on the other hand due to the (broken out) steering column. The skipper immediately dropped the anchor but had to spontaneously extend the anchor line with another line because the high water depth (about 18-19 m). The anchor held.

Meanwhile, the IDA RAMBOW sailed astern and relatively close to the SANTA CECILIA at about 3.5 kts. At this point, the skipper was not sure whether his yacht would remain buoyant and could not rule out a collision with the IDA RAMBOW. Therefore, he launched a liferaft. In the end, the ship's command of the container ship noticed the yacht and kept clear. Since there was no water ingress due to damage below the yacht's waterline and the yacht remained buoyant, nobody climbed into the liferaft.

WS35 from Hamburg WSPK1 reached the scene of the accident at 1615 and then WS37 about four minutes later. The waterway police took several passengers, including the female with the head injury, ashore at the Oevelgönne museum port. The harbour tug HOFE took the SANTA CECILIA alongside and towed the heavily damaged yacht to the WSPK1's berth at Waltershofer Damm. The alcohol and drug test carried out on the skipper was negative.

2.2 Investigation

2.2.1 Motor Yacht SANTA CECILIA

The motor yacht SANTA CECILIA is a so-called 'Salongsbåt' (commuter, motor cruiser). She was designed in 1937 by the Dane Knud Hjelmberg Reimers and completed in 1938 at the Moranäs boatyard in Saltsjöbaden, Sweden. Over the years, the yacht changed names and owners several times, was laid up in a building for several years and found her way to northern Germany in the late 1980s/early 1990s. She was given a new engine that was more economical and new electrics but otherwise kept seaworthy in her original condition.

The skipper's family took ownership of the yacht in 2004 and she was named SANTA CECILIA in 2005. From the summer of 2015, the SANTA CECILIA spent about one year at the Lütje boatyard in Hamburg, during which extensive works were carried out, including:

– a modern plotter, an autopilot, a hot water boiler and a hot air heater were installed;
– the engine was soundproofed;
– several steel plates were repaired or replaced (now stainless steel);
– chrome fittings were refurbished;

- numerous rotten and unsound wooden parts were repaired or replaced:
  - stem;
  - parts of the hull's planking;
  - wooden deck;
  - helm position;
  - window frames;
  - lounge walls;
- paint removed and the entire yacht repainted (including underwater hull), and
- preservation of bilge according to good professional practice.

The skipper only used the SANTA CECILIA on the River Elbe for trips from Wedel, both alone and with friends and family. He has sailed the yacht from the berth in Wedel to Hamburg and back countless times.

2.2.2 Skipper

The SANTA CECILIA's skipper has practiced water sports since he was six years old. He has occasionally sailed as a competitive athlete and spent holidays on a ship for almost 30 years. He holds a pleasure craft skipper’s licence 'C' issued for the first time in 1984 by the German Motor Yachting Association (DMYV) and an international certificate for operators of pleasure craft in coastal waters not exceeding 12 nm (SKS) issued in 2001. He has also held a Restricted Operator's Certificate (ROC) since 2001.

2.2.3 Environmental Conditions

When the accident happened at 1603 an incoming current still prevailed at Athabaskakai just before the high tide of 3.93 m at 1626 (reference point: Seemannshöft, tide turned at about 1650). At < 0.4 kts, the current speeds were significantly lower immediately at the quay wall than in the middle of the fairway. An east-north-easterly wind of 1-2 Bft prevailed, the sky was slightly cloudy and visibility was good.[8]

2.2.4 Autopilot on the SANTA CECILIA

The SANTA CECILIA was equipped with an autopilot from the Raymarine® Evolution series at the time of the accident. The autopilot acted on the rudder stock directly. The steering wheel (incl. transmission systems) was disabled when the autopilot was active and could not be moved. A combined sensor (attitude heading reference system, see 0) was used for course measurement. The system could be controlled by means of a permanently installed control unit with display ('p70R') or a remote control ('SmartController') as a slave control unit.

[8] Germany's National Meteorological Service; Federal Maritime and Hydrographic Agency; HPA WI221 (hydrological advice); timeanddate.de: Weather Review for Hamburg – September 2021.

Figure 6: Autopilot Control Units on the SANTA CECILIA[9]

The Evolution system was installed about two years before the accident and used only in the 'AUTO' mode (compass control, see 0). The system was reportedly still working properly when they were sailing from Wedel to the port of Hamburg. The owner and skipper had charged the autopilot's remote control for about 2-2.5 hours in the charging unit on the day of the accident. Accordingly, he reportedly assumed that the remote control did not fail due to a lack of power. However, he stated that he had not checked the remote control's state of charge before or after the accident.

The skipper also told the BSU that he had not attempted to alter course to port with either the autopilot's remote control or the permanently installed control unit. Course alterations can be made in 1 and 10 degree increments at the push of a button. However, the skipper reportedly does not usually make use of this function but rather makes course alterations manually and switches back to autopilot as soon as the yacht is on the desired course. In retrospect, he believes that a course alteration by means of the SmartController would not be suitable for avoiding the allision because a hard-over rudder position would have been necessary very soon after. Based on past experience, the skipper felt that course corrections with the help of the autopilot reportedly occurred slowly and with a small delay. He believed that the allision could not have been avoided in this manner but rather that only the angle of impact could have been altered.

The manufacturer reportedly advised the owner of the yacht that the autopilot's software had frozen but the reason for this could not be clarified. Further investigations by the waterway police in cooperation with the autopilot's manufacturer regarding the system failure were inconclusive.

[9] Source: Left: RAYMARINE UK LIMITED: *p70/p70R Installation and operating instructions*. Document number: 81355-1-EN, 2014.
Right: RAYMARINE UK LIMITED: *SmartController – Wireless remote control for SeaTalk autopilots*. Archive number 81243_2, 2005.

2.2.5 Similar Accidents

2.2.5.1 WILDLIFE – PLANET (Ref.: 329/21)

At 1343 on 2 September 2021, a collision occurred on the Kiel Canal (NOK) between the sailing yacht WILDLIFE and the research and survey vessel PLANET.

Table 1: Vessel and Voyage Particulars: WILDLIFE / PLANET

Name of ship:	WILDLIFE	PLANET
Type of ship:	Recreational craft, sailing yacht	Research and survey vessel
Flag:	Netherlands	Federal service flag
Port of registry:	Amsterdam	Eckernförde
Call sign:	PH4425	DRLA (IMO 9245732)
Year built:	2020	2005
Shipyard:	/	Schaaf Industrie AG (SIAG) Nordseewerke, Emden, Germany
Length overall:	22.00 m	73.00 m
Breadth overall:	5.81 m	27.20 m
Draught:	2.30 m	6.80 m
Engine rating:	/	4,160 kW
Hull material:	Aluminium	Steel
Port of departure:	Helsinki, Finland	Kiel, Germany
Port of call:	Makkum, Netherlands	Lisbon, Portugal
Crew:	1	5 people on the bridge
Time of the accident:	2 September 2021, 1343 (CEST)	
Scene of the accident:	φ = 53°59.5'N, λ = 009°17.2'E NOK, canal kilometre 16 – level with Burg	

Both vessels were sailing westbound at varying speeds on the NOK towards Brunsbüttel. During the passage, the PLANET (traffic group 5) had to reduce her speed several times in the sidings to allow other ships to pass but otherwise sailed slightly faster than the WILDLIFE. This led to the two vessels overtaking each other several times during the canal passage. Between canal kilometres 17 and 16 near Burg and still before Audorf, the PLANET and the WILDLIFE sailed side by side, the PLANET at just under 9 kts in the middle of the fairway and the WILDLIFE at about 8 kts on her starboard side closer to the embankment. As the passage continued, the PLANET reduced her speed to about 7 kts, so the WILDLIFE was the faster vessel again. The WILDLIFE was offset behind the PLANET at canal kilometre 16 and slowly approached her again. Instead of following the fairway described as a slight right-hand bend, the WILDLIFE continued to sail straight ahead, causing her to collide with the PLANET's stern on the starboard side.

Figure 7: Collision between the WILDLIFE and PLANET[10]

The risk of collision was reportedly not recognised beforehand on the bridge of the PLANET. Everyone on the bridge (pilot, master, canal helmsman, officer on watch, rating) were reportedly looking ahead when reportedly a scraping noise was suddenly heard through the bridge wing door that was open on the starboard side. The WILDLIFE had reportedly become wedged with parts of the standing rigging on the upper edge of the railing (upper deck bulwark) of the PLANET, which according to the pilot reportedly immediately reduced engine power to a minimum and then stopped the starboard engine. Moreover, the course was reportedly initially maintained in spite of the right-hand bend in the canal. Following that, the sailing yacht reportedly broke free, creating a lot of noise in the process. The shroud on the port side of the WILDLIFE and her railing were damaged by the collision and parts that had broken off were found on the deck of the PLANET, which had sustained only minor damage to the paintwork. Nobody suffered any injuries.

One of the PLANET's ship mechanics (anchor watch at the bow) reportedly saw that nobody was at the WILDLIFE's helm position, on her deck or in her cockpit when the collision happened. Investigations by the waterway police, which stopped the WILDLIFE at the emergency mooring at the Kudensee ferry crossing and interviewed the skipper, revealed that an automatic steering system had reportedly been switched on at the time of the collision. It was not possible to establish why the skipper had left the helm position.

[10] Source: ANDREAS REQUARD, https://nok-schiffsbilder.de/modules/myalbum/photo.php?lid=126663 (06/07/2023).

2.2.5.2 FRÄULEIN VOM RHIN – CASTOR (Ref.: 330/21)

At 1125 on 13 August 2021, another collision on the NOK occurred between the sailing yacht FRÄULEIN VOM RHIN and the moored inland waterway vessel CASTOR.

Figure 8: Photograph of the FRÄULEIN VOM RHIN[11]

Table 2: Vessel and Voyage Particulars: FRÄULEIN VOM RHIN / CASTOR

Name of ship:	FRÄULEIN VOM RHIN	CASTOR
Type of ship:	Recreational craft, sailing yacht (Hanseat 69)	Inland motor vessel
Flag:	Germany	Germany
Port of registry:	Wismar	Hamburg
Call sign:	DH2765	DJ5764
Year built:	1969	1907
Shipyard:	Asmus KG Yachtbau, Glückstadt, Germany	/
Length overall:	10.30 m	85.24 m
Breadth overall:	2.98 m	9.47 m
Draught:	1.65 m	/
Engine rating:	23 BHP	589 kW
Hull material:	GFRP	Steel
Port of departure:	Brunsbüttel, Germany	Moored at the 'Dyhrrsenmoor' berth
Port of call:	Rendsburg, Germany	
Crew:	2	/

[11] Source: Owner.

Time of the accident:	13 August 2021, 1125 (CEST)
Scene of the accident:	φ = 53°57.5'N, λ = 009°15.2'E NOK, 'Dyhrrsenmoor' berth, canal kilometre 12.8

On the day of the accident, the sailing yacht FRÄULEIN VOM RHIN was proceeding eastbound on the NOK at a speed of about 5.5 kts on a north-easterly course of 039° after a sailing trip. By all accounts, the skipper had been steering the yacht from the cockpit, while his female crew member had reportedly been on the forecastle. During the voyage, shortly after passing the Kudensee siding area, the boat hook attached to the backstay reportedly came loose. No other traffic was located astern or ahead on the long straight visible section of the canal.

According to the skipper, he switched on his autopilot and initially observed the steering behaviour of his yacht. He would not normally have used the autopilot on the NOK, as he reportedly felt that this was too dangerous in the presence of maritime traffic. However, due to the straight and open section of the canal, he reportedly assessed the risk of using the autopilot as low at that moment. All in all, the autopilot reportedly worked as expected for about ten minutes before the skipper reportedly took care of the detached boat hook. He saw no need to involve his female crew member in the manoeuvre.

After the skipper had reportedly been busy at the backstay for some four to five minutes and while passing the inland waterway vessel CASTOR, moored at the Dyhrrsenmoor berth, at a distance of about 6-7 m, the autopilot reportedly suddenly made a 90° course alteration to starboard.

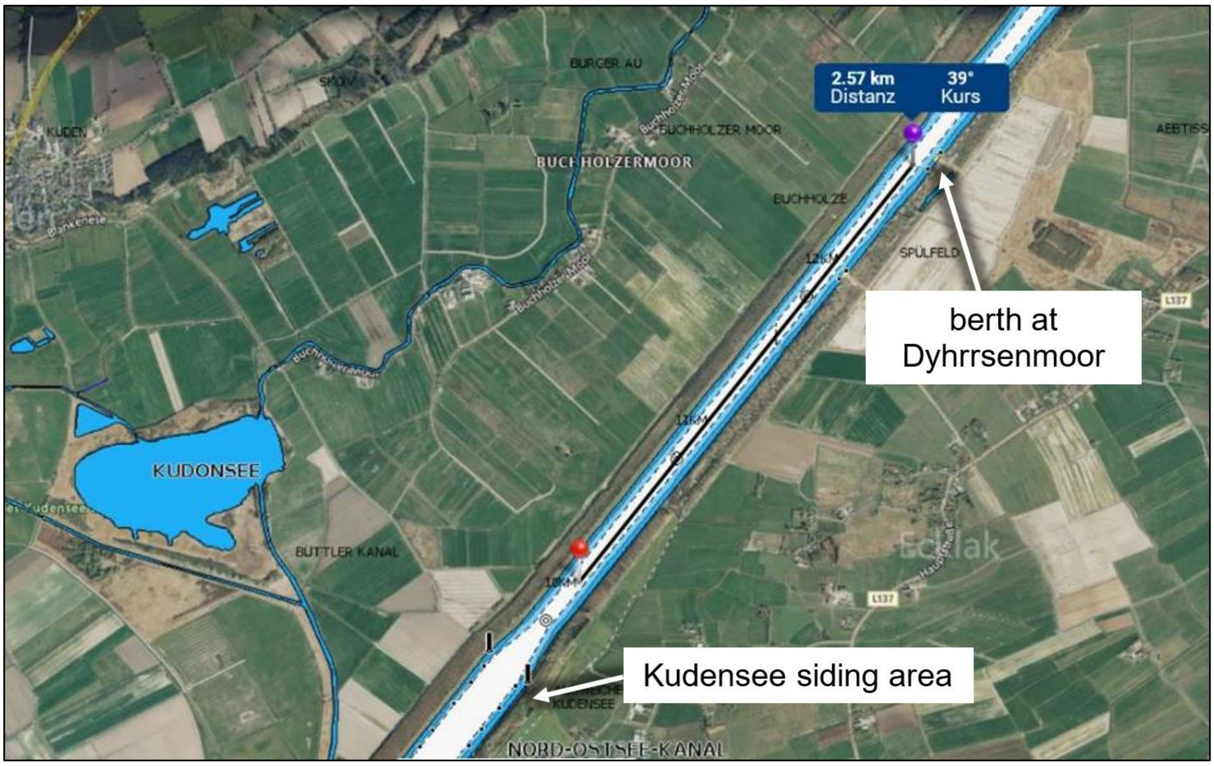

Figure 9: Stretch on which the Autopilot Was Active[12]

Due to the low distance to the CASTOR, it was reportedly no longer possible for the skipper to disconnect the mechanical connection between the autopilot and tiller in time and alter course back to port manually. The course alteration was reportedly so violent that his crew member noticed it immediately and drew attention to it from the forecastle. Immediately afterwards, the sailing yacht's starboard bow collided with the side of the inland waterway vessel at an angle of about 45°, causing the yacht to veer to port.

After the accident, the FRÄULEIN VOM RHIN was instructed to moor at the emergency berth south of the Burg ferry crossing, where the waterway police inspected the yacht.

The sailing yacht suffered damage to the gelcoat above the waterline and there was some paint damage on the starboard side. The shell was not damaged structurally and nobody was injured. There was also minor material damage to the inland waterway vessel. The waterway police found minor paint abrasions and a damaged metal support from a removable rail.

The skipper reportedly assumes that the CASTOR's large iron mass had deflected the fluxgate compass (see 2.2.5.4) of his autopilot (Autohelm 2000).

[12] Source: NAVIONICS (https://webapp.navionics.com/?lang=de#boating/mapOptions@11&key=gtihIyskw%40), notes by the BSU.

2.2.5.3 LIESEL (Ref.: 398/21)

The sailing yacht LIESEL struck a dolphin on the NOK at canal kilometre 21.5 in the Dückerswisch siding area at between 0815 and 0845 on 20 June 2021.

Table 3: Vessel and Voyage Particulars: LIESEL

Name of ship:	LIESEL
Type of ship:	Recreational craft, sailing yacht (HC 43 T)
Flag:	Germany
Port of registry:	Ditzum
Call sign:	DG5479
Year built:	1991
Shipyard:	Shin Hsing Yachting, Taiwan
Length overall:	16.00 m
Breadth overall:	4.21 m
Draught:	/
Engine rating:	66 BHP
Hull material:	Timber
Port of departure:	Emden, Germany
Port of call:	Kiel, Germany
Crew:	2
Time of the accident:	20 June 2021 between 0815 and 0845 (CEST)
Scene of the accident:	φ = 54°02.4'N, λ = 009°18.3'E NOK, Dückerswisch siding area, canal kilometre 21.5

On the day of the accident, the sailing yacht LIESEL was proceeding eastbound on the NOK with two people on board and passed the Dückerswisch siding area on a course over ground of 009°. The skipper had reportedly used the permanently installed autopilot as an aid to keeping the course and remained aft in the cockpit while his crew member was below deck.

The skipper had reportedly decided to leave the control position briefly so as to clear lines that were flapping in the wind on the foredeck. He saw no need to involve his crew member in this manoeuvre. The yacht reportedly went off course to starboard in the process and collided with one of the dolphins in the siding area. Nobody was injured and the sailor below deck reportedly merely felt a strong jolt.

The waterway police did not find any damage on the dolphins. The LIESEL's wooden jib boom, which was about 2 m above the waterline, broke as a result of the accident. A sidelight was also lost.

The owner/skipper reportedly assumed that the wide metal reinforcement on the dolphins had deflected the fluxgate compass (see 2.2.5.4), which was installed on the starboard side, of his autopilot and that passing the dolphins at insufficient distance and inattentiveness reportedly contributed to the accident.

Figure 10: Photograph of the LIESEL After the Accident[13]

2.2.5.4 SINFONIE SYLT (Ref.: 166/05)

On 5 May 2005, the sailing yacht SINFONIE SYLT was involved in a very serious maritime accident on the Flensburg Firth, which resulted in the death of one person. On 1 June 2006, the BSU published the corresponding investigation report 166/05. This accident is presented again in this summary investigation report in order to also shed light on the special aspects of using an autopilot under sail.

Figure 11: Photograph of the SINFONIE SYLT[14]

[13] Source: Waterway Police Brunsbüttel.
[14] Source: BSU.

The sailing yacht was manned by three people and en route from the Danish port of Høruphav to Hamburg. Shortly before the fatal accident, a course of 140° was steered and the yacht was sailing downwind (5-6 Bft with gusts of 6-7 Bft from the north-west) at a speed of about 10 kts with the main and genoa sails on the port side. The helmsman and a crew member were aft in the yacht's cockpit at the port helm position and the skipper had just gone below deck when the helmsman reportedly stated that control of the yacht could reportedly be taken over by the autopilot, as he intended to clean a cockpit window. The helmsman reportedly made the appropriate adjustments to the autopilot and then immediately went to the forward part of the cockpit. As he was making his way there, the yacht reportedly suddenly ran out of the rudder and there was reportedly a violent course alteration to port, causing the stern of the yacht to turn through the wind and then the sails to swing abruptly to the starboard side. When the helmsman hurried back to the helm position to put the yacht back on course, he was reportedly struck by the mainsheet and hurled against the starboard side of the cockpit, sustaining fatal head injuries in the process.

It was not possible to clarify with absolute certainty what caused the yacht to bear away to lee, i.e. the event that triggered the accident. Three possible explanations were identified:

1) The autopilot was activated but the 20 to 30 second adjustment phase was not allowed for and the helm position vacated too soon. It is possible that the rudder will oscillate during the adjustment phase, especially when under sail, causing the yacht to luff or bear away.

2) Although the autopilot should have been activated, the automatic key was not pressed to a sufficient extent.

3) A sudden change in wind direction caused the vessel to bear away and the main boom to swing.

2.2.6 Autopilots on Recreational Craft

2.2.6.1 Types of Autopilot

Various different autopilots are installed on recreational craft:

1) Cockpit Systems (tiller and wheel drives)

   In the case of tiller drives, a movable arm installed on the side of the cockpit replaces the person steering. The tiller is either pulled in the direction of the installation bracket (corresponds to a course alteration to port on the yacht in Figure 12) or pushed away (course alteration to starboard):

Figure 12: Tiller Drive on the FRÄULEIN VOM RHIN[15]

In the case of wheel drives, the steering wheel is turned by means of a device mounted directly on it, e.g. by means of an electrically powered toothed belt or wheel drive.

Such systems can reach their limitations for various reasons, especially when sailing in following seas or on a broad reach course. One example is the system-induced damping of the pulse-transmitting fluxgate compass, which thwarts fast course adjustments. An additional directional gyroscope/rate of turn sensor, which practically responds to course alterations without delay, can eliminate the damping of the fluxgate compass.[16]

2) Permanently Installed Autopilots

On larger yachts and/or when offshore and in heavy swell, permanently installed autopilots that can act on the rudder directly via a hydraulic drive, for example, are more suitable (especially for continuous use). These can apply more power than cockpit systems.[17]

[15] Source: Owner.

[16] DEUTSCHER HOCHSEESPORTVERBAND »HANSA« E. V.: *Seemannschaft – Handbuch für den Yachtsport*. 32nd edition Bielefeld, Delius Klasing Verlag, 2022. – ISBN 978-3-667-11658-1. P. 99.

[17] BERND GRÖNEVELD on BLAUWASSER.DE: *Elektrischer Autopilot: Dimensionierung, Kalibrierung, Steuerverhalten, Wartung und Service*. https://www.blauwasser.de/autopilot (10/07/2023).

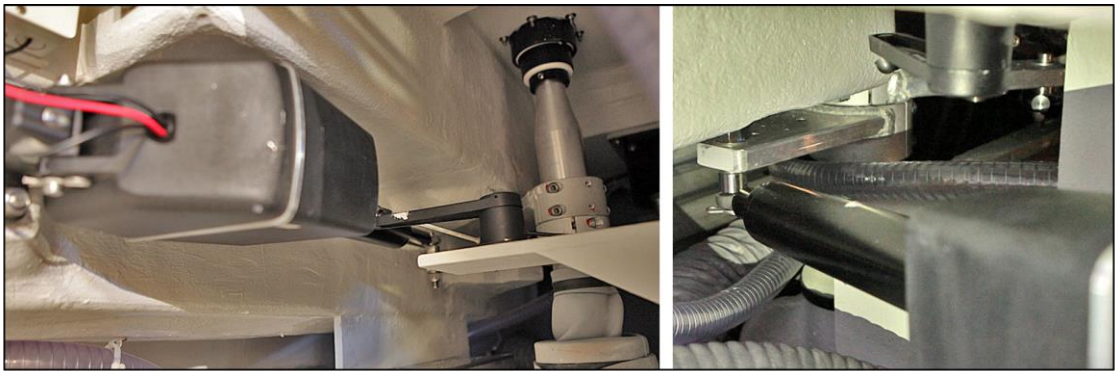

Figure 13: Linear Drives on Long-distance Yachts[18]

In addition to the specific requirements that an autopilot must meet (duration of use, precision, features, etc.), the dimensioning of the drive unit in relation to the size and displacement of the yacht, as well as the rudder pressure must also be considered when selecting the system. Possible types of drive include hydraulic (movement of the rudder by hydraulic pump and cylinder), linear (hydraulic or mechanical), geared motor (movement of the rudder by chain and gear wheel), and rotary (for steering systems by means of cable and steering rods).

3) Wind Vane Steering

Such steering systems keep sailing yachts at a constant angle to the relative wind, meaning the position of the sail does not have to be changed. They use an auxiliary rudder or are connected to the main rudder, have a vertical or horizontal wind vane and steer with wind or water power, meaning no external energy is needed.

An online article with explanatory illustrations on the basics of wind vane steering on yachts[19] ('Grundlagen der Windfahnensteuerung auf Yachten') and the yachting handbook ('Seemannschaft – Handbuch für den Yachtsport'[20]) [both in German] provide further explanations, for example.

[18] Source: SÖNKE ROEVER on BLAUWASSER.DE. https://www.blauwasser.de/autopilot (10/07/2023).
[19] Last retrieved on 29/08/2023.
[20] DEUTSCHER HOCHSEESPORTVERBAND »HANSA« E. V.: *Seemannschaft – Handbuch für den Yachtsport*. 32nd edition Bielefeld, Delius Klasing Verlag, 2022. – ISBN 978-3-667-11658-1.

2.2.6.2 Sensors

Electronic autopilots use different course-measuring systems and possibly other sensors, depending on design:

1) Magnetic Compass

   The needle of a magnetic compass sets itself in the direction of the horizontal component of the magnetic earth field when in a location where there is no iron or other interfering magnetic fields.[21] Since the earth's magnetic field is not homogeneous and the magnetic and geographical North Pole are not at a single point, a magnetic compass does not point to true north. This results in a variation (Var).

   Larger iron masses (e.g. a hull structure) and other magnetic fields (e.g. live power lines), course, position and time affect magnetic compasses. This deviation (Dev) must be partially compensated regularly.[22]

2) Gyrocompass

   Gyrocompasses are north/meridian seeking, so-called 'locked' gyros with two degrees of freedom and one limited degree of freedom (horizon locking)[23]. A distinction is made between heavy gyroscopes, gyroscopes with mercury vessels and electronic gyroscopes. The gyrocompass's operating principle is not based on the earth's magnetic field but rather on gravity and the earth's rotation. With increasing convergence with the poles, a gyrocompass loses its ability to function because the earth's axis of rotation points almost vertically out from its surface and the torque projected onto the horizontal plane becomes very small.

   Gyrocompasses are subject to a constant gyro error (GE), steaming error (SE) and acceleration error (AE), which are caused by the speed and course of the ship on the earth's curved surface.[24] Due to relatively high power consumption, the required settling time spanning several hours and susceptibility to interference from ship movements, gyrocompasses are usually not appropriate for small yachts.[25]

[21] BERKING; HUTH: *Handbuch Nautik – Navigatorische Schiffsführung*. Hamburg: DVV Media Group GmbH, 2010. – ISBN 978-3-87743-821-3. P. 126.
[22] Ibid. P 126f.
[23] Ibid. P. 123 ff.
[24] Ibid. P. 119.
[25] DEUTSCHER HOCHSEESPORTVERBAND »HANSA« E. V.: *Seemannschaft – Handbuch für den Yachtsport*. 28th/32nd) edition Bielefeld, Delius Klasing Verlag, 2008/2022. – ISBN 978-3-7688-0523-0/978-3-667-11658-1. P. 457/452.

3) Directional Gyroscope

A directional gyroscope is a force-free symmetrical gyroscope in a gimbal suspension (three degrees of freedom) that maintains its position/direction in space (with respect to the fixed-star sky) once set due to the conservation of angular momentum. The force-free gyroscope is therefore only suitable as a directional gyroscope, not as a north-seeking gyroscope for course measurements. Additional technical devices must be used to force it to maintain its direction in the earth's coordinate system.[26] Unlike a gyrocompass, the directional gyroscope is a so-called free gyroscope.

4) Fibreoptic Gyroscope

In a fibreoptic gyroscope, the measurement is based on the interference of the wave trains of a coherent (monochromatic) light beam. The wave trains are divided and fed into a closed circular optical fibre (glass fibre) and pass through it in opposite directions. A course alteration rotates the fibreoptic gyroscope, which is permanently installed on board, creating a phase difference between the two wave trains. This is evaluated by a photodetector and is a proportional measure of the rotational speed of the system and thus of the ship. As a purely electronic course-measuring system, a fibreoptic gyroscope depends on a permanent power supply. On the other hand, it is virtually wear- and maintenance-free.[27]

5) Fluxgate Compass

A fluxgate compass contains two fixed, cross-shaped coil probes filled with magnetically saturated ferromagnetic material, which scan the horizontal component of the earth's magnetic field[28] and operates electronically. The coils measure the field lines of the earth's magnetic field and detect changes in course that affect the output signals of each coil.

Similar to conventional magnetic compasses, fluxgate compasses need to be compensated regularly. They are internally gimballed so as to output correct values even when the ship is heeling/listing. However, depending on the design, the functionality is limited by a maximum compensable heel/list angle.[29]

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[26] BERKING; HUTH: *Handbuch Nautik – Navigatorische Schiffsführung*. Hamburg: DVV Media Group GmbH, 2010. – ISBN 978-3-87743-821-3. P. 119.
[27] Ibid. P. 129.
[28] Ibid. P. 127.
[29] DEUTSCHER HOCHSEESPORTVERBAND »HANSA« E. V.: *Seemannschaft – Handbuch für den Yachtsport*. 32nd edition Bielefeld, Delius Klasing Verlag, 2022. – ISBN 978-3-667-11658-1. P. 451.

6) GNSS[30] (Compass) & Trackpilot

A GNSS compass works either with two GNSS receivers, which can calculate a compass course based on their position relative to each other or with a combination of GNSS receiver and other integrated sensors, such as gyroscope and inclination sensors. Simple GNSS receivers with only one antenna can only calculate the compass course from the yacht's earlier movement and do not show a (reliable) course when the yacht is stationary.

Some autopilots have their own GNSS sensor or can be coupled with a GNSS-based navigation device via an NMEA[31] interface. This enables waypoint control (see 0).

7) Combination of Multiple Sensors, Attitude Heading Reference System

Two or more course-measuring systems or sensors with different operating principles and error influences can be combined to form a multi-compass system. This increases redundancy and reliability. Moreover, in addition to the course, it also makes it possible to measure rate of turn, heel, roll and pitching movements.

In the case of a so-called attitude heading reference system (AHRS), the rotation, acceleration and position of three axes are recorded, requiring at least nine individual sensors (three gyroscopes, three accelerometers, and three magnetometers).[32]

8) Wind Sensor

Linking the autopilot with a wind sensor (anemometer) or a corresponding integration enables wind transducer control (see 0).

9) Miscellaneous

Additional sensors can be connected for calibration and other system-specific computations by the autopilot, e.g. for the ship's speed (through water or over ground).

30 **G**lobal **N**avigation **S**atellite **S**ystem.
31 Standard of the **N**ational **M**arine **E**lectronics **A**ssociation (American trade organisation for marine electronics) for communication between navigation devices on ships.
32 VECTORNAV: *Educational Material – 1.6 Attitude & Heading Reference System (AHRS)*. https://www.vectornav.com/resources/inertial-navigation-primer/theory-of-operation/theory-ahrs (10/07/2023).

2.2.6.3 Operation

Depending on type, autopilots can be operated using various control units. These include a multifunction display belonging to the navigation system, a permanently installed dedicated control unit for the autopilot, in the case of cockpit systems directly on the device or the control arm, or with an additional portable remote control.

After any necessary calibration, autopilots can be used in different modes depending on manufacturer and type of sensors connected:

1) Compass Control: The compass course entered is maintained. Drift due to wind and current is not compensated.

2) Waypoint Control: Steering to a waypoint as a destination and/or navigating a previously planned route comprising several waypoints. Drift is compensated.

3) Wind Transducer Control: Steering at a set angle to the wind on variable courses. The sail position does not need to be changed.

4) Pattern control: Navigating a selected pattern, e.g. to search for someone who has fallen overboard.

Depending on design, the autopilot's steering behaviour can also be adapted to suit specific requirements. For example, the system can keep course very precisely (constant small corrections) or only approximately (less frequent control of the rudder with still acceptable course deviations).

2.2.7 Specifics of the Kiel Canal

According to Section 42(4) in conjunction with Section 60(1) SeeSchStrO[33], autopilots may only be used on the NOK under the conditions published in the Notice of the Federal Waterways and Shipping Agency, Outstation North[34], under 24.1 and 24.2:

- the vessel belongs to traffic groups 1 and 2[35] and is not in a pushed or towed convoy;
- the autopilot complies with IMO performance standards;
- the autopilot operates with a gyrocompass;

[33] German Traffic Regulations for Navigable Maritime Waterways, as amended and promulgated on 22 October 1998 (Federal Law Gazette I p. 3209; 1999 I p. 193), as amended by Article 2 of the Ordinance of 11 May 2023 (Federal Law Gazette 2023 I No 127).

[34] Of 28/01/2014 (BAnz AT 31.01.2014 B7), as amended by the Tenth Notice amending the Notice of the Federal Waterways and Shipping Agency, Outstation North to the German Traffic Regulations for Navigable Maritime Waterways of 16 May 2023 (BAnz AT 24.05.2023 B6). The Notice can be viewed via the version of the SeeSchStrO published by the ELWIS (electronic waterways information service): https://www.elwis.de/DE/Schifffahrtsrecht/Verzeichnis-Rechtsverordnungen-Gesetze-Richtlinien/SeeSchStrO.pdf?__blob=publicationFile&v=11.de (24/08/2023).

[35] Length: 45-85 m. Breadth: 8.5-13 m. Draught: 3.1-3.7 m. See: https://www.wsa-nord-ostsee-kanal.wsv.de/Webs/WSA/WSA-Nord-Ostsee-Kanal/DE/2_Schifffahrt/b_Verkehrsmanagement/2_Verkehrsgruppen/Verkehrsgruppen_node.html (11/07/2023).

- the vessel has a single-hand control position and the autopilot is equipped with an override tiller or hand wheel;
- the autopilot is able to keep the set course after switching from manual to automatic steering;
- the unit's configuration is appropriate for the area of operation;
- a minimum speed of 8 km/h (4.3 kts) can be maintained;
- the range of visibility is not less than two nautical miles, and
- the unit will be switched to manual operation in good time before overtaking or head-on situations.

It is also noted that the use of an autopilot in accordance with the above conditions does not release a master from other regulations.

The Administration has laid down these rules to prevent marine casualties, taking into account the technical state of the art of autopilots. These rules are also mandatory for recreational craft and constitute a de facto prohibition of use given the above conditions.

The Federal Waterways and Shipping Administration (WSV) has produced a guide for operators of recreational craft on the Kiel Canal to help them navigate the NOK in close contact with commercial shipping safely and with as few problems as possible. The guide dated June 2022 did not contain any information on autopilots. From the perspective of the BSU, a suitable notice regarding the prohibition of the use of autopilots on recreational craft was missing.

3 ACTIONS TAKEN

3.1 Owner of the SANTA CECILIA

The owner of the SANTA CECILIA informed the BSU that an emergency stop switch for the autopilot has reportedly been installed directly at the control console. This is to ensure that the autopilot can be switched off at any time, even in the event of a malfunction of the remote control or the system in general, and that manual control can be assumed.

3.2 Waterways and Shipping Office Kiel Canal (WSA NOK)

The WSA NOK's guide for operators of recreational craft on the Kiel Canal was revised to now also contain information on the use of autopilots on the NOK. It was published with the new title „Merkblatt für Sportbootfahrende – Nord-Ostsee-Kanal“.

4 CONCLUSIONS

4.1 Accident Causes and Contributing Factors; Alternative Actions in Retrospect

4.1.1 SANTA CECILIA (Ref.: 284/21)

The cause of the motor yacht SANTA CECILIA's allision with the Athabaskakai was chiefly a technical defect in the autopilot. The severity of the accident was facilitated by the fact that the autopilot was switched on in a busy area in close proximity to the quay facilities and by a relatively high speed during the allision. The accident was also facilitated by the fact that a loose object (mobile phone) in the vicinity of the control console was not secured in a seaworthy fashion against slipping or falling off.

The consequences of the accident would have been reduced or even avoided if the speed had been decreased earlier and more resolutely after control of the steering system had been lost. The accident would probably also have been avoided if the skipper had quickly picked up the dropped mobile phone without engaging the autopilot or had asked someone else to pick it up.

4.1.2 WILDLIFE – PLANET (Ref.: 329/21)

The collision between the sailing yacht WILDLIFE and the research and survey vessel PLANET was presumably caused by the WILDLIFE's skipper leaving the cockpit. This meant that it was no longer possible to maintain a proper look-out and continuously verify the vessel's position. The collision was facilitated by the short passing distances of vessels on the NOK, which necessitate a short response time for required course changes when reaching a bend. The option of handing over control of the yacht to another crew member to make it possible to go below deck during the long NOK passage may have prevented the accident. However, due to the fact that the yacht was manned by only one person, this option was not available.

4.1.3 FRÄULEIN VOM RHIN – CASTOR (Ref.: 330/21)

The sailing yacht FRÄULEIN VOM RHIN collided with the moored inland waterway vessel CASTOR because the skipper did not take into account the possible deflection of his tiller drive's sensors by external influences, was not able to intervene in the steering quickly enough and passed the inland waterway vessel at relatively close proximity. The incident was facilitated by the failure of the boat hook attachment, an incorrect assessment of the potential risk of using the autopilot and the skipper's failure to delegate tasks to his crew member. The accident could have been avoided if the tasks involved (steering/re-attaching the boat hook) had been divided among the existing crew members.

4.1.4 LIESEL (Ref.: 398/21)

From the perspective of the investigation team, the allision with a dolphin by the sailing yacht LIESEL was also due to the deflection of the autopilot's sensors by external influences, facilitated by the fact that the skipper left the cockpit and was thus unable to intervene in the steering quickly enough. A close passing distance to the dolphins and the skipper's failure to delegate tasks (stand at the helm or fasten lines) to the crew member facilitated the allision. The accident could have been avoided had the autopilot not been used and the helm been continuously manned while the lines were being cleared.

4.1.5 SINFONIE SYLT (Ref.: 166/05)

The fatal accident on board the sailing yacht SINFONIE SYLT was caused by the navigator passing through the mainsheet's danger area as the yacht was bearing away while sailing downwind. Inter alia, the accident was facilitated by the navigator's failure to delegate tasks (stand at the helm or clean the cockpit window) to the crew member and the fact that a gybe preventer[36] was not used. It was not possible to determine the actual cause of the accidental gybe[37]. According to Investigation Report 166/05, conceivable factors that caused the yacht to bear away could have been improper operation of the autopilot (not switched on properly or not allowing sufficient time for the adjustment phase) or also a sudden wind shift. The accident would probably not have happened if the helm had been continuously manned during the planned cleaning of the cockpit window and the mainsheet's danger area had been avoided.

4.2 Use of Autopilots on Recreational Craft

Section 3(1) SeeSchStrO states: "The conduct of every person taking part in shipping traffic shall be such as to ensure the safety and easy flow of shipping traffic and to avoid any other person to be exposed to any damage or detriment, to be put at risk, or to be impeded or molested any more than is inevitable in the circumstances prevailing. Every person taking part in shipping traffic shall, in particular, take any precaution as may be required by the practice of good seamanship or by the special circumstances of the case."[38] Rule 5 (Look-out) of the International Regulations for Preventing Collisions at Sea (COLREGs)[39] states: "Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision."[40] These requirements are also always applicable to the operation of a recreational craft using autopilot.

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[36] Safety line intended to prevent the boom and mainsheet from swinging out of control to the other side of the vessel.

[37] Unintentional, uncontrolled and sudden gybe (sailing manoeuvre in which the stern goes through the wind and the sails are then operated on the other side of the vessel), in which the main boom swings from one side to the other at high speed.

[38] German Traffic Regulations for Navigable Maritime Waterways, as amended and promulgated on 22 October 1998 (Federal Law Gazette I p. 3209; 1999 I p. 193), as amended by Article 2 of the Ordinance of 11 May 2023 (Federal Law Gazette 2023 I No 127).

[39] International Regulations for Preventing Collisions at Sea of 13 June 1977 (Federal Law Gazette I p. 816), as amended by Article 1 of the Ordinance of 7 December 2021 (Federal Law Gazette I p. 5188).

[40] Ibid.

From the perspective of the BSU, the use of an autopilot offers advantages (provided that the system is adequately dimensioned, calibrated, configured and operable), but also poses dangers:

Table 4: Pros and Cons of Using an Autopilot

PROs	CONs
– helmspeople are less likely to be exhausted – good for longer trips with a small crew;	– unexpected deflection of sensors – unintended, sometimes sudden and violent courses deviations;
– precise adherence to the course possible;	– danger if used when on a broad reach course/in following seas/planing – accidental gybe possible on sailing yachts;
– sailing in various modes (course steered/over ground, wind, track, search pattern, etc.) if sensors allow – helpful depending on the situation;	– risk of blind/over-reliance on autopilot – use of automatic system more likely in unsuitable situations;
– reduced fuel consumption – adaptive systems (e.g. yaw filter) and economic steering behaviour can be adjusted if necessary.	– risk of less accurate monitoring of the yacht's course – loss of situational awareness[41] more likely;
	– increasingly complex systems – extensive knowledge, appropriate configuration and calibration are essential for safe operation.

[41] Current information and data must be gathered before decisions can be made. The meaning of this information must be processed, understood and interpreted. Based on this, an assumption as to the probability with which something will happen next can be made. On the basis of this assumption, anticipatory action can be taken by making and implementing a decision.

In principle, the following points can be learned from the accidents involving the SANTA CECILIA, the WILDLIFE, the FRÄULEIN VOM RHIN, the LIESEL and the SINFONIE SYLT and must always be observed before/when using an autopilot on board a recreational craft:

- Recreational craft may not use an autopilot on the NOK[42];
- Recreational craft manned by only one person wishing to transit the NOK should plan for the possibility of making short stops when preparing for the voyage;
- To maintain situational awareness, a proper look-out must always be ensured, even when using an autopilot;
- The more confined the water and the smaller the space for unintentional course deviations or autopilot errors, the faster a person must be available to switch to manual steering and take over;
- It must be technically possible to quickly switch to manual steering at any time (even in the event of an autopilot system failure) and helmspeople must know the procedures for doing this;
- Autopilot users must know the technical limitations of the system installed, the characteristics of the sensors that are connected/used and the importance of the settings made on the autopilot (operating mode, steering behaviour, etc.);
- Large masses of steel/iron (other ships), live power lines (submarine cables, overhead power lines across rivers and canals) and other external influences can significantly deflect magnetic and fluxgate compasses, resulting in unintentional and violent course alterations in conjunction with an autopilot;
- The autopilot's steering behaviour must be monitored for several minutes (inter alia, to ensure the system is actually working) before consideration can be given to temporarily leaving the helm in open sea areas;
- On vessels under sail, there is no guarantee that a course deviation or similar will be avoided when using an autopilot. Even a wind transducer control system can reach its limitations under certain conditions, e.g. in the event of inappropriate sail management;
- On sailing yachts, autopilots are to be used only with the utmost caution when on a broad reach course and/or in following seas, ideally only with additional protection from a gybe preventer.

[42] with the exception of vessels which fulfil the conditions set out in Chapter 2.2.7.

Irrespective of the accidents investigated here, the following advice should also always be considered before/when using an autopilot on a recreational craft:

– If the speed is too low and/or in heavy seas, it should be noted that the automatic course control may not be able to maintain the course with the required accuracy due to design, i.e. it is necessary to switch to manual steering[43];

– A prerequisite for reliable steering is appropriate dimensioning (including performance in relation to vessel size and rudder pressure) as well as proper calibration of the autopilot. Regular software updates are recommended[44];

– The autopilot should not be switched on when sailing until the sails have been optimally trimmed and the rudder pressure is as low as possible in order to avoid increased energy consumption and a slow response to external influences (e.g. gusts of wind)[45];

– In the case of a waypoint control system, the user must know whether the system initiates the course alteration automatically or only after confirmation (pressing a button) when a course alteration point is reached (and, depending on the situation, take this into account);

– Steering should not be left to an autopilot in situations that are especially challenging for helmspeople and require quick, concentrated and proficient action.

The above points constitute generally applicable advice that is not suitable for a safety recommendation for lack of specific addressees. The BSU will publish Lessons Learned based on this investigation.

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[43] BERKING; HUTH: *Handbuch Nautik – Navigatorische Schiffsführung*. Hamburg: DVV Media Group GmbH, 2010. – ISBN 978-3-87743-821-3. P. 227.

[44] BERND GRÖNEVELD on BLAUWASSER.DE: *Elektrischer Autopilot: Dimensionierung, Kalibrierung, Steuerverhalten, Wartung und Service*. https://www.blauwasser.de/autopilot (17/08/2023).

[45] Ibid.

5 SOURCES

- Enquiries of the waterway police (WSP)
- Witness testimony
- Navigational charts, Federal Maritime and Hydrographic Agency (BSH)
- Ship and movement data (MarineTraffic.com)
- Radar and radio recordings from the Vessel Traffic Centre Hamburg
- Internet and literature sources shown in the footnotes